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Climate Investment Opportunities in India's Cooling Sector

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Abbreviations and Acronyms

APEDA	Agricultural and Processed Food Products Export Development Authority
APMC	Agricultural Produce Market Committee
BAU	Business As Usual
BEE	Bureau of Energy Efficiency
BIS	Bureau of Indian Standards
BLDC	Brushless Direct Current
°C	degree centigrade
CaaS	Cooling as a Service
CAFCS	Corporate Average Fuel Consumption Standards
CAFÉ	Corporate Average Fuel Economy
CAGR	Compound Annual Growth Rate
CREDAI	Confederation of Real Estate Developers Associations of India
CSIR-IICT	Council of Scientific and Industrial Research - Indian Institute of Chemical Technology
CSISAC	Central Sector Integrated Scheme on Agricultural Cooperation
CSR	Corporate Social Responsibility
DAY-NRLM	Deendayal Antyodaya Yojana – National Rural Livelihoods Mission
DBT	Department of Biotechnology
DCS	District Cooling System
DFI	Doubling Farmers' Income
Discom	Distribution Company
DPIIT	Department for Promotion of Industry and Internal Trade
DST	Department of Science & Technology
DX	Direct Expansion
EC Act	Energy Conservation Act
ECBC	Energy Conservation Building Code
EDGE	Excellence in Design for Greater Efficiencies
EESL	Energy Efficiency Services Ltd
EIA	Environmental Impact Assessment
ENS	Eco- Niwas Samhita
EPR	Extended Producer Responsibility
ESCO	Energy Service Company
FAME	Faster Adoption and Manufacturing of Electric Vehicles
FI	Financial Institution
FPO	Farmer Producer Organization
FSSAI	Food Safety and Standards Authority of India
GDP	Gross Domestic Product
GeM	Government e Marketplace
GHG	Greenhouse Gas
GRIHA	Green Rating for Integrated Habitat Assessment
GSP	Good Servicing Practice
GWP	Global Warming Potential

GW	gigawatt
HCFC	Hydrochlorofluorocarbons
HFC	Hydrofluorocarbons
HFO	Hydrofluoroolefins
HUDCO	Housing and Urban Development Corporation Ltd.
HVAC	Heating, Ventilation and Air Conditioning
HWD	Heat Wave Duration
HWF	Heat Wave Frequency
ICAP	India Cooling Action Plan
ICAR	Indian Council of Agricultural Research
IEA	International Energy Agency
IFC	International Finance Corporation
IGBC	Indian Green Building Council
IISc	Indian Institute of Science
IITs	Indian Institutes of Technology
IMD	India Meteorological Department
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
ISHRAE	Indian Society of Heating, Refrigerating and Air Conditioning Engineers
KIP	Kigali HFC Implementation Plan
KwH	Kilowatt-hour
LEED	Leadership in Energy and Environmental Design
MAC	Mobile Air Conditioning
MDB	Multilateral Development Bank
MEPS	Minimum Energy Performance Standards
MIDH	Mission for Integrated Development of Horticulture
MIS	Management Information System
mm	millimeter
MNRE	Ministry of New and Renewable Energy
MoAFAHD	Ministry of Fisheries, Animal Husbandry and Dairying
MoAFW	Ministry of Agriculture and Farmers Welfare
MoCI	Ministry of Commerce and Industry
MoEFCC	Ministry of Environment, Forest and Climate Change
MoFAHD	Ministry of Fisheries, Animal Husbandry and Dairying
MoFPI	Ministry of Food Processing Industries
MoHFW	Ministry of Health and Family Welfare
MoHUA	Ministry of Housing and Urban Affairs
MoRD	Ministry of Rural Development
MoRTH	Ministry of Road Transport & Highways
MoUD	Ministry of Urban Development
MSDE	Ministry of Skill Development & Entrepreneurship
MT	metric ton

mtCO$_2$e	million ton of carbon dioxide equivalent
mtoe	Million tons of oil equivalent
MW	megawatt
NbS	Nature-based Solutions
NCCD	National Centre for Cold-chain Development
NDMA	National Disaster Management Authority
NEMMP	National Electric Mobility Mission Plan
NHB	National Horticulture Board
NHB	National Housing Bank
NHM	National Horticulture Mission
NIT	National Institute of Technology
NIUA	National Institute of Urban Affairs
NSDC	National Skill Development Corporation
O&M	Operation and Maintenance
PHFI	Public Health Foundation of India
PM-KUSUM	Pradhan Mantri Kisan Urja Suraksha evem Utthan Mahabhiyan
PMAY	Pradhan Mantri Awas Yojana
PMFME	PM Formalisation of Micro food processing Enterprises
PMKSY	Pradhan Mantri Kisan Sampada Yojna
PMKVY	Pradhan Mantri Kaushal Vikas Yojana
PNGRB	Petroleum and Natural Gas Regulatory Board
PWD	Public Works Department
R&D	Research and Development
RAC	Room Air Conditioner
RCP	Representative Concentration Pathway
RE	Renewable Energy
S&L	Standards and Labelling
SAPCC	State Action Plan on Climate Change
SDG	Sustainable Development Goal
SIDBI	Small Industries Development Bank of India
SMAM	Sub-Mission of Agriculture Mechanizatio
sq km	square kilometer
TCPO	Town and Country Planning Organisation
TR	Ton of Refrigeration
TWh	terawatt-hour
UDD	Urban Development Department
UHI	Urban Heat Island
ULB	Urban Local Bodies
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
URDPFI	Urban and Regional Development Plans Formulation and Implementation
VRF	Variant Refrigerant Flow
W	watt

Executive Summary

India's cooling strategy can simultaneously mitigate the heat-related risks on lives and livelihoods, lower carbon emissions, and position India as a global hub for green cooling manufacturing.

1. Severe heat waves, responsible for thousands of deaths across India over the last few decades, are increasing with alarming frequency. The country is experiencing higher temperatures that arrive earlier and stay far longer. In April 2022, India was plunged into the grip of a punishing early spring heat wave that brought the country to a standstill, with temperatures in the capital, New Delhi, topping 46 degrees Celsius (°C) (114 degrees Fahrenheit). The month of March, which witnessed extraordinary spikes in temperatures, was the hottest ever recorded.

2. Soon India could become one of the first places in the world to experience heat waves that break the human survivability limit.[1] The recent heat wave supports what many climate scientists have long cautioned about with reference to rising temperatures across South Asia. In August 2021, the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) warned that the Indian subcontinent would suffer more frequent and intense heat waves over the coming decade.[2] The G20 Climate Risk Atlas also warned in 2021 that heat waves across India were likely to last 25 times longer by 2036-65 if carbon emissions remain high, as in the IPCC's worst-case emission scenario.[3]

3. As temperatures rise across India, so will the demand for cooling. However, in a country where two-thirds of the population live on less than US$2 a day, and where the average cost of an air-conditioning unit can vary between US$260 and US$500, air-cooling systems are a luxury available only to a few.[4] According to analysis presented in the India Cooling Action Plan (ICAP), only 8 percent of Indian households own air-conditioning units.[5] Indoor and electric fans can help to maintain thermal comfort, but these too are expensive to buy and inefficient. As a result, many poor and marginalized communities across India are more vulnerable to extreme heat, living in inadequately ventilated, hot and crowded homes without proper access to cooling. Staying cool during extreme heat is about more than just comfort – it can constitute the precarious line between life and death. In a 2021 study by the Lancet Planetary Health journal, researchers found that nearly 740,000 excess deaths in India annually can be attributed to abnormal hot and cold temperatures related to climate change.[6]

4. Rising heat across India can jeopardize economic productivity. Up to 75 percent of India's workforce, or 380 million people, depend on heat-exposed labor, at times working in potentially life-threatening temperatures. With heat-exposed work[i] contributing to nearly half of the country's Gross Domestic Product (GDP), the country is extremely vulnerable to job losses.[1] By 2030, India may account for 34 million of the projected 80 million global job losses from heat stress associated productivity decline.[7] In December 2021, a Nature study found that India showed the largest heat exposure impacts on heavy labor among South Asian countries, with more than 101 billion hours lost a year.[8] Analysis by global management consulting firm, McKinsey & Company shows that lost labor from rising heat and humidity could put up to 4.5 percent of India's GDP – approximately US$150-250 billion – at risk by the end of this decade.

[i] As per the McKinsey (2020) study, exposed sectors include exclusively outdoor sectors such as agriculture, mining and quarrying as well as indoor sectors with poor air-conditioning penetration including manufacturing, hospitality and transport.

5. India's long-term food security and public health security will depend on a reliable cold chain network. Transporting food and pharmaceutical goods across India requires a system of cold chain refrigeration that works every step of the way. A single temperature lapse in the journey can break the cold chain, spoiling fresh produce and weakening the potency of vaccines. With only 4 percent of fresh produce in India covered by cold chain facilities, annual estimated food losses total US$13 billion. The third largest producer of pharmaceuticals in the world, pre-COVID-19, India lost approximately 20 percent of temperature-sensitive medical products and 25 percent of vaccines due to broken cold chains, leading to losses of US$313 million a year.[9]

6. Unlocking opportunities to create a sustainable cooling strategy can help India in its post-COVID recovery by boosting investments, creating jobs, reducing emissions, and securing the supply chains of medical care products, health infrastructure as well as food. Priority must be given to transitioning to energy-efficient, climate-friendly cooling solutions that do not cause a spike in electricity demand. Sustainable cooling is not just essential for economic growth but is critical for a country's health, security and productivity.

7. Leveraging existing schemes, the government can position India as a global hub for green cooling manufacturing. As per an International Energy Agency analysis, the demand for space cooling alone has risen at an average pace of 4 percent per year since 2000, twice as quickly as for lighting or water heating.[10] This offers a great opportunity for India to foster future innovation and investment in the sector by providing a conducive policy environment. Existing government programs such as Make in India or the Production Linked Incentive (PLI) scheme can be further honed to promote manufacturing of components, refrigerants, and machinery that form an integral part of the cooling value chain. Efforts to this end will help the country meet its growing domestic demand while also enabling it to position itself as a manufacturing hub for cooling technologies.

Making India's Cooling Action Plan a Success: Study Findings

8. Anticipating the complex cooling energy trends and challenges facing India, in 2019, the Government of India launched the India Cooling Action Plan (ICAP)[5] to help provide sustainable cooling and thermal comfort for all. In preparing one of the first-ever comprehensive cooling action country plans, the Government of India has signaled a mature understanding of the challenge. It recognizes that extreme heat is not a future risk and is already employing strategies to adapt to the heat stress.

9. ICAP recognizes that the cooling requirement is cross-sectoral and essential for economic growth.[11] Released by the Ministry of Environment, Forests and Climate Change and built over a 20-year timeline, ICAP is a multi-stakeholder-driven framework that identifies diverse sustainable cooling needs and suggests recommendations across key sectors including space cooling in buildings, agriculture and pharmaceutical cold chains, refrigeration, passenger transportation and refrigerants transition. It also lists actions, across sectors, to help reduce India's cooling demand. The ICAP's goals include:

- **Reduction of cooling demand across sectors by up to 25 percent by 2037-38;**
- **Reduction of refrigerant demand by up to 30 percent by 2037-38;**
- **Reduction of cooling energy requirements by up to 40 percent by 2037-38;**

- Recognition of "cooling and related areas" as a key sphere of research under India's national science and technology program; and
- Training and certification of 100,000 servicing sector technicians by 2022-23 and building synergy with the Skill India Mission.

10. Cooling demand in India is expected to grow exponentially across all sectors over the coming years. According to ICAP, cooling demand across India is projected to rise at a rate of 15-20 percent annually and aggregated cooling demand will grow to around eight times by 2037-38, as compared to the 2017-18 baseline.[5] Space cooling for buildings has the largest current and projected cooling demand, refrigerant demand, energy consumption and associated greenhouse gas (GHG) emissions as compared to other sectors.

11. While progress has been made on ICAP's short-term recommendations for space cooling, energy standards and policy action, ICAP has faced some challenges in overall implementation. To realize the ICAP goals, a well-designed, pragmatic implementation plan, supported by a robust institutional framework and timely access to adequate financial resources and technologies, is needed.

12. There is an unprecedented opportunity for a transformative change in course to implement a sustainable cooling strategy that will not only save lives but boost India's economy. To help India achieve this goal, The World Bank commissioned this study to develop an actionable roadmap – comprising policy, investment and knowledge guidelines – to help guide the implementation of India's ICAP. The study was conducted in partnership with environmental and climate-solution consulting groups, Iora Ecological Solutions, Energe-se, Tessol and Vertiver.

13. This study focused on ICAP's thematic cross-sectoral areas including space cooling in buildings, cold chain and refrigeration, transport air-conditioning and refrigerants. The refrigerants sector covers the ICAP thematic areas of Research and Development (R&D), refrigerant demand and indigenous production, and the refrigeration and air-conditioning servicing sector. The authors identified specific and scalable interventions that can be achieved through partnerships with various actors to help implement the ICAP goals.

14. For some sectors, the study analysis revealed data for investment opportunities, job potential and climate impacts of a sustainable cooling strategy. The analysis showed that a well-implemented sustainable cooling strategy can lead to multiple indirect benefits for the economy and society including improved supply chains, new jobs, better health and increased livelihoods.

15. The analysis identifies eight key clustered opportunities where concessional finance can play a significant role in advancing the goals of ICAP and sustainable cooling in India. The study presents actionable roadmaps for four cooling sectors and includes prioritized[ii] opportunities for concessional financing and private sector investments. The roadmaps also identify key policy actions that are required to jumpstart action in each of the associated sectors. The analysis also recognizes the key stakeholders required for planning and implementation.

ii A two-step multicriteria prioritization framework was applied to the longlist of clustered sustainable cooling opportunities. The first step covered the criteria of climate benefits, development benefits and ability to implement. The second prioritization step focused on evaluating the role of concessional financing and private sector investments.

Key Recommendations

Sector 1: Summary of Space Cooling

Opportunities in space cooling where leveraging of concessional finance can deliver results with high climate and development benefits:

- Mainstreaming thermal comfort parameters in affordable housing policies and programs at the national and state levels
- Enabling market transformation towards super-efficiency for high energy impact cooling technologies
- Supporting the uptake of tri-generation and district cooling systems
- Mainstreaming passive cooling measures in urban planning

16. Over the next two decades, India will experience significant growth in residential and commercial floor space. With 10 million new homes required to be built annually to keep up with Indian housing[12], a huge opportunity exists to introduce natural cooling techniques into new construction. Policies and investments must prioritize climate-responsive construction to avoid long-term lock-in of inefficient building stock.

17. In India, 45 percent of the country's peak electricity demand in 2050 is expected to come from space cooling alone.[13] Space cooling interventions across India will need to prioritize "thermal comfort for all" while facilitating cooling access for 1.4 billion people and reducing the impact on an already overburdened electricity system. This will require sizable investments in creating costly peak generating capacity and result in a significant increase in GHG emissions, unless suitable low-energy alternatives are available to meet thermal comfort needs in buildings.

18. The study estimates that the market potential and investment opportunity in space cooling will be US$1.5 trillion by 2040. Of this, the green buildings market in India has an investment potential of about US$1.25 trillion for residential buildings and US$228 billion for commercial buildings.[14] It is imperative for the government to create an adequate enabling investment framework that can attract financing from the private sector.

19. Sustainable cooling can also support India's development and help in a green COVID-19 recovery by creating jobs and boosting the economy. For example, the servicing of low-Global Warming Potential (GWP) refrigerant air-conditioning units is expected to see a 10-fold increase in jobs over the next two decades, from a base of 0.2 million technicians in 2017 to 2 million.[15] While space cooling has a high potential to create new jobs in the sector, estimates for these figures are unavailable as the data must encompass the retraining and reskilling of workers across all dimensions of the energy-efficiency industry.

20. The study estimates that provision of thermal comfort through sustainable space cooling offers an emissions reduction potential of over 200 million tons of carbon dioxide equivalent (mtCO_2e) annually by 2040. Of this the emission reduction potential accruing from the provision of sustainable cooling solutions to the residential sector is over 80 mtCO_2e.

21. As noted earlier, this study identifies four key concessional finance opportunities across the space cooling sector that have strong technical feasibility and can result in high climate and development benefits.

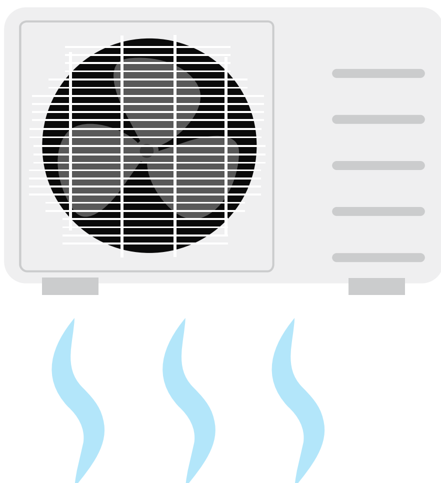
They include:

- **Mainstreaming thermal comfort parameters in affordable housing policies and programs at the national and state levels.** Affordable housing policies and programs need to recognize thermal comfort as an essential criterion for current and future programs. Energy costs to achieve comfort must be made affordable for occupants in addition to the cost of home ownership. The government's flagship housing program, Pradhan Mantri Awas Yojna (PMAY), can be leveraged to effectively mainstream passive cooling measures in affordable housing construction across India.

- **Enabling market transformation towards super efficiency for high energy impact cooling technologies.** There is a need to align the Standards and Labelling (S&L) program to transition to best available technologies in the market. Enabling market transformation for high energy impact cooling technologies such as ceiling fans and Room Air Conditioners (RACs) is also imperative. Higher upfront costs of energy-efficient models are a key barrier in the price-sensitive Indian market. Upstream incentives for manufacturers to reduce costs and support domestic manufacturing of Brushless Direct Current (BLDC) motor fans – low-energy consuming fans that create less noise and have long lifespans – should be explored. These can leverage the government's Make in India program, an initiative to encourage companies to develop, manufacture and assemble products made in India. Additionally, the government's Production Linked Incentive (PLI) program incentivizes domestic manufacturing of multiple high value RAC components (such as compressors, heat exchangers, expansion valves) which are key to the efficiency of RACs.[16]

- **Supporting the uptake of tri-generation and District Cooling Systems (DCS).** Large-scale cooling requirements can be efficiently met through district energy technologies often using Cooling as a Service (CaaS) delivery models. Viable business and implementation models need to be established in the Indian context to support the uptake of large merchant DCS. In India's context, DCS can consume 20-30 percent less power than the most efficient conventional cooling solutions. However, savings become higher, about 60-80 percent, when compared to an average 3-star RAC.[17] It is evident that shifting high density cooling requirements in cities to district energy technologies will lead to multiple benefits in terms of significant reduction in the growth of space cooling-related GHG emissions and averted power generation capacity.

- **Mainstreaming passive cooling measures in urban planning.** Land use planning combining passive urban cooling measures is key to strengthening heat resilience in cities. The use of Nature-based Solutions (NbS) can help cities prioritize actions towards equitable access to cooling for all.[18] Cities will need guidance across effective measures, implementation and private sector participation. Guidelines for implementation of local and city-wide urban cooling measures, such as cool roofs and NbS, can support urban planning frameworks in integrating a response to heat stress in city planning. There is also a need to develop business cases for all sizes of NbS and especially for private sector participation to ensure necessary funding,[19,20] as public funds are likely to be limited.



Key Policy Approaches Needed to Scale Up Action in Space Cooling

- Update affordable housing policies and programs at the national and state levels to include thermal comfort as an essential criterion

- Align the S&L program strategy to achieve ICAP goals–stringent standards and market transformation initiatives

- Enact a national policy for district cooling: Mandate deployment of DCS in high density cooling greenfield developments

- Guidelines for cities to integrate urban passive cooling measures in planning frameworks

Key Recommendations

Sector 2: Summary of Cold Chain and Refrigeration

Opportunities in the cold chain and refrigeration sector where leveraging concessional finance can deliver results with high climate and development benefits:

- Supporting the development of sustainable and energy-efficient end-to-end cold chain networks, including refrigerated transport
- Promoting better operations and servicing through capacity building of all stakeholders and incorporating effective monitoring systems

22. Across India, major gaps exist in its agricultural and pharmaceutical cold chain infrastructure. Even though cold storage capacity in the country has grown steadily, in 2015, the National Centre for Cold-chain Development (NCCD) identified a gap of 3.27 million metric tons for long-term holding of fresh produce.[21] The integrated development of the cold supply chain across India is severely lacking, with major essential components inadequately developed.

23. Major barriers to addressing these gaps include a lack of investment, enabling infrastructure, such as roads and power, and the highly fragmented nature of the industry.[22] To address these gaps, a multi-dimensional approach is required that includes technology, policy support and training to meet supply requirements in a sustainable manner, along with better demand management and forecasting, and inventory planning.

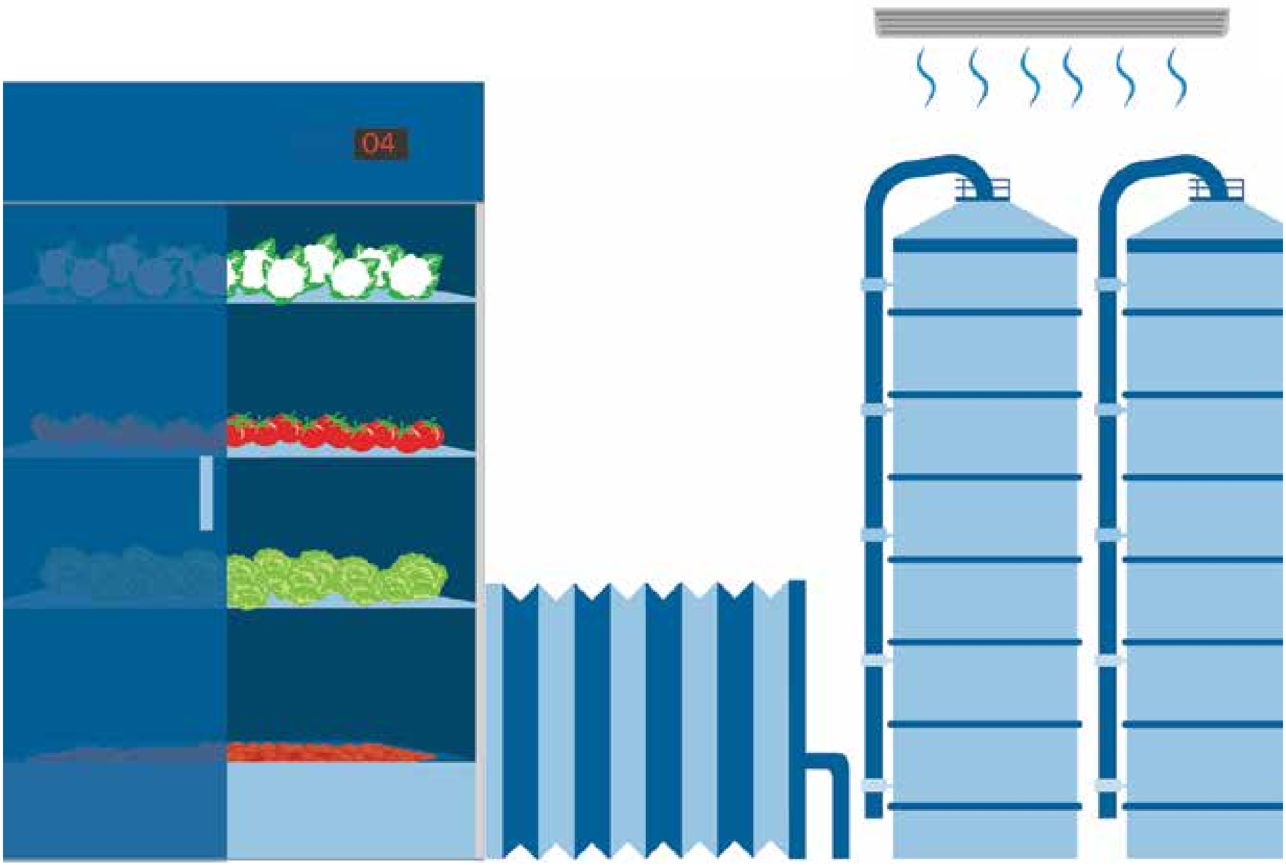
24. The study estimates that the market potential and investment opportunity in the cold chain and refrigeration sector will be US$29 billion by 2038. The agricultural cold chain sector alone has the potential to create 1.7 million jobs,[23] helping boost post-COVID recovery efforts.

25. Gaps in cold chain storage must be filled to minimize environmental impacts. This could lead to an emissions reduction potential of 77 $mtCO_2e$ annually by 2038.

26. This study identified two key concessional finance opportunities across the cold chain and refrigeration sector that have strong technical feasibility and can result in high climate and development benefits. These include:

- **Supporting the development of sustainable and energy-efficient end-to-end cold chain networks, including refrigerated transport.** Combined with a conducive policy environment and administrative structure to help support implementation, this opportunity has high technical feasibility. To ensure that development is carried out in a sustainable manner, the opportunity requires large investments. NCCD estimates that close to US$11.75 billion is required to develop the physical infrastructure and transport-related elements of the agriculture cold chain, with the biggest investment designated for building modern packhouses (about US$8.5 billion). In addition, there is also a need to modernize the retail end of the cold chain, requiring US$1.3-1.9 billion.[24] Decentralized cold chains need to be developed through support provided to farmer groups and agri-entrepreneurs. Business models for the decentralized adoption of renewable energy-based cold chain solutions at the farm or village levels – that can be implemented by individual farmers or farmer groups – should be developed. It is also important to support R&D for the development of low-cost renewable energy (RE) solutions that can be implemented at the farm gate and in the rural healthcare sector. There is also a a larger gap in the availability of refrigerated vehicles to meet demand in the country. The study explores the efficacy of using new business models and multimodal systems to overcome this gap. Domestic and commercial refrigeration, the end of a cold chain, is a rapidly growing sector in India and it is important that this growth is sustainable. Incentives and market transformation initiatives can help promote higher efficiency refrigerators. Setting up target-based programs, such as the state-operated Energy Efficiency Services Limited's (EESL's) UJALA[25] for light emitting diode (LED) bulbs, can lead to an increase in market share of 5-star refrigerators.

- **Promoting better operations and servicing through capacity building of all stakeholders and incorporating effective monitoring systems.** Capacity building of farmers and other users in post-harvest management and equipment handling is a requisite, offering development benefits for a trained workforce. Improved monitoring at different stages of the cold chain will also help reduce food and pharmaceutical losses. These interventions have the potential to attract concessional finance in the form of grants for capacity building as well as subsidies and loans for incorporating monitoring systems. These interventions can be implemented in partnership with national and state governments. Use of Internet of Things (IoT) based monitoring and an understanding of temperature requirements of different crops are necessary for a robust cold chain network. There is a need to promote the uptake of these systems in cold chains. With the incorporation of advanced technologies in cold chain, the skill levels of technicians to service newer equipment also needs to be enhanced. The creation of a certification program coupled with an awareness program on benefits of hiring certified technicians could spur demand for trained technicians.



Key Policy Approaches Needed to Scale Up Action in Cold Chain and Refrigeration

- Action plan for setting up small-scale decentralized cold chain links
- Committee to identify challenges in the implementation of "Integrated Cold Chain, Value Addition and Preservation Infrastructure" scheme, and implement committee findings
- Incentives and policies to jumpstart a market transformation program for improvements in equipment efficiency (domestic refrigerators and commercial deep freezers)
- Incentives to promote fuel free or electric reefer systems
- Policy and regulation to promote IoT for monitoring in cold chains and refrigeration
- Training and certification program for cold chain and refrigerator operators

Key Recommendations

Sector 3: Summary of Passenger Transport Air Conditioning

Opportunity in passenger transport air conditioning where leveraging concessional finance can deliver results with high climate and development benefits:

- Improving the efficiency of Mobile Air Conditioning (MAC) systems in passenger transport systems

27. Transport air conditioning, also known as MAC, has grown considerably in India. Over the last 15 years, an overall growth of over 12 percent and 2.5 percent Compound Annual Growth Rate (CAGR) has been observed in the road and rail transport sectors, respectively.[5] India's automotive heating, ventilation and air conditioning market size comprised US$822 million in 2018 and is projected to reach over US$2 billion by 2026, registering a CAGR of 11.6 percent.[26]

28. The Indian passenger car air-conditioners market alone is forecasted to surpass US$1 billion by 2023.[27] An analysis of the transport sector suggests that the MAC segment is projected to double in terms of energy consumption as well as total emissions within the next decade. ICAP has estimated that MAC is responsible for 15 to 18 percent of energy consumption in passenger vehicles, thereby projecting the highest energy demand for passenger cars followed by buses and then railways. In line with this, under a Business-As-Usual (BAU) scenario, refrigerant demand for the MAC sector is expected to increase by over four times, from an average of 5,172 metric tons (MT) in 2017-18 to 22,142 MT in 2037-38.

29. This study estimates that the market potential and investment opportunity in passenger transport is US$8 billion. Improving the efficiency of MAC systems in passenger transport vehicles (passenger cars, buses and rail) can result in an estimated 20 percent energy savings between BAU and improved efficiency scenarios. A further 29 percent carbon savings are possible by the mitigation of direct emissions through better MAC servicing and maintenance practices, and recovery at end of life. This opportunity will lead to direct climate benefits in the form of GHG emissions reduction as well as developmental benefits in the form of new jobs for servicing, maintenance and recovery at end of life.

30. The passenger transport sector in India provides considerable opportunity for emissions reduction given the country's needs for sustainable cooling in the future. The study estimates that this could lead to an emissions reduction potential of 14 $mtCO_2e$ annually by 2038.

31. As noted earlier, this study identified one concessional finance opportunity for passenger transport that has a strong technical feasibility and can result in high climate and development benefits. It includes:

- **Improving the efficiency of MAC systems in passenger transport systems.** The analysis in this study found that a sustainable cooling pathway for passenger transport in India is possible through the large-scale adoption of efficient MAC systems. It will also require optimization of the demand by shifting to public transport systems and new vehicle designs which help reduce cooling load. The technical and administrative feasibility of this opportunity are high given that proven efficient MAC systems are available globally and in India and through a series of supportive regulations. This can be achieved by building demand for energy-efficient MAC systems through S&L programs for vehicles and by leveraging R&D to support the improvement of MAC systems.

Key Policy Approaches Needed to Scale Up Action in Passenger Transport Air Conditioning

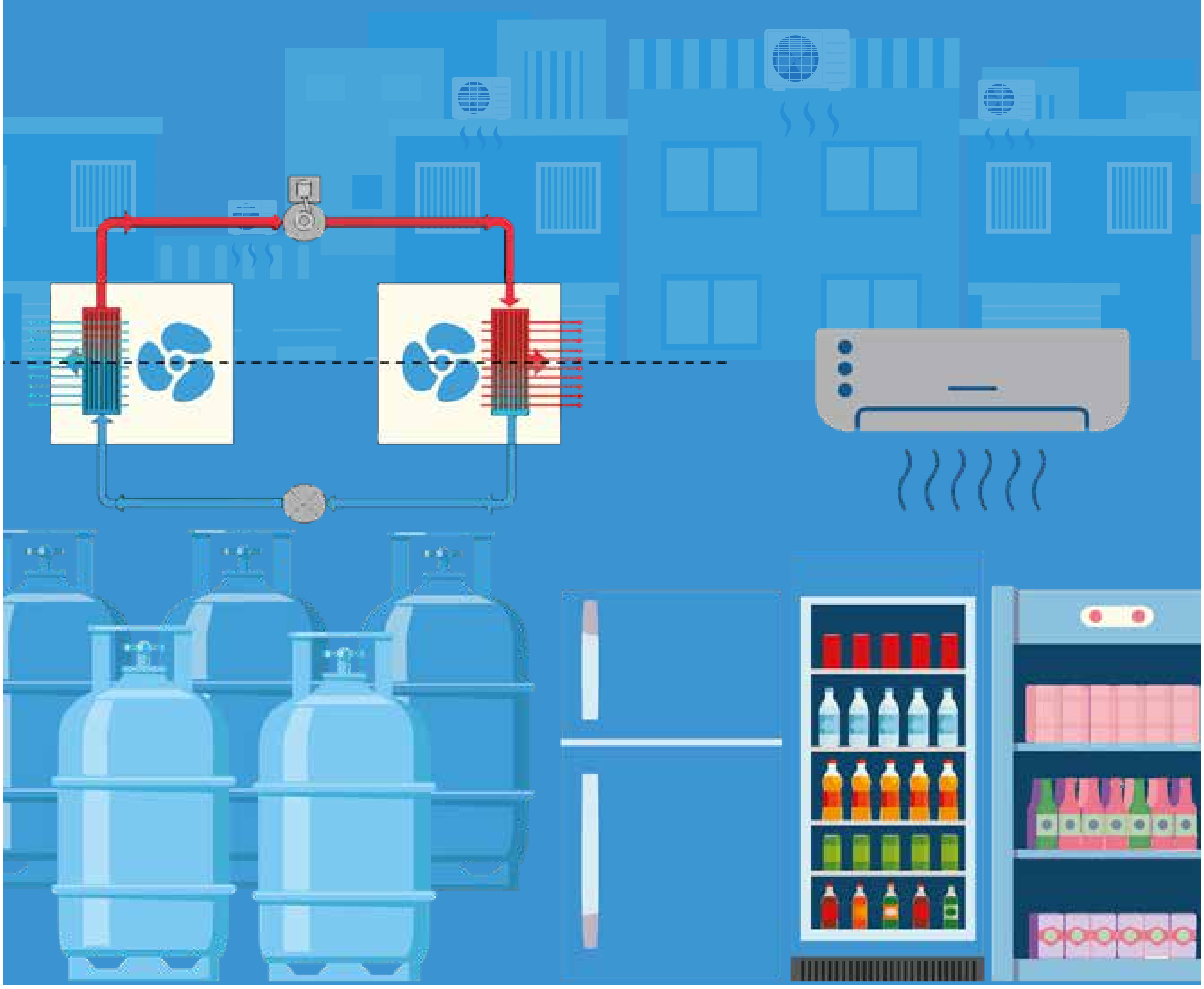
- Labelling system for cars to build public awareness on energy efficiency and emission savings
- Policy to promote private sector R&D on energy efficiency and low-GWP refrigerant-based MAC systems

Key Recommendations

Sector 4: Summary of Refrigerants

Opportunity in refrigerants where leveraging concessional finance can deliver results with high climate and development benefits:

- Improving servicing, maintenance, and disposal to reduce refrigerant demand across India



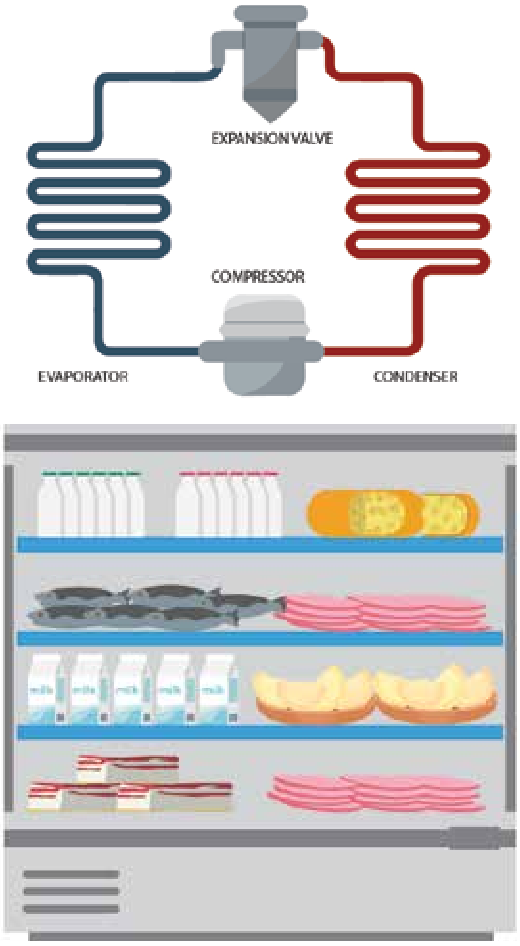
32. Refrigerant demand is expected to grow more than six times over two decades. In 2015, the air conditioning sector had the largest market share of all the sectors, estimated at 62 percent of refrigerant consumption in India. India's commercial refrigeration sector was the highest consumer of hydrochlorofluorocarbons at 22 million tons of refrigeration (TR), followed by mobile air-conditioning at 20 million TR.[5]

33. Under a BAU scenario, annual refrigerant demand for cooling across all sectors in India is expected to grow more than six times from 22,522 MT in 2017-18 to 149,392 MT in 2037-38.[5] The demand for refrigerant-based vapor compression technologies to meet the cooling requirements of buildings will primarily drive the projected refrigerant demand.

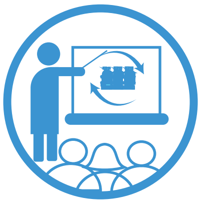
34. The analysis in this study showed that an effective phase down of hydrofluorocarbons (HFC) across India requires a two-pronged approach of ensuring a reliable low/zero -GWP refrigerants supply and efficient refrigerant demand management. While several alternatives to HFCs exist and are used across the world, these are yet to be put into large-scale commercial use in India with the intention of replacing HFCs. However, India's RAC industry has exemplified leadership in the adoption of the latest technologies. Studies have estimated that annual refrigerant demand in India could be reduced by 31 percent from a BAU scenario by 2038. This HFC phasedown could be supported through roadmaps, policies and public procurement to enable deployment of low-GWP refrigerants and technologies with lower refrigerant demand.

35. As noted earlier, this study identified one concessional finance opportunity for the refrigerants sector that has a strong technical feasibility and can result in high climate and development benefits. It includes improving servicing, maintenance, and disposal to reduce refrigerant demand across India. This can be achieved by:

- The uptake of trained service technicians to ensure proper servicing and maintenance of refrigerant-based equipment to reduce refrigerant leakage; and
- Measures to support the recovery, recycling and reclamation of refrigerants.



Key Policy Approaches Needed to Scale Up Action in Refrigerants



Policy and training programs to support recovery, recycling and reclamation or the effective destruction of refrigerants

Refrigerant disposal guidelines embedded within the Extended Producer Responsibility and e-waste guidelines for reclaiming electronic components at end of life, particularly for RACs

Technician training on the recovery and transport of refrigerants to reclamation centers; mandatory public sector utilization of licensed service technicians only

Conclusion:
Equitable Sustainable Cooling for All

36. Sustainable cooling is not just essential for economic growth but is critical for a country's health, security, and productivity. In a post-COVID world with rising global temperatures, familiar ways of doing business will not pay dividends. Creating a sustainable cooling strategy for India will require government and business leaders to transform their mindset and adapt to a new low-carbon landscape. It will necessitate new policies and actions across multiple sectors to support sustainable cooling growth. It is both an enormous challenge and an unprecedented opportunity. But it can be done.

37. As the analysis in this study shows, eight key clustered opportunities can be leveraged by concessional financing to advance ICAP goals and to implement sustainable cooling across India. Our analysis presents actionable roadmaps for four cooling sectors – space cooling, cold-chain and refrigeration, refrigerants and passenger transport air-conditioning – and identifies aligned national and state policies to enable convergence as well as the key stakeholders required for planning and implementation. Unlocking these opportunities can help India boost sustainable cooling investments, create jobs, reduce emissions and secure the supply chains of food, medical care products and health infrastructure.

38. Building a conducive policy, business and institutional sustainable cooling ecosystem will require the support of government alongside partnerships between the public and private sectors and civil society. Private sector investment alone will not enable the growth, scale and speed that is required without significant and robust government action. A coalition of public and private actors is required, one where government action can create the necessary regulatory and institutional framework to foster innovation and investment.

39. Across India, precedents for cross-sectoral transformative change on such a large scale already exist. Take, for example, India's recent uptake of LED lighting, one of the most remarkable energy-efficient transitions seen anywhere in the world. Thanks to a policy initiative known as Unnat Jyoti by Affordable LEDs for All or UJALA,[25] the Indian government procured LED bulbs for the national market, lowering prices through competitive bidding. A state-owned company, Energy Efficiency Services Limited (EESL), was created to distribute LED bulbs to citizens. Since beginning in 2014, EESL has distributed millions of LED bulbs and energy-efficient fans with an estimated energy savings of nearly 48 billion kilowatt hours (kWh) per year and estimated annual GHG emissions reduction of nearly 39 million mtCO_2e.[29]

40. India's LED bulb transition offers a roadmap to develop a similar model at scale to support the uptake of affordable energy-efficient fans for low-income households across India. Given rising temperatures, ICAP estimates an explosive, nearly two-fold, growth in the stock of fans from 450 million units in 2017 to 950 million by 2038.[5] By offering energy-efficient fans to the market, this offers a potential to save

20 terawatt hours by 2038[5], the equivalent of nearly 2.5 million tons of coal. With adequate incentives, strategic and multifaceted policy initiatives, and an appropriate policy ecosystem, the Government of India can jumpstart the creation of a market for energy-efficient cooling technologies such as BLDC fans – low-energy consuming fans that create less noise and have long lifespans. Initiatives such as India's PMAY – a government scheme to provide 20 million affordable homes to India's rural and urban poor by 2022 – could be galvanized to distribute energy-efficient BLDCs. Government supported models such as PMAY could be also explored to enhance the uptake of efficient RACs in middle-income households.

41. To turn ICAP's vision into a reality, a flagship Indian government mission to galvanize 'Thermal Comfort and Sustainable Cooling for All' should be established. This can be achieved by enabling resource flow from both public and private sectors as well as promoting convergence across central, state and local levels. India's national missions including Smart Cities, Swachh Bharat, Jal Jeevan and Make in India provide applicable roadmaps for decentralizing objectives across India's complex federal structure and inspire target-based interventions for different sectors. Streamlining budgetary allocations and financial flows could also help provide the institutional framework for continuous monitoring and evaluation of ICAP implementation to inform planning across sectors. India's Jal Jeevan mission to provide clean tap water to every union territory and state by 2024 provides an excellent budgetary allocation roadmap. A tap in every home may seem like an ambitious aim for one of the most water-stressed countries in the world. However, Jal Jeevan's success has been grounded in a solid regulatory framework that allocated funds under individual State Action Plans, approved by the Department of Drinking Water and Sanitation. In 2019, at the outset of Jal Jeevan, about one-sixth of households in India had a clean water tap. Now, almost half have one.[30]

42. Building a conducive policy environment will also help spur action and investments by the private sector toward sustainable cooling. As the results in this study show, concessional finance by multilateral development banks, financial institutions and the private sector will play a key role in helping India develop financial instruments and innovative models to accelerate the adoption of sustainable cooling measures. These innovative financial instruments will be crucial to develop and transform the cooling market in India. Leveraging the power of concessional finance constituted a key step in the creation of India's giant 750 megawatts (MW) Rewa solar park, an ambitious attempt by the state government of Madhya Pradesh to push the boundaries of India's private renewable energy market. Driven in part by prescient long-term planning, capital availability and market-based solutions, in the past decade, India has purposefully transformed its energy sector, emerging as a global champion of solar power.

43. India stands at historic crossroads. Providing sustainable cooling and thermal comfort for all will require investment, ingenuity and innovation. The good news is that there is no shortage of commitment and enthusiasm to take India's cooling advances into a new era of opportunity. Thanks to the policies laid out in the ICAP, new technologies and scientific findings, India is already on a path to rapidly scale up policies and practices to enable the market transformation for high-impact space cooling technologies. Deploying 'living laboratories' for thermal comfort – spaces where users and researchers can collaborate and create energy-efficient solutions for affordable cooling – will enable the government to pilot multi-stakeholder engagement and new technologies. So too will supporting the development of sustainable and energy-efficient cold chains, incorporating effective monitoring systems, and promoting better operations and servicing through the capacity building of all stakeholders.

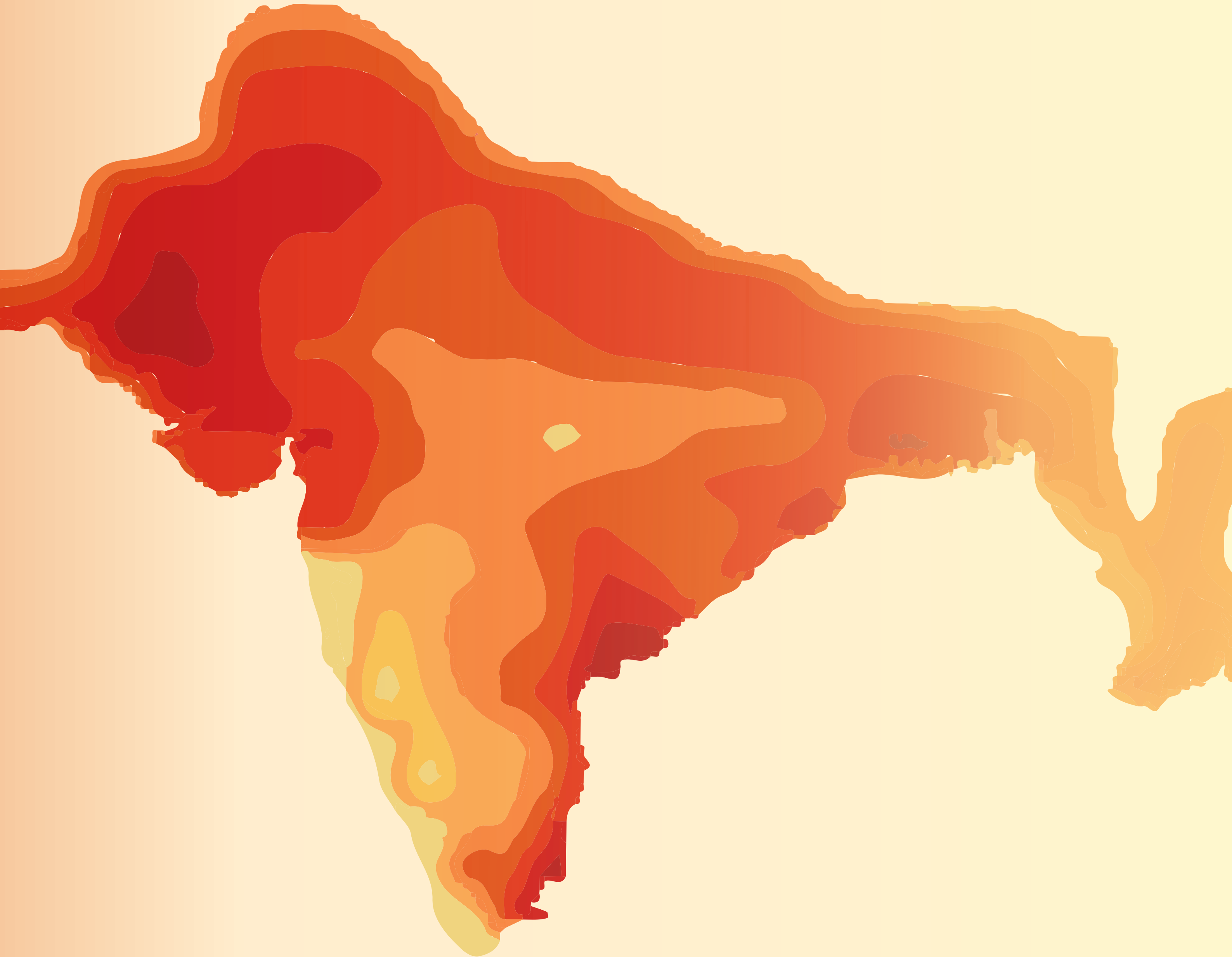
44. As India's brutal spring of 2022 has already shown, the poor bear a disproportionate burden of a hotter planet. Thermal comfort is not a luxury but a human right for all. Implementing a sustainable cooling strategy for India presents a multi-sectoral opportunity for the country to meet its development and climate goals, and for those at the bottom of the economic ladder to avoid one of climate change's most destructive human hazards. Thanks to the eight investment opportunities outlined in this study, India's government, multilateral development banks, financiers, the private sector and civil society now have a chance to make ICAP an actionable reality.

What is Concessional Finance?

Concessional finance is below market rate finance provided by major financial institutions, such as development banks and multilateral funds, to developing countries to accelerate development objectives. The term concessional finance does not represent a single mechanism or type of financial support but comprises a range of below market rate products used to accelerate a climate or development objective.

Chapter 1

Introduction



1.1 Cooling India: Development Prerogatives and Need for Sustainable Cooling

45. India will witness rising temperatures and heat stress due to climate change and will require massive cooling infrastructure to mitigate negative impacts on health and productivity. India, with its predominantly tropical climate, is experiencing escalating temperatures along with population growth and rapid urbanization, contributing to a steep increase in cooling demand for which India will require massive cooling infrastructure across sectors.[31] Currently, in India, the wet-bulb temperature[iii] during the worst heat waves rarely, if ever, exceeds 32°C (degree centigrade).[1] However, climate models project that these temperatures could exceed the survivability threshold (that is, 35°C) at a few locations in the Chota Nagpur Plateau and North-Eastern India under future climate scenarios of the Intergovernmental Panel on Climate Change's (IPCC's) Fifth Assessment Report, known as Representative Concentration Pathway (RCP)

India could become one of the first places in the world to experience heat waves that cross survivability limit.

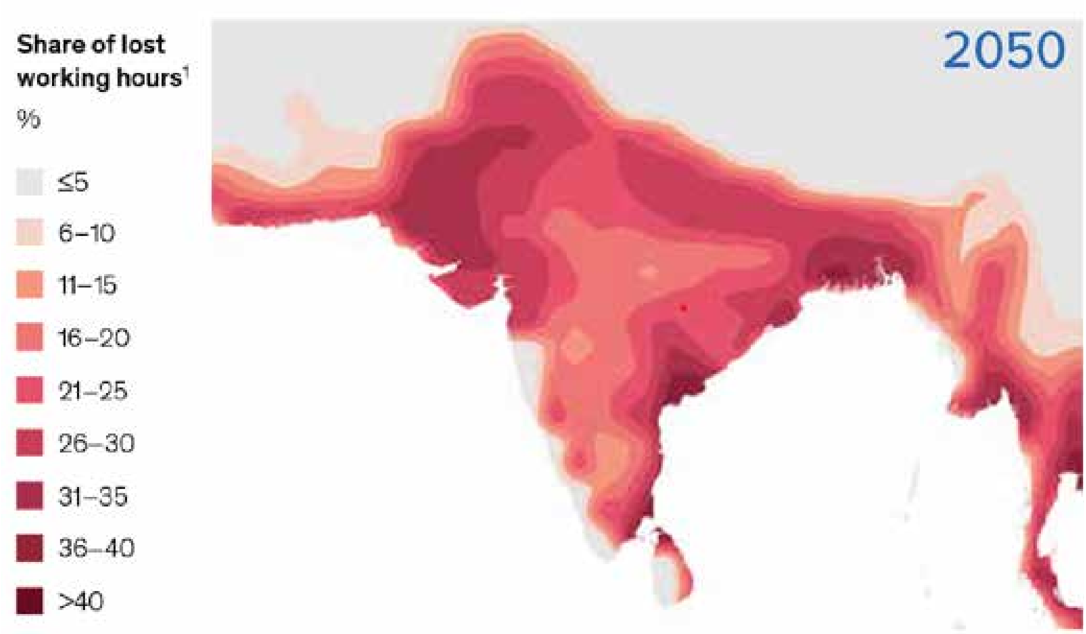


*Figure 1: Rising temperatures across India [*McKinsey. (2020). *Climate risk and response: Physical hazards and socioeconomic impacts. Will India get too hot to work? McKinsey Global Institute]*

[iii] Wet-bulb temperature is an indicator that combines air temperature and relative humidity. It provides a more accurate measure of heat stress on the human body than air temperature alone.

scenarios. Wet-bulb temperatures are projected to approach the 35°C threshold under RCP8.5 scenario by the end of the 21st century over the Ganges River valley, North-Eastern India, eastern coast of India, and Chota Nagpur Plateau.[32] Under the RCP4.5 scenario, vast regions of South Asia are projected to experience episodes exceeding 31°C, which is considered extremely dangerous for most humans. Urban heat-island effect may amplify the effects in urban or peri-urban centers exposed to these temperatures.[1] Without targeted adaptation actions that provide access to sustainable cooling, around 160-200 million people could be exposed to lethal heat waves as early as 2030 in India annually. Under a Business As Usual (BAU) scenario for air-conditioning growth till 2030, only about half of the population will have access to air-conditioning.[1] Access to cooling for the rest of the population will require the implementation of other measures. As of 2017, heat-exposed work[iv] contributed to about 50 percent of India's Gross Domestic Product (GDP), drove about 30 percent of the country's GDP growth, and employed about 75 percent of its workforce, i.e., 380 million people.[1] Ensuring thermal comfort for all will be critical to mitigate negative impacts on health and productivity.

46. Sustainable cooling can support India's development and help in a green recovery from COVID-19. Cooling is a developmental

[iv] As per the McKinsey (2020) study, exposed sectors include exclusively outdoor sectors such as agriculture, mining and quarrying as well as indoor sectors with poor air-conditioning penetration including manufacturing, hospitality and transport.

necessity and will contribute to the achievement of several Sustainable Development Goals (SDGs) including no poverty (SDG 1), zero hunger (SDG 2), good health and wellbeing (SDG 3), affordable and clean energy (SDG 7), decent work and economic growth (SDG 8), sustainable cities and communities (SDG 11) and climate action (SDG 13). A sustainable cooling strategy for India will also help in post-COVID recovery by creating jobs, securing the supply chains of medical care products and food, and boosting the economy.[33] The development of the agriculture cold chain sector alone has the potential of creating 1.7 million jobs.[23] Further, the servicing of low-Global Warming Potential (GWP) refrigerant air-conditioning units is expected to see a 10-fold increase in jobs over the next two decades from a base of 0.2 million technicians in 2017 to 2 million.[15]

47. Cooling will contribute to the increase in refrigerant and energy consumption and Greenhouse Gas (GHG) emissions with space cooling having the largest share amongst all sectors. Annual carbon emissions from space cooling in buildings, Mobile Air Conditioning (MAC) (i.e., for passenger transportation), refrigeration (domestic and commercial), cold chains (agriculture and pharmaceuticals) and industrial process cooling in India stood at 208.7 metric ton of carbon dioxide equivalent ($mtCO_2e$) in 2017,[28] which was 8 percent of India's total GHG emissions in 2016 (i.e., 2,531 $mtCO_2e$).[34] Figure 2 shows that space cooling in buildings has the largest current and projected cooling demand, refrigerant demand, energy consumption and associated GHG emissions as compared to other sectors, namely cold chain and refrigeration and passenger transport air-conditioning.

By 2027	Growth from 2017	Space Cooling	Cold Chain and Refrigeration	Passenger Transport Air Conditioning
By 2027	Cooling Demand/yr	4x to 246 M TR (↑718)	2x to 45 M TR (↑93.9)	3x to 74 M TR (↑151.5)
	Refrigerant Demand/yr	3x to 46,830 MT (↑117,700)	2x to 4,724 MT (↑9.775)	2x to 12,199 MT (↑19,181)
	Energy Consumption/yr	2x to 24.1 mtoe (↑50.21)	3x to 15.6 mtoe (↑28.35)	2x to 12.6 mtoe (↑25.7)
	Carbon Emissions/yr	2x to 284 $mtCO_2e$	2x to 115.1 $mtCO_2e$	2x to 22.6 $mtCO_2e$

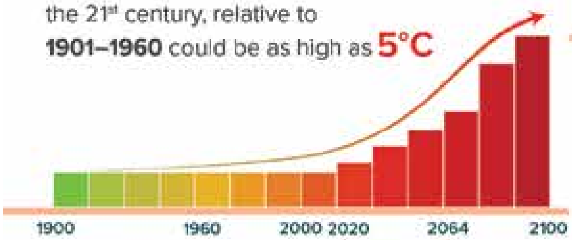
MTR: Million Ton of Refrigeration; MT: Metric Ton; mtoe: Million Ton of Oil Equivalent; mtCO2e: Million Ton of Carbon Dioxide Equivalent; (↑XX): Indicates the increased value in 2037

Figure 2: Annual growth in cooling demand, refrigerant demand, energy consumption and GHG emissions[28, 5]

Need for Sustainable Cooling Access Across Sectors in India

Climate change will lead to a rise in temperatures and shifts in **spatio-temporal trends** of heat wave events across India

On average, projected change in temperature by the end of the 21st century, relative to **1901–1960** could be as high as **5°C**



under RCP 8.5 emission scenarios

Projections also suggest increase in **Heat Wave Frequency (HWF)** and **Heat Wave Duration (HWD)** in India

HWF and HWD will increase significantly over central and northwest India between **2020-2064**

HWD **4-7** days/decade

HWF **0.5** events/decade

India's access to cooling across sectors remains low

Low per capita annual energy consumption of **69 kWh** for space cooling, compared with the global average of **272 kWh**

As of 2018, merely **8%** of households owned air-conditioning systems

In urban residential buildings current requirement for cooling access is **3.5** times that of consumption

US$313 million/year loss

25% 20%

20% of temperature sensitive healthcare products and **25%** of vaccines amounting to **US$313 million/year** are damaged and degraded due to broken cold chains

US$13 billion/year loss

4%

96% loss

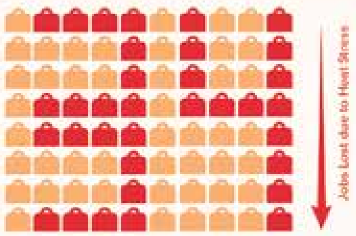
Only **4%** of fresh produce is covered by cold chains leading to estimated food loss of **US$13 billion/year**

45% of India's peak electricity demand in 2050 is expected to come from space cooling alone

By 2030

About **40%** of India's GDP will still depend on heat-exposed work.

Lost labour hours from rising heat and humidity will lead to **2.5% - 4.5%** GDP loss in India equivalent to roughly **US$150-250 billion**.



34 million of the global **80 million** job losses associated with productivity decline due to heat stress will be in India.

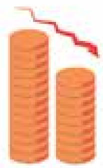
Lack of cooling access will have significant negative impact on

Wellbeing

Food security

Productivity (jobs lost from heat stress)

Access to Pharmaceuticals



GDP

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1.2 Study Objectives and Methodology

48. The ICAP was launched to provide sustainable cooling and thermal comfort for all while securing environmental and socioeconomic benefits for the society. Anticipating the multifaceted cooling energy trends and challenges that India would have to confront, the Government of India launched ICAP in 2019. It presents a multistakeholder driven comprehensive framework for achieving a sustainable cooling roadmap across various sectors, covering residential and commercial buildings, cold chains for agriculture and pharmaceuticals, refrigeration, passenger transport and industries. The plan provides "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 (2017-18 to 2037-38)", covering short-, medium- and long-term recommendations.[11] ICAP highlights synergies of its recommendation with existing governmental schemes and programs. Figure 3 presents its thematic areas and goals.

Thematic Area

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

Goals

- Reduce cooling demand across sectors by 20% to 25% by 2037-38
- Reduce refrigerant demand by 25% to 30% by 2037-38
- Reduce cooling energy requirements by 25% to 40% by 2037-38
- Recognize "cooling and related areas" as a thrust area of research under national Science & Technology Program
- Training and certification of 100,000 servicing sector technicians by 2022-23, synergizing with Skill India Mission

Figure 3: Thematic areas and goals of ICAP[5]

49. The World Bank study aims to develop an actionable roadmap comprising policy, investment and knowledge interventions to help achieve ICAP goals. The study has taken forward the ICAP analysis and recommendations by:

- Proposing short-term (2022-24), medium-term (2025-30) and long-term (2031-38) interventions in each cooling sector to:
    - Implement the ICAP recommendations;
- Identify additional opportunity areas which have not been covered in the ICAP but are critical to a sustainable cooling pathway for India, such as demand side interventions in space cooling, heat stress in cities, etc.; and
- Prioritize sustainable cooling opportunities for concessional financing and private sector investments.

50. The study undertook extensive literature review and stakeholder consultations to arrive at prioritized opportunities in the cooling sector. A series of interconnected steps were followed to identify holistic, inclusive, viable, specific and scalable interventions that can operate through partnerships with various actors and add impetus to the implementation of ICAP goals. The study focused on all identified thematic areas under ICAP including space cooling in buildings, cold chain and refrigeration, transport air-conditioning and refrigerants (covering the ICAP thematic areas of Research and Development (R&D), refrigerant demand & indigenous production, and refrigeration & air-conditioning servicing sector). As a result, it presents actionable roadmaps for each of the cooling sectors as well as prioritized opportunities for concessional financing and private sector investments. The roadmaps have also identified aligned national and state policies for convergence as well as key stakeholders required for planning and implementation. To begin with, an extensive literature review was carried out under this study, with a detailed analysis of the existing policies, programs and initiatives in India that are directly or indirectly relevant to the multisectoral actions recommended under ICAP. This analysis covered the existing governmental schemes and programs mapped in ICAP and went beyond to identify any other relevant policies and programs to identify areas for strengthening existing policies and formulating new ones in each of the cooling sectors. Building on the ICAP sectoral analysis for cooling demand, energy savings and emission reduction, the study identified key opportunity areas for cooling in each sector and collected data on their investment potential or market size and developmental benefits (such as job creation potential, and so on). The key barriers for unlocking each opportunity area were identified through literature review and extensive consultations with government and private sector stakeholders. This included identification of the associated institutional, financing, regulatory and market barriers and required interventions. The study has followed a highly consultative process to help identify and prioritize opportunities and their associated interventions which are pragmatic, implementable and have the desired interest and buy-in of the key stakeholders in all cooling sectors and across their value chains.

51. This World Bank study identifies eight sustainable cooling opportunities where multilateral development banks and financial institutions can play a significant role in advancing the goals of ICAP in India. The study began by analyzing the landscape of sustainable cooling interventions which were clustered based on institutional set up, ease of implementation and complementarity of actions. This clustering resulted in a total of 10 opportunities in space cooling, four in cold chain and refrigeration, two in passenger transport air-conditioning and three in refrigerant sectors. Following this, a multi-criteria prioritization framework was applied. The criteria assess climate and development benefits and implementability for all clustered opportunities. The analysis has been presented as part of the sectoral chapters in this report. Further the role of concessional financing and private sector investments was evaluated leading to prioritization of eight key clustered opportunities where Multilateral Development Banks (MDBs) and Financial Institutions (FIs) can play a significant role in advancing the goals of ICAP and sustainable cooling in India. The multicriteria framework is explained in detail in Annex 1. The sectoral chapters present actionable roadmaps for the prioritized clustered opportunities covering short-, medium-, and long-term interventions. The roadmaps for the remaining opportunities are provided in Annexes 2 to 5.

Chapter 2

Space Cooling

2.1 Summary

52. Exponential growth is projected in space cooling demand over the next two decades, making it the largest opportunity for achieving ICAP goals. India will witness 2-2.5x growth in floor area across residential and commercial buildings between 2018-38.[5,35] Climate benefits in this upcoming building stock can be maximized if passive measures are combined with efficient technology adoption.

53. Integrating passive cooling strategies in buildings can achieve a 20-30 percent reduction in projected energy use in 2038.[35] This has significant potential to improve thermal comfort, especially for vulnerable communities in affordable housing with limited access to space cooling technologies. Similarly, integration of passive measures such as blue-green infrastructure in city planning can reduce urban temperatures and cooling energy demand. Each 1°C drop in air temperature has been found to lower peak electricity demand for cooling by 2-4 percent.[36]

54. Efficient cooling technologies have the potential to achieve 30 percent energy savings from projected demand by 2038.[5] Robust efficiency standards and market transformation initiatives that address higher upfront costs, especially for high impact cooling technologies such as ceiling fans, room air-conditioners and chillers can support the transition to best available technologies sooner. In areas with significant cooling demand, shifting to highly efficient District Cooling Systems (DCS) is recommended. Thirty percent of the commercial space cooling demand in 2038 can be potentially met through DCS, if viable business and implementation models are established in the Indian context.[17]

55. Together these four key impact areas detail a holistic approach to meeting space cooling requirements sustainably by prioritizing 'thermal comfort for all' and facilitating cooling access, while reducing the impact on the electricity system.

2.2 Sectoral Overview

56. Sustainable space cooling interventions need to prioritize 'thermal comfort for all' and facilitate cooling access while reducing impact on the electricity system. Space cooling is the fastest growing energy use in buildings globally. At least 45 percent of India's peak electricity demand in 2050 is expected to come from space cooling alone.[13] This will require sizable investments in creating costly peak generating capacity and result in a significant increase in GHG emissions, unless suitable low energy alternatives are available to meet thermal comfort needs in buildings. Access to space cooling is also a development need, crucial for wellbeing and productivity in hot climate countries such as India. Within this context, the space cooling strategy lists four key impact areas detailing an approach to meeting space cooling requirements sustainably:[37]

i. Reduce demand by integrating passive measures in buildings;
ii. Improve efficiency of cooling technologies;
iii. Shift demand to district cooling technologies; and
iv. Aid cities' adaptation into managing heat stress.

57. Climate benefits can be maximized when passive measures are combined with efficient technology adoption. The four strategic interventions focus on demand reduction through passive measures in buildings and cities as well as supply-side solutions through efficient cooling technologies. The interventions are closely interlinked and provide a holistic response for achieving sustainable space cooling. Passive cooling measures limit heat gain inside buildings and improve thermal comfort. These measures are the first step towards meeting cooling requirements sustainably and are especially important as a large section of the population might have limited access to cooling technologies for meeting thermal comfort requirements. They also help in reducing overall demand for cooling and associated energy consumption and GHG emissions, even when cooling technologies, such as air-conditioning, are used. Meeting this cooling demand through efficient cooling technologies in buildings, and through district cooling technologies that aggregate cooling demand across multiple buildings, can further significantly reduce cooling energy requirement, including peak power demand. Finally, the interlinkages between overheating and adverse productivity and health impacts, especially in urban areas due to heat absorption by built-up area, further reiterate the need for passive cooling measures in buildings and urban development.

2.3 Landscape of Cooling Opportunities in the Sector

2.3.1 Reduce Demand by Integrating Passive Measures in Buildings

58. India will witness significant growth in floor space; hence, it is imperative to construct efficient buildings. Figure 4 shows the projected growth in residential and commercial floor area over the next two decades. Passive cooling measures help in improving thermal comfort and reduce the need for active cooling in buildings. Policies and investments must prioritize climate responsive construction to avoid long-term lock-in of inefficient building stock. As per

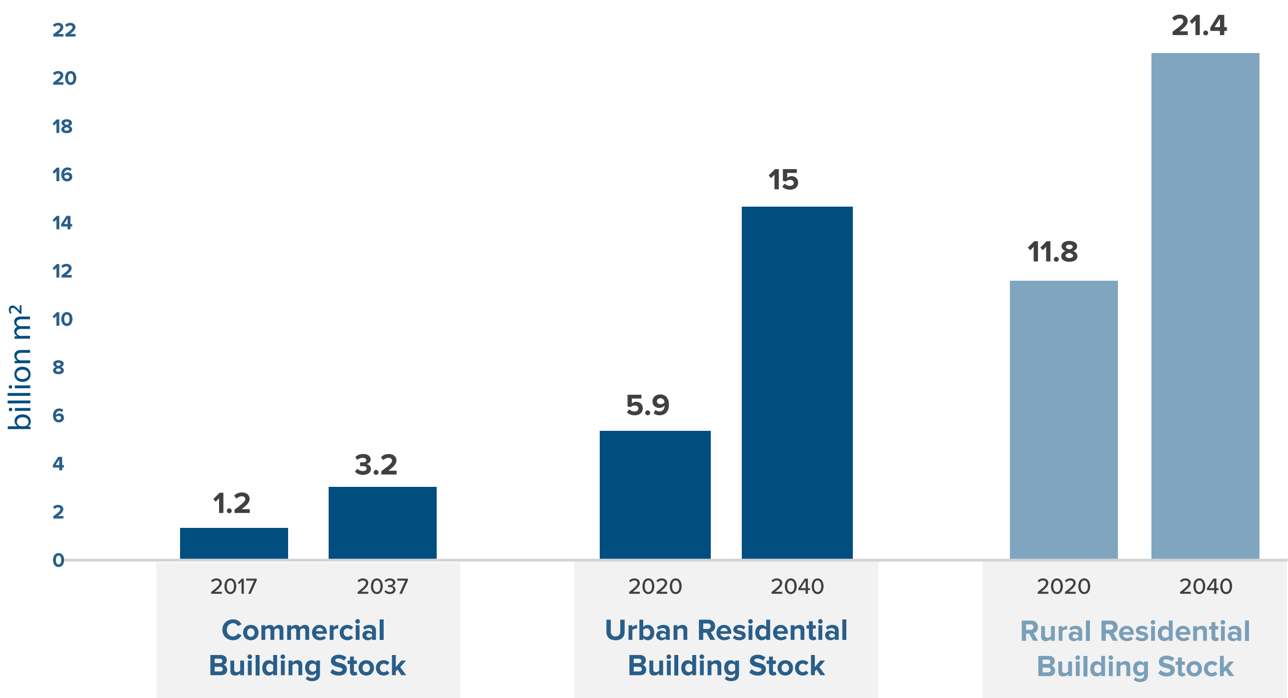

Figure 4: Projected growth in commercial and urban and rural residential floor space[5, 35]

International Finance Corporation (IFC), the green buildings market in India will have an investment potential of about US$1.25 trillion for residential buildings and US$228 billion for commercial buildings.[14]

59. Electricity use in the residential sector is nearly three times that of the commercial sector. India's residential sector is responsible for 24 percent of the total electricity use in the country[38] which is projected to increase to 39 percent in 2047, overtaking industry to be the highest electricity consuming sector.[39] Space cooling is expected to contribute a significant share of this electricity use. As per a recent study that evaluated the long-term space cooling demand for meeting thermal comfort requirements for all urban households in India, close to 30 percent reduction in projected cooling energy requirement can be achieved in 2050 through efficient building envelope measures alone. A combination of successively stringent codes in new buildings and retrofitting of existing buildings can save almost 100 terawatt-hour (TWh)/year of electricity by 2040 and 180 (TWh)/year by 2050. Additionally, the study estimated that the reduction potential increases to over 50 percent, if both passive measures and efficient cooling technologies are prioritized.[35]

60. Residential building energy code implementation can significantly reduce the projected growth in space cooling demand. In new residential buildings, implementation of mandatory building energy codes and green building ratings as a market instrument can significantly help in limiting energy use and GHG emissions from space cooling. The residential building energy code – Eco Niwas Samhita (ENS)[40] – is currently voluntary, as it is not supported by the Energy Conservation Act 2001 in its current form. It is, however, expected that the Act will be modified soon to include residential buildings as a key sector with potential for energy efficiency measures. This amendment will enable states to mandate the adoption and enforcement of ENS. Energy and cost-benefit analyses show that the implementation of ENS Part 1 (building envelope) is cost-effective and requires around 1-2 percent of additional construction cost for integrating passive building envelope measures.[35] Though first costs are low, developers will need a business case combined with effective enforcement mechanisms for code implementation. Making efficient building materials and technologies easily accessible and bridging the additional cost through market transformation approaches combined with construction guidance and skill-based training can significantly help with code implementation in the initial phase. Code implementation can substantially reduce the projected growth of GHG emissions from space cooling demand in the residential sector. It also has high potential for development benefits in terms of health and productivity gains for occupants due to improved thermal comfort as well as creation of new jobs in the sector. This opportunity also scores high on technical feasibility as solutions exist; however, large-scale implementation will depend on effective enforcement by urban local bodies.

61. The Pradhan Mantri Awas Yojana (PMAY) can be leveraged to effectively mainstream passive cooling measures in government-supported housing construction. PMAY was launched in 2015 by the Government of India. It aims to construct 11.2 million houses under the PMAY-Urban[v] mission and around 29.5 million rural houses as part of the PMAY-Rural[vi] mission. Government-supported affordable housing programs hence provide a significant opportunity for integrating passive measures in a large segment of new residential construction leading to direct climate benefits. Additionally, improving thermal comfort in social housing is critical for equitable and sustainable cooling access in low-income households, resulting in significant development benefits.

62. Retrofitting houses and upgrading them to meet energy efficiency and thermal comfort standards will become crucial in the near future. India's residential sector has been growing rapidly and building energy policies have rightly focused on new buildings first, as it is easier and relatively more cost-effective to integrate passive measures in new buildings than retrofitting later. However, in another decade, India's rate of construction is likely to start declining. Experts also point out that current housing construction is not accounting for thermal comfort parameters and space cooling requirements of occupants. Housing built since 2000 will still be around till 2050. This, as well as housing to be built in the near future, will need to adapt to respond to a changing climate with higher average summer temperatures, frequent and more intense heat waves and increasing temperatures due to Urban Heat Island (UHI) effect in urban areas. There is, hence, an urgent need to also focus on identifying retrofitting solutions that are suited to India's construction context, especially for social housing. While significant climate and development benefits are envisaged from housing retrofits, there are challenges due to lack of appropriate technical solutions and policy support. Fuel poverty and weatherization assistance-related retrofit programs in the U.S. and Europe, respectively, provide vital entry points to assess various programs, including governance and financing instruments that can be adapted to India's context.[41]

63. The Energy Conservation Building Code (ECBC)[vii] is a key policy for new commercial buildings to integrate energy efficiency measures. All non-domestic buildings are addressed together in India's ECBC. Commercial buildings are responsible for nearly 8 percent of the total electricity use in the country currently.[38] Commercial buildings have significant cooling energy demand as the adoption and

[v]PMAY: Government of India's affordable housing mission provides direct monetary assistance or subsidized credit towards construction of low- and middle-income housing. https://pmaymis.gov.in/

[vi]https://pmayg.nic.in/netiay/home.aspx

[vii]ECBC was released in 2007 and revised for stringency in 2017. The code includes guidance on building envelope, heating, ventilation and air-conditioning, other building services, and also renewable energy integration in commercial buildings. It is applicable to all new commercial buildings that have a connected load of 100 kW or greater, or a contract demand of 120 kVA or greater.

intensity of air-conditioning is high. As per ICAP, approximately 50 percent of the total commercial floor space in 2038 is likely to be air conditioned. ECBC is a key policy for new commercial buildings to integrate energy efficiency measures and is applicable to all large nondomestic buildings including offices, malls, hotels, hospitals, airports, educational institutions, and so on. ICAP estimates that rigorous implementation of ECBC can reduce around 32 million Ton of Refrigeration (TR), nearly 23 percent of the total projected cooling demand of 140 million TR in new commercial buildings by 2037-38. While around 20 states and union territories have notified adoption of ECBC, and a further 48 urban local bodies across eight states have also included them in modified building by-laws,[42] implementation by urban authorities is still limited and varies considerably across cities.[43] Multiplicity of government departments, lack of capacity within these to enforce, and reluctance on the part of building developers and the absence of a strong enforcement framework are key reasons for the slow implementation process.[44] A recent report by the Ministry of Environment, Forest and Climate Change (MoEFCC) on operationalizing ICAP recommendations for space cooling lists actions to be taken by a number of government ministries and departments to integrate ECBC within their construction activities.[42] This will help facilitate ECBC implementation across a large segment of government-led construction. However, implementation by the private sector is also needed. This requires a renewed focus on plugging in implementation gaps, especially by providing focused support to cities where construction rates of large commercial buildings are higher. Voluntary green building ratings systems (for example, Leadership in Energy and Environmental Design (LEED), Green Rating for Integrated Habitat Assessment (GRIHA), Indian Green Building Council (IGBC), Excellence in Design for Greater Efficiencies (EDGE)) have been more successful in the commercial building segment than residential buildings, especially driven by first movers in the market, and supported by organizational policies of large corporations requiring green buildings. These are a useful market mechanism to drive the construction of energy efficient commercial buildings.

64. Commercial building retrofit programs need to integrate building envelope solutions. Retrofitting of commercial buildings in India has largely focused on replacing cooling technologies and other appliances, including lighting, with limited building envelope upgradation. Similarly, retrofitting has not been a focus of commercial building energy policies. There is a need for R&D for building envelope solutions as well as a roadmap for retrofitting commercial buildings in the near term.

2.3.2 Improve Efficiency of Cooling Technologies

65. ICAP classifies building-level cooling technologies into three categories. ICAP discusses three types of cooling technologies: refrigerant based (room air conditioners and central air-conditioning systems), non-refrigerant based (fans and air coolers) and not-in-kind technologies (such as radiant cooling,[viii] indirect direct evaporative cooling,[ix] etc.).

66. Nearly 52 percent of the total space cooling electricity consumption is attributed to the adoption of a single technology – Room Air Conditioners (RACs) – largely used in residential buildings. Hence, the residential sector is likely to drive space cooling demand in the next 20 years. RACs will also account for 88 percent of the total refrigerant-based technology stock in 2037-28. RAC stock is projected to increase from about 55 million TR (2017-18) to 633.5 million TR (2037-38), with a potential to save 100 TWh by 2038 through efficiency improvements.[5] Currently, less than 10 percent of Indian households has access to air-conditioning. ICAP estimates that, by 2037-38, access will increase to about 40 percent households, with much higher adoption in urban areas as compared to rural households.

67. Most Indian households will continue to rely on non-refrigerant-based cooling technologies such as fans and air coolers. Air conditioner access is likely to be limited due to high upfront and operational costs and the requirement of reliable electricity supply, especially in rural areas. Hence, in the next two decades, a significantly higher percentage of households will rely on non-refrigerant-based cooling technologies. Fans and air coolers are low-energy and low-cost non-refrigerant-based technologies that are widely used across building types and in urban and rural areas. Ceiling fans are the most used type of fan, representing nearly two-thirds of the annual sales.[45] ICAP estimates a growth in the stock of fans from 450 million units (2017-18) to 950 million units (2037-38), with a potential to save 20 TWh by 2038 through efficiency improvements.

68. Central air-conditioning systems [chillers, Variant Refrigerant Flow (VRF[x]) and packaged Direct Expansion (DX[xi]) systems] are used in large commercial buildings and will account for 24 percent of the total space cooling electricity consumption in 2038. Amongst these, the larger savings potential is envisaged in chiller-based applications, representing nearly 72 percent of the total savings potential of 45 TWh from the three technologies in 2037-38.[5]

69. Enable market transformation towards super-efficiency for high energy impact cooling technologies. Figure 5 summarizes the energy savings opportunity for the six key cooling technologies discussed above, across the reference and intervention scenarios as estimated by ICAP. In the 2037-38 intervention scenario, efficiency savings of RACs are the most significant, followed by chillers and fans. Interventions are needed to align the market to super-efficient/best available technology standards along with suitable incentives to increase their adoption amongst consumers. Hence, market transformation towards super efficiency

[viii]Radiant cooling provides cooling by circulating cooled water through pipes embedded in floors, ceilings, etc., to absorb heat from the room.
[ix]In indirect/direct evaporative cooling, the primary air stream is cooled first with indirect evaporative cooling and then cooled further with direct evaporative cooling. This does not increase the humidity of the supply air.
[x]Variable refrigerant flow.
[xi]Packaged DX (Direct Expansion).

represents a key priority opportunity for reducing the growth in space cooling related GHG emissions. Technical feasibility for achieving super efficiency already exists, and the opportunity scores high on potential for both large-scale adoption and administrative feasibility of energy efficiency standards. Additionally, the opportunity can also lead to significant development benefits in the form of new jobs within the cooling

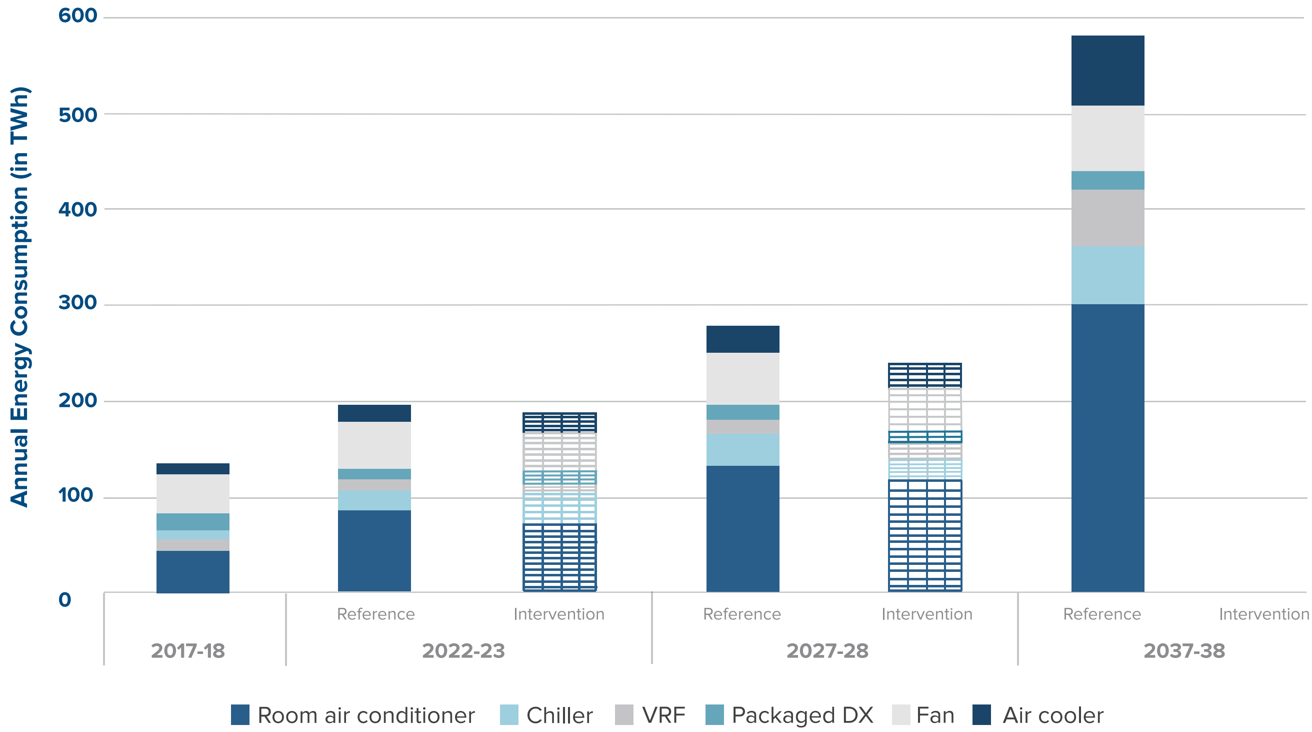

Figure 5: Projected annual energy consumption for key space cooling technologies in reference and intervention scenarios[5]

technology industry.

70. The efficient performance of central air-conditioning systems is highly dependent on not just selecting efficient components, but also on the Heating, Ventilation and Air Conditioning (HVAC) system design, operational and maintenance practices. Cooling energy performance of commercial buildings varies greatly, as commercial buildings comprise a large range of building types from offices, malls, hotels, hospitals, and so on. The HVAC design, operational and maintenance practices are hence closely linked to the type and use of the building. There is a need for a national benchmarking and disclosure policy for commercial buildings, with a focus on energy performance data for HVAC systems to improve operational energy use in centrally air-conditioned commercial buildings. Additionally, the current pandemic has also highlighted the issue of ventilation within centrally air-conditioned buildings. The possibility of increased transmission of the Coronavirus and infection rates prompted a worldwide discussion on ventilation standards and building design. Guidance for adequate ventilation rates in central air-conditioning systems along with change in standards to efficiently cool and dehumidify air, retrofitting guidance for existing HVAC systems, and checks for indoor air quality monitoring should be established. These, along with integration of adaptive thermal comfort standards in the operation of commercial buildings, have the potential to significantly alter the way commercial buildings are cooled, leading to both direct climate benefits and development benefits due to improved indoor air quality. Mixed-mode buildings with their reliance on natural ventilation, when weather conditions permit, can also greatly reduce the need for air conditioning and allow for adoption of low-energy, not-in-kind technologies.

71. Not-in-kind technologies can play a key role in increasing cooling access to multiple sectors with low levels of comfort cooling penetration. There has been limited adoption of not-in-kind technologies in commercial buildings as they need careful assessment for applicability depending on the climate, comfort requirements and building use. However, these technologies can play a key role in increasing cooling access to multiple sectors such as manufacturing, public spaces such as railway and bus stations, courts, and so on, with low levels of comfort cooling penetration currently. Studies carried out in several Indian manufacturing facilities with no or limited access to comfort cooling found that worker productivity reduced by 2-4 percent per° C above threshold comfort temperature.[46] The study also found that air-conditioning was not an economically viable solution in these sectors. A strong case for access to affordable, low-energy comfort cooling therefore exists in these sectors which will lead to high climate and development benefits. However, large-scale adoption needs concerted efforts to match technologies to building types/cooling requirements and support demonstration projects. There is also a need to develop business models to enable affordable comfort for productivity in these sectors to spur investment in supply chain development. Due to limited adoption of not-in-kind technologies, data about growth potential and resultant energy savings impact are not available. Further research in this area is needed to look at solutions for meeting thermal comfort and cooling needs of the vast, labor-intensive manufacturing sectors.

2.3.3 Shift Demand to District Cooling Technologies

72. Large-scale cooling requirements can be efficiently met through district energy technologies often using Cooling as a Service (CaaS) delivery models. District energy technologies such as district cooling[xii] or combined cooling, heating and power (tri-generation[xiii]) have the potential to reduce cooling energy requirement, including peak power demand, and refrigerant requirements considerably. Due to this, the role of distribution utilities also needs to be considered in enabling this

[xii]District Cooling Systems generate chilled water in a central plant which is then distributed to multiple buildings via underground insulated pipes for space and process cooling. Individual buildings benefit as they do not need to install their own chillers or cooling towers and instead purchase chilled water from the DCS operator.

[xiii]Tri-generation (also known as Combined Cooling, Heating and Power), an extension of cogeneration, is a process that provides cooling, heat and power generation from a single generator or process. Tri-generation can use a range of fuels such as natural gas, liquefied petroleum gas and biofuels to produce electricity and utilizes a part of the waste heat from the process to generate chilled water for air conditioning or refrigeration using an absorption chiller.

transition towards district cooling and CaaS delivery approaches.

73. Tri-generation has been a relatively unexplored technology in India. While there is some experience on tri-generation, especially in large hospitals, high capex has been a challenge for larger uptake. Additionally, there is limited awareness about the associated lower energy cost benefits and increased reliability due to captive generation. Tri-generation can reduce the primary energy demand of a consumer by 60-70 percent, increase overall efficiency by almost 75 percent, and cut GHG emissions by up to 30 percent.[47] With the increase in commercial real estate, the market for tri-generation technology has been estimated at 20 gigawatt (GW) in India while currently installed capacity is 1,000 megawatt (MW).[48,49] Tri-generation plants are highly reliant on natural gas currently; however, neither gas supply nor its pricing structure is established, which is also another significant challenge in scaling up the technology unless alternate fuels like bio-fuels are also considered.

74. DCS that aggregate different demand groups in a CaaS model are still at a very nascent stage in India. DCS that aggregate different demand groups such as mixed-use development, special economic zones, large commercial business districts, etc., in a CaaS model [also referred to as merchant district cooling by the United Nations Environment Programme's (UNEP's) study for India] are still at a very nascent stage in India with GIFT city in Gujarat as a prominent example.[17] Viable business and implementation models need to be established in the Indian context to support uptake of large merchant district cooling systems. In India's context, DCS can consume 20-30 percent lesser power than the most efficient conventional cooling solution, but savings become higher, about 60-80 percent, if compared to an average 3-star RAC. DCS potential for India has been estimated to be nearly 12.57 million TR (≈315 DCS plants) with an emissions reduction potential of 6.6 mtCO_2e per year by 2037-38 under an optimistic scenario[xiv] with a strong policy push as a city-led initiative. This would require an additional investment of US$35.9 billion.[17]

75. CaaS models can enable significant efficiency gains in operational energy cooling through better Operation and Maintenance (O&M) practices. CaaS is a model where consumers pay for the service rather than the cooling equipment. The most widely known model for this is the merchant district cooling system; however, CaaS models can utilize a range of other cooling technologies, beyond district cooling. CaaS models save the customer the significant upfront cost of selecting, procuring and installing air-conditioning technology as well as O&M costs, leaving the task of cooling provision to technology experts. As a result, CaaS removes a key energy efficiency barrier of split incentive[xv] in buildings. This is also a likely opportunity for Energy Service Companies (ESCOs) to provide sustainable

[xiv]An optimistic scenario with strong policy push: assumptions include 30 percent of total air-conditioning demand from new commercial buildings and 7 percent of total air-conditioning demand from new residential buildings in 2037-38.
[xv]Split incentive: the developer or building owner has no incentive to invest in efficient equipment as eventual buyers or tenants get the benefit of reduced energy bills.

and efficient cooling to businesses through innovative pay-per-use financing models. CaaS models can also extract huge efficiencies just through better O&M, data gathering and fine tuning systems to meet cooling requirements.

76. The uptake of tri-generation and DCS by cities will need business models and supporting policies with clear direction and vision. Based on the above analysis, it is evident that shifting high density cooling requirements in cities to district energy technologies will lead to multiple benefits in terms of significant reduction in the growth of space cooling related GHG emissions and averted power generation capacity. While these technologies have been proven in India and globally, high capex and low awareness of the benefits are key barriers for scaling up DCS and CaaS models.

77. Engaging with electric utilities will be beneficial for the transition to CaaS and district-energy infrastructure. The International Energy Agency (IEA) estimates that 28 percent of the total electricity consumption and 45 percent of India's peak electricity demand in 2050 will be from space cooling alone.[13] Peak demand necessitates the need for higher capacity and infrastructure requirements and has significant implications for the choice of generators, Renewable Energy (RE) integration, load factors and GHG emissions, which in turn drive the Distribution Companies (discoms) economics.[50] It is a serious concern because of its impact on the financial viability of the already debt-laden discoms due to the high cost of marginal power generation. Large-scale cooling aggregation can provide an opportunity to discoms to manage their rising peak load and further use it as a reliable revenue generator. Hence, adoption of DCS in areas with high density cooling requirements can reduce impact on the electricity grid, including peak load and power procurement requirements. To understand the benefits of this transition, utilities should be engaged to evaluate these impacts, including the role of off-peak tariff structures, large-scale integration of thermal storage and renewables in DCS.

2.3.4 Adapt Cities to Manage Heat Stress

78. Design of open spaces and blue-green infrastructure can significantly reduce heat exposure in cities. Overheating can be evaluated with respect to three criteria: thermal comfort in building design; loss of productivity linked to heat stress; and health impacts including heat-related illnesses and increase in mortality.[51] Along with appropriate passive measures in building design, construction and use of efficient cooling technologies to provide thermal comfort (as discussed in earlier sections), design of open spaces and blue-green infrastructure can significantly impact microclimates by reducing urban temperatures to increase urban resilience to future heat wave incidents. Cities with populations greater than 1 million may experience an annual mean air temperature difference ranging anywhere from 1-3°C to 12°C more than their surroundings due to

[xvi] UHI refers to the increase in microclimatic temperatures of city regions compared to the surrounding landscape due to an increase in built-up area and impermeable materials, reduced vegetation cover and fewer water bodies, leading to higher heat absorption in cities.

the UHI effect.[xvi,52] Higher temperatures also increase the demand for cooling and use of air-conditioning, while adversely impacting the efficiency of cooling technologies. An increase of every 0.6°C in air temperature leads to around 0.25–2.5 percent increase in peak electricity demand.[53] Additionally, air-conditioning, along with other combustion processes such as in industries and motorized transport, further adds to the heat balance in a city (through waste heat), creating a vicious cycle. Global warming is likely to exacerbate this increase in urban temperatures and heat wave incidents. Further, the urban poor are disproportionately affected by UHI impacts and heat stress in cities due to poor quality housing with limited access to cooling technologies often located in high density neighborhoods with few open green spaces.[54]

79. Mainstreaming passive cooling measures in urban planning is key to strengthening heat resilience in cities. Buildings and surface characteristics such as paving and greenery have maximum impact on urban temperatures at local scale.[36] While cool roof programs for existing public buildings and low-income housing have been piloted by cities in India for almost a decade[55,56,57,58] to achieve multiple benefits of thermal comfort in buildings and reduction of UHI impacts in cities, the recent interest in the potential of Nature-based Solutions (NbS) provides a much larger framework to design and embed adaptation solutions in urban planning. NbS are essentially an umbrella concept for ecosystem-related approaches and can include a range of measures within cities such as building level green roofs and walls; urban green areas such as street trees, house gardens; public parks; semi natural urban areas and urban forests; blue areas such as rivers, lakes, wetlands, etc.; green areas for water management such as sustainable urban drainage systems; and all other green areas in the city.[59] Mainstreaming passive cooling measures such as NbS in land use planning will have direct climate benefits, as well as significant development benefits related to health and productivity of people in urban areas. However, implementation is likely to be a challenge. Rapidly urbanizing Indian cities face challenges in assigning land for green spaces, urban forests and green corridors due to competing claims from construction of housing, industry and commercial areas that generate revenue as well as public infrastructure such as roads and water works, which drive land use planning in cities.[60]

80. Disaster management plans in India also recognize the need to adopt long-term heat resilience measures in cities. Effective management of heat waves has come into focus due to the development of urban heat action plans in India. Ahmedabad was the first city in India to come up with a dedicated Heat Action Plan in 2016.[61] The Heat Action Plan comprises four key strategies: operationalizing an early warning system, building public awareness on heat-related health risks and recommended actions, building capacity of health workers, and implementing measures to reduce heat exposure such as building cooling shelters while also building adaptive capacity through initiatives such as the Ahmedabad cool roofs[xvii] program, especially for low-income households. The focus, hence, is largely on effective disaster response in the event of an extreme heat wave incident. However, improvement of urban resilience to heat stress requires long-term measures, such as integration of NbS[xviii] in urban design and planning. The National Disaster Management Authority also recommends that long-term plans to manage heat stress need to include other sectors, and recommendations should be integrated with Disaster Management Plans at all administrative levels in urban and rural areas, based on hazard risk and vulnerability assessment.[62] This requires actions at two key levels: first, climate change impacts necessitate prediction of future risk using climate science, especially for heat wave incidents, which are likely to be more intense, frequent and of longer duration than before. Since this measure impacts many urban residents, development benefits from integration of long-term measures are high. However, implementation in the current framework of disaster response is likely to be challenging. To address institutional ambiguity in implementation of these long-term adaptation measures, such as coordination with urban planning and housing departments, governance frameworks and dedicated finance sources will need to be identified as a second critical measure. State and city action plans for climate change, as part of India's Nationally Determined Contributions also provide avenues for addressing heat-related risks and prioritizing key action areas.

2.4 Prioritized Opportunities for Concessional Finance

81. Space cooling presents four key opportunities for concessional financing. Amongst all the opportunities discussed in the section above, the following opportunities have significant potential to leverage large-scale financing by MDBs, FIs and the private sector. These opportunities have strong technical feasibility and can be unlocked to result in high climate and development benefits through concessional financing and effective convergence with public finance.

Opportunity 1: Mainstream thermal comfort parameters in affordable housing policies and programs at the national and state level including in the PMAY-Urban Mission and PMAY-Rural Mission

Opportunity 2: Enable market transformation towards super-efficiency for high energy impact cooling technologies

Opportunity 3: Support uptake of tri-generation and DCS

Opportunity 4: Mainstream passive cooling

[xvii] Cool roofs reflect incident solar radiation and also efficiently emit some of the absorbed radiation back into the atmosphere, instead of transferring the heat to the building below (ENS, BEE 2018). Cool roofs can reduce indoor temperatures by 2 to 5°C as compared to standard construction and hence help improve thermal comfort, reduce cooling energy, and strengthen heat resilience in buildings.

[xviii] IUCN pioneered 'Nature-based Solutions' in the late 2000s and defines it as "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits."

measures in urban planning

2.4.1 Mainstream thermal comfort parameters in affordable housing policies and programs at the national and state levels

82. Affordable housing policies and programs need to recognize thermal comfort as an essential criterion for current and future programs such that energy costs (to achieve comfort) are also affordable for occupants, in addition to the cost of home ownership.

83. PMAY-Urban can be leveraged to effectively mainstream passive cooling measures in affordable housing construction in urban areas. Low-income households are highly vulnerable to impacts of heat stress due to poor quality housing and limited access to cooling technologies. In the absence of a mandatory residential building energy code, there is currently no guidance for integrating thermal comfort parameters and efficient building envelope-related measures in affordable housing programs. Ensuring that applicable developer-built, multi-family housing projects within PMAY adopt the residential building energy code (ENS) is of critical urgency due to the large number of houses being constructed through the affordable housing program. Green credit lines can be provided to support states towards technical assistance along with bridging the additional costs of residential building energy code compliance in demonstration projects. Additionally, market barriers such as affordability and accessibility need to be addressed for high performance building envelope solutions (building blocks, reflective and insulating roof tiles, shading solutions, and so on). These can be embedded in procurement tenders to increase adoption. Skill development programs are required to impart technical know-how of passive design and construction materials through local skilling centers as well as national-level skill development programs. There is also a need for sensitizing decision makers about improving thermal comfort in affordable housing through passive measures. Additionally, PMAY-Urban, through its beneficiary-led construction component, provides direct monetary assistance to beneficiaries for constructing or expanding houses. These self-built houses are outside the purview of the residential building energy code due to the smaller size of the housing units. Experts believe that more than half of the urban housing shortage is likely to be met through self-build housing. State governments can be directly supported through technical assistance grants to develop a contextual strategy for self-build housing within their affordable housing programs. This should include embedding design guidance on passive measures such as ventilation, shading, cool (reflective) roofs, and so on, and improving the access and availability of low-cost, efficient building materials for these houses. This guidance can be disseminated through self-help groups, community participation approaches, local training centers, and so on.

84. Guidance on passive cooling measures

needs to be integrated within the PMAY-Rural housing mission. PMAY-Rural provides financial and technical assistance to build houses in difficult areas (defined by poor availability of materials, poor connectivity, and areas with harsh terrain and climate), hill regions and integrated action plan areas. Like self-build housing in the PMAY-Urban mission, guidance for rural housing should include low-cost, efficient, and simple solutions to integrate passive cooling measures, allowing for the use of local building materials and designs. These can be supported through local skilling centers. This knowledge and skills transfer can also be linked to institutional funding sources beyond PMAY-Rural mission to include nonbanking financial companies, microfinance lending, disaster reconstruction funds, and so on.

2.4.2 Enable market transformation towards super-efficiency for high energy impact cooling technologies

85. Robust energy efficiency standards are needed to transition to best available technologies in the market. Bureau of Energy Efficiency's (BEE's) Standards and Labelling (S&L) Program provides energy ratings (1-to-5-star ratings, one star represents minimum efficiency level) for a number of cooling technologies. This includes mandatory standards for RACs and voluntary ones for chillers and fans (beestarlabels.com). Energy standards are being developed for packaged DX while VRF systems are also being considered. To achieve ICAP goals for energy reduction from key impact technologies such as RACs, fans and chillers, there is a need to align the S&L program to transition to best available technologies in the market. This requires identification of pathways and timelines for increasing stringency of standards, combined with periodic impact assessments to understand the program's impact on energy savings, upfront costs and market share of efficient cooling technologies.

86. Increasing adoption of super-efficient technologies requires interventions to address higher upfront costs. Beyond standards, enabling market transformation for high energy impact cooling technologies such as ceiling fans and RACs is also imperative. Higher upfront costs of energy-efficient models are key barriers in the price sensitive Indian market. Most consumers tend to focus on mid-segment 3-star-rated air conditioners, which accounted for a 66 percent market share in 2018-19.[63] Similarly, efficient fans with Brushless Direct Cool (BLDC) motors drastically reduce the energy required for a regular fan from 70-80 watt (W) to 30-35 W but are priced at US$57 which is nearly two or three times the cost of economy and standard fans (US$20-33) and have an 80 percent market share.[45,64] Interventions are, hence, needed to align the market to super-efficient/best available technology standards. Upstream incentives to manufacturers to reduce costs and support domestic manufacturing of BLDC fans should be explored. These can leverage the government's Make in India program. Additionally, the government's

Production Linked Incentive (PLI) program incentivizes domestic manufacturing of multiple high value RAC components (such as compressors, heat exchangers, expansion valves) which are key to the efficiency of RACs.[16] Setting up of new manufacturing infrastructure provides a critical opportunity for inclusion of climate-friendly standards. The program can be leveraged to achieve overall higher system efficiencies in RACs. The industry expects a boost in domestic manufacturing capacities due to this initiative; however, cost-competitiveness will be crucial in determining the success of the program. The program has a budget outlay of US$830 million for five years, with the possibility of incremental investment of US$1 billion, and is expected to create 400,000 additional jobs [including RAC and light-emitting diode (LED)].[65] Energy Efficiency Services Limited's (EESL's) bulk procurement program for fans and the Super-Efficient AC program [xix] –which reduce upfront costs for consumers, should be scaled up, with a targeted outreach strategy. For example, affordable energy efficient fans can be provided through the earlier discussed PMAY scheme to low-income households. Program outreach to domestic consumers has been a challenge for the Super-Efficient AC program. Opportunities for aggregating demand for efficient ACs should be evaluated. For example, mid-to high-income housing apartments are increasingly sold with fitted-in air conditioners by developers, which are likely to be low efficiency. A significant segment of high-income consumers is, hence, designed out of choosing air conditioners. Similarly, the air conditioner rental market has aggregators providing high-end furniture and white goods on rent to urban consumers. These provide opportunities to increase adoption of super-efficient air conditioners. Collaborating with utilities as part of demand-side management programs can also help in reaching out to a larger number of consumers. EESL has also initiated a national chiller replacement program to increase the market penetration of energy-efficient chillers. The program will create viable implementation frameworks for ESCOs through innovative investment and repayment models[66] to enable market transformation for this key refrigerant-based cooling technology.

2.4.3 Support uptake of tri-generation and district cooling systems

87. District cooling technologies will benefit from a national roadmap and policy, outlining the applicability of DCS for greenfield developments. Development zones with large-scale cooling requirements [minimum 8,000 TR per square kilometer (sq km)] such as mixed-use developments, special economic zones, commercial business districts, and so on, should mandatorily be required to carry out feasibility assessments for DCS. The policy should also encourage the use of alternative energy sources in DCS such as waste heat streams, free cooling through lakes, integration of biofuels, treated wastewater

[xix] EESL's Super-Efficient AC Program[1] (ESEAP) aims to deploy RACs that are at least 20 percent higher in performance than the best available 5-star rated air conditioner in the market. This amounted to a 5.4 ISEER[1] as compared to the 4.5 ISEER 5 star-rated air conditioners along with a refrigerant specification of low global warming potential of 675.

and integration of large-scale renewables and thermal storage to assess the impacts on efficiency and resource use of the DCS system, as compared to conventional central air-conditioning systems.

88. Viable business and implementation models for tri-generation and district cooling need to be established in the Indian context. Pilot projects, especially for merchant district cooling systems need to be supported as this will help in establishing and standardizing project development processes, business models and contracting. IFC has recently announced its first direct investment in district cooling through a strategic partnership with Tabreed, targeting a portfolio of about 100,000 refrigeration tons servicing industrial, commercial and retail developments, with a mandate to invest up to US$400 million in projects for the next five years in India.[67] Worldwide, district cooling projects are developed under a wide variety of business models. These business models are categorized by the organizations owning the DCS and operating it. A variety of stakeholders such as municipal corporations, national and state governments, utilities, building developers, international finance providers, ESCOs, Smart City special purpose vehicles, and so on, can invest in such a project. For example, in Dubai, building developers become multi-utility operators providing services such as water, waste, power, cooling in integrated townships. Other models in cities such as London, Paris and Toronto are based on public utilities either making a direct investment or having a partial stake, depending on the value of incentives they provide such as land, access to energy sources, access to city-owned wastewater utilities and connections, creating a revenue stream for the city.[68] In the Indian context, there is a need for an implementation agency, amongst the many stakeholders – urban local bodies, distribution utilities or a special purpose vehicle – that will need to develop institutional expertise of managing the process of tendering, financing and setting up a district cooling network, along with other public and private stakeholders. Tri-generation plants currently are highly reliant on natural gas; however, neither gas supply nor its pricing structure are established. Current gas-based power plants in the country are underutilized due to poor indigenous gas availability and high prices of natural gas in India. Clarity about gas prices was, hence, mentioned as a key factor in the uptake of tri-generation plants by private sector technology providers in the country. Further, though natural gas is a much cleaner fossil fuel than coal, with the declining prices of hybrid RE[xx] along with lowering storage costs, it is worthwhile to explore if new investments in fossil-fuel based sources compare from a viability as well as environmental and energy security perspective for the uptake of gas-based tri-generation plants. In March 2021, EESL signed a memorandum of understanding with GAIL (India) Limited to develop tri-generation projects in India.[69] EESL is also

[xx] Hybrid RE systems are becoming popular as standalone systems that usually consist of two or more RE sources used together to provide increased system efficiency and round-the-clock power supply.

introducing an integrated turnkey solution for tri-generation and combined heat and power technology on a zero-capex model. EESL will be responsible for the upfront capital costs and risks, including installation, O&M services and will provide metered heating, cooling and power through a 10-15-year cooling, heating and power purchase agreement. Costs will be recovered through savings in consumers' operating expenses.[47] This will support the development of a much-needed ecosystem for tri-generation projects and financial models along with standard contractual and operating processes for ESCOs to develop cooling as a service model. Finally, scaling up of these technologies will require that cities become engaged in a longer-term outlook towards meeting space cooling demand as well as their energy and climate commitments sustainably. Cities need clear incentive structures to become active stakeholders in DCS adoption as, currently, energy planning is not a core responsibility for cities. Infrastructure development programs such as the Smart Cities Mission can also be leveraged for DCS adoption.

2.4.4 Mainstream passive cooling measures in urban planning

89. Land use planning that combines passive urban cooling measures is key to strengthening heat resilience in cities. NbS are amongst actions that cities can prioritize towards equitable access to cooling for all.[70] They provide additional benefits of reducing air pollution and protecting biodiversity. Several forward-looking global cities have started to target or incorporate issues related to overheating or cooling;[54] however, multiple challenges remain in achieving the full potential of NbS.

90. Cities will need guidance across effective measures, implementation and private sector participation. Guidelines for implementation of local and city-wide urban cooling measures, such as cool roofs and NbS, can support urban planning frameworks in integrating a response to heat stress in city planning. There is also a need for developing business cases for all sizes of NbS and especially for private sector participation to ensure necessary funding,[18,19] as public funds are likely to be limited. Additionally, integration of NbS across public and private land is also a challenge for city authorities. Hence, public-private sector partnerships will be critical. Examples of innovative business models exist in India and globally that need to be adapted to quantify and communicate benefits, identify beneficiaries and develop revenue streams.[20] For example, Maharashtra's first ever urban forestry project, Warje urban forest in Pune, was developed by a non-profit along with Tata Motors under a public-private partnership model as a Corporate Social Responsibility (CSR) initiative.[71] In Melbourne, the municipality has created an urban forest fund, pooling finances from different government departments and real estate firms, to encourage private greening in the city. Communities and businesses can propose projects and have to meet 50 percent of the costs while the fund provides the remaining costs. In Malmö, a business improvement district program has been developed through partnerships between the city housing associations, property owners, businesses and civil society to develop solutions to upgrade the neighborhood with a focus on developing blue-green infrastructure.[59] Knowledge alliances through collaboration with local academic institutions, civil society and global city-to-city partnerships to exchange best practices can also support cities in implementing urban cooling measures and NbS Funding through CSR and philanthropic grants can also be accessed to demonstrate pilot solutions and collaboration models.

Table 1 provides the roadmap for the prioritized opportunities in the space cooling sector. More details on these and all other opportunities and their proposed interventions can be found in Annex 2.

Table 1: Roadmap for prioritized opportunities in the space cooling sector

Terms: Short Term (2022-24); Medium Term (2025-30); Long Term (2031-38)

Instrument: Policy; Knowledge; Investment

Topic		Proposed Intervention	P	I	K	Key Stakeholders	National & State Policy Alignment
1 Reduce demand by integrating passive measures in buildings: mainstream thermal comfort parameters in affordable housing policies and programs at the national and state levels	A.1	Thermal comfort as an essential criterion in affordable housing policies	✓		✓	MoHUA, MoRD, State UDD	PMAY- Urban; PMAY- Rural; state-level affordable housing policies
	A.2	Update affordable housing policies and programs at the national and state levels					
	B.1	Demonstration projects integrating residential energy code (ENS) provisions	✓	✓		State UDD, city housing departments, ULBs, State PWD, MDBs	
	B.2	Update procurement process to include ENS solutions					
	C	Green credit lines to housing departments		✓		MDBs, FIs	
	D	- Guidance for self-built housing including low-cost, efficient and simple building solutions - Local skilling centers			✓	NHB, HUDCO, MoHUA, MoRD, State UDD, NDMA	PMAY- Urban; PMAY- Rural; state-level affordable housing policies, Disaster Management Act
	E	Leverage institutional finance streams to disseminate guidance to homeowners of self-build affordable housing		✓		MDBs, FIs	

Topic	Proposed Intervention	P	I	K	Key Stakeholders	National & State Policy Alignment
2 Improve efficiency of cooling technologies: enable market transformation towards super-efficiency for high energy impact cooling technologies	A.1 Align the S&L program strategy to achieve ICAP goals - stringent standards, market transformation initiatives and supporting infrastructure such as test labs	✓			BEE	EC Act, S&L program, Make in India
	A.2 Implement the S&L pathways for key impact appliances - RACs, fans, chillers					
	A.3 Monitoring and impact assessment to inform review of strategy					
	B.1 Upstream incentive BLDC fans/ motor manufacturers	✓	✓		BEE, EESL, MDBs	
	B.2 Implementation, outreach and impact assessment					
	B.3 Monitoring and impact assessment to inform review of strategy					
	C.1 Leverage PLI program for manufacturing efficient RAC components		✓		MDBs, FIs	PLI program, S&L program
	C.2 Impact assessment including RAC system design, performance and costs					
	C.3 Monitoring and impact assessment to inform review of strategy					
	D.1 Scale-up EESL'S Super-Efficient Air Conditioner bulk procurement program		✓		EESL	S&L program
	D.2 Monitoring and impact assessment to inform review of strategy					
3 Shift demand to district cooling technologies: support uptake of tri-generation and district cooling systems	A.1 Policy outlook on natural gas allocation and pricing for tri-generation projects	✓			EESL, PNGRB, GAIL India Ltd.,	PNGRB regulations
	B.1 CaaS business models for ESCOs	✓	✓		MDBs, FIs, EESL, state UDD, state TCPO	Smart Cities Mission
	B.2 Feasibility assessments and pilot projects of merchant DCS					
	B.3 Establish and standardize project development process, business models and contracting					
	C.1 Long-term benefit model for cities to adopt DCS (equity/revenue models)	✓	✓		MDBs, FIs MoHUA, state UDD, state TCPO	
	C.3 Establish and standardize project development process, business models and contracting					
	D.1 Feasibility of alternate fuels, waste heat streams, treated wastewater, free cooling via natural water bodies etc.	✓	✓			
	D.2 Demonstration projects					
	D.3 Establish and standardize project development process, business models and contracting					

Topic	Proposed Intervention	P	I	K	Key Stakeholders	National & State Policy Alignment
	E.1 District cooling roadmap including value chain and applicability	✓			BEE, EESL, MoHUA, State UDD, state TCPO, MoEFCC, MoCI, green building rating agencies	URDPFI guidelines; City Masterplans; EIA, EC Act
	E.2 Mandate feasibility of DCS in high density cooling greenfield developments (minimum 8,000 TR per sq km)					
	E.3 National Policy for DCS					
4 Adapt cities to manage heat stress: mainstream passive cooling measures in urban planning	A.1 Guidelines for cities to integrate urban passive cooling measures in planning frameworks	✓			MoHUA, NIUA, State UDD, ULBs, state environment departments	Local area plans, urban masterplans SAPCC
	A.2 Synergies with existing urban regulations and funding streams for implementation climate change action/adaptation plans					
	A.3 Mainstream urban passive cooling measures through pilot projects, capacity building and updating standard contracting processes					
	B.1 Knowledge alliances to support cities	✓		✓	NIUA, ULBs, academia, NGOs	
	B.2 Impact assessment to inform replication and scaling up of solutions					
	C.1 Private sector participation in implementing NbS	✓	✓	✓	State UDD, ULBs, CSR, grants	CSR, SAPCC
	C.2 Impact assessment to inform replication and scaling up of solutions					
	D.1 - Measures for vulnerable communities in urban areas - Frameworks for intersectoral coordination and budgets across urban planning and heat-related disaster response	✓			NDMA, ULBs, PHFI, MoHUA, NIUA, state environment departments	Disaster Management Act, Urban Heat Action Plans, SAPCC
	D.2 Implementation of urban cooling action plans for vulnerable communities					

CSR: Corporate Social Responsibility; DPIIT: Department for Promotion of Industry and Internal Trade; EC: Energy Conservation; EIA: Environmental Impact Assessment; HUDCO: Housing and Urban Development Corporation Ltd.; MoCI: Ministry of Commerce and Industry; MoHUA: Ministry of Housing and Urban Affairs; MoRD: Ministry of Rural Development; NDMA: National Disaster Management Authority; NGO: Nongovernmental Organization; NHB: National Horticulture Board; NIUA: National Institute of Urban Affairs; PHFI: Public Health Foundation of India; PNGRB: Petroleum and Natural Gas Regulatory Board; PWD: Public Works Department; SAPCC: State Action Plan on Climate Change; TCPO: Town and Country Planning Organisation; UDD: Urban Development Department; ULB: Urban Local Body; URDPFI: Urban and Regional Development Plans Formulation and Implementation

Chapter 3

Cold Chain and Refrigeration

3.1 Summary

91. Presently there exist major gaps in the cold chain in India and only 4 percent of fresh produce is covered by it.[9] While the holding capacity for agriculture produce has grown over the past few years, integrated development of the entire cold chain has been inadequate, resulting in major food and pharmaceutical losses. This not only contributes substantially to GHG emissions but also negatively impacts India's food and nutritional security as well as health and well-being. Gaps in the cold chain infrastructure will need to be filled over the coming decades which is projected to increase the demand for cooling and refrigerant by this sector as well as energy consumption, leading to higher carbon emissions. The implementation of proposed interventions to develop an integrated cold chain network can lead to a reduction in refrigerant demand by 10 percent[5] and this study estimates a potential emissions reduction of 77 $mtCO_2e$ annually by 2038. Additionally, the study estimates that the market potential and investment opportunity in the cold chain and refrigeration sector will be US$29 billion by 2038, and the sector has the potential to create 1.7 million[23] jobs. To achieve this potential growth in a sustainable manner, it will be necessary to address the barriers of current lack of major investment and inadequate supporting infrastructure such as roads and power supply.[22] Additionally, the highly fragmented nature of the sector is also a major challenge in developing a sustainable integrated cold chain network; interventions would need to be designed to ensure participation of all key stakeholders.

92. This study has identified two key opportunity areas; 'development of new energy efficient and sustainable cold chain networks' is the key opportunity for this sector and has been prioritized. The sub-opportunities identified within this offer multiple developmental as well as climate benefits and have policy and administrative support at both the state and national levels. Based on a current estimation of need, studies show that an investment of close to US$11.75 billion is required to develop the physical infrastructure and transport-related elements of the cold chain, and modernizing its retail end will require US$1.3-1.9 billion.[24] While the NCCD has identified the required capacity of different cold chain components, our stakeholder consultations highlighted this to likely be an underestimation of actual need. Further, there is a lack of accurate and reliable information on food and pharmaceutical losses. There is a need to carry out a nation-wide needs assessment, along with a study to identify region- and subsector-wise losses due to the lack of cold chains. These data will help in the development of a region-specific action plan for the development of a sustainable cold chain network.

93. The second opportunity, 'improving energy efficiency and integrating RE in existing cold chain infrastructure, and strengthening systems' is important to carry out; however, given its implementation challenges, it has not been prioritized. India has the largest footprint of cold stores in the world. A majority of these cold stores use zero GWP ammonia refrigerant which makes them energy inefficient and high GHG emitters due to the use of obsolete technologies. Modernization of existing infrastructure, while required, poses a major challenge of implementation as the sector is highly fragmented and largely unorganized. Additionally, low electricity tariffs across the country for this sector act as a disincentive for owners to invest in energy efficiency measures. Similarly, while there is a need for developing standards and certifications for integration of RE and energy efficient design and technologies in the cold chain, the unorganized nature of the sector poses an implementation challenge for this intervention as well.

3.2 Sectoral Overview

94. Major gaps exist in cold chain infrastructure across the country. The agriculture cold supply chain network consists of three important pillars: static infrastructure, primarily used for aggregating and storing readied goods for onward logistics connectivity; mobile infrastructure, as connecting links for post-production and premarket stages; and information flow for regular and dynamic information on ready capacity and accessibility of requisite infrastructure.[21] The pharmaceutical industry also relies on a cold supply chain which, for the sector, is extremely complex and consists of strict parameters for holding temperatures, delivery time restrictions, handling and transportation requirements, and storage needs. While cold storage capacity in the country has steadily grown, the NCCD identified a gap of 3.27 million metric ton (MT) in 2015 for long-term holding of fresh produce.[21] This has been somewhat filled in the last few years and, as of August 2020, the total cold storage capacity in India was 37.4 million MT with 8,186 cold stores, compared to 5,387 cold storages with a capacity of 24.9 million MT in 2010.[72, 73] However, integrated development of the cold chain has been severely deficient, with major essential components not adequately developed. In this regard, the largest gap can be noted in modern packhouses, with a requirement of 70,080, indicating an average need for one packhouse for every 10 villages (Table 2).[5, 21, 23] While main barriers to addressing these gaps are a lack of initial investment and an enabling infrastructure, such as roads and power, the highly fragmented nature of the industry is also a major shortcoming.[22]

Table 2: Gaps in cold chain infrastructure in India in 2014-15[5]

S. No.	Infrastructure Component	Requirement (MT)	Available (MT)	Gap (MT)
1.	Modern packhouse	11,21,274	3,984	-11,17,290 (99.6%)
2.	Ripening chamber	91,306	8,120	-83,186 (91%)
3.	Reefer transport	4,94,608	72,000	-4,22,608 (85%)

95. Gaps in the cold chain result in food and pharmaceutical losses. The current absence of an integrated cold chain results in major food loss. The total fruit and vegetable loss primarily occurs between farms and mandis, where a lack of packhouses with precooling capacity, inadequate transport facilities and breakages in cold chain each account for 10-20 percent, 20-25 percent and 10-15 percent of losses, respectively.[21, 24] This has a negative impact not just on the environment, contributing 8-10 percent towards annual global GHG emissions, but also on food security including wasted labor, water, energy, land and other inputs. Food loss can result in doubling of fruit and vegetable prices and a 50 percent price rise of milk.[74, 75]

The fragmented nature of the cold chain also impacts the healthcare sector where a vast proportion of cold storages available are used only for agricultural produce. Additionally, logistics for healthcare is also unevenly distributed, being concentrated mainly near manufacturing hubs.[76,77] To fill the gaps outlined above, a large amount of mobile and static infrastructure needs to be developed; this is projected to increase cooling and refrigerant demand as well as energy consumption in this sector, leading to higher carbon emissions.[5]

3.3 Landscape of Cooling Opportunities in the Sector

96. The bridging of gaps in the cold chain and minimization of impacts on the environment require a multi-dimensional approach that includes technology, policy support and training to meet supply requirements in a sustainable manner, along with better demand management and forecasting as well as inventory planning. In the ICAP, recommendations for this sector are outlined for short- and medium-terms and range across policy, investment, and capacity building. The implementation of all interventions can help reduce refrigerant demand in this sector by up to 10 percent (Figure 6)[5] and an estimated potential emissions reduction of 77 $mtCO_2e$ annually by 2038. To achieve this goal, we identified two key opportunity areas: (1) support development of new energy efficient and sustainable cold chain networks; and (2) improve energy efficiency and integrate RE in existing cold chain infrastructure while strengthening systems. Within these, multiple sub-opportunities were identified (refer to graphic 'sectoral pathways for impact') and are discussed in the following sections.

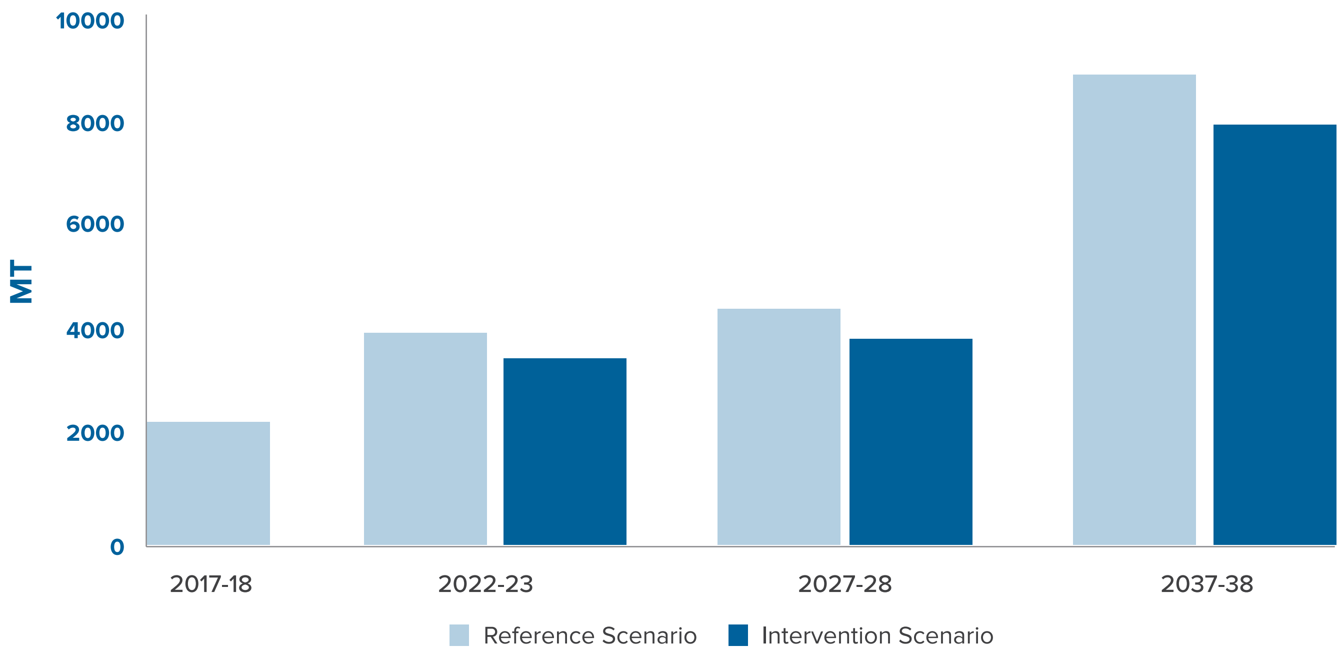

Figure 6: Refrigerant demand in cold chain and refrigeration[5]

3.3.1 Development of new energy efficient and sustainable cold chain networks

97. Development of sustainable and energy efficient end-to-end cold chain networks, including refrigerated transport, is a key opportunity for this sector, offering high climate and development benefits. The huge infrastructure development required to fill the gaps identified in the cold chain, when carried out in a sustainable manner, will help reduce projected energy consumption as well as cooling and refrigerant demands for this sector. Additionally, interventions proposed within this sub-opportunity will help reduce food loss, as studies show that investing in precooling and refrigerated transport in India can help reduce food loss, leading to a reduction of CO_2e emissions by 16 percent.[78] The development of a cold chain also has national and state policy support as there are presently a number of schemes by different national government agencies such as the National Horticulture Board (NHB), Mission for Integrated Development of Horticulture (MIDH) and Agricultural and Processed Food Products Export Development Authority (APEDA), that support development of the cold chain. However, these schemes have all focused on individual elements of the cold chain, providing subsidies for the development of different components.[79] While subsidies offered under MIDH were created to fill gaps identified by NCCD, there are still huge holes in the cold chain infrastructure. Thus, it is necessary to modify these schemes to ensure integrated development. The technical feasibility of developing an energy efficient and sustainable cold chain network is also high, as the equipment, technologies and expertise required are available in India and globally.

98. The promotion of better operations and servicing through capacity building and effective monitoring systems can help bring in efficiency in the cold chain and provide significant developmental benefits. Currently, storage facilities are often managed by inexperienced staff unaware of the latest technology and techniques in handling and storing fresh perishable produce.[75] Building their capacity can help reduce both food loss and emissions. A sustainable agriculture cold chain has the potential of creating 1.7 million jobs, both directly and indirectly, for the management of physical infrastructure and refrigerated transport systems.[23] This opportunity also offers climate benefits as an important aspect for reducing losses faced by agriculture and healthcare industries is capacity building of users at different levels of the supply chain. Food loss can be reduced through improved postharvest handling of produce, and vaccine and medical loss through improved handling at the last mile. The technical and administrative feasibility of this opportunity is also high as the NCCD and NHB already carry out training on postharvest management for agri-entrepreneurs that can be tailored towards farmers and other stakeholders.

3.3.2 Improve energy efficiency, integrate RE in existing cold chain infrastructure and strengthen systems

99. Given the large amount of existing cold storages and refrigeration systems in the country, there is a need to retrofit them to reduce cooling and refrigerant demand as well as energy consumption. India has the largest footprint of cold stores in the world, and majority of these use natural refrigerant gas ammonia (R-717), with zero GWP. Despite this, these cold storages are high GHG emitters due to the use of obsolete technologies. Presently, the sector is highly fragmented and largely unorganized with more than 3,500 small and big players,[80, 81] posing a major challenge for the implementation of a retrofitting program. Additionally, most states across the country have very low electricity tariffs which results in a lack of incentive for private cold storage owners to invest in energy efficiency measures.[82] While retrofitting interventions have the necessary technology access for upgradation and can provide climate benefits, there are multiple challenge with their implementation.

100. Development of standards and certification for RE integration and inclusion of energy efficient design and technologies is an important aspect in developing a sustainable cold chain. Though this opportunity has high technical feasibility with several such standards existing across the world which can be adapted for India, it does not offer significant development benefits as it has limited job creation potential or direct beneficiaries. Additionally, the opportunity has low GHG mitigation potential compared to other opportunities in this sector and poses challenges with large-scale implementation due to the unorganized nature of the cold chain.

3.4 Prioritized Opportunities for Concessional Finance

3.4.1 Support development of sustainable and energy efficient end-to-end cold chain networks, including refrigerated transport

101. A sustainable and integrated cold chain network offers multiple development and climate benefits. This opportunity has high technical feasibility; the presence of a conducive policy environment and administrative structure will all help support its implementation. To ensure that development is carried out in a sustainable manner, the opportunity requires large investments. NCCD estimates that close to US$11.75 billion is required to develop the physical infrastructure and transport-related elements of the agriculture cold chain, with the biggest investment needed for building modern packhouses (about US$8.5 billion).[24] In addition, there is also a need to modernize the retail end of the cold chain, requiring US$1.3-1.9 billion to strengthen the last mile.[24] Though most of the cold chain in India is privately owned, it has been developed with the support of subsidies, grants and incentives provided by the public sector. Assuming that a similar model will be followed for the development of new infrastructure and transport elements, this opportunity offers significant avenues for concessional finance. This can be met through grants, loans, credit lines and subsidies, where the potential source of funding will vary based on the type of intervention, likelihood of returns, scale of investment needed, etc.

102. It is important to first identify infrastructure gaps and assess sector-wise losses to build a sustainable large-scale and decentralized cold chain network. An accessible, affordable, scalable, reliable, climate-friendly and safe cold chain requires a systems thinking approach that considers all elements, such as temperature requirements of different products, refrigerants, space cooling, reefer transport, servicing, capacity building, RE sources, and so on, with its application at centralized and decentralized levels, depending on requirements.[83] To achieve this, it is important to first identify region-wise infrastructure gaps in cold chain and the losses occurring due to this for each subsector. While ICAP outlines infrastructure gaps, which are discussed above, our stakeholder consultations highlighted that these numbers might be an underestimation of actual need. Additionally, accurate numbers regarding food and pharmaceutical losses are not available and various studies, using different methodologies, present differing data. It is also important to know geographic and subsector-wise requirements. This needs assessment should lead to the development of regional action plans for building large- and small-scale sustainable cold supply chains, which can be implemented with state governments, private players and farmer groups. To support this at a decentralized scale, it is necessary to develop business models that promote producer-owned cold chains. Additionally, incentives should be created for Farmer Producer Organizations (FPOs) to become a part of this system where they are not just users of cold chain but also owners, thus promoting awareness of the need for energy efficiency. A similar scheme has been initiated by the Government of Haryana called the Crop Group Development Scheme that supports farmers in building integrated packhouses. The government will develop 200 such packhouses at a budget of US$6.5 million.[84]

103. Decentralized cold chains need to be developed through support provided to farmer groups and agri-entrepreneurs. To understand the potential of producer-owned supply chains, pilots should be carried out for different subsectors where an end-to-end model is demonstrated. In addition to this, there is a need to incentivize and support Agricultural Produce Market Committees (APMCs) in developing cold chain links at mandis, particularly for crops that currently do not find space in the existing infrastructure. In 2018-19, the Government of India proposed to upgrade 22,000 existing rural haats and develop them into Gramin Agricultural Markets with strengthened physical infrastructure. However, till December 2021, only 6 percent of haats (local markets) across the country were upgraded.[85, 86] To ensure that existing mandis and haats are developed as integrated cold chain systems, synergies should be explored with this scheme. It is also necessary to identify alternate business models for these cold chain links as they would mainly be used for short-term storage, thus requiring different types of investment and ownership models. To develop an effective decentralized cold chain network, there is also a need to explore the potential of leasing and renting of cold chain components. Under the Sub-Mission of Agriculture Mechanization (SMAM), the government supports renting of farm equipment and establishment of

Custom Hiring Centers.[87] This scheme can be expanded to include elements of the cold chain as a pay-per-use renting model where the burden of developing cold chain infrastructure is not on the users and they pay only for use of cold chains. Further, to scale up this opportunity, it would be useful to develop synergies with initiatives such as CaaS[88] and implement pilot projects to assess the feasibility of such a system in India.

104. There is a need to identify implementation challenges of cold chain development schemes and enhance these to support development of an end-to-end energy efficient cold chain network. Until recently, the focus was on developing single commodity cold storages, as these are usually the first point of storage for farmers. Cold stores have also become concentrated around a few products and in a few regions in India. Potato or potato seed storage dominates cold store usage, using about 85-90 percent of total capacity across the country. Meat, fish, milk and milk products, and other commodities such as chilies, account for only 1 percent of total capacity.[22] While subsidies offered under MIDH were developed to fill lacuna identified by NCCD, huge gaps in major components still exist (Table 2). The Integrated Cold Chain, Value Addition and Preservation Infrastructure scheme, under the Pradhan Mantri Kisan Sampada Yojna (PMKSY), aims to provide cold and preservation infrastructure facilities from farm to fork and promotes development of all components of the cold chain for different subsectors in the agriculture supply chain. While this scheme was introduced in 2008, there have been challenges in its implementation.[89] The 17th Report of the Lok Sabha Standing Committee on Agriculture, Animal Husbandry, and Food Processing (2020-21) noted that several approved projects were stalled due to delays in obtaining statutory approvals such as change in land use, consent to establish, building plan, power connection, Food Safety and Standards Authority of India (FSSAI) license, final sanction of term loans, and so on.[89] To identify challenges leading to these delays and suggest policy and regulatory measures for effective and large-scale implementation, there is a need to set up a committee. It is important to ensure that this committee comprises all key stakeholders, including farmer groups and those responsible for implementation. Along with bringing in measures for effective implementation of this scheme, it is also necessary to modify existing schemes that support development of individual elements of the cold chain (by NHB, MIDH and APEDA) and use an end-to-end approach, ensuring that essential elements are not left wanting during development.

105. Monitoring the development of new cold chain infrastructure will be an important aspect to ensure that the next phase of growth is carried out in a holistic manner, not resulting in large gaps, while having minimal impact on the environment. ICAP recommends the development of a Management Information System (MIS) through inter-ministerial collaboration to help track relevant data on infrastructure development and e-performance monitoring to improve efficiency, along with capacity building of key stakeholders for proper handling and maintenance of the cold chain. The nodal ministry for development and implementation of the MIS, and for decision making based on it, could be the

Ministry of Agriculture and Farmers Welfare (MoAFW), with support from other key national ministries and state governments representatives. To encourage transparency and knowledge sharing, the MIS can also have public facing elements.

106. To achieve potential emissions reduction in this sector, an important aspect in development is RE integration. This offers not only an opportunity for climate change mitigation but also a reduction in the system's dependence on an unreliable electricity supply while offering long-term economic benefits due to lower O&M costs. It is important to identify scalable technologies that are easily implemented in Indian conditions in both large on-grid as well as off-grid cold chain links. Feasibility studies should be carried out in collaboration with research institutes and private sector start-ups to understand the potential of different technologies, such as solar, wind, biomass, and so on, in different regions in the country. Presently MIDH offers subsidies for the use of RE and other alternate technologies in the cold chain (100 percent of invoice cost, maximum INR 3.5 million per project). However, there has not been large-scale adoption, one of the major barriers being high initial capital cost of installation[90] and lack of the ability to access existing schemes. To overcome these deterrents, business models for decentralized adoption of RE-based cold chain solutions at the farm or village levels, that can be implemented by individual farmers or farmer groups, should be developed. These can be linked to low interest loans that should be introduced for farmers/users. To scale up adoption of these technologies, there is also a need to create awareness amongst farmers on their lower O&M costs, along with other benefits, such as energy security and availability of subsidies. Life cycle costs of alternate technologies should also be considered when calculating O&M costs. It is also important to support R&D for the development of low-cost RE solutions that can be implemented at the farm gate and in the rural healthcare sector. This can be carried out through an incubation center, offering support to start-ups and researchers. To understand the potential scalability of proven technologies, such as those offered by Ecozen, Inficold and Bharat Refrigerations, it is important to assess their application in different regions and support scaling up of promising solutions.

107. In addition to the agriculture sector, it is important to ensure that healthcare also has a well-established and sustainable cold supply chain. This industry currently faces gaps in last mile delivery of vaccines and temperature sensitive medicines, especially in remote areas.[91] During the COVID-19 pandemic, funds under CSR were deployed to strengthen healthcare cold chains, with organizations providing equipment to support the vaccination programs.[92] To ensure end-to-end development of the healthcare cold chain, CSR funds can be further accessed as a source of investment. These can help support R&D projects and establishment of a center of excellence to develop and scale up domestic low-cost solutions for last mile delivery of vaccines and temperature-sensitive medicines. This center of excellence could also explore other aspects of the cold chain where low-cost solutions can help scale up energy efficiency. Additionally, there is also a need to establish linkages between the health and food cold chains where multi-commodity cold storages can service both sectors. These can help build last-mile storage and delivery solutions for healthcare, especially in remote locations.

108. Domestic and commercial refrigeration, the end of a cold chain, is a rapidly growing sector in India and it is important that this growth is sustainable. Increasing urbanization and improving living standards are projected to drive refrigerator ownership from 0.18 per household in 2012 to 0.64 in 2030. This will have a major impact in terms of energy consumption and refrigerant and cooling demands, and it is important that this growth occurs in a sustainable manner. Presently, the market is dominated by single- and double-door, 1- to 3-star rated domestic refrigerators. While 5-star refrigerators consume 30-35 percent less energy compared to a 3-star refrigerator, their higher cost is a major deterrent to adoption.[45] Till there is a substantial price difference, the market will continue to be dominated with sale of lower efficiency refrigerators. It is necessary to bring in market transformation programs that help reduce costs of higher efficiency refrigerators. In India, the domestic refrigeration manufacturing industry includes major global players, with well-established R&D. While the sector is price sensitive and competitive, there might be potential for developing incentives and tax breaks for upstream manufacturers of component technologies. To support these measures, synergies with initiatives under Make in India need to be identified to help reduce component costs. Additionally, there is also a need to support R&D for those component technologies currently not being produced in the country or where cost of production is too high. Research and market support can help in bringing down costs of these components, driving down prices of higher efficiency appliances.

109. Incentives and market transformation initiatives can help promote higher efficiency refrigerators. Target setting programs, such as to EESL's UJALA for LED bulbs,[25] can lead to an increase in market share of 5-star refrigerators. For replacement of inefficient refrigerators, there is a need to develop a similar initiative where incentives such as subsidy, on-bill financing and differential tax rates are given on purchase of 5-star refrigerators. If a program like UJALA is developed for refrigerators, it will be important that high costs, installation and maintenance as well as disposal challenges are addressed. Additionally, the program should be carried out alongside building public awareness on purchase cost versus equipment life cycle (operational) costs. This can be tied to retrofitting and recycling programs for the replacement of inefficient appliances, where consumers are provided additional incentives when replacing old refrigerators. Adoption of inverter technology in RACs in Japan and China has been extremely successful with 100 percent and 50 percent market adoption, respectively. Models followed in these countries can be studied and adapted for replication in the Indian refrigerator market.[93] Further, R&D for the development of low-cost alternate energy refrigerators that can be used in rural areas should be supported, along with exploring the potential of scaling up existing technologies such as ChotuKool and MittiCool. Currently, there is a wide difference in refrigerator ownership in urban and rural households. In rural areas, even in the highest income category, less than 50 percent of households own refrigerators whereas, in urban areas, even in the lowest income group, refrigerator ownership is above 50 percent.[94] It is important that growth of the rural refrigerator market occurs along with adoption of higher efficiency appliances. To ensure uptake of low-cost solutions, manufacturing should be supplemented with marketing support, as appliances such as refrigerators are seen as an aspirational purchase and the tag of low-cost can be a deterrent to acceptance.[95]

110. There is a large gap in availability of refrigerated vehicles to meet the demand in the country. An important component of the cold chain is refrigerated vehicles. An NCCD study estimated that, in 2015, there were about 7,000-9,000 reefer (refrigerated) vehicles in India, catering to only about 12-15 percent of the country's storage capacity; the number was projected to rise to 13,000 in 2017-18.[5,96] The reefers mostly cater to frozen processed foods, imported products and the pharmaceutical sector, not to domestic supply of fruits and vegetables. This is partly due to lack of packhouses, which results in these commodities not being part of the cold chain in the first place. The dairy industry uses about 30,000-40,000 vehicles to transport milk; however, these are insulated not refrigerated trucks. Though there exists a gap in this section of the market as well, with not enough trucks being available to fulfil demand. A majority of cold stores, up to 79 percent, also do not own transport systems and, as a result, there is a growing disconnect between transport and storage units.[9, 24] Though, by 2025, the number of reefer vehicles is forecast to increase to 246,000, feasibility projections (based on affordability) show a demand of 755,953 units, and aspirational projections (assuming cold chain capacity reaches the same per capita level as the UK) show a demand of 2,415,947 units, highlighting the gap that will still remain in this segment despite significant growth.[9]

111. It is necessary to ensure that this sector's growth occurs in a sustainable manner. There is a need to extend policy support for adoption of alternate cooling technologies in refrigerated transport, especially for proven and commercially viable technologies, such as phase change material and thermal energy storage. This should include extending the recent draft Automotive Industry Standard (2021) under consideration on "Constructional and Functional Requirements for Insulated Vehicles" to incorporate energy efficiency parameters, apart from the existing parameters of design and performance of refrigerated transport systems.[97] Further, creating linkages with the Faster Adoption and Manufacturing of Electric Vehicles (FAME) scheme to incorporate adoption of fuel-free technologies for refrigeration of reefers, as part of the subsidies offered under it, will help in promoting adoption. It is also important to develop infrastructure support for the reefers by leveraging schemes such as FAME II and National Electric Mobility Mission Plan (NEMMP) that are developing charging stations for e-vehicles to also include infrastructure for charging of refrigeration equipment.

112. The unorganized nature of the sector requires the development of incentives and alternate business models to bring in energy efficiency. As cold chain logistics are presently operated by a fragmented and informal sector, it is important that owners are incentivized to move their fleets to electric and non-fossil fuel-based cooling.

These incentives can be fiscal in nature or be implement through replacement programs, along with the provision of low-interest loans. In the long term, it should be mandatory to use only electric and non-fossil fuel-based cooling in all refrigerated transport. There is also a need to provide support to carry out R&D with both public research institutes and private logistics companies for the development and piloting of alternate new energy efficient technologies for reefers. Proven technologies should be scaled up through grants and subsidies and service providers given support to adopt these new technologies. There is also potential for developing linkages with the Aajeevika Grameen Express Yojana that supports the development of public transport links in rural areas,[98] supporting movement of both people and produce. To assess the potential of cold chain logistics as a public transport model, it is necessary to carry out feasibility studies. An Uber-like system where mobility companies can invest in this idea can also be explored.[99] If found to be a viable option, business models for small-scale, public transport-based links in remote areas should be developed.

113. Developing multimodal cold chain links can help establish a green corridor for perishables. Railways can also be a very important element in the development of a sustainable cold chain, not only help speed up logistics connectivity, necessary for perishables, but also cover large distances in an energy efficient manner. While major food grains are regularly transported through railways, the lack of refrigerated containers has meant that perishables are not moved through this mode.[100] The 'Kisan Rail' scheme was introduced in the Union Budget 2020-21 to move perishables including fruits, vegetables, meat, poultry, fishery and dairy products from production or surplus regions to consumption or deficient regions as well as for speedy movement to ensure minimum damage during transit.[101] Multimodal cold chain links developed through rail and highways can help establish robust transport linkages for the movement of bulk produce. This should be linked with the development of a fast-track green corridor for perishables, and linkages established with the Ministry of New and Renewable Energy's (MNRE's) Green Energy Corridor Project. Given policy support, the development of railway links for perishables faces few challenges, whereas establishing road links and sustainable road freight can be difficult. This is due to the fragmented nature of the trucking industry and poor road connectivity, particularly in remote areas.[102] It is important to carry out the development of these multimodal links in a holistic manner by first understanding needs and identifying regions where refrigerated rail and highway links will have the biggest advantages, in terms of both energy efficiency and reducing food loss.

3.4.2 Promote better operations and servicing through capacity building of all stakeholders and incorporation of effective monitoring systems

114. Improved operations and servicing in the cold chain offers climate benefits through potential reduction in GHG emissions due to averted food loss and improved equipment efficiency. Capacity building of farmers and other users in postharvest management and equipment handling is a requisite, offering development benefits of a trained workforce. Additionally, improved monitoring at different stages of the cold chain will also help reduce food and pharmaceutical losses. These interventions have the potential for attracting concessional finance in the form of grants for capacity building as well as subsidies and loans for incorporation of monitoring systems. These interventions can be implemented in partnership with national and state governments.

115. Monitoring standards and guidelines are needed to bring operational efficiency and quality control in the cold chain. NCCD has developed guidelines for building energy efficient cold chains; however, standards and guidelines for effective monitoring are lacking in India. Certain food products may become spoiled if they reach a certain temperature for even an hour or two, and India currently does not have food safety standards that specify cooling requirements. Additionally, in the health sector as well, there is a lack of uniform implementation of standards and accreditations, where the maintenance and monitoring of temperature-controlled environments can be a challenge.[77] Those developed by other countries and international organizations should inform the development of guidelines and standards for India. Monitoring is necessary at every stage to ensure maintenance of temperature and humidity, as fluctuation in storage conditions can lead to product quality deterioration or spoilage.

116. Use of IoT-based monitoring and an understanding of temperature requirements of different crops are necessary for a robust cold chain network. Currently, most cold stores have manual systems that need timely monitoring and skilled labor; they do not allow for precautionary measures to avoid accidents. IoT-based technologies play a huge role in monitoring of perishables and healthcare products. There is a need to promote uptake of these systems in cold chains. Subsidies offered by MIDH for inclusion of monitoring controllers that help optimize functioning of machinery need to be leveraged for this. Pilot projects can help assess the feasibility of these controllers in the unorganized cold chain in India. These can be carried out through partnerships with technology and logistics service providers along with government agencies responsible for developing the cold chain. To promote the incorporation of strict monitoring in supply chains and adherence to safety standards, there is a need to develop schemes that provide incentives to service providers. In the long-term, policy measures for mandatory adherence to safety standards for perishables, vaccine and medicine handling and implementation of temperature monitoring, with checks in place to address any faults identified, need to be brought in. In addition to lack of monitoring, there is also minimal understanding of temperature and cooling requirements of different crops in Indian conditions. Most studies only look at benefits and effects of cooling postharvest produce, not specific requirements for a crop. The biggest fallout of the lack of this understanding is the build-up of heat (more than 5°C), which promotes growth of microorganisms and pathogens, impacting food quality. There is a need for research on this subject to build an understanding of temperature and cooling requirements for major perishables and to incorporate these guidelines in food safety standards.

117. Capacity building of users at different levels of the supply chain is an important aspect for reducing losses. Food loss can be reduced through improved postharvest management, and vaccine and medical loss through improved handling at the last mile. ICAP recommends specialized training for cold chain professionals and technicians to promote proper O&M of technology as well as energy efficiency, along with training of farmers on postharvest management of produce. NCCD, recognizing that servicing and maintenance of cold chain was not being carried out by trained technicians, began training in 2013 with four programs which were converted to online courses during the pandemic.[103] The NHB has also developed training courses on post-harvest management. While awareness-building and outreach by both NHB and NCCD are aimed at farmers, training courses are tailored towards agri-entrepreneurs only. It is important to develop the capacity of individual smallholder farmers and other users of the cold chain, particularly in proper handling and temperature requirements of produce as that will help not just reduce food loss but also enhance livelihoods. Such courses and training programs that outline important elements for handling of perishables should be developed in regional languages and can leverage public-private partnerships to extend their reach. The African Affordable Storage Solutions model consists of awareness, acceptance, accessibility and affordability as its core principles and used many outreach methods, including partnering with companies such as Ergos and Tessol to conduct outreach programs such as exhibitions, demonstrations and roadshows to showcase solutions. The model also consists of farm level engagements, where face-to-face interactions help build trust and create a bank of local knowledge. Conventional channels of information dissemination such as newspaper articles and blogs were also adopted to convey information.[104] Additionally, the Africa Centre of Excellence for Sustainable Cooling and Cold Chain, established in 2020, aims to train trainers from across Africa on new technologies and business models for sustainable cooling, along with capacity building of academicians, technicians and practitioners by engaging them in R&D projects. Both examples can be adapted for India and implemented across the country.

118. With the incorporation of advanced technologies in cold chain, skill levels of technicians to service newer equipment also need to be enhanced. In addition to farmers, capacity building should also be carried out for operators and technicians in both agriculture and healthcare on proper functioning and maintenance of energy efficient and clean energy technologies in cold chains and refrigeration systems. In 2018, the government set aside US$5.25 million for skill development of 100,000 RAC service technicians under the Pradhan Mantri Kaushal Vikas Yojna (PMKVY), to be implemented by the Electronic Sector Skill Council of India and Ozone Cell, MoEFCC.[105] It is important to leverage these resources and include them in training and skilling of technicians for cold chain O&M. There is a need to create training programs along with an academic institute and agency such as American/Indian Society of Heating, Refrigerating and Air-conditioning Engineers and an Edtech platform with expertise in curating and producing content for semi- and un-skilled personnel. These training programs could be along the lines of programs that provide a license to practice and service specific grade of cold chain equipment.[106] As certification would result in a premium price attached to these technicians, it is important to also ensure demand for certified technicians. This can be achieved through awareness programs on the benefits of hiring certified technicians, along with incentives for customers in the early phase of certification. To encourage demand, higher costs of trained technicians might need to be subsidized in the early stages. In the long term, certification of all technicians working on cold chain elements should be made mandatory.

Table 3 provides a roadmap for the prioritized opportunities outlined above for the cold chain and refrigeration sector. A detailed roadmap of these two opportunities, along with those that were not prioritized, can be found in Annex 3.

Table 3: Roadmap for prioritized opportunities for the cold chain and refrigeration sector

Terms: Short Term (2022-24); Medium Term (2025-30); Long Term (2031-38)

Instrument: Policy; Investment; Knowledge

Topic	Proposed Intervention	P	I	K	Key Stakeholders	National & State Policy Alignment
1 Supporting the development of sustainable and energy efficient end-to-end cold chain networks, including refrigerated transport	A.1 Nation-wide assessment to get accurate numbers on sector-wise losses and identify infrastructure gaps			✓	MoFPI, MoFAHD, MoAFW	PMKSY, MIDH, NHM
	A.2 Establishing sustainable large-scale cold chain infrastructure through models like Mega Food Parks					
	B.1 Action plan for setting up small-scale decentralized cold chain links	✓	✓	✓	MoFPI, MoFAHD, MoAFW	DFI, PMFME
	B.2 FPOs to develop decentralized sustainable cold chains					
	B.3 APMCs to develop cold chain links at mandis					
	C.1 Leasing and renting models for small scale cold storages	✓		✓	MoAFW, MoHFW	SMAM, CSISAC
	C.2 Schemes to include cold chain components as rental options					
	C.3 Pilots for cold chain in a leasing model					
	C.4 Scale up of successful models					
	D.1 Committee to identify challenges in implementation of "Integrated Cold Chain, Value Addition and Preservation Infrastructure" scheme	✓			MoFPI, MoAFW, FSSAI, MoFAHD	PMKSY
	D.2 Implement measures proposed by committee					
	D.3 Enforce measures proposed by committee					
	E.1 Existing schemes to promote development of multi-commodity cold chain	✓	✓		MoFPI, NCCD, MoAFW, APEDA	PMKSY, MIDH, NHM
	E.2 New schemes/incentives to ensure development of an integrated cold chain					
	F.1 MIS to track infrastructure development and e-performance monitoring to improve efficiency of cold-chain systems			✓	MoFPI, MoAFW, MoHFW, MoRTH, MNRE	PMKSY

Topic	Proposed Intervention	P	I	K	Key Stakeholders	National & State Policy Alignment
	F.2 Ensure decision making and monitoring for infrastructure development through regularly updated MIS			✓	MoFPI, MoAFW, MoHFW, MoRTH, MNRE	PMKSY
	G.1 Identify and promote technologies for RE integration	✓	✓		MNRE, MoFPI, MoAFW, MoFAHD, MoHFW, MIDH	Make in India, PMKSY
	G.2 Demonstration projects to showcase scalable RE technologies					
	G.3 Incubation center for research on low cost RE solutions for cold chain					
	G.4 Scale up of proven technologies					
	H.1 R&D for low-cost solutions for last mile delivery of healthcare products		✓	✓	MoHFW, DST	Make in India, Atmanirbhar Bharat Abhiyan
	H.2 Scale up proven technologies.					
	I.1 Market growth of super-efficient domestic and commercial refrigeration systems	✓	✓	✓	BEE, MoCI, DBT	Make in India, Energy Conservation Act, Atmanirbhar Bharat Abhiyan
	I.2 Scale up manufacturing of low-cost energy efficient refrigerators					
	J.1 Market transformation program for improvements in equipment efficiency (domestic refrigerators and commercial deep freezers)	✓	✓	✓	BEE, MoCI, DST	
	J.2 Incentives to upstream manufacturers to reduce costs					
	J.3 R&D for domestic production of technologies					
	K.1 Policy for adoption of alternative clean cooling technologies for refrigerated transport	✓	✓		MoRTH, Ministry of Power, MoFPI, MoAFW, MoFAHD, MoHFW, NCCD	Automotive Industry Standard, FAME, NEMMP
	K.2 Development of infrastructure needed to scale up application of alternative clean cooling technologies					
	L.1 Policy that incentivizes refrigerated transport service providers to move fleets to electric and non-fossil fuel-based cooling	✓			MoFPI, MoAFW, MoHFW, MoRTH, MoRD	DAY-NRLM
	L.2 Mandatory to use electric and non - fuel-based cooling in all refrigerated transport					
	M.1 Linkages with Aajeevika Grameen Express Yojana to explore refrigerated transport as a public transport/ sharing model		✓	✓		
	M.2 Pilots with SHGs/FPOs to develop small-scale refrigerated public transport systems					
	M.3 Scale up successful models					
	N.1 Demonstration projects to showcase use of new technology in reefer systems		✓	✓	MoRTH, Ministry of Power, DST, research institutes, private logistics companies	Make in India, Priority Sector Lending, SMAM
	N.2 Low interest loans on fuel free or electric reefer systems					
	N.3 Scale up of proven technologies through grants and subsidies					

Topic	Proposed Intervention	P	I	K	Key Stakeholders	National & State Policy Alignment
	O.1 Multimodal cold chain links aiming at a fast-track green corridor for perishables		✓		Ministry of Railways, MoRTH, MoAFW, MNRE	Kisan Rail, Green Energy Corridor
	O.2 Development of linkages to different regions					
2 Promote better operations and servicing through capacity building of all stakeholders and incorporation of effective monitoring systems	A.1 IoT in cold chains and refrigeration energy efficiency codes	✓	✓		FSSAI, MoHFW, MoAFW, MoFAHD, MoFPI, ICAR	The Food Safety and Standards Act, 2006, National Vaccine Policy
	A.2 IoT used in cold-chain logistics					
	A.3 Scale up of low-cost solutions for monitoring					
	A.4 Service providers to incorporate IoT-based monitoring					
	A.5 Temperature monitoring made mandatory					
	B.1 Research to understand temperature and cooling requirements of different crops	✓	✓			
	B.2 Crop specific temperature requirements in food safety standards					
	B.3 Temperature monitoring made mandatory					
	C.1 Training and certification for cold chain and refrigerator operators and technicians on Good Service Practices	✓		✓	MSDE, NCCD	Skill India Mission - PMKVY
	C.2 Successful implementation of skill development program					
	C.3 Universal mandatory certification for all technicians					
	F.1 Training/awareness programs for farmers, middlemen, traders, etc., and medical staff	✓		✓		
	F.2 Updating training modules in line with latest research and technologies					

CSISAC: Central Sector Integrated Scheme on Agricultural Cooperation; DAY-NRLM: Deendayal Antyodaya Yojana – National Rural Livelihoods Mission; DBT: Department of Biotechnology; DFI: Doubling Farmers' Income; DST: Department of Science & Technology; ICAR: Indian Council of Agricultural Research; MoFAHD: Ministry of Fisheries, Animal Husbandry and Dairying; MoFPI: Ministry of Food Processing Industries; MoHFW: Ministry of Health and Family Welfare; MoRTH: Ministry of Road Transport & Highways; MSDE: Ministry of Skill Development & Entrepreneurship; PMFME: PM Formalisation of Micro food processing Enterprises; PM KUSUM: Pradhan Mantri Kisan Urja Suraksha evem Utthan Mahabhiyan

Chapter 4

Passenger Transport Air Conditioning

4.1 Summary

119. Transport air conditioning, also known as Mobile Air Conditioning (MAC), has grown considerably in India. The India automotive HVAC market size was US$822 million in 2018 and is projected to reach US$2,033 million by 2026, registering a Compound Annual Growth Rate (CAGR) of 11.6 percent.[26] The Indian passenger car air conditioners market alone is forecasted to surpass US$1 billion by 2023.[27] Analysis of the transport sector suggests that the MAC segment is projected to double in terms of energy consumption as well as total emissions within the next decade. In line with this, under a BAU scenario, refrigerant demand for the MAC segment is expected to increase by over four times, from an average of 5,172 MT in 2017-18 to 22,142 MT in 2037-38.[5] In India, the highest energy demand has been projected for passenger cars followed by buses and then railways.[5] The World Bank study analysis estimates that, in 2038, the market size and investment potential of passenger transport in India could be US$8 billion and providing sustainable MAC solutions could lead to annual emissions reduction potential of 14 mtCO2e.

120. A sustainable cooling pathway for passenger transport in India will entail promotion of large-scale adoption of efficient MAC systems and optimization of demand by shifting to public transport systems and new vehicle designs which help reduce cooling load. Improving the efficiency of MAC systems in passenger transport vehicles can result in an estimated 20 percent energy savings between BAU and improved efficiency scenarios. Further 29 percent carbon savings are possible, mostly from mitigation of direct emissions through better MAC servicing and maintenance practices and recovery at end of life.[28]

121. In India, fuel economy 'mileage' is the most important consideration for consumers while purchasing a vehicle. MAC systems have an impact on vehicle mileage as they are responsible for 15 to 18 percent of energy consumption in passenger vehicles.[5] Within MAC systems, compressors act as the energy guzzlers by consuming about 77 to 89 percent of the energy supplied to them.[107] Currently, air conditioning is not included while testing vehicles for compliance with Corporate Average Fuel Economy (CAFÉ) in India, and the air conditioner is switched off. The incorporation of MAC into vehicle fuel emissions testing alongside mandatory equipment/ vehicle labelling programs across transport modes could help create a clear incentive for manufacturers to pursue air conditioning efficiency improvements.[108]

122. Further, dedicated domestic R&D is needed to develop efficient technology solutions to reduce direct and indirect emissions associated with the MAC sector, with a special focus on passenger cars, taking India's transition to e-mobility into consideration as well. As India is promoting e-mobility (covering both electric and hybrid vehicles) through its FAME India scheme, the energy consumption by batteries for air conditioning purposes in e-vehicles should be recognized as a major issue and potential R&D focus area. Air conditioners in e-vehicles can consume up to 40 percent of battery energy.

123. Another opportunity in this area is presented by the exploration of measures to

incentivize the commercialization of proven MAC technologies which are energy efficient. MAC baseline scenarios show that the current R134a system in India suffers from high system leakage and fuel consumption. With the introduction of enhanced R134a systems, there has been steady progress in improving the leak lightness, resulting in a 50 percent reduction in leakage and 40-44 percent lower emissions compared to the non-enhanced systems. However, the associated cost deters automakers from upgrading their systems in more price-sensitive vehicle markets.[109] There are efficient MAC systems that are being developed and piloted in the country. Measures which can support their scale up would help ensure energy efficiency and emission reductions.

124. Therefore, improving the efficiency of MAC systems in passenger transport vehicles is a key opportunity for concessional financing. Supported with a conducive policy environment, this opportunity can unlock private sector investments to shift passenger transportation systems towards energy efficiency and low GHG emissions. This can be achieved by building demand for energy-efficient MAC systems through S&L programs for vehicles and by leveraging R&D to support the improvement of MAC systems.

4.2 Sectoral Overview

125. Passenger transport air conditioning largely focuses on cars and buses in India. Cooling in the passenger transport sector is majorly covered by road and rail in India. Road transport comprises passenger cars, buses, goods vehicles and other vehicles while rail transport includes railways and metro rail networks. Under the passenger transport air conditioning sector, ICAP focuses on passenger light duty vehicles (cars, jeeps, taxis for public and private use), passenger heavy duty vehicles (air-conditioned buses) and the railway sector (air-conditioned passenger coaches). The aviation sector does not use refrigerant gases for cooling purposes, rather air is used as a refrigerant for air conditioning and refrigeration purposes. The shipping sector has data gaps as information on refrigerant use in the sector is not widely available.[5]

126. The market size of MAC has been growing in the country. MAC has grown considerably in India. Over the last 15 years, an overall growth of over 12 percent and 2.5 percent CAGR has been observed in the road and rail transport sectors, respectively.[5] The India automotive HVAC market size was US$822 million in 2018 and is projected to reach US$2,033 million by 2026, registering a CAGR of 11.6 percent.[26] The Indian passenger car air conditioners market alone is forecasted to surpass US$1 billion by 2023.[27] Analysis of the transport sector suggests that the MAC segment is projected to double in terms of energy consumption as well as total emissions within the next decade. ICAP has estimated that MAC is responsible for 15 to 18 percent of energy consumption in passenger vehicles, thereby projecting the highest energy demand for passenger cars followed by buses and then railways (Figure 7).[5] In line with this, under a BAU scenario, refrigerant demand for the MAC segment is expected to increase by over four times, from an average of 5,172 MT in 2017-18 to 22,142 MT in 2037-38.[5]

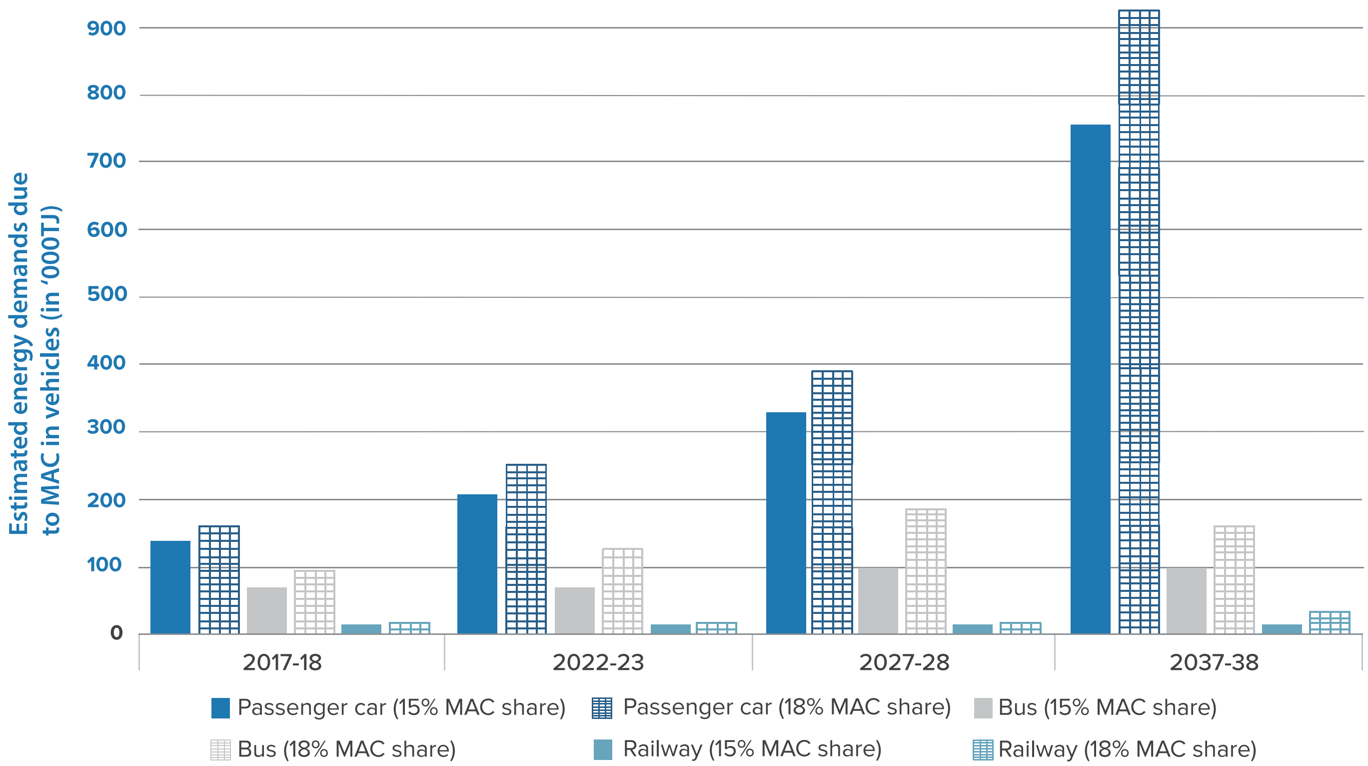

Figure 7: Energy demand projection due to MAC in passenger cars, buses and railways under two scenarios (MAC shares being 15 percent and 18 percent of the total energy consumption)[5]

4.3 Landscape of Cooling Opportunities in the Sector

127. Improving the efficiency of MAC systems in passenger transport vehicles presents a key cooling opportunity which will lead to significant energy savings and emission reduction. A sustainable cooling pathway for passenger transport in India will entail promotion of a large-scale adoption of efficient MAC systems and optimization of demand by shifting to public transport systems and new vehicle designs which help reduce cooling load. Improving the efficiency of MAC systems in passenger transport vehicles (passenger car, buses and rail) can result in an estimated 20 percent energy savings between BAU and improved efficiency scenarios and a further 29 percent carbon savings are possible, which will mostly come from mitigation of direct emissions through better MAC servicing and maintenance practices and recovery at end of life (Table 4).[28] This opportunity will therefore lead to direct climate benefits in the form of GHG emission reductions as well as developmental benefits in the form of new jobs for servicing, maintenance and recovery at end of life. The technical feasibility of this opportunity is high given that proven efficient MAC systems are available globally and in India. Further the administrative feasibility is high as well for this opportunity given that supportive regulations, i.e., CAFÉ standards are in place in the country along with relevant ongoing programs and schemes such as the S&L program, FAME scheme and Mission Innovation for convergence. The opportunity requires a limited number of stakeholders for decision-making, primarily the Ministry of Road Transport and Highways (MoRTH), thereby ensuring a relative ease of implementation. The likelihood of large-scale adoption of efficient MAC systems would require concerted efforts on R&D and commercialization which are supported by a conducive policy environment.

Table 4: Projected results for MAC energy consumption and emissions under BAU and improved scenarios[28]

	2017	2027 (BAU)	2027 (Improved)	Saving Potential in 2027
Annual energy consumption (mtoe)	3.0	5.5	4.4	20%
Total emissions ($mtCO_2e$)	10.8	22.6	16.1	29%

128. Building efficient and convenient public transport infrastructure is a key focus area for the transport sector in India and can help reduce cooling demand. The modal shift to public transportation systems and towards better designed vehicles which reduce cooling load presents a key opportunity which can significantly reduce refrigerant and energy demand. However, given the status of public transport infrastructure in India, there is a long road ahead for the sector. Building efficient and convenient public transport infrastructure is a key focus area for the sector which can help solve the twin problems of pollution and congestion.[110] This transition will require removal of barriers and capitalization of sectoral-level opportunities which are beyond the scope of the sustainable cooling agenda alone.

4.4 Prioritized Opportunities for Concessional Finance

129. Improving the efficiency of MAC systems in passenger transport vehicles is the priority opportunity for this sector given its potential climate and development benefits, high technical feasibility, presence of a policy environment and administrative structure that can ensure implementation in the short term. Supported by a conducive policy environment, this opportunity can unlock private sector investments to shift passenger transportation systems towards energy efficiency and low GHG emissions. The key interventions to be undertaken within this opportunity are:

- Measures which build demand for energy efficient MAC systems such as S&L programs for vehicles; and
- R&D to support improvements in energy efficiency of MAC systems while ensuring cost competitiveness, performance and durability.

130. S&L needed to support efficiency improvements in MAC systems. In India, fuel economy 'mileage' is the most important consideration for consumers while purchasing a vehicle. MAC systems have an impact on vehicle mileage, and within MAC systems, compressors act as the energy guzzlers by consuming about 77 to 89 percent of the energy supplied to them.[107] Currently, air conditioning is not included while testing vehicles for compliance with CAFÉ in India, and the air conditioner is switched off. The incorporation of MAC into vehicle fuel emissions testing alongside mandatory equipment/vehicle labelling programs across transport modes could help create a clear incentive for manufacturers to pursue air conditioning efficiency improvements.[108] The first-ever fuel efficiency standards for passenger cars in India, termed Corporate Average Fuel Consumption Standards, were implemented in 2017-18 and Stage 2 standards are scheduled for implementation in 2022–23. The Fuel Consumption Standards provide a mandate to manufacturers to continuously reduce the average fuel consumption of cars sold by them. Moving forward, India should consider the process of tightening the next round of targets under Fuel Consumption Standards for 2026 and 2030.[111]

131. R&D to support further improvements in energy efficiency of MAC systems, particularly for e-mobility, is needed. ICAP provides an overview of the R&D being carried out in the MAC industry and mentions that the focus has been on improvement of energy efficiency as well as on making the system more cost competitive and durable. This can be augmented by improving other components of the vehicle, for instance, the use of reflective windows, thermal insulation, heat load reducing body paint, as well as optimizing power trains. Such measures, in combination with other best-in-class technologies, could help in the reduction of MAC energy demand by up to 67 percent and halve the energy-related MAC emissions.[112] Dedicated domestic R&D is needed to develop efficient technology solutions to reduce direct and indirect emissions associated with the MAC sector, with a special focus on passenger cars, taking India's transition to e-mobility into consideration as well. As India is promoting e-mobility (covering both electric and hybrid vehicles) through its FAME India scheme, the energy consumption by batteries for air conditioning purposes in e-vehicles should be recognized as a major issue and potential R&D focus area. Air conditioners in e-vehicles can consume up to 40 percent of battery energy.

132. Incentivization of proven efficient MAC technologies can help accelerate their adoption in the country. Another opportunity in this area is presented by the exploration of measures to incentivize the commercialization of proven MAC technologies which are energy efficient. MAC baseline scenarios show that the current R134a system in India suffers from high system leakage and fuel consumption. With the introduction of enhanced R134a systems, there has been steady progress in improving the leak lightness, resulting in a 50 percent reduction in leakage and 40-44 percent lower emissions compared to the non-enhanced systems. However, the associated cost deters automakers from upgrading their systems in more price-sensitive vehicle markets.[109] There are efficient MAC systems that are being developed and piloted in the country. Measures which can support their scale up would help ensure energy efficiency and emission reductions. Examples of such efficient technologies include:

- **For the passenger car segment:** TATA Motors Limited along with German automotive supplier Mahle and the Institute for Governance & Sustainable Development has developed a new MAC system known as Secondary Loop MAC. It uses the HFC-152a, which has one-10th the GWP of the common refrigerant, HFC-134a, and is more fuel-efficient as well. The Secondary Loop MAC system was piloted in a TATA SUV which showed overall vehicle fuel savings of 1.9 to 2.6 percent. This would save 23-31 liters per year for a typical SUV driver in India with the vehicle being driven 15,000 km per year;[113] and

- **For metro rail:** Danfoss' Variable Frequency Drives have been installed at the air handling units and track way exhaust fans at Delhi Metro which have helped achieve energy efficiency of up to 20 percent. This has resulted in an estimated cost savings of over INR 400,000 (over US$5,000) per annum per Metro station. Similarly, in Kolkata Metro Rail Corporation and Chennai Metro Rail, installation of Danfoss Variable Frequency Drives has contributed to 15-25 percent energy savings across various applications.[114]

Table 5 provides a roadmap for the above mentioned prioritized opportunity in the passenger transport air conditioning sector. More details on the opportunity and its proposed interventions can be found in Annex 4.

Table 5: Roadmap for prioritized opportunities in passenger transport air conditioning sector

Terms: Short Term (2022-24); Medium Term (2025-30); Long Term (2031-38)

Instrument: Policy (P); Investment (I); Knowledge (K)

Topic		Proposed Intervention	Term	P	I	K	Key Stakeholders	National & State Policy Alignment
1 Improve Efficiency of MAC System in Passenger Transport Vehicles	A.1	Vehicle fuel efficiency standard improvement and effective implementation	Short Term	✓			MoRTH	CAFÉ norms
	A.2	Increased stringency of targets for 2026 and 2030	Medium Term					
	A.3	Effective enforcement and updation of targets	Long Term					
	B.1	Amendment in testing methodology for CAFÉ standard to include switching on of air conditioning while testing	Short Term	✓				
	B.2	Effective enforcement of amended testing methodology	Long Term					
	C.1	Ensured compliance of revised CAFÉ standard through development of incentive mechanism (such as a certification and trading system) for manufacturers	Short Term	✓	✓			
	C.2	Implementation of incentive mechanisms for manufacturers to adopt efficient MAC systems	Long Term					
	D.1	Labelling system for cars to build public awareness on energy efficiency and emission savings	Short Term	✓			MoRTH, BEE	S&L program
	D.2	Introduction and periodic updation of labels for cars	Long Term					
	E.1	R&D to improve energy efficiency of air conditioners in hybrid and electric vehicles	Short Term	✓		✓	DST, Ministry of Heavy Industries, R&D institutes, electric vehicle manufacturers	FAME Scheme Mission Innovation
	E.2	Policy support for adoption of energy efficiency and low-GWP refrigerant based MAC systems in hybrid and electric vehicles	Long Term					
	F.1	Program to enable private sector R&D on energy efficiency and low-GWP refrigerant based MAC systems	Short Term	✓		✓	DST, MoRTH, MoRD, manufacturers	Mission Innovation
	F.2	Incentives and policy guidance to support commercialization of proven technologies, particularly public transportation systems	Long Term					

Chapter 5

Refrigerants


R-414A
R-22

5.1 Summary

133. In India, refrigerant demand is expected to grow more than six times under a BAU scenario, from 22,522 MT in 2017-18 to 1,49,392 MT in 2037-38.[5] The demand for refrigerant-based vapor compression technologies to meet cooling requirements of buildings will primarily drive the projected refrigerant demand. After successfully implementing the first phase of the Hydrochlorofluorocarbons (HCFC) Phase-out Management Plan under the Montreal Protocol on Substances that Deplete the Ozone Layer, India is now implementing its Stage II. Under this, HCFCs with Ozone Depletion Potential will be phased out in India by 2030. India recently approved the ratification of the Kigali Amendment to the Montreal Protocol, and now the focus will shift to phase-down of Hydrofluorocarbons (HFCs). The baseline years for this have been set as 2024-25-26, and India will phase down HFCs in four steps starting in 2032, with a cumulative reduction of 10 percent in 2032, 20 percent in 2037, 30 percent in 2042 and 85 percent in 2047. India has also committed to freezing its HFC production and consumption in 2028.[115]

134. The analysis in this study showed that an effective phase down of HFC across India requires a two-pronged approach of ensuring reliable supply of low/zero GWP refrigerants and efficient refrigerant demand management. Several alternatives to HFCs are in use across the world, but these are not used at large scale in India, apart from in the RAC industry that has adopted the latest technologies. The RAC sector in India is phasing out HCFC-22 (with GWP 1,760) by deploying the comparatively lower-GWP R-32 (with GWP 677): however there is potential for adopting even lower GWP refrigerants. In 2018-19, R-32 and R-410 (with GWP 1,924) RACs had a market share of 80 percent in India, while R-290 (with GWP 3), an HFC alternative, had only a 2 percent market share.[63]

135. Annual refrigerant demand in India could be reduced by 31 percent from a BAU scenario by 2038 with key interventions such as refrigerant transitions away from HCFC-22 and R-410A to low-GWP refrigerants, reduced tube diameter in heat exchangers from 7 millimeter (mm) to 5 mm, large-scale introduction of micro channel heat exchangers (resulting in significant reduction in refrigerant charge per unit), and use of good servicing practices.[116] The largest estimated reduction potential for refrigerant demand is shown by the space cooling in the buildings sector, with a 33 percent reduction over BAU scenario. The cold chain and refrigeration sector can also contribute to a reduction in refrigerant demand, with a 11 percent potential reduction over BAU scenario.[5]

136. Achievement of India's HFC phase down strategy requires robust and practicable sector-wise action plans, technology roadmaps and a conducive policy environment. To this end, India plans to develop a 'National strategy for phase down of HFCs as per the applicable phase down schedule for India' based on consultations with all industry stakeholders by 2023. Further, the country can benefit from domestic innovation and production of alternative low-GWP refrigerants that are cost-effective and best suited to Indian climatic conditions. The ammonia refrigeration industry alone is estimated to be worth around US$200 million, with an average growth rate estimated to be 10 percent.[117] India's collaborative R&D program for low-GWP refrigerants should be supported by necessary policy frameworks and reliable supply chain development of the identified affordable alternative refrigerants and compatible equipment.

137. Effective servicing and maintenance will be critical in reducing refrigerant leakage, minimizing indirect emissions from energy inefficient equipment and creating significant employment opportunities. The servicing sector consumes more than 40 percent of the total refrigerant currently used in the country.[5] ICAP recognizes that with the growth in cooling demand, there will be increased demand for servicing. Therefore, this study concludes that in the refrigerants sector, the key opportunity for concessional financing is in improving servicing, maintenance and disposal to reduce refrigerant demand across India. This can be achieved by ensuring a minimum threshold for training, certifications for service technicians and appropriate policy mandates that help formalize the service sector in India. India also needs to develop a conducive policy framework and infrastructure for recovery, recycling and reclamation at disposal.

5.2 Sectoral Overview

138. India will be phasing down HFC production and consumption as per the Kigali Amendment to the Montreal Protocol. India is currently implementing Stage II of HCFC Phase-out Management Plan after successful implementation of its first phase under the Montreal Protocol on Substances that Deplete the Ozone Layer. Under this, the phase out of HCFCs that have Ozone Depletion Potential in India will be completed by 2030. India is the first Article 5 country to completely phase out consumption of HCFC-141b in the foam manufacturing sector (1 January 2020) by deploying low-GWP refrigerants without moving to HFCs, as has been done in the USA and several other developed countries. With the recent government approval for the ratification of the Kigali Amendment to the Montreal Protocol, the focus now will shift to phase-down of HFCs. India has committed to freeze its HFC production and consumption in 2028. With 2024-2025-2026 as the baseline years, India will complete its phase down of HFCs in four steps from 2032 onwards with cumulative reduction of 10 percent in 2032, 20 percent in 2037, 30 percent in 2042 and 85 percent in 2047.[115]

139. Annual refrigerant demand is expected to grow more than six times over two decades. In 2015, the air-conditioning sector had the largest market share of all sectors, estimated at 62 percent of refrigerant consumption in India.[118] With respect to HFC consumption, the commercial refrigeration sector was the highest at 22 million TR, followed by MAC at 20 million TR. Under the BAU scenario, annual refrigerant demand for cooling across all sectors in India is expected to grow more than six times from 22,522 MT in 2017-18 to 1,49,392 MT in 2037-38.[5] Figure 8 presents the sector-wise growth in refrigerant demand between 2017-18 and 2037-38 as shown in ICAP. The demand for refrigerant-based vapor compression technologies to meet cooling requirements of buildings will primarily drive the projected refrigerant demand.

5.3 Landscape of Cooling Opportunities in the Sector

140. Effective HFC phase down requires a two-pronged approach of ensuring reliable low/zero GWP refrigerants supply and efficient

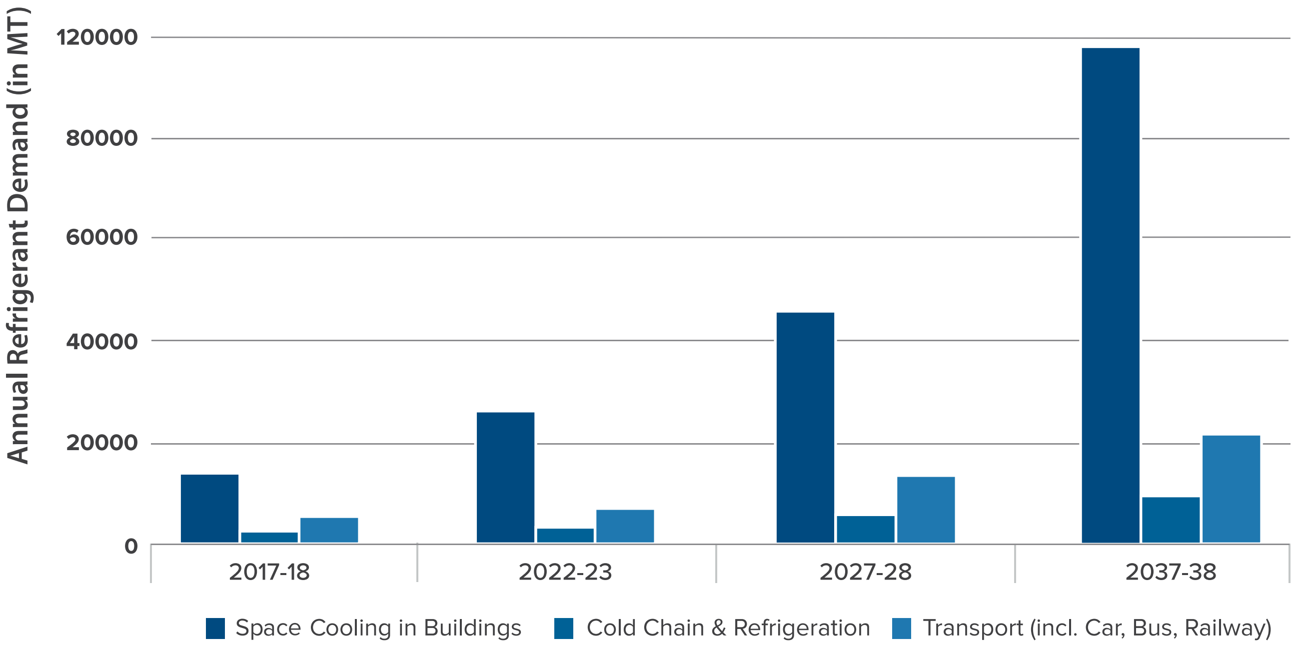

Figure 8: Annual refrigerant demand under the BAU scenario[5]

refrigerant demand management. While several alternatives to HFCs exist and are used across the world, including in India, these are yet to be put into large-scale commercial use in the country with an intention of replacing HFCs. However, particularly the RAC industry in India has been quite ahead in adoption of the latest technologies. India is phasing out HCFC-22 (with GWP 1,760) in the RAC sector by deploying the comparatively lower-GWP R-32 (with GWP 677), while several developed countries go with high-GWP R-410A. In 2018-19, R-32 (with GWP 677) and R-410 (with GWP 1,924) RACs had a market share of 80 percent in 2018-19 in India while R-290 (with GWP 3), an HFC alternative, had 2 percent market share in the same year.[63] An effective phase down of HFC would require a two-pronged approach of ensuring reliable supply of alternative low/zero GWP refrigerants and managing the demand for refrigerants across all sectors. To this end, the key opportunities as presented in the sectoral pathways for impact in Chapter 1 include:

1. Support HFC phase down through roadmaps, policies and public procurement to enable deployment of low-GWP refrigerants and technologies with lower refrigerant demand;
2. Promote domestic R&D and indigenous production of low-GWP refrigerants; and
3. Improve servicing, maintenance and disposal to reduce refrigerant demand.

5.3.1 Support HFC phase down through roadmaps, policies and public procurement

141. Studies have estimated that the annual refrigerant demand in India could be reduced by 31 percent from the BAU scenario in 2038. This reduction has been estimated based on key interventions such as refrigerant transitions away from HCFC-

22 and R-410A to low-GWP refrigerants, reduced tube diameter in heat exchangers from 7 mm to 5 mm, large-scale introduction of micro channel heat exchangers (resulting in significant reduction in refrigerant charge per unit), and use of good servicing practices.[116] Amongst sectors, the space cooling in buildings sector shows the largest estimated reduction potential in refrigerant demand in 2037-38 of 38,500 MT, which is a 33 percent reduction over the BAU scenario, and the cold chain & refrigeration sector which shows an estimated reduction potential in refrigerant demand of 1,100 MT in 2037-38, a 11 percent reduction over the BAU scenario.[5]

142. Achievement of India's HFC phasedown strategy requires robust and practicable sector-wise action plans, technology roadmaps and a conducive policy environment. India plans to develop a 'National strategy for phase down of HFCs as per the applicable phase down schedule for India' based on consultations with all industry stakeholders by 2023. The Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol has highlighted the need for HFC phase-down plans known as Kigali HFC implementation plans (KIPs).[119] Effective implementation of the national strategy for HFC phase down or India's KIP will require sector-wise action plans which provide technology roadmaps combined with modeling phase down requirements. This would help India identify the availability of viable technologies for each sector and inform the prioritization exercise required for phasing down HFCs, including assessment of the economic importance of the sector and market trends. In India, information relevant to the development, testing and approval of new refrigerants is often scattered among various industry entities that each conduct their own investigations. A single repository or system which can consolidate knowledge on various alternative refrigerants in terms of their application, safety standards, performance, availability and affordability could be beneficial in guiding industry transitions. Finally, public procurement in India is estimated to be 15-20 percent of its GDP[120] and can provide direction and help influence consumers and market behavior towards the adoption of low-GWP refrigerant-based and energy efficient technologies. India will be making concerted efforts in implementing this opportunity given the country's commitment to the Kigali Amendment of the Montreal Protocol. The targeted HFC phase down will lead to direct and indirect climate benefits such as reduced GHG emissions from HFCs and green jobs which promote low-GWP refrigerant-based equipment across all cooling sectors.

5.3.2 Promote domestic R&D and indigenous production of low-GWP refrigerants

143. India can benefit from domestic innovation and production of alternative low-GWP refrigerants that are cost-effective and best suited to Indian climatic conditions. Currently, most of the low GWP alternative refrigerants are heavily patented and costlier than the existing refrigerants in use. ICAP highlights the need for sustained R&D efforts in both public and private sector to reduce India's reliance on imported refrigerant-based equipment and parts. This also requires a greater push for a domestic manufacturing base that can produce refrigerants, equipment and components specifically for the Indian market. The ammonia refrigeration industry alone is estimated to be worth around US$200 million, with an average growth rate estimated to be 10 percent.[117]

144. India's collaborative R&D program for low-GWP refrigerants should be supported by necessary policy frameworks and reliable supply chain development of the identified affordable alternative refrigerants and compatible equipment. The lack of industry awareness, particularly in smaller enterprises, on the viability and availability of alternatives to high-GWP HFCs can be a key barrier to investments.[121] The need for a government-initiated R&D program to identify, measure and test alternatives could greatly contribute to filling this information gap. As a first step, MoEFCC launched a collaborative R&D program to develop cost-effective low-GWP sustainable refrigerant technologies as an alternative to HFCs in 2016.[122] This R&D initiative brings together government, research institutes, industry and civil society. Another key driver for domestic R&D pertains to the aspect of Intellectual Property Rights. The ICAP notes that low-GWP alternatives are heavily patented by multinational companies. Particularly those pertaining to Hydrofluoroolefins (HFOs) are a key challenge for HFC phase down. HFO-1234yf is a substitute for HFC-134a (GWP 1,430) that is widely used in commercial refrigeration and MAC currently. HFO patents can be classified under two major categories of production process patents[xxi] and application patents.[xxii] Application patents can be a barrier in early adoption of lower-GWP technologies. The Montreal Protocol's Multilateral Fund,[xxiii] to some extent, has compensated for the cost of licenses and access to patented technologies. However, further evaluation is needed to assess if a licensing arrangement supported by the Multilateral Fund can be used as a way to address the application patent barrier[123] that exists today. A World Bank study notes that a significant share of HFO process and application patents will become off-patent (available to the public) by 2025.[124] An Indian refrigerant manufacturer has developed a process to produce lower-GWP HFC-32 refrigerant and there is already production of this refrigerant not only to meet the domestic market but also cater to the needs of other countries. Also, in the case of low-GWP HFO, while there are a large number of production process patents filed, chemical producers in China and India have invented new production processes that were not

[xxi] Production process patents cover a specific process or use of raw materials and/or other inputs to manufacture the products.
[xxii] Application patents covering new product design to work with the substances or use of the substances in a particular equipment type.
[xxiii] The Multilateral Fund for the Implementation of the Montreal Protocol, in operation since 1991, aims to assist developing country parties to the Montreal Protocol whose annual level of consumption of the ozone depleting substances chlorofluorocarbons and halons is less than 0.3 kilograms per capita to comply with the control measures of the Protocol. Currently, 147 of the 197 Parties to the Montreal Protocol meet these criteria and are referred to as Article 5 countries. As at December 2021, the contributions received by the Multilateral Fund from developed countries, or non-Article 5 countries, totaled over US$4.37 billion. The Fund has also received additional voluntary contributions amounting to US$25.5 million from a group of donor countries to finance fast-start activities for the implementation of the HFC phase down. To facilitate phase-out by Article 5 countries, the Executive Committee has approved 144 country programs, 144 HCFC phase-out management plans and has funded the establishment and operating costs of ozone offices in 145 Article 5 countries.

covered by these patents.[124] This Indian producer is awaiting the expiration of the application patent for commercial production which will happen in 2024. Finally, reliable supply of affordable alternative refrigerants can act as a barrier to adoption by industry. In the past, the refrigerant transition in India had caused a dramatic rise in prices and an accompanying shortage in refrigerants in smaller cities and towns. This further led to unorganized black markets selling refrigerants, many of them uncertified blends, at an even higher price.[121] A strong domestic manufacturing base for refrigerant production could help address this barrier in India's HFC phase down pathway. In addition to this, a shift towards new low-GWP refrigerants will require the availability of the requisite infrastructure to ensure their adoption, including the availability of compatible equipment, adequate supply of the refrigerants to ensure low downtime of equipment, and so on. This opportunity of domestic R&D and indigenous production of low-GWP refrigerants will require significant efforts to implement and scale up, thereby offering limited direct and indirect climate benefits.

5.3.3 Improve servicing, maintenance and disposal to reduce refrigerant demand

145. Effective servicing and maintenance will be critical in reducing refrigerant leakage, minimizing indirect emissions from energy inefficient equipment and creating significant employment opportunities. The servicing sector consumes more than 40 percent of the total refrigerant currently used in the country.[5] ICAP recognizes that, with the growth in cooling demand, there will be increased demand for servicing. Servicing can help reduce direct carbon emissions from refrigerants by:

- Ensuring operational efficiency through proper installation and maintenance of refrigerant-based equipment across cooling sectors; and
- Carrying out proper end-of-life recovery (for recycling and reuse) and disposal of refrigerants across cooling sectors.

India is estimated to have more than 200,000 RAC service technicians, most of them being in the informal sector.[115] Servicing of low-GWP refrigerant air conditioning units is expected to see a 10-fold increase in jobs over the next two decades from a base of 0.2 million technicians in 2017 to 2 million.[15] Similarly other refrigeration and air conditioning sectors will also have requirements of skilled service technicians.

146. Quality and safety of servicing practices need to be ensured through minimum threshold for training, certifications for service technicians and appropriate policy mandates that help formalize the service sector in India. A sustainable cooling pathway for India will require quality and safety of servicing practices to remain intact by ensuring a minimum threshold for training through updated and well-designed curricula and, more importantly, certifications for service technicians. Several countries prohibit non-licensed or non-certified service technicians from installing, servicing, or repairing refrigeration and air-conditioning equipment, or handling refrigerants. These measures also allow for social welfare and security systems to be put in place for service technicians through targeted insurance and repeated training sessions. India will need to move towards such a model of formalization of the service sector to create an ecosystem in which several refrigerant gases can exist in the Indian market.[121] This process will need to be complemented by policy instruments such as mandating leak tests (in large and mobile applications, especially) and establishing standardized professional servicing practices. Good policy-directed practices which have been introduced in India, such as the banning of disposable cylinders, also need to be implemented effectively.[121] This opportunity will result in significant climate mitigation and development benefits while also presenting a high potential for scaling up. India has relevant policies and ongoing programs which ensure administrative feasibility of this opportunity. Particularly the Ozone Cell at the MoEFCC in partnership with the Electronic Sector Skill Council of India is implementing a project for upskilling and certifying 100,000 RAC service technicians under the Skill India Mission-PMKVY of the Ministry of Skill Development & Entrepreneurship (MSDE).[115]

5.4 Prioritized Opportunities for Concessional Finance

147. Improving servicing, maintenance and disposal to reduce refrigerant demand is the priority opportunity for this sector given that it will result in significant climate and development benefits. It is implementable and has high need and potential for leveraging concessional finance and private sector investment towards the creation of skilled service technicians and required infrastructure. The key interventions to be undertaken under this opportunity are:

- Creation and uptake of trained service technicians to ensure proper servicing and maintenance of refrigerant-based equipment to reduce refrigerant leakage; and
- Measures to support recovery, recycling and reclamation of refrigerants.

148. A well-designed program to support skilling of technicians along with measures to ensure their employment will help mainstream proper servicing and maintenance of refrigerant-based equipment. This would include training and certification programs for service technicians on Good Service Practices (GSP) across sectors to better manage and reduce refrigerant losses during recharge and end-of-life. Amongst sectors, priority should be given to the RAC sector which has tremendous market share and growth potential. MoEFCC recently released the book on 'Good Servicing Practices for Energy Efficient Operations of Room Air Conditioners' which should be taken forward through a dedicated training program. Further, state-level engagement to understand the status and need of trained service technicians as well as availability and quality of training institutions would be critical to ensure effective implementation across the country. To this end, it is important to engage industry to participate in training delivery and commit to employing trained candidates to facilitate large-scale adoption of this intervention. The training programs should be complemented with a central voluntary certification scheme through a single government entity under a single framework. Finally, customer awareness programs which help create demand for certified technicians across sectors will be beneficial in the long run.

149. India needs to develop a conducive policy framework and infrastructure for recovery, recycling and reclamation at disposal. ICAP identifies recovery, recycling, and reclamation at disposal as a weak link in the judicious use of currently employed high-GWP refrigerants. There are significant refrigerant leaks in residential and commercial air conditioners, and in MAC used in cars. Recovery, recycling and reclamation are expensive processes and the servicing industry in India is not aligned toward affordable and requisite skills needed for these. Moreover, there is lack of credible data on the refilling requirements of refrigerants due to leakage in the Indian context. Refrigerant recovery systems are readily available, including in India. Recovery of refrigerant, especially from systems with relatively large quantities, has become a conventional part in servicing practices in most countries, the main incentive being the cost of refrigerants, besides environmental protection. In non-A5 countries (developed countries that have ratified the protocol) under the Montreal Protocol, the regulatory framework is driving the recovery of refrigerants. The analysis of regulations in the U.S., UK, Germany and Singapore to understand how recovery and disposal of refrigerants is managed (US EPA, 2011,2020; GIZ GmbH,2015; NEA 2020; IOR UK,2018) showed that refrigerants are either recovered on-site by a qualified technician or the final person in the disposal chain such as e-waste recyclers. India does not have any mandate in place to recover, reclaim or destroy refrigerant gases effectively.[121] Even where disposal facilities exist for gases, the recovery and transportation costs are high and act as a huge disincentive.[121] For India to meet its HFC phase down targets, end-of-life disposal of refrigerants is important, as is reducing emissions during the operational life cycle. Given the lack of infrastructure, policy and business action in India on this front, there is a need to identify and understand different business cases for effective policy implementation to minimize operational and end-of-life emissions.[121] A key intervention for end-of-life recovery in the case of RACs is that these are covered under the Extended Producer Responsibility (EPR) and e-waste guidelines for reclaiming electronic components at end of life. This provides a possible opportunity to embed refrigerant disposal guidelines within existing regulatory mechanisms of end-of-life disposal of RACs. Both EPR and e-waste rules are yet to be implemented and are likely in the early stages of the implementation process. Currently central air conditioners are not included in the E-waste Policy. EPR specifies the responsibility of the manufacturer/producer to make sure that the product at the end of its life is collected and either recycled, reused, or disposed in a climate responsible way.

Table 6 provides a roadmap for the prioritized opportunities in the refrigerants sector. More details on the opportunities and their proposed interventions can be found in Annex 5.

Table 6: Roadmap for prioritized opportunities in refrigerants sector

Terms: Short Term (2022-24); Medium Term (2025-30); Long Term (2031-38)

Instrument: Policy; Investment; Knowledge

Topic		Proposed Intervention	P	I	K	Key Stakeholders	National & State Policy Alignment
1 Improve servicing, maintenance and disposal to reduce refrigerant demand	A.1	Skilling of technicians and supporting their employment through: i) Training and certification programs for service technicians on GSP with priority in RAC sector ii) State-wise assessment of the demand and availability of trained service technicians and availability and quality of training institutions iii) Dialog with industry to encourage participation iv) Central voluntary certification scheme through a single government entity under a single framework	✓		✓	MSDE, MoEFCC, MoHUA, MoCI, MoFPI, MoRTH	Skill India Mission - PMKVY
	A.2	Successful implementation of the skill development program of technicians by: i) Establishing training centers/centers of excellence across India and upgradation of training centers ii) Promoting online refresher training courses iii) Designing programs for building customer awareness on the need and benefits of hiring only certified technicians. Mandate the hiring of only certified technicians by large facilities	✓		✓	MSDE, MoEFCC, MoHUA, MoCI, MoFPI, MoRTH	Skill India Mission - PMKVY
	A.3	Universal mandatory certification for all technicians	✓		✓	MSDE, MoEFCC, MoHUA, MoCI, MoFPI, MoRTH	Skill India Mission - PMKVY
	B.1	Listing of empaneled certified or ITI- trained servicing personnel on GeM portal	✓			MoCI	GeM
	C.1	Policy and training program to support recovery, recycling and reclamation or effective destruction of refrigerants	✓			MSDE, MoEFCC, Sector Skill Councils	Skill India Mission - PMKVY
	D.1	Subsidies to bring down cost of recovery equipment	✓	✓		MoEFCC, MDBs, FIs, private companies	
	E.1	Infrastructure development and incentives to support recycling and reclamation of refrigerants and end-of-life management of gases	✓	✓		MoEFCC, MDBs, FIs, private companies	
	F.1	Technician training on recovery and transport of refrigerants to reclamation centers; mandatory public sector utilization of licensed service technicians only	✓			MSDE, MoEFCC, Sector Skill Councils	Skill India Mission - PMKVY
	G	Refrigerant disposal guidelines embedded within the EPR and e-waste guidelines for reclaiming electronic components at end of life, particularly for RACs	✓			MoEFCC	EPR and e-waste guidelines

GeM: Government e Marketplace;

Chapter 6

Conclusion and Way Forward

150. India is experiencing severe heat waves with higher temperatures arriving earlier in the summer season and for longer durations. While April 2022 saw temperatures in the capital, New Delhi, reaching above 46°C, the month of March was the hottest ever recorded. The majority of poor and marginalized communities across India without proper access to cooling are extremely vulnerable to this heat. This rising heat can also jeopardize economic productivity as up to 75 percent of India's workforce depends on heat-exposed labor.[1] One of the consequences of this rise in temperatures will be an increase in demand for cooling. India's long-term food and health security also depends on a reliable cold chain as transport of fresh produce and pharmaceuticals needs an end-to-end refrigerated system. Recognizing the risks of extreme heat, in 2019 the Government of India launched the ICAP to provide sustainable cooling and thermal comfort for all. This current study presents an overview of the opportunity in each of the cooling sectors, along with actionable roadmaps comprising policy, investment, and knowledge interventions to help achieve ICAP goals through short-, medium- and long-term actions. The sustainable cooling opportunities have also been prioritized for concessional financing and private sector investments, and eight key clustered opportunities have been identified as being key to advancing ICAP goals.

151. In the space cooling sector, the demand for cooling in buildings is likely to increase by 11x (in TR) by 2037-38, mainly due to the projected increase of two-and-a-half to three times in commercial and residential floor area. The majority of this projected space cooling demand (52 percent) will be due to an increase in household air conditioner ownership increasing from 8 percent (2018) to 40 percent (2038), and 50 percent of commercial buildings becoming air conditioned. It will be important to integrate passive cooling measures in these buildings to not just improve thermal comfort but also achieve 20 percent energy savings by 2037-38. Another avenue for energy savings is improved efficiency of cooling technologies through implementing stringent standards and supporting domestic manufacturing. This will help reduce costs and promote their uptake. Social housing offers a huge opportunity for both integrating passive measures and promoting the use of high efficiency appliances, and developing linkages with the PMAY scheme offers an opportunity to influence the rural and urban social housing sectors. It is also necessary to reduce demand, along with shifting it to low carbon cooling technologies service delivery models. District cooling offers such an opportunity that can not only increase efficiency, but also reduce refrigerant and peak power demand. Demand for cooling, along with a reduction in urban temperatures can also be achieved by incorporating NbS in urban planning.

152. Growth of the cold chain and refrigeration is projected to double cooling and refrigerant demands, and triple the energy consumption for the sector by 2027.[5] To be able to implement energy efficiency measures and reduce the projected cooling, refrigerant and energy demands, it is important to first understand cold chain infrastructure needs across the country, along with getting accurate data on food and pharmaceutical losses. As technologies for bringing in energy efficiency and renewable energy into the cold chain already exist, there is a need to now strengthen existing policies to promote their adoption, and explore innovative business models that support different stakeholders at a decentralized level. Refrigerated transport also needs directed policy support to promote uptake of alternate clean cooling technologies in reefers, and for the development of multimodal cold chain links through rail and highways. One of the key requirements of the sector, providing both climate and developmental benefits, is capacity building of key stakeholders such as operators and technicians on proper functioning and maintenance of energy efficient technologies and farmers on better management of produce. As refrigerator ownership is projected to grow from 0.18 per household in 2012 to 0.64 in 2030, the retailer and consumer end of the chain also needs support with implementation of energy efficiency measures. This offers the second largest opportunity (after space cooling) in terms of growth in cooling demand and energy consumption. In this sector as well, implementing stringent standards and supporting domestic manufacturing can help reduce costs of high efficiency domestic and commercial refrigeration systems, increasing their uptake.

153. Vehicle population in India is projected to grow more than five times for cars and more than twice for buses over the next two decades. As MAC is responsible for 15-18 percent of energy consumption in passenger cars and buses, refrigerant demand is expected to increase by over four times in this period. This sector is also projected to double its energy consumption as well as total emissions between 2017 to 2027. Improving the efficiency of MAC systems and fuel use can help achieve 20 percent energy savings, and better MAC servicing and maintenance practices, along with recovery at end of life can result in 29 percent GHG emissions reduction. This can be achieved by supporting R&D in energy efficiency of MAC systems and building demand for these by developing and implementing a S&L program for vehicles. A key means of reducing demand for transport air conditions is implementing behavior change programs that help shift load towards public transportation systems.

154. Given the growth of each of the cooling sectors discussed, annual refrigerant demand for cooling across sectors is expected to grow by more than six times by 2038 compared to 2018.[5] In view of India's approval for ratification of the Kigali Amendment of the Montreal Protocol, effective phase down of HFCs is needed. This requires a two-pronged approach that ensures reliable supply of low/zero GWP refrigerants and management of demand for refrigerants across sectors. India has been ahead in phasing out HCFC-22 in the RAC sector by deploying the lower-GWP R-32 and introducing R-290 (with a very low GWP of 3) based RACs in the market, and this experience will be highly beneficial during phase out of HFCs. The RAC industry's example can be followed for phasing out HFCs by promoting domestic supply of low-GWP refrigerants. This will require provision of support to R&D and domestic production of such refrigerants. There is also potential for reducing demand by bringing in GSP and maintenance of refrigerant-based equipment to reduce refrigerant leakage, along with recovery, recycling and reclamation of refrigerants.

155. Multistakeholder engagement and capacity building will help enable adoption of new business models and sustainable cooling

technologies across sectors. The private sector will need to play a key role in mobilizing investments toward sustainable cooling. To this end, India will need to adopt a systematic approach for engaging industry and other relevant stakeholders in piloting and scaling up successful business models and sustainable cooling technologies across sectors. There are several global success stories of platforms and frameworks that have accelerated the uptake of sustainable cooling solutions, which can be adapted for India. For instance, the Africa Centre of Excellence for Sustainable Cooling and Cold Chain discussed in Chapter 3 – that deploys 'Living Laboratories' in strategic locations in rural areas to conduct research and offers technical assistance, demonstrations and knowledge transfer to rural communities – can be an excellent means for building capacities and scientific knowledge and developing the necessary infrastructure for a decentralized sustainable agriculture cold chain in India. On the end-user side, effective communications campaigns that are informed by robust data and analytics across cooling sectors will be essential, and a key step for reducing and shifting demand.

156. Concessional financing can play a key role for sustainable cooling in India. Concessional finance by multilaterals such as The World Bank will need to play a key role in helping India develop financial instruments and innovative models that accelerate the adoption of sustainable cooling measures. This will ensure that sustainable cooling solutions are accessible and affordable for consumers and help build demand for these. Therefore, these innovative financial instruments will be crucial to develop and transform the cooling market in India. The study identifies eight prioritized opportunities for concessional financing in this area. These opportunities will need to be studied in greater detail through deep-dive assessments to unlock their potential for meeting India's cooling needs in a sustainable manner. This should include detailed financing plans for these opportunities, which cover their cost-benefit analyses and probable financing sources beyond MDBs.

157. Innovative financing models can support scale up measures for ensuring Thermal Comfort for All in India. India's transition to LED lightbulbs is a successful example of uptake of energy efficient technology at scale that can be replicated for the cooling sector. The Government of India's bulk procurement and distribution of LED bulbs through EESLs UJALA program has led to an estimated annual energy savings of about 48 billion kWh and estimated GHG emission reduction of 39 million metric ton of CO_2 per year.[29] Similar opportunities can be explored for scaling up adoption of higher efficiency fans and refrigerators as well. However, for a higher value product such as refrigerators, it will be important to first address challenges of high costs, the need for installation and maintenance, and end of life disposal, before such a bulk procurement program can be developed. Funds can also be raised for sustainable cooling through Cooling Bonds along the lines of the recently issued Rhino Bond by The World Bank. This bond – Wildlife Conservation Bond – was rolled out in South Africa for protecting the endangered black Rhinos and closing the biodiversity funding gap in the country. The first of a kind

US$150 million five-year bond offers investors a return on their investments if the black Rhino population rises in two protected areas. This bond also includes a potential performance related payment from the Global Environment Facility (GEF).[125] Similar bonds can be explored for the cooling sectors as well, where investors get a return on their investment based on the energy savings and GHG emission reduction, along with reduction for cooling and refrigerant demands. Another opportunity that can help raise finance for energy efficiency interventions in the sector is through the carbon market which can provide funding based on the potential avoided GHG emissions and energy savings due to the interventions. Currently in the agriculture sector, carbon credits can be earned from a range of activities such as agroforestry, biogas production, and low tillage farming, all of which reduce CO_2 emissions. Similarly, the potential of earning carbon credits for activities carried out to develop and implement a sustainable cold chain can be explored. This can help raise additional funding for farmer groups to implement decentralized solutions.

158. Launch "Sustainable Cooling and Thermal Comfort for All" as a national mission. ICAP provides the guiding framework for building the cooling infrastructure in a sustainable, climate-friendly manner in India. To achieve ICAP's objectives, there is a need to enable resource flow from both public and private sectors as well as promote convergence across central, state, and local levels. This could possibly be achieved through a mission mode by establishing "Sustainable Cooling and Thermal Comfort for All" as one of the government's flagship missions. India has experience in achieving such decentralized objectives through missions such as Smart Cities Mission, Swachh Bharat and Jal Jeevan Mission, amongst others. Similarly, the objective of providing sustainable cooling and thermal comfort for all can be pursued through a mission mode as well as by streamlining budgetary allocations and financial flows. This could also help provide the institutional framework for continuous monitoring and evaluation of ICAP implementation to inform planning across sectors. Building a conducive policy environment will help spur action and investments by the private sector as well towards sustainable cooling. Under this mission, The World Bank and Government of India partnership on sustainable cooling on the eight prioritized opportunities identified in this study could be developed to:

(i) deploy 'living laboratories' to pilot multistakeholder engagement and new technologies;
(ii) enable market transformation for high impact space cooling technologies;
(iii) support development of sustainable and energy efficient cold chains; and,
(iv) promote better operations and servicing through capacity building of stakeholders, and incorporation of effective monitoring systems.

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Annexes

Annex 1: Prioritization of Sustainable Cooling Opportunities

The study focuses on all identified thematic areas under ICAP including space cooling in buildings, cold chain and refrigeration, transport air conditioning and refrigerants (covering the ICAP thematic areas of R&D, refrigerant demand & indigenous production, and refrigeration & air-conditioning servicing sector). It presents actionable roadmaps for each of the cooling sectors as well as prioritized opportunities for concessional financing and private sector investments. A series of interconnected steps were followed to identify holistic, inclusive, viable, specific, and scalable interventions that can operate through partnerships with various actors and add impetus to the implementation of ICAP goals. These steps are presented below:

Step 1 – Literature Review: The study began with an extensive literature review and covered a detailed analysis of the existing policies, programs and initiatives in India that are directly or indirectly relevant to the multisectoral actions recommended under ICAP. This analysis covered existing governmental schemes and programs mapped under ICAP and went beyond to identify other relevant cooling policies and programs to strengthen India's cooling policy strategy. Building on the ICAP sectoral analysis for cooling demand, energy savings and emissions reduction, the study identified various areas and actions for sustainable cooling in each sector and collected data on investment potential and developmental benefits, including job creation potential for some sectors.

Step 2 – Multistakeholder Consultations: The study authors undertook stakeholder consultations with government, private sector and sectoral experts to identify and assess the key barriers for sustainable cooling in each of the sectors. This included identifying associated institutional, financing, regulatory and market barriers and the required sustainable cooling interventions. The study followed a highly consultative process to help identify and prioritize opportunities and associated interventions that were pragmatic, implementable and have the buy-in of key stakeholders in all cooling sectors and across value chains.

Step 3 – Clustering of Sustainable Cooling Opportunities: The identified sustainable cooling interventions were clustered based on institutional set up, ease of implementation and complementarity of actions. This clustering resulted in a longlist of 19 sustainable opportunities with 10 opportunities in space cooling, four opportunities in cold chain and refrigeration, two opportunities in passenger transport air conditioning and three opportunities in the refrigerant sector.

Step 4 – Prioritization of Sustainable Cooling Opportunities: A two-step multicriteria prioritization framework was applied to the longlist of clustered sustainable cooling opportunities. The first step covered the criteria of climate benefits, development benefits and ability to implement.

Table A 1.1 provides details of these three criteria, their sub-criteria, weightage, scoring scale and rationale used in the first step prioritization. The second step prioritization focused on evaluating the role of concessional financing and private sector investments. Notably, the criteria covered in this step, that is, the need and potential for leveraging concessional finance or private sector investment, has been given higher weightage as compared to other criteria with a scoring scale of 1 to 3 (from low to high potential for accessing concessional and private finance).

The potential of an opportunity to leverage different financing instruments is an important criterion for understanding the role and scope of involvement of financing institutions and MDBs in implementation. Given the importance of this criterion in selecting opportunities where concessional finance instruments or private sector investment can enable implementation, financing has been given double weightage compared to the other criteria.

Prioritization Criteria for Concessional Financing

- Study adopted two-part prioritization to identify key areas where concessional finance can bring about significant impact.
- Multi-criteria assessment approach:

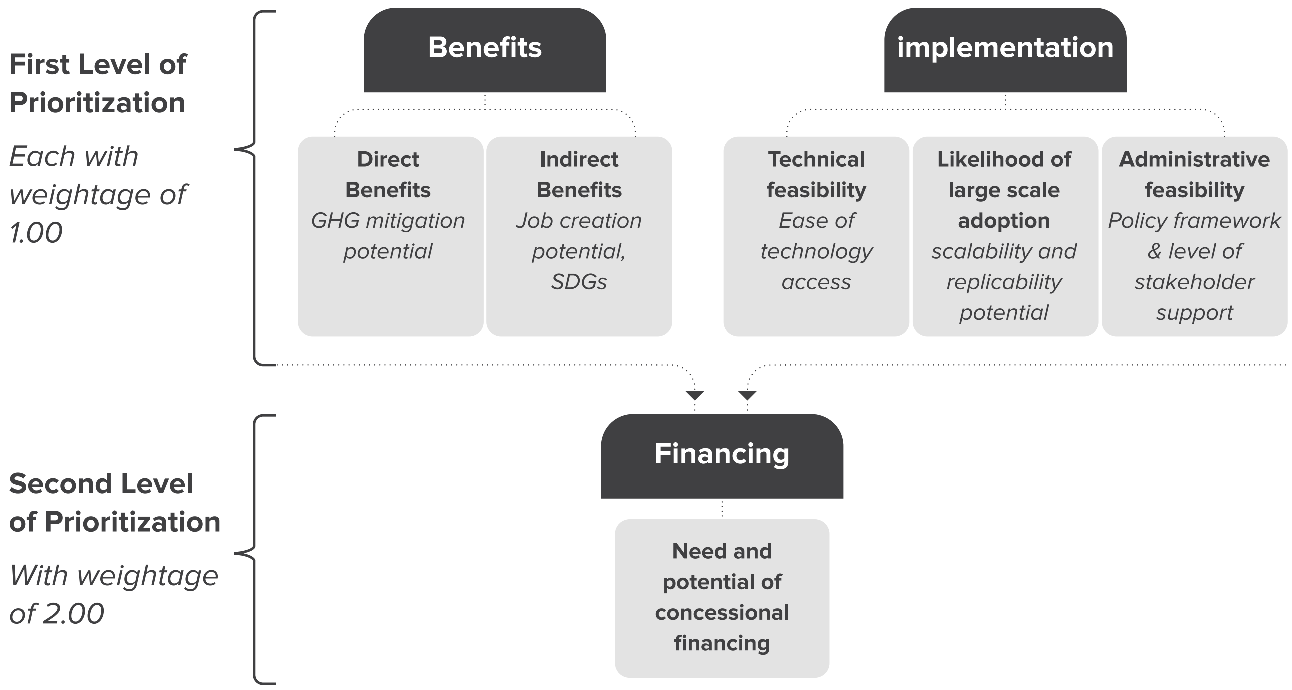

Table A 1.1: Method used to prioritize sector opportunities

Criteria	Sub-criteria	Description	Criteria/ Sub-criteria Weightage	Scoring Scale	Rationale
Benefits	Climate mitigation benefits	GHG mitigation potential for the cooling opportunity	1.00	0: No GHG mitigation from cooling 1: Low GHG mitigation from cooling 2: Medium GHG mitigation from cooling 3: High GHG mitigation from cooling	Providing sustainable cooling and thermal comfort for all, along with delivering environmental and socioeconomic benefits is the overarching goal of ICAP To identify opportunities that can help achieve this goal, climate mitigation benefits, assessment of GHG mitigation potential, and development benefits, accounting for job creation potential, SDG linkages, etc., have been selected as criteria for prioritization Given the key role that prioritized opportunities can play in fulfilling the main ICAP goal, each benefit criterion has been given a weightage of 1
	Develop-ment benefitsw	Job creation potential, SDGs, number of beneficiaries covered by the opportunity	1.00	0: No development benefits 1: Low development benefits 2: Medium development benefits 3: High development benefits	
Implemen-tation	Technical feasibility	Ease of technology access which covers easy access to the associated technology knowledge with no restrictions in terms of Intellectual Property Rights; market preparedness and adaptability of technologies	0.33	0: No technical feasibility 1: Low technical feasibility & market preparedness 2: Medium technical feasibility & market preparedness 3: High technical feasibility & market preparedness	To identify opportunities that have high ease of implementation, it is important to assess them on their technology and knowledge access, scalability, presence of an enabling policy environment, and level of stakeholder complexity. Additionally, it is also important to ensure that opportunities identified are driven by a sustainable cooling agenda

Criteria	Sub-criteria	Description	Criteria/ Sub-criteria Weightage	Scoring Scale	Rationale
Implemen-tation	Likelihood of large-scale adoption	• Sustainable cooling is a key driver in ensuring adoption of the opportunity • Potential for scalability and replicability of opportunity	0.33	0: Not implementable from a cooling perspective 1: Low implementability & scalability 2: Medium implementability & scalability 3: High implementability & scalability	To develop an actionable roadmap for ICAP, *technical feasibility, likelihood of large-scale adoption and administrative feasibility* were identified as the key criteria encompassing the factors outlined above, and were thus selected for prioritization Each of these criteria together indicate the implementability of an opportunity and have been given a total weightage of 1.
	Administ-rative feasibility	• Policy feasibility: Supportive laws, regulations and policies in place for the opportunity; ongoing programs & schemes in place for convergence • Level of stakeholder participation needed to plan & implement the opportunity, e.g., multiple ministries or central-state-local government coordination or only central government action, etc.)	0.33	1: Low policy feasibility and/ or several stakeholders across different governance levels required for planning & implementation 2: Policy feasibility and few stakeholders required for planning and implementation 3: Policy feasibility and one key decision-maker for planning for the opportunity	

Criteria	Sub-criteria	Description	Criteria/ Sub-criteria Weightage	Scoring Scale	Rationale
Financing	-	Need and potential for leveraging various concessional finance instruments and/or private sector investment to implement the opportunity	2.00	1: Low potential for accessing concessional/ private finance 2: Medium potential for accessing concessional/ private finance 3: High potential for accessing concessional/ private finance	The potential of an opportunity to leverage different financing instruments is an important criterion for understanding the role and scope of involvement of financing institutions/MDBs in implementation Given the importance of this criterion in selecting opportunities where concessional finance instruments or private sector investment can enable implementation, financing has been given double weightage compared to the other criteria.

Annex 2: Detailed Roadmap for Space Cooling Sector

Note: Prioritized opportunity and its roadmap has been highlighted

Proposed Interventions			Instrument	Key Stakeholders	National & State Policy Alignment
Short Term (2022-24)	**Medium Term (2025-30)**	**Long Term (2031-38)**			
1. Reduce demand by integrating passive measures in buildings					
1.1 Support implementation of residential and commercial building energy codes in new buildings					
Amend EC Act to support mandatory implementation of ENS	Mandate ENS adoption across states: • Integrate in by-laws • Integrate in building approval processes	Review ENS implementation status and impact to inform stringency revision of the code	Policy	BEE, Ministry of Power	EC Act, ENS
Support states and cities to adopt and implement the residential building energy code – ENS: • Develop demonstration projects • Update central and state schedules of rates to incorporate building materials and construction solutions • Facilitate technical assistance to private and government projects to implement the code			Policy	BEE, ULBs SDAs, state UDD, CPWD, state PWD	
Provide green credit lines to catalyze energy efficient housing: • Increase housing supply through preferential terms for developers, state and city housing departments, combined with technical assistance • Increase housing demand through benefits for homeowners such as preferential loans combined with awareness about the benefits of thermally comfortable housing			Investment: public and private finance	MDBs, FIs	

Proposed Interventions			Instrument	Key Stakeholders	National & State Policy Alignment
Short Term (2022-24)	**Medium Term (2025-30)**	**Long Term (2031-38)**			
Develop market transformation programs (such as supporting manufacturing, developing standards, providing tax rebates, etc.) to address affordability and accessibility of high-performance building envelope solutions (high performance windows, reflective and insulating roof tiles, shading solutions, etc.) for ENS implementation • Create awareness among private sector design and construction professionals about passive cooling measures and ENS adoption • Create awareness campaigns for end users about thermal comfort and energy efficiency benefits in homes to create a demand pull from homeowners			Knowledge	BEE, MoHUA, state UDD	
Develop a streamlined strategy for ECBC implementation assistance (technical and financial) in 8-10 large cities and ULBs with the technical potential and implementation capacity	Capture learnings from this program to inform ECBC implementation in other cities		Policy	State UDD, ULBs, BEE, SDAs	Energy Conservation Building Code
Assess skill requirements and training specific to energy efficient/green building construction, new materials in close collaboration with industry Create knowledge packs for identified skill sets.	Training and support for inclusion in the work force		Knowledge	National Skill Development Council, Skill Council for Green Jobs, CREDAI	National Skill Development Mission

Proposed Interventions			Instrument	Key Stakeholders	National & State Policy Alignment
Short Term (2022-24)	Medium Term (2025-30)	Long Term (2031-38)			
1.2 Mainstream thermal comfort parameters across affordable housing programs and policies at the national and state levels					
Advocate for inclusion of thermal comfort as an essential criterion in national, state and city level affordable housing policies and programs: • Sensitize relevant government departments on thermal comfort benefits in affordable housing design and construction through awareness and training programs	Update affordable housing policies and programs at the national and state level to include thermal comfort as an essential criterion for housing construction		Policy, knowledge	MoHUA, MoRD state UDD	PMAY- Urban; PMAY- Rural; state-level affordable housing policies
Support demonstration projects for affordable Support demonstration projects for affordable housing: • Integrate residential energy code, ENS, provisions in large (applicable) housing projects	Support states and cities in institutionalizing the integration of passive cooling measures through their procurement mechanisms: • Update tenders with applicable construction materials, technologies and costs, ENS compliance criteria		Policy, investment: public finance	State UDD, departments, ULBs, state PWD, MDBs	

Proposed Interventions			Instrument	Key Stakeholders	National & State Policy Alignment
Short Term (2022-24)	Medium Term (2025-30)	Long Term (2031-38)			
Provide green credit lines to state and city housing departments to catalyze construction of thermally comfortable affordable housing			Investment: public finance	MDBs, FIs	
• Develop and disseminate guidance for self-build housing (outside the purview of ENS energy code) including low cost, efficient and simple building solutions. • Support self-build housing with local skilling centers providing technical know-how of construction techniques, new materials, design guidance and possibly supply of materials.			Knowledge	NHB, HUDCO, MoHUA, MoRD, state UDD, NDMA	PMAY- Urban; PMAY- Rural; state-level affordable housing policies, Disaster Management Act
Leverage institutional finance streams to disseminate guidance and provide technical assistance to homeowners of self-build affordable housing. Avenues could include: • Government's housing programs such as PMAY-Urban's beneficiary linked component, PMAY-Rural • Development finance streams to state and city housing departments; financial intermediaries such as banks, affordable housing finance companies, private sector developers, etc., and post disaster housing reconstruction			Investment: public & private finance	MDBs, FIs	

Proposed Interventions			Instrument	Key Stakeholders	National & State Policy Alignment
Short Term (2022-24)	Medium Term (2025-30)	Long Term (2031-38)			
1.3 Retrofit existing buildings to improve thermal comfort through efficient building envelope and cooling technologies					
Develop an industry led R&D program for India-specific retrofitting solutions (insulating plasters/renders, roof insulation tiles, radiative films, smart windows, etc.)		Support commercialization of retrofitting solutions and products	Policy, investment: public and private finance	BEE, DST, MDBs, FIs	Energy Conservation Act
	• Develop a retrofitting policy roadmap and economic viability assessment for different building types • Develop a retrofitting program for low-income households, referring to the global energy poverty/ weatherization assistance • Support demonstration projects across social housing and public sector buildings	Support implementation of retrofitting roadmap	Policy, investment: public finance	BEE, MDBs, FIs	

Proposed Interventions			Instrument	Key Stakeholders	National & State Policy Alignment
Short Term (2022-24)	**Medium Term (2025-30)**	**Long Term (2031-38)**			
2. Improve efficiency of cooling technologies					
2.1 Enable market transformation towards super-efficiency for high impact cooling technologies					
Assess pathways for aligning the S&L program to achieve ICAP goals: • Set targets for ratcheting up standards (MEPS, best available technologies available) and timelines for key appliances • Assess supporting market transformation initiatives and incentives to achieve acceleration/adoption of key super-efficient technologies. This could include upstream incentives to manufacturers, synergies with initiatives under the Make in India program, addressing higher upfront costs for consumers, etc. • Assess supporting infrastructure requirements, especially testing capacity through test labs and protocols	Implement the S&L pathways for key impact appliances such as RACs, fans, chillers, etc. • Large-scale industry consultations to identify bottlenecks, gaps • Supporting analysis for ratcheting up MEPS • Setting up testing capacity and protocols Awareness and behavior change programs to support creation of consumer demand	Review and revise the S&L strategy: • Monitor impact of S&L on energy savings • Appliance costs • Market share of higher efficiency models • Consumer uptake and feedback	Policy	BEE	Energy Conservation Act, S&L Program, Make in India

Proposed Interventions			Instrument	Key Stakeholders	National & State Policy Alignment
Short Term (2022-24)	Medium Term (2025-30)	Long Term (2031-38)			
Develop an upstream incentive program for BLDC fan/motor manufacturers: • Set market transformation targets to be achieved in consultation with industry • Finance the program • Devise a monitoring and impact assessment strategy • Develop a communications strategy for end users	Implement the program, including effective outreach Monitor impact on costs and energy savings, uptake by consumers		Policy, investment: public finance	BEE, EESL, MDBs	
Leverage the PLI program for manufacturing RAC components: • Integrate environmental performance standards for high efficiency impact RAC components (compressors, heat exchangers and expansion valves) to achieve higher system efficiencies in RACs • Assess the impact on costs of higher efficiency RACs due to domestic manufacturing • Develop financial mechanisms to bridge any additional costs, and nudge manufacturing towards high system efficiency components	Impact assessment of the program: • Impacts on the performance, costs of each component Impacts on RAC system design and performance		Investment: public and private finance	MDBs, FIs BEE, DPIIT – MoCI	PLI program, S&L program

Proposed Interventions			Instrument	Key Stakeholders	National & State Policy Alignment
Short Term (2022-24)	Medium Term (2025-30)	Long Term (2031-38)			
Support the scaling up of EESL's Super-Efficient Air Conditioner bulk procurement program: • Revise the outreach and beneficiary strategy, looking at demand aggregation across large residential projects, RAC rental markets through suppliers, etc. • Develop a framework for assessing energy savings impact and consumer feedback • Support the development of a voluntary label for super-efficient air conditioners			Investment: public finance (preferential procurement)	EESL	S&L program
2.2 Accelerate uptake of not-in-kind technologies, especially to enable access in sectors with low adoption of comfort cooling					
Assessments of not-in-kind technologies, applications and benefits: • Feasibility for specific technologies for particular building types based on energy consumption requirements, including potential for hybrid technology applications	Enable uptake of not-in-kind technologies: • Evaluate impacts on productivity of workers, energy system costs and performance of demonstration projects • Develop business models for affordable comfort for productivity to spur investment in developing supply chain and	Enable accelerated uptake of not-in-kind technologies: • Investments for supply chain integration, component manufacturing Innovative financing models, for technology	Policy, investment: public and private finance	BEE, MDBs, FIs, SIDBI	National Mission on Enhanced Energy Efficiency

Proposed Interventions			Instrument	Key Stakeholders	National & State Policy Alignment
Short Term (2022-24)	**Medium Term (2025-30)**	**Long Term (2031-38)**			
• Support demonstration projects in manufacturing sectors and other public buildings with limited access to comfort cooling • Create a roadmap on enabling productivity across sectors (with low access to comfort cooling), including consultations with micro, small and medium enterprises and MoCI	and building expertise for 2-3 promising not-in-kind technologies. Awareness and capacity building programs for architects, mechanical engineers and building owners	adoption including via pay as per use, and CaaS models			
2.3 Optimize operational cooling energy use in commercial buildings through energy performance data, disclosure and benchmarking, and review of ventilation standards in view of COVID-19 guidance					
Develop a framework for disclosure and benchmarking for commercial buildings, including space cooling performance • Consult with government and building industry • Explore synergies with BEE's designated consumer notification, mandating energy audits for energy intensive buildings Increased adoption of digitization and IoT applications to aid availability of energy use data	Institutionalize the benchmarking and disclosure program: • Identification of an organization to anchor this process and program funding	Carry out periodic assessments to understand the impact of energy efficiency intervention such as codes and equipment standards on operational energy use Use this data to inform energy efficiency and space cooling policies	Knowledge	BEE, ISHRAE	PAT, ECBC

Proposed Interventions			Instrument	Key Stakeholders	National & State Policy Alignment
Short Term (2022-24)	Medium Term (2025-30)	Long Term (2031-38)			
Detailed technical assessment of change in ventilation requirements in centrally air-conditioned buildings in view of the health-related guidance issued due to COVID-19 • Assessment of impacts on system design,performance and costs Large scale industry consultations to inform the process	Implementation guidance for new buildings and retrofitting of existing systems: • Develop case examples for good practices, use of alternative building design and cooling technologies that can meet criteria • Monitoring of buildings to collect data on indoor air quality	Mainstream guidance on indoor air quality in air conditioned and mixed mode buildings Inform changes in standards for design, O&M of central air-conditioning systems	Knowledge	BEE, ISHRAE	
3. Shift demand to district cooling					
3.1 Support uptake of DCS and tri-generation, including development of business models and policy roadmap					
Convene stakeholders to assess policy outlook on natural gas allocation and pricing for tri-generation projects Clarity on the role of gas to meet thermal requirements versus limiting it as a transition fuel to meet peak power requirements and balancing intermittent and variable RE technologies			Policy	EESL, PNGRB, GAIL India Ltd., EESL	PNGRB Regulations
Support CaaS business models for ESCOs. Example: EESL's tri-generation program (comprising total upfront investment and 'Pay as you Save' model) to enable private sector financing.		Scale up DCS implementation, establish and	Policy, investment:	MDBs, FIs, EESL, State	Smart Cities Mission

<table>
<tr><th colspan="3">Proposed Interventions</th><th rowspan="2">Instrument</th><th rowspan="2">Key Stakeholders</th><th rowspan="2">National & State Policy Alignment</th></tr>
<tr><th>Short Term (2022-24)</th><th>Medium Term (2025-30)</th><th>Long Term (2031-38)</th></tr>
<tr><td colspan="2">Support feasibility assessments and pilot projects to assess commercial viability of merchant DCS model across greenfield/ brownfield developments</td><td rowspan="3">standardize project development process, business models and contracting.</td><td rowspan="2">public & private finance</td><td rowspan="2">UDD, State TCPO</td><td rowspan="3"></td></tr>
<tr><td colspan="2">Develop models for long-term benefits for cities to adopt DCS infrastructure (equity/revenue models)</td></tr>
<tr><td>Assess techno-economic feasibility and promote R&D for alternate fuels, waste heat streams, treated wastewater, free cooling through natural water bodies, etc.</td><td>Support demonstration projects</td><td>Policy, investment: public & private finance</td><td>MDBs, FIs MoHUA, state UDD, state TCPO</td></tr>
<tr><td colspan="2">Develop direct cool roadmap, focusing on the value chain of projects and applicability in upcoming sectors such as cold chain, warehouses, industrial applications, etc.</td><td rowspan="2">National Policy for DCS defining a code of practice, cooling service agreements, customer protection measures, tariffs, applicable taxes, etc.</td><td rowspan="2">Policy</td><td rowspan="2">BEE, EESL, MoHUA, State UDD, State TCPO MoEFCC, MoCI, Green building rating agencies</td><td rowspan="2">URDPFI guidelines; city masterplans; environmental impact assessment; Energy Conservation Act</td></tr>
<tr><td colspan="2">Integrate feasibility evaluation of DCS for greenfield developments for high density cooling requirements (minimum 8,000 TR per sq km) through:
• “Connect unless” policies integrated in urban planning, zoning, or building codes, green building rating systems whereby developers of buildings in priority zones are required to connect to a DCS system
• Environmental clearances for major real estate and industrial projects issued by MoEFCC
• Special Economic Zones allow CaaS models to provide cooling for buildings by third parties</td></tr>
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Proposed Interventions			Instrument	Key Stake-holders	National & State Policy Alignment
Short Term (2022-24)	Medium Term (2025-30)	Long Term (2031-38)			
3.2 Assess the role of discoms in space cooling transition to district energy and cooling as a service models					
Assess the role discoms can play in the space cooling transition to district energy technologies and CaaS models: • Impact on the grid from rapid additional space cooling demand in the next 20 years, including peak load, power procurement, and excess power export to the grid • Leveraging data from smart meters • Role of off-peak tariff structures, large-scale integration of thermal storage and renewables Design of targeted space cooling DSM programs through periodical load research, understanding consumer-wise load curves, etc.			Knowledge	Discoms, BEE, Ministry of Power	DSM Regulations
4. Adapt cities to manage heat stress					
4.1 Integrate climate data and long-term measures to increase resilience of at-risk communities, as part of disaster risk reduction and preparedness planning in cities					
Mapping future climate risk to design disaster response: • Assess long-term heat wave risk incorporating climate modelling to predict impacts (likely frequency, intensity and duration of heat waves) • Map risks for vulnerable communities and city-wide impacts	Support states and cities in developing and implementing an integrated disaster response framework including: • Systematic long-term data collection and assessment of likely heat risk • Cooling action plans of heat related impacts for vulnerable communities, including coordination frameworks with other departments such as housing and urban planning		Knowledge, policy	NDMA, IMD, DST	National Mission on Strategic Knowledge for Climate Change, National Disaster Management Act, Urban Heat Action Plans

Proposed Interventions			Instrument	Key Stake-holders	National & State Policy Alignment
Short Term (2022-24)	Medium Term (2025-30)	Long Term (2031-38)			
• Assess critical infrastructure's (electricity grids, health infrastructure, etc.) ability to respond in a heat wave incident and resilience measures needed	• Guidance on impacts and resilience of critical infrastructure services for relevant ministries and departments				
4.2 Mainstream passive cooling measures in urban planning, enable private sector participation and knowledge alliances to aid implementation in cities					
Develop guidelines for cities to integrate and implement urban passive cooling measures in local and city level planning frameworks. This should include: • Passive cooling measures, application and costs Guidance on how to integrate in new design and retrofits	Mainstream urban passive cooling measures across local and urban planning policies and frameworks in cities. • Technical and financial support for pilot projects such as upgrading of pavements, street design, urban parks, etc. • Capacity building of relevant city officials/ planners about the need for passive urban cooling measures and implementation guidance • Leveraging trigger points for cost-effectively dovetailing specific urban cooling interventions Inclusion of design requirements and materials in standard contracting processes		Policy	MoHUA, NIUA, state UDD, ULBs, state environ-ment depart-ments	Local area plans, urban masterplans state/ city action plans on climate change/ adaptation plans
Assess synergies with existing urban regulations and funding streams for implementing urban cooling measures, such as state and city level climate change action plans/ adaptation plans					

Proposed Interventions			Instrument	Key Stake-holders	National & State Policy Alignment
Short Term (2022-24)	Medium Term (2025-30)	Long Term (2031-38)			
Create knowledge alliances to support cities through collaboration with local academic institutions, civil society and global city-to-city partnerships to exchange best practices. Create awareness about pilots, best practices and assessment of multiple benefits (public health, urban resiliency and climate change) for the city and the community.		Assess impact of successful models to inform replication and scaling up of solutions in cities.	Knowledge, policy	NIUA, ULBs, state government, academic and civil society institutions	
Develop and pilot innovative models for states and cities to enable private sector participation in implementing urban cooling measures such as NbS: • Earmark CSR funding for urban climate adaptation measures including passive cooling measures. • Access CSR, philanthropy-based grants to demonstrate pilot solutions Develop assessment methods for value creation for communities combined with community participatory models for local level solutions			Policy, investment: public and pri-vate finance, knowledge	State UDD, ULBs, CSR, grants	CSR, State Action Plans for Climate Change
Develop guidelines to address heat stress for vulnerable communities in urban areas. • Identifying short- and long-term measures such as access to cooling shelters, cool roof programs for publicand private buildings, retrofitting informal and other social housing, integrating targeted NbS	Support cities in implementation of urban cooling action plans for vulnerable communities • Integrating long-term measures for increasing resilience in urban heat action plans		Policy	National & state disaster management agencies, ULBs, state environment departments	National Disaster Management Act, Urban Heat Action Plans, State Action Plans for Climate Change

Proposed Interventions			Instrument	Key Stake-holders	National & State Policy Alignment
Short Term (2022-24)	**Medium Term (2025-30)**	**Long Term (2031-38)**			
• Enabling community participation in developing action plans including creation of awareness about heat-related impacts, response during a heat wave incident, communicating tangible benefits Frameworks for inter-sectoral coordination and budgets for adaptation measures in urban planning and heat related disaster response	• Inter-departmental governance mechanisms for implementation of these measures Identifying and accessing funding sources including municipal, climate adaptation, public health and disaster response budgets			PHFI, Mo-HUA, NIUA	

CPWD: Central Public Works Department; CREDAI: Confederation of Real Estate Developers' Associations of India; DSM: Demand Side Management; IMD: India Meteorological Department ISHRAE: Indian Society of Heating, Refrigerating and Air Conditioning Engineers; NHB: National Housing Bank; PAT: Perform Achieve and Trade; SDA: State Designated Agency; SIDBI: Small Industries Development Bank of India

Annexure 3: Detailed Roadmap for Cold Chain and Refrigeration Sector

Note: Prioritized opportunity and its roadmap has been highlighted

Proposed Interventions					
Short Term (2022-24)	**Medium Term (2025-30)**	**Long Term (2031-38)**	**Instruments**	**Key Stakeholders**	**National & State Policy Alignment**
1. Support development of new energy efficient and sustainable cold chain networks					
1.1 Supporting development of sustainable and energy efficient end-to-end cold chain networks, including refrigerated transport					
Conduct nation-wide assessment to identify infrastructure gaps for each cold chain subsector (i.e., horticulture produce, fish, meat, dairy, healthcare) that results in losses	Establishing sustainable large-scale cold chain infrastructure where gaps identified through models similar to Mega Food Parks		Knowledge	MoFPI, MoFAHD, MoAFW	PMKSY, MIDH , NHM
Develop action plan for setting up small-scale decentralized cold chain through cooperatives/FPOs at village/cluster level • Develop business models for producer owned cold supply chains • Explore potential of rural cold chain corridors through e-logistics online platforms that connect growers with consumers using a sustainable end-to-end cold chain	Create incentives for FPOs to develop direct market linkages with end-to-end decentralized sustainable cold chains Support APMCs to develop cold chain links at mandis to reduce food loss at market		Knowledge, policy, investment private finance, MDBs/FIs	MoFPI, MoFAHD, MoAFW	DFI, PMFME
Develop leasing and renting models for small-scale cold storages, similar to pay per use models for for farm equipment	Modify existing schemes to include cold chain components as rental options	Scale up of successful renting and leasing models across the country	Policy, knowledge	CaaS, MoAFW, MoHFW	SMAM, CSISAC

Proposed Interventions					
Short Term (2022-24)	**Medium Term (2025-30)**	**Long Term (2031-38)**	**Instruments**	**Key Stakeholders**	**National & State Policy Alignment**
• Develop linkages with initiatives such as CaaS to assess feasibility of such models in India	Implement pilot projects for cold chain components in a CaaS, pay as you go, leasing model CaaS, pay as you go, leasing model				
Set up inter-ministerial committee, with MoFPI as nodal entity, to identify challenges in implementation and propose policy/regulatory measures for large-scale effective implementation of "Integrated Cold Chain, Value Addition and Preservation Infrastructure"	Implement measures proposed by committee to bring in ease of implementation of an integrated cold supply chain	Enforce measures proposed by committee	Policy	MoFPI, MoAFW, FSSAI, MoFAHD	PMKSY
Modify existing schemes (MIDH, etc.) to provide preference for development of multi-commodity cold chain (rather than single commodity cold chain as has been the case thus far)	Bring in schemes/ incentives to ensure that construction of all new cold chain components is carried out in a holistic manner, ensuring end-to-end linkages		Policy, investment public finance, MDBs/FIs	MoFPI, NCCD, MoAFW, APEDA	PMKSY, MIDH, NHM
Develop MIS through inter-ministerial collaboration, to track infrastructure development and e-performance monitoring to improve overall efficiency of cold-chain systems: • Can be built along lines of MoHFWs eVIN portal	Ensure that all decision making and monitoring for cold chain infrastructure development is carried out with the support of the MIS, ensuring sustainable development • Regularly upgrade MIS in line with new research and technology advancements		Knowledge	MoFPI, MoAFW, MoHFW, MoRTH, MNRE	PMKSY

Proposed Interventions					
Short Term (2022-24)	**Medium Term (2025-30)**	**Long Term (2031-38)**	**Instruments**	**Key Stakeholders**	**National & State Policy Alignment**
Identify technologies for RE integration • Conduct feasibility studies for different components of cold chain, in different regions across the country • Assess feasibility of scaling up existing RE solutions (Ecozen, Inficold, Bharat Refrigerations, etc.) • Support domestic R&D on decentralized RE-based cold chain solutions for both agriculture and healthcare	Support demonstration projects to showcase scalable RE technologies – both at farm gate and at scale. Develop incubation center for research on low cost RE solutions for cold chain	Support scale up of proven technologies	Policy, investment public and private finance, MDBs/FIs	MNRE, MoFPI, MoAFW, MoFAHD, MoHFW, MIDH	PM KUSUM, Make in India, PMKSY
Support R&D for development of domestic low-cost solutions for last mile delivery of vaccines and temperature sensitive medicines	Promote scale up of proven technologies through grants and loans		Knowledge, investment public and private finance	MoHFW, DST	Make in India, Atmanirbhar Bharat Abhiyan
Support market growth of super-efficient domestic and commercial refrigeration systems • Support target setting for market transformation/ adoption of energy efficient	Support scale up/ manufacturing of low-cost alternate energy refrigerators developed, including providing support with marketing		Policy, investments, knowledge public finance (incentive/	BEE, MoCI, DBT	Make in India, Energy Conservation Act, Atmanirbhar Bharat Abhiyan

Proposed Interventions					
Short Term (2022-24)	**Medium Term (2025-30)**	**Long Term (2031-38)**	**Instruments**	**Key Stakeholders**	**National & State Policy Alignment**
refrigeration systems • Create incentives for consumers on higher efficiency refrigeration systems • Build public awareness on usage and operation efficiency, along with lifetime costs of higher efficiency refrigeration systems • Introduce retrofit/upcycle program for replacement of inefficient refrigeration systems • Support R&D for development of low-cost, alternate energy supply-based refrigerators for rural areas			subsidy/ preferential procurement)		
Initiate market transformation program for driving improvements in equipment efficiency (domestic refrigerators and commercial deep freezers) • Assess potential for upstream incentives, and explore synergies with initiatives under Make in India program (for refrigeration components such as highly efficient compressors, fan motors, vacuum insulation panels, etc.)	Create programs for giving incentives to upstream manufacturers to reduce costs of components such as BLDC fans Support R&D for domestic production of technologies not currently being produced in the country/cost of manufacturing is too high, e.g., energy-efficient heat exchanger technology, super-efficient design technology for small compressors and motors, insulation, etc.		Policy, investments, knowledge public finance (incentive/ subsidy/ preferential procurement)	BEE, MoCI, DST	Make in India, Energy Conservation Act, Atmanirbhar Bharat Abhiyan

Proposed Interventions			Instrument	Key Stakeholders	National & State Policy Alignment
Short Term(2022-24)	**Medium Term (2025-30)**	**Long Term (2031-38)**			
Introduce policy to support adoption of commercially viable alternative clean cooling technologies for refrigerated transport	Support development of infrastructure needed to scale up application of alternative clean cooling technologies across the country, e.g., development of charging stations for PCM based reefer trucks • Develop linkages with schemes (e.g., FAME II, NEMPP2) that are developing charging stations for e-vehicles to also include infrastructure for reefers		Policy, investment National Automotive Board, EESL	MoRTH, Ministry of Power, MoFPI, MoAFW, MoFAHD, MoHFW, NCCD	Automotive Industry Standard, FAME, NEMMP
Design policy that incentivizes refrigerated transport service providers to increasingly move their fleets to electric and non-fossil fuel-based cooling		Make it mandatory to use electric and non-fossil fuel-based cooling in all refrigerated transport	Policy	MoFPI, MoAFW, MoHFW, MoRTH, MoRD	DAY-NRLM
Develop linkages with Aajeevika Grameen Express Yojana that supports development of public transport links in rural areas, supporting movement of people and produce • Feasibility studies to assess possibility of developing refrigerated transport as a public transport/ sharing model • Develop business models for refrigerated transport as a public transport/ sharing model	Support pilot projects with self-help groups/FPOs to develop small-scale refrigerated public transport systems	Support scale up of successful models, with priority given to remote regions	Knowledge, investment public finance, MDBs/FIs	MoFPI, MoAFW, MoHFW, MoRTH, MoRD	

Proposed Interventions					
Short Term (2022-24)	**Medium Term (2025-30)**	**Long Term (2031-38)**	**Instruments**	**Key Stakeholders**	**National & State Policy Alignment**
Support state-wise demonstration projects to showcase use of new technology in reefer systems	Support scale up of proven technologies in energy efficient reefers through grants and subsidies		Knowledge, investment private finance, MDBs/FIs	MoRTH, Ministry of Power, DST, research institutes, private logistics companies	Make in India
Introduce low interest loans on fuel free or electric reefer systems based on thermal battery/PCM technology, etc.			Investment private finance, MDBs/FIs	MoRTH, Ministry of Power	Priority Sector Lending, SMAM
Develop multimodal cold chain links through rail and highways, aiming at a fast-track green corridor for perishables • Identify linkages with Kisan Rail scheme and Green Energy Corridor Project • Needs assessment to understand critical regions where development of refrigerated rail and highway links will have biggest advantage, in terms of both energy efficiency and reducing food loss • Prioritize regions with high production of perishables	Scale up development of green corridor/ better railway and highway linkages to other regions in the country		Investment public finance	Ministry of Railways, MoRTH, MoAFW, MNRE	Kisan Rail, Green Energy Corridor

Proposed Interventions			Instrument	Key Stakeholders	National & State Policy Alignment
Short Term (2022-24)	Medium Term (2025-30)	Long Term (2031-38)			
1.2 Promote better operations and servicing through capacity building of all stakeholders, and incorporation of effective monitoring systems					
Incorporate IoT in cold chains and refrigeration energy efficiency codes with minimum reporting standards on efficiency and O&M	Incentivize service providers and logistics owners to incorporate IoT-based monitoring in cold supply chain and to adhere to safety standards	Introduce legislation/ policy to make temperature monitoring/ logging mandatory for perishable, vaccine and medicine handling	public and private finance, MDBs/ FIs Policy, investment	FSSAI, MoHFW, MoAFW, MoFAHD, MoFPI, ICAR	The Food Safety and Standards Act, 2006, National Vaccine Policy
Promote use of IoT in cold-chain logistics (similar to eVIN) for maintenance and remote monitoring of temperature-controlled refrigeration systems to adhere to standards -Support pilot demonstration projects for IoT implementation and reporting norms in different components of the cold chain					
Promote scale up of low-cost solutions for monitoring and reporting to increase energy efficiency and maintain safety standards					
Support research to understand temperature and cooling requirements of different crops	Incorporate crop specific temperature requirements into food safety standards				

Proposed Interventions			Instrument	Key Stakeholders	National & State Policy Alignment
Short Term (2022-24)	Medium Term (2025-30)	Long Term (2031-38)			
Develop and promote training and certification courses for cold chain and refrigerator operators and technicians on GSP • Limited validity programs with regular license renewal every 2-3 years	Ensure successful implementation of skill development program: • Establish training centers/ centers of excellence across India and upgrade training centers • Promote online refresher courses on new and upcoming technologies as skill enhancement support for technicians • Design programs for building customer awareness on need and benefits of hiring only certified technicians • Develop incentives for customers to engage certified technicians in early phase of certification	Introduce universal mandatory certification for all technicians	Policy, knowledge	MSDE, NCCD	Skill India Mission - PMKVY
Develop training/ awareness programs for: • Farmers, middlemen, traders, etc., on better post-harvest handling and management of produce • Medical staff, who handle vaccines and temperature-controlled medicines, on optimal functioning of cold chain equipment		Ensure updating of training modules • To be in line with latest research and technologies • Carry out regular awareness programs			

Proposed Interventions			Instrument	Key Stakeholders	National & State Policy Alignment
Short Term (2022-24)	**Medium Term (2025-30)**	**Long Term (2031-38)**			
2. Improve energy efficiency and integrating RE in existing cold chain infrastructure, and strengthen systems					
2.1 Retrofitting of existing static cold-chain infrastructure and refrigeration systems					
Develop specific program for retrofitting of existing cold storages to improve efficiency and integrate renewables • Identify convergences with existing ongoing programs • Develop guidelines that outline requirements for retrofitting of different cold chain infrastructure components • Assign targets to state level horticulture departments for achieving retrofits • Develop guidelines for safe disposal of old and obsolete equipment, including provisions for enforcing EPR and e-waste guidelines	Bring incentives for private owners to retrofit • Enhance existing schemes for energy efficiency (CSISAC) to include retrofitting of existing cold chain infrastructure • Develop awareness amongst owners on energy savings achieved with retrofitting	Make retrofitting of old cold storages mandatory	Policy, investment public finance, MDBs/FIs	NCCD, MoFPI, MoAFW, MoHFW	PMKSY, MIHD, NHM, CSISAC
2.2 Developing standards and certification for RE integration, and inclusion of energy efficient design and technologies in cold chain and refrigeration					
Notify standards for energy efficient design of cold chain infrastructure and RE integration, along with recommended efficient technologies:	Create incentives for voluntary adoption of energy efficient design standards, and RE integration	Make mandatory the inclusion of energy efficient design standards	Policy	BEE, NCCD, MoFPI, MoAFW, MoFAHD, MoHFW	PMKSY, PM-KUSUM, Capital Investment

Proposed Interventions			Instrument	Key Stakeholders	National & State Policy Alignment
Short Term (2022-24)	Medium Term (2025-30)	Long Term (2031-38)			
• Enhance existing standards for promoting adoption of energy efficient technologies, including RE technologies under "Guidelines & Minimum System Standards for Implementation in Cold-chain Components" (published by NCCD75) • Integrate with guidelines outlined in "The Design Guide Energy Efficiency Improvements in Commercial Buildings" by BEE, to include elements relevant for development of cold chain infrastructure	• Link with existing schemes (Capital Investment Subsidy Scheme of NHB) that provide subsidies for construction of cold chain infrastructure to include incentives for adoption of energy efficiency design standards and technologies, and RE integration • Introduce low interest loans for energy efficient design integration in cold chain	when constructing any new cold chain infrastructure components			Subsidy Scheme (NHB), MIDH, NHM
Introduce dedicated credit lines for small-scale and large projects integrating criteria for energy efficient cold chain design			Investment MDBs/FIs	NCCD, MoFPI, MoAFW	Priority Sector Lending, Make in India
Develop an efficiency rating/ certification system for measuring energy efficiency in new and retrofitted cold chain infrastructure	Bring in guidelines for mandatory annual energy audits of cold chain infrastructure to get benefits of schemes and subsidies	Mandatory energy efficiency certification of all new cold chain components • Certification linked to annual energy audits • Provide incentives for maintaining high energy efficiency rating	Policy, knowledge	BEE, NCCD, MoAFW	PMKSY, MIDH, NHM, Make in India

Proposed Interventions			Instrument	Key Stakeholders	National & State Policy Alignment
Short Term (2022-24)	Medium Term (2025-30)	Long Term (2031-38)			
Upgrade star rating for frost-free and district cooling refrigerators every 2-3 years • Needs to follow pace of best available technologies in international markets to bring about energy efficiency improvements in appliances • Include multi-door and side-by-side refrigerators in mandatory star rating label	Ensure regular upgradation of star rating		Policy	BEE	Energy Conservation Act, S&L Program
Shift from voluntary BEE star rating (2020) to mandatory star label for commercial deep freezers and chillers			Policy	BEE	Energy Conservation Act, S&L Program
Design voluntary star ratings for other commercial refrigeration technologies such as drinking water coolers, etc.	Shift from voluntary to mandatory star labels	Ensure regular upgradation of star rating			

Annex 4: Detailed Roadmap for Passenger Transport Air Conditioning Sector

Note: Prioritized opportunity and its roadmap has been highlighted

Proposed Interventions			Instrument	Key Stake-holders	National & State Policy Alignment
Short Term (2022-24)	**Medium Term (2025-30)**	**Long Term (2031-38)**			
1. Improve efficiency of MAC systems in passenger transport vehicles					
1.1 S&L for vehicles					
Implement and continuously improve the fuel efficiency standards for vehicles: • Introduce Standard 2 of fuel efficiency norms for passenger cars in 2022-23 • Fast track implementation of fuel efficiency standards for passenger buses which will drive manufacturers to improve fuel efficiency. Per ICCT, 20-25% fuel reduction is possible by improving rolling resistance and auxiliary loads, optimizing driver behavior, improved engine and transmission efficiencies and reducing vehicle weight.	Develop more stringent targets of fuel efficiency for 2026 and 2030	Enforce targets and periodically update the same	Policy	MoRTH	CAFÉ a norms
Notify mandatory testing of all new manufactured air-conditioned passenger cars with air conditioner 'ON' condition to provide realistic fuel efficiency and emissions profile to encourage improved MAC efficiency. Revise testing methodology for CAFÉ standard compliance to include switching on of air conditioner while testing to give a more realistic fuel consumption scenario.	Enforce amendment in testing methodology effectively		Policy	MoRTH	CAFÉ norms

Proposed Interventions			Instrument	Key Stake-holders	National & State Policy Alignment
Short Term (2022-24)	Medium Term (2025-30)	Long Term (2031-38)			
Encourage compliance of revised CAFÉ standard by: • Developing an incentive mechanism (such as a certification and trading system) for manufacturers to increase compliance with CAFÉ standards and promote usage of energy efficient MAC system. • Designing a carbon finance program to support compliance	Implement incentive mechanisms for manufacturers to adopt efficient MAC systems		Policy, investment (carbon finance)	MoRTH	CAFÉ norms
Introduce a labelling system for cars to build public awareness on energy efficiency of vehicles. Explore incorporation of emission intensity in the label by integrating low-GWP refrigerants into the equation	Introduce and periodically update labels for cars		Policy	MoRTH, BEE	S&L program
1.2 R&D and commercialization of efficient MAC systems					
Support R&D to improve energy efficiency of air conditioners in hybrid and electric vehicles and reduce battery energy consumption. Energy consumption by batteries for AC purposes in e-vehicles is a major issue, especially in hot climate countries such as India. Air conditioners in e-vehicles tend to consume up to 40% of battery energy	Policies to support adoption of energy efficiency and low-GWP refrigerant-based MAC systems in hybrid and electric vehicles		Knowledge, policy	DST, Ministry of Heavy Industries, R&D institutes, electric vehicle manufa-cturers	FAME Scheme

Proposed Interventions			Instrument	Key Stake-holders	National & State Policy Alignment
Short Term (2022-24)	Medium Term (2025-30)	Long Term (2031-38)			
Develop a program which encourages private sector R&D on technologies that have high energy efficiency and use low-GWP refrigerants.	Create incentives and policy guidance to support commercialization/scale up of proven technologies, particularly those which have application in public transportation systems		Knowledge, policy	DST, MoRTH, manufa-cturers	Mission Innovation
2. Optimize demand for transport air conditioning					
2.1 Modal shift to public transportation					
Develop guidelines for appropriate thermal comfort and heat stress management approaches in public transport systems, particularly for vehicle operators in cities with higher ambient temperature climates and prone to heat waves	Build integrated and high-quality public transport systems to shift passenger traffic from private vehicles		Policy	MoRTH	Atal Mission for Rejuvenation and Urban Transformation – Public Transportation National Mission on Sustainable Habitat Smart Cities Mission, 2015 Green Urban Mobility Scheme, 2017 Metro Rail Policy 2017 National E-Mobility Program, 2018

Proposed Interventions			Instrument	Key Stake-holders	National & State Policy Alignment
Short Term (2022-24)	Medium Term (2025-30)	Long Term (2031-38)			
2.2 Load reduction					
Develop vehicle design specifications/ guidelines which support load reduction through: (a) improving ventilation/insulation of vehicles; and (b) using targeted cooling that directly cools a passenger without having to cool the entire vehicle. Combined, the two strategies can reduce air conditioner energy consumption by 22-31%, depending on the climate[123]	Implement and periodically update vehicle design specifications based on latest technology developments		Policy	MoRTH, MoHUA	

Annex 5: Detailed Roadmap for Refrigerants

Note: Prioritized opportunity and its roadmap has been highlighted

Proposed Interventions			Instrument	Key Stakeholders	National & State Policy Alignment
Short Term (2022-24)	Medium Term (2025-30)	Long Term (2031-38)			
1. Support HFC phase down through roadmaps, policies and public procurement					
1.1 Roadmaps, standards and guidelines for low-GWP refrigerants					
Develop India's KIP. The Government of India has announced that a 'National strategy for phase down of Hydrofluorocarbons' is to be developed by 2023	Support implementation of India's KIP by: • Developing technology roadmaps combined with modelling phasedown requirements • Amending Ozone Depleting Substances (Regulation and Control) Rules 2000 and its amendment to align with Kigali Amendment to the Montreal Protocol • Introducing a licensing system for controlling the import and export of HFCs	Conduct periodic monitoring and evaluation of the implementation of India's KIP	Policy	MoEFCC, MoCI, MoFPI, MoAFW, MoHUA, MoUD, MoRTH	India's ratification of Kigali Amendment to the Montreal Protocol
Develop safety standards and appropriate building codes for flammable and toxic refrigerants across all sectors. In line with this, develop safety regulations particularly for ammonia-based cooling and ensure its strict implementation in industrial process cooling and cold chain as ammonia is cost effective and zero GWP refrigerant with abundant usage in India.	Implement and update safety standards building codes periodically to reflect latest developments in low-GWP refrigerants		Policy	BIS, BEE	Standards by BIS (for safety) and BEE (for building code)

Proposed Interventions			Instrument	Key Stakeholders	National & State Policy Alignment
Short Term (2022-24)	Medium Term (2025-30)	Long Term (2031-38)			
Promote adoption of low-GWP refrigerants and technologies with lower refrigerant demand (i.e., clean technologies) by: i) Creating a rating system to provide preference to low-GWP refrigerants and clean technologies in codes and standards. ii) Supporting pilots to demonstrate performance and viability			Policy	MoEFCC, BEE, BIS	Mission Innovation, Start-up India
1.2 Incentives for adoption of low-GWP refrigerants					
Conduct assessment and industry-wise dialogs to design pragmatic regulations for HFC phase down across each sector. The assessment should explore the feasibility of various regulatory options such as quota/cap and phase-down, tax and refund, limits on GWPs and incentives for low-GWP products, environmental cess, subsidies for using low GWP refrigerants and products	Introduce regulatory mechanisms for HFC phase down which consider sector-specific technology access and economic viability aspects. These should be aligned to support achievement of India's KIP		Policy	MoEFCC, MoCI	India's ratification of Kigali Amendment to the Montreal Protocol

Proposed Interventions			Instrument	Key Stakeholders	National & State Policy Alignment
Short Term (2022-24)	Medium Term (2025-30)	Long Term (2031-38)			
Expanding the 'green category', currently assigned only for RACs, to all refrigerant based products under GeM portal			Policy	MoCI	GeM
Mandating the procurement of refrigeration and air-conditioning products with low-GWP refrigerants in government offices			Policy	Ministry of Finance, state governments	General Financial Rules
2. Promote domestic R&D and indigenous production of low-GWP refrigerants					
2.1 Research & Development of low-GWP refrigerants					
Establish a domestic R&D program by: • Instituting a government operated steering committee with representation from relevant ministries, R&D institutes, experts and private sector companies to identify and map the knowledge, expertise and capabilities available both in terms of manpower and lab facilities, while developing a R&D roadmap for low-GWP refrigerants • Operationalizing an R&D program to identify and pilot test low GWP alternative and natural refrigerants which are	Create business models and value chain development for commercialization of low-GWP alternatives identified through indigenous R&D		Knowledge	DST; MoEFCC; prominent R&D institutes such as CSIR-IICT, IITs, IISC, and NITs; MoCI	Mission Innovation, Start-Up India
	Support new molecule research, possibly from two R&D institutions with clear review mechanism and incentives for corporates for	Support further development and deployment of new molecule research: • Review molecule research and, application lab effectiveness	Knowledge, policy	DST, MoEFCC, prominent R&D institutes such as CSIR-IICT, IITs, IISC, and NITs	Mission Innovation

Proposed Interventions			Instrument	Key Stakeholders	National & State Policy Alignment
Short Term (2022-24)	Medium Term (2025-30)	Long Term (2031-38)			
suited to the Indian market needs and ambient conditions while ensuring achievement of safety standards and energy efficiency	molecule research	• effectiveness prog-ress and further strengthening of infrastructure • Review regulatory/ policy framework for launching the newly developed molecules			
2.2 Indigenous production of low-GWP refrigerants					
Support indigenous production of hydrocarbon (R600A and R290) refrigerants	Develop low-GWP alternative production process and setting up of production facility for them which are based on indigenous R&D	• Support commercial scale production of HFOs • Demonstration of bench and pilot production of newly developed molecules based on indigenous R&D	Policy, investment (private finance)	MoEFCC, MoCI, MDBs, FIs	Make in India
Develop knowledge/training centers for enhancing capabilities of refrigerant manufacturers for energy-efficient and low-GWP refrigerants			Knowledge	MoEFCC, MSDE	Skill India Mission - PMKVY

Proposed Interventions			Instrument	Key Stakeh-olders	National & State Policy Alignment
Short Term (2022-24)	Medium Term (2025-30)	Long Term (2031-38)			
3. Improve servicing, maintenance and disposal to reduce refrigerant demand					
3.1 Proper servicing and maintenance of refrigerant-based equipment to reduce refrigerant leakage					
Design a program to support skilling of technicians and supporting their employment by: i) Designing training and certification programs for service technicians on GSP across sectors to better manage and reduce refrigerant losses during recharge and end-of-life. Amongst sectors, priority should be given to RAC sector which has tremendous market share and growth potential. MoEFCC recently released the book on 'Good Servicing Practices for Energy Efficient Operations of Room Air Conditioners' which should be taken forward through dedicated training programs ii) Conducting a state-wise assessment of the demand and availability of trained service technicians as well as availability and quality of training institutions iii) Conducting dialog with industry to encourage participation in training delivery and seeking its commitment to employ a fixed number of trained candidates iv) Operationalizing central voluntary certification scheme through a single government entity under a single framework	Ensure successful implementation of the skill development program of technicians by: i) Establishing training centers/centers of excellence across India and upgradation of training centers ii) Promoting online refresher training courses on new and upcoming technologies as skill enhancement support for technicians iii) Designing programs to build customer awareness on the need and benefits of hiring only certified technicians iv)Developing a system to mandate the hiring of only certified technicians by large facilities	Introduce universal mandatory certifications for all technicians	Policy, knowledge	MSDE, MoEFCC, MoHUA, MoCI, MoFPI, MoRTH	Skill India Mission - PMKVY

Proposed Interventions			Instrument	Key Stakeholders	National & State Policy Alignment
Short Term (2022-24)	Medium Term (2025-30)	Long Term (2031-38)			
Listing of empaneled certified or ITI-trained servicing personnel on GeM portal to ensure competitive cost and reliable servicing for zero ozone-depleting substances /lower GWP products.			Policy	MoCI	GeM
3.2 Recovery, recycling and reclamation of refrigerants					
Design policy and training program to support the recovery, recycling and reclamation or effective destruction of refrigerants			Policy	MSDE, MoEF-CC, Sector Skill Councils	Skill India Mission - PMKVY
Introduce subsidies to bring down cost of recovery equipment			Policy, investment (public/ private finance)	MoEFCC, MDBs, FIs, private com-panies	
Support infrastructure development and incentivize recycling and reclamation of refrigerants and for safe and effective end-of-life management of gases			Policy, investment (public/ private finance)	MoEFCC, MDBs, FIs, Private Com-panies	
• Training of technicians to support recovery and transport of refrigerants to reclamation centers • Mandate public sector to utilize licensed service technicians only			Policy	MSDE, MoEFCC, Sector Skill Councils	Skill India Mission -PMKVY

Proposed Interventions			Instrument	Key Stakeholders	National & State Policy Alignment
Short Term (2022-24)	Medium Term (2025-30)	Long Term (2031-38)			
Embed refrigerant disposal guidelines within existing regulatory mechanisms of end-of-life disposal of RACs, i.e., EPR and e-waste guidelines for reclaiming electronic components at end of life			Policy	MoEFCC	EPR and e-waste guidelines

BIS: Bureau of Indian Standards; CSIR-IICT: Council of Scientific and Industrial Research Indian Institute of Chemical Technology; IIT: Indian Institute of Technology; IISC: Indian Institute of Science; NIT: National Institute of Technology

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