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SHAKTI SUSTAINABLE ENERGY FOUNDATION

POLICY BRIEF 3 GREEN COOLING

Mainstreaming Not-in-Kind Cooling in India: Status check

Summary

Not-in-kind (NIK) cooling technologies offer non-fluorocarbon and energy efficient refrigeration and cooling, making them a climate-friendly option. NIK includes a range of technologies both new and old, such as district cooling for building clusters and evaporative cooling commonly used as household desert coolers. Despite the relative advantage of NIK technologies and a positive policy signal from the ICAP, they are still not a mainstream choice in India. Through this Policy Brief we aim to explore the current status, existing barriers and required interventions to mainstream NIK cooling technologies in India.

NIK technologies for space cooling and commercial refrigeration are largely ready for deployment with several demonstration projects being set up across the country. A core challenge for NIKs is the lack of awareness resulting in low demand for these technologies, which in turn, drives up their costs. Moreover, given that the use of NIK is still at its nascent stage, there is a need to create standards to continually augment the quality of NIK technologies, as well as explore ease of deployment of these technologies. Interventions required to promote NIK cooling in terms of economic incentives, policy action, technology support and capacity building are as follows:

- Economic incentives to drive down the cost of NIKs should be provided to builders, consumers, DISCOMs, and start-ups/small businesses. Financial aid should also be provided to bolster R&D and testing facilities.
- Policy action, albeit, not the main driver for uptake of NIKs at this point, should promote these alternative technologies through supportive regulations in energy consumption.
- Technology support forms an important driver for mainstreaming NIKs through R&D, demonstration projects, and other kinds of technical research that can help make these technologies aesthetic, accessible and deployment-friendly.
- Capacity building efforts, focused on training and awareness should target a range of stakeholders including builders, consumers, engineering/ architecture students, installers and service providers.

Introduction

The India Cooling Action Plan (ICAP) was released in March 2019 targeting a decrease in refrigerant use by 25-30 percent and energy use by up to 30 percent by 2037-38 relative to 2017-18. The ICAP is a multi-stakeholder effort emphasizing on both active and passive cooling as well as efficient and climate-friendly appliances and equipment. The document brought to the forefront alternate cooling systems such as radiant and structure cooling commonly classified under NIK technologies. These NIK-based cooling technologies are non-fluorocarbon and deviate substantially from conventional cooling systems in both design and operating principles. Thus, successful implementation of the ICAP has the potential to create a competitive market for alternative climate-friendly technologies.

NIK cooling technology refers to the use of non-fluorocarbons for refrigeration and cooling applications. NIK break away from traditional refrigeration and air-conditioning systems that rely on vapour compression cycles using a gaseous refrigerant. NIK includes a range of technologies both new and old, such as district cooling for building clusters and evaporative cooling commonly used as household desert coolers. A key advantage of these technologies is that they are not dependent on ozone depleting or high global warming potential (GWP) refrigerants.

Despite the relative advantage of NIK technologies and a positive policy signal from the ICAP, they are still not a mainstream choice in India. With increasing affluence, in addition to increasing warming due to climate change, cooling demand for comfort, food security and health will see an exponential increase. To this end, the TEAP report of September 2020 on energy efficient technologies stated that the influence of market mechanisms and national policies can play an important role on the availability and costs of equipment and components and are essential drivers of a refrigerant transition.[1] Thus, through this policy brief we aim to explore the current status, existing barriers and required interventions to mainstream NIK cooling technologies in India.

Current landscape of NIK

There are a range of options in NIK cooling technologies that have evolved over the years. Interest in NIK cooling/ heating emerged when the cooling industry was mandated to find alternatives for ozone depleting refrigerant-based technologies under the Montreal Protocol. However, in the early years, NIK was not suitable to replace vapour compression systems. Over the past two decades, owing to rapid research and development in this space, NIK technologies have made a significant breakthrough resulting in a decrease to their cost and enhanced performance.[2]

We conducted a scoping study on existing NIKs in India and their market preparedness (see Table 1). A total of eleven technologies were found based on a literature review mainly for space cooling. Many of these NIKs are well developed technologies that are finding use in different parts of the country. The table summarises advantages, limitations, and market preparedness of these technologies. From the review it is evident that many of these NIK technologies, also listed in the ICAP, are ready for deployment. Additionally, many of these technologies are already being demonstrated by government projects.

Table 1: Technology landscape of current NIK cooling in India

Sl. No.	Technology	Description	Advantages	Limitations	Market Preparedness	Example projects
1	Solar Thermal (Solar/Biomass Cogeneration)	Producer gas from a biomass gasifier drives a gas engine to produce the electricity required to drive a vapour absorption cooling system.	1.Balance heat available from the engine can be utilized for drying, humidifying, sanitizing needs of the cold storage. 2.The solar thermal collectors supplement the heat to the vapour absorption system during day time.	1. Unavailability of woody biomass at all places. 2.Can be expensive when taking into account the cost of harvesting, extracting, transporting and handling biomass.	Demonstration cum performance project	Solar Energy Centre (SEC), Gurgaon, a technical institution under Ministry of New and Renewable Energy (MNRE), in collaboration with Thermax (cold storage component) and TERI (gasifier component), implemented a demonstration-cum-performance evaluation project at the SEC campus.

Sl. No.	Technology	Description	Advantages	Limitations	Market Preparedness	Example projects
2	Geothermal Cooling / Heating	Uses the earth as a heat sink as the earth's temperature at a certain depth is lower than that of atmospheric temperatures.	1.With lower ground temperatures available to the cooling systems, energy efficiency increases significantly 2. Suitable for stationary cooling applications 3. Geothermal AC systems are much quieter than conventional AC systems (which are noisy)	1.Geographical constraints as there are few hotspots. 2. High upfront cost	Pilot project	Few government funded projects operational in collaboration with foreign organizations. 1.ONGC, Belgian Talboom pilot geothermal plant in Gujarat. 2.Islandsbanki, Iceland; Mannvit, Iceland and Bhilwara Group, India have set up a Joint -Venture i.e. Bhilwara Mannvit Green Energy Ltd (BMGEL).
3	Solar VAM system	The VAM uses both the heat energy from the solar parabolic concentrators and the waste heat from the biomass gasifier to cool the storage chamber.	1. High energy savings as compared to other existing technologies. 2. Capital cost is moderate.	The VAMs occupy a large space because of their low coefficient of performance (COP). To increase their COP, machines need to be developed with double effect and triple effect absorption cycles which require a higher degree of heat to operate at that efficiency.	Deployed	An aggregate of nearly 1 million TR of solar VAM air conditioning (replacing an equivalent amount of conventional air conditioning) has been installed.
4	Evaporative cooling	Water is used as a refrigerant and operates on thermal energy. Latent heat is used to evaporate the water resulting in cooling effect	1.Optimal indoor air quality 2.Energy-efficient climate control 3.No harmful refrigerants used	It cannot lower the ambient temperature as much as a vapor-compression or refrigerant-based air conditioning units	Deployed	Symphony, the world leader in air cooling, has recently executed two very prestigious projects, one for a typical secondary school in New Delhi and another one for a well-known university from Ahmedabad.
(a)	Indirect Direct Evaporative cooling system-(IDEC)	A 2-stage "indirect/ direct" cooling represents the most advanced cooling system - utilizing evaporative cooling technology.	1.Very low operational cost 2.Energy saving potential is quite high 3.Cools the process air without adding humidity to the supply air stream 4.Can be deployed in all Climatic zones	1.IDECs increase water consumption. 2.Evaporative media need to be replaced and circulating pumps require regular maintenance. 3.Increased complexity of the system	Deployed	Replacement of approximately 0.1 million TR or conventional air conditioning An example of a project using IDEC is the Bihar Museum in Patna. For the same DBT, the supply air temperature by the IDEC system is 40°C lower compared to the evaporative cooling systems.

Sl. No.	Technology	Description	Advantages	Limitations	Market Preparedness	Example projects
5	District Cooling	Distributes (supplies and collects back) cooling energy in the form of chilled water from a central district cooling plant to multiple buildings through a distribution network of insulated, underground pipes for space cooling.	1.Lower cost cooling for customers. 2.High reliability and resilience. 3.Can access waste heat or renewable sources of energy that are unavailable to a single building level. 4. Most viable for comfort cooling applications in dense and mixed-use developments, i.e. a combination of commercial, residential, institutional etc	The key challenges are high initial investment, lack of technical expertise for design, little policy level support, and absence of favourable financial and business mechanisms	Pilot project	5 city rapid assessments. Methodologies and tools developed for all cities. 1.Gujarat International Finance Tec-City or GIFT City is India's first merchant DCS developed by the Government of Gujarat. 2.Another successful example of district cooling for commercial buildings is DLF Cyber city, Gurgaon.
6	Trigeneration	Trigeneration is the production of combined cooling, heat, and power from a single generator or process. The system produces electricity and useful heat which is utilised for hot water, space heating or steam production, as well as energy efficient cooling.	1.Onsite generation of electricity, heat and power 2.Maximum total fuel efficiency, reduced fuel and energy costs, lower electrical demand during peak time 3.Elimination of HCFC/CFC refrigerants and emission reduction	Limited to specific applications where there is a simultaneous demand for heat and power and uninterrupted availability of fuel	Deployed with a growing market and huge growth potential in the years to come.	The tri-generation plant inside the trauma centre is the government's demonstration project to evaluate the feasibility of the technology in the country. Started in 2008, the pilot project was jointly implemented by the Bureau of Energy Efficiency (BEE), a statutory body under the Ministry of Power, and GIZ. The project was funded by the federal government of Germany.
7	Structure Cooling system	In this system, water chilled by a two-stage cooling tower is passed through pipes embedded in the concrete core	1.Very Low capital cost/ setup cost. 2. GWP and ODP for structure cooling system is zero (significant reduction in GHG emissions)	Requires prior planning as it needs to be integrated into the building structure.	Deployed	An aggregate of approximately 0.6 million sq. ft. built-up area in India uses structural cooling technology, replacing approximately 4,600 TR or conventional air conditioning. Green Space Realtors has developed the commercial project of Thaker Industrial Estate, Mumbai

Sl. No.	Technology	Description	Advantages	Limitations	Market Preparedness	Example projects
8	Radiant Cooling System	It is a hydronic system that circulates chilled water through plastic pipes embedded in the floor or ceiling, or through copper pipes embedded in ceiling panels.	1.It has high durability 2.Energy saving. opportunities are considerably high. 3.Reduces the cooling load 4.Viable retrofit option for existing buildings.	These systems pose an inevitable risk of condensation in humid conditions and hence call for an ancillary dedicated outdoor air system to avoid condensation which increases the initial investment.	Deployed	An aggregate of approximately 4 million+ sq. ft. built-up area in India is cooled using radiant cooling, replacing approximately 18,000 TR of conventional air conditioning. Radiant cooling system has been installed at the Indian Institute of Tropical Meteorology.
9	Magnetic Refrigeration Systems	Based on the MagnetoCaloric Effect (heating or cooling of a magnetic material when the applied magnetic field changes). Temperature of MCM increases when they are exposed to a magnetic field and decreases when they are removed from it.	1.High COP. 2.Reduces energy consumption up to 40%. 3.Less noise and vibrations.	The materials level hysteresis irreversibility limits the potential COP significantly in the low temperature lift range.	Research & Development	Small scale demonstration projects in the UK, none in India so far.
10	a) Liquid Air Cooling b) Liquid air Power and cooling	Liquid air based cold chains recover stranded cold air from regasification. There are engines that use this liquid air/nitrogen to deliver zero emissions power and cooling.	1. This technology will reduce fuel costs in reefer transports. 2.Highly efficient with no emissions released.	Expensive setup cost	Research & Development	Indian industry has taken lead in harnessing waste cold with Petronet LNG helping develop an integrated cold storage facility at Dahej, Gujarat

Source: http://ozonecell.nic.in/wp-content/uploads/2019/03/INDIA-COOLING-ACTION-PLAN-e-circulation-version080319.pdf; SOLAR THERMAL COOLING TECHNOLOGIES - UNDP in India; https://www.sathguru.com/news/wp-content/uploads/2017/05/Cold-Chain-Report.pdf; http://164.100.94.214/sites/default/files/uploads/faq_Geothermal.pdf; https://renewablesnow.com/news/ongc-belgian-talboom-plan-pilot-geothermal-plant-in-indias-gujarat-report-297465/; https://www.energyforum.in/fileadmin/user_upload/india/media_elements/publications/10_Cooling_Demand_AEEE; https://www.oxy-com.com/advantages-evaporative-cooling; https://www.coolingindia.in/evaporative-cooling-technologies-for-buildings/; https://shaktifoundation.in/wp-content/uploads/2017/06/Mapping-Natural-Refrigerant-Technology-Uptake-in-India.pdf; https://eeslindia.org/wp-content/uploads/2021/03/Final-Report_National-District-Cooling-Potential-Study-for-India.pd; https://www.districtenergyinitiative.org/sites/default/files/District%20Energy%20and%20Trigeneration%20-%20Energy%20Efficient%20Solutions%20Workshop_0.pdf; https://www.climatecolab.org/contests/2018/commercial-and-industrial-energy-efficiency/c/proposal/1334503; https://fairconditioning.org/knowledge/sustainable-cooling-technologies/structure-cooling/#1525347588865-b4ac988a-dad6

Box 1: Global Cooling Prize & NIK technologies

The Global Cooling Prize was launched in November 2018 by Rocky Mountain Institute (RMI) and the Department of Science & Technology (DST), Government of India and Mission Innovation. The Prize was an open call to businesses from across the world to build a room air-conditioning unit with five times less climate impact and affordable such that it costs not more than two times the current bulk produced packaged AC units. There were additional requirements in terms of maximum power drawn, refrigerant used and water consumed.[3] Out of the eight finalists for this competition, four proposed novel NIK cooling technologies. Below are summaries of these technologies.

Barocal developed a non-vapour compression technology, called the barocaloric cooling, which makes use of solid organic "plastic crystal" materials to provide cooling. The application of pressure and resultant solid-to-solid phase changes in the crystals produces a cooling effect. These plastic crystals are easily available, low in cost and non-toxic.[4]

Kraton developed NexarCoolTM technology that integrates a membrane-based dehumidifier with a water based direct evaporative cooling system to achieve air conditioning without the use of any refrigerant.[5]

M2 Thermal Solutions developed a cooling solution that integrates evaporative cooling technology with a membrane system in a packaged design that is able to independently cool and dehumidify room air, with the potential to dramatically lower energy consumption relative to conventional ACs. The solution has the capability to bypass either of these processes and be used in ventilation mode depending on outdoor weather conditions. The vast majority of water supplied to the cooler is generated by the membrane, thereby decreasing its water footprint.[6]

Transaera Inc.'s cooling solution is designed to operate a high-efficiency room AC in parallel with a novel humidifier. By separating temperature and humidity control processes, this AC has the potential to reduce energy consumption by as much as 70 percent relative to standard air conditioners. The system further has the option for direct evaporative cooling as well as the option to connect to a photovoltaic panel and battery to reduce peak grid consumption.[7]

Current barriers for NIK

The status of NIK technology is comparable to natural refrigerant-based cooling in that while the technology exists they are not mainstream choices. Perceptions on current barriers to NIK technologies are summarised below:

- **Lack of awareness:** The absence of awareness among end-users as well as lack of knowledge on NIK technologies among architects/ engineers and builders was stated to be an significant barrier to the adoption of these technologies. Experts further speculated that in residential building projects, often, greater weightage was placed on aesthetic aspects rather than an emphasis on the principles of green building.
- **Lack of standards:** There are currently no standards for NIK technologies both to monitor the quality, for testing and safety aspects of the technology. There is further no energy efficiency rating, such as BEE's star rating and labelling that help benchmark the energy consumption of NIK technologies.
- **Skeletal manufacturing setup:** There are few/ no large manufacturers in NIK when compared with the conventional AC industry. Additionally, existing suppliers of NIK do not have the market presence of conventional room AC manufacturers. The manufacturing of radiant or structure cooling is currently largely in the EU and China. With the current lack of demand in India it is cheaper to import the components required. Serviceability of these technologies was listed as an issue as there isn't sufficient technical know-how on the user's/ operators' end.
- **Cost factor:** While cost of the technology was not a concern for industry respondents, policy experts speculated that the current high-cost acts as a barrier for the adoption of NIK technologies. The lack of scale of these technologies also means the supply chain for NIK technologies is sparse making them relatively more expensive than conventional cooling technologies. Further, some NIKs are better suited for cluster cooling, making them difficult to implement in existing buildings, thereby requiring high capital investment. However, the industry respondents remarked that setting up manufacturing for NIK technologies like radiant or structure cooling was not expensive and could be established easily once economies of scale exist.

Box 2 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.

Key interventions to mainstream NIK cooling

A core challenge for NIK adoption is the lack of awareness resulting in low demand. However, there are currently several pilot and demonstration projects across the country for various NIK technologies (as depicted in Table 1). Industry experts state that with increasing demand in these technologies, a manufacturing setup is inevitably going to come into existence which in turn can drive the costs down. In addition to increasing demand, there is a need to explore the need for standards to continually augment the quality of NIK technologies. To this end, it became quite apparent that while there is a need to develop a manufacturing ecosystem for NIK space cooling technologies, a lot of NIK based refrigeration technologies have an indigenous origin with existing manufacturing setups.

Economic incentives

- Incentives should be provided to:
  - » Consumers to encourage efficiency-based behaviours;
  - » Builders that adopt NIK in the form of tax reduction;
  - » Start-ups in this sector in the form of seed funds;
  - » Concerned stakeholders targeting R&D, testing facilities and to cover the capital cost of changing/ establishing manufacturing lines;
  - » DISCOMs to provide incentives in terms of discounted tariffs on buildings that have used NIK cooling technology.
- Higher depreciation rates on NIK technologies

Policy action

- Policy mandates to promote the use of NIK technology in a phase-wise manner.
- Policies to impose energy use limitations for buildings that push building owners to explore sustainable technologies for cooling and in turn create a market for these technologies.
- Impose a penalty on buildings that do not use energy efficient cooling technology - similar to BEE's PAT scheme for industries.

Technology support

- Technology support largely rests on monetary incentives to facilitate the transition, given the technology exists but requires R&D to be implemented in India.
- Need to establish testing facilities to ratify the performance of NIK technologies, develop standards and extend energy star rating to these systems.
- Demonstration of NIK technology and R&D for their use in the country.
- Focus should be on developing aesthetic NIK systems.
- Systematic mapping of existing NIK technologies and suitable climatic conditions for their use must be carried out.
- Some areas for further R&D are:

» IDEC-Hybrid air for industrial processes both low temperature and low humidity;

» Low energy cooling solutions like radiant cooling, structure cooling, geothermal cooling and waste heat recovery based cooling;

» Solar Thermal Vapour absorption technology based air-conditioners and refrigerators in domestic and commercial applications with: (A) Water as refrigerant, Lithium Bromide solution as absorbent; and (B) Ammonia as refrigerant, Water as Absorbent.

» Improve design of systems to make them fit-and-forget or easy to deploy at the very least.

Education, training and capacity building

- Technical training on NIK technologies for:
  - » Installers, plant operators and technicians;
  - » Manufacturers and service providers;
  - » Architects and building designers;
  - » HVAC consultants and contractors; and » Final year students of engineering.
- Knowledge about various options available and possibilities for techno-economically viable options should be disseminated.

ANNEXURE 1

List of experts consulted for the survey and interviews

Survey

Name	Affiliation
Ms. Shikha Bhasin	CEEW
Mr. S P Garnaik	EESL
Dr. M.P.Maiya	IIT-M
Ms. Ritika Jain	Shakti Sustainable Energy Foundation
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

ENDNOTES & REFERENCES

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3 https://globalcoolingprize.org/prize-details/criteria/

4 https://globalcoolingprize.org/barocal-ltd/

5 https://globalcoolingprize.org/kraton-iitbombay-porus-and-infosys/

6 https://globalcoolingprize.org/m2-thermal-solutions/

7 https://globalcoolingprize.org/transaera-inc/

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