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POLICY BRIEF 2 GREEN COOLING

Adopting natural refrigerant-based cooling in India: The road ahead

Summary

India's third refrigerant transition, the phasedown of high global warming potential (GWP) hydrofluorocarbon (HFC) gases, is scheduled to commence by the end of this decade. Simultaneously, ozone depleting refrigerants namely hydrochlorofluorocarbons (HCFC) will be phased-out by 2030. Among the alternative refrigerant gases that are being explored, low-GWP natural refrigerants have emerged as a front-runner due to their low climate impact and patent free status. Moreover, natural refrigerant-based cooling technologies are market ready. Despite the relative advantages, these technologies remain on the fringes while high-GWP refrigerants remain the mainstream choice. In this Policy Brief, we explore barriers and interventions to create a conducive ecosystem for natural refrigerant-based cooling in India.

Using stakeholder surveys and expert interviews, this Policy Brief explores the current state of the sector, barriers and opportunities for natural refrigerants. While there are several natural refrigerant cooling options across various applications, current barriers to their uptake include: lack of awareness among consumers, high costs, and challenges with retrofitting. Given that synthetic refrigerant-based cooling is the dominant cooling technology today, a growth towards alternatives is not likely to occur without governmental intervention.

Despite this, incremental progress has been made through two important actions that have contributed to favourable conditions for alternative cooling technologies. First, the ICAP's promotion of 'sustainable' and 'climate-friendly' cooling. Second and more importantly, Bureau of Indian Standard's (BIS) adoption of safety standards for natural refrigerants. In this Policy Brief, promotion of natural refrigerants is proposed through targeted economic interventions, policy actions, technology support and capacity building as follows:

- Economic interventions must be in the form of subsidies to companies that manufacture natural refrigerant-based systems and financial aid to set up testing and R&D facilities.
- Any policy for refrigerant transition in India must account for natural refrigerants, either through mandating their use in certain technologies or through fast-track approvals.
- As technology already exists for natural refrigerant-based cooling, there is a need to create a conducive environment for start-ups as well as R&D centres to facilitate their easy deployment.
- Finally, capacity building must focus on training and awareness activities on natural refrigerants among different stakeholders ranging from engineering and architecture students, technicians, plant operators, factory inspectors to policy makers, senior executives and consumers.

Introduction

A total of 197 countries across the world were mandated under the Montreal Protocol on substances that deplete the ozone layer (here after Montreal Protocol) to phase out refrigerant gases with ozone depleting potential (ODP). In India, the phaseout of ozone depleting chlorofluorocarbons (CFC) is complete while the phaseout of hydrochlorofluorocarbons (HCFC) is expected to be completed by 2030. Simultaneously, with a freeze in 2028, under the Kigali Amendment to the Montreal Protocol, hydrofluorocarbons (HFC) with no ODP but with large global warming potentials (GWP) are set for a phase-down in India. In the coming decade, the cooling industry in India will simultaneously be grappling HFC phase-down targets, energy efficiency enhancement and rapidly increasing demand for space cooling.

Among the alternative refrigerants that are being explored, low-GWP natural refrigerants have emerged as a front-runner. Natural refrigerant-based cooling technologies are market-ready with the promise of climate-friendly cooling, are patent-free and in some case are known to enhance energy efficiency. Despite the relative advantages, these technologies remain on the fringes while high-GWP refrigerants and allied technologies remain the mainstream choice. A critical need today is to understand what it would take to create a conducive ecosystem for the uptake of these alternative technologies.

While the ICAP remains technology and refrigerant agnostic, its emphasis on 'sustainable' and 'climate-friendly' sends a positive signal to the industry. Further, BIS's adoption of safety standards for natural refrigerants under IEC 60335-2-40:2018 and MED 3 (14430) in 2020 has a direct positive implication on natural refrigerant-based cooling applications. However, given that synthetic refrigerant-based cooling is the dominant cooling technology, a growth towards alternate technology is not likely to occur organically. In this Policy Brief, through data collected from online surveys with industry, academia and policy experts as well as detailed interviews with sector experts, we explore the current status of natural refrigerant-based and possibilities for creating a competitive market for alternative, climate-friendly cooling in India.

Status of natural refrigerant-based cooling

Natural refrigerants are low-GWP (GWP values <10) as well as non-ODS gases that are a climate-friendly refrigerant option for cooling systems. Commonly used natural refrigerants in the air-conditioning and refrigeration applications are hydrocarbons (HC), ammonia (R-717), water and carbon dioxide (R-744). Table 1 draws a comparison between sector-wise alternatives for high-GWP refrigerants.

Hydrofluoroolefins (HFOs) are another set of refrigerants with low GWP (<10) and no ODP, that are emerging as a synthetic replacements for HCFCs and HFCs. These synthetic refrigerants are favoured due to their potential to be drop-in replacements for HFCs. However, due to the synthetic nature of HFOs, they are being studied for potential impacts on the environment and health. A recent study found the atmospheric degradation of HFO 1234ze, a potential replacement for HFC 134a, leads to the production of HFC 23 (GWP 12,500)[1], one of the most potent greenhouse gas known and monitored under the Montreal Protocol requirements.[2] A 2017 study by the Norwegian Environment Agency, found the decomposition product of HFO 1234yf, trifluoroacetic acid (TFA), in water bodies such as rivers, lakes, streams and wetlands.[3] The accumulation of TFA, from HFO 1234yf degradation, in drinking water is a central concern of a project funded by the German Environment Agency. The results for this study are awaited.[4]

Natural refrigerants are being promoted due to their significantly low climate impact as well as their ability to augment the energy efficiency of cooling systems[5,6]; thereby reducing both direct and indirect emissions in comparison to conventional cooling systems. Table 2 summarises various natural refrigerant based technologies in the market today.

Table 1: Comparison between current refrigerants with emerging alternatives

	Mobile air-conditioning		Room air-conditioning		Super-market refrigeration		
	HFC 134a	HFO 1234yf	HFC 32	HC 290	HFC 404a	CO_2	NH_3
Type	**Synthetic**	**Synthetic**	**Synthetic**	**Natural**	**Synthetic**	**Natural**	**Natural**
GWP (100 year)[1]	1360	<1	702	5	3922	1	0
Advantages		Drop-in replacement and low-GWP	Commercial-ly viable	Low-GWP, energy efficient, and commercially viable		Low-GWP	Low-GWP
Limitations	High GWP	Degradation products persist in water bodies, degradation into potential pollutants.[2]	Medium to high GWP value	Flammable	High GWP	High working pressure	Toxic

Source: Author's analysis (2021)

[1] OzonAction. (2016). Global Warming Potential (GWP) of refrigerants: Why are particular values used?. OzonAction Fact Sheet. https://wedocs.unep.org/bitstream/handle/20.500.11822/28246/7789GWPRef_EN.pdf?sequence=2&isAllowed=y

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Table 2: Technologies compatible with natural refrigerants

Technology	Description	Sector/ Application	Refrigerant options	Market preparedness
Vapour absorption systems	In these systems, the cooling effect is driven by heat energy rather than mechanical energy.	Commercial and industrial refrigeration	NH_3-Water	Thermax manufactures vapour absorption systems for industrial applications such as comfort cooling and process cooling.
Cascade systems	As an alternative to single-refrigerant system, cascades are used for CO_2 refrigerant used in tandem with a fluorocarbon, HC or alkali in High Ambient Temperature (HAT) conditions. These are two separate but thermally connected systems.	Commercial refrigeration/ supermarket refrigeration	Low stage – CO_2 High stage – Fluorocarbon, HC or alkali	R&D and demonstration projects in IIT Madras
Secondary loop systems	A secondary loop has two refrigerants working together in a single system. The primary and secondary loops use two different refrigerants, such that at the evaporator heat is exchanged with the secondary refrigerant.	Commercial refrigeration/ supermarket refrigeration	Primary loop – NH_3, CO_2 Secondary loop – HC, fluorocarbon	R&D

Technology	Description	Sector/ Application	Refrigerant options	Market preparedness
HC 290 air conditioners	HCs-based systems provide cooling along with energy savings.	Residential and Commercial air-conditioning	HC 290	Being sold by Godrej & Boyce in India since 2012.
Solar assisted cooling	The combination of solar thermal energy and natural refrigerants make the perfect business case for sustainable cooling. A sorption technology is used to convert gas at low pressure to high pressure using heat instead of electricity.	Cluster air-conditioning	NH_3 or water	Market ready

Source: Author's analysis (2021); cBalance Solutions Hub. (2016). Mapping Natural Refrigerant Technology Uptake in India. https://shaktifoundation.in/wp-content/uploads/2017/06/Mapping-Natural-Refrigerant-Technology-Uptake-in-India.pdf ; Khanderkar, S. (n.d.). Vapor Absorption Refrigeration Systems. ME340A: Refrigeration and Air Conditioning. IIT Kanpur. ;http://home.iitk.ac.in/~samkhan/ME340A/Lecture_14_Vapor_Absorption_Refrigeration_OK.pdf; Desai, D., Prasad, W., Vaghasia, R. (2015). Innovative Refrigeration Technology. Cooling India. https://www.coolingindia.in/innovative-refrigeration-technology/

Box 1: Methodology for stakeholder survey and expert interviews

Judgmental sampling method, also called purposive sampling, was used to select the respondents for the online expert survey in August 2020. This is a non-probabilistic sampling technique in which the sample members are chosen only on the basis of the sample's knowledge and judgment. Therefore, only those industries operating in the field of natural refrigerants and not-in-kind-technologies were approached, other than those in the mobile air conditioning businesses. Similarly, research and academic institutions, consultants and government agencies working in the field of natural refrigerants and not-in-kind-technologies were selected. The survey questionnaire was developed to address aspects such as awareness towards the ICAP and the Kigali Amendment, refrigerant use and impediments to mainstream natural refrigerant and not-in-kind technologies. Respondents were also asked to suggest interventions to help overcome barriers to these technologies.

In order to further supplement this data, semi-structured interviews with seven policy and industry experts were conducted in April 2021. These interviews focused on gathering qualitative data on implementation of the ICAP and barriers for adopting natural refrigerant and not-in-kind technologies in India. Annexure 1 contains a list of experts consulted for the survey and interviews.

Current use of natural refrigerants

India is undergoing the second stage of HCFC phase-out management program (HPMP), which will ensure a complete phaseout of these gases by 2030. Simultaneously, the Kigali Amendment to Montreal Protocol comes into force in 2028 in India, with a 10% decrease in HFCs by 2032 (relative to baseline years of 2024, 2025 and 2026). Due to such overlap in refrigerant transition in India, at any given point there is more than one refrigerant for a given sector and application.

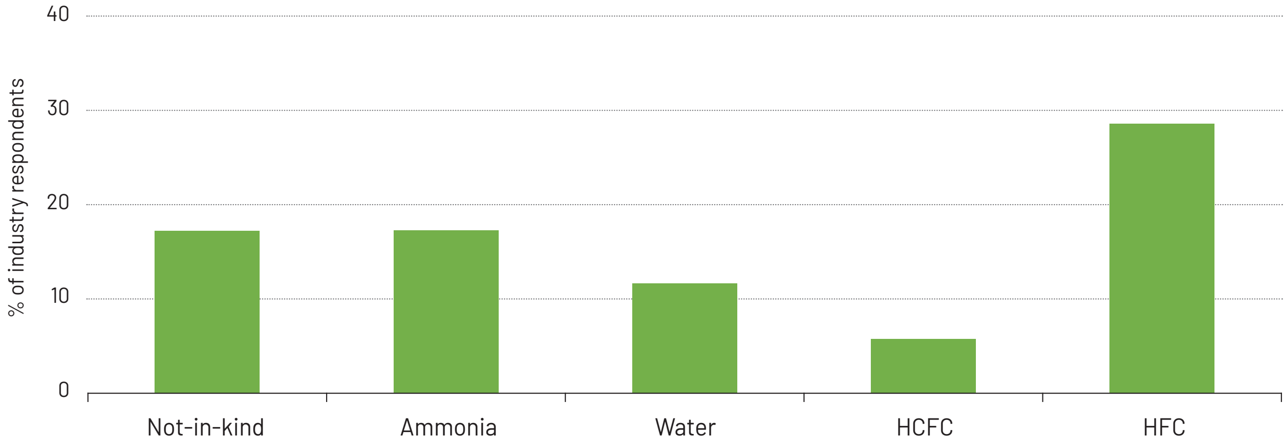
In the room air conditioner sector, there are currently five refrigerants – HCFC 22, HFC 32, HFC 410A, HFC 407c and HC 290. Among these, HFC 32 and HC 290, with GWP values of 675 and 3 respectively for high-GWP refrigerants and are market ready. With the HPMP II underway, the use HCFC 22 in air conditioners will decrease over the course of this decade. This trend is evidenced in an observed decrease in use of HCFC 22 from 50% in 2016 to 38% in 2017. Moreover, with alternatives life HFC-32, air conditioners with HFC 410A (with a GWP of 2088) have decreased from 41% in 2016 to 36% in 2017.[7] Simultaneously, there was an observed increase in both HFC 32 and HC 290, estimated at 17% and 6% of the refrigerant in air-conditioning in 2017.[8]

The businesses surveyed indicated the use of HFCs predominantly, used by 5 out of 7 industry respondents (see Figure 1). Only one of the seven businesses, a manufacturer and exporter of refrigeration and air-conditioning equipment, indicated the use of HCFCs (HCFC 22, HCFC 123) in their products/servicing at less than 1 tonne of refrigerant in 2019-2020. This respondent also indicated the usage of 1 - 10 tonnes of HFC during the same time span. Three businesses working in commercial refrigeration (CR), industrial refrigeration (IR) and space cooling (both residential and commercial) indicated using less than 1 tonne of HFC in 2019-20. The mobile air conditioning (MAC) business working on buses and trucks used between 10-50 tonnes of HFC in 2019-20.

While the businesses showed an intention to move to natural refrigerants, none of them currently use HC or CO_2 refrigerants. However, three businesses used NH_3. The business in the IR sector indicated the use of NH_3 at 10-50 Tonnes, while the two businesses in CR and space cooling indicated 1 tonne each of NH_3 usage for 2019-20. Two space cooling sector respondents indicated the use of water as refrigerant, one of which specified using 50 - 100 tonnes of water as refrigerant for 2019-20.

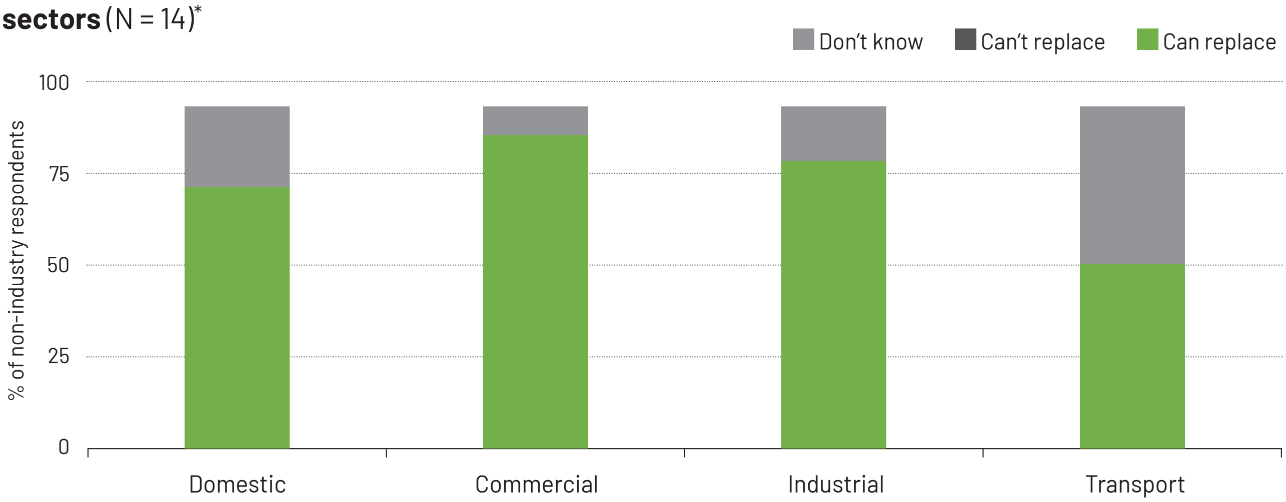
In addition to the willingness to transition, the possibility of moving to natural refrigerants is important. There are ample examples of applications where this transition has already taken place with relative success: room air conditioners with HC 290 constitute around 6%,[9] residential refrigerators are increasingly HC 600a based,[10] and about 90% of cold storages are ammonia based.[11] However, there are several applications that have still not ventured into natural refrigerants.

Figure 1: Refrigerant usage of industry respondents (N = 7)



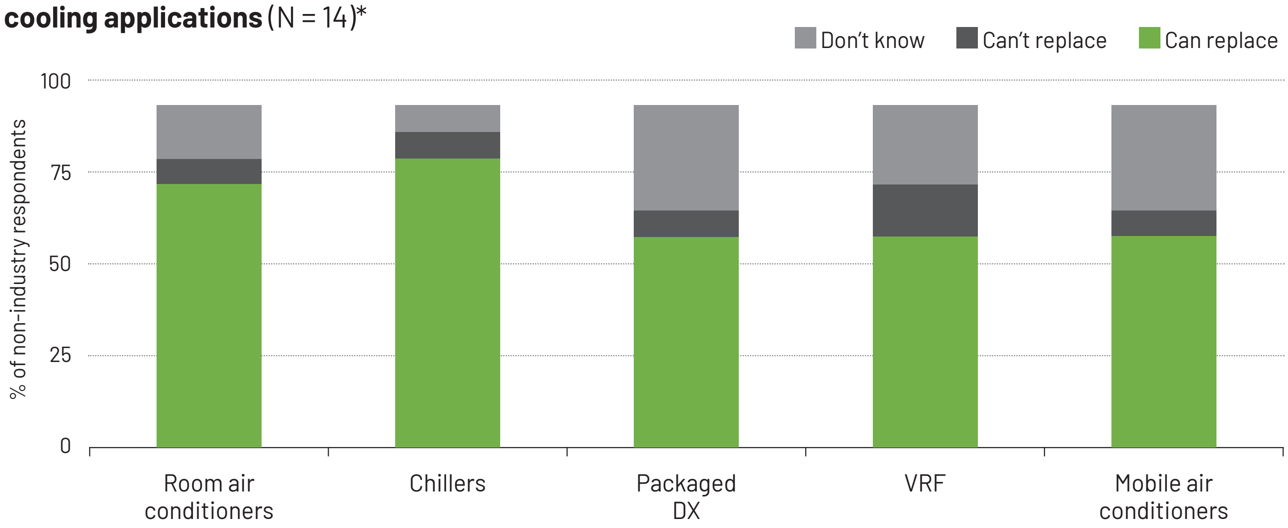
Source: Author's analysis (2021)

Figure 2: Perceptions on replaceability of synthetic refrigerants with natural refrigerants in various sectors (N = 14)*



Source: Author's analysis (2021); *The % in the above figure do not add up to a hundred as one respondent did not provide any response.

Figure 3: Perceptions on replaceability of synthetic refrigerants with natural refrigerants in various cooling applications (N = 14)*



Source: Author's analysis (2021); *The % in the above figure do not add up to a hundred as one respondent did not provide any response.

Responses from the non-industry actors affirmed the replaceability of synthetic refrigerants with natural alternatives in all the sectors and specific applications in air-conditioning and refrigeration (see Figure 2 and 3). Among these, the most ambiguity was observed in the transport sector, which immediately points to a lack of information on this among non-sector and non-industry personnel. In a previous study by cBalance, natural alternatives to synthetic refrigerants were found to be available for all except the mobile air-conditioning and transport refrigeration sectors. However, in Germany where refrigerant gases above 150 GWP in MAC were banned in 2011 as per an EU directive, CO_2 refrigerant is being used as a viable alternative.[12] Here, an impediment for widespread use of CO_2 for car air conditioners is the need to develop and test pressure resistant components and develop safety standards specific to India. Refrigerant HC 290 has also been recommended for transport refrigeration in trucks.[13] Thus, while there are some viable options, there is a need for R&D for the use of natural refrigerants in transport related applications.

Applications like variable refrigerant flow (VRF), packaged DX and MACs had fewer responses in favour of replaceability of synthetic refrigerants relative to RACs and chillers. The perceived barriers are discussed below.

Barriers for natural refrigerant-based cooling

Current barriers for natural refrigerants are as follows:

- **Lack of consumer awareness:** Studies in the past have shown that decision making on residential air conditioner purchase are not based on the refrigerant gas.[14] Further, in the absence of any substantive awareness efforts on natural refrigerants, HFC-based air conditioners continue to be the mainstream choice, both for residential and commercial cooling needs. This was a barrier identified both by industry and non-industry respondents.
- **High cost:** Decisions related to purchase and installation of cooling systems is not made based on the refrigerant's GWP value but on cost and ease of production. Natural refrigerant systems have been found to have a high initial cost although operational costs are low. Moreover, the manufacturing capacity for these technologies is currently small, thereby driving up the costs of these systems. This will also have a bearing on dealers and traders, who are more likely to promote these technologies to consumers when they make economic sense. The high initial investment required for these systems, often clubbed with scarcity of expertise both in terms of technical experts and servicing technicians has led to low uptake of this technology.

- **Difficulty with retrofitting:** Difficulty with retrofitting equipment with natural refrigerants especially in large charge size equipment like chillers, VRF and packaged DX is a commonly noted challenge. Often with synthetic refrigerants like the HFOs, this challenge is overcome as they behave as drop-in replacement. This was particularly a concern listed among industry respondents as the large number of existing chillers may not be suitable for retrofitting with natural refrigerant-based systems as per ICAP's timeline.

Thus current barriers for natural refrigerant-based cooling are lack of awareness among consumers, high costs, and challenges with retrofitting. Additional barriers arising from low demand resulting in the lack of domestic manufacturing of suitable components (e.g. hermetic compressors for ammonia and cost effective carbon dioxide compressors). Natural refrigerant businesses will thus not only need intensive capital investment for manufacturing at all stages but also capacity building in preparing technical capacity for its installation and maintenance.

Box 2: Facilitating the transitioning to natural refrigerant based technologies

In spite of the existence of safety standards, natural refrigerants are generally not suitable for retrofitting thereby requiring a complete overhaul of the equipment. Natural refrigerants are technology-ready, however, there are several market barriers preventing their widespread use. Often economic incentives are suggested for overcoming these barriers. However, while financing the steep upfront costs through incentive programs is necessary, it rarely is sufficient. A supportive ecosystem that addresses policy, standards, awareness and training needs to mainstream natural refrigerants is imperative. One existing example of how this can be done and successfully at that is the North American Sustainable Refrigeration Council (NASRC).

The NASRC was established with the intention to remove barriers to the adoption of climate-friendly natural refrigerants with a specific focus on commercial refrigeration. Some of the barriers they have targeted over the years are: high-upfront costs; shortage of workforce training; and lack of performance data on natural refrigerants. They have partnerships and have created a network of supermarket industry stakeholders providing all forms of support to those moving to natural refrigerants. The NASRC works across six areas to address barriers to natural refrigerant adoption:

- Acceleration of incentives and other financial resources to offset the upfront costs and reach cost parity;
- Ensuring that current and future generation of technicians are trained on natural refrigerants;
- Providing data on return on investment (RoI) of different natural refrigerant technologies to reduce uncertainty;
- Supporting and accelerating the creation of codes and standards to enable safe and widespread use of natural refrigerants;
- Advising on policies and regulations to address industry standards while meeting regulatory targets; and
- Facilitating knowledge sharing and distributing best practices to accelerate solutions and scale adoption.

Interventions and way ahead

Based on the various barriers identified for natural refrigerants, the following interventions in the form of economic incentives, policy action, technology support and education, training and capacity building were suggested by experts.

Economic incentives

- Subsidies should be offered to:
  - Equipment as well as refrigerant manufactures for shifting to natural refrigerants;
  - To manufacturers on capital cost including phase-wise hand holding to ensure additional cost is not a burden; and/or
  - To consumers on the installation and use of natural refrigerant in systems.
- Incentives should be provided:
  - For setting up testing facilities (e.g. determining coefficient of performance);
  - R&D centres;
  - To offset the high working capital and provide tax exemption to make natural refrigerant-based systems affordable; and/or
  - To users to compensate for the high first cost.
- Promote natural refrigerants under public procurement programmes
- Provide higher depreciation on natural refrigerant-based equipment.

Policy action

- Promote natural refrigerants by placing GWP limit on refrigerants or a limit on quantity of synthetic refrigerants used in cooling equipment.
- Promote natural refrigerants by mandating a minimum % use of these in systems through timelines.
- Provide fast track approval of standards for natural refrigerants and allied technology.
- Create in-situ demonstrations of these technologies in government and corporate houses and public procurement.
- Reduce import duty for compressors for natural refrigerants.

Technology support

- Create a single window domain for technology access and support manufacturing in acquiring technology.
- Technology transfer projects should be promoted through collaboration between industry and academics, sanctioning R&D and international collaboration.
- Create a conducive environment for start-ups in this sector.
- Some areas for R&D are:
  - Ammonia refrigerant for industrial refrigeration;
  - Reduced HFC charge size in mobile cooling application; and
  - Carbon dioxide refrigerant for MAC.

Education, training and capacity building

- Technical training for:
  - Service technicians, plant operators and engineer heads;
  - Architects, consultants and dealers;
  - Final year engineering students; and
  - Factory inspectors and Pollution Control Board officials on ammonia refrigerants.
- Awareness based educations for:
  - Consumers;
  - Senior management in the corporates dealing with cooling technology; and
  - Policymakers (BIS, MoEF&CC, BEE etc).
- Refrigerant-specific awareness is critical to this transition to climate-friendly cooling. Awareness among residential end-users could begin with something as basic as manufacturers being asked to provide the name of the refrigerant used in the appliance both through using labels on appliances and introducing these in brochures. It may also be beneficial to replace the 'R' for refrigerants with chemical-specific abbreviations of the refrigerants such as 'HFC-134a', HFC-410A' instead of 'R-134a' and 'HFC-410A'.

ANNEXURE 1

List of experts consulted for the survey and interviews

Survey

Name	Affiliation
Ms. Shikha Bhasin	CEEW
Mr. S P Garnaik	EESL
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Dr. Bijan Kumar Mandal	IIEST, Shibpur
Mr. Aswani Kumar Sharma	WIPRO
Dr. M V Rane	IIT-B
Dr. Neeraj Agrawal	DBATU
Mr. Ashish Rakheja	AEON
Ms. Nisha Menon	DESL
Mr. Rajmohan Rangaraj	DESL, Veolia Environment Ingineering Council
Mr. Piyush Patel	Paharpur Cooling Technologies
Dr. Prasanna Rao Dontula	A.T.E Group
Mr. Shubhashis Dey	Shakti Sustainable Energy Foundation
Mr. Mohanlal Basantwani	Shankar Refrigeration & Engineering
Mr. Rajendra Bhavsar	Refcon Technologies & Sysetms Pvt ltd
Mr. Nikhil Raj	Neptune Refrigeration Co P Ltd
Mr. Shatrughan Kumar	Trans ACNR Solutions Private Limited
Mr. Ramesh Kumar Gupta	EVAPOLER ECO COOLING SOLUTIONS
Mr. Madhusudhan Rapole	Oorja Energy Engineering Services Pvt Ltd
Mr. Sudharshan Rapolu	TechnoDyne RS

Interviews

Mr. Tanmay Tatagath	Green Building Analyst, Executive Director Environmental Design Solutions
Ms. Sumedha Malaviya	Manager Energy Program, WRI India
Mr. Madhusudhan Rapole	Oorja Energy Engineering Services Pvt Ltd
Ms. Smita Chandiwala	Energe-se
Dr. Satish Kumar	AEEE
Mr. Vivek Ghilani	cBalance
Mr. Krishna Nagahari	Danfoss

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