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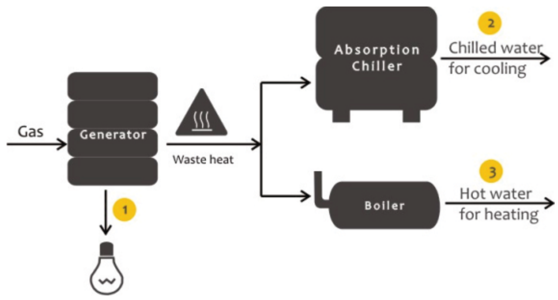
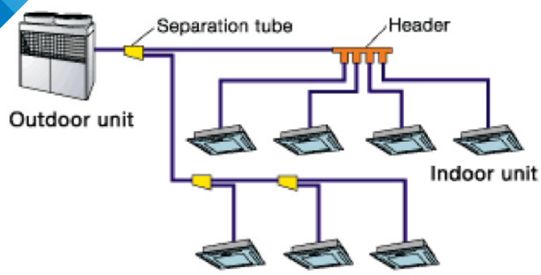
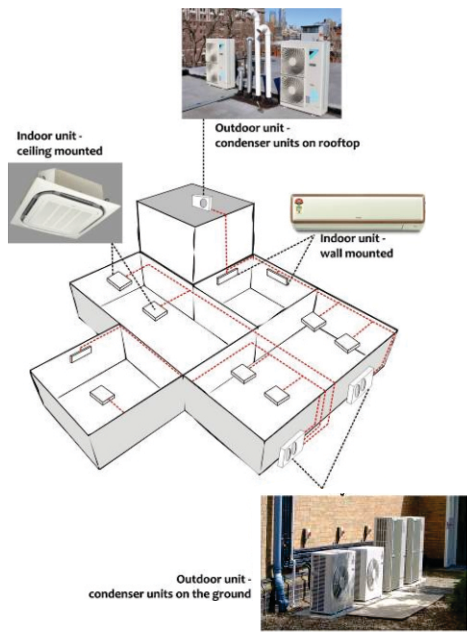
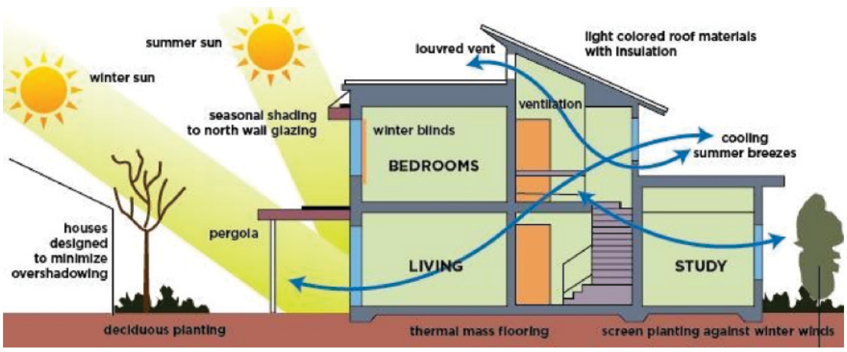
STUDY REPORT ON SENSITIZING BUILDING CONSTRUCTION COMMUNITY ON PASSIVE COOLING DESIGN, NON-ODS, LOW-GWP AND ENERGY EFFICIENT TECHNOLOGIES









Submitted to:

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

Submitted by:

CONSTRUCTION INDUSTRY DEVELOPMENT COUNCIL
801, Hemkunt Chambers, 89, Nehru Place, New Delhi-110 019
Fax: 011-26451604 Email: cidc@cidc.in, Website: www.cidc.in

STUDY REPORT ON SENSITIZING BUILDING CONSTRUCTION COMMUNITY ON PASSIVE COOLING DESIGN, NON-ODS, LOW-GWP AND ENERGY EFFICIENT TECHNOLOGIES

SEPTEMBER, 2022

सत्यमेव जयते
GOVERNMENT OF INDIA

OZONE CELL
MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE
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- Dr. P. R. Swarup, Director General
- Dr. Shuchita Kumar, Director (Projects)
- Dr. Niranjan Swarup
- Ms. P V Lakshmi

मंत्री
पर्यावरण, वन एवं जलवायु परिवर्तन
और
श्रम एवं रोज़गार
भारत सरकार

सत्यमेव जयते

MINISTER
ENVIRONMENT, FOREST AND CLIMATE CHANGE
AND
LABOUR AND EMPLOYMENT
GOVERNMENT OF INDIA

स्वच्छ भारत
एक कदम स्वच्छता की ओर

भूपेन्द्र यादव
BHUPENDER YADAV

आज़ादी का अमृत महोत्सव

MESSAGE

A significant amount of electricity is consumed to maintain comfort inside the residential and commercial buildings in countries with hot arid climate like India. To meet the cooling load, the energy requirement is growing year by year radically. During summer, the electricity demand is more to meet the cooling load for air conditioners, air coolers and fans. Adoption of passive designs during building construction not only reduces the energy use including the greenhouse gas emissions, but also improves the comfort and health of the occupants.

Performance of passive design systems depends mostly on natural and environmental elements like the sun, wind, earth, water and the relationship of these elements to the building site. Integration of passive cooling systems within the design process is important, as their performance requirements are affected by orientation, height, materials and characteristics of many architectural elements.

Well-designed envelopes maximise cooling movement of air and exclude the sun in the summer season. Passive design techniques being adopted globally and those minimise the need for mechanical cooling systems include proper window placement and daylight design, selection of suitable glazing for windows or skylights, proper sized shading of glass the use of light or reflective-coloured materials for the building envelope and roof. Each degree temperature drop inside the room with the assistance of passive cooling technique will considerably reduce the energy consumption by the cooling appliances.

The study report on "Sensitizing building construction community on passive cooling design, non-Ozone Depleting Substances, low Global Warming Potential and energy efficient technologies" aims to provide a guide for architects, building professionals and others associated with the construction industry to adopt passive design strategies for construction and to improve thermal comfort of the users.

I congratulate all team members involved in the preparation of this Report.

With best wishes.

Date: 10 .09.2022

(Bhupender Yadav)

पर्यावरण भवन, जोर बाग रोड़, नई दिल्ली–110003, फोनः 011–20819275, 20819225, फैक्सः 011–20819299
Paryavaran Bhawan, Jor Bagh Road, New Delhi-110003 Tel.: 011-20819275, 20819225, Fax: 011-20819299
ई–मेल/E-mail: mefcc@gov.in

अश्विनी कुमार चौबे
Ashwini Kumar Choubey

राज्य मंत्री
पर्यावरण, वन एवं जलवायु परिवर्तन
उपभोक्ता मामले, खाद्य और सार्वजनिक वितरण
भारत सरकार
MINISTER OF STATE
ENVIRONMENT, FOREST AND CLIMATE CHANGE
CONSUMER AFFAIRS, FOOD & PUBLIC DISTRIBUTION
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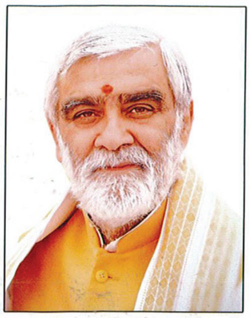

MESSAGE

Demand for cooling in the building sector has been rising steadily over the last decade due to a combination of factors such as rising population living largely in tropical climate, growing aspirational needs backed by sustained economic growth over the last two decades. India is witnessing significant growth in the construction sector. In view of the rapid increase in building stock and the associated demand for air-conditioned area, it becomes increasingly important to reinforce the need to build in strategies and interventions to reduce the heat load of buildings.

For sustainable cooling in buildings, a balanced approach of both passive cooling and active cooling strategies as well as optimization of cooling loads, encompassing natural and mechanical ventilation in building design, thermal comfort standards specifying pre-setting of temperatures for air-conditioning equipment, promoting use of energy efficient refrigerant based appliances etc. need to be adopted.

Good Management Practices in the building construction industry for adopting passive cooling techniques, cessation of Ozone Depleting Substances (ODS) and using low global warming potential (GWP) alternative technologies for air conditioning will significantly contribute towards providing thermal comfort and reduction of cooling demand. This would also significantly contribute to the goals of the India Cooling Action Plan relating to reduction of cooling demand.

The studies on sensitizing building construction community on passive cooling design, Non-ODS, low GWP and energy efficient technologies are timely and the findings of the same would help the construction industry for promoting awareness on passive cooling measures amongst the construction community. The study would also serve as an important resource material and should be disseminated widely amongst all concerned stakeholders.

(ASHWINI KUMAR CHOUBEY)

कार्यालय: 5वां तल, आकाश विंग, इंदिरा पर्यावरण भवन, जोर बाग रोड, नई दिल्ली-110003, दूरभाष: 011-20819418, 011-20819421, फैक्स: 011-20819207, ई-मेल : mos.akc@gov.in
Office : 5th Floor, Aakash Wing, Indira Paryavaran Bhawan, Jor Bagh Road, New Delhi-110003, Tel.: 011-20819418, 011-20819421, Fax : 011-20819207, E-mail : mos.akc@gov.in
कार्यालय: कमरा नं.173, कृषि भवन, नई दिल्ली-110001, दूरभाष: 011-23380630, फैक्स: 011-23380632
Office : Room No. 173, Krishi Bhawan, New Delhi-110001, Tel. : 011-23380630, Fax : 011-23380632
निवास: 30, डॉ. एपीजे अब्दुल कलाम रोड़, नई दिल्ली-110003, दूरभाष: 011-23794971, 23017049
Residence : 30, Dr. APJ Kalam Road, New Delhi-110003, Tel.: 011-23794971, 23017049

EXECUTIVE SUMMARY

Construction Industry Development Council (CIDC), through a Memorandum of Agreement (MoA) with the Ozone Cell, Ministry of Environment, Forest and Climate Change (MoEFCC), carried out a study to sensitize the building construction community on Passive Cooling, non-Ozone Depleting Substances (ODS), low Global warming Potential (GWP) and energy efficient technologies. The objective of the study is to assess the awareness of the different categories of personnel associated with the building construction industry including the top, medium and lower level management personnel on these concepts and the steps taken to promote awareness leading to adoption of these measures in the building construction industry, with the overall goal of reduction of cooling demand through adopting passive cooling design measures, reduced energy use and adoption of non-ODS and low GWP alternatives for cooling equipment in the building construction.

The approach and methodology followed for the study was review of secondary available literature, ground level assessment through a survey using a well structured questionnaire, analysis of the survey data and proposing recommendations. As part of the survey, four awareness workshops were also conducted for all categories of personnel associated with the building construction industry.

The key outcomes and recommendations emerged from this study are presented below:

a) There is a need for promoting wider penetration of climate responsive built spaces to bring indoor temperatures within acceptable thermal comfort band through passive cooling thus reducing refrigerant based cooling requirement.

b) There is a need to incorporate relevant provisions of energy efficient building design stated in Energy Conservation Building Codes (ECBC) to minimize active cooling needs by using passive design elements for all commercial (non-residential) buildings. Towards, this, the Bureau of Energy Efficiency (BEE) should take steps for nation-wide adoption and enforcement of ECBC for both commercial and residential sectors, including at the municipal and urban and local body level and through development of city level action plans.

c) There is a need for promoting awareness and understanding of passive cooling principles and devises including organizing specially structured training programmes to different categories of personnel associated with the building construction industry.

d) The study recommends promoting awareness on Energy Efficiency Building Code (ECBC), HVAC equipment and non- HCFC and low-GWP technologies. Some of the proposed measures include the following:

    a. Revision of curricula of architecture, engineering, diploma, ITIs, vocational institutions, etc. with the objective to provide knowledge of design of energy efficient building incorporating principles of passive cooling and environmental friendly building material to reduce active refrigerant-based cooling requirement, energy consumption and refrigerant demand;

    b. Training programmes to focus on deploying non-HCFC/low-GWP alternatives, reduction in cooling requirement of refrigerant based active cooling, energy use and refrigerant demand in upcoming building projects.

e) The study further recommends steps for Indoor air temperature controls and SOPs for Operation and maintenance of HVAC equipment.

Implementation of the recommendations through this study will greatly help in achieving the goals indicated in the India Cooling Action Plan (ICAP) as well as the recommendations for the thematic area on space cooling in buildings. The study also lays a direction for the different levels of personnel associated with the construction industry to adopt principles of passive cooling, non-ODS, low GWP and energy efficient technologies in building construction, which would in the long run, lead to thermal comfort of the users, besides protection of the environment and climate system.

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ABBREVIATIONS

BOCW Act	Building and Other Construction Workers' (Regulation of Employment and Conditions of Service) Act 1996
AICTE	All India Council for Technical Education
BEE	Bureau of Energy Efficiency
BIS	Bureau of Indian Standards
CCGR	CIDC Comprehensive Green Rating
CFCs	Chlorofluorocarbons
CIDC	Construction Industry Development Council
CIVTC	Construction Industry Vocational Training Council
CIPTC	Construction Industry Professional Training Council
COA	Council of Architecture
CP	Country Program
CPD	Continued Professional Development
CTC	Carbon Tetra Chloride
DGCIS	Directorate General of Commercial Intelligence and Statistics
DGET	Directorate General for Employment and Training
DGFT	Directorate General of Foreign Trade
ECI	Engineering Council of India
ECBC	Energy Conservation Building Code
ECO-NIWAS	Energy Conservation – New Indian Way for Affordable & Sustainable homes
EE	Embodied Energy
Ex-Com	Executive Committee of the Multilateral Fund
GRIHA	Green Rating for Integrated Habitat Assessment
GIZ Deutsche	Gesellschaftfur Internationale Zusammenarbeit, Proklima, Government of Germany
GHG	Green House Gas
GWP	Global Warming Potential
HVAC	Heating Ventilation and Air Conditioning
ICC	International Council of Consultants
ICAP	India Cooling Action Plan
IGBC	Indian Green Building Congress
HCFCs	Hydrochlorofluorocarbons
HFCs	Hydrofluorocarbons
HPMP	HCFC Phase-out Management Plan
IndSTT	Indian Society for Trenchless Technology
IS	Indian Standards
IPUA	Indian Polyurethane Association
ITIs	Industrial Training Institutes
MoA/MOA	Memorandum Of Agreement Between Ozone Cell and CIDC

MLF	Multilateral Fund for the Implementation of the Montreal Protocol
MoEF&CC	Ministry of Environment, Forest and Climate Change
MOP	Meeting of the Parties to the Montreal Protocol
MT	Metric tons
NBC	National Building Code of India
OEM	Original Equipment Manufacturer
ODP	Ozone Depleting Potential
ODS	Ozone Depleting Substances
PE	Professional Engineer
PMU	Project Management Unit
RAC	Refrigeration and Air-conditioning
RAMA	Refrigeration and Air-conditioning Manufacturers Association
MSMEs	Micro, Small and Medium Enterprises
TERI	The Energy and Resource Institute
TR	Tons of Refrigeration
ULB	Urban Local Body
UNDP	United Nations Development Program
UNEP	United Nations Environment Program

Chapter 1: Introduction

1.1 Background

India is one of the fastest growing economies in the world. While the economic growth indicates several employment and wealth creation opportunities for the country, there is a growing concern about the impact on environmental resources. It is important to meet this rising energy demand in the most sustainable manner with the least environmental impact.

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

Construction industry can play an important role in reducing energy consumption in both new buildings which are yet to be built or under construction buildings by way of efficient design of building envelops incorporating passive cooling concepts, use of environment friendly and local building materials with less embodied energy, avoiding unsound or poor construction processes, material wastage, avoiding active refrigerant based cooling or heating. Solutions to these issues are good practices that ensure efficient building designs, selection of materials with least possible embodied energy, adoption of proper design processes both structural as well as spatial, deployment of best construction practices with minimum energy and resources.

The need of the day, therefore, is to sensitize, educate, and train the building construction industry stakeholders, and assist in establishing systems and protocols that limit energy uses as low as reasonably possible and protect the global environment. In total there are two primary agents that need to be contained to achieve these objectives, move towards non-ODS, low GWP refrigeants and usage of passive cooling strategies.

To this end Ozone Cell, MoEF&CC, jointly with CIDC have taken up an initiative for sensitizing building construction community on passive cooling design, non-ODS, low-GWP and energy efficient technologies.

Primary objective of this study is aimed at sensitizing, educating, and training the building construction industry stakeholders at all levels about design, usage/application of materials, processes, and systems in building works in order to optimize the uses of energy, both during construction as well as operation phase of building.

1.2 Montreal Protocol

In March, 1991, India acceded to the Vienna Convention for the Protection of the Ozone Layer and ratified the Montreal Protocol on Substances that Deplete the Ozone Layer in June 1992. India has also ratified all the amendments to the Montreal Protocol including the London amendment in 1992, Copenhagen, Montreal, Beijing amendments in 2003 and Kigali Amendment for phase-down of hydrofluorocarbons (HFCs) in 2021.

India is a Party to the Montreal Protocol operating under Paragraph 1, Article-5 of the Montreal Protocol and is thus qualified for technical and financial assistance from the Multilateral Fund (MLF), established as the financial mechanism of the Montreal Protocol.

As a party operating under Article-5 of the Montreal Protocol, India is committed to phase-out Ozone Depleting Substances (ODSs) including Hydrochlorofluorocarbons (HCFCs) by 2030 in accordance with the accelerated phase out schedule of the Montreal Protocol.

1.2.1 Implementation of the Montreal Protocol

India has taken progressive measures to phase out designated controlled substances and is following the Montreal Protocol control phase-out schedule. This has been successfully accomplished through assistance from the MLF for implementation of the Montreal Protocol by undertaking technology conversions, technical assistance, training and capacity building, information dissemination and awareness-raising, management, and coordination.

India has also established an effective policy and regulatory framework for phase out production and consumption of ODSs. The regulatory framework for ODSs is set forth in the Ozone Depleting Substances (Regulation and Control) Rules, 2000 that are amended from time to time to align with the Amendments to the Montreal Protocol and National Policies & Regulations. The final version of the rules has been amended for aligning with the accelerated phase-out of HCFCs and complete phase-out of HCFC-141b in polyurethane foam manufacturing sector.

India had taken proactive steps for implementation of the accelerated phase-out schedule of HCFCs, in line with the decision XIX/6 of the 19th Meeting of Parties of the Montreal Protocol.

India had prepared a roadmap as early as 2009, describing the long-term vision and action plan, including the policy instruments, for phase-out of production and consumption of HCFCs in the country. It took into account expected availability of technologies that are sustainable and have minimum cost impact on industry and consumers. The current initiative focused on building construction industry is the next step in this direction.

India has been implementing in close cooperation with industry stakeholders the HPMPs and successfully meeting the phase out targets of production and consumption by converting the manufacturing of RAC equipment based on HCFCs to non-ODS and low-GWP technologies.

1.3 Approach and Methodology adopted for the Study

Primary objective of the study is to sensitize building construction community on passive cooling design, non-ODS, low-GWP and energy efficient technologies.

The study has been performed by involving collection, collation and analysis of information through desk study as well as field visits, covering the following:

- Survey of existing practices involved in building design;
- Scope for passive cooling designs in upcoming building construction;
- Consultation with members of the construction community, building designers, architects, urban policy makers, building developers, building development associations, etc.;
- Information on the use of efficient refrigeration and air-conditioning (RAC) equipment based on non-HCFC and low-GWP refrigerants for active cooling systems;
- Status of skill of the existing manpower engaged in building construction activity in respect of passive cooling concept;
- Identify the skill gaps and suggestions for incorporating passive cooling designs to achieve the objective of reducing the cooling demand; and

Collate and analyze the information collected and make recommendations for different personnel associated with construction industry.

It is becoming increasingly important to promote the application of Passive Design in Construction Processes by use of non-HCFC/low-GWP applications in upcoming building through undertaking the following:

- Application details of Passive Cooling Designs,
- Application details of Active Cooling Designs,
- Inputs on the following:
    - Significant Design Construction Process Implementing Stakeholders.
    - Availability of Applicable Standards and Specifications.
    - Passive Cooling Adoption requirements.
- Current industry trends through a multi-layered sampling mechanism to identify

  - o Initial inputs on the impediments in adoption.
  - o Main issues and their possible solutions/alternatives.
- Development of Survey Questionnaire for validating the initial postulates.
- Survey of the industry stakeholders based on the survey mechanism devised for
  - o Validation of initial postulates.
  - o Identification of impediments in adoption.
  - o Selecting impediment removal mechanisms.
  - o Establishing basic process for impediment removal.
- Identification of Stakeholders Essential for Impediment Removal
- Recommendations for fulfilling the gaps emerge in this study report for implementation of the study findings.

To sensitize the contruction community on the process adopted covered in the steps above in a sequential manner. Actions were initiated by identification of the scope and applicability of passive cooling processes. As the passive cooling processes would meet the entire cooling energy demands, the modes, and their scope for meeting the balance energy demands through active cooling process was identified. Current industry trends were identified through a set of multi-layered interactions that also enabled proper sampling to present the closest picture of the industry.

Steps undertaken for this initiative also included conducting a secondary research to identify various aspects essential for sensitizing, both the construction community, as well as users, to the benefits of energy efficient buildings by introducing Passive Cooling designs, to reduce operational costs, improve health and comfort and promote use of non-HCFC and low-GWP alternatives.

This research, inter-alia included review of related literature, landscaping of the existing policy, and actual trends in the building construction industry. Having identified the requisite factors, the subsequent action was to define survey methodology. Finally, the entire planned process was implemented. Salient features of the approach and methodology adopted are discussed hereafter.

- Organization of consultation and awareness workshops.

To achieve the above objectives a series of four regional awareness workshops have been conducted.

- Secondary Research

The secondary research activities comprised the inputs provided by the Ozone Cell on the HPMP Stage II document[1]and India Cooling Action Plan (ICAP) [2] that provided the background information for identifying the primary factors essential for the study activities. Based on the information gathered relevant inputs from the building construction community were identified.

[1]http://ozonecell.nic.in/wp-content/themes/twentyseventeen-child/Documentation/assets/pdf/1492069863014-HPMP-STAGE-II-LAUNCH-2017-BOOK.pdf
[2]http://ozonecell.nic.in/wp-content/uploads/2019/03/INDIA-COOLING-ACTION-PLAN-e-circulation-version080319.pdf

- Literature Review

Through the secondary research, primary literature providing relevant information were identified. These were from the publications of IS Codes and National Building Code (NBC) from BIS, Energy Conservation Building Code (ECBC) from the Bureau of Energy Efficiency (BEE), CIDC Comprehensive Green Rating Frameworks & Rules from CIDC, Green building rating framework from TERI, GRIHA, and other similar green building rating framework and rules from IGBC. These publications provided primary inputs essential for sensitizing building construction community to wards energy efficient building construction and maintenance. In addition to these, inputs from Ozone Cell on the outcomes of the earlier stages of HPMP were also evaluated and the stipulations relevant to building construction industry were identified.

- Landscaping of the Existing Policy

All identified sources of literature defined the energy efficient technologies building construction industry. Some aimed directly and others indirectly, at energy conservation. From the literature review specifications, rules, processes, methodologies, or systems were identified with respect to both types.

Such results were combined to compile a comprehensive framework to evaluate the prevalent trends of the building construction industry.

- Trends

Trends of the building construction industry were identified through a series of consultations with stakeholders that included construction professionals, consultants, representatives of construction companies, academicians, learners, vocational workers, works supervisors etc. Primarily these consultations were executed through telephonic and physical discussions conducted while sensitizing them about the joint initiative of Ozone Cell with CIDC. These consultations were of two parts, in the first part respondents were informed about various requirements associated with passive cooling and non-ODS, low-GWP alternatives. In the second part their preferenceswere chosen in adopting such practices in their activities if not being applied currently. These responses provided the basis for establishing the research methodology and the implementation strategy.

1.4 Survey and Questionnaires

Prime objective of this initiative was to sensitize building construction community on passive cooling design, non-ODS, low-GWP and energy efficient technologies.

To meet these objectives, the primary requirement was to conduct a survey about these issues from the industry stakeholders. This was done in a multiple stage interaction set with the initial desk study, followed by primary interactions with stakeholders, followed by the literature review. With such literature review salient features of the desired energy efficient technologies were identified.

These guidelines in turn assisted in establishing the survey questionnaire for circulation to the larger respondent base amongst the target audience groups. This survey was assisted through the consultative and awareness workshops as the underlying issues and points were explained to the audience prior to receiving their inputs.

1.5 Building Codes

Codes and specifications are the starting points or the building blocks for any building construction or maintenance activity. Objective here was to identify the sound engineering practices currently in use on the one hand, and evaluating their sufficiency to deliver the desired outcomes. In addition to the engineering specifications, there was need to check the usage of green construction processes. A combination of these two was the basic input for sensitizing building construction community on passive cooling design, non ODS, low GWP and energy efficient technologies.

Based on this premise the literature review was conducted for the codes of practice stipulated by the BIS.

Literature review was also conducted on the green rating processes currently in vogue across the nation. With these processes builders aim to achieve rating certification for demonstrating the greenness of their structures. This process is conducted by CIDC, TERI, and IGBC in India. Process followed by CIDC provides a major advantage over other systems by way of considering the Embodied Energy (EE) accounting in the greenness evaluation process. The system followed by CIDC is termed as CIDC Comprehensive Green Rating (CCGR) and includes an embodied energy calculator that defines the extent of embodied energy invested in each item of construction. In this rating one can calculate the extent of energy invested by evaluating the detailed itemized bill of quantity of the works. Underlying concept here is that higher the EE, less green would be the structure. This rating system also provides opportunities of altering the quantities on a real-time basis to enhance greenness of the building under evaluation.

1.6 Conclusion

This chapter is an overview of the objective, approach & methodology and the secondary literature resources for the study.

Chapter 2: Scope for passive cooling designs in upcoming building construction

2.1 Introduction

Passive cooling, as the name implies, aims at reducing the demands of active cooling energy by appropriality designing the building envelope. For developing the application protocols for passive cooling designs we need to identify the applicable design approaches or processes. This chapter presents a brief on such approaches to assist the reader in defining the scope for passive cooling of building envelopes. This is done by analyzing the climate, sun, wind, rain, geology and surrounding context and designing the building in response to these parameters.

Further, to qualify for low energy consuming system compliances, the building envelope needs to adhere to the ECBC norms. These norms define the total energy demand of the building envelope and assists in optimizing the energy usage over the lifecycle of the building. Having established the scope of energy demand, the next step is to ensure that the building envelope meets the threshold conditions of green building. Compliance of such conditions are verified through the Green Rating systems. In India, primarily three Green Rating Systems are in vogue currently. These are GRIHA, IGBC, and CCGR. In this chapter, subsequent to passive cooling, we shall be discussing the salient features of ECBC, GRIHA, & IGBC, and CCGR to identify the scope of passive cooling designs in upcoming building construction activities for both new constructions as well as rehabilitation works.

The Ministry of Environment, Forest and Climate Change, Government of India published the India Cooling Action Plan (ICAP) in March, 2019. This chapter provides the salient features of ICAP at the end. A combination of these inputs with other specifications and codes, and the active cooling processes, have been used to prepare the final implementation plan.

2.2 Passive Cooling

To identify the scope of actions and creation of the final survey questionnaire, passive cooling design aspects are presented hereafter.

A "passive cooling" design involves the use of fenestrations, shading devices, cool roofs and materials that ensure the building is designed to be climate responsive, minimizing heat gains and reducing cooling requirements. The heat gain in the building occurs through the building envelope by radiation, conduction, or convection without using any electrical device. Maintaining a comfortable environment within a building in a hot climate relies on reducing the rate of heat gains into the building and encouraging the removal of excess heat from the building. To prevent heat from entering the building, or to remove heat once it has entered, is the underlying principle for accomplishing cooling in passive cooling concepts.

To attain maximum benefits from passive cooling design concepts, specific spatial arrangements of the building components and use of materials that were produced with least embodied energy could maximize the living comforts and indoor environment quality while consuming least energy for cooling through proper placements.

- Passive cooling systems are the least expensive means of cooling a building by maximizing the efficiency of the building envelope without any use of mechanical devices.
- It relies on natural heat sinks to remove heat from the building. They derive cooling directly from evaporation, convection, and radiation without using any intermediate electrical devices.
- All passive cooling strategies rely on daily changes in temperature and relative humidity.
- The applicability of each of the passive cooling system option depends on the climatic conditions.
- These design strategies reduce heat gains to internal spaces.
- Passive cooling techniques use ambient cooling sinks like building material, air, water, night sky, and several others aspects to mitigate the temperature rise of the building due to heat sources such as ambient air, direct solar heat gain, building and internal heat gain.
- Passive techniques monitor the system parameters and compare them to pre-set threshold values to detect islanding. Active techniques interact with the power systems by introducing minor disturbances and monitoring their impact on the system.
- Passive design is a system or structure that directly uses natural energy such as sunlight, wind, temperature differences or gravity to achieve a result without electricity or fuel. Active design is a system or structure that uses or produces electricity.
- Passive ventilation uses doors, windows, opening skylights and clerestory windows, vents, louvers, and other openings to let fresh air into and through your home. This helps to provide cooling, as well as removing moisture and airborne pollutants.

2.2.1 Passive Cooling Strategies

2.2.1.1. Natural Ventilation
2.2.1.2. Shading
2.2.1.3. Induced ventilation techniques
2.2.1.4. Courtyard Effect
2.2.1.5. Earth Air Tunnels

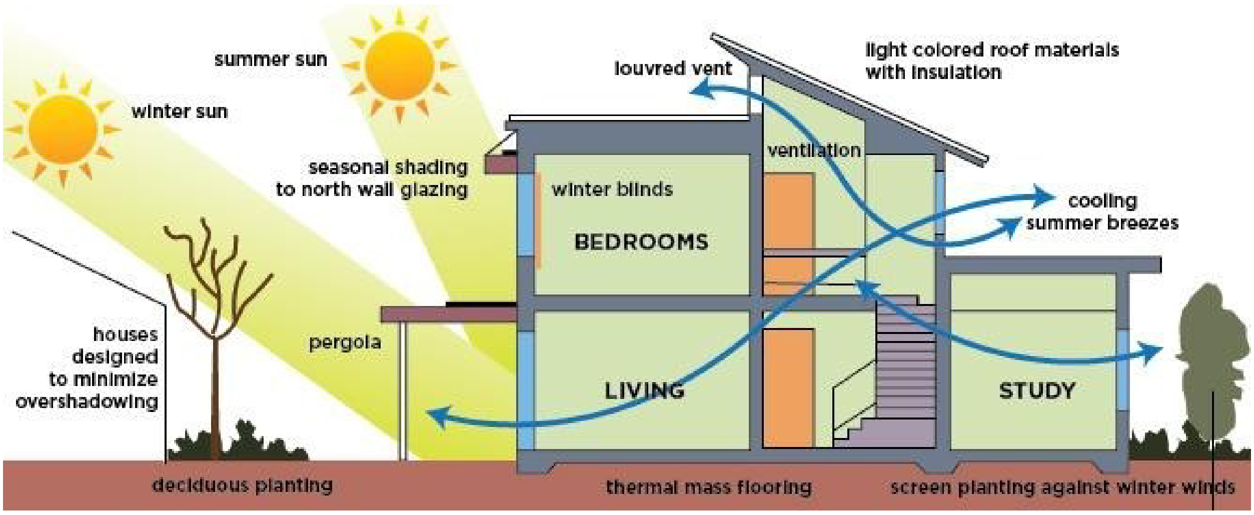
2.2.1.6. Evaporative Cooling
2.2.1.7. Desiccant cooling

2.2.1.1 NATURAL VENTILATION

- Outdoor breezes create air movement through the house interior by the 'push-pull' effect of positive air pressure on the windward side and negative pressure (suction) on the leeward side. In order to have a good natural ventilation, openings must be placed at opposite pressure zones. Also, designers often choose to enhance natural ventilation using tall spaces called stacks in buildings. With openings near the top of stacks, warm air can escape whereas cooler air enters the building from openings near the ground. Windows, play a dominant role in inducing indoor ventilation due to wind forces.
- In most homes, exhausting the warm air quickly can be a problem. With the design of high ceilings throughout the breeze zone combined with clerestory windows at the 142 ceiling height on three walls, the rising hot air is allowed to escape which in turn does two things.
    i) Firstly the rising air creates a low pressure zone on the cool mass floor, pulling air along the floor from other areas of the house as well as any open doors.
    ii) Secondly the rising and escaping air creates an interior low pressure that should pull in large volumes or exterior air from the patio doors.

Depending on the primary wind direction and which doors are opened relative to time of day and shade, we can create a breeze of cooler incoming air.

Fig. 2.1 Natural Ventilation

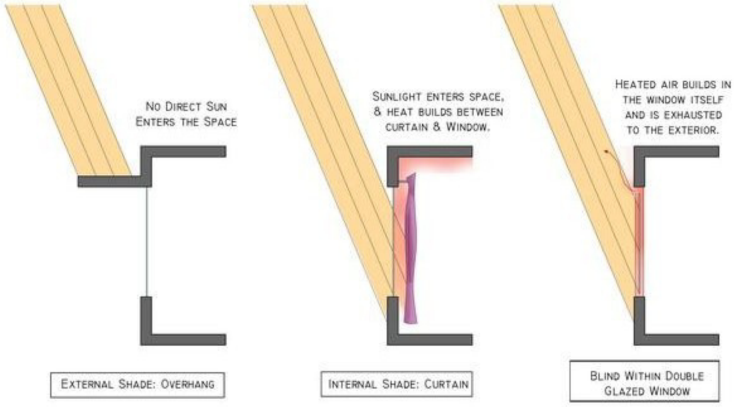


2.2.1.2 SHADING

- The most effective method of reducing direct solar radiations in the built space is to shade windows, minimize walls and roof of building from exposure to direct solar radiation.
- Heavily insulated walls and roofs need less shading.
- Can use overhangs on outside facade of the building.
- Solar control is a critical requirement for both cooling-load dominated and passively solar-heated buildings. Each project should be evaluated depending on its relative cooling needs.

- Extend the overhang beyond the sides of the window to prevent solar gain from the side.
- Use slatted or louvered shades to allow more daylight to enter, while shading windows from direct sunlight.
- Reduce solar heat gain by recessing windows into the wall.

Fig. 2.2 Shading Effect



Various shading techniques include the following:-

- Solar shading
- Shading by overhangs, louvers and awnings etc.
- Shading of roofs
- Shading by textured surfaces
- Shading by trees and vegetation

2.2.1.3 INDUCED VENTILATION TECHNIQUES

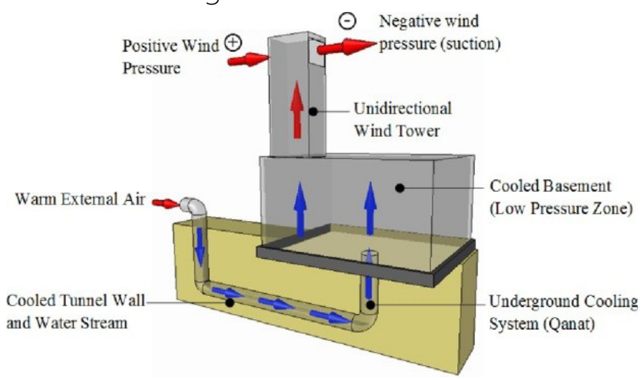
The various induced ventilation techniques include:

- Wind tower
- Solar chimney
- Air vents

WIND TOWER

- In a wind tower, the hot air enters the tower through the openings in the tower, gets cooled, and thus becomes heavier and sinks down.
- The inlet and outlet of rooms induce cool air movement.
- In the presence of wind, air is cooled more effectively and flows faster down the tower and into the living area.
- After a whole day of air exchanges, the tower becomes warm in the evenings.
- During the night, cooler ambient air comes in contact with the bottom of the tower through the rooms.
- The tower walls absorb heat during daytime and release it at night, warming the cool night air in the tower.
- Warm air moves up, creating an upward draft, and draws cool night air through the doors and windows into the building.
- The system works effectively in hot and dry climates where fluctuations are high.
- A wind tower works well for individual units not for multistoried apartments.
- In dense urban areas, the wind tower must be long enough to be able to perform efficiently.

Fig. 2.3 Wind Tower



2.2.1.4 COURTYARD EFFECT

- Due to incident solar radiation in a courtyard, the air gets warmer and rises.
- If this heat exchange reduces roof surface temperature to wet bulb temperature of air, condensation of atmospheric moisture occurs on the roof and the gain due to condensation limits further cooling.

Fig. 2.4 Court Yard Effect

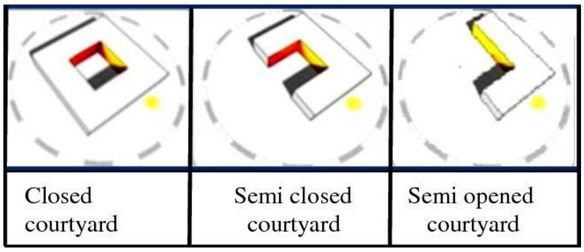
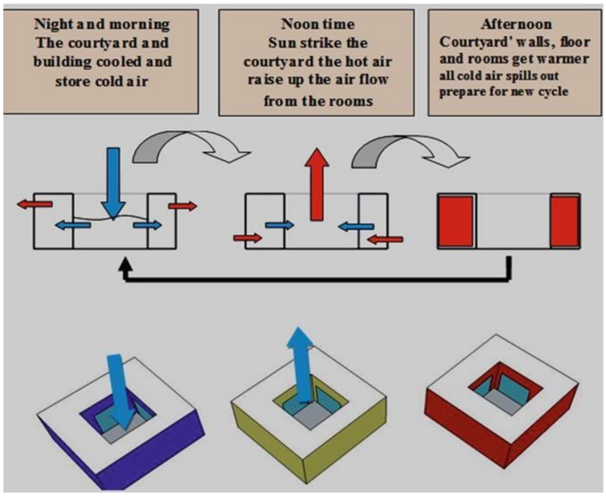


Fig. 2.5 Court Yard Effect during day



2.2.1.5 EARTH AIR TUNNEL

- Daily and annual temperature fluctuations decrease with the increase in depth below the ground surface.
- At a depth of about 4 m below ground, the temperature inside the earth remains nearly constant round the year and is nearly equal to the annual average temperature of the place.
- A tunnel in the form of a pipe or otherwise embedded at a depth of about 4 m below the ground will acquire the same temperature as the surrounding earth at its surface. Therefore, the ambient air ventilated through this tunnel will get cooled in summer and warmed in winter and this air can be used for cooling in summer and heating in winter.

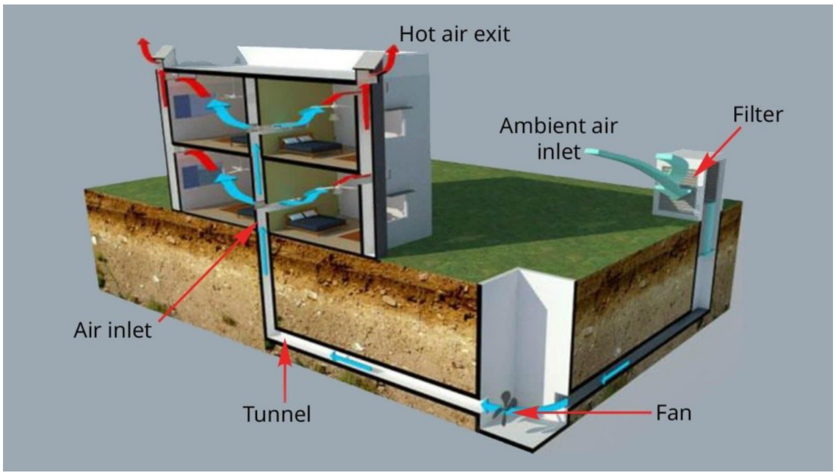
2.2.1.6 EVAPORATIVE COOLING

Evaporative cooling is a passive cooling technique in which the outdoor air is cooled by evaporating water before it is introduced in the building. Its physical principle lies in using the heat of air to evaporate water, thus cooling the air, which in turn cools the living space in the building. However passive evaporative cooling can also be indirect.

The roof can be cooled with a pond, wetted pads or spray, and the ceiling transformed into a cooling element that cools the space below by convection and radiation without raising the indoor humidity.

- Passive downdraft evaporative cooling (PDEC)
- Roof surface evaporative cooling (RSEC)

Fig. 2.6 Earth air tunnel effect



2.2.1.7 DESICCANT COOLING

Desiccant cooling is effective in warm and humid climates. Natural cooling of human body through sweating does not occur in highly humid conditions. Therefore, a person's tolerance to high temperature is reduced and it becomes desirable to decrease the humidity level. In the desiccant cooling method, desiccant salts or mechanical dehumidifiers are used to reduce humidity in the atmosphere. Materials having high affinity for water are used for dehumidification. They can be solid like silica gel, alumina gel and activated alumina, or liquids like triethylene glycol. Air from the outside enters the unit containing desiccants and is dried adiabatically before entering the living space. The desiccants are regenerated by solar energy. Sometimes, desiccant cooling is employed in conjunction with evaporative cooling, which adjusts the temperature of air to the required comfort level.

2.3 ECBC Norms

Detailed briefly hereafter are the published ECBC norms though the BEE website[3]. These are being included to present the scope of the Code. For detailed working the cited code must be referred.

The Energy Conservation Building Code (ECBC) was developed by the Govt. of India for new commercial buildings on 27th May 2007. BEE introduced the ECBC 2017 that would aspire to strengthen the ECBC, 2007. The purpose of Energy Conservation Building Code (ECBC) is to provide minimum requirements for energy-efficient design and construction of buildings and their systems. The building sector represents about 33% of electricity consumption in India, with commercial sector and residential sector accounting for 8% and 25% respectively. Estimates based on computer simulation models indicate that ECBC-compliant buildings can use 40-60% less energy than conventional buildings. It is estimated

[3] https://beeindia.gov.in/sites/default/files/BEE_ECBC%202017.pdf

that the nationwide mandatory enforcement of the ECBC will yield annual savings of approximately 1.7 billion kWh. The ECBC is expected to overcome market barriers, which otherwise result in under-investment in building energy efficiency. The ECBC was developed as a first step towards promoting energy efficiency in the building sector. The ECBC is the result of extensive work by the Bureau of Energy Efficiency (BEE) and its Committee of Experts.

Salient features of ECBC are as follows:

- Building envelope, including thermal performance requirements for walls, roofs, and windows;
- Lighting system, including day lighting, lamps and luminaries' performance requirements;
- HVAC system, including energy performance of air distribution systems;
- Electrical system; and
- Water heating and pumping systems, including requirements for solar hot-water systems.

2.3.1 ECBC Norms for Residential Buildings

The code for residential buildings[4] sets minimum performance standards for building envelope to limit heat gains (for cooling dominated climates) and limit heat loss (for heating dominated climates) through it. The code gives the following provisions to this effect:

- Building Envelope (except roof)
- Maximum value of residential envelope transmittance value (RETV) for building envelope (except roof) applicable for four climate zones, namely, Composite Climate, Hot-Dry Climate, Warm-Humid Climate, and Temperate Climate.
- Maximum value of thermal transmittance of building envelope (except roof) for Cold Climate zone (Uenvelope, cold).
- Roof: Maximum value of thermal transmittance of roof (Uroof) for all climate zones.

2.3.1.1 The code sets minimum building envelope performance standard for adequate natural ventilation potential by specifying minimum openable window-to-floor area ratio (WFRop).

2.3.1.2 The code sets minimum building envelope performance standard for adequate daylight potential by specifying minimum visible light transmittance (VLT) for the non-opaque building envelope components.

2.3.1.3 The code applies to (a) 'Residential buildings' built on a plot area e"500 m^2 and (b) Residential part of 'Mixed land-use building projects', built on a plot area of e"500 m^2

[4]https://www.beeindia.gov.in/sites/default/files/ECBC_BOOK_Web.pdf

'Residential building' includes any building in which sleeping accommodation is provided for normal residential purposes with or without cooking or dining or both facilities. This definition includes:

- One or two family private dwellings: These shall include any private dwelling, which is occupied by members of one or two families and has a total sleeping accommodation for not more than 20 persons.
- Apartment houses: These shall include any building or structure in which living quarters are provided for three or more families, living independently of each other and with independent cooking facilities. This also includes 'Group Housing'.

The following are excluded from the definition of 'residential building' for the purpose of this code.

- Lodging and rooming houses: These shall include any building or group of buildings under the same management in which separate sleeping accommodation on transient or permanent basis, with or without dining facilities but without cooking facilities for individuals, is provided. This includes inns, clubs, motels, and guest houses.
- Dormitories: These shall include any building in which group sleeping accommodation is provided, with or without dining facilities for persons who are not members of the same family, in one room or a series of closely associated rooms under joint occupancy and single management. For example, school and college dormitories, students, and other hostels and military barracks.
- Hotels: These shall include any building or group of buildings under single management, in which sleeping accommodation is provided, with or without dining facilities.

2.3.2 ECBC Norms for Commercial Buildings

The Code is applicable to buildings or building complexes that have a connected load of 100 kW or greater or a contract demand of 120 kVA or greater and are intended to be used for commercial purposes.

Buildings intended for private residential purposes only are not covered by the Code.

2.3.2.1 Energy Efficiency Performance Levels

The code prescribes the following three levels of energy efficiency:

(a) Energy Conservation Building Code Compliant Building (ECBC Building)
ECBC Buildings shall demonstrate compliance by adopting the mandatory and prescriptive requirements listed under ECBC Compliant Building requirements in §4 to §7 (ECBC 2017), or by following the provisions of the Whole Building Performance (WBP) Method in §9.

(b) Energy Conservation Building Code Plus Building (ECBC+ Building)
ECBC+ Buildings shall demonstrate compliance by adopting the mandatory and prescriptive requirements listed under ECBC+ Compliant Building requirements in

§4 to §7(ECBC 2017), or by following the provisions of the Whole Building Performance (WBP) Method in §9.

(c) Super Energy Conservation Building Code Building (Super ECBC Building)
Super ECBC Buildings shall demonstrate compliance by adopting the mandatory and prescriptive requirements listed under Super ECBC Compliant Building requirements in §4 to §7(ECBC 2017), or by following the provisions of the Whole Building Performance (WBP) Method in §9 (ECBC 2017).

2.3.2.2 Building Systems

The provisions of this code apply to:
(a) Building envelope,
(b) Mechanical systems and equipment, including heating, ventilating, and air conditioning, service hot water heating,
(c) Interior and exterior lighting, and
(d) Electrical power and motors, and renewable energy systems.

The provisions of this code do not apply to plug loads, and equipment and parts of buildings that use energy for manufacturing processes, unless otherwise specified in the Code.

2.3.3 Reference Document

The National Building Code of India 2016 (NBC) is the reference standard for lighting levels, heating, ventilating, and air conditioning (HVAC), thermal comfort conditions, natural ventilation, and any other building materials and system design criteria addressed in this Code.

Standards and labelling (S&L) Program of BEE will be applicable for minimum equipment efficiency standards, wherever specified. In case the schedule of S&L is revised for any equipment, the design approval year of building will be considered as base year for ECBC compliance.

2.3.4 Building Classification

Any one or more building or part of a building with commercial use is classified as per the functional requirements of its design, construction, and use. The key classification is as below:
(a) Hospitality: Any building in which sleeping accommodation is provided for commercial purposes, except any building classified under Health Care. Buildings and structures under Hospitality shall include the following:

i. No-star Hotels – like Lodging-houses, dormitories, no-star hotels/motels
ii. Resort
iii. Star Hotel

(b) Health Care: Any building or part thereof, which is used for purposes such as medical or other treatment or care of persons suffering from physical or mental illness, disease, or infirmity; care of infants, convalescents, or aged persons, and for penal or correctional detention in which the liberty of the inmates is restricted. Health Care buildings ordinarily provide sleeping accommodation for the occupants. Buildings and structures like hospitals, sanatoria, out-patient healthcare, laboratories, research establishments, and test houses are included under this type.

(c) Assembly: Any building or part of a building, where number of persons congregate or gather for amusement, recreation, social, religious, patriotic, civil, travel and similar purposes. Buildings like theatres or motion picture halls, gathering halls, and transport buildings like airports, railway stations, bus stations, and underground and elevated mass rapid transit system are included in this group.

(d) Business: Any building or part thereof which is used for transaction of business, for keeping of accounts and records and similar purposes, professional establishments, and service facilities. There are two subcategories under Business – Daytime Business and 24-hour Business. Unless otherwise mentioned, Business buildings shall include both Daytime and 24-hour subcategories.

(e) Educational: Any building used for schools, colleges, universities, and other training institutions for day-care purposes involving assembly for instruction, education, or recreation for students. If residential accommodation is provided in the schools, colleges, or universities or coaching/ training institution, that portion of occupancy shall be classified as a No-star Hotel. Buildings and structures under Educational shall include following types

   i. Schools
   ii. All other types of institutes, e.g. college, university, training institutes etc.

(f) Shopping Complex: Any building or part thereof, which is used as shops, stores, market, for display and sale of merchandise, either wholesale or retail. Buildings like shopping malls, stand-alone retails, open gallery malls, super markets, or hyper markets are included in this type.

(g) Mixed-use Building: In a mixed-use building, each commercial part of a building must be classified separately, and –

   i. If a part of the mixed-use building has different classification and is less than 10% of the total above grade floor area, the mixed-use building shall show compliance based on the building sub-classification having higher percentage of above grade floor area.
   ii. If a part of the mixed-use building has different classification and one or more sub-classification is more than 10% of the total above grade floor area, the compliance requirements for each sub-classification, having area more than 10% of above grade floor area of a mixed-use building shall be determined by the requirements for the respective building classification in §4 to §7.

Any building which does not fall under any of the categories defined above shall be classified in a category mentioned above that best describes the function of the building.

2.4 Green Rating Processes

In this section we present three main green rating processes used in India. These are GRIHA, IGBC & CCGR. All the three help in evaluating the greenness parameters of buildings and through these one can evaluate the possibilities of attaining passive cooling through various actions, inclusions/omissions, and construction process controls to achieve the least energy expenditure during the entire life cycle of the building. Energy consumption continues all through the lifecycle of the building, which starts at the stage of the conceptualization and ends at the demolition stage (cradle to grave). These rating systems check and evaluate the extents of energy investment/consumption for the defined parameters and grade the greenness of the building.

2.4.1 Green Rating for Integrated Habitat Assessment (GRIHA)

Detailed hereafter are descriptions of GRIHA rating process as presented briefly on the website of GRIHA. It is being reproduced here for reference purpose. For detailed deliberations readers can communicate with TERI.

2.4.1.1 Introduction to GRIHA

GRIHA is an acronym for Green Rating for Integrated Habitat Assessment. GRIHA is a Sanskrit word meaning – 'Abode'. Human Habitats (buildings) interact with the environment in various ways. Throughout their life cycles, from construction to operation and then demolition, they consume resources in the form of energy, water, materials, etc. and emit wastes either directly or in the form of municipal wastes or indirectly as emissions from electricity generation. GRIHA attempts to minimize a building's resource consumption, waste generation, and overall ecological impact within certain nationally acceptable limits / benchmarks.

Going by the old adage 'what gets measured, gets managed', GRIHA attempts to quantify aspects such as energy consumption, waste generation, renewable energy adoption, etc. so as to manage, control and reduce the same to the best possible extent.

GRIHA is a rating tool that helps people assesses the performance of their building against certain nationally acceptable benchmarks. It evaluates the environmental performance of a building holistically over its entire life cycle, thereby providing a definitive standard for what constitutes a 'green building'. The rating system, based on accepted energy and environmental principles, will seek to strike a balance between the established practices and emerging concepts, both national and international.

2.4.1.2 Evolution of GRIHA

The rapid increase in Indian population and growth of Gross Domestic Product (GDP) has given rise to an enormous demand for buildings, putting pressure on availability of resources. Another key challenge for the built-environment of Indian cities is the diminishing availability of water for urban areas.

In order to be sustainable, the environmental pressures of increased demand for resources coupled with a rapidly changing climate are being addressed by policy makers at various levels. Several policy and regulatory mechanisms to address the urban challenges, implemented through national plans and programmes have been devised. The Ministries and agencies at the Centre have designed frameworks such as Environmental Clearance to ensure efficiency in resource use for large projects (i.e. more than 20,000 sq m built up area), the Energy Conservation Building Code (ECBC) is applicable to air conditioned commercial buildings with a connected load more than 100 kW and the Solar Buildings Programme for Energy Efficient Buildings, for implementation by designated State agencies and municipal bodies.

However as in most countries, there is a huge scope to optimize the effectiveness of policy by encouraging a more holistic life cycle approach to buildings. Lack of disincentives for non-compliance, agencies and systems working in factions (i.e. various departments at Centre and States looking at issues related to energy efficiency, renewable energy, water resources, waste management independently; as opposed to a holistic approach that would address the building sector encompassing water, energy etc. as a whole); and implementation of codes and standards prior to verification on site, leading to implementation challenges on site are some of the difficulties faced during implementation of policies on sustainable habitats.

In view of the above, and with an overall objective to reduce resource consumption, reduce greenhouse gas emissions and enhance the use of renewable and recycled resources by the building sector, TERI has played a crucial role in convergence of various initiatives, essential for effective implementation and mainstreaming of sustainable habitats in India. With over two decades of experience on green and energy efficient buildings, TERI has developed GRIHA (Green Rating for Integrated Habitat Assessment), which was adopted as the national rating system for green buildings by the Government of India in 2007.

Internationally, voluntary building rating systems have been instrumental in raising awareness and popularizing green design. However, most of the rating systems devised have been tailored to suit the building industry of the country where they were developed.

This tool has been adopted by the Ministry of New and Renewable Energy. This tool, by its qualitative and quantitative assessment criteria, is able to ‘rate' a building on the degree of its ‘greenness'.

2.4.2 Indian Green Building Council (IGBC)

Detailed hereafter are descriptions of IGBC rating process as presented briefly on the website of IGBC. It is being reproduced here for reference purpose. For detailed deliberations readers can communicate with IGBC.

2.4.2.1 Introduction to Indian Green Building Council (IGBC)

The Indian Green Building Council (IGBC), part of the Confederation of Indian Industry (CII) was formed in the year 2001. The vision of the council is, "To enable a sustainable built environment for all and facilitate India to be one of the global leaders in the sustainable built environment by 2025".

The council offers a wide array of services which include developing new green building rating programmes, certification services and green building training programmes. The council also organises the Green Building Congress, its annual flagship event on green buildings.

The council is committee-based, member-driven and consensus-focused. All the stakeholders of construction industry comprising of architects, developers, product manufacturers, corporate, government, academia and nodal agencies participate in the council activities through local chapters. The council also closely works with several State Governments, Central Government, World Green Building Council, bilateral, multi-lateral agencies in promoting green building concepts in the country.

2.4.2.2 Brief about IGBC Rating System

Green building rating brings together a host of sustainable practices and solutions to reduce the environmental impacts. Green building design provides an integrated approach considering life cycle impacts of the resources used.

An important development in the growth of green building movement in India is the launch of the several IGBC Green Building Rating Systems. Details about such systems could be accessed from the website of IGBC.

2.4.3 CIDC Comprehensive Green Rating (CCGR)

Detailed hereafter are descriptions of the CCGR process as presented briefly on the CIDC website. It is being reproduced here for reference purpose. For detailed deliberations readers can communicate with IGBC.

2.4.3.1 Introduction to CCGR

Construction Industry Development Council (CIDC) has established a green rating framework for conducting a holistic analysis of complete life-cycle considerations. This framework provides building owners, architects, consultants, developers, facility managers and project managers the tools they need to design, construct and operate green buildings.

It promotes a whole-building approach to sustainability by recognizing performance in the following five key areas: Sustainable site development, Water savings, Energy efficiency, Materials selection and Indoor Environmental quality

2.4.3.2 Brief on CCGR

CIDC Green Building Rating System is structured in a manner that it can function as a standalone rating system or as an addendum to existing rating systems to correct the highlighted anomaly. It covers all the three stages of building products, receiving, using, and then disposing. The rating framework has six categories covering different aspects of the construction activities. These range from Non-Polluting Construction Works, Water Conservation, Embodied Energy Investments, usage of Locally Manufactured Materials, Construction & Post Construction Phase Energy Expenses & Recoveries, and finally Recycling of Wastes.

The green building rating developed by CIDC considers the complete life cycle of building for rating. This rating takes in to account the energy embodied in material and energy spent in transporting the same.

Popular rating systems in the market miss out initial parts of Life cycle sections and miss out the energy expenses incurred material production and their transportation to project sites post manufacture.

The green rating process starts with the project registration and the completion of the application form. A copy of the CCGR Registration form is attached at Attachment 5.

2.5 India Cooling Action Plan

The Ministry of Environment, Forest and Climate Change (MoEF&CC) has developed and launched the ICAP during March 2019, to provide an integrated vision towards cooling across sectors encompassing inter alia reducing cooling demand, refrigerant transition, enhancing energy efficiency and better technology options with a 20-year time horizon. Linkages of cooling with Sustainable Development Goals are well acknowledged. The cross-sectoral nature of cooling and its use in development of the economy makes provision for cooling an important developmental necessity

India is one of the first countries in the World to have a comprehensive cooling action plan, which has been appreciated internationally as an important policy initiative which has the potential to provide socio-economic and environmental benefits related to reduced refrigerant use, climate change mitigation and Sustainable Development Goals.

The development of ICAP involved extensive stakeholder consultation and interaction with different Government Ministries/ Departments/ Organizations, Industry and Industry Associations, think tanks, academic and R&D institutions. The ICAP provides short, medium and long-term recommendations across different sectors and proposes synergies with ongoing government programmes and schemes to maximize socio-economic co-benefits.

2.5.1 Development of ICAP

❖ *Development Framework:* For the development of the ICAP, following thematic working groups were constituted:

a) Space cooling in buildings, air-conditioning technology,
b) Cold-Chain and refrigeration,
c) Domestic manufacturing and Production sector Alternative refrigerants and technologies
d) Servicing sector,
e) Transport air-conditioning,
f) Research & development.

The development of the ICAP involved extensive stakeholder interaction with government organizations/Departments, experts, representatives of industry associations, and think tanks.

- *Inter-ministerial coordination:* Steering Committee with representatives of various ministries was constituted for guiding and reviewing the documentation, reports, and recommendations developed by the ICAP thematic working groups.

  An Inter-ministerial committee comprising subject matter experts, eminent representatives of think tanks, and industry representatives was also formed under the chairmanship of the Secretary, EF&CC to oversee the development process. These Committees helped dovetail the ICAP recommendations with ongoing and planned policies and programmes residing with different ministries.

- *Dovetailing existing policies and priorities:* The ICAP recommendations were deeply embedded within the context of the Kigali Amendment to the Montreal Protocol, i.e., harmonizing the energy efficiency of cooling appliances with the refrigerant transition towards more climate-friendly refrigerants. At the more in-depth level, the ICAP cross-referred and forged synergies with ongoing and planned government policies and programmes residing with different ministries, such as Nationwide adoption and implementation of Bureau of Energy Efficiency's (BEE's) Energy Conservation Building Code 2017 for commercial building, BEE's Standards & Labeling (S&L) programme already covers Room and Split Air-Conditioners, Chillers and Fans and can be expanded to include evaporative air-coolers and fast-growing Variable Refrigerant Flow air-conditioners, ensuring thermal comfort in houses constructed under Pradhan Mantri Awas Yojna-Urban (PMAY-U) and many other schemes.

2.5.2 Overview of Space Cooling in Buildings

In 2017, approximately 272 million households were estimated in India, expected to increase to 328and 386 million by 2027 and2037, respectively.

In 2017, approximately 8% of the current households were estimated to have room air conditioners, anticipated to rise to 21% and 40% by 2027-28 and 2037-38, respectively.

In 2017, the estimated commercial floor was around 1.2million sqft and was expected to grow about 1.5 to 2 times by 2027-28 and 2.5 to 3 times by 2037-38, respectively.

2.5.3 Operationalization of Recommendations

To operationalize recommendations for each thematic area, thematic working groups comprising representatives from line ministries/departments, industry and industry associations, think tanks and experts have been constituted by the Ministry to develop an implementation framework for the recommendations given in the ICAP for each thematic area. A Steering Committee under the Chairmanship of Additional Secretary (Ozone Cell), MoEF&CC has also been constituted to guide and oversee the implementation framework and finalize the action points identified by the Thematic Working for operationalizing the recommendations.

The thematic working group on space cooling in buildings during its six meetings has identified a list of action points for operationalizing the recommendations of the ICAP. The action points have been identified after mapping of the recommendations given in the ICAP with the on-going government programmes/schemes handled by different ministries/ departments/agencies of the Government and inputs provided by the members during the meeting.

A list of action points has been finalised after mapping of the recommendations of the India Cooling Action Plan with the ongoing government programmes/ schemes of the various Ministries. Action Points have been published and circulated to the concerned Ministries/Departments/Agencies for implementation. The publication on the Action points for implementation of the recommendations for Space Cooling in Buildings was launched on the World Ozone Day held on 16th September, 2021 and widely disseminated.

The energy-efficiency in existing and up-coming building infrastructure plays a pivotal role in addressing the challenges associated with growing electricity demand in cities and urban areas, where more than 50 % of the electricity goes into space cooling during the peak summer months.

When it comes to cooling buildings, several strategies can be applied in combination such that their positive impact, as a whole, is greater than the sum of the parts. One of the approaches for addressing space cooling requirement is a sequential approach that first reduces heat gain by passively cooling buildings, followed by installation of energy-efficient HVAC appliances/systems coupled with smart controls to efficiently meet the reduced cooling needs, and finally the deployment of green/natural refrigerants and renewable energy to meet the cooling demand.

One of the recommendations of ICAP is enforcing efficient building envelope guidelines in the construction of commercial and residential buildings. Further, Ozone Cell, MoEF&CC has mentioned in its action plan that ECBC be notified in all States /UTs, Energy Conservation Act to be amended to include Eco Niwas Samhita (ENS) for Residential, ENS to be notified in all States/ UTs, Provisions for building envelope to enhance energy efficiency should be incorporated in the Model Building Bye Laws, 2016, Passive cooling related infrastructure" may be incorporated in URDPFI Guidelines, State/UT TCPOs should be encouraged to adopt ECBC & ENS and have requested all the concerned Ministries/ departments/ agencies to work in this direction.

ICAP also talks about wider adoption of ECBC and ECBC-R in various infrastructure scheme of Government. Ozone Cell has mentioned in its action plan that ECBC norms are to be incorporated in commercial buildings having electric load equal to or greater than 100 KVA, Eco Niwas Samhita (ENS) norms to be incorporated in the Residential building projects, Advisory to be issued to industry associations of real estate developers (CREDIA) regarding compliance of ECBC/ ENS norms and have listed various schemes and projects where these can be applied.

One of the recommendations of ICAP is to incorporate relevant provisions of energy efficient building design stated in Energy Conservation Building Code (ECBC) to minimize active cooling needs by using passive design elements for all commercial (non-residential) buildings and also ratchet up Minimum Energy Performance Standards (MEPS) for Room ACs while taking into account most energy efficient models available and their affordability.

ICAP also recommends to Promote use of not-in kind technologies DCS, solar Vapour absorption chiller (VAM), tri generation etc. and Solar assisted systems.

ICAP also talks about awareness campaigns to sensitize both the construction community and users regarding efficient buildings. It has requested the Ministry of Education that Energy efficient building design by using passive design to be incorporated in the curriculum of civil engineering/architecture / degree courses/ Mechanical Engineering.

2.6 Conclusion

This chapter present an overview of passive cooling measures in various types of building. An overview of ECBC, processes for ratings of building is also addressed. In addition an overview of ICAP and the measures to be taken in space cooling to promote passive cooling technologies has also been addressed.

Chapter 3: Refrigeration and Air-conditioning (RAC) equipment based on non-HCFC and low GWP refrigerants for space cooling

3.1 Introduction

This chapter discusses Refrigeration and Air-conditioning (RAC) equipment based on non-HCFC and low GWP refrigerants for space cooling. Use of these equipment along with passive cooling designs provide most optimum solutions for cooling the building envelope with least energy consumption. While designing and constructing the building envelope under passive design systems, the designer must have proper understanding of mechanical cooling and the capabilities to design the complete system. This chapter aims at providing the basic information of such issues to the reader and provides pointers for developing essential capabilities in this direction.

3.2 Cooling Technologies

Cooling demand in the country for space cooling has been increasing steadily over the last decade due to a combination of factors, such as rising population living largely tropical climate, rapid urbanization, low penetration of cooling, sustained economic growth, etc. Comfort environment and indoor air quality are increasingly recognized as the key to health, wellbeing and productivity of the people in hot climates prevailing in the most part of the country.

A large part of the country's cooling requirements across sectors is met by active refrigerant-based heating, refrigeration and air conditioning-based technologies. Currently, vapour compression-based technologies cater to more than 85 percent of cooling requirements across sectors in the country. Mechanical compression has been the choice of technology for more than a century as systems based on this technology are convenient to use across sectors, applications and situations. The cooling systems provide precise required conditions, temperature, humidity and air circulation efficiently. The dominance of this technology is the result of continued focus on research and development.

There are various type of air conditioning equipment used depending on application, cooling capacity and temperature. These can broadly be classified into the following the sub-sectors, Space cooling systems comprising of Room Air conditioners (RAC), Chillers, Variable Refrigerant Flow (VRFs) systems, Ducted Systems, package systems, etc. Refrigeration systems comprising of cold storages/cold rooms, process chillers, supermarket display cabinets, standalone units: deep freezers, vending machines, chest coolers, Water-Coolers, Server Cooling Solutions, domestic refrigerators, etc.

The compression-based heating, ventilating and air conditioning and refrigeration (HVAC) equipment use either synthetic refrigerants or natural refrigerants. Most of the refrigerants are either Ozone Depleting Potential (ODP) or have high Global Warming Potential (GWP) or both. These refrigerants are regulated for phase out/phase-down as per the agreed schedules under the Montreal Protocol on Substances that Deplete the Ozone Layer.

Recognizing, the exponential growth of chlorinated and brominated fluorocarbons which are responsible for depletion of the stratospheric ozone and adverse effects on the environment particularly on climate, the Montreal Protocol came in existence for phase-out of production and consumption of Ozone Depleting Substance and now phase-down of high GWP-HFCs. The Montreal Protocol has been the main driver for adoption of environmentally friendly and energy efficient technologies for more than three decades. This section discusses the non-ODS and low-GWP technologies for space cooling sector which is one of the fast growing sectors in the country.

3.3 Refrigerant Based Cooling Technologies for Space Cooling

Space cooling is about the 57% of the total cooling requirement in the country. Space cooling technologies for thermal comfort can be categorized in three types, the refrigerant based technologies, non-refrigerant based technologies (fans, coolers) and not-in-kind technologies. A variety of air conditioning equipment with various cooling capacity operating at different temperatures are used depending on the application and systems requirement.

3.3.1 Chillers

Air conditioning in medium to large commercial buildings is achieved with chilled water systems using chillers. The chillers can be sub-categorized into scroll chillers from 10 to 150 TR, screw chillers from 50 to 500 TR and centrifugal chillers from 300 to 2500 TR or more. The current share of Scroll chillers is approximately 10%, centrifugal chillers about 35% and the remaining 55% are screw chillers. These chillers could be either air-cooled or water cooled, especially the scroll and screw chillers, however all the centrifugal chillers are water cooled. Flooded evaporators, oil-free compressors using fixed and variable speed, are being adopted in screw and centrifugal type chillers.

The scroll chiller market is fragmented, and still continues to be with fixed Speed, with R-22 as refrigerant. There are many small-scale manufacturers in the country which manufacture scroll chillers. The refrigerant used in screw and centrifugal chillers, are predominantly HFC-

134a, and R-123. As per Ozone depleting substance (Regulation and Control) Rules, 2000 and its amendment rules, 2014 the manufacturing of all products using HCFCs will be banned from 1st January, 2025. The production and consumption of high GWP HFCs will also be phased-down as per the Kigali Amendment to the Montreal Protocol.

The non-ODS low- GWP refrigerants like R-513A, HFO-1233zd, R-514A, etc., are being introduced in this sector in the Indian market. HCFC-123 is one of the HCFCs whose production and consumption will be completely phased-out by 2030. The construction industry and equipment manufacturing industry should gear up for adoption of non-ODS and low-GWP based chillers for all upcoming commercial buildings.

3.3.2 Unitary Systems: Split & Window Air-Conditioners with <3 TR Cooling Capacity

Room Air Conditioners are commonly used in residential space cooling. This segment is growing with a rapid rate in the country as the current penetration is very low (7-9%). The CAGR in this subsector is around 11% to 15%. It has been estimated in India Cooling Action Plan (ICAP) that total installed stock of room AC will grow from 39 million in 2017-18 to 350-400 million units by 2037-38 (ICAP, 2019).

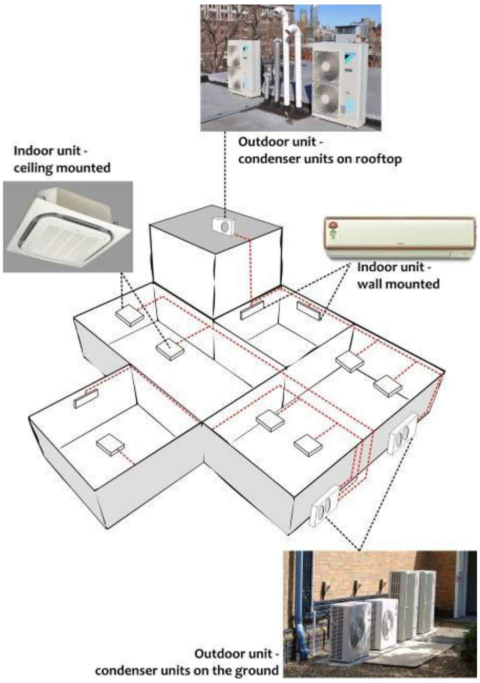
Room air conditioners will continue to be the key cooling appliance for space cooling in the country due to living pattern of the society. Air conditioners are window/ through-the-wall, mini or single split both fixed speed and inverter types. Historically, window type AC was commonly used but over the years there is a trend towards use of split ACs. The current market share of split AC is more than 90%. Recognizing that, inverter ACs are more energy efficient than fixed speed, there is a very rapid adoption of inverter technology in this subsector. Currently inverter market share in India is more than 85%.

Split and window AC have been predominantly using HCFC-22 as refrigerant, especially in the fixed speed category. In case of inverter Room ACs, R-410A was the choice of refrigerant prior to implementation of HMP Stage-II in the country. Recognizing, R-410A (GWP=2010) is one of the high GWP refrigerants, industry is converting their manufacturing facilities of room ACs to HFC-32 and R-290. Currently, all variable speed units are in the split category with R-410A & HFC-32 as refrigerant. Both, micro-channel and copper tube heat exchanger technologies are used for the condenser.

3.3.3 Multi-Split Systems

These are used to cool several rooms or an entire residential/small commercial building. The working principle is similar to that of the individual split system but involves multiple fan coil units and condensing units. The indoor fan coil units supply cool air to the occupied areas and the outdoor condensing units are typically placed on the roof or on the ground adjacent to the building. Cooling capacities range from 4.5 kW to 135 kW for a non-ducted multi-split system, and the charge sizes range from 0.5 kg to 90 kg; cooling capacities. The Figure 3.1 illustrates the working of multi-split unit for a residential building. These systems could utilize non-ODS low-GWP refrigerants as cooling capacity is divided in number of units, thus the refrigerant charge quantity is also reduced for a given space.

Fig 3.1: Multi-split unit for residential/small commercial building



3.3.4 Unitary Light Commercial Systems – Ducted / Packaged Systems

Ducted/packaged systems are also unitary systems where all the air-conditioning components and air supply fans are included in a single assembly. The system is located outdoors, either on the roof or on the ground adjacent to the building. Ducted packaged units supply the filtered, cooled and dehumidified air to the building through ducts. The cooling capacity of unitary & light commercial system starts from 3TR and are available upto 22 TR. These systems use single compressor upto 10 TR cooling capacity and multiple compressors, thereafter. With low growth, technology adoption is slow in this category with some signs of introduction of inverter technology; predominantly HCFC-22 and R410A used in such systems. The manufacturing of these units is being converted to non-ODS low-GWP technologies. Figure 3.2 shows an installation of 10TR ducted package unit.

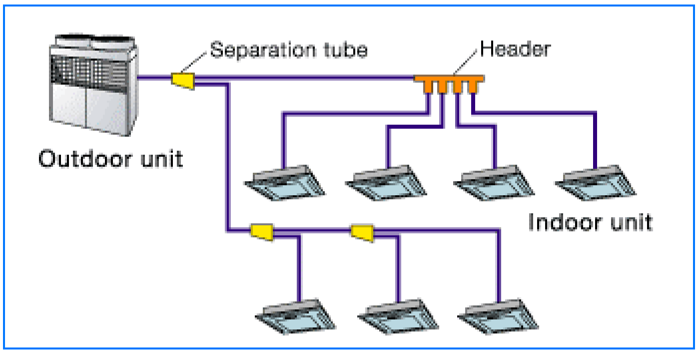
Fig 3.2: Installation of a ducted package unit

3.3.5 Variable Refrigerant Flow (VRF) Systems

The variable refrigerant flow (VRF) systems are used in medium size commercial buildings and in a limited way in residential buildings. It is the fastest growing segment, and is based on R-410A as Refrigerant and variable speed compressors. The units are available from 2.5 to 20 TR as standalone module, and from 6 to 100 TR in multi module outdoor units, coupled together. The outdoor units are connected to multiple types and numbers of indoor units, such as wall mount, cassette, ducted and DX AHUs. The energy saving is achieved through diversity, as well, variable capacity, to meet the indoor heat load. VRF Systems are built with highly advanced controllers, with communication capability which offers the end-user flexibility in operation. The VRF systems are available, both, in cooling and heat pump options.

VRF systems will continue to use R-410A refrigerant for a reasonably long time as currently no low-GWP and commercially viable refrigerant has been identified. However, R & D is continuing to synthesize safe, low-GWP and commercially viable refrigerant for high pressure and medium cooling capacity applications. The Figure 3.3 depicts the working of VRF system.

Fig 3.3: Variable Refrigerant Flow (VRF) System



3.3.6 Refrigerant Based Not-in-Kind Technologies

Vapour Absorption technology

Vapour absorption systems are the low-grade (heat) energy operated systems and use very small amount of electricity in comparison to vapour compression technology. Electricity is only required for operating internal pumps and controls. The heat source can be natural gas, steam, hot water, waste heat recovered from as industrial process, or solar energy.

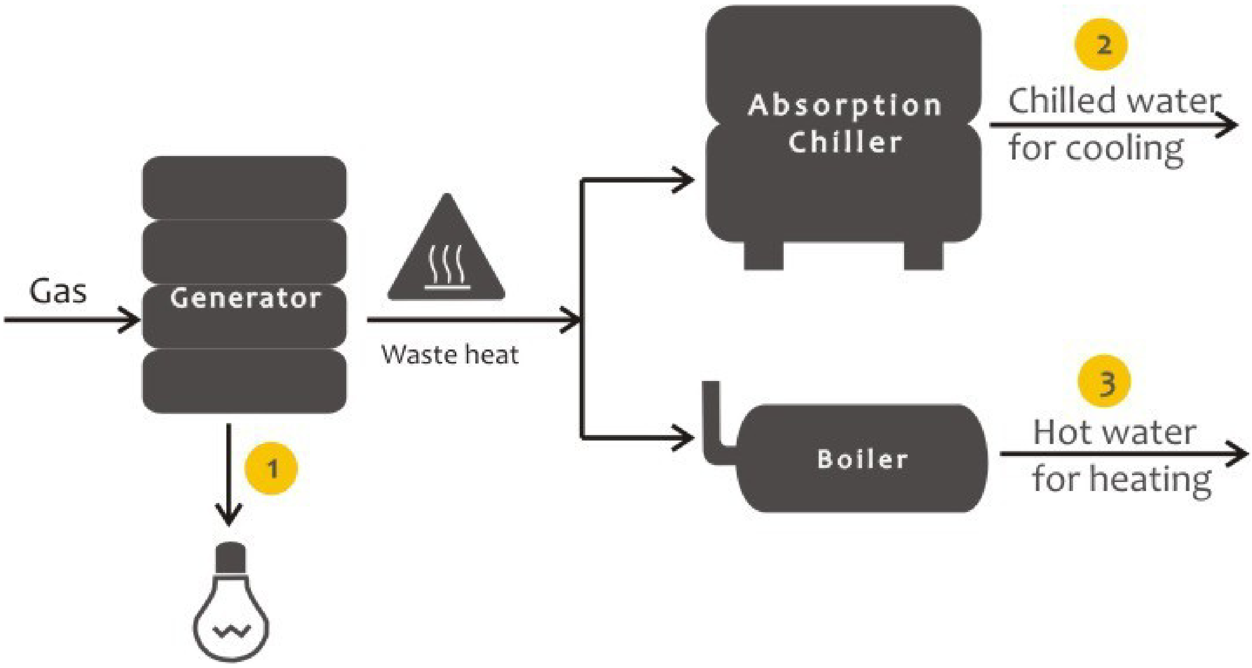
The vapour absorption systems do not use any synthetic refrigerants like HCFCs and or HFCs, thus there is no adverse impact on ozone layer and/or climate system. These systems use a combination of a refrigerant and absorbent to provide cooling. Typically, a combination of water (refrigerant) and lithium bromide (absorbent), or ammonia (refrigerant) and water (absorbent) are commonly used as working fluids.

The efficiency of these systems tend to be relatively lower than the vapour compression heat operated systems. Several efforts are being made to improve energy efficiency of these systems that are being deployed wherever feasible.

Trigeneration Technology

Trigeneration is the simultaneous production of cooling, heating and power from only one fuel input. In a typical trigeneration system, gas fired generators are used to produce electricity. This process generates waste heat, which is then directed to the chillers and boilers. In this system, steam turbine(s) is used for power generation, absorption chillers to produce chilled water for space cooling and boiler to generate hot water for space heating and other purposes. In a trigeneration plant, up to 80% of primary energy reaches end use, as opposed to only 33% in conventional power plants. Thus, this system can be extremely efficient. Figure 3.4 shows the various components and operation of trigeneration (1. electricity; 2. cooling; 3. hot water for heating).

Fig 3.4: Trigeneration System



Trigeneration has its greatest benefits where electricity, heating and cooling are needed simultaneously. Such installations include universities, hospitals, hotels, colleges and other large commercial buildings. Since electricity is produced on-site, it minimizes the greenhouse gas emissions and transmission losses that occur when using electricity from the grid. Not only is trigeneration efficient, but it is also a relatively independent energy source. In critical applications, such as hospitals, this system can provide a reliable level of back-up power.

By using recovered waste heat to operate absorption chillers instead of grid-produced electricity, trigeneration systems offer substantial cost savings and reduce greenhouse gas emissions. Absorption chillers commonly use water or ammonia as a refrigerant, which makes this a zero ODP and GWP system. It is one of the non-ODS and low-GWP options for cooling.

District Cooling (DC) System

District cooling (DC) is a system in which water is chilled (cooled) at the central water chilling plant and distributed to residential, commercial and/or industrial consumers for air conditioning, process cooling and other industrial applications. The chilled water is distributed through a network of insulated water pipe-lines for both supply and return. The DC system eliminates installation of water chilling plant at each building or facility. Only heat exchangers/ air-handling units with air distribution systems are installed at each building site.

In principle DC system is similar to central air conditioning system designed for a building or building complex but scale and modalities of operations are entirely different as the water chilling plant is remotely located at the appropriate place owned by a public Utility or a Private Energy Distribution Utility. The utility owner is responsible for its operation, distribution, metering of chilled water, maintenance of DC plant/ installation, collection of revenue, etc.

The water chilling plant could be comprised of vapour compression-based electricity driven centrifugal/screw chillers and/ or gas/steam turbine driven chillers and/or absorption technology-based chillers. It can also be a combination of mechanically driven systems and thermally driven absorption system.

DC system typically requires about 15% less cooling capacity (ICAP 2019) of the plant than a conventional distributed cooling system for the same cooling loads due load diversity and flexibility in capacity design and installation. In addition, it offers several advantages like energy efficient cooling (It usually consume 65-80% energy compared to conventional central conditioning systems), use of non-ODS low –GWP refrigerants due to possibility of its remote location, space saving in buildings, cost saving due to economies of scale of operation, etc.

The challenges are high investment, relatively less technical expertise/experience of design, installation (likely to improve) and operation, and absence of favorable financial and business mechanisms. A number of projects have already been initiated in the country.

3.4 Alternative Refrigerants to HCFCs and high GWP HFCs.

Building air conditioning systems use various types of cooling equipment, viz., unitary air conditioning units (window/split air conditioners), ducted package units, scroll chillers, variable refrigerant flow (VRF) units, screw and centrifugal chillers. These systems can be categorized based on the operations pressures like high- pressure, medium-pressure and low-pressure systems. HCFC-22 and HCFC-123 are the commonly used ODS refrigerants for high pressure and low-pressure equipment respectively. CFC-12 was historically used as medium pressure ODS refrigerant which has already been phased out from 1st January, 2010 and HFC-134a is being used in this category of RAC equipment. Manufacturing of any type of equipment using HCFCs will be banned from 1st January, 2025. HFCs have evolved as the alternatives to all the ODSs including HCFC refrigerants. HFC-134a, R-410A, R-407C are the dominant replacement of HCFCs in this sector. However, HFCs being high GWP refrigerant, the production and consumption of high-GWP HFCs is controlled under the Montreal Protocol. The production and consumption of HFCs will be phased-down as per the Kigali Amendment to the Montreal Protocol schedule.

Thus, the construction industry should make all efforts to deploy only non-ODS and low-GWP refrigerants. The subsequent section discusses the non-ODS and low- GWP based technologies for various types of air-conditioning equipment used for space cooling in buildings.

3.4.1 Non-ODS and Low-GWP alternatives to HCFC-22

R-410A (a blend of R-32 and R-125) has emerged as the main alternative to R-22 for various types of equipment for this sector and which has been adapted globally. Recognizing, R-410A has high Global Warming Potential (GWP), it would is desirable to leapfrog from R-22 to low-GWP alternatives. Search for low-GWP refrigerants options to R-22 has been continuing for more than a decade. Industry has identified HFC-32 and some of the HFC/ HFO blends as alternatives to HCFC-22 and R-410A. HFC-32 being lower-GWP (GWP-675) has widely been adopted in this sector. Table 3.1 provides equipment wise non-ODS and low-GWP technical options for high-pressure applications where currently HCFCs and HFCs are commonly used.

Table 3.1: Alternative Technologies to HCFC-22 and R-410A

ODS Low-GWP Refrigerants for air conditioning Equipment (high pressure Applications)			
Equipment	HCFC Refrigerant	HFC Refrigerant(GWP) (Currently Used)	Potential Low –GWP Refrigerant
Room ACs	HCFC-22 (1810)	R-410 A (2100) R-407 C (1700)	-HFC-32 (675), A2L -R-290 (3), A3 -HFC/HFO blends, e.g., R - 452B (680); A2L R - 444B (310); A2L Several others yet to be commercialized.
Ducted & Packaged AC	HCFC-22 (1810)	R-410A (2100) R-407A (1700)	-HFC-32 (675), A2L -HFC/HFO blends e.g, R - 452B (680); A2L R - 444B (310); A2L
Scroll Chiller	HCFC -22 (1810)	R-410A (2100) R-407C (1700)	-HFC-32 (675); A2L -HFC/HFO blends R - 452B (680); A2L R - 444B (310); A2L
Variable Refrigerant Flow Units (VRF)	-----	R-410A (2100)	Alternative options yet to be developed

Class of Flammability is denoted in red color

3.4.2 Non-ODS and Low-GWP Technology Options for Screw and centrifugal Chillers

Screw and centrifugal chillers are widely used in air conditioning of commercial buildings. Currently, these chillers use HFC-134a and HCFC 123 as refrigerants. The manufacturing of all new equipment using HCFCs will be banned from 1st January, 2025 as per the Ozone Depleting Substances (Regulation and Control) Rules 2000 and its Amendment Rules, 2014. Chillers with non-ODS, low-GWP alternatives, the HFO and HFC blends have been developed and marketed. Such chillers are already being installed in a number of upcoming buildings in India. Table 3.2 lists the non-ODS and low-GWP technology options of HCFC-123 and HFC-134a for screw and centrifugal chillers.

Table 3.2: Alternatives to HFC-123 and high GWP Refrigerants for screw and centrifugal chillers

Non-ODS Low-GWP Refrigerants (HFC-134a) for Low and Medium Pressure Chillers			
Equipment	HCFC Refrigerant	High GWP Refrigerant	Non-ODS Low –GWP Refrigerant
Screw Chiller (medium pressure)	------	HFC -134a (1430) (Medium Pressure)	(Medium Pressure: -HFO-1234yf (<1); A2L -HFO-1234ze (<1); A2L -R-513A (600); A1
Centrifugal Chiller	HCFC -123 (79) (low pressure)	HFC -134a (1430) (medium pressure) Medium Pressure	Low Pressure: -HFO-1233 zd (1); A1 -HFO-1336mzz (2); A1 - HFC/HFO blend, e.g., R-514A A1 Medium Pressure: -HFO-1234yf (<1); A2L -HFO-1234ze (<1) A2L - R-513A (1.7) B1

Class of Flammability is denoted in red color

3.4.3 Non-ODS and Low-GWP Technical Options for Not-in-Kind technologies

The commercially available refrigerant based Not-in-Kind technologies have discussed in section 5.2.6. The absorption chillers and trigeneration technologies are heat operated technologies. These technologies are either Lithium-water where refrigerant is water and ammonia-water where ammonia is the refrigerant. Thus these technologies have no environmental impact.

The district cooling systems use centrifugal chillers and/or absorption chillers or a combination of both. The technical options for DC systems are same as listed for centrifugal chillers and absorption chillers.

3.5 Energy Efficient Materials

In addition to providing passive cooling assistance to building envelope, we also need to use energy efficient materials which would have the least energy expenditure during the entire life cycle of the building envelope. This would amount to selecting an installing material with least embedded energy invested in production and transport to the project site. Any material higher hire embedded energy would result in overall larger energy investment in the building envelope. This needs to be complemented with the optimum energy expenses during the period of usage. An aggregate value of expected energy expenditure during the entire life cycle could be developed for different alternatives and the one alternative with the least energy expense could be selected for usage

3.6 Conclusion

This chapter addresses non-HCFC & low-GWP technology options including Not-in-kind technologies for space cooling in buildings.

Chapter 4: Survey Details

4.1 Introduction

This chapter presents details about the survey methodology, process adopted to develop the questionnaires, evaluation of existing industry practices, identification of target stakeholders, and linked information and outcomes. Activities performed under this part of the initiative laid the foundations for the communications with stakeholders, conducting awareness and consultation workshop events, conducting the detailed survey determining the impediments, identifying ways and means to remove such impediments and chart the Building Envelope Design Action Plan.

4.2 Methodology adopted for the survey

The methodology for the survey process was configured to address the concepts as outlined hereafter:

4.2.1 Methodology Objectives

Objective of the survey is to assess the understanding and competencies of different categories of construction personnel in passive cooling, non ODS, low GWP energy efficient related cooling technologies.

This study aims at assessment of awareness and understanding about the two issues required for reducing the active cooling or heating needs by incorporating in building designs passive cooling principles and environment friendly materials and non-HCFC and low-GWP materials.

The complete solution for the building industry is an optimum combination of these two issues. We need to create buildings that are designed and constructed to maximize the natural cooling or heating conditions in tandem with the environmental conditions prevailing in the area and constructed by using materials that are conducive to natural heat reflection or retention processes in line with the actual requirements. Having designed such buildings, the balance HVAC needs could be met by choosing the appropriate systems with non-HCFC and low-GWP materials.

4.2.2 Survey Methodology

Primarily, we are talking about two core issues, application of passive cooling designs and usage of non-HCFC and low-GWP materials and processes in the building design and construction. There is departure from the conventional building design & construction processes in vogue currently. Though, most of such construction processes are identified in specifications, codes of practice, or guidelines, their adoption is scant because of low sensitization levels, and ignorance of a large section of the stakeholders. Discussed hereafter are the various segments of the stakeholders of Indian Building Construction Industry:

4.2.2.1 Municipal / Urban Local Bodies

If we look at the first part, though, there are municipal laws and rules that stipulate a specific spatial arrangement of buildings in the command areas of the respective urban local body (ULB), passive cooling objective are seldom a part of such rules. The primary cause here is the age of such rules as most of such regulations were established when passive cooling concepts were not in vogue. Even the nationally approved & implemented codes face difficulty in getting implemented due to the bureaucratic processes in vogue. The second part about the usage of non-HCFC and low-GWP becomes more complex due to reduced availability of such materials, professional manpower with specialized skills for installation and servicing, and construction/erection equipment at the local levels. With the changing scenario, these requirements need to be brought in the regulations for building construction or rehabilitation approvals and linked resources need to be made available at local levels. Further, as this segment of stakeholder is spread out, communicating, advising, and convincing them is a complex exercise.

4.2.2.2 Practicing Professionals

Like with ULBs the situation is equally complex with respect to the practicing professionals like architects, town planners, or engineers. Levels of sensitization about passive cooling and non-HCFC or low-GWP items are quite varied ranging from almost nil for older professionals to somewhat barely passable for the younger lot. As the constituents of this segment are also interacting with the ULBs, inertia in the path of change becomes higher. The need, in this case is to have a dialogue with such professionals for showcasing the benefits of the proposals and provide proper educational inputs for enhancing professional and vocational capabilities.

4.2.2.3 Industry Entrants

This segment comprises of individuals freshly trained in the building construction fields and come from a varied range of sources. Those could be the Universities, architectural educational institutions, engineering colleges, Polytechnics, ITIs, vocational training institutes, and informal on-the-job-training setups created by builders or trainers. Sensitization levels here, again varies from almost zero to somewhat passable levels. Though the segment is quite large, the younger age helps in communicating the concepts to these persons. One of the major challenges however is to upgrade the knowledge they gained while pursuing their educational programs and this brings us to the next set of stakeholders, the academia.

4.2.2.4 Academia

Application of passive cooling in building design process and usage of non-HCFC or low-GWP materials requires adequate mid-term training. Educational programs in India, however, are again structured with conventional construction methods somewhat ignoring passive cooling design process and use of non-HCFC/low-GWP products. Though the forward-thinking institutions have started including these options in their educational or training programs, a vast majority of institutions is still bereft of any such inputs. The issues here are the absence of proper educational materials, adequately exposed/trained faculty members, absence of actual industrial training/internships in the sector.

4.2.3 Survey Deliverables

The survey methodology was devised to address these four stakeholder groups wherein the aim was to seek the following inputs

- Basic understanding of passive cooling & usage of non-HCFC/low-GWP materials
- Understanding about the possible benefits of passive cooling and usage of such materials.
- Checking the availability of relevant code provisions useful for HPMP Stage II.
- Status of applications of such code provisions in the Building Sector.
- Knowledge of such provisions with the applicators/professionals.
- Current application / usage patterns.
- Knowledge gap identification.
- Evaluation of the available operating or execution skills in professionals and artisans serving the Building Sector.
- Skill Gap identification.
- Identification of the guidelines for the gap closures.

Based on the above thought process the survey questionnaire was designed and developed as discussed in the next section.

4.3 Development of Questionnaires

For the development of questionnaire, the desk study, the literature review, and personal interviews/interactions were conducted. The desk study was initially conducted on the available inputs from the CIDC Database[4]. Based on the initial findings personal interviews/interactions were conducted with individuals connected with the building construction industry as well as other stakeholders like representatives of ULBs, academia members, and students. These interactions provided inputs for the final questionnaire a copy of which is attached as Attachment 2.

4.4 Existing Practices Involved

As highlighted earlier majority of the users continue to use conventional construction processes with less or almost negligible attention towards passive cooling when mass scale housing is considered. The passive cooling design approach was generally observed in

[4]https://cidcdatabase.com/

higher end building projects as in such cases the finance for investing in the higher end products was available.

For mass housing projects, the root cause of non-application, as observed, was the limited land availability and restricted Floor Area Ratio (FAR) permissions in urban areas forcing the builder to make maximum use of the permissible limits at one hand and reduce expenses on passive cooling designs or non-HCFC/low-GWP alternatives. In addition, low exposures to the latest code provisions is also a challenge for the construction industry.

4.5 Targeted stakeholders

CIDC has a substantially large network that includes project owners, developers/builders, architects, engineers, building services engineers and other building professionals as well as by manufacturers of building materials apart from the authorities concerning land and building development, government and private construction agencies and academic and research institutions.

4.6 Specific Applications

With smart cities coming into existence, of late, the energy conservation or expense optimization therein could be an important objective for the smart city SPV. It would be quite apt to explore the possibilities of developing the passive cooling designs and the use of non HCFC/low-GWP alternatives within the rules and regulations of the specific Smart City. This could result in a substantially positive development for support to the manufacturers of non-HCFC/low-GWP alternative products. This, as highlighted earlier, could result in achieving economies of scale and assist the nation in a big way.

4.7 Consultation with Stakeholders

This section provides details about Consultation with the members of the construction community, building designers, architects, urban policy makers, building developers, building development associations, etc. These interactions have been undertaken during conduct of the charter study. It covers details of the stakeholders contacted and their position on various issues linked with the implementations of HPMP Stage II in building construction industry.

4.7.1 Stakeholders consulted

4.7.1.1 BIS

Adoption of National Building Codes 2016 by the engineers and architects in their projects would help in bringing quality and safety in the built environment. It would also assist in bringing sustainability in construction activities. Based on these premises CIDC includes inputs of various stipulations in CIDC training and educational programs for better education. For the national roll out of the initiative we would need a two-pronged approach, one to sensitize the practicing professionals, and other to make the application of the identified code provisions as mandatory parts of the educational syllabus. For practicing professionals actions could be taken jointly with technical guilds as discussed in the next section. For fresh candidates, role of AICTE and the ministry of Labour, Government of India would be quite important. These departments could pass directives to their constituents to stipulate mandatory inclusions at relevant locations.

4.7.1.2 Engineering Council of India (ECI)

Engineering Council of India (ECI) promotes the professionalization of engineers and registers qualified practicing engineers as Professional Engineers (PEs). It also assists in Continued Professional Development (CPD) of engineers. ECI covers all engineering disciplines and therein CIDC interacts with the professionals serving Building Sector apart from other infrastructure construction activities. ECI comprises of 32 different professional guilds serving the engineering and technology industry. Most of these constituents could be of assistance in promoting the passive cooling strategies.

CIDC has included all such individuals as respondents in the study survey for receiving the real-time picture. As CIDC provides CPD training to such professionals, the skill gap closure actions for such individuals could be one direction for future actions. As pointed out in the previous section, we need to the sensitize the construction community on passive cooling design, non ODS, low GWP and energy efficient technologies. Professional guilds like ECI could assist in promoting these applications. CIDC would be able to work with them as well. A detailed set of recommendations are discussed subsequently in this report.

4.7.1.3 Universities/Colleges

CIDC works extensively with All India Council for Technical Education (AICTE). It also has numerous MoUs/Agreements with several Universities and colleges engaged in imparting technical and professional education to individuals to serve the Building Industry. In developing the new professionals for serving the Building Sector CIDC has included constituents from this segment. These include professors and other support staff engaged in teaching or instructing learners. In CIDC internship programs, offered to students, provisions are being created to cover codal stipulations for HPMP Stage II linked actions.

4.7.1.4 Project Owners

CIDC is the apex organization of construction industry and has, amongst its member most of the large organizations building the national assets or serving the construction industry. Details about the CIDC membership can be seen from its website at http://www.cidc.in/aboutus3.html With respect to HPMP Stage II CIDC has been interacting with its members extensively. Primary aim is to generate consultative dialogue and create awareness among all such stakeholders.

CIDC proposes to issue the Good Management Practices to the industry constituents, including its members, registered vendors, and other enlisted organizations. As some of the inclusions could be new, adequate education must be provided to such constituents by CIDC. For a proper execution of this proposal CIDC would require funding assistance from the ministry.

One of the most effective actions could be to advise the project owners to introduce a mandatory provision in their procurement practices to engage a certain percent of the workers, having skill certification for implementing the passive cooling designs and use of non-HCFC/low-GWP materials.

CIDC, has already extended the support in this direction to various key project owners which include CPWD, State PWD's, MES & many others, which has been found to be very effective.

Special skilling program could be designed & offered by CIDC in association with the MOEF&CC. The section 4.7.1.6 elaborates this further.

4.7.1.5 Manufacturers/Vendors

To assist the Indian Construction industry CIDC maintains a database of evaluated and approved vendors serving the construction industry. All the vendors/manufacturers enlisted in this database must meet the minimum qualifying criterion. Details about this database can be seen at https://cidcdatabase.com. All enlisted manufacturers are being sensitized about the HPMP Stage II and the relevant code provisions and sustainability initiatives.

Educating the manufacturers and vendors is again an essential activity for sensitizing construction community.

4.7.1.6 Vocational Workers

CIDC is the largest training organization for construction workers in India. It has developed training programs for 49 different trades and skills. All such programs are created to address Quality, Safety, & Productivity needs of the construction industry. Details about this initiative are hosted on CIDC website at http://cidc.in/activities8a.html#03.

The guidelines provided later in this report, has a specific section for skill enhancement needs of vocational workers. The same could be implemented with the assistance of the Ministry of Labour.

A consolidated list of deliberation participants is attached as Attachment 6

4.8 Inputs received

Inputs from the stakeholders have been analysed and outcomes of the responses are presented in the report.

4.9 Conclusion

This chapter address various stakeholders identified for survey and the collaborative role of CIDC with the identified institutions.

Chapter 5: Survey Outcomes

5.1 Introduction

This chapter presents the outcomes of the initiative starting from the status of skill of the existing manpower engaged in building construction activities in respect to passive cooling concept. The outcomes of the survey, including status of the building construction industry with respect to the passive cooling concepts, future growth prospects of the sector, skilling and certification needs with respect to Ozone Depleting Substance phase out, energy efficiency issues for the buildings and the fittings therein, and safety and alternate refrigerants. It also discusses the occupational safety, access to finance and social security schemes, and would conclude with the recommendations for the sector.

5.2 Survey and questionnaire Background

Post the basic interactions, desk study, literature review, landscaping the existing policy, and identifying the trends, a questionnaire to assess the skill trends of the industry was developed. This was done under five heads, viz. *building design*, *materials*, *machinery*, *energy*, and *refrigeration*. In all, there were 51 multiple choice questions spread over these five heads to provide an in-depth analysis.

The questions framed were designed to evaluate the understanding levels of the respondents, use of various passive cooling designs and systems in projects, general perception about the changes to be brought necessary for implementing HPMP Stage II, and respondent's acceptance levels thereof. In addition to providing vital information about the industry trends, responses to these questions, also provided inputs to evaluate the skilling requirements by providing inputs for the skill gap analysis.

This chapter details such skill gaps vis-à-vis the identified heads. Graphic representations of the responses are presented. A select few are detailed in the next section hereafter. Inferences of the responses and resulting suggestions are covered in this chapter.

5.3 Participant Responses and Analysis

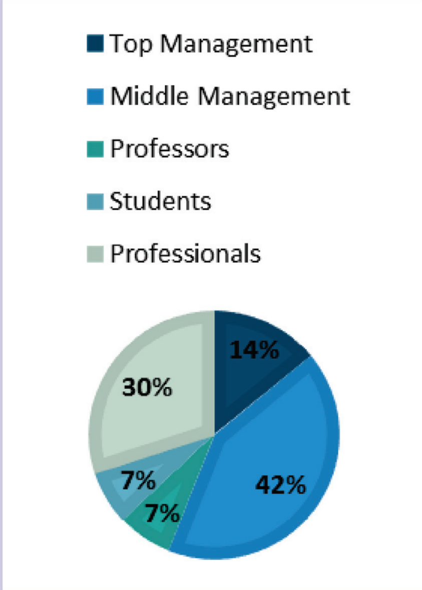
5.3.1 Participation in the Survey

Respondents of the questionnaire were from the following five stakeholder groups:

- Top Management
- Middle Management
- Working Professionals
- Professors; &
- Students.

Overall distribution of the respondents is presented in figure 5.1

Fig 5.1 Respondent Distribution



5.4 Outcome of the Survey

As discussed in the previous chapters CIDC undertook a multi-level consultation process has been adopted prior to initiating the interactions and survey activities. These included individual contacts with stakeholders, multiple group discussions with the groups of individuals which included working professionals, academia members, students, project owners, consultants etc. Primary objective of these interactions was to assess the trends about the understanding of passive cooling concepts in design and construction of buildings and status of understanding about use of non-HCFC and low-GWP alternatives

Outcomes of the multi-level interactions are tabulated in table 5.1.

Table 5.1: Percentage Knowledge Awareness Matrix

Knowledge Level	0-10%	11-20%	21-30%	31-40%	41-50%	51-60%	61-70%	71-80%	81-90%	91-100%
Percentage of Respondents	67	9	6	4	4	4	3	2	1	0

Note: The above respondents are the Engineers / Managers. Individual working as artisans or tradesmen are not part of this matrix as in case of those individuals the awareness levels for almost all the respondents was zero.

5.5 Status of awareness levels of holistic cooling concepts for energy efficient buildings and non-ODS, low-GWP technologies

A survey questionnaire was developed after the initial interactions and consultations with key stakeholders for getting requisite information with respect to cooling concepts and technologies used for commercial and residential building in the construction industry. The questionnaire was circulated amongst several organizations and individuals engaged in design, training and construction of buildings, etc., among various levels of personnel of the construction industry and other related organizations , Top Management of Organizations, Middle Management of Organizations, Professionals working in the sector, Members of Academia, and Students.

The survey was focused on building design, materials, machinery, energy, and non-ODS, low GWP refrigerants. Responses received have been collated and analyzed. Status of awareness and use of energy efficent and passive cooling design in the construction industry is presented in this section.

The Survey covered a wide spectrum of topics of building designs to reduce cooling demand, energy consumption and refrigerant use and its emissions. These topics could be clubbed in the following broad areas:

(i) Aware and understanding of Passive cooling principles and devises
(ii) Awareness on Energy Efficiency Building Code (ECBC)
(iii) HVAC equipment and non-HCFC and low-GWP technologies
(iv) Indoor air temperature, controls and operation and maintenance of HVAC equipment

5.5.1 Awareness and understanding of Passive cooling principles and devises

The questionnaire used for the survey included several questions related to passive cooling in buildings to assess the awareness and understanding level of the professionals involved in the construction industry. Figures 5.2 to 5.9 presents the findings of the survey. In general, there is good awareness among respondents except for the professional understanding about the passive cooling design processes. However, most of the respondents have limited understanding on various passive cooling elements/devises. The understanding level is varying from passive cooling processes/elements and category of respondents. The overall gap varies from 31% to 91% which clearly indicates there is a need for intervention to improve the awareness and in-depth understanding of various processes and elements of passive cooling.

Fig. 5.2 Awareness of Passive Cooling

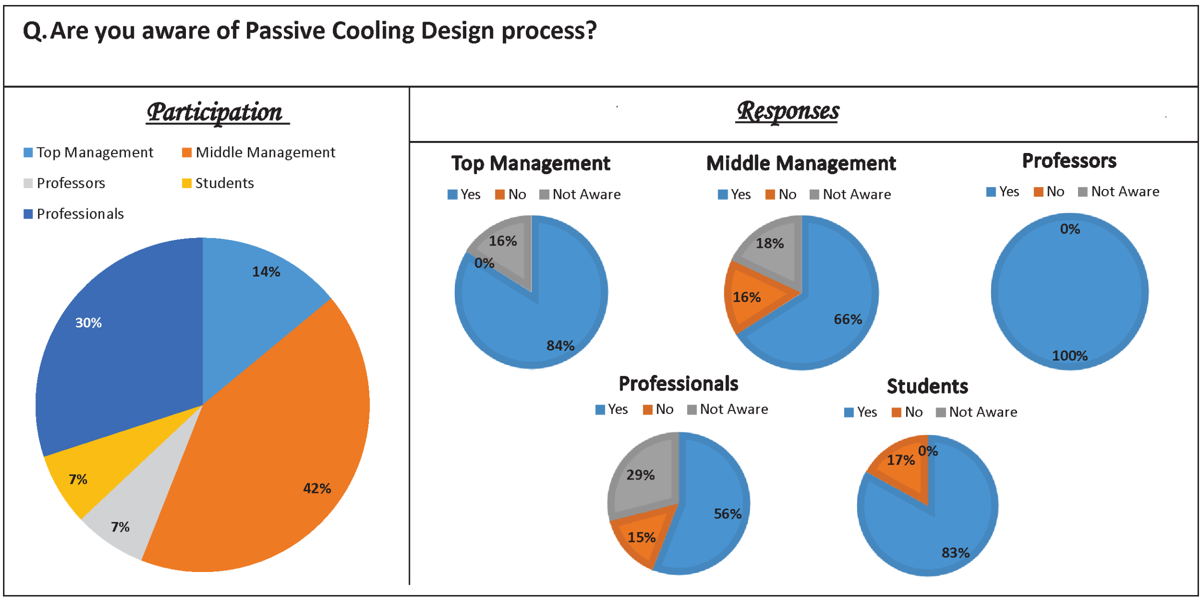


Fig 5.3 Energy efficient Building Envelope

Q. Have you checked the Building Envelope for: i) Mandatory requirements ii) Fenestration iii) Opaque Construction iv) Day lighting v) Building

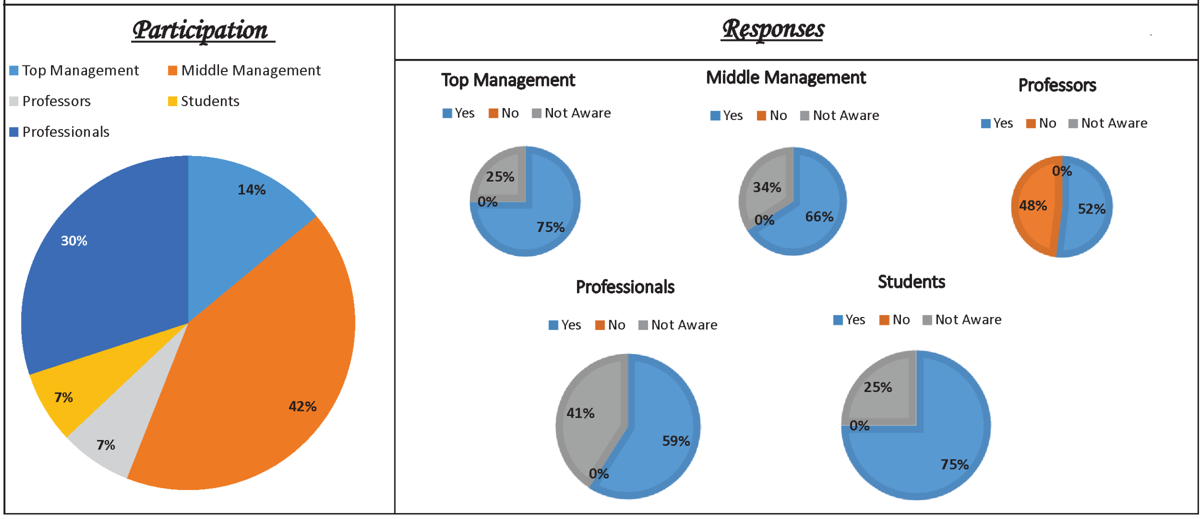


Fig. 5.4 Role of facades of building structure

Q. Are the facades of your structures designed to help reducing the heat gain by them?

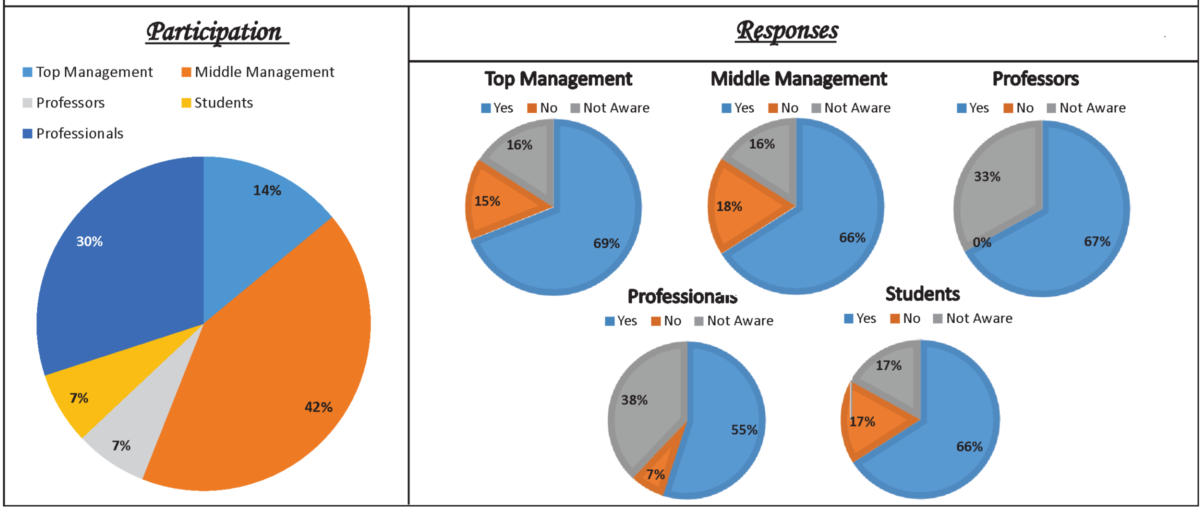


Fig 5.5 External shadings for reducing heat gain

Q. Does your structure have external shading for reducing the direct heat load, ranging 0% (no shading) to 30% (High-level shading)?

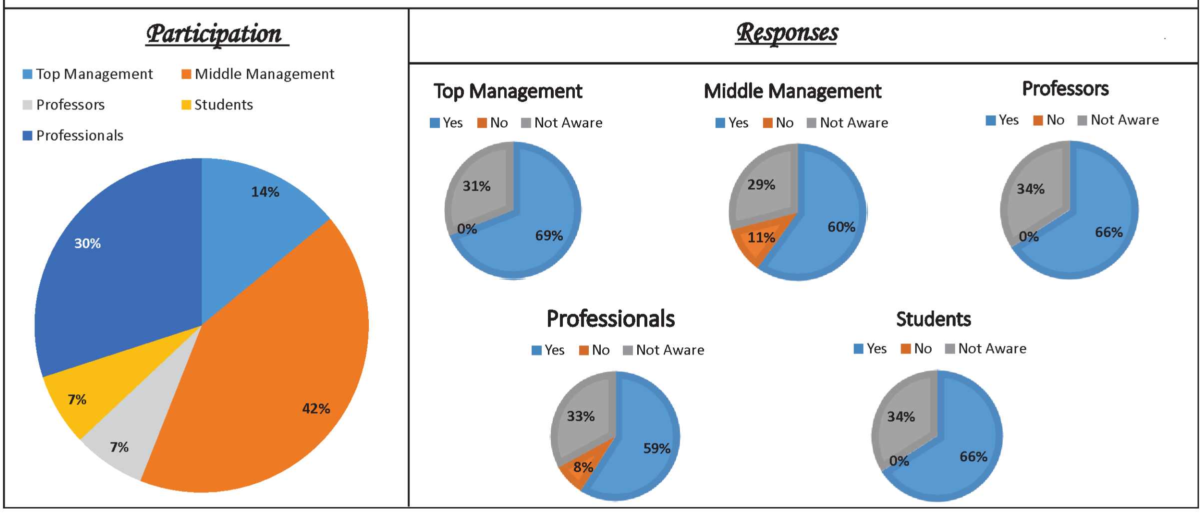


Fig. 5.6 Role of cool roofs

Q Whether you are aware that the Cool roof is a roof with top layer of material that has high solar reflectance and high thermal emittance properties. Cool roof surfaces are characterized by light colours so that heat can be rejected back to the environment.

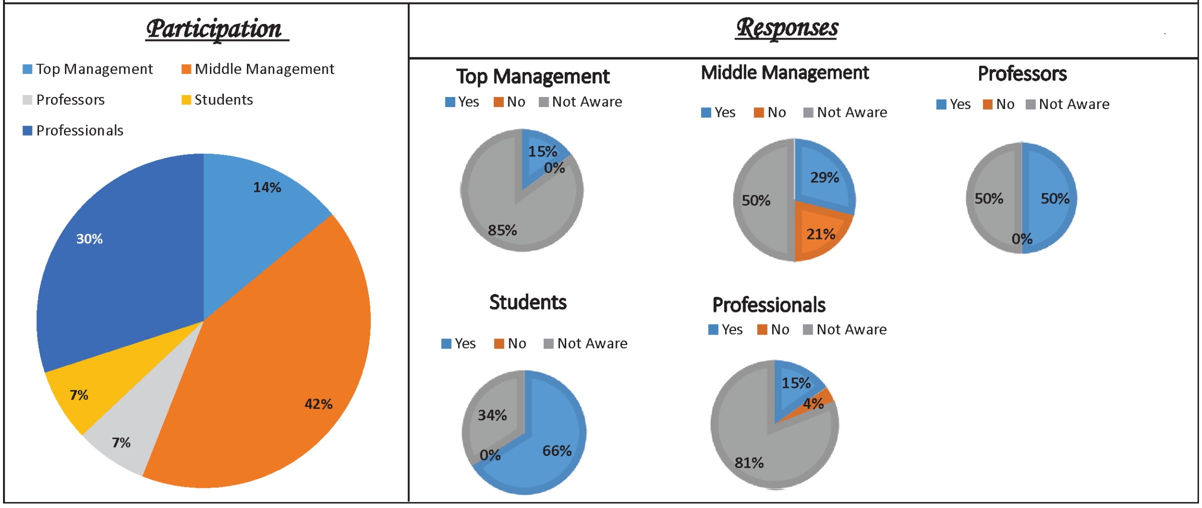


Fig. 5.7 Awareness about the day light provisions

Q. Whether you are aware that adequate day lighting can result in 20-30% of energy savings.

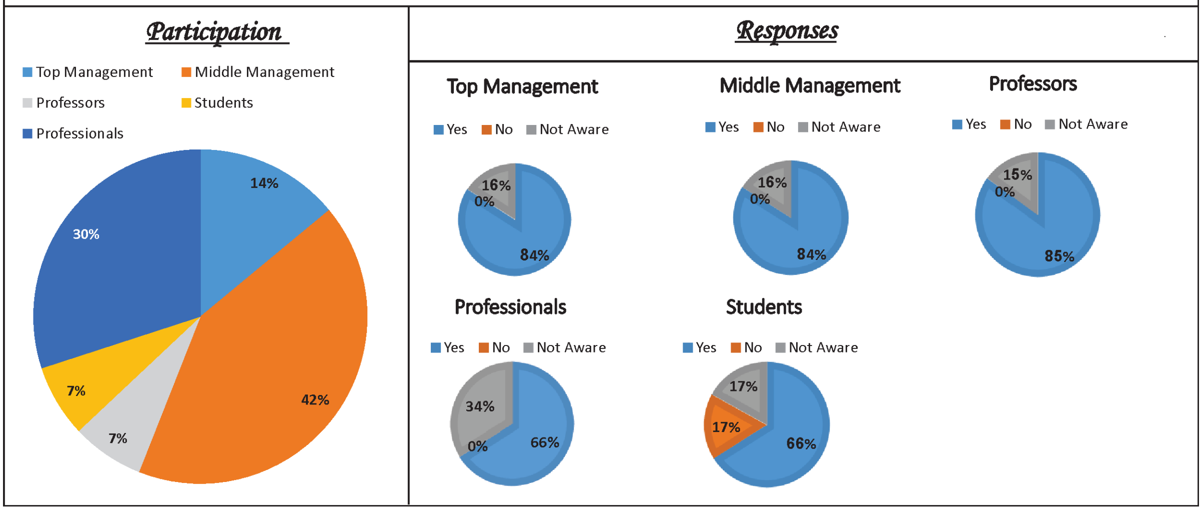


Fig. 5.8 Knowledge of properties of construction materials

Q. Whether you are familiar with various construction materials and their thermal properties while finalizing building design.

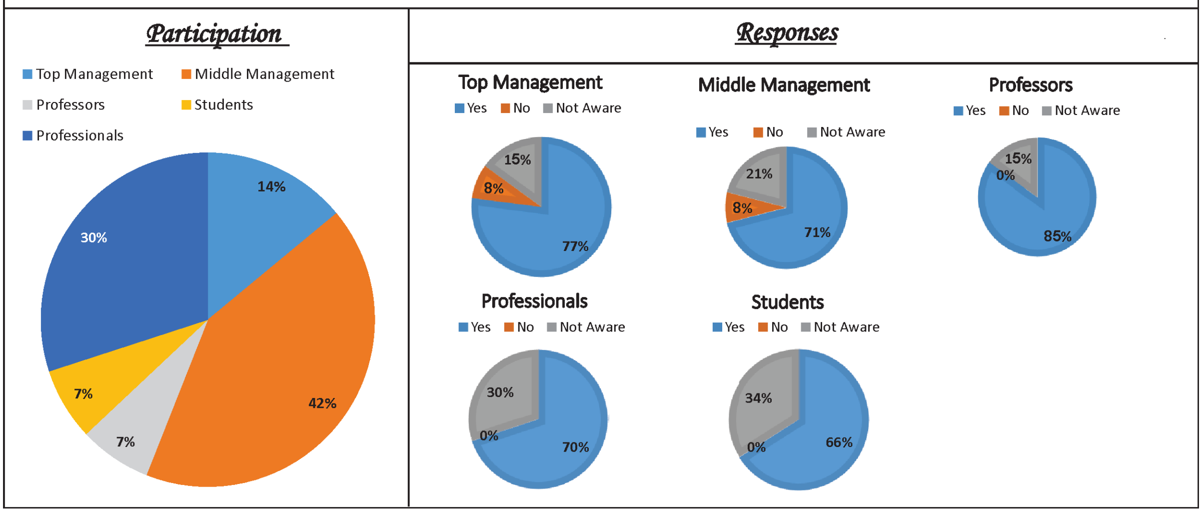
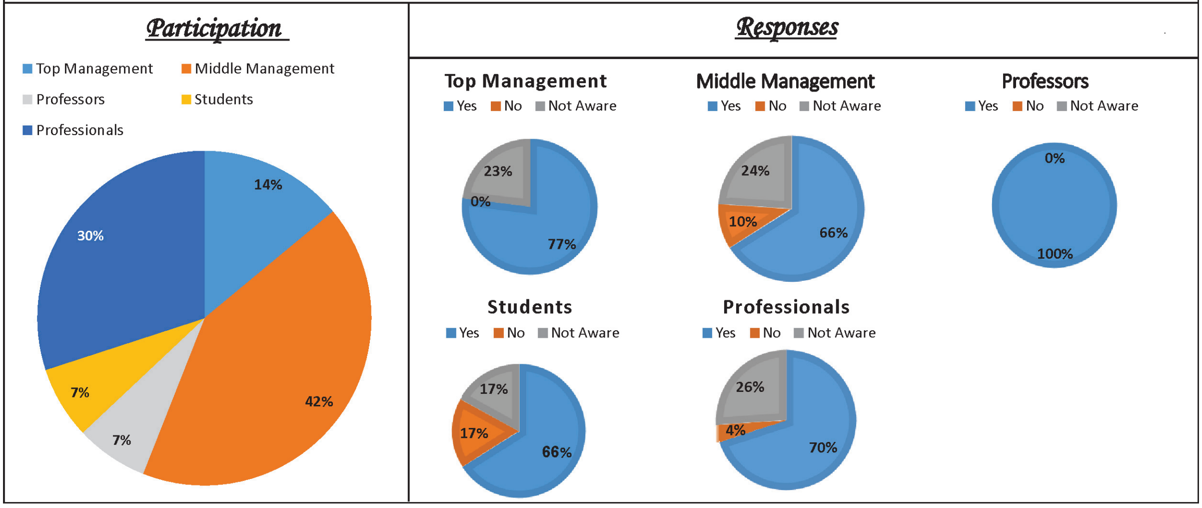


Fig. 5.9 Consideration of local conditions

Q. Does your passive design consider local conditions in reducing the heating or cooling requirements of your structure?



5.5.2 Awareness on Energy Efficiency Building Code (ECBC)

ECBC is the key for implementation of passive cooling principles in building envelope designs. The questionnaire used for the survey adequately covered questions related to awareness and provisions of ECBC. Figs. 5.10 to 5.15 present the survey findings. The responses reveal that there is reasonably good awareness among the respondents except the professionals level about the ECBC. However, most of the respondents have limited understanding of the provisions of ECBC except the top management. The overall gap varies from 13% to 50% which indicates there is a need for intervention to improve the awareness and in-depth understanding of various provisions of the ECBC for achieving required Energy Performance Indicator (EPI) in the upcoming/future buildings.

Fig. 5.10 Awareness about ECBC

Q. Are you aware that ECBC code is applicable for commercial buildings having a connected load of 100kW or contract demand of 120 KVA and above.

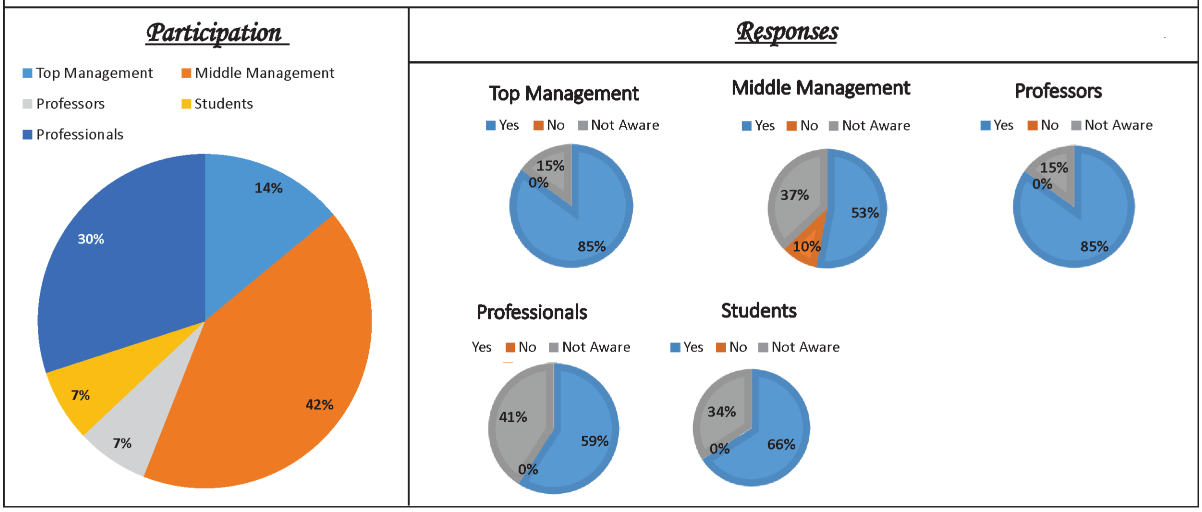


Fig. 5.11 Energy saving-ECBC compliant buildings

Q. Whether you are aware that the ECBC-compliant buildings deliver 20-25% of energy savings in different climates, when compared with typical buildings.

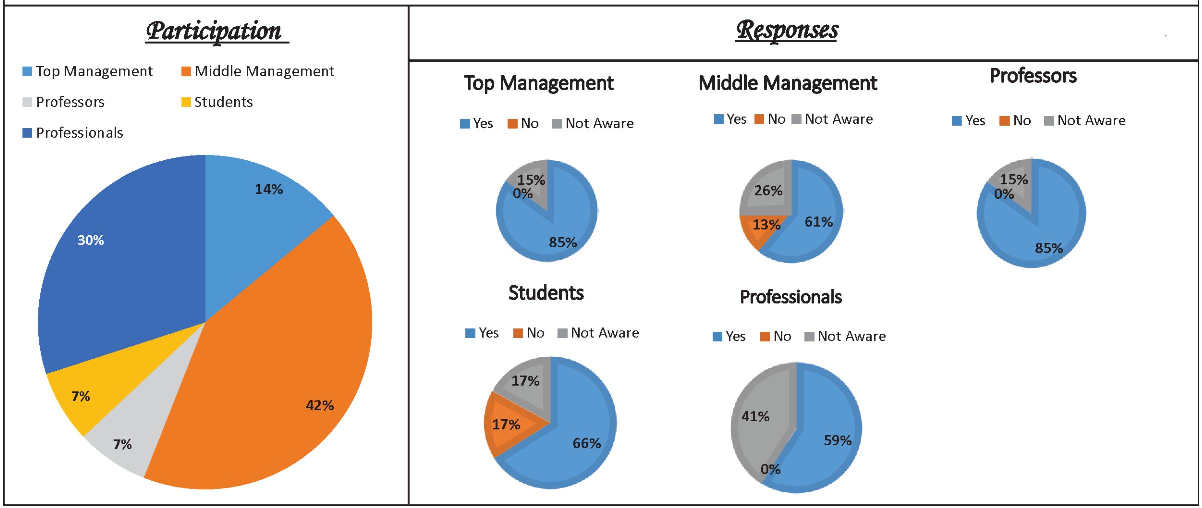


Fig. 5.12 ECBC requirements

Q. Whether are you considering the ECBC norms while preparing or reviewing the Bill of quantity?

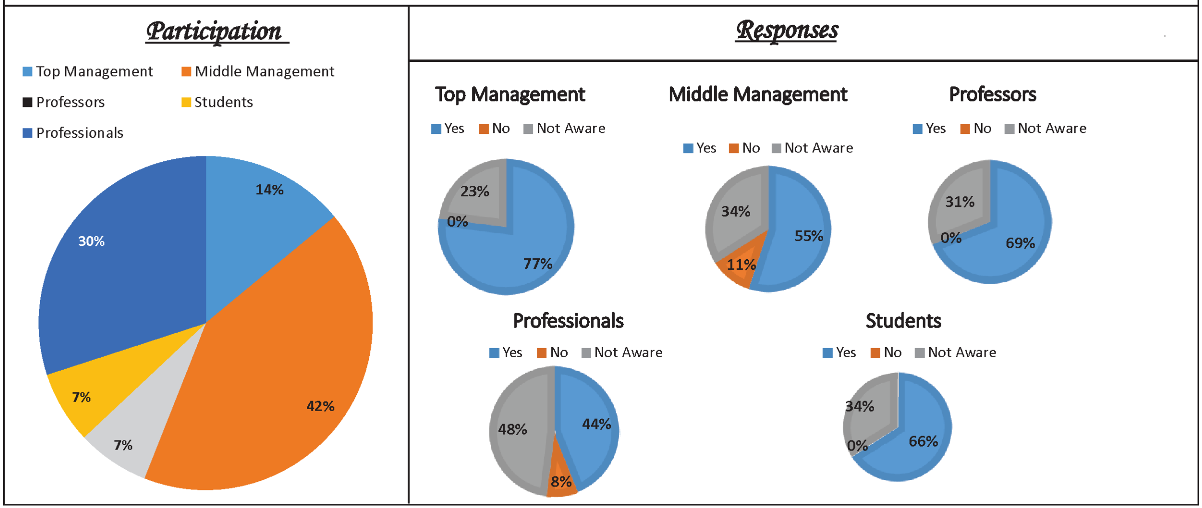


Fig. 5.13 Compliance audit of building as per ECBC

Q. Whether your company conducts audit after completion of building construction for ensuring compliance of implementation of provision of energy conservation building code in their building construction.

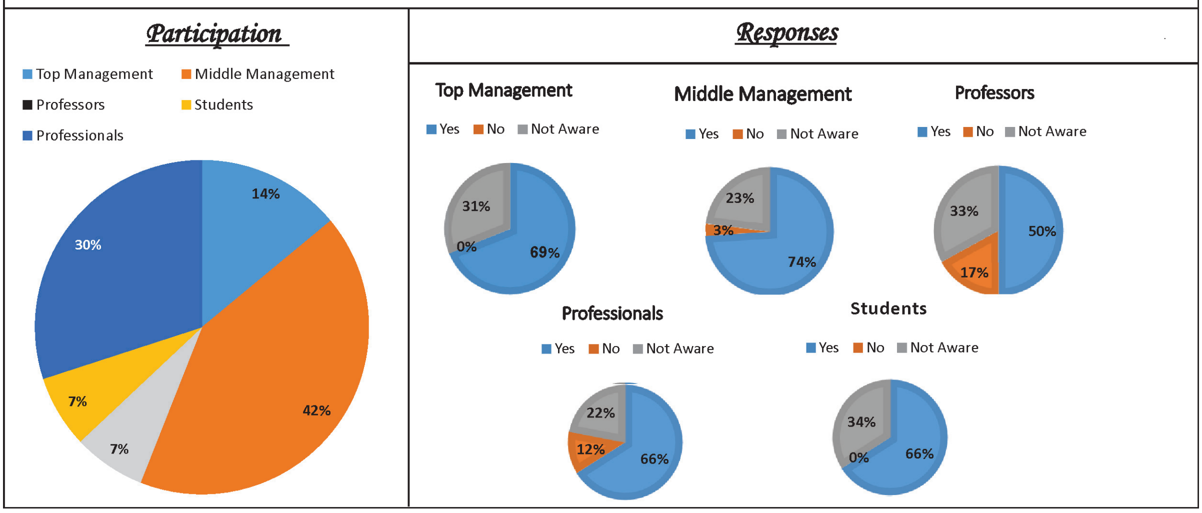


Fig. 5.14 Awareness about building control systems

Q. Is there a focus on Comfort Systems and Controls:

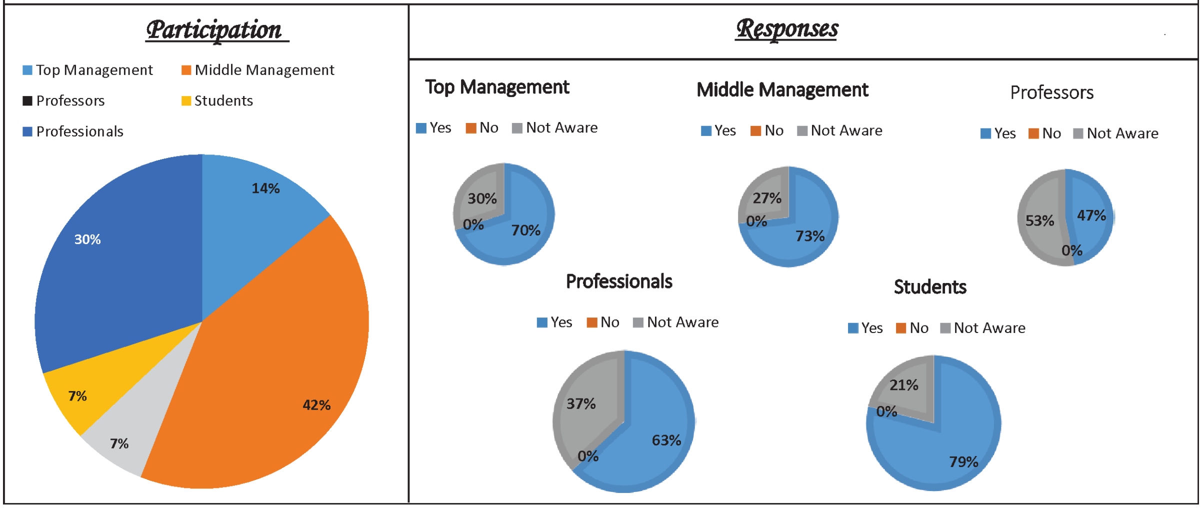


Fig. 5.15 Compliance audit of building as per ECBC

Q. Whether your company conducts audit after completion of building construction for ensuring compliance of implementation of provision of energy conservation building code in their building construction.

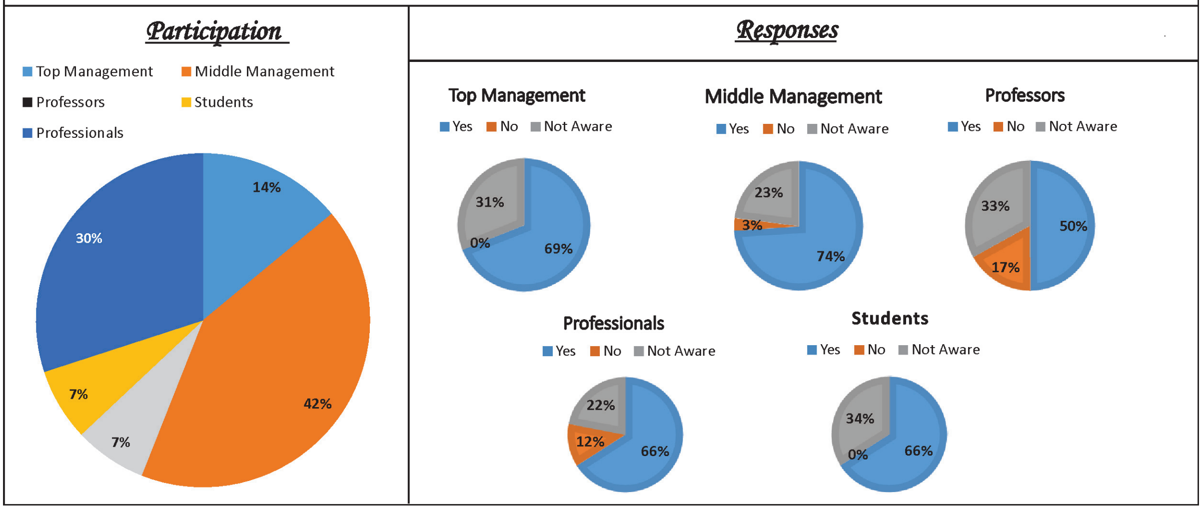


Fig. 5.16 ECBC is in curriculum of degree courses

Q. Whether the ECBC was covered in your curriculum of course under Degree program for engineering courses.

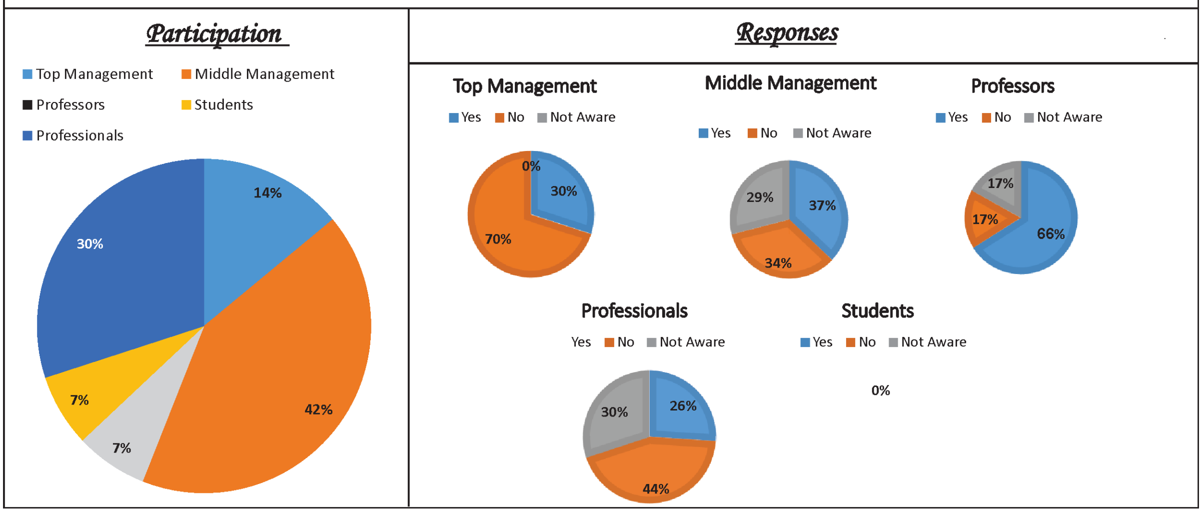
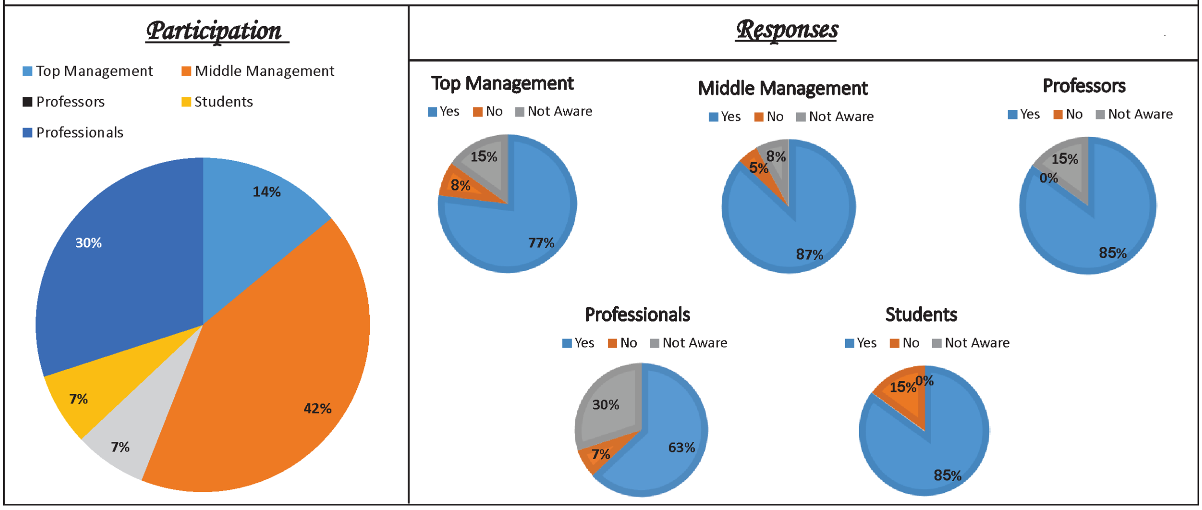


Fig. 5.17 Compliance audit of building as per ECBC

Q. Does your structure use LED lighting fittings?



5.5.3 HVAC equipment and non-HCFC and low-GWP technologies

HVAC equipment is widely used for providing comfort conditions in the built space. It is the major consumers of energy in the buildings. HVAC equipment and non HCFC and low-GWP technologies are very well covered in the survey. The responses reveal that there is a limited awareness among the construction community, especially among the professionals who are the key for implementation. The gaps vary from element to element. The overall gap varies from 15% to 100% which indicates that there is a need for intervention to improve the awareness and in-depth understanding of various aspects of the HVAC technologies.

Fig. 5.18 Energy efficient HVAC equipment

Q. Whether you are aware that ECBC encourage optimal size/capacity of HVAC systems, which helps decrease energy costs.

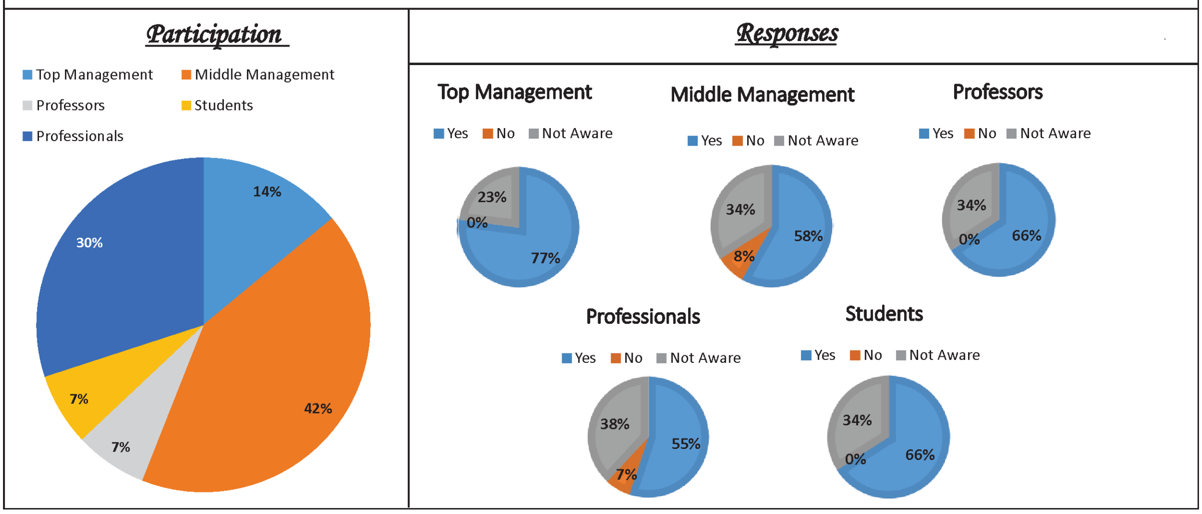


Fig. 5.19: Awareness about HVAC system components

Q. Heating, Ventilation and Air-conditioning: system and equipment types, sizes, efficiencies and controls; economizers; variable speed drives; piping insulation; duct sealing, insulation and location; solar water heating system; requirement for balance report.

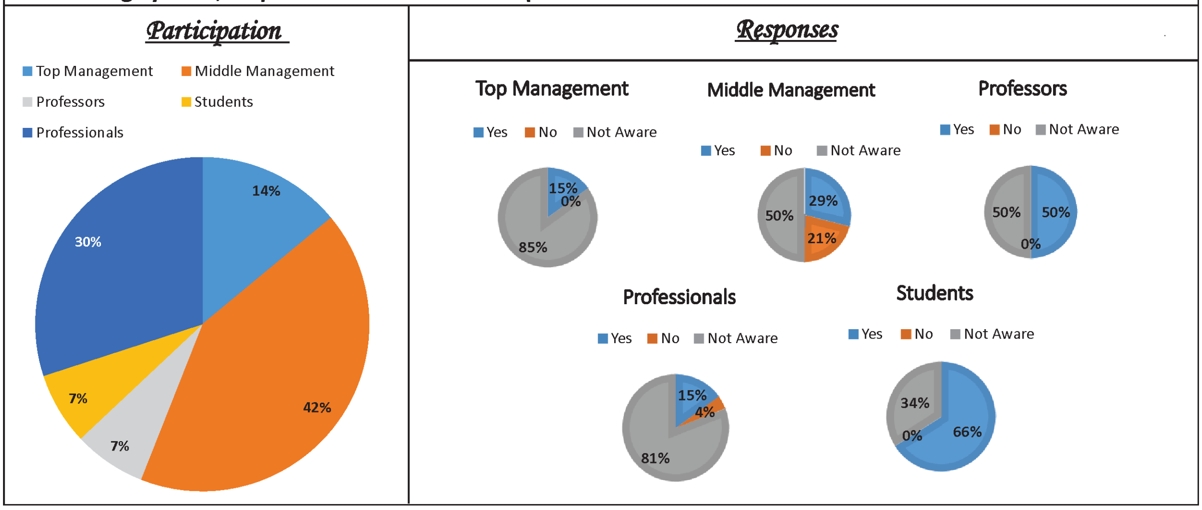


Fig. 5.20 Non-HCFC & low-GWP technologies

Q. Does your organization use non-HCFC and low Global warming potential (GWP) refrigerants for active cooling systems.

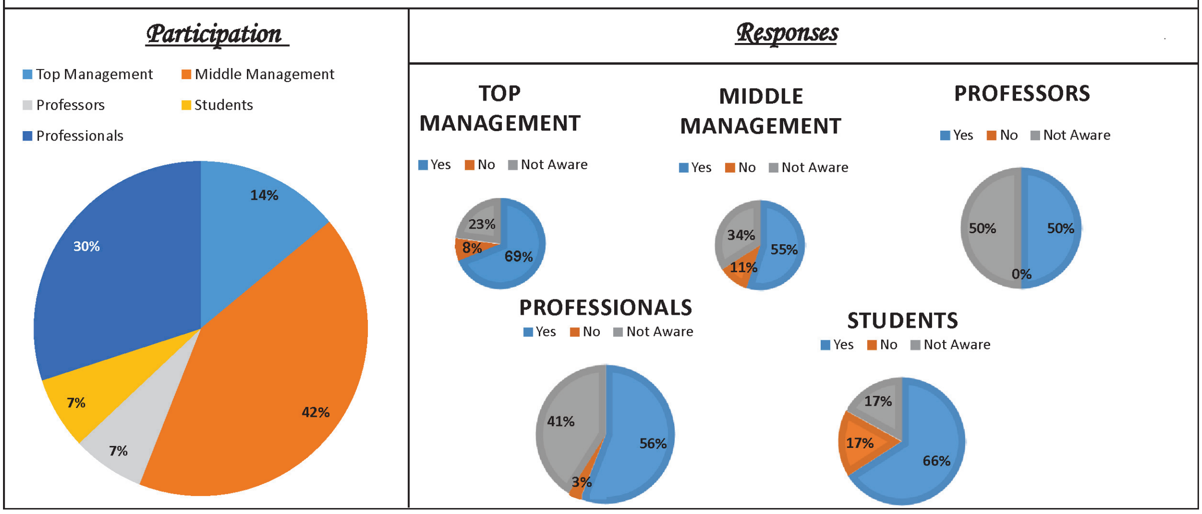


Fig. 5.21 Knowledge of alternatives to HCFCs

Q. Are you aware of common alternatives of HCFCs?

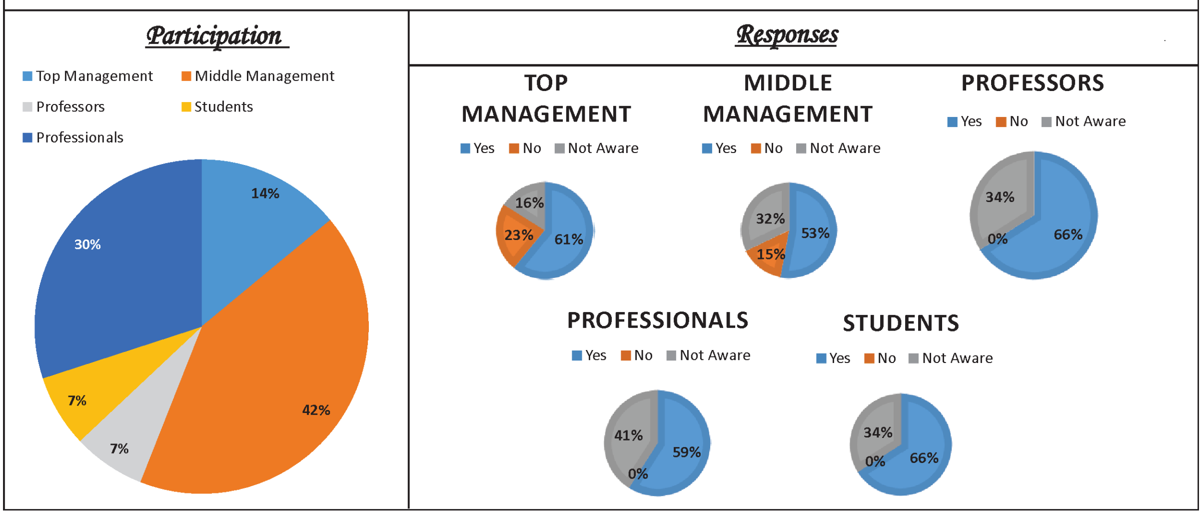
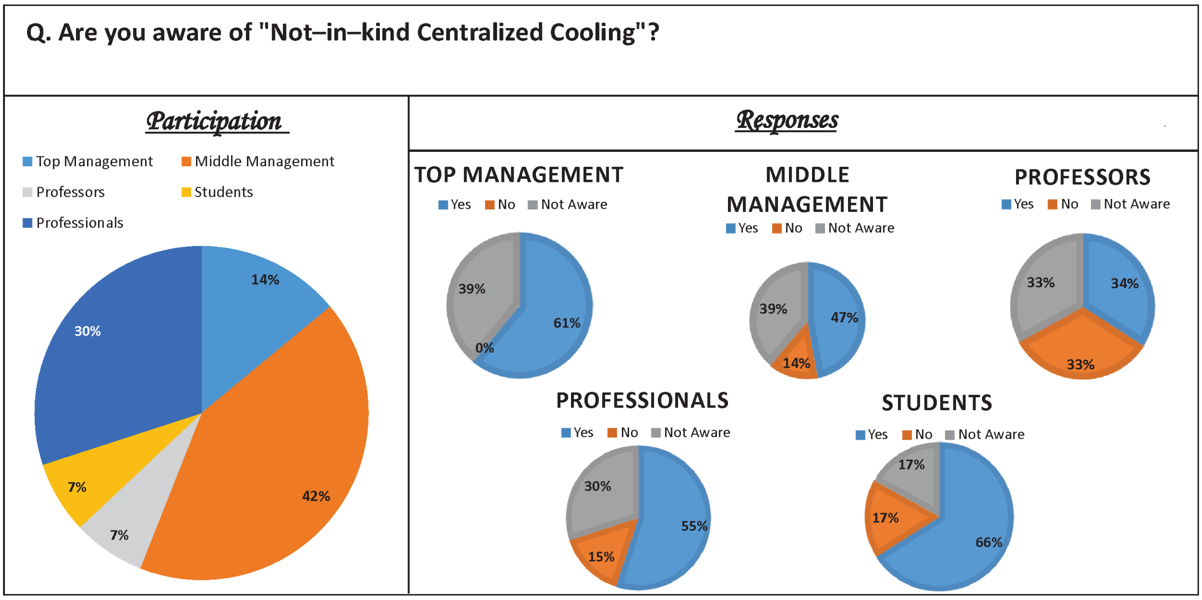


Fig. 5.22 Awareness of not-in-kind HVAC technologies



5.5.4 Indoor air temperature, controls and operation and maintenance of HVAC equipment

Indoor air temperature and its control play a significant role not only in reduction of cooling requirement and energy consumption for the given space without sacrificing the comfort level and health of occupants in the buildings. Another important aspect to reduce refrigerant demand and its emissions to the environment to follow proper operation and maintenance practices to reduce breakdowns, leakage of refrigerant and energy use. This element has also been covered in the survey. The responses reveal that there is lack of awareness among the respondents about this important element and gaps vary from element to element. The overall gap varies from 15% to 85%, indicating a need for intervention to improve the awareness and in-depth understanding about the maintaining indoor air temperature, controls and maintenance of HVAC equipment.

Fig. 5.23: Strategies for indoor air temperature

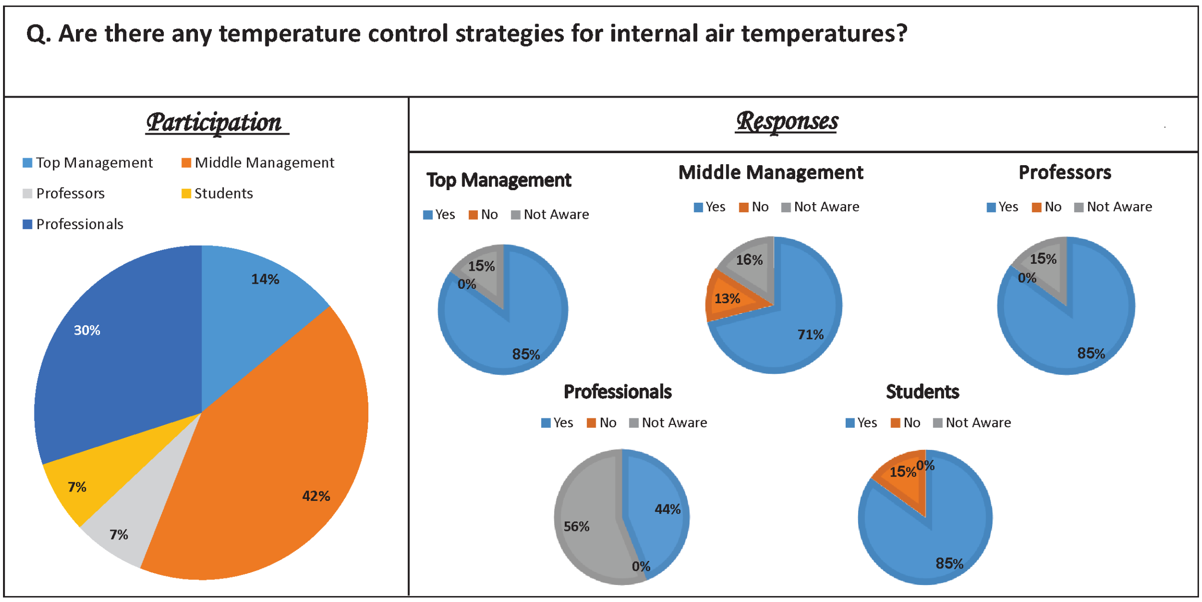


Fig. 5.24: Assessment of comfort indoor conditions

Q. Are the occupants' dissatisfaction with indoor comfort conditions? Are the occupants' dissatisfaction with indoor comfort conditions?

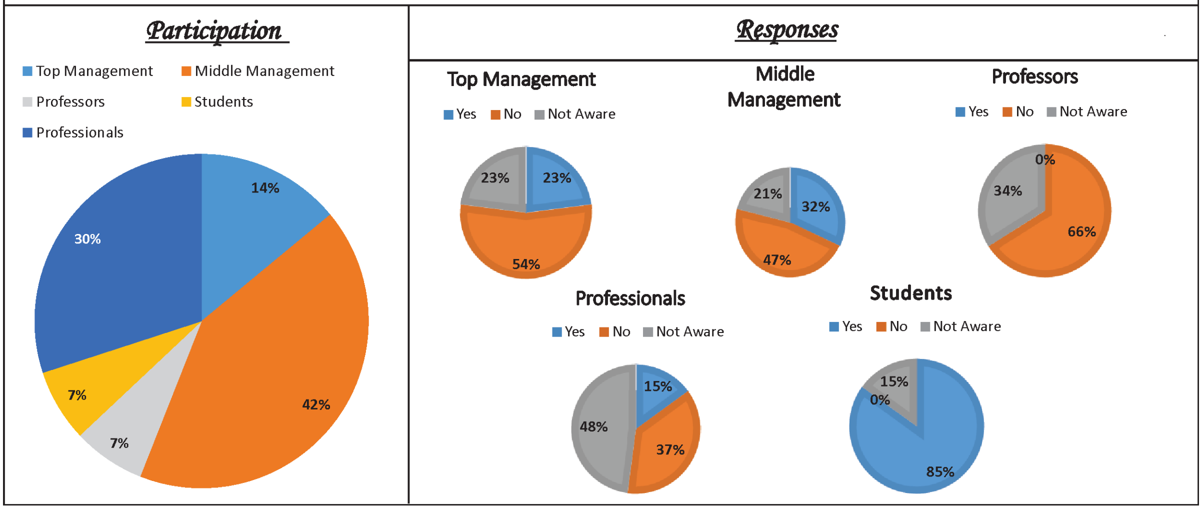


Fig. 5.25: Comfort systems and controls

Q. Is there a focus on Comfort Systems and Controls:

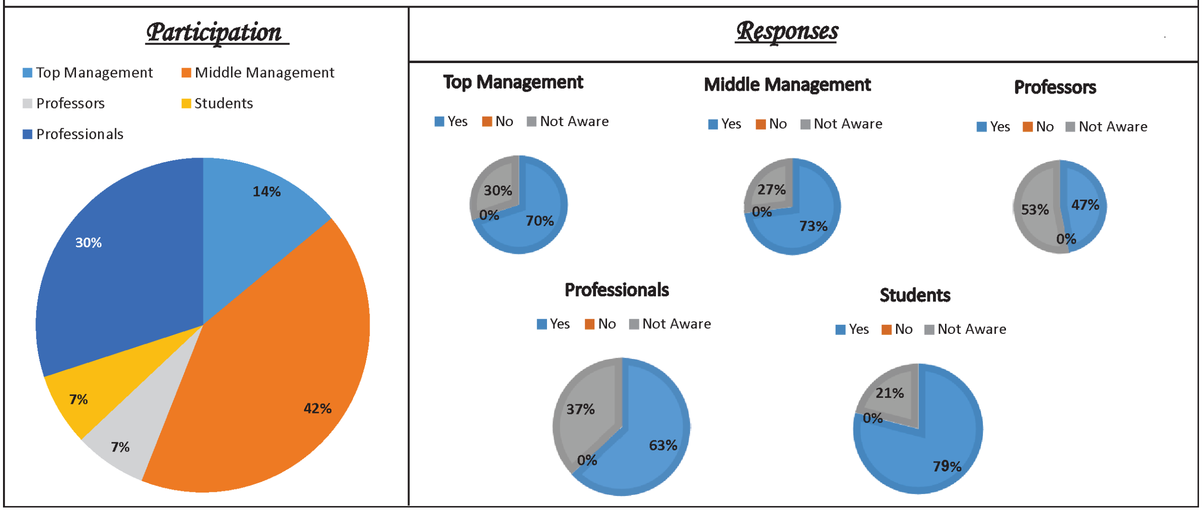
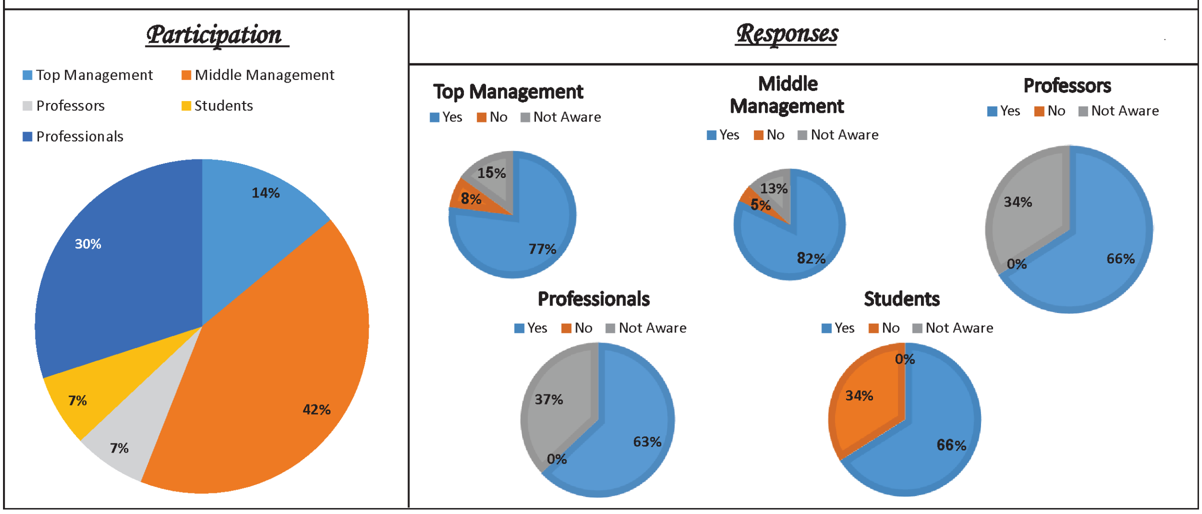


Fig. 5.26: Operation and maintenance system of HVAC equipment

Q. Are the standard operating procedures for the maintenance of Air Conditioning Systems available?



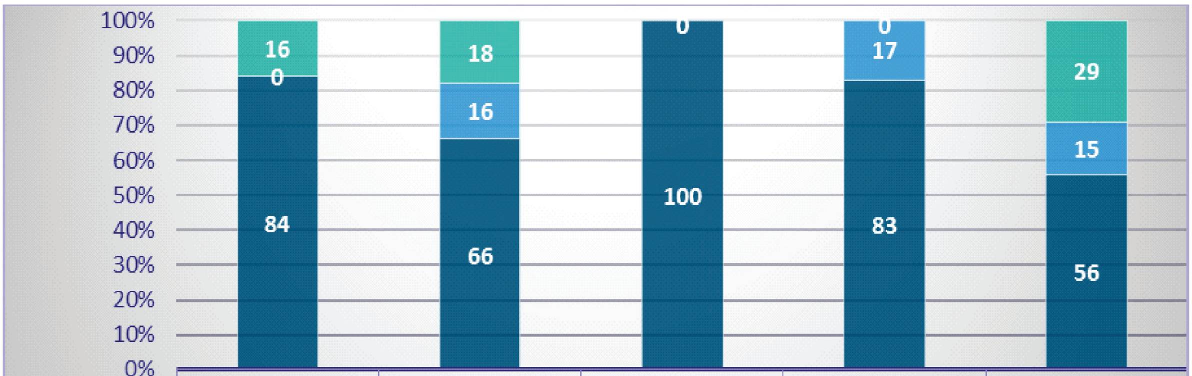
5.6 Skill Gap Analysis

Skill gap analysis, as the name indicates, is the process of the comparison of the current skill levels with the expected skill levels of the respondents to meet the chartered objectives, which in this case is the incorporation of passive cooling designs for reducing the overall cooling needs in the buildings, energy consumption and the refrigerant demand. A qualitative analysis of the responses of the stakeholders, the organizations and individuals engaged in the construction industry and related areas. The skill gaps have been identified and presented for some of the elements in Figures from 5.26 to 5.28.

Skill gap about passive cooling design process

Figure 5.27 shows that the top management and academicians are well aware about the passive cooling design process. However, more than 40% of professionals who are the key to implement the passive cooling principles and devices are not aware which is the key to reduce the cooling requirement leading to reduce energy consumption and refrigerant use.

Fig. 5.27: Skill gap in passive cooling design process

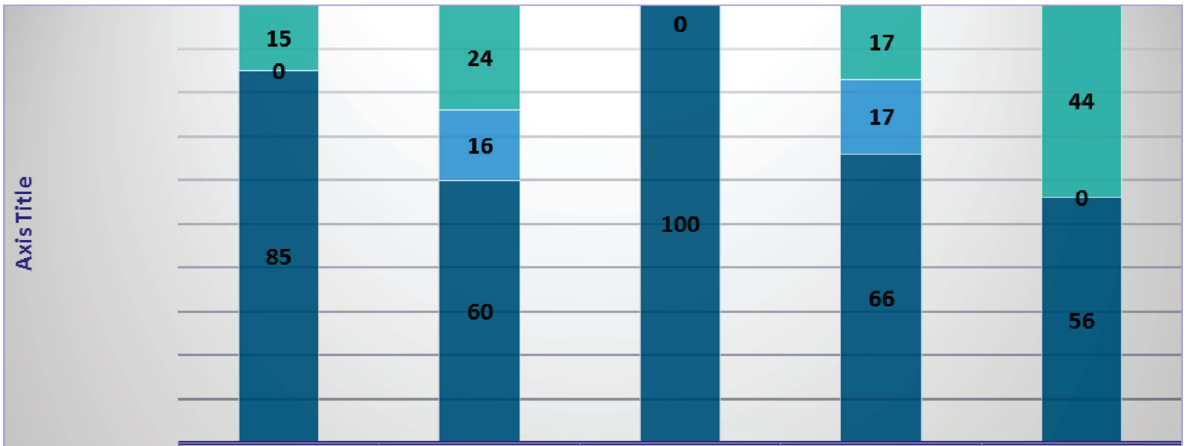


	Top Management	Middle Management	Professors	Students	Professionals
Not Aware	16	18	0	0	29
No	0	16	0	17	15
Yes	84	66	100	83	56

Awareness gap for reduction in Cooling costs over the lifecycle of structures by passive cooling measures

Figure 5.28 shows results of another parameter which is quite important for the building owners, the reduction in cooling costs during the life cycle of the building. This parameter is very much related to understanding of principles of passive cooling and devises, the results are more less similar, the top management, middle management and professors are aware about the passive cooling design process. In this case also only 56% of practicing professional are aware about it, in the middle management segment 40% of the respondents are also not aware about it. The practicing professional are the key to implement in the field.

Fig. 5.28: Awareness gap for reduction in Cooling costs over the lifecycle of structures by passive cooling



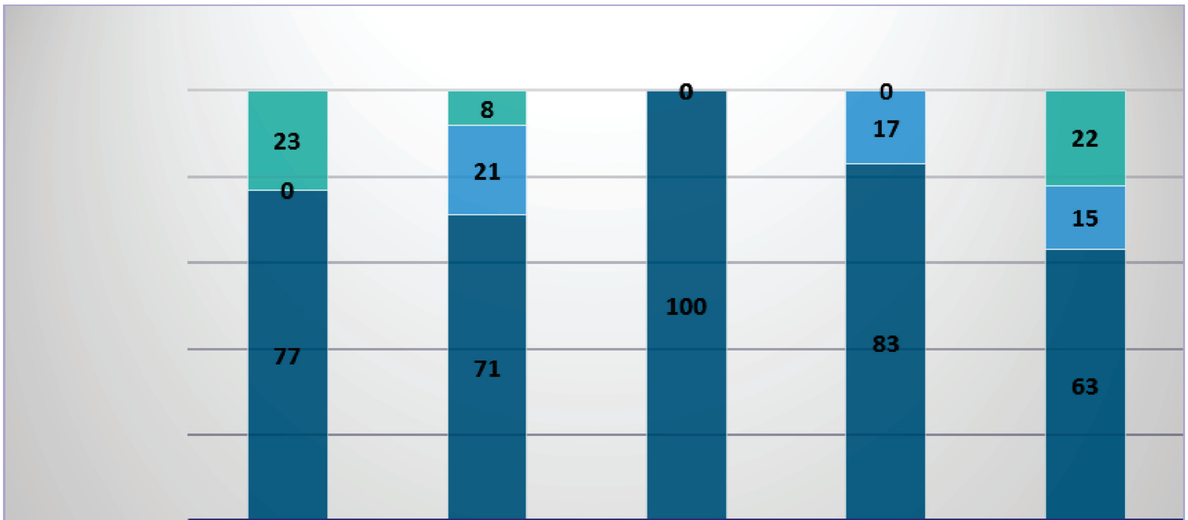
	Top Management	Middle Management	Professors	Students	Professionals
Not Aware	15	24	0	17	44
No	0	16	0	17	0
Yes	85	60	100	66	56

Axis Title

Awareness gap about Awareness of Green Building Concept

Figure 5.29 shows results of the awareness of Green Building Concept which is one of the important tools to move the construction industry and building owners for adoption of passive cooling principles. The Green building rating systems in the country are well established and are being opted by several building developers and owners. This parameter is very much related to understanding of principles of passive cooling and devises, the results are more or less similar, the top management, middle management, professors are quite familiar with Green Building Rating systems. In this case only 8% to 37% of the respondents are not aware about the Green Building Rating systems used in the county. The construction industry professionals need to be educated in the country.

Fig. 5.29: Awareness of Green Building Concepts



	Top Management	Middle Management	Professors	Students	Professionals
Not Aware	23	8	0	0	22
No	0	21	0	17	15
Yes	77	71	100	83	63

5.7 Interventions to fill up the awareness and knowledge gaps

The analysis of the outcomes of the survey demonstrates that overall there is a wide gap among the various key categories of the stakeholders in the construction industry about passive cooling principles in the building design to reduce cooling requirement, energy consumption for cooling and refrigerant use. It has been observed that the percentage knowledge enhancement needs for the building construction industry would be as presented in the table 5.2

Table 5.2: Percentage Knowledge Enhancement Needs Matrix

Knowledge Level Enhancement needs	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%
Percentage of Respondents	67	9	6	4	4	4	3	2	1	0

Evaluation of table indicates various input extents of the knowledgebase enhancements that would be required to meet the objectives of reducing the cooling needs in line with India Cooling Action Plan and other related policies of Government of India. The skilling initiative, therefore, could be focused towards creating program ranges aimed at passive cooling and non-HCFC/low-GWP alternatives. Most optimum approach could be the creation of a system of modular training programs taking into account skill levels of the manpower involved in the various activities in the construction industry with forward integration possibilities (Allowing the trained individual to progress ahead on the competency scale and grow vocationally/professionally with time and experience).

It has been revealed by this study that the awareness levels of a large proportion of respondents are very low or scant awareness about passive cooling concepts or non-HCFC/ low-GWP alternatives. This provides good opportunities for Human Resource capacity creation in this field. Our recommendations for the sector could be summarized in the following subsections:

5.7.1 Identification of focus Areas of skilling for promoting passive cooling

Passive cooling approaches need to be focused on creating commissioning, using & maintaining, and decommissioning the passively cooled buildings at the end of their economic life. So, the complete complement of skills for implementing passively cooled buildings should cover all the required activities of needed for the entire life cycle of the buildings. Broadly speaking these could be summarized in the following focus areas/streams:

- Site selection activities,
- Passive cooling approach identification suiting the site requirements,
- Spatial designing for incorporating the passive cooling concepts,
- Designing the structures to meet passive cooling requirements,
- Selecting suitable materials and fixtures,

- Constructing/installing selected materials,
- Commissioning the building envelope,
- Providing maintenance services and assistance for passively cooled building envelopes, and finally
- Decommissioning the buildings reaching the end of their effective economic lives.

For creating a sizeable stock of passively cooled buildings we require capable compliment of human resources to address each of above-mentioned areas. Each of the focus areas need to be served by proper skill level manpower. The following section discusses the skill levels that we need to cultivate in all these focus areas.

5.7.2 Skill Levels

For executing any construction project, we require planners, designers, procurement professionals, construction professionals, tradesmen and finally artisans. With respect to passively cooled buildings the level of human resources to be developed would include the following:

- Tradesmen/Artisans in various construction trades

Currently there are 47 trades in the construction wherein CIDC conducts trainings. This number could be increased to include new streams, or the contents of few of these programs could be enhanced to meet the sector specific requirements, if needed.

- Supervisory Trades

Currently there are 10 streams wherein CIDC conducts trainings. These could also be increased to include new streams, or the contents of few of these programs could be enhanced to meet the sector specific requirements, if needed.

- Engineering & Management Skills

These are the next level skills where we need to cultivate the executing prowess of the professionals, both practicing as well as sector entrants. This could be done through specific sabbaticals for practicing professionals, and internships for students directed towards different focus areas, as highlighted earlier in this section. Currently CIDC is working with AICTE, ECI, CIDC Members, Infrastructure Project owners, ULBs, Smart City Owners, Universities, Engineering Colleges, and other major constituents of building construction industry for providing such trainings to students, teaching faculty members, working professionals, design professionals, and likewise. CIDC is one of the leading organizations engaged in imparting training at various skill levels of the construction industry in the country. The CIDC is in the best position to further enhance its skilling activities to meet the upcoming challenges as outlined by the ICAP.

5.7.3 Skilling and certification needs with respect to ODS phase out, energy efficiency, safety and alternative refrigerants

Skilling and certification of the individuals serving the building industry at different skill levels needs to be trained on design and construction of energy efficient building envelopes using principles of passive cooling designs as outlined in ECBC-2017 for reducing in cooling requirement of refrigerant based active cooling, energy use and refrigerant demand to meet the goals of ICAP by 2037-38 and with a focus on deploying non-HCFC/low-GWP alternatives in upcoming building projects.

These could be imparted through a bouquet of programs that could range from short, medium or long-term training and awareness programmes. Such programs could include:

- Awareness and consultation workshops.
- Interactive workshops with municipal bodies/ULBs for inclusion of HPMP provisions in municipal rules.
- Conferences and seminars.
- Topic specific dedicated short-term training programs on related subjects including passive cooling, ODS phase out, energy efficiency, and alternative refrigerants.
- Vocational Training programs for creating artisans trained in applying stipulations of HPMPs
- Recognition of Prior Learning of technicians and operators engaged in current Green Building projects.
- Executive Development Programs for junior, mid, and senior management.
- Specialized topic specific full-length training programs.
- Revision of curricula of architecture, engineering, diploma, ITIs, vocational institutions, etc. with the objective to provide adequate knowledge and training on these important topics
- Educational programs run with Colleges/Universities resulting in skill certifications, diplomas, and degrees.
- Research initiatives to develop newer methodologies, systems, materials, or building components.

CIDC is one of the apex institutions conducting knowledge-based courses and long terms and short-term programmes at several of skill levels to cater needs of construction industry in association with the line ministries/department and apex institutions organizations. The same could be strengthened to continue this important mission.

5.8 Policies for facilitating Implementation

While looking at developing Human Resources there is also a need to streamline the policy and implementation framework at different levels including the municipalities level with an objective to facilitate smooth implantation. Ministry of Housing and Urban Affairs (MoHUA), Government of India, the core ministry would play a vital role in stream lining the policies and rules at various levels including municipalities level for the implantation of development energy efficient building envelopes to reduce cooling requirement. This also includes energy consumption and refrigerant demand for cooling in commercial and residential buildings for successful achieving the goals of ICAP and other Sustainable Development Goals (SDGs).

5.9 Conclusion

In this chapter we discussed the survey outcomes as identified in the survey, the skill gap analysis, identified skill enhancement needs, proposed knowledge base enhancement mechanisms and suggestions for implementing the skill enhancement initiatives. These details provide inputs for the next chapter where we are discussing the recommendations of the initiative for building construction industry.

Chapter 6: Recommendations

6.1 Introduction

Recognizing that cooling requirement is cross sectoral and growing fast with a CAGR of 8% in the country being an essential part of economic growth and meeting several sustainable goals (SDGs). Space cooling is one of the major and important sectors of the total cooling requirement in the country and it is growing with a CAGR of 11%. Indoor thermal comfort is increasingly becoming, an essential for well-being, health and productivity of the people. India Cooling Action Plan (ICAP) published in March, 2019 provides an integrated and long-term vision across sectors with a prerequisite to provide "Thermal Comfort for All" and sustainable cooling across sectors. Whilst the cooling demand in India is related to hot and humid climate prevailing in most part of the country, increasing population and rising aspirations and growth of economy also drive demand.

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

Thus, it calls for promoting wider penetration of climate responsive built spaces to bring indoor temperatures within acceptable thermal comfort band through passive cooling thus reducing refrigerant based cooling requirement. It is the key for meeting the challenging growth of cooling in the country in coming decades. This would necessitate to incorporate relevant provisions of energy efficient building design stated in ECBC to minimize active cooling needs by using passive design elements for all commercial (non-residential) buildings. Efforts are underway by BEE for a nation-wide adoption and enforcement of ECBC for both commercial and residential sectors at the municipal and urban and local body level and through development of city level action plans.

ICAP has made a number of recommendations for early implementation of ECBC across the country. The Ozone Cell, MoEF&CC has developed and published document outlining the Action Points along with identification of agencies/ departments in close cooperation with line ministries/departments and other stakeholders for Operationalizing Space Cooling Recommendations of the ICAP by drawing synergies with existing frame work and Government schemes/programmes. It has been showing very encouraging outcomes towards the implementation of recommendations in the space cooling sector of the ICAP.

In addition, the ongoing refrigerant transition is moving towards the use of HVAC equipment with non-ODS and low-GWP refrigerants. Active air-conditioning equipment using natural or non-HFC, low-GWP refrigerant must only be deployed.

Acknowledging that aggressive market awareness campaigns to sensitize both the construction community , building owners as well as users about the multiple benefits of passive cooling principles to reduce cooling, energy consumption and refrigerant demand and use of non-HCFC and low-GWP refrigerant based HVAC equipment/appliances will go in a long way in the implantation of ICAP recommendations, the current study was undertaken to assess awareness and knowledge gaps among the various segments of personnel engaged in the construction industry.

6.2 Recommendations

The outcomes of the survey as presented in Chapter 4 clearly brings out that the survey covered a wide spectrum of topics of building designs to reduce cooling demand, energy consumption and refrigerant use and its emissions. These topics have been clubbed in the following broad areas:

(i) Awareness and understanding of Passive cooling principles and devises;
(ii) Awareness on Energy Efficiency Building Code (ECBC);
(iii) HVAC equipment and non-HCFC and low-GWP technologies;
(iv) Indoor air temperature controls and
(v) Operation and maintenance of HVAC equipment.

Further, the analysis of responses of the survey for the areas listed above reveals that there is a need to enhance awareness, skills and subject understanding of personnel engaged in the construction industry for the wider adoption of passive cooling principles and non-HCFC, low-GWP technologies. This also provides good opportunities for Human Resource capacity creation in this field.

6.2.1 Skilling and certification of Personnel

Skilling and certification of the individuals serving the building industry at different skill levels will play a vital role in design and construction of energy efficient building envelopes using principles of passive cooling designs as outlined in ECBC-2017 for reducing cooling requirement of refrigerant based active cooling, energy use and refrigerant demand to meet the goals of ICAP by 2037-38 and with a focus on deploying non-HCFC/low-GWP alternatives in upcoming building projects.

The trainings could be imparted through a bouquet of programs that could range from short, medium, and long-term training and awareness programs. Such programmes could include:

- Awareness and consultation workshops.
- Interactive workshops with municipal bodies/ULBs for inclusion of ECBC provisions in municipal rules.
- Conferences and seminars.
- Topic specific dedicated short-term training programs on related subjects including passive cooling, ODS phase out, energy efficiency, and alternative refrigerants.
- Vocational Training programs for creating artisans trained in applying stipulations of HPMPs
- Recognition of Prior Learning of technicians and operators engaged in current Green Building projects.
- Executive Development Programs for junior, mid, and senior management and other related categories of construction personnel.
- Specialized topic specific full-length training programs.
- Revision of curricula of architecture, engineering, diploma, ITIs, vocational institutions, etc. with the objective to provide adequate knowledge and training on these important topics
- Educational programs run with Colleges/Universities resulting in skill certifications, diplomas, and degrees.
- Research initiatives to develop newer methodologies, systems, materials, or building components.

6.2.2 Long-term sustainable framework for skill development

- Revision of curricula of engineering, diploma, ITIs, vocational institutions, etc. with the objective to provide adequate knowledge and training of design of energy efficient building incorporating principles of passive cooling and environmentally friendly building material to reduce active refrigerant-based cooling requirement, energy consumption and refrigerant demand. The courses related to refrigeration and air conditioning must include changing technical development, especially the non-ODS and low-GWP refrigerants as well as related issues of safety as most of the low-GWP refrigerants likely to be flammable. The nodal ministries/ department may be requested to take up this issue at the earliest.

- The Council of Architecture (COA) constituted by the Government of India under the provisions of the Architects Act, 1972 is the apex body to regulate the education and practice of profession the throughout country besides maintaining the register of architects. The architects play vital role in building design and execution. The Council of Architecture should not to only consider the revising the curriculum but also involve in educating and training to the personnel of construction industry on this important subject design of energy efficient buildings taking in account passive cooling principles and environmentally friendly building materials.

- Ministry of Housing and Urban Affairs (MoHUA), Government of India, the core ministry would play a vital role in stream lining the policies and rules at various levels including amendments to the municipalities bylaws for implementation of development energy efficient building envelopes to reduce cooling requirement. Energy consumption and refrigerant demand for cooling in commercial and residential buildings for achieving the goals of ICAP and other Sustainable Development Goals (SDGs).

- Bureau of Energy Efficiency (BEE) to expedite the adoption of ECBC for commercial and residential buildings.

- The Engineering Council of India (ECI) which conducts Continued Professional Development (CPD) programs, should incorporate this important subject in their programmes.

- CIDC is the apex body for imparting education and training at various skill levels and should consider to include the subject of passive cooling design, non-ODS, low-GWP and energy efficient technologies in their training programmes on continuous basis.

- Ozone Cell, MoEF&CC should continue to develop knowledge documents for dissemination to the target group, the construction and HVAC industry, as part of ICAP implementation.

Summary of recommendation for successful implementation passive cooling principles in the design of buildings for reducing refrigerant based cooling requirement, energy consumption for cooling and refrigerant demand and promoting use of non-HCFC, low-GWP technologies for HVAC systems in buildings are presented in Table 6.1.

Table 6.1: Recommendations

Areas	Recommendations
Awareness and understanding of Passive cooling principles and devises	Skilling programmes through training or consultation workshops to be organized for individuals serving the building industry at different skill levels.
	Inclusion of "Energy efficient building design by using passive design element" in the training programmes.
	Research initiatives to develop newer methodologies, systems, materials, or building components incorporating Passive cooling principles.
	The Council of Architecture should involve in educating the personnel of construction industry on the design of energy efficient buildings taking in account passive cooling principles and environmentally friendly building materials.
	CIDC should consider to include Passive cooling principles in their training programmes on continuous basis.
Awareness on Energy Efficiency Building Code (ECBC)HVAC equipment and non-HCFC and low-GWP technologies	Organize interactive workshops with municipal bodies/ULBs for inclusion of ECBC provisions in municipal rules.
	Revision of curricula of architecture, engineering, diploma, ITIs, vocational institutions, etc. with the objective to provide adequate knowledge of design of energy efficient building incorporating principles passive cooling and environmentally friendly building material to reduce active refrigerant-based cooling requirement, energy consumption and refrigerant demand.
	Stream lining the policies and rules at various levels including amendments to the municipalities bylaws for implementation of development of energy efficient building envelopes to reduce cooling requirement.
	Nation-wide adoption and enforcement of ECBC for both commercial and residential buildings at the municipal and urban and local body level and through development of city level action plans.
	Training programmes to focus on deploying non-HCFC/low-GWP alternatives, reduction in cooling requirement of refrigerant based active cooling, energy use and refrigerant demand in upcoming building projects.
	Architecture, engineering, diploma, ITIs courses related to refrigeration and air conditioning must include technical development, especially the non-ODS and low-GWP refrigerants as well as related issues of safety as most of the low-GWP refrigerants likely to be flammable.
	Ozone Cell, MoEF&CC should continue to develop knowledge documents for dissemination to the target group, the construction and HVAC industry.
	Promote use of not-in-kind technologies including trigeneration system, district cooling, thermal energy storage etc.
	Procurement guidelines for highest star labeled superefficient ACs, fans, chillers etc. with non-HCFC and low GWP options, wherever feasible
Indoor air temperature controls	Mandatory minimum indoor temperature settings (adaptive thermal comfort standards) in commercial buildings to reduce cooling requirement and energy consumption and promote healthy living/ working environment.
	Create public awareness on guidelines for default temperature setting of 24^{o}C issued by BEE for the commercial buildings viz. hotels, malls, offices, multiplex etc.
Operation and maintenance of HVAC equipment	Need to develop standard operating procedures for the operation and maintenance of HVAC equipment.
	To engage services of trained & certified RAC technicians.
	Customer awareness programmes reinforcing the need for hiring certified technicians.

ANNEXURES

Survey

Study report on

"Sensitizing Building Construction Community on Passive Cooling Design, Non-ODS, Low-GWP and Energy Efficient Technologies"

Name: ____________________ Organization: ____________________

Designation: ____________________ Contact Details ____________________

Type of Building: ____________________ Completed/Under Construction: ____________________

Dear Participant,

This questionnaire has been developed to evaluate the understanding of passive cooling designs and the use of non- Hydrochlorofluorocarbon (HCFC) and Low GWP alternatives practices in Building in the Industry. Please evaluate your own building, completed or under construction, with reference to:

I. Building Design:

1. *What type of Buildings are you constructing?*

   i) Residential Building ii) Hospitals iii) Health Care iv) Assembly v) Business

   vi) Educational vii) Shopping Complex viii) Mixed use building ix) Other

   Comments: --

   ----

2. *Are you aware of Green Building Concepts?*

   Have you applied them in your construction? Yes / No / Not Aware

   Comments: --

   ----

3. *Has the buildings designed as per CIDC's CCGR Green Norms:* Yes / No / Not Aware

   Comments: --

Passive Cooling Design:

Passive Cooling means using design approaches to reduce heat gain and increase heat loss. To ascertain that the structure being constructed has been designed to accrue the benefits of passive cooling design following is to be enquired from the stakeholders:

4. Are you aware of Passive Cooling Design process? [Yes] [No] [Not Aware]

   Comments: --
   ----

5. Are you applying such designs/processes for the structures you design or construct?

   [Yes] [No] [Not Aware]

   Comments: --
   ----

6. Are you aware that the cooling costs over the lifecycle of your structure could be reduced through passive cooling designs?

   [Yes] [No] [Not Aware]

   Comments: --
   ----

7. *If you are applying passive cooling design in your structures, what are main passive cooling design approaches being followed, Solar Control, Ventilation for cooling, Ground Cooling, Evaporative Cooling, or Radiative Cooling?*

   [Yes] [No] [Not Aware]

   Comments: --
   ----

8. Are any of the following arrangements used in your structures:

   a. Louver Shading Devices; [Yes] [No] [Not Aware]
   b. Double Glazing of openings; [Yes] [No] [Not Aware]
   c. Natural Ventilation of building spaces; [Yes] [No] [Not Aware]
   d. Green roofing; [Yes] [No] [Not Aware]
   e. Insulation; [Yes] [No] [Not Aware]
   f. Evaporative Cooling via water bodies/fountains; [Yes] [No] [Not Aware]
   g. Indirect Radiant cooling; [Yes] [No] [Not Aware]
   h. Light Colour Reflective painting? [Yes] [No] [Not Aware]

   Comments: --

   ----

9. Can the structure be modified to include the missing systems from the above list, if any?

Yes | No | Not Aware

Comments: ---

----

10. Are the facades of your structures designed to help reducing the heat gain by them?

Yes | No | Not Aware

Comments: ---

----

11. If yes, what is the estimated heat load reduction by such façade design?

Yes | No | Not Aware

Comments: ---

----

12. Does your passive design consider local conditions in reducing the heating or cooling requirements of your structure?

Yes | No | Not Aware

Comments: ---

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13. Is your structure exposed to a longer duration of sunlight?

Yes | No | Not Aware

Comments: ---

----

14. In case the structure is exposed to longer durations, are there systems to reduce the absorption of heat by your structure?

Yes | No | Not Aware

Comments: ---

----

15. Is the code in your Building is applied to:

i) Building envelope — Yes | No | Not Aware

ii) Mechanical systems and equipment, including heating, ventilating, and air conditioning, service hot water heating — Yes | No | Not Aware

iii) Interior and exterior lighting and — Yes | No | Not Aware *iv) Electrical power and motors and renewable energy systems*

Yes	No	Not Aware

Comments: --

----

16. If yes, what is the estimated heat load reduction by the application of such systems?

Yes	No	Not Aware

Comments: --

----

17. Are you aware that the construction drawings and specifications shall show all pertinent data and features of the following:

(a) Building envelope i.e. opaque construction materials and their thermal properties including thermal conductivity, specific heat, density along with thickness; fenestration U-factors, solar heat gain coefficients (SHGC), visible light transmittance (VLT) and building envelope sealing documentation; overhangs and side fins, building envelope sealing details;

Yes	No	Not Aware

(b) Heating, Ventilation and Air-conditioning: system and equipment types, sizes, efficiencies and controls; economizers; variable speed drives; piping insulation; duct sealing, insulation and location; solar water heating system; requirement for balance report.

Yes	No	Not Aware

Comments: --

----

18. Whether you are aware that the Cool roof is a roof with top layer of material that has high solar reflectance and high thermal emittance properties. Cool roof surfaces are characterized by light colors so that heat can be rejected back to the environment.

Yes	No	Not Aware

Comments: --

----

19. Does your structure include systems supporting passive evaporative cooling?

Yes	No	Not Aware

Comments: --

----

20. If yes, what is the heat load reduction achieved/expected through such systems?

Yes | No | Not Aware

Comments: --

----

21. Whether are you considering the ECBC norms while preparing or reviewing the Bill of Quantity.

Comments: --- Yes | No | Not Aware

----

22. Whether you are aware that the ECBC-compliant buildings deliver 20-25% of energy savings in different climates, when compared with typical buildings.

Yes | No | Not Aware

Comments: --

----

23. Are you aware that ECBC code is applicable for commercial buildings having a connected load of 100kW or contract demand of 120 KVA and above.

Yes | No | Not Aware

Comments: --

----

24. Have you calculated Energy Performance?
(as with ECBC Mandatory requirements nos.4.2, 5.2,6.2 and 7.2)

Yes | No | Not Aware

Comments: --

----

25. Whether you are familiar with various construction materials and their thermal properties while finalizing building design.

Yes | No | Not Aware

Comments: --

----

26. Whether the ECBC was covered in your curriculum of course under Degree programme for engineering courses.

Yes | No | Not Aware

Comments: --

----

27. Whether you have attended any training programmes or sessions on application of ECBC norms in the building design.

Yes | No | Not Aware

Comments: --

----

28. Whether you are aware that ECBC 2017 prescribes minimum requirements for opaque components (wall and roof), fenestration systems (window, skylight), shading, and day lighting.

Yes | No | Not Aware

Comments: --

----

29. Whether you are aware that adequate daylighting can result in 20-30% of energy savings.

Yes | No | Not Aware

Comments: ---

----

30. Whether you are aware that ECBC encourage optimal size/capacity of HVAC systems, which helps decrease energy costs.

Yes | No | Not Aware

Comments: ---

----

31. Whether you are aware that ECBC provides insulation requirements for the pipes and ducts used in HVAC systems.

Yes | No | Not Aware

Comments: ---

----

32. Whether your company conducts audit after completion of building construction for ensuring compliance of implementation of provision of energy conservation building code in their building construction.

Yes | No | Not Aware

Comments: ---

----

33. Have you checked the Building Envelope for:

i) Mandatory requirements — Yes | No | Not Aware

ii) Fenestration — Yes | No | Not Aware

iii) Opaque Construction — Yes | No | Not Aware

iv) Day lighting — Yes | No | Not Aware

v) Building Envelope Sealing — Yes | No | Not Aware

Comments: ---

----

34. Is there a focus on Comfort Systems and Controls:

i) Ventilation	Yes	No	Not Aware
ii) Minimum Space Conditioning Equipment Efficiencies	Yes	No	Not Aware
iii) Controls	Yes	No	Not Aware
iv) Additional Controls for ECBC + and Super ECBC Buildings	Yes	No	Not Aware
v) Condensers	Yes	No	Not Aware
vi) Service Water Heating	Yes	No	Not Aware
vii) Pumps	Yes	No	Not Aware
viii) Cooling Towers	Yes	No	Not Aware
ix) Variable Flow Hydronic Systems	Yes	No	Not Aware
x) Energy Recovery	Yes	No	Not Aware

Comments: ---

----

35. Is there Total System Efficiency – Alternate Compliance Approach — Yes | No | Not Aware

Comments: ---

----

36. Which of the following have you used as low energy Comfort System/s

i) Evaporative cooling	Yes	No	Not Aware
ii) Desiccant Cooling system	Yes	No	Not Aware
iii) Solar air conditioning	Yes	No	Not Aware
iv) Tri-generation (waste to heat)	Yes	No	Not Aware
v) Radiant Cooling Systems	Yes	No	Not Aware
vi) Ground Source heat pump	Yes	No	Not Aware
vii) Adiabatic cooling system	Yes	No	Not Aware
viii) None of the above	Yes	No	Not Aware

Comments: --

----

37. *Are Electrical Installations compliant with Renewable Energy Systems*

Yes | No | Not Aware

Comments: ---

----

38. *Are all the motors installed, ECBC compliant*

Yes | No | Not Aware

Comments: --

II. Reducing Operational Costs:

By implementing Passive Cooling Design process, we can reduce the operational costs by reducing the thermal loading. To ascertain that the structure being constructed can reduce the operational costs following can be enquired from the stakeholders:

1. Does your structure have external shading for reducing the direct heat load, ranging 0% (no shading) to 30% (High-level shading)?

   Yes | No | Not Aware

   Comments: --

   ----

2. Does your structure use LED lighting fittings?

   Yes | No | Not Aware

   Comments: --

   ----

3. Does your structure use natural ground, evaporative cooling?

   Yes | No | Not Aware

   Comments: --

   ----

4. Does your structure use night ventilation techniques to reduce heat load?

   Yes | No | Not Aware

   Comments: --

   ----

5. Does your structure use ceiling fans?

   Yes | No | Not Aware

   Comments: ---

   -

6. Are there any temperature control strategies for internal air temperatures?

   Yes | No | Not Aware

Comments: --

----

7. Are the standard operating procedures for the maintenance of Air Conditioning Systems available?

   Yes | No | Not Aware

   Comments: --

   ----

8. Do you have a system to evaluate the reduction in operating costs for cooling systems of your facility?

   Yes | No | Not Aware

   Comments: --

   ----

9. If yes, please indicate the actual values if the facilities are operational/ design values If facilities are under construction.

   Yes | No | Not Aware

   Comments: --

III.<u>Improve Health & Comfort</u>

Passive cooling design approach aims at improving the indoor thermal comfort with low or no energy consumption. Human comfort can be defined as "that range of microclimate conditions under which a person feels good. To ascertain that the structure being constructed can help in improving the comfort and protect health of habitants¸ following can be enquired from the stakeholders:

1. Does the passive cooling design of your structure results in thermal load reduction?

   Yes | No | Not Aware

   Comments: --

   ----

2. If yes, does the installed air conditioning plant size accounts for that reduction?

   Yes | No | Not Aware

   Comments: --

   ----

3. For structures under construction are there reports of increased illness symptoms (lethargy, headache, blocked or runny nose, dry or sore eyes, dry throat and sometimes dry skin and asthma), in the construction workers?

   Yes | No | Not Aware

   Comments: --

   ----

4. For the structures under use are there reports of Increased illness symptoms (lethargy, headache, blocked or runny nose, dry or sore eyes, dry throat and sometimes dry skin and asthma), in residents.

   Yes | No | Not Aware

Comments: --

----

5. Are the occupants' dissatisfaction with indoor comfort conditions?

Yes	No	Not Aware

Comments: --

IV. Usage of non-HCFC & Low GWP Alternatives

Ozone-layer depletion can be caused by CFCs and HFCs (the most common refrigerants of used in air-conditioning units) from possible leakage during manufacture, system maintenance or unit failure. It is imperative that non-HCFC & Low Global Warming Potential alternatives are used in cooling systems. To ascertain this compliance¸ following can be enquired from the stakeholde rs:

1. Are you aware of common alternatives of HCFCs?

Yes	No	Not Aware

Comments: --

----

2. *Are all the HVAC and refrigeration equipment used by your organisation free of HCFCs.*

Yes	No	Not Aware

Comments: --

----

3. *Does your organization use non-HCFC and low Global warming potential (GWP) refrigerants for active cooling systems*

Yes	No	Not Aware

Comments: --

----

4. Is any of the following items is in use in your air conditioning plants:

a. Propane;	Yes	No	Not Aware
b. Isobutane;	Yes	No	Not Aware
c. Ammonia;	Yes	No	Not Aware
d. Carbon Dioxide?	Yes	No	Not Aware

Comments: --

----

5. Does your Air Conditioning system use Puron (R-410A)/ Furon (R-22)?

Yes	No	Not Aware

Comments: ---

----

6. Are there any old Air Conditioning systems in your facility?

Yes	No	Not Aware

Comments: ---

----

7. *Is the building Cooling Centralized?*

Yes	No	Not Aware

Comments: ---

----

8. *Are you aware of "Not–in–kind Centralized Cooling"?*

Yes	No	Not Aware

Comments: ---

----

9. If yes, are they using Freon or has the refrigerant been changed to non-HCFC alternative?

Yes	No	Not Aware

Comments: ---

----

10. *There is Awareness among the existing manpower engaged in our building construction activity in respect of Passive Cooling Concept & adequate Skills to carry out such constructions*

    Please share the details of the skills of man power engaged & specific skills they are trained in

Yes	No	Not Aware

Comments: ---

V. Material & Machine:

1. Is the material used calculated for its embodied energy?

Yes	No	Not Aware

Comments: ---

----

2. *Is the source of material manufactured as per green norms?*

Yes	No	Not Aware

Comments: ---

----

3. *The fire suppression systems and fire extinguishers installed in the building are free of HCFCs*

Yes	No	Not Aware

Comments: --

----

4. *Is the machinery used, Energy Efficient using latest technology?*

Yes	No	Not Aware

Comments: --

----

5. *Is the energy used generated from Renewable energy e.g.: Hydro, wind, solar, bio etc.*

Yes	No	Not Aware

Comments: --

Signature: *Date:*

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WHOM TO CONTACT TO LEARN MORE ABOUT OZONE

Ozone Cell
Ministry of Environment, Forest and Climate Change
1st Floor, 9 Institutional Area, Lodhi Road, New Delhi - 110003
P: 011-24642176 | F: 011-24642175 | ozonecell.nic.in