Frankfurt School
FS-UNEP Collaborating Centre
for Climate & Sustainable Energy Finance

Theory of Change

REDUCE SHORT-LIVED CLIMATE POLLUTANTS IN INDIA

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ABBREVIATIONS

BEE	Bureau of Energy Efficiency
CCAC	Climate & Clean Air Coalition
CFM	Cubic Feet per Minute
CREDAI	The Confederation of Real Estate Developers Association of India
ECBC	Energy Conservation Building Code
EESL	Energy Efficiency Services Ltd
ESCO	Energy Service Company
ESPC	Energy Service Performance Contracting
FAR	Floor Area Ratio
FEEED	Framework for Energy Efficient Economic Development
GIZ	Gesellschaft für Internationale Zusammenarbeit
GRIHA	Green Rating for Integrated Habitat Assessment
GWP	Global Warming Potential
IGBC	Indian Green Building Council
JICA	The Japan International Cooperation Agency
MNRE	Ministry of New and Renewable Energy, Government of India
MSMEs	Micro, Small and Medium Enterprises
MoEFCC	Ministry of Environment, Forest and Climate Change
NMEEE	National Mission for Enhanced Energy Efficiency
NCCoPP	National CFC Phase-out Plan
NHB	National Housing Bank
PAT	Perform Achieve and Trade Scheme
PFI	Participating Financial Institutions
PRGFEE	Partial Risk Guarantee Fund for Energy Efficiency
SCT/S	Sustainable Cooling Technologies & Strategies
SIDBI	Small Industries Development Bank of India
SLCP	Short-Lived Climate Pollutants
SSSCC	Sustainable & Smart Space Cooling Coalition
SVAM	Solar Vapour Absorption Machines
TA	Technical Assistance
TAM	Technology Acceptance Model
ToT	Training of Trainers
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
VCFEE	Venture Capital Fund for Energy Efficiency

1. INTRODUCTION: MAKING A CASE FOR ACTING

Amidst the pressing undertaking by governments across the globe to drastically reduce greenhouse gas (GHG) emissions towards prevention of catastrophic climate change, some exceptionally potent greenhouse gases have been unfortunately ignored – Short Lived Climate Pollutants (SLCPS) like HCFCs and HFCs.

The world is currently at a crossroad; wherein we could either opt for HFCs and energy-guzzling air-conditioning, and let their growth go unchecked to a point of no return and cause catastrophic climate change or leapfrog from HCFCs directly to tried and tested, environmentally safe natural refrigerants and sustainable cooling technologies. These alternatives only have the potential to meet present needs, but can easily fulfil our future ones. Leapfrogging to natural refrigerants and sustainable cooling is of utmost importance especially since developing countries are already transitioning from HCFCs to HFCs, it is crucial that this scenario is avoided.

The Climate & Clean Air Coalition (CCAC), Frankfurt School of Finance & Management and cBalance Solutions join hands to co-create a democratically conceived strategic response to this case for acting. They propose to identify barriers preventing the uptake of sustainable – energy-efficient and zero/low global warming potential – cooling technologies/systems, and design practical approaches to overcome these barriers.

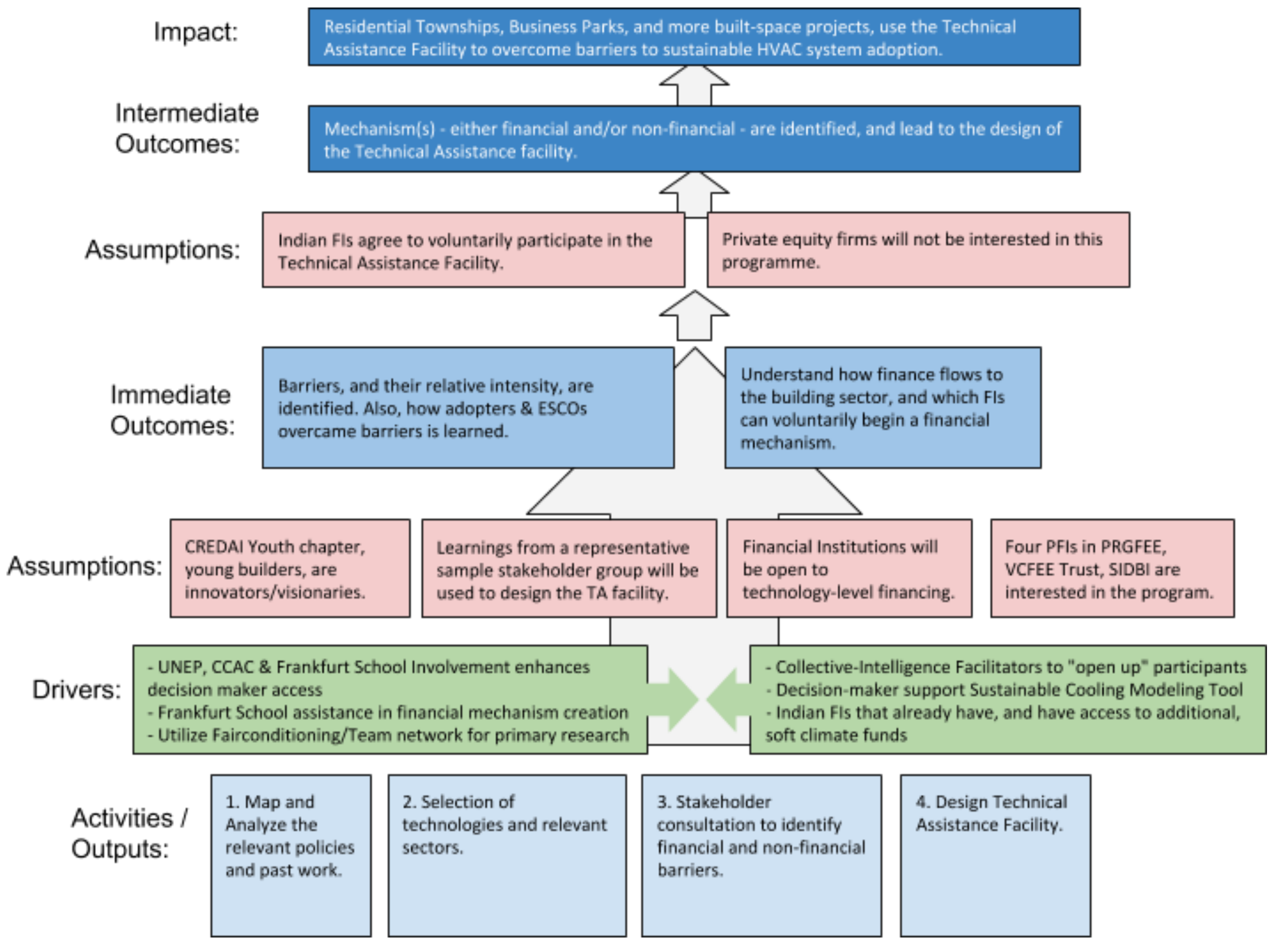
These barriers will be identified through dialog with the *influencers* of cooling in the built-space eco-system. These influencers are companies who design/build/operate real-estate for their own use or as a service, sustainable cooling manufactures, and energy-saving companies (ESCOs). This could also include financial institutions that can catalyze the mainstreaming of sustainable cooling through finance.

A solutions-oriented approach will be followed to seek innovative ways to overcome the identified barriers to sustainable cooling adoption, deconstruct the status-quo prevalent in the built-space economy and redirect the consequent trajectory of rising greenhouse gas emissions through cooling built-spaces efficiently.

This document outlines the theory that will bring about the change of mainstreaming adoption of non-fluorinated-refrigerant cooling technologies through a technical assistance facility. The current mandate of the programme is to establish the design of the facility with select partners, which could potentially lead to further activities in implementing and managing the facility in the near future.

2. THE THEORY OF CHANGE

The following report enfleshes the hypothesis of ecosystem transformation that forms the central logic of the exercise. The figure presented below is a crisp articulation of the overarching logic. It delineates the end impact that we seek to achieve through the effort, defines the measurable intermediate and immediate outcomes which will be endeavored through a spectrum of on-ground activities. Also presented are the underpinnings of the cause-effect linkages that are postulated in this hypothesis; the drivers and assumptions comprise the substance of these underpinnings. Collectively, they express the current state of the cooling sector and the associated the market, the domestic and international policy climate which has a bearing on the endeavors being attempted, and acknowledgement of the discernable latent potential in the relevant stakeholder groups that can be harnessed to catalyze transformation.



The ensuing report presents the plan of activities with granular detail.

Section 3 encapsulate the domestic and international policy climate as well as prior efforts of governmental and non-governmental institutions towards mainstreaming energy efficiency and curbing high global warming potential (GWP)-refrigerant use through direct or indirect approaches. This section defines the broad historicty of the issue and the pre-existing context which irrigated the process of crafting the ‘Theory of Change’. The material presented was utilized for illuminating the central issue, its pivotal challenges, and learning or lacunae that are evident from studying prior efforts in this direction.

Section 4 delves into a key component of the ‘transformation’ that we seek to achieve through the establishment of the Technical Assistance Facility in subsequent phases of the project; alternate cooling systems that either involve direct replacement for high GWP-refrigerants or in-kind replacements for conventional vapor compression refrigeration technologies which provide the same utility (cooling) but through other technical means which either obviate artificial refrigerants all together or greatly limit their need. Furthermore, the choice of economic sectors which form the 'subject' of the proposed intervention, and the underlying rationale for selecting a well defined intersection of cooling technologies and economic sectors is also presented therein.

Section 5 addresses the core 'execution' phase of the project which involves exhaustive stakeholder consultations, investigations into existing non-financial and financial barriers encountered by the spectrum of stakeholders that are involved in the specific discourses occurring at the intersection of the selected economic sectors and technologies. This section elaborates upon the methodology of the investigative processes including collective-intelligence creation workshops and 1-1 surveys with key personnel in decision making positions in institutions that comprise the ecosystem.

Section 6 forms the penultimate portion of the report and represents the 'analytical' period of the project which assimilates the learnings of the prior phases, including policy, technical and economic analysis, and most importantly, the stakeholder consultation process addressed earlier. The section articulates the process that will be followed for devising the proposed Technical Assistance Facility based on the insights and learning derived through the investigative phase of the project.

The report concludes with a discussion on the process that will be followed for discerning the project impact in Section 7; also included in this section are concluding remarks related to anticipated next steps for evolving into a expanded program in the subsequent phases which draws and builds upon the efforts of this project.

3. ACTIVITY 1: ANALYSE POLICIES AND RELEVANT PAST WORK

3.1. The Policy Landscape

This section explores the policy undercurrents which shape the cooling sector's development and trajectory in India. The ensuing dissection and articulation of the policy 'landscape' makes it evident that while certain policy levers are already in place that can be harnessed by a new 'intervention' in this space to enhance uptake of energy efficient and climate friendly technologies, none of them singularly lend themselves (as yet) to mainstreaming the procurement and installation of the alternates to conventional cooling systems, which therefore continue to be perceived as 'fringe' or 'niche' technologies in India.

A vital policy that has the potential to influence the discourse of sustainable cooling in India is the state-sponsored Energy Efficiency Services Ltd (EESL) announced on 26 May 2017 an order of 100,000 super-efficient room ACs that will have achieve an Indian Seasonal Energy Efficiency Ratio (ISEER) of 5.2.[1] The ISEER 5.2 room ACs qualify for the highest 5-Star energy efficiency rating and use up to one third less energy than the average room AC sold in India (3-Star). This contract went to two suppliers, Panasonic and Godrej & Boyce (Godrej). Through bidding, both suppliers offered the same price, however Panasonic will utilize the high global warming potential (GWP) HFC-410A refrigerant (GWP = 2088), whereas Godrej will utilize the HC-290 natural refrigerant (GWP = 3). That the price of both bids matched is evidence that super-efficient ACs using environmentally superior HC-290 refrigerant can be no more expensive to manufacture than the HFC-based ACs and could be justification for disqualifying HFC-410A and HCFC-22 from future tenders. This policy, while directly addressing and catalyzing the vital low-GWP refrigerants issue with respect to space cooling, does not address the financial constraints of the first cost (capital cost) of these ACs being higher and their specialized maintenance needs possibly becoming a future impediment owing to the limited national experience and technical expertise for working with these new refrigerants. Furthermore, this mechanism only addresses split unit ACs and that too encompasses a small fraction of the annual space cooling demand in India (the installed capacity of split ACs in India is approximately 30 million and grows by approximately 3 to 4 million new units every year). It is unreasonable to expect that 100,000 units will significantly alter the dynamics of the ecosystem.

Another government initiative approved in 2010, The National Mission for Enhanced Energy Efficiency (NMEEE) is one of the eight missions under the National Action Plan for Climate Change to promote the market for energy efficiency by fostering innovative policies and effective market instruments. Under NMEEE, there is a Perform Achieve and Trade (PAT) Scheme where industrial consumers are provided a specific energy consumption reduction target. These consumers could meet this target by using an Energy Service Company (ESCO) in Energy Performance Contract (EPC) mode. Recently, the PAT scheme has been partially extended to the hospitality sector, one of our target end-user sectors. Like industries, large hotel buildings are in the list of Designated energy-intensive Consumers (Designated Consumers). This will require them to submit their audited energy consumption to the government periodically. This schemes expansion to Hotels is a promising development and could be harnessed by the proposed Technical Assistance Facility. However, working with this policy framework will only enable accelerating the uptake of high efficiency conventional cooling systems which are based on f-gas technologies (HCFC and HFCs). It is clear that the project must look beyond the PAT scheme as a locus of its interest.

Another key element of the NMEEE aimed at industry is the establishment of a Framework for Energy Efficient Economic Development (FEEED), which mainly focuses on developing fiscal and investment guarantee instruments to promote energy efficiency. FEEED includes a Partial Risk Guarantee Fund for Energy Efficiency (PRGFEE) and a Venture Capital Fund for Energy Efficiency (VCFEE). The PRGFEE is a risk-sharing mechanism that provides commercial banks with partial coverage of risk exposure against loans issued for energy efficiency projects. The participating financial institutions in the PRGFEE, and the VCFEE trust, may help devise our financial mechanism, and potentially, include a guarantee component. While both these mechanisms under FEEED are meant for promoting energy-efficiency, they have not specified their applicability for energy-efficient *cooling* technologies; this may be a stumbling block.

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[1] ISEER methodology factors in variance in higher temperature in India and rates air conditioners accordingly. As per Indian Weather Data Handbook, 2014, weather profile of 54 major cities shows that 65% of the total number of hours in a year have a temperature above 24 degrees Celsius (5778 hours out of 8760).

The Small Industries Development Bank of India (SIDBI) has three specific schemes – JICA, 4E Financing Scheme, and SFS – that may consider supporting a financing mechanism for cooling technologies. They are relevant to our chosen end-use sectors. Further, the bank also has a Partial Risk Sharing Facility (PRSF) that could serve the same purpose as the PRGFEE described above. As SIDBI primarily finances SMEs we may explore working with SIDBI suitably if identified sub-sector(s) are financed by SIDBI.

On the private sector, several international banks are signing on internal environmental principles such as the Equator Principles. One private Indian bank that has signed on to them is IDFC Bank. We believe that the environmental & social commitment that the bank has made externally and internally, will foster the commitment to create a special financing program for sustainable cooling technologies. It is therefore imperative to include this specific progressive bank in the consultative process of devising the Technical Assistance Facility which is elaborated addressed later in the report, as well as make determined efforts to forge a fruitful alliance with the key decisions makers in their Real Estate and Energy Efficiency Financing divisions.

The Indian Real-Estate ecosystem is increasingly becoming a highly activated space with the establishment of some robust and sophisticated certification programs that seek to drastically increase the market share of sustainable and energy efficient built space relative to the overall supply of residential and commercial built space.

The newly revised (2017) Energy Conservation Building Code (ECBC) published by the Indian Bureau of Energy Efficiency is perhaps the most pivotal building energy efficiency program that the proposed project must embrace within its fold. The ECBC was launched in 2007 by Bureau of Energy Efficiency (BEE) as a mandate under Energy Conservation Act 2001. It prescribes a minimum standard of energy use in new and retrofit buildings having a connected load of 100 kW or contracted demand of 120 kVA or above. The ECBC's ECBC+ and Super ECBC certified buildings could be a standard that our chosen end-users should meet to achieve higher market value for their property, and could use sustainable cooling technologies as one way to achieve it. Its increasing relevance for the real estate sector underscored by a recent landmark development by the Ministry of Environment and Forests and Climate Change (MoEFCC) which sought to bridge the gap between the Ministry of Power's mandate to enhance energy efficiency and its own mandate to shift the development trajectory of key economic sectors (such as construction) towards a low-carbon pathway. The Gazette of India part II section 3 sub section ii, published by the MoEFCC in December 2016, states the amendments made in Environmental Impact Assessment Notification (2006) whose clearance is required for any kind of construction to happen in India. The energy compliance with Energy Conservation Building Code (ECBC) is mandatory for residential and commercial buildings of area 5,000m^2 – 1,50,000$m^{2.}$ This ushering in of a 'compliance' climate in the real estate sector is welcomed and can be used for addressing some of the non-financial barriers to mainstreaming energy efficient cooling in buildings in India. It however, does not address high GWP-refrigerant phaseout and therefore lacks a significant element to make it completely relevant for exploiting by the Technical Assistance Facility.

India also has two other voluntary green building certifications of considerable importance within the real estate ecosystem – Indian Green Building Council (IGBC), and Green Rating for Integrated Habitat Assessment (GRIHA). Both can apply to commercial, institutional, and residential buildings. GRIHA mentions only these cooling technologies: night ventilation, evaporative cooling, earth tunnel system, geothermal heat pumps. While IGBC awards only 1 point for using a refrigerant that has low or no Global Warming Potential (GWP), 1 point for using a 5-star rated AC or higher. Total points awarded are 100. Several Indian states/cities are incentivizing using these voluntarily certifications by offering a mix of the following: awarding free of cost 5% additional Floor Area Ratio (allowing more built-space as a proportion of the land) to builder-developers, fast track environmental clearance, and a discount in property tax for home owners, for projects for complying with 4 or 5 Star GRIHA Rating / Gold or above by IGBC. Both green building certifications are progressive and commendable efforts, however they are still voluntary, and do not cover the breadth of sustainable cooling options and, nor award these options sufficient “points” within their framework.

The Maharashtra state government will soon be amending the development control rules (DCR) to make it mandatory for all new constructions to follow 'green building guidelines'. These guidelines have not been defined yet, however it is likely they will follow conventional green building practices, like those outlined by GRIHA & IGBC, and will probably fail to substantially include sustainable cooling. This is a significant announcement, though, as Maharashtra is the richest, and second most populous, state in India; and thus will see lion’s share of the newest residential townships, and corporate parks/campuses. Our first workshop will be focusing on real-estate developers based in Maharashtra’s two main cities – Mumbai and Pune.

The recent policy established by the Government of India, called The Real Estate (Regulation and Development) Act, 2016 deserves significant attention. It is widely considered a landmark realty law in India which seeks to protect home-buyers as well as help boost investments in the real estate industry. The Act establishes Real Estate Regulatory Authority (RERA) in each state for regulation of the real estate sector and also acts as an adjudicating body for speedy dispute redressal. Before the act, the real estate sector was largely unregulated in India. While the introduction of the act includes the following paragraph ”since ‘sustainability’ and ‘sustainable development’ encompasses economic security and growth, environmental quality and integrity, social cohesion and quality of life, empowerment and governance, hence, the role of the real estate sector in the promotion of the sustainable development become predominant…”. However, the act only mentions sustainability in one context: In order for promoters to apply for registration of their real-estate projects they must submit the plan of development works to be executed including, among several other categories, use of renewable energy. It currently does not make any further mention of energy-efficiency or sustainability. Although, it is a positive sign for energy-efficiency as the real estate sector is now regulated carefully, and if green-buildings become mandatory (such as in Maharashtra), it will now be easier to enforce.

Another pivotal policy that might shape this space is the nascent effort by the Government of India in mid-2017 to devise a National Cooling Action Plan. The plan aims to bring together experts on the cooling industry, energy efficiency, and alternative refrigerants (low- and zero-GWP) and other stakeholders to formulate a national cooling framework. The India Ozone Cell [within] Ministry of Environment, Forest and Climate Change also announced plans to establish a national committee to integrate discussions on energy efficiency and the Montreal Protocol. It is however a nebulous effort at this stage and the project must seek to track its development to explore possible linkages with addressing financial or non-financial barriers encountered by stakeholders in the ecosystem

It is also vital to consider policies or self-regulatory efforts being devised by Industry bodies for enhancing the efficacy of their specific sector. In this context, it is prudent to study the efforts of CREDAI, NASCCOM and CII.

In Andhra Pradesh, Confederation of Real Estate Developers' Associations of India (CREDAI) and Indian Green Building Council (IGBC) are working with developers to create energy efficient buildings. A steering committee on energy efficiency is created by state and local stakeholders with support from National Resource Defense Council (NRDC) and Administrative Staff College of India (ASCI) to support the adoption and implementation of building efficiency measures. In Gujrat as well, CREDAI and IGBC are working towards developing green buildings. Under CREDAI Green Building Initiative, IGBC and CREDAI have collaborated to work towards energy efficient buildings. Under this[2],

1. **IGBC local chapters**: IGBC would seek the support of CREDAI members in all its local chapters and work closely with the stakeholders in the Region/ State in taking forward the green building movement.
2. **IGBC Technical Committees**: Senior members of CREDAI would be invited to become members of various technical committees and steering committees of IGBC green building rating system.
3. **Spread CREDAI's green building footprint:** IGBC through its local chapters and technical support would facilitate CREDAI projects go green and enable them achieve the desired green building rating
4. **Priority focus on affordable housing**: IGBC has a separate rating for green affordable housing and IGBC would offer technical support for CREDAI projects go green under this rating system
5. **Capacity Building & Skill Development:** IGBC and CREDAI shall jointly organise training & awareness programmes to facilitate capacity building to the stakeholders of CREDAI and IGBC chapters across the Country. IGBC would organise exclusive skill development workshops for CREDAI members to take up IGBC Accredited Professionals (AP) exams.
6. **Policy Advocacy:** IGBC and CREDAI shall work together and coordinate with the Government- both Central and State for offering Policy incentives to IGBC rated projects. It will also work for faster environmental clearance for IGBC projects and other Government initiatives
7. CREDAI have partnered with International Finance Corporation (IFC), a member of the World Bank Group to promote green buildings in the country through EDGE certification. EDGE is poised to jumpstart the mainstreaming of green buildings across the country in a fast, simple and affordable way.

The vitality of this Industry body, evidenced through these progressive efforts towards self-regulation and stewardship of environmental values, must be harnessed in the design of the Technical Assistance Facility. Key builder-members of this group must be consulted and formally included in dialogs to devise linkages with financial and technical institutions to address financial and non-financial barriers to uptake.

The NASSCOM **(**www.nasscom.in**)** is India's National Association of Software and Service Companies, the premier trade body and the chamber of commerce of the IT software and services industry in India. It is not-for-profit industry association, and the apex body for the 154 billion dollar Indian IT BPM industry; over 1850+ companies are registered. This industry body pushes sustainability / energy-efficiency best practices among it's registered members. NASSCOM has launched a Green IT Initiative in the past that has focused on "**Make IT Green"** through the "**A**doption by industry of green technologies and practices including green buildings…" This well-coordinated apex body can easily share best-practices with members. Hence, the IT sector is one where influencing a few companies and sharing this best-practice with NASSCOM, can have a ripple effect across the industry.

[2] CREDAI Green Building Initiative, https://credai.org/credai-green-buildings

The Confederation of Indian Industry (CII) is a non-government, not-for-profit, industry-led and industry-managed organization, playing a proactive role in India's development process. Founded in 1895, CII has over 8,500 members, from the private as well as public sectors, including SMEs and MNCs, and an indirect membership of over 200,000 enterprises from around 250 national and regional sectoral industry bodies. CII – Sohrabji Godrej Green Business Centre through Indian Green Building Council (IGBC) has launched several IGBC Green Building Rating Systems. CII – Sohrabji Godrej Green Business Centre has developed the 'Greenco rating' system for evaluating the 'greenness of companies'. The rating system is the "first of its kind in the world" to assess and analyze the environmental impact of the company's activities or operations. The rating will also help in defining the path forward to ecologically sustainable business growth.

CII has been key in regularizing, and streamlining, environmental practices. While CII has not worked directly on promoting sustainable cooling, they could play an important role in spreading such best-practices.

It is evident from the analysis that incremental changes or more policies which incentivize merely energy efficiency in buildings but do not address specifically the life-cycle GHG emissions of HVAC systems. will not be adequate triggers to resoundingly shift the trajectory of space cooling in India towards a low-carbon development pathway.

A comprehensive list of relevant public policies is attached in the Annex of this document.

3.2. Understanding & Learning from Related Past Work

We assimilated related work done so far that could contribute to the programme. The related work studied was:

- *Market Assessment for Partial Risk Guarantee Fund for Energy Efficiency & Venture Capital Fund for Energy Efficiency.* (2016). Published by the BEE and USAID PACE-D TA Program.
- *Training Manual for Energy Efficiency Financing in India.* (2015). Published by the BEE and USAID PACE-D TA Program.
- *HVAC Market Assessment and Transformation Approach for India.* (2014). Published by the BEE and USAID PACE-D TA Program.
- Vineeta Kanwal, 2016, Bureau of Energy Efficiency's Financing Initiatives. Presentation.
- Chandra Bhushan, 2016, *Prioritizing Natural Refrigerants in India*, Centre for Science and Environment, New Delhi
- *G20 Energy Efficiency Investment Toolkit.* (2017). Published by the G20 Energy Efficiency Finance Task Group under the content direction of the International Energy Agency (IEA), the UN Environment Finance Initiative (UNEP FI) and the International Partnership for Energy Efficiency Collaboration (IPEEC).

Below are some key learnings each with a takeaway (idea or constraint) for the programme's development.

Technical Assistance (TA) Facility Design:

- According to the 'Market Assessment for Partial Risk Guarantee Fund for Energy Efficiency & Venture Capital Fund for Energy Efficiency' study, two commonly accepted classifications of ESCOs are vendor-driven ESCOs (these use their own technologies or products for implementation of energy improvement measures), and general ESCOs (these may be product-neutral).
    - *Takeaway:* There is a precedent mechanism already recognized and practiced in the ESCO realm wherein technology-selection decisions are influenced by the organization's familiarity and preference to work with a select set of technologies 'driven' by the ECO. This can provide an avenue for intervention and the selection criteria for technologies could be brought in alignment with climate and appliance efficiency policy.
- According to the 'Market Assessment for Partial Risk Guarantee Fund for Energy Efficiency & Venture Capital Fund for Energy Efficiency' study, it is also found "that most of the FIs do not differentiate between a normal project application and an EE project application." Hence, "EE investments can scale up if commercial banks get techno-commercial assistance in developing appraisal procedures for EE applications and are encouraged to provide low-interest rate loans for EE projects."
    - *Takeaway:* This reiterates the importance of providing techno-commercial assistance to FIs to develop appraisal procedures for sustainable cooling technologies. While it is important to recognize the unprecedented nature of a private FIs developing its own appraisal procedures, it is also important to take

cognizance of the latent potential of this possibility and 'test' its merit, acceptability, and, affinity for it, by the private FIs during the stakeholder consultation phase of the project.

- According to the *'Training Manual for Energy Efficiency Financing in India'*, there are "high transaction costs due to small project size: Energy efficiency projects are relatively small in size and have a high transaction cost, compared to other conventional lending by banks and FIs. This not only makes energy efficiency projects less attractive for conventional bank financing, but also limits the interest of international FIs (such as multilateral and bilateral donor organizations) to whom the scale of financing is important. In order to increase project size, small energy efficiency projects are often bundled together and this makes evaluation more complex due to different technologies being included in the overall project."
    - *Takeaway:* Consider bundling together projects using the same technology, as to keep evaluation the same, yet increase project size.
- According to the *'HVAC Market Assessment and Transformation Approach for India', "*lack of expertise in O&M is the most common reason for higher than expected energy use by the HVAC systems."
    - *Takeaway:* If our programme's TA facility has a technical capacity building/awareness focus, it should stress O&M training for sustainable cooling technologies.
- According to the 'HVAC Market Assessment and Transformation Approach for India'*, "...*entering into complicated agreements outside of core business areas for many owners and developers, results in the HVAC system not being updated or enhanced."
    - *Takeaway:* Strive to simplify the facility's agreements, including the Energy Performance Contracting (EPC) agreements.
- According to the *'HVAC Market Assessment and Transformation Approach for India'*, and our own perception of the real-estate development market, there is a split-incentive between builder-developers and end-users. The builder-developers pay for the additional first (initial) cost, whereas the end-users are the beneficiaries of the operational energy savings.
    - *Takeaway:* This is a pre-identified barrier for builder-developers to uptake sustainable cooling. Any successful facility that targets built-spaces where the occupant and builder are different (like residential townships), will solve this 'split incentive' constraint. One early thought on solving this is: builder-developers showcasing their property as energy-efficient, which allows them to charge a premium (hence, recovering their additional first cost).
- According to the 'Prioritizing Natural Refrigerants in India' study, "77 percent of India's RAC sector can be converted to naturals by using currently available technologies."
    - *Takeaway:* This facility could consider the possibility of addressing barriers of another air-conditioning manufacturer pursuing Natural Refrigerants (NRs), and thus achieve a tipping point in the Room Air-Conditioning (RAC) market.
- According to the *'HVAC Market Assessment and Transformation Approach for India'*, "...the first cost of energy efficiency technologies is still a major barrier to widespread adoption."

    - *Takeaway:* The potential finance mechanism within this facility could address bringing down the first (initial) cost of the sustainable cooling technologies (SCTs), while also showcasing the lower life-cycle costs of using SCTs.

Consultations/Partnerships:

- According to the 'Market Assessment for PRGFEE & VCFEE' study, BEE empanelled ESCOs, have higher credibility, ability to apply for state tenders, eligible to avail guarantee schemes such as Partial Risk Sharing Facility (PRSF), PRGFEE, etc.
    - *Takeaway:* We can learn that we should partner/consult with BEE empanelled ESCOs.
- According to the 'Market Assessment for Partial Risk Guarantee Fund for Energy Efficiency & Venture Capital Fund for Energy Efficiency' study, the major beneficiaries of the PRGFEE and VCFEE schemes are expected to be Grade 3, 4, 5 ESCOs due to their small size, lack of collaterals, or provisions to provide bank guarantees. Hence, it may be helpful to partner/consult with some ESCOs of these grades.
- Through the G20 Energy Efficiency Investment Toolkit, we learned that Bank of India and YES Bank have signed the G20 Bank Statement on Energy Efficiency.
    - *Takeaway:* We should consult with them for this programme.
- Through the *'Press release for fourth ToT workshop held on 19-21 April 2017*', we learned that "on 2nd day all the participants were taken for a site visit to SBI's building in Kolkata where Energy Efficiency and Renewable Energy projects were implemented. Participants from various banks got practical experience of witnessing Energy Efficiency project and appreciating its financial proposition too."
    - *Takeaway:* We can learn that it would be beneficial if we hold the workshop in, and/or organize a site visit to, a sustainable / sustainable cooled venue.
- Through the *'Press release for fourth ToT workshop held on 19-21 April 2017',* we learned that "in this workshop 7 Banks had nominated 17 trainers to be trained on Energy Efficiency Financing.
    - *Takeaway:* We could speak with BEE to see which banks participated in the workshops, and consult these banks about this programme.
- According to the *'HVAC Market Assessment and Transformation Approach for India',* "Building owners are the key decision makers for purchasing HVAC systems, followed by design engineers, and consultants".
    - *Takeaway:* Ensure the consultations include building owners / owners of real-estate development firms.
- According Ms. Kanwal's *'Bureau of Energy Efficiency's Financing Initiatives'* presentation and the Bureau of Energy Efficiency's website (https://beeindia.gov.in/content/contact-details-pfi-prgfee) IDFC Bank, Yes Bank, Andhra Bank and Tata Cleantech have been empanelled with BEE and ESCOs can approach these empanelled banks to get finance for EE projects and get benefit from PRGFEE.
    - *Takeaway:* Consult with these PFIs, and explore possibilities to work with one more as partners for development of potential finance mechanism.

Sector Selection (*Where* to focus the TA facility):

- According to the *'Market Assessment for Partial Risk Guarantee Fund for Energy Efficiency & Venture Capital Fund for Energy Efficiency'* study, commercial buildings are the primary target market for ESCOs.
    - *Takeaway:* The commercial built-space sector need to be given appropriate weight (Score) when selecting sectors to focus on.
- According to the *'HVAC Market Assessment and Transformation Approach for India*' study, "Residential, commercial/office and hospitality sector will experience maximum growth till 2030. Expected energy use will also be proportionately higher if efficiency of HVAC systems installed in these sectors is not improved."
    - *Takeaway*: Evaluate all of these sectors during selection / stakeholder consultation.
- According to the *'Prioritizing Natural Refrigerants in India' study*, "The largest increase in annual sales in 2030 will be in the residential air- conditioning sector (6-folds)".
    - *Takeaway:* Strongly consider the residential air-conditioning sector when selecting sectors to focus on.

Technical / M&V:

- According to the 'Market Assessment for Partial Risk Guarantee Fund for Energy Efficiency & Venture Capital Fund for Energy Efficiency' study, it will be required for the PRGFEE and VCFEE, to ensure "that ESCOS include with the applications received for guarantees from the participating financial institutions a robust, and yet simple, M&V plan developed in consultation with the client."
    - *Takeaway:* Ensure that there is such an M&V plan for all sustainable cooling technologies that ESCOs will adopt.
- According to the *'HVAC Market Assessment and Transformation Approach for India'*, "Energy efficiency and reliability prevail over other parameters during the purchase of HVAC systems across categories covering large systems. Interestingly, for smaller systems, maintenance and good after sale service are overriding concerns. Reasonable price emerges as the next important reason for a purchase consideration in the case of HVAC systems."
    - *Takeaway:* Take these market requirements into account when selecting the sustainable cooling technologies.

3.3. Identified Barriers

After study of the sustainable cooling landscape, it is clear that in India, ESCOs and end-users in industry, need a *catalyst* for implementing sustainable cooling technologies and strategies (SCT/S) that have zero, or low, energy-use and GWP; as there is:

- a dearth of technical awareness of off-the-shelf technologies and systems with a verifiable track record of performance,
- absence of a cooperatively-organized and thriving sustainable-cooling services ecosystem,
- information asymmetry perpetuated by dominant enterprises which throttles transition to technologies which challenge their relevance,
- the split-incentive or principal-agent conflict in the residential building space, and;

- the perception of difficulty to guarantee cost savings due to absence of contextualized measurement and verification protocols to estimate energy savings.

This programme seeks to co-create a democratically conceived strategic response to design a facility that will *be this catalyst* to reduce the short-lived climate pollutants (SLCPs) in India.

4. ACTIVITIY 2: ACTING WITH SUSTAINABLE COOLING SYSTEMS

4.1. NATURAL REFRIGERANTS

Natural refrigerants are chemicals which occur in nature's bio-chemical processes. These can be used as cooling agents in refrigerators and air conditioners. The natural refrigerants do not deplete the ozone layer and make negligible contribution to global warming. Natural refrigerants also provide high efficiency which means lower indirect contribution to global warming than many standard HVAC systems. Natural refrigerants also deliver on the Montreal and Kyoto Protocols and have no or very low GWP. These refrigerants can be used in split AC systems as well as central AC systems. Natural refrigerant can be divided into three categories:

- Hydrocarbons:
  Propane (HC-920): GWP = 3
  Propylene (HC-1270): GWP = 2
  HC-600a: GWP = 3
- Ammonia: GWP = 0
- Carbon dioxide: GWP = 1

Applications and Limitations

Natural refrigerants	Limitation	Application
Hydrocarbons	Extremely inflammable.	• Industrial and domestic air conditioning • Domestic appliances • Commercial and industrial refrigeration • Chill cabinets and vending machines • Heat pumps • Low- and ultra-low temperature applications.
Ammonia	Ideal & efficient refrigerant if used in accordance with national safety standards and codes of practice.	• Large air conditioning systems (chillers) • Commercial & industrial refrigeration (storage, food, brewing, heat extraction, ice rinks etc.)
Carbon Dioxide	Often used as a secondary refrigerant along with ammonia, thereby opening up applications where ammonia as a single-stage refrigerant would not be applicable.	• Static/mobile air conditioning systems • Warehousing • Commercial refrigeration • Chill cabinets and vending machines • Process chilling • Low- and ultra-low temperature applications.

4.2. SPLIT AIR CONDITIONERS USING R290 (PROPANE) AS A REFRIGERANT

Background

The R290 (Propane) refrigerant has a long history in refrigeration and has been in use since even before CFCs were developed, hence the technology required to use this refrigerant was already available.

R290 is currently being used for stationary Air-conditioning and Refrigeration purposes across both, domestic and commercial sectors in India. At present, Godrej Boyce is the only manufacturer in India currently manufacturing and installing 1 TR and 1.5 TR Split AC units based on the R290 refrigerant. For this purpose, the programme has considered statistics provided by Godrej & Boyce.

R290 has a very low global warming potential (GWP) of 3 (compared to R22 with a GWP of 1810, and R410A with a GWP of 2088). The only drawback of using R290 is the limitation on the amount of charge used to avoid risk of inflammation.

Installed/Sold Capacity

Godrej & Boyce, since the inception of the R290 project in 2011 until 2015 had sold/installed 240,000 ACs, out of which 84,000 (35%) are 1 TR and 156,000 (65%) are 1.5 TR based ACs. At the start in 2012, Godrej & Boyce sold only 3,000 units (3,975 TR) increasing to 22,000 units (29,150 TR) the very next year at a growth rate of 633.33%. In 2014, the installations increased significantly by another 240.91% and reached 75,000 units (99,375 TR), and reached 1,40,000 units (1,85,500 TR) at an increase in growth by 86.67% in 2015. The installed number of units capacity by March 2017 was estimated to be 5,35,680 split-AC units yielding a total capacity of approximately 7,09,776 TR

GHG, Power and Energy Savings

Cumulative GHG emissions from both electricity and refrigerant for installed R290 units in 2017 accounted for 17,96,368 MT CO_2e, whereas, from equivalent number of conventional ACs the GHG emissions would have been 24 % higher at 23,56,764 MT CO_2e. In 2017, R290 units also yielded approximately 145 MW of power savings and 3,23,922 MWh of energy sainvgs.

Manufacturing Capacity

Godrej & Boyce, reported a manufacturing capacity of 1,80,000 units of R290 based ACs per year.

Design & Installation Capacity

The R290 based ACs have a refrigerant charge of 350 - 360 gms for 1.5 TR and 310 gms for 1 TR ACs (Colbourne and Usinger, 2015) with and a rate EER of 3.70.

Reliability

If using best practices, 10 years minimum. 10 Years compressor warranty & 5 Years condenser warranty.

Maintainability

Regular Spilt-AC maintenance.

Installation Feasibility

Off-the-shelf technology; can be installed in one day.

4.3. Compatible Technologies

Several technologies are currently available that adopt natural refrigerants. Some of these technologies are discussed below:

4.3.1 SOLAR VAPOUR ABSORPTION MACHINE (SVAM):

Background

Solar cooling technologies convert solar thermal energy directly into cooling power by means of thermally driven chillers. The combination of the solar thermal energy and the natural refrigerants can be a potential business case for sustainable cooling technologies. The technology used in solar cooling systems is absorption technology in which ammonia or water is used as refrigerant. In the case of a SVAM, the solar collector directly heats the refrigerant through the help of collector tubes and then circulates it to achieve cooling.

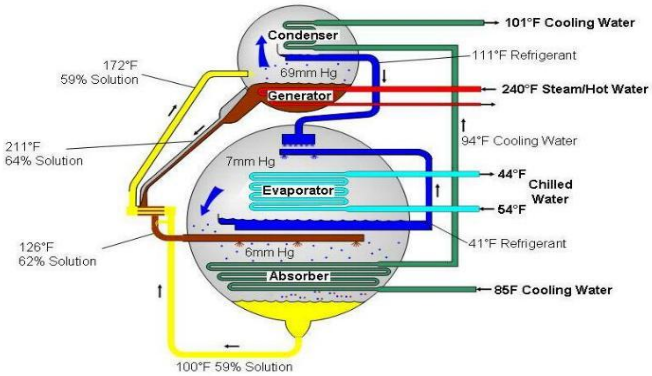

Figure: Solar Vapour Absorption Machine[3]

Benefits	Constraints	Applications
• Environment Friendly (No HCFCs involved). • Low power consumption (Fractional Power for small pumps only). • Part load efficiency is as good as efficiencies at full load. • Meets variety of cooling loads like air-conditioning, process cooling. • Requires negligible maintenance since there are no moving parts. • Absorbent and refrigerant are less costlier unlike refrigerant gas in mechanical chillers. • VAM circuit is subject to lesser operating pressure eliminating chances of leakages • Rigid construction and no fragile-weak extensions • No special foundations and sheds required • Noiseless and Vibration free operation • Fully Automatic micro-processor based operation and/or BMS integration available	• The major constraint is the absence of true-value accounting or green accounting principles; such accounting would increase the price of fossil fuels to include it's externalities • This subsidization economy artificially suppresses the cost of conventional fossil fuel based sources and conversely inflates the cost of renewable sources of energy which do not have a shadow price unlike fossil fuels • Space requirements for cooling towers, solar heat harvesting makes it suitable for large applications only • Long capital payback period for residential and other low annual usage and energy tariff scenarios (7 to 8 years)	• For facilities that use lot of thermal energy for their processes • For facilities that have a simultaneous need for heat and power (cogeneration system), • Absorption chillers can be utilized for facilities that have high electrical demand charges. Absorption chillers minimize or flatten the sharp demand spikes as part of a peak shaving strategy • For facilities where the electrical supply is not robust, expensive, unreliable, or unavailable • For facilities, where the cost of electricity verses fuel oil/gas tips the scale in favor of fuel/gas • For facilities wanting to use a "natural refrigerant and aspiring for LEED certification as absorption chillers do not use CFCs or HCFCs.

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[3] Image Source. Website Title: HVAC System , HVAC Water Chillers,Valves and Pumps. Article Title: Absorption Chiller in HVAC system. Date Accessed: December 04, 2017

• Allows completely renewable energy-based operation and has short payback period of approx. 3 years for sectors/regions with high annual cooling demand upwards of 8,000 hours/year and high overall system 'on-time'.		

Installed/Sold Capacity

As per data received by five manufacturers of NH_3 and LiBr VAM systems from 2007 till March 2015 and trend projections till March 2017, an aggregate of 7,12,104 TR is estimated to be installed/sold.

GHG, Power and Energy Savings

Until March 2017, power consumption from installed NH_3/LiBr systems was estimated to be 4,27,263 kW, while that from conventional systems was 8,22,486 kW, higher by 92.5%. Similar trend line was observed for energy consumption, NH_3/LiBr was estimated at 9,53,650 MWh/yr and conventional systems were estimated at 18,35,790 MWh/yr. A total of 15,01,711 MT CO_2e of GHG emissions were estimated to be avoided through NH_3/LiBr based systems in 2017. Emissions from conventional systems were estimated to be 132% more than from NH_3/LiBr systems, primarily since the GWP and ODP of Ammonia and Lithium Bromide is zero.

Design & Installation Capacity

The design capacity of NH3 & LiBr HVAC based systems range from of as low as 3 TR to a maximum (installed till date in India) of 3,000 TR.

Reliability

If using best practices, 10 years minimum.

Maintainability

Low maintenance; need to clean collectors often. VAM requires maintenance (External).

Schedule Feasibility

For a typical installation size of 50 to 75 TR, it can take approximatively 5-6 months.

4.3.2 Radiant Cooling System

Background

In a radiant cooling system, the heat is removed from the roof and the floor by laying plastic pipes in loops between the slab and the tiles, the pipes are filled with water. A radiator is connected to the water loop, which cools the water passed in the pipes. Thus, the structural heat load is removed, thereby reducing the cooling load imposed on the air conditioning system. The basic working principle is same as structure cooling but this system uses chilled water which is cooled down by conventional chiller.

There are three types of radiant cooling systems:

- **Chilled ceiling/floor/slab/wall** – They work by means of convective and radiant heat transfer, and induce air movement in the room in which they are placed. The sensible cooling capacity is approximately 24 BTU/hour per square foot of beam. Chilled ceilings lack the ability to control the humidity of a room and must be paired with a ventilation system.
- **Passive chilled beam** – Passive beams use a pipe surrounded by a coil in order to form a radiator system, often used in conjunction with an under-floor air distribution system. The cooling capacity is approximately 400 BTU/hour per linear foot of beam. These too do not have any method for maintaining the humidity of a room, and must be paired with a ventilation system.
- **Active chilled beam** – They have a ventilation air ducted through the chilled beam. The ventilation air must first be de-humidified upstream of the passive chilled beam, to avoid condensation potential at the chilled beam.

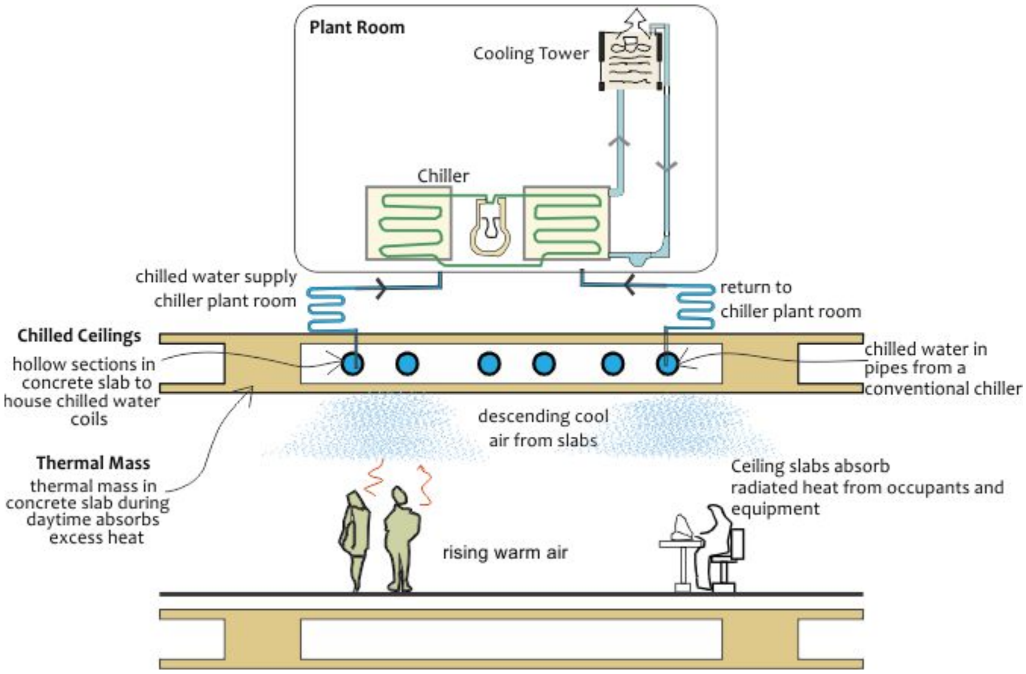


Figure: Radiant floor cooling system[4]

Benefits	Constraints	Applications
• Specific Heat Capacity of water ~ 4 times that of air: for the same flow rate, 4 times more heat can be removed by using water than by using air. • Air flow rate and fan power consumption reduced drastically: To remove 1 kW of heat from a room, an AC needs ~140 W of fan power. For the same load, a radiant system needs ~ 3 W to run the circulation pump.	• Surface temperature should not be equal or below the dew point temperature in the space. • Supplementary air-conditioning system is required: for the removal of the latent load (moisture removal) and fresh air • In dry regions, radiant system can work independently for most time of the year (except during monsoon time)	• Commercial Area – office spaces, schools, and few applications in hotels. • Residential – in homes, in areas where humidity is less. • Industry – Capillary tubes maybe used for an industrial application, as well as a fire suppression system • Hospitals and Laboratories –

[4] Image Source. Website Title: Net Zero Energy Buildings. Article Title: Radiant Cooling Systems. Date Accessed: December 04, 2017

• Reduced energy loss due to duct leakage & fan motor heat loss • Lower life cycle cost compared to conventional, due to decreased maintenance • It has lower first costs attributed to integration with structure and design elements and smaller chiller requirement. • Low air volume and hence duct sizes are significantly reduced. • Fewer air handling unit; in some cases, only treated fresh air units may be required. • Air Handling Unit room in the building can be eliminated • Additional floor can be added in same FSI / Building Height due to vertical-space saving from eliminated ducts • Space saving from smaller chiller size • Space heating can be done using the same system • Absolutely noiseless & vibration free • Does not produce any draft • Provides uniform temperature • Surface temperature or supply temperature is always above dew point and hence, no chance of condensation		Radiant cooling can be effective to maintain aseptic environment in hospitals and laboratories. It provides a silent, draft-free, thermally stable environment for sedentary patients.

Installed/Sold Capacity

As per data received by four manufacturers of Radiant Cooling systems from 2008 till March 2016 and projections till March 2017, an aggregate of 39,48,599 Sq. ft. has been cooled, which would be approximately equivalent to 17,524 TR worth of conventional system cooling.

GHG, Power and Energy Savings

Until March 2017, power consumption from installed Radiant Cooling systems was estimated to be 12,207 kW, while that from conventional systems was 20,241 kW, higher by 66%. Similar trend line was observed for energy consumption, Radiant Cooling was estimated at 27,246 MWh/yr and conventional systems were estimated at 45,177 MWh/yr. A total of 29,992 MT CO_2e of GHG emissions were estimated to be avoided through Radiant Cooling systems in 2017.

Manufacturing Capacity

The manufacturing capacity purely depends on the scale of the project. There is no defined limit as such to the area which can be cooled using Radiant Cooling.

Design & Installation Capacity

Radiant Cooling systems have been successfully installed to cool areas as small as 500 Sq. ft. (replacing approximately 2.2 TR of conventional air conditioning) to a maximum (installed at one site as of reporting date) of 4,19,000 Sq. ft. (replacing approximately 1,860 TR of conventional air conditioning)

Reliability

If using best practices, 10 years minimum. Investigating further about actual life-span, warranty, and annual performance deterioration if any. Compressor will usually have warranty.

Maintainability

Four moving parts: Compressors, Fans, Pump, Motors. All parts are common and locally available. Usually the compressor is manufactured/sold by a third-party who will provide servicing for it.

Schedule Feasibility

Possible to install 1500 - 2000 sq. ft. per day; based on project urgency this can increase.

4.3.3 Structure Cooling (Therm-O-Drain)

Background

The ancient Indian architecture has provided us with many strategies for cooling the interiors of structures by adding features to the design of the building. By the use of structure cooling, Mean Radiant Temperature of the rooms in reduced, thus ensuring thermal comfort of the occupants. The structure cooling works on three basic principles:

- **Thermal Barriers:** This principle says that barriers should be created against sunlight in the form of hollow walls, trees, or shading devices. The barriers act as resistors to the incident heat and help in reducing the temperatures.
- **Mass as Heat Sink:** The thick walls don't let the heat to be transmitted to the inside of the building, thus acting as a capacitor. In the day, the walls absorb heat without much change in the interior temperature and during the night, it radiates the heat back to the atmosphere.
- **Heat Drainage:** The residual heat should be channeled to be drained out into flowing water or flowing wind during the night for preventing the interiors to heat up.

This technology is similar to Radiant Cooling technology, but chilled water may not be used. Water is drawn from a storage tank and allowed to flow through pipes (embedded in slabs) in direct contact with the surface of the structure. Water absorbs heat from the structure and flows back to the tank again, where it gives away the heat gained. The cooling of this water in the tank requires radiators (heat exchangers) in bigger applications. Polypropylene pipes (corrugated) are generally used. This technology reduces heat ingress and keeps the room temperature from rising too high, thereby reducing the cooling requirement of the building significantly. Pumps are the main power consumers in this system. Structure cooling is generally used in conjunction with active Air-conditioning systems (Cooling India, 2013).

Figure: Shrujan Living-Learning-Design center, Kutch (Gujarat)

Installed/Sold Capacity

Panasia Engineers are the only manufacturers of Structure cooling system. As per data shared by Panasia from 2005 till March 2014 and projections upto March 2017, an aggregate of 5,46,053 Sq ft has been covered with Structure Cooling system (replacing approximately 4,598 TR of conventional air conditioning).

GHG, Power and Energy Savings

Until March 2017, power consumption from installed Structure cooling systems was estimated to be 2,397 kW, while that from conventional systems was 5,311 kW, higher by 54%. Similar trend line was observed for energy consumption, Structure Cooling was estimated at 5,349 MWh/yr and conventional systems were estimated at 11,854 MWh/yr. A total of 8,438 MT CO_2e of GHG emissions were estimated to be avoided through Structure Cooling systems from in 2017.

Manufacturing Capacity

The manufacturing capacity varies on project to project bases.

Design & Installation Capacity

The design capacity of structure cooling system range from of as low as 300 sq.ft (replacing approximately 1.3 TR of conventional air conditioning) to a maximum (installed at one site as of reporting date) of 1,00,000 sq. ft. (replacing approximately 444 TR of conventional air conditioning)

Reliability

As per the life of the building: 50-100 years; as this technology is embedded in the structure’s slab.

Maintainability

Three moving parts: Pump/Motor, Fan, Radiator. Parts are simple and locally available; hence low-chance of failure, and local vendors can service.

Schedule Feasibility

Possible to install 1500 - 2000 sq. ft. per day; based on project urgency this can increase.

4.3.4 Indirect-Direct Evaporative Cooling (IDEC)

Background

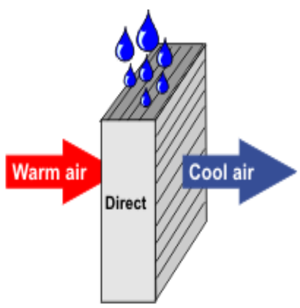
The evaporative cooling technology works on the same principle as the perspiration of our body. When dry air comes in contact with water, some of the water in the liquid state evaporates into vapor state and in this process heat is taken away from the dry and hot air leaving it cool and moist.

There are 3 types of evaporative cooling:

In the **Direct Evaporative Cooling** technique, the hot and dry air passes through the wet media converting it into cool air with added humidity. This technique is used for pre-cooling the air for the vapor compression cycle for increasing efficiency.

In **Indirect Evaporative Cooling,** air from outside enters the system and its temperature is reduced without increasing the relative humidity as it is passed through the dry part of the opening. Outside air is cooled without gaining moisture as it is passed through the dry section of an evaporative cooling heat exchanger. Energy efficiency is increased by passing pre-cooled air through the system.

Indirect-Direct Evaporative Cooling (IDEC) is used for cooling the ambient air before it enters the condenser coil and the while indirect evaporation is used for cooling the make-up air through the heat exchanger.



Direct Evaporative Cooling

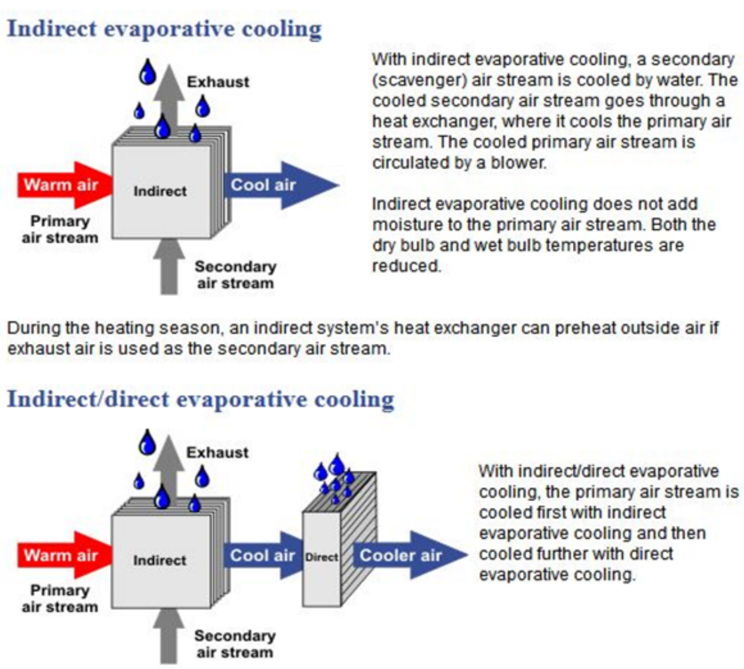


Figure: Evaporative Cooling[5]

Installed/Sold Capacity

As per data received from four manufacturers of IDEC systems from 2008 till March 2015 and projections until March 2017 , an aggregate of 4,27,09,236 CFM System has been installed/sold. This equates to replacement of approximately 1,06,773 TR or conventional air conditioning.

GHG, Power and Energy Savings

Until March 2017, power consumption from installed IDEC systems was estimated to be 74,741 kW, while that from conventional systems was 1,22,789 kW, higher by approximately 64%. Similar trend line was observed for energy consumption, IDEC was estimated at 1,66,673 MWh/yr and conventional systems were estimated at 2,73,820 MWh/yr. A total of approximately 1,27,505 MT CO_2e of GHG emissions were estimated to be avoided through IDEC systems from in 2017.

Manufacturing Capacity

The manufacturing capacity of ATE-HMX[6] is 1,20,00,000 CFM annually (replacing approximately 30,000 TR of conventional air conditioning).

Design & Installation Capacity

The design capacity of IDEC systems range from as low as 1,000 CFM (replacing approximately 2.5 TR to conventional air conditioning) to a maximum (installed at one site as of reporting date) of 1,45,000 CFM (replacing approximately 362 TR to conventional air conditioning).

[5] Image Source. Website Title: All Seasons Hire. Article Title: How Evaporative Coolers Work. Date Accessed: December 04, 2017

[6] HMX is a registered trademark of the A.T.E group.

Reliability

With the implementation of recommended maintenance practices, the life of many parts of an Indirect-Direct Evaporative Cooler (IDEC) can be 15 years. However, parts such as heat exchangers may require replacement as and when their fouled condition reaches a stage where it's no longer possible to clean them further.

Maintainability

The following parts of an IDEC need routine maintenance:

1. Suction strainers of pumps
2. Heat exchangers
3. Air pre-filters
4. Water tank

Critical spares for operation are belts, filters and a spare pump. Will need to replace cellulose pad.

Schedule Feasibility

Unit can be purchased off-the-shelf; ducting to be done. For HMX[7], 2-3 weeks for deployment in Bangalore; for other cities may be a bit longer.

View the Annex of this document for Case Studies for each technology.

4.4. Market Share and Growth Potential

What is the current market size of conventional cooling and what is the growth potential?

Current Refrigerant Uptake in Air-Conditioning

In 2015, the residential air-conditioning sector saw maximum refrigerant consumption from HCFC-22 at 94%, 2.6% came from HFC-410A, 1.8% from H123, 0.9% from HC-290 and only 0.5% from R32. HCFCs constitute 95.9%, while 3.2% is HFCs and 0.9% natural refrigerants. In sectors such as residential Airconditioning, where the transition has not yet begun, or is in the nascent stage,

[7] HMX is a registered trademark of the A.T.E group.

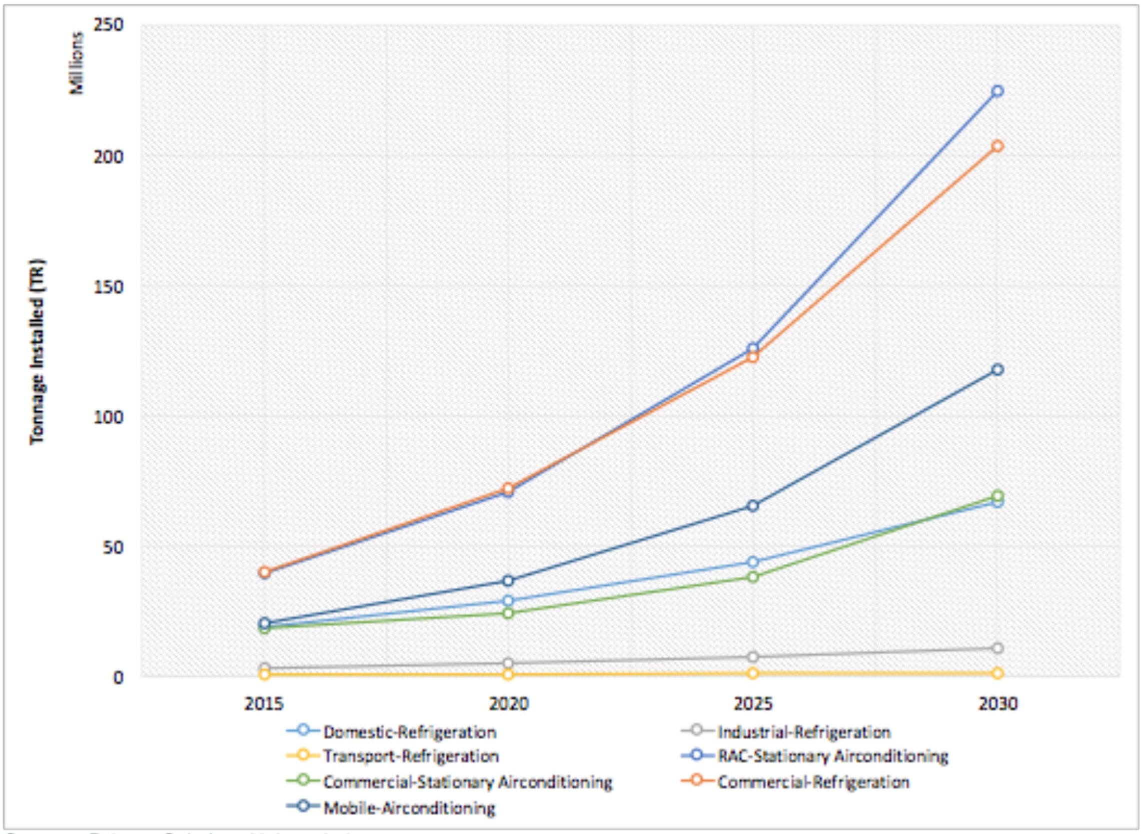
leapfrogging to natural refrigerants such as HC-290 would be reasonably easier and feasible especially considering that the technology is already known to work and further, is economically viable to the end user when the entire life cycle is considered.

With respect to the commercial air-conditioning sector, HFC-134a forms the chunk of all the refrigerants consumed in 2015. It constitutes 53% of the total consumption, followed by HCFC-22 with a 41% uptake.

Sectoral Growth Projections

Calculations to project growth of refrigerants suggest a 4-time growth for commercial refrigeration and an increasing trajectory for all sectors, however, by varying growth rates. Room air-conditioning sector witnesses the maximum growth towards installed tonnage with a 5.6-fold increase in 2030 from 2015 levels, it increases from 38 million TR in 2015 to 216 million TR in 2030. Such a significant growth would essentially result in proportional increase in emissions from HFCs and HCFCs, suggesting the importance of leapfrogging to natural refrigerants and compatible technologies. Figure 9 shows the sector wise tonnage projection from 2015 till 2030.

Figure 1 | IPCC Sector-wise Tonnage projection (2015-2030)



Source: cBalance Solutions Hub analysis

The table below provides a comparison of the estimated installed capacities of the 5 most dominant sustainable cooling technologies in India. These technologies collectively represent 15,50,775 TR of replaced capacity from conventional air conditioning technologies. The installed capacity of conventional air conditioning in 2017 is estimated to be 6,84,16,837 TR (stock). This leads to the conclusion that sustainable cooling technologies have replaced approximately 2.3% of the total air conditioning demand (stock) in India. In terms of annual sales, the sustainable cooling technologies accounted for 4,74,158 TR in 2017 (in terms of replaced TR relative to conventional systems). The this represents approximately 4.7% of the annual 99,85,722 TR space cooling sales market.

Table: Comparative Analysis

Sr. No.	Technology Type	GHG Emission Savings (%)	Capacity (TR) Replaced (March 2017)	Sales (TR) in 2017	Commercialization Stage	Reliability	Maintainal
1	**Structure Cooling Hybrid**	55%	4,598	538	Pre-market Development	Good	Good
2	**VAM (Solar and others)**	57%	7,12,104	1,34,968	Commercialization	Good	Good
3	**Radiant Cooling Hybrid**	46%	17,524	4,176	Commercialization	Good	Good
4	**Indirect-Direct Evaporative Cooling Hybrid**	48%	1,06,773	27,194	Commercialization	Good	Average
5	**R290 Split AC**	24%	7,09,776	3,07,282	Commercialization	Excellent	Good

Commercialization Stages:

1. **Product Development**
   a. Development: High cost of development
   b. Risk: High level of risk
   c. Financing: Innovation Financing
2. **Pre-market Development**
   a. Development: Pilot level development
   b. Risk: Moderate to low risk
   c. Financing: Special financing (low interest rate)
   d. Suppliers: 1 or less supplier
   e. Projects: Less than 10 projects/sales per year
3. **Commercialization**
   a. Development: Commercial scale
   b. Risk: Normal business risk
   c. Financing: Conventional finance; yet can be catalyzed with special financing.
   d. Suppliers: 2 or more suppliers
   e. Projects: More than 10 projects/sales per year

Reliability: The ability of a system or component to perform its required functions under stated conditions for a specified time - taking into account lifespan of equipment, performance deterioration.

Maintainability: The probability of performing a successful repair action within a given time. In other words, maintainability measures the ease and speed with which a system can be restored to operational status after a failure occurs. This does not mean how fast the customer service responds. This means, what are the chances a failure will occur, and if it does occur, and if customer service does respond quickly, how fast can it be repaired. This may be based on availability/complexity of parts, etc.

4.5. COST BENEFIT ANALYSIS

Methodology to follow for cost-benefit analysis: "A structure-cooling based HVAC system saves the occupant(s) money, and allows builders to earn more per sqft." *How will we prove that structure cooling in fact does increase profit?*

- Benchmark: Check if current building's in India & Internationally with a structure-cooling based HVAC system have a higher market price.
- Do verified research to see if 'Green Buildings', including ECBC+ and SuperECBC buildings fetch higher than average market rates. At the workshops, inform PFIs that ECBC+ and SuperECBC buildings, have greater market value (sale price), and Alternative Cooling Systems can greatly help buildings in their portfolios meet these standards. Consider beneficial terms in the finance program for buildings that have met these standards; ECBC includes Residential and Commercial Buildings.
- Marketing: Understand what methods/explanations Indian & International builders who use a structure-cooling based HVAC system use to sell, increase the sale price of, their property.
- After the structure-cooling based HVAC system solution is customized for each sector, and climate type, get specific numbers for cost savings vs. conventional system; compare "average buildings" for each sector.

Cost benefit analysis has been conducted for the five technologies discussed in the sections above. The analysis is done on a 10 year project lifecycle. Data on technology system costs, its annual operational & maintenance costs, energy costs was compiled for each of the 5 technologies in each sector and compared the corresponding costs of the conventional systems to derive the benefits of using SCTs.[8] The analysis below shows savings conducted on 1 TR of each system over 10 years. Since, most technologies have an average lifetime of 10 years no replacement costs have been included in the current analysis. After receiving detailed inputs and feedback from the workshop and subsequent meetings, the CBA will be amended to reflect a more realistic scenario. The input data is given in Annex 3.

Split Air Conditioners Using R290

Results - R290	Unit	Banking	Residential	Hospitality	Commercial
Savings of opex using R290	INR	88,032	78,577	167,059	89,485
Net savings using R290	INR	74,828	65,373	153,855	76,281
IRR on the net system savings	%	103%	92%	191%	105%
Simple Payback period	years	1.02	1.13	0.54	1.00

Source: own analysis

[8] Source of Input Data: cBalance Solutions Hub. 2016. *Mapping Natural Refrigerant Technology Uptake in India.* Pune, Maharashtra, India.

Solar Vapour Absorption Machine (SVAM)

Results– Solar VAM	Unit	Banking	Residential	Hospitality	Commercial
Savings of opex using SVAM	INR	236,531	203,829	509,869	241,556
Net savings using SVAM	INR	-102,231	-134,932	171,107	-97,206
IRR on the net system savings	%	5%	2%	22%	5%
Simple Payback period	years	8.12	9.17	4.17	7.98

Source: own analysis

Radiant Cooling System

Results - Radiant Cooling Hybrid	Unit	Banking	Residential	Hospitality	Commercial
Savings of opex using RCS	INR	84,122	76,386	148,780	85,310
Net savings using RCS	INR	33,932	26,196	98,590	35,120
IRR on the net system savings	%	26%	23%	47%	26%
Simple Payback period	years	3.78	4.13	2.22	3.73

Source: own analysis

Structure Cooling (Therm-O-Drain)

Results - Structure Cooling System	Unit	Banking	Residential	Hospitality	Commercial
Savings of opex using SCS	INR	81,709	74,260	143,973	82,854
Net savings using SCS	INR	50,627	43,178	112,891	51,772
IRR on the net system savings	%	42%	38%	73%	42%
Simple Payback period	years	2.48	2.72	1.44	2.45

Source: own analysis

Indirect-Direct Evaporative Cooling

Results - IDEC + DX Hybrid	Unit	Banking	Residential	Hospitality	Commercial
Savings of opex using IDEC	INR	103,050	91,876	196,446	104,767
Net savings using IDEC	INR	61,644	50,470	155,040	63,361
IRR on the net system savings	%	39%	35%	74%	40%
Simple Payback period	years	2.62	2.92	1.41	2.58

Source: own analysis

Key findings of the analysis from the cost benefit analysis are summarized below:

- In case of solar VAM, scale of operations is needed to offset the high investments costs of the system by increased savings from energy costs. This is possible when the system is run for a continuous period, as seen in the case of Hospitality sector.
- R290 is the most feasible technology in terms of savings
- The CBA results of IDEC + DX hybrid and Structure Cooling System are similar with respect to IRR and simple payback due to similar system costs.
- Although radiant cooling system does not require annual maintenance costs, the relatively lower viability is due to the higher capital costs of the system compared to IDEC and SCS.
- Hospitality is the most profitable sector. This is attributed to the longer operational hours.

4.6. Where to Act?

4.4.1 Sector Rationale

The project's locus of interest is the intersection of the following built-space scenarios (also depicted in the subsequent table):

- New Residential Real Estate Developments at Township Scale, Buyer Occupied, Occupant & Professional Management as Operator
- New and Existing Commercial Real Estate Development at the Campus/Park scale in the IT Sector, Owner Occupied, Occupant & Professional Management as Operator

Sector	Scale		Status		Occupant			Operator	
	Individual unit	Large	New	Existing	Builder	Buyer	Tenant	Occupant	Professional Management
Residential									
IT									

The rationale for selection of these 2 intersections amongst all possible intersections between commercial (including hotels, bank branches, IT, healthcare, education), residential (new-existing), scale (individual-unit and large) was arrived at through a dialectic process amongst the project's management team and formal-informal advisors to the project working in academia, industry and civil society advocacy organizations related to the field of buildings and energy efficiency. A distillation of the dialectic which informed this process is presented below.

4.4.2 Sector choices:

The choice of sectors to 'act' in, was made by exploring, amongst other factors, the relative 'growth' potential of real-estate versus industrial and commercial cooling and amongst real estate, the relative growth projections for various sub-sectors like hospitality, banking, IT, residential etc.
Based on credible real-estate growth statistics from 2012 study[9], the built residential space constructed in 2005 was expected to rise by approximately 53,000 million ft^2 by 2030 and built commercial and office space was expecting a growth of 17,000 million ft^2 by 2030. Whereas the growth in built space for hospitality and retail sector was expected to be approximately 7,100 million ft^2 and 5,400 million ft^2 respectively.

The residential sector was selected due to the exceptional non-linear growth in AC installations and the concomitant rise in energy consumption that is anticipated from this sector over the coming decades. "Under the business-as-usual scenario, the annual electricity use per household is predicted to increase from 650 kWh in 2012 to 2750 kWh by 2050. Using a very aggressive policy strategy, the increase in household electricity consumption could be cut to 1170 kWh per household in 2050."[10] It was also selected to explore new financial models and non-financial narratives,

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[9] Constructing Change: Accelerating Energy Efficiency in India's Building's Market, NRDC & ASCI, 2012

[10] RESIDENTIAL BUILDINGS IN INDIA: ENERGY USE PROJECTIONS AND SAVINGS POTENTIALS, Global Buildings Performance Network, 2014

techniques to address the formidable challenges posed by the principal-agent conflict (builder-buyer split-incentive).

New residential townships are witnessing growth for several reasons:

- Under the 'Make in India' initiative, the Government of India government has permitted 100% foreign direct investment (FDI) for townships and cities.
- Within the smart city project, the Indian government has announced plans to develop 100 smart cities with an aim to modernize the existing cities which includes development of townships; specifically "Greenfield development – aimed for city extension by developing new townships in new cities or vacant lands which follows all the norms of smart city.[11]"
- Lack of land within the city to meet individual housing demand (hence townships are built in peri-urban areas) VS rising demand for housing.
- For consumers, townships offer more than just a standalone building – convenient travel, employment opportunities closer to home, playground, parks, hospital, schools, etc.

The IT sector was selected amongst the other significant contributors to India's commercial real-estate development due to its evident thrust towards environmental stewardship, its existing progressive building practices (some of the most exhaustively researched, documented and credible efforts in energy efficiency building design and construction are associated with buildings owned and operated by Infosys, WIPRO, Tata Consultancy Services, etc.), its alignment with global discourse on energy efficiency in buildings, its transparent corporate practices and decision making processes. Further, the IT sector industry body (NASSCOM) is highly accessible, assertive, and well-respected. It champions causes and missions that provide pervasive benefits to the sector, while fostering a collaborative, best-practice sharing, environment between IT companies. India's total software product market grew at 9.5% in FY 2017, and overall domestic IT/BPM sector is expected to grow at 8.5% in 2017[12]

Further, India's building sector is forecasted to grow five-fold (500 %) by 2030 over 2005 figures. If those who design, build, and manage buildings, manufacturers of cooling equipment, financial institutions, and ESCOs do nothing but 'more of the same', installed Rooms ACs in India balloon from 32 million ACs in 2015 to 225 million ACs in 2035, and Commercial ACs grow from 9 Million-TR in 2015 to 104 Million-TR in 2035[13]. If we allow this to happen, this will lead to a substantial GHG emissions from the cooling sector in India. For IT companies, Campus/Business-Park scale projects increase in the energy demand in the buildings sector which currently accounts for around 30% of total final energy consumed in India; India will need to build 1,010 new power plants (dominated by Thermal Power) of 250 MW each by 2030 for addressing merely the AC power load.

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[11] **Source:** Smart Cities Mission, www.smartcities.gov.in, accessed 5 August 2016

[12] Press Information Bureau, Government of India, Ministry of Electronics & IT (2017, May 23 Published). *Employment prospects in India's IT Sector: Robust Outlook.* Retrieved from http://pib.nic.in/newsite/PrintRelease.aspx?relid=162046

[13] Fairconditioning & Chaturvedi V, Sharma M, Chattopadhyay S, and Purohit P. HFC emission scenarios for India. CEEW report

This programme has not selected the Industrial and transport cooling and refrigeration sectors, as they are currently a small fraction of overall cooling in India, and are anticipated to have much lower growth than built-space cooling.[14] Further, the transformation of those sectors to sustainable cooling is purely a technical matter, and does not lend itself to a progressive discourse. Our competence is in the intersection of multiple stakeholders to address a problem; largely unidimensional.

Furthermore, it must be noted that while the preceding cost-benefit analysis does indicate that payback periods for use of any cooling technology replacement are lower for the hospitality and banking sector (due to higher annual AC usage hours; banking companies are estimated to have longer working hours and also operate on weekends and centrally air conditioned hospitality properties operate their AC systems round the clock) these sectors are not selected for further investigation in this project. The primary rationale for eliminating these 2 sectors is presented below:

- Hospitality: customer preferences for conventional cooling systems is seen to be very high. This couples with the varying occupancy rates through the year often obviates the use of alternate cooling systems that are more suitable for relatively fixed capacity operations. Also, space constraints and the imperative need to provide a high degree of thermal comfort control to guests (as opposed to trained operators) in these facilities also warrant precluding of alternate cooling technologies at this stage of the project.
- Banking: The banking sector presents similar operational characteristics to the IT sector. However, banks are often operated from leased properties in urban built spaces and not in exclusive IT parks/SEZs – which is often the case with large IT hubs in India. The space and ownership status constraints with this sector making it a less attractive choice for further exploration relative to the IT sector and has therefore been eliminated from consideration.

4.4.3 Scale choices:

Townships scale developments were selected to allow non-unitary (i.e. window and split ACs) sustainable AC systems to be explored as suitable alternatives. The financial feasibility for these larger scale systems improves when applied at a multi-building scale (eg. structure cooling using common chiller-plants, cooling mechanisms through a 'district-cooling' approach). Furthermore, township scale development requires investment at scales which are likely to be more attractive to energy-efficiency inclined banking and non-banking financial institutions/PE firms.

IT companies, Campus/Business-Park scale projects were selected for similar considerations of expanding the spectrum of appropriate sustainable cooling technologies that could be explored, including systems which enable complete off-gridding (for at least the high cooling demand periods of the year when abundant solar energy is available during the daytime in summers) through harvesting solar energy (for which space requirements are significant); like Solar VAM systems.

4.4.4 Status choice:

For residential townships, only new townships are considered relevant since these are expected to dominate the upcoming proliferation of peri-urban construction around major Indian metros and that retrofit solutions for existing buildings provided limited technological intervention room while

[14] cBalance Solutions Hub. (2016). *Mapping Natural Refrigerant Technology Uptake in India.* Pune, Maharashtra, India.

inflating installation costs of sustainable cooling technologies, adversely affecting the magnitude and perception of payback periods.
In the case of IT parks, both existing and new constructions are seen as robust populations (in terms of constituting a sector with adequate economic vitality) for the interventions. This sector is also known to conduct routine infrastructure overhauls in a planned and timely manner which makes it suitable for conflating structural and other infrastructure quality improvements with HVAC system refurbishment.

4.4.5 Occupant Choice:

For residential townships, only buyer occupied scenarios are relevant. This stems from the ontological characteristics of this sector where flats in townships are sold to individual buyers who then continue to own these properties through their life-cycle or transfer ownership rights to other individuals. In either case, the principal (builder) does not remain involved with the built space in any meaningful manner which related to building operations (and therefore insulated from energy efficiency benefits; the source of the principal-agent or split-incentive conflict).
The ontological situation with IT company campuses or parks is contrastingly different from the above; large campuses are often occupied by the builder (in many cases the IT company itself) and hence the other occupancy situations were excluded from the locus of interest for this project.

4.4.6 Operator Choice:

Both types of operator scenarios were considered (occupant operated/managed and professionally managed) and hence doesn't really require justification as a 'choice'.

4.7. Application

All the sustainable cooling technologies outlined in the earlier section have already been commercialized and can work in any climate type. However, it is noteworthy to mention that while indirect-direct evaporative cooling can work in any climate type, it will perform better in hot & dry climates.

All of the five sustainable cooling technologies chosen are suitable for different use cases in both selected sectors - new residential townships and new/existing business parks.

In new residential townships that usually have high-rise buildings - like Hiranandani Gardens in Powai, Mumbai[15] - the following technologies could be applied:

- Structure cooling or Radiant cooling can be applied throughout the structure or in each flat, respectively.
- IDEC provides pre-treated cooled air to all flats. Ducting is provided.
- District Cooling: Solar Vapor Absorption

[15] Website title: Hiranandani.com. Retrieved November 25, 2017, from http://www.hiranandani.com/Hiranandani_Gardens.aspx

- R290-refrigerant-based split air conditioners

In new and existing business parks - like Wipro Campus in Electronic City, Bangalore[16] - all technologies can be applied:

- Structure Cooling can be applied in each slab for new buildings, or on the roof slab as a retrofit.
- Radiant cooling can be applied in both new buildings and as a retrofit.
- Solar VAM can be installed instead of, or can replace, a conventional water-cooled chiller
- IDEC can become a precooler for a conventional system/chiller
- R290 Split ACs can be used to cool individual rooms

[16] Website title: Electronic-city.in, Retrieved November 25, 2017, from http://www.electronic-city.in/

5. ACTIVITY 3: CONSULTING THE STAKEHOLDERS/ACTORS:

5.1. WHO ARE THE STAKEHOLDERS/ACTORS?

We plan to consult adopters, potential adopters, aggregators, financial institutions, ESCOs, and sustainable cooling technology vendors.

In this context we are defining the adoption-series, and aggregator, stakeholders as follows:

Adopters: Final decision-makers who are real-estate developers, companies who contract their own real-estate development, or contractors of real-estate, who have adopted sustainable HVAC systems, such as the sustainable cooling technologies chosen in this programme.

Near-Adopters: Final decision-makers who are real-estate developers, companies who contract their own real-estate development, or contractors of real-estate, who have tried to adopt sustainable HVAC systems. However, faced some barrier(s) that prevented their adoption.

Potential-Adopters: Final decision-makers who are real-estate developers, companies who contract their own real-estate development, or contractors of real-estate who have not even considered adopting sustainable HVAC systems yet. However, may be potential adopters if their potential barriers to adoption are addressed.

Aggregators: A classification of final decision-makers who are real-estate developers, companies who contract their own real-estate development, or contractors of real-estate, that could be included in either the adopters, near-adopters, or potential-adopters categories, who have large building portfolios including several built and planned residential townships and/or commercial business-parks.

5.2. ANALYSE BARRIERS AND MEASURES TO OVERCOME IDENTIFIED BARRIERS

To extend our analysis of the identified barriers (financial and non-financial) to technology adoption/acceptance for builders, financial institutions and ESCOs, the technology acceptance models (TAMs) – TAM 2[17] & TAM 3[18] will be used. For sustainable cooling manufacturers, the 'Evaluating R&D and New Product Development Ventures'[19] paper's 'checklist analysis' will be used to explore potential barriers in developing their products and the market.

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[17] Dr. Sullivan, M. (2000). Extended technology acceptance model. Retrieved from http://realkm.com/2016/08/24/extended-technology-acceptance-model-tam2-personality-tkms-series/

[18] Venkatesh, V., & Bala, H. (2008). Technology Acceptance Model 3 and a Research Agenda on Interventions. Decision Sciences (May 2008) Volume 39 Number 2

[19] Office of Productivity, Technology and Innovation U.S. Department Of Commerce. (1986). *Evaluating R&D and New Product Development Ventures*. U.S. Department of Commerce.

Both these approaches will serve as flexible frameworks for a model that seeks to examine the causes that entrench the status quo in the built-space ecosystem, and lead us to identify mechanisms to overcome those barriers.

The following questions have emerged after study of the TAMs. They will further be refined to become more pertinent and succinct.

For the Builders, Financial Institutions, ESCOs:
Have you already worked on projects involving building energy efficiency or sustainable cooling technologies?

1. If not,
    a. What were the financial and non-financial barriers?
    b. Is there a way finance can help? How?
    Note: We seek to understand from the Near-Adopters what barriers stymied their efforts, and from the Potential Adopters what barriers may impede their adoption adopting. We will illustrate the process of understanding their potential barriers in the next section.
2. If yes,
    a. Why did you adopt?
    b. What were the initial financial and non-financial barriers?
    c. How were these addressed?
    d. Is there a way finance can help? How?
    e. Who initiated the adoption? Seek to map out the process.
    f. Who was the decision maker? And how were they convinced?
    g. How did they go back to the design team to commission the project?
    h. For non-ESCOs: Was the project supported by ESCOs, what was their role?

Financial Institutions (FIs)
We seek to understand through primary research with FIs, and secondary research:

- Their existing perception and struggle with non-financial barriers that might have derailed earlier well-intended and intellectually rigorous financial schemes/products/programs for supporting mainstreaming of energy efficiency in buildings.
- Their level of voluntariness to participate in creating/hosting a financial mechanism in a Technical Assistance Facility without the presence of a government or multilateral institution mandate/push.
- The quantity of finance and path it takes to reach the Building Sector (Commercial and Residential), and how is it distributed; i.e. private equity, commercial finance, etc.
- Their openness to finance specific technologies, or technology groups.
- Identity whether any FIs are working on similar finance projects nationally or internationally.

ESCOs: We seek to understand from ESCOs any existing barriers relating to the selected technologies and existing business park sector, and what they would like to see in the program design; through primary and secondary research.

Sustainable Cooling Technology (SCTs) Vendors: As the SCTs vendors are at the forefront of seeking to get end-user adoption every day, we will consult them to understand what are common barriers they experience to adoption, and how they feel these barriers could be overcome. We will use the 'Evaluating R&D and New Product Development Ventures' paper's 'checklist analysis' to guide the discussion to identify potential barriers in developing their products and the market.

5.3. METHODOLOGY TO ANALYSE BARRIERS

We will consult each of the above set of stakeholders through two workshops and one-on-one meetings.

5.3.1 Workshops

The vision for these two collective-intelligence workshops are to further analyze identified barriers that prevent the stakeholders from adopting sustainable HVAC systems, and begin the dialog on how those barriers can be addressed.

The workshops will be held in Mumbai-Pune region and the Bangalore-Chennai region, at environmentally-sensitive venues that offer participants a relaxed setting that stimulates present-mindedness.

The workshops will aim to co-create a democratically conceived strategic response(s) to the barriers faced by each stakeholder group in adoption of sustainable HVAC systems. The workshops will be a series of thoughtfully crafted, intimate and candid dialogs and group-work sessions to spur collective-intelligence creation.

The dialogs will dwell upon pertinent questions that may draw out barriers/reservations to adoption of sustainable HVAC systems. The effort will be to create profound and transformative ownership of a common intervention roadmap that will seek to deconstruct the status-quo prevalent in the built-space economy and redirect the consequent trajectory of rising greenhouse gas emissions.

All participants can be assured that the issues raised, the views articulated by actors during the workshop will remain confidential and not be disseminated in any form that can be attributed to emerge from the actors i.e. *what happens in Vegas, Stays in Vegas*

Based on our learning from similar past work with real-estate developersand professional facilitators, we consciously plan to limit the size of the workshop as the dynamics, open-sharing, and engagement-level in a smaller group is significantly better, than a larger one.

During the workshops, the following group dialogs will be explored:

Builders Group Dialog:
(*responses to the following 'seed' questions will be explored further to understand the intensity relative to other influences, and possible ways of altering perceptions of the problem)*

1. Do international climate change commitments by India, related to buildings, matter to us?
2. Does the image of our company, amongst peers or customers, as a guardian of the environment matter to us?
3. What is our perception about the performance, ease-of-use and reliability of the SCTs and the associated professional network?
4. Are we convinced about the energy and cost savings emerging from sustainable buildings?
5. Is there are 'business case' here for either stakeholder to explore?
6. What financial models could work to increase the adoption of sustainable cooling?

FI/ESCOs Group Dialog:
(*responses to the following 'seed' questions will be explored further to understand the intensity relative to other influences, and possible ways of altering perceptions of the problem)*

1. What can we learn from past efforts to mainstream energy efficiency in buildings through a finance approach?
2. Are we convinced about the energy and cost savings emerging from sustainable buildings?

3. Is there are 'business case' here for either stakeholder to explore?
4. What financial models could work to increase the adoption of sustainable cooling?

SCT Manufacturer Group Dialog:

1. Do we see ourselves providing cooling as a utility in the future?
2. What is our potential client's perception about the performance, ease-of-use and reliability of the SCTs and the associated professional network?
3. Are our potential clients convinced about the energy and cost savings emerging from sustainable buildings?
4. Is there are 'business case' here for either stakeholder to explore?
5. What financial models could work to increase the adoption of sustainable cooling?

Further, we will set up sessions between the FIs, SCT vendors, ESCOs, and Builders to specifically see how the identified 'resonant' non-financial barriers can be addressed through a multi-pronged interdisciplinary approach, whether new finance mechanisms are needed, and if yes, how the capital can flow, and under what terms. Some of examples of these exploratory questions are:

Builders + FI/ESCO Dialog:

1. How significant and measurable, reportable, verifiable (MRV) are the life-cycle cost savings of SCTs?
2. Is there are 'business case' here for either stakeholder to explore?
3. How will we address the builder-occupant split-incentive issue?
4. What financial models could work to increase the adoption of sustainable cooling?

Builders + SCT Manufacturer Dialog:

1. Do we see ourselves providing cooling as a utility in the future?
2. What is our perception about the performance, ease-of-use and reliability of the SCTs and the associated professional network?
3. How significant and measurable, reportable, verifiable (MRV) are the life-cycle cost savings of SCTs?
4. What financial models could work to increase the adoption of sustainable cooling?

5.3.2 1-1 Meetings

We perceive that key decision-makers of large institutions will be unlikely to attend the multi-day workshop; hence, we will have 1-1 meetings with them. These meetings will consist of and introduction of the programme and sustainable cooling technologies, and exploratory questions, using the flexible framework defined above, to guide us to identify barriers to sustainable cooling adoption.

These aggregators will most likely be decision-makers at some of the following companies. However, this is only an indicate list as we cannot assure that meetings can be set up with all of these stakeholders.

Real-Estate Developers	IT Business Parks
• Hiranandani Group, Mumbai	• Wipro, Bangalore
• DLF, Delhi	• Infosys, Bangalore
• Unitech, Delhi	• Mindtree, Bangalore
• Omaxe, Delhi	• Mphasis, Bangalore
• Prestige Group, Bangalore	• Tech Mahindra, Pune
• Godrej Properties, Mumbai	• TSC, Mumbai

• Ansal API • Kolte Patil, Pune • Sobha Group, Bangalore • Emaar India • Hafeez Contractor, Mumbai	• Oracle, Mumbai • HCL Technologies, Noida

Contractors/Managers of real-estate	Financial institutions
• JLL India • Knight Frank • AECOM	• YES Bank • ICICI Bank • IDFC • SIDBI

ESCOs
• Smart Joules • SEE-Tech Solutions Pvt. Ltd. • Bosch • Energized Solutions • STEAG • Enfragy Solutions • Honeywell

5.4. IMMEDIATE OUTCOMES, ASSUMPTIONS AND DRIVERS

In relation to the TOC, following immediate outcomes are expected to be achieved after completion of activity 3:

Immediate outcomes:

- Identification of any barriers, both financial and non-financial, that adopters, near-adopters, potential-adopters have faced, and how they overcame them. Grouping these barriers together and collectively deciding on how to qualitatively, and if required quantitatively, articulate the barriers.
- Initial thoughts about how these barriers could be addressed - through what types of mechanism(s) and how - in consultation with FIs, ESCOs, and SCTs vendors.

Following assumptions are taken into considerations for achieving these immediate outcomes:

Assumptions:

- The Confederation of Real Estate Developers Association of India (CREDAI) Youth Chapter made up of young real-estate developers fall into the end-user segment categories defined earlier as ‘innovators/visionaries’ and ‘early adopters’. We will target these young real-estate developers for the first two workshops.
- Aggregators that we are targeting will fall into the ‘early adopters’ and/or ‘early majority’ end-user segment categories. If even 2 Aggregators adopt aggressively, the rest of market will follow.
- Financial Institutions will be open to technology-level financing

- Four FIs in PRGFEE, VCFEE Trust, and SIDBI are interested in the program
- Learnings from a representative-sample stakeholder group will be used to design an accurate Technical Assistance facility.

Drivers to achieve these immediate outcomes are as follows:

Drivers:

- UNEP-CCAC & Frankfurt School Involvement builds credibility to enhance decision maker access. Especially for aggregators, who may be swayed to schedule a meeting with us on the basis that we represent international-bodies such as UNEP-CCAC and Frankfurt School.
- Collective-Intelligence Professional Facilitators will encourage safe, candid, and introspective sharing at workshops. This will occur through selecting professional facilitators who are interested in the subject, are open to building their own personal capacity on technical matters about the technologies, and have experience working with diverse stakeholder groups. The cBalance team has experience directly working with two such India-based facilitators who will join the workshops under this programme.
- The network within this programme's management team, and the Fairconditioning[20] network, have valuable contacts that will streamline the outreach for conducting primary research through workshops and 1-1 discussions.

[20] cBalance Solutions and Noé21. Established in 2012. The Fairconditioning Programme. Website: http://www.fairconditioning.org

6. ACTIVITY 4: DESIGN TECHNICAL ASSISTANCE FACILITY

After the collectively identified barriers are clearly articulated, understood, and initial brainstorming of solutions has taken place, we will seek to design mechanism(s) to address the barriers, and bring these mechanisms together in a Technical Assistance (TA) facility. Nature of barriers will govern the solutions. These solutions may include communications, technical assistance and financing approaches / mechanisms. On the other hand, one of two technologies will be selected for developing financing mechanisms / approaches. Technologies will be selected through suitable evaluation parameters.

6.1. WHO

The mechanism(s) will be designed through a dialectic process amongst the project's management team, CCAC, stakeholder consultations (workshops and 1-1 meetings), and formal-informal advisors to the project working in, industry and civil society advocacy organizations related to the field of buildings and energy efficiency. The project management team proposes to design the financing mechanisms / approaches in consultation with CCAC, stakeholder organisations including financing institutions, vendors ESCOs and end-users. These mechanisms have to be practical to implement, hence wider consultations are needed upfront.

6.2. HOW?

A first draft of the technical assistance facility design will be created by the project's team including Frankfurt School, and then brief consultations will be undertaken with the stakeholder organisations mentioned above. After adequate revisions spawned from a dialogical process, the mechanism(s) and technical assistance facility is generally agreed by all associated stakeholders to adequately address the barriers and is shared formally with the stakeholders again.

Some considerations:

- Stakeholder consultations will provide leads to develop technical assistance support needed.
- Other technical assistance support needs will be identified such as need for wider dissemination of technologies among the stakeholder organization, training / orientation to specific groups e.g. architects.

At present conventional cooling systems can be financed through simple debt or through corporate finance (commercial loans from banks on conventional terms). As these rates vary from bank to bank and also credit rating of borrowers, we indicate range - 12% to 18% p.a. with varying tenors. Many financing agencies do provide equipment finance loans on commercial terms. Most banks lend on the basis of strength of balance sheet of a borrower company.

A brief on financing needs:

SCT financing projects are classified broadly on the following two categories:

A. New establishments (new equipment) projects: While construction finance will take care of financing of building construction whereas equipment finance and lease financing. Financing mechanism(s) / approach(es) will be based on these basic instruments.
B. Retrofit projects in existing buildings: There are several options to structure financing of retrofit projects. ESCOs can play significant role in these projects. suitable ESCO financing could be explored.

6.3. Seek Feedback on the TA Facility

In the subsequent step, the draft design will be shared with the concerned stakeholders for receiving their further input and feedback. We will re-consult similar, if not the same, stakeholders who were consulted during the first consultation. Feedback from this re-consultation is used to revise and finalize TA facility.

6.4. Intermediate outcomes, assumptions and drivers

After completion of activity 4, following outcomes are expected to be achieved:

Intermediate outcomes:

- Identification of mechanism(s) – financial and non-financial – and a draft design of the Technical Assistance facility to catalyze action towards sustainable cooling adoption in the selected sectors.
- Identification of possible partners for the TA Facility.

Following assumptions are taken into considerations for achieving these intermediate outcomes:

Assumptions:

- Banks that already have/ have access to soft climate funds will agree to use these funds for this programme.
- Indian FIs voluntarily agree to participate in the TA facility
- There is need of financing to adopt sustainable cooling technologies
- A qualitative sense of interest among the end-use stakeholders is perceived

Drivers to achieve these intermediate outcomes are as follows:

Drivers:

- Frankfurt School team member's meetings with financial institutions and aggregators, will drive design of a sound financial mechanism.

7. IMPACT ANALYSIS

Through these activities, the programme team hopes to *catalyze* adoption of sustainable cooling technologies, so as to reduce the use of short-lived climate pollutants. If the technical assistance facility plays a seminal role in the adoption of sustainable cooling for at least five pilot projects, we shall consider the programme successful and hope to deploy the facility widely.

Annex 1: Relevant Public Policies / Programs / Frameworks

- ## Highly Relevant

Relevance?	Mission/Institution	Mechanism Name	Type	DEFINE the Policy/Framework	WHY is it relevant?	HOW can it be leveraged?	Source(s) - Online
High	Energy Efficiency Services Ltd (EESL)	Mechanism name not disclosed, similar to the LED & Efficient-Fan Schemes	Future Program	State-run Energy Efficiency Services Ltd (EESL) is in talks with manufacturers, power utilities and authorities to sell 'super-efficient' ACs that consume less power than a 5-star rated AC.	"EESL will be buying a significant quantity of 5.2 EER ACs soon (around 1 or 2 Lakh of them). May be used only for EESL's projects in buildings - their CPWD contract in Maharashtra and railway contract, however they may make these available to ESCOs and end-users this time or in the future" - Smart Joules, Grade 3 rated Energy Service Company (ESCO) by Bureau of Energy Efficiency.	Waiting for EESL announcement. After type of ACs are disclosed, we will know whether natural refrigerant ACs are selected. If so, it will help natural refrigerant ACs achieve a lower/preferred price, push them to become mainstream, and ensure M&V of savings is done for them - lowering risk to financial institutions, and end-users, to engage in a finance program for natural refrigerant ACs.	http://www.livemint.com/Companies/kKgulIEpdmotuRyBSuemMP/EESL-draws-up-plan-to-sell-super-efficient-air-conditioners.html
High	NATIONAL MISSION FOR ENHANCED ENERGY EFFICIENCY (NMEEE)	Perform Achieve and Trade Scheme (PAT) under National Mission for Enhanced	Current Program	Under PAT Cycle-II (2016-17 to 2018-19), energy reduction targets have been assigned and notified to 621 DCs. This energy saving will translate in to avoiding of about 5,764 MW of demand.	Under PAT, the industrial consumer could achieve the Specific Energy Consumption (SEC) reduction target by using an ESCO to undertake the investment in Energy Performance Contract (EPC)	Hotels, one of our target end-users, is now included in PAT; ensuring that the sector will have high demand for meeting energy efficiency targets that could be met by SCT/S.	https://eesindia.org/User_Panel/UserView.aspx?TypeID=1086

		Energy Efficiency (NMEEE)			mode. Hotels may have recently been included in this scheme (to be confirmed with conversations from industry insiders).		
High	NMEEE	Partial Risk Guarantee Fund for Energy Efficiency (PRGFEE) under FEEED	Current Program	PRGFEE is a risk sharing mechanism to provide commercial banks with a partial coverage of risk involved in extending loans for energy efficiency projects. The Government of India has approved around INR 312 crores for PRGFEE. The guarantee provided by the fund will directly support financing of energy efficiency projects by: • Addressing the risks and barriers faced and/or perceived by the financial institutions to financing ESCOs for implementing ESPC-based EE projects in India • Engaging Participating Financial Institutions (PFIs) and building their capacity to finance EE projects on a commercially-sustainable basis • Engaging commercial financial institutions and building their capacity to finance energy efficiency projects on a commercially sustainable basis	Guarantee available for government buildings, municipalities, SMEs, industries and private buildings (having commercial or multi-storey residential accommodation). Project must be implemented by BEE empanelled ESCO on performance contracting mode'. The PFI's under PRGFEE who have signed MoU with BEE are: - Yes Bank - Tata Cleantech Capital Ltd - IDFC Bank - Andhra Bank (a Public Sector Bank) These four participating Financial Institutions are eligible to get risk guarantee. Guarantee will not exceed INR 300 lakhs per project or 50 percent of loan amount, whichever is less.	Approach the four PFI's who have joined this scheme, to participate in our workshops. The PFI's can help devise this financial program, including a guarantee component through the PRGFEE. Note: Private buildings (having commercial or multi-storey residential accommodation) are included within this program's mandate.	https://www.beeindia.gov.in/content/prgfee

High	NMEEE	Venture Capital Fund for Energy Efficiency (VCFEE) under Framework for Energy Efficient Economic Development (FEEED)	Current Program	The Venture Capital Fund for Energy Efficiency (VCFEE), established by the BEE, is one of the financial instruments under the Framework for Energy Efficient Economic Development of NMEEE. The VCFEE provides risk capital support to EE investments in new technologies, goods and services. The Government of India has approved about INR 210 crores for the VCFEE. BEE has selected SIDBI as a Fund Manager for management of the funds of VCFEE and will be primarily responsible for making investment on behalf of VCFEE.	Eligibility Criteria: • Seek to achieve demonstrable energy savings and mitigate in emissions of greenhouse gases and project sponsors/participants must offer a viable method to monitor and verify the same. • Be a new project, not takeover of an existing project. • Use viable technologies and to be developed after energy audit/ feasibility studies. Last mile equity support to our partner ESCOs, limited to a maximum of fifteen per cent of total equity/debt required through special purpose vehicle or rupees two crore, whichever is less. A single investment by the fund shall not exceed INR 2 crore.	Approach the VCFEE Trust, get them to join the workshops and help design the finance program; include the VCFEE in the model. This fund supports EE in government buildings, private buildings having commercial or multi-storey residential accommodations, and municipalities. Contact SIDBI to gain access to the VCFEE.	https://www.beeindia.gov.in/content/vcfee
High	Small Industries Development Bank of India (SIDBI)	The Japan International Cooperation Agency (JICA) Phase 3: Scheme for Energy Saving	Current Program	The Japan International Cooperation Agency (JICA) has extended a Line of Credit to Small Industries Development Bank of India (SIDBI) for financing Energy Saving projects in Micro, Small and Medium Enterprises	Energy Saving Equipment that JICA Phase 3 supports: For Commercial Buildings: - Heat Absorbing Glass / Low Emissivity Glass (Window Panel) - Heat insulating opening	Approach SIDBI to get JICA Phase 3 officials to our workshop, and to help design the finance program; focused around the SCT/S they support, or similar. They support commercial buildings.	https://www.sidbi.in/Financing_Schemes_for_Sustainable_Development_including_Energ

		Projects in MSME Sector		(MSMEs) Sector. The project is expected to encourage MSME units to undertake energy saving investments in plant and machinery to reduce energy consumption, enhance energy efficiency, reduce CO2 emissions, and improve the profitability of the units in the long run.	material - Energy Efficient Air Conditioner - Heat Reclaim Ventilation / Air Conditioning System - Vapour Absorption Refrigeration (supporting Thermax Pvt. Ltd.)		y_Efficiency_and_Cleaner_Production_in_MSMEs.php
High	SIDBI	4E Financing Scheme - Revolving Fund Scheme for Financing End to End Energy Efficiency Investments in MSMEs	Current Program	SIDBI is implementing a World Bank (WB)-Global Environment Facility (GEF) funded project viz. “Financing Energy Efficiency at MSMEs”. With a view to create a demonstration effect of financing of energy efficiency measures, a revolving fund has been created to provide loans for such energy efficiency projects to MSMEs at concessional interest rates and soft terms. Under the scheme, term loans of up to 90% of the project cost shall be provided to eligible MSMEs. The interest rate for loans under 4E Financing Scheme shall be 2.5% below the normal lending rate.	For implementing Energy Efficiency measures on an end to end basis. For meeting part cost of (i) capital expenditure including for purchase of equipment/machinery, installation, civil works, commissioning, etc. for implementing the Energy Efficiency measures as recommended in the Detailed Project Report prepared by BEE's Energy Auditors or ESCOs, (ii) any other related expenditure required by the unit, provided it is not more than 50% of (i).	Approach SIDBI to get 4E Financing scheme officials to the workshops to help design the finance program for ESCO/EE-measures towards the service sectors of Banking and IT/BPO (4E Scheme Eligibility: MSME units in the manufacturing or services sector).	https://www.sidbi.in/files/4E_Financing_Scheme.pdf, https://www.sidbi.in/files/SIDBI_Ebrochure_4E_Financing.pdf
High	SIDBI	Sustainable Finance Scheme (SFS)	Current Program	Sustainable development projects which have significant impact towards energy efficiency / cleaner production but not covered under the international / bilateral lines of credit (JICA) as	Suitable assistance by way of term loan / working capital to ESCOs implementing EE / CP / Renewable Energy project provided either the ESCO	Approach SIDBI to get Sustainable Finance Scheme (SFS) officials to the workshops, to help design the finance program. They offer financial services to MSME's	https://www.sidbi.in/files/SIDBI_Ebrochure_SFS.pdf

				above shall be assisted under SFS.	should be an MSME or the unit to which it is offering its services is an MSME.	who are ESCOs or end-clients (such as IT/BPOs, Banks, Hospitality, Real-Estate sectors).	
High	SIDBI	Partial Risk Sharing Facility (PRSF) by Small Industrial Development Bank of India	Current Program	PRSF provides guarantees to the PFIs i.e., Banks/FIs/NBFCs for the Energy Efficiency loans extended by them through Energy Service Companies (ESCOs). BEE has appointed the consortium of REC-RECPDCL-EESL as the Implementing Agency (IA) for PRGFEE in 2015. IA shall give approval on proposals for PRGFEE and sign guarantee agreements, carry out regular monitoring of project and appointment of M&V Agency for processing guarantee claims, etc.	Project should be implemented at a) MSME, b) Large industries (excluding thermal power plants), c) Commercial buildings and d) Municipalities. The Guarantee will be Rs.15 crore per project or 75% of loan amount, whichever is minimum. Contact the IA after a few proposals are created for SCTs uptake to avail the PRGFEE.	Approach a Participating Financial Institution (PFI) of the PRSF, and/or Approach SIDBI to use the PRSF to guarantee loans made through the finance program to commercial buildings or MSMEs from our target sectors (IT/BPO, Banking, Commercial Builders).	http://prsf.sidbi.in
High	Energy Conservation Building Code (ECBC) by BEE	ECBC Voluntary Star Rating Programme	Current Program	Star Ratings are provided based on the actual performance of a building, in terms of energy usage in the building over its area expressed in kWh/sqm/year. More than 150 commercial buildings have been ECBC star rated under different categories.	Low Energy Comfort Systems/Alternative HVAC systems recognized under ECBC: (a) Evaporative cooling (b) Desiccant cooling system (c) Solar air conditioning (d) Tri-generation (waste-to-heat) (e) Radiant cooling system (f) Ground source heat pump (g) Adiabatic cooling system If a Low Energy Comfort System is used in more than	At the workshops, inform PFIs that ECBC+ and SuperECBC buildings, have greater market value (sale price), and Alternative Cooling Systems can greatly help buildings in their portfolios meet these standards. Consider beneficial terms in the finance program for buildings that have met these standards. ECBC includes Residential and Commercial Buildings.	http://powermin.nic.in/en/content/overview-2, http://knowledgeplatform.in/wp-content/uploads/2016/01/ECBC-Comprehensive-Note.pdf

					50% of the building, ECBC+ is awarded, if in more than 90% then SuperECBC awarded.		

● Moderately Relevant

Relevance?	Mission/Institution	Mechanism Name	Type	DEFINE the Policy/Framework	WHY is it relevant?	HOW can it be leveraged?	Source(s) - Online
Medium	MoEFCC	Environment Ministry announces Major Initiative for R&D into Next Generation HFC refrigerant alternatives	Current Program	Collaborative R&D programme to develop next generation, sustainable refrigerant technologies as alternatives to HFCs. "...the initiative is focused on prioritising areas of research in new refrigerant technologies and natural refrigerants."	"...there is an urgent need for developing new technologies indigenously as alternatives available today are patented apart from being expensive. A research based programme to look for cost effective alternatives to the currently used refrigerant gases is, therefore essential."	This initiative could mainstream natural refrigerants and, if so, will lower prices and risk for natural refrigerant cooling.	http://pib.nic.in/newsite/printrelease.aspx?relid=149825

Medium	GRIHA by TERI (The Energy and Resources Institute) with support from MNRE (Ministry of New and Renewable Energy, Government of India)	Green Buildings Rating System India (GRIHA)	Current Framework	GRIHA, a green building rating framework, along with the activities and processes that lead up to it, benefit the community at large with improvement in the environment by reducing greenhouse gas emissions, reducing energy consumption, and the stress on natural resources. Over 330 projects across India.	Includes Night ventilation, Evaporative Cooling, Earth Tunnel System, Geothermal Heat Pump. Also demand reduction strategies such as shading, insulation, and reduced Window-to-Wall ratio to maximize natural light while minimizing solar heat gain.	Based on research that determines the additional market value of GRIHA buildings, the banks credit terms could require that ESCOs/end-users use the SCT/S suggested to meet the appropriate GRIHA standard that provides the required market value, thereby reducing risk for the bank, and thus offering better credit-terms. Used for commercial, institutional and residential buildings.	https://goo.gl/H46aDt

- Less Relevant

Relevance?	Mission/Institution	Mechanism Name	Type	DEFINE the Policy/Framework	WHY is it relevant?	HOW can it be leveraged?	Source(s) - Online

Low	NMEEE	Market Transformation for Energy Efficiency (MTEE)'s Super Efficient Equipment Programme (SEEP)	Current Program	Accelerating the shift to energy efficient appliances in designated sectors through innovative measures to make the products more affordable.	Currently SEEP is focused on Ceiling Fans.	This will help super efficient ACs achieve a lower/preferred price, push them to become mainstream, and ensure M&V of savings is done for them - lowering risk to financial institutions to extend special lines-of-credit.	https://www.beeindia.gov.in/content/seep-0, http://fan.ujala.gov.in/
Low	NMEEE	Energy Efficiency Financing Platform (EEFP)	Current Program	EEFP provides a platform to interact with financial institutions and project developers for implementation of energy efficiency projects. Under this programme, MoUs have been signed with financial institutions to work together for the development of energy efficiency market and for the identification of issues related to this market development.	MoUs with M/s. PTC India Ltd, M/s. SIDBI, HSBC Bank, Tata Capital and IFCI Ltd have been signed by BEE to promote financing for energy efficiency projects. Main objective of these MoUs is to promote lending in the areas of performance contracting, DSM initiatives, energy efficiency in commercial sector, industrial complexes, power plants etc.	Assist in M&V development for SCT/S. Share the Training Manual for EE with ESCOs, understand the lacunae to develop it further.	https://www.beeindia.gov.in/content/eefp
Low	SIDBI	Technology and Quality upgradation	Current Program	If you are an MSME and want to upgrade the technology of manufacturing the product	Under the scheme, Grant (Subsidy) to the extent of 25% of the	Only for manufacturing sectors. Additional subsidy can be provided through	https://www.sidbi.in/Technology_a

		Support to Micro, Small & Medium Enterprises (TEQUP)		through institutional finance, then you have to approach the concerned nodal bank/eligible financial institution for loan.	project cost for implementation of Energy Efficient Technologies (EET) subject to maximum of 10 lakh is provided.	TEQUP for EET/SCT after a loan/credit-line is provided through SIDBI, State Bank of India, State Bank of Bikaner and Jaipur, Bank of Baroda, Canara Bank Punjab National Bank and Bank of India.	nd_Quality_upgradation_Supportto_Micro_Small_and_Medium_Enterprises_TEQUP.php
Low	ECBC	United Nations Development Programme (UNDP) - Global Environment Fund (GEF) - Bureau of Energy Efficiency (BEE) Energy Efficiency Model Buildings (EEMB) Project	Current Framework	Support 62 buildings to become ECBC compliant cumulating to over 2.5 million m2 [vis-à-vis our target of 1.47 m m2]	Project owners will be given a financial incentive of Rs. 65 per sq. mt. of verified ECBC compliant built space.	If we can get some of the model buildings in this project to adopt SCT/S, it will increase their uptake in future ECBC-compliant buildings.	http://www.in.undp.org/content/india/en/home/operations/projects/environment_and_energy/energy_efficiencyimprovementsincommercialbuildings.html
Low	Indian Green Building Council	IGBC	Current Framework	Enabling 3.84 Billion sq.ft of green buildings	Demonstrate that refrigerants used in the buildings Heating, Ventilation & Air-	Not relevant, as very few points awarded for eco-friendly HVAC systems.	https://igbc.in/igbc/redirectHtml.htm?redVal=sho

	(IGBC)				conditioning (HVAC) equipment are eco-friendly and have low or no Ozone Depletion Potential (ODP) and Global Warming Potential (GWP) - only 1 point. Passive Architecture - 2 points. 5-star rating AC or higher is 1 point. Total 100 points		wResourcesnosign
Low	GRIHA	Environmental Clearance	Current Framework	Fast track environmental clearance for GRIHA/IGBC pre-certified projects.	Incentive to builders to go for energy-efficient building design through GRIHA/IGBC frameworks	Share incentive with builders at the workshops. Demonstrate how 5% additional FAR reduces project risk - by increasing a project's potential success as more flats, or more facilities, offered - for financial institutions, and seek better credit terms.	http://www.grihaindia.org/static/GRIHA-linked-incentives-Flyer.pdf
Low	IGBC	Environmental Clearance	Current Framework				https://igbc.in/igbc/redirectHtml.htm?redVal=showGovtIncentivesnosign
Low	GRIHA	Additional Floor Area Ratio (FAR)	Current Framework	Greater NOIDA and Punjab have incentivized GRIHA projects (on a plot of more than 5000 sq. m and above) with free of cost 5% additional FAR for projects for	Additional FAR incentive to builders to go for energy-efficient building design through GRIHA/IGBC frameworks	Share incentive with builders at the workshops. Demonstrate how 5% additional FAR reduces project risk - by increasing a project's potential success as more flats, or more	http://www.grihaindia.org/static/GRIHA-linked-incentives-Flyer.pdf

				complying with 4 or 5 Star GRIHA Rating.		facilities, offered - for financial institutions, and seek better credit terms.	
Low	IGBC	Additional FAR	Current Framework	Additional 5% FAR free of charge is offered in Greater Noida, Uttar Pradesh, Punjab and Rajasthan for projects which are rated as Gold or above by IGBC.			https://igbc.in/igbc/redirectHtml.htm?redVal=showGovtIncentivesnosign
Low	IGBC	Additional FAR	Current Framework	West Bengal additional 10% FAR for projects which are Pre-certified/ Provisionally Certified as Gold or above by IGBC.			https://igbc.in/igbc/redirectHtml.htm?redVal=showGovtIncentivesnosign
Low	IGBC	Additional FAR	Current Framework	Pune Municipal Corporation (PMC), Government of Maharashtra offers an additional FAR of 3%, 5% and 7% for Green Buildings rated as Silver, Gold and Platinum respectively by IGBC.			https://igbc.in/igbc/redirectHtml.htm?redVal=showGovtIncentivesnosign
Low	GRIHA	Additional FAR	Current Framework	Ministry of Urban Development issues a notification for local authorities to incentivize and provide 1% to 5% extra ground coverage and FAR for projects of more than 3000 sq. m. plot size on basis of GRIHA evaluation.			https://igbc.in/igbc/redirectHtml.htm?redVal=showGovtIncentivesnosign

Low	GRIHA	Discounts for Building Permission Charges/Property Tax	Current Framework	Pimpri Chinchwad Municipal Corporation (PCMC) gives discounts to developers on the Premium amount of building permission charges, as per the level of GRIHA rating. Also, there is a 10% discount in Property Tax for home owners.	Incentive to builders, and home-owners, to go for energy-efficient building design through GRIHA/IGBC frameworks		http://www.grihaindia.org/static/GRIHA-linked-incentives-Flyer.pdf
Low	IGBC	Subsidies for Buildings	Current Framework	Government of Andhra Pradesh offers 25% subsidy of total fixed capital investment of the project (excluding cost of land, land development, preliminary and preoperative expenses and consultancy fees) for buildings which obtain green rating from IGBC. This incentive is applicable for MSME and large industries.	Incentive to builders to go for energy-efficient building design through the IGBC frameworks	Share incentive with builders at collective-intelligence dialog workshops. Demonstrate to financial institutions how this subsidy reduces project risk, and thereby warrants better credit terms.	https://igbc.in/igbc/redirectHtml.htm?redVal=showGovtIncentivesnosign
Low	GRIHA / IGBC	Concessional rate of interest by SIDBI	Current Framework	Concessional rate of interest for GRIHA/IGBC rated projects by SIDBI: SIDBI has been providing national assistance to green buildings certified by Accredited Rating Agencies including GRIHA/IGBC by offering concessional rate of interest, presently 50 basis points.	Incentive to builders to go for energy-efficient building design through GRIHA/IGBC frameworks to get better loan terms	Speak to SIDBI to see if builders use SCT - reducing energy & SLCP - they can get a lower rate of interest / better line-of-credit.	http://www.grihaindia.org/static/GRIHA-linked-incentives-Flyer.pdf, https://igbc.in/igbc/redirectHtml.htm?redVal=sho

							wGovtIncentivesnosign
Low	IGBC	Mandate IGBC in Maharashtra	Current Policy	Public Works Department (PWD), Government of Maharashtra has mandated that the renovation of existing buildings and the development of all new government buildings in Maharashtra shall be carried out as per the suitable IGBC Green Building Rating system.	Mandated IGBC in Maharashtra for new buildings and renovation.	Through this policy, Financial Institutions will know that builders/ESCOs will need to use energy-efficient technologies; hence their special line-of-credit for SCT/S will be used.	https://igbc.in/igbc/redirectHtml.htm?redVal=showGovtIncentivesnosign

- ## Recommended (may become relevant)

Mission/Institution	Type	DEFINE the Policy/Framework	WHY is it relevant?	HOW can it be leveraged?	Source(s)
Sustainable & Smart Space Cooling Coalition (SSSCC)	Recommended Policy	Leverage ongoing government initiatives and require designers/architects of government-funded projects (residential or commercial) to design buildings incorporating the principles of lean-mean-green cooling strategies.	Establish protocols for a National Home Energy Cost Benchmarking and Verification System for new developments. This could begin with a government-backed apartment-level energy cost calculation 'cell' (using 3-D Building Energy Modelling software) for builders to estimate and	This 'cell' could provide recommendations to banks/builder, also communicate home-loan costs and banks could offer financial reductions on EMIs/home-loans for energy-efficient homes, thereby increasing demand for energy-efficient homes, and thereby increasing demand for builders to use energy-efficient	SSSCC's Thermal Comfort for All Paper

			communicate energy costs to potential home-buyers. The goal of this effort would be to demonstrate, through certified home life cycle energy cost values, the cost-effectiveness of energy efficient homes.	technologies (SCT/S).	
SSSCC	Recommended Policy	" "	Establish policy framework to enable DISCOMS to implement a Demand Response (DR) programme for room air conditioners. Subsidies for residential renewable energy capacity or bulk-procurement of super-efficient ACs for large developments could be linked with cooling load demand-side management performance (verified through submission of building energy modelling reports) of approved building designs.	Partner builders could use these subsidies, partner Financial Institutions could extend financial-support for these subsidies, partner SCT manufacturers could become suppliers of super-efficient ACs/Cooling-Systems, as part of the eco-system building efforts of this programme.	SSSCC's Thermal Comfort for All Paper

SSSCC	Recommended Policy to action in the Medium-Term	Institute comprehensive legislation as a cornerstone to achieve a viable market for smart cooling	Establish policy to create state-level financial facilities for low-cost/preferential line of credit to real estate projects with a demonstrably high cooling efficiency.	Use the state-level financial facilities to offer these low-cost/preferential line of credit to builders and ESCOs using SCT/S.	SSSCC's Thermal Comfort for All Paper
SSSCC	Recommended Policy to action in the Long-Term	" "	MNRE should consider providing financial support and structuring performance based incentives for solar air conditioning and trigeneration	Use this financial support from MNRE to builders and ESCOs using solar-ACs/solar-VAM.	SSSCC's Thermal Comfort for All Paper
SSSCC	Recommended Policy for the Short-Term	Generate market momentum towards smart cooling through awareness campaigns, access to information and technical assistance.	Facilitate market transformation efforts for penetration of labelled products. Educate customers to make informed product choices based on operational savings, rather than the first cost alone.	Govt. Financial Institutions, like SIDBI, can offer financial incentives for energy-efficient cooling products/appliances through EMIs.	SSSCC's Thermal Comfort for All Paper

SSSCC	Recommended Policy for the Medium-Term	Drive adoption of energy efficient building materials and equipment into mainstream through consistent testing and rating protocols, and market transformation strategies.	Stimulate the market transformation for building materials through range of financing mechanisms such as upstream incentives for manufacturers and similar mechanisms for consumers.	Through NMEEE SIDBI, or another similar govt. FI, could offer these financing mechanisms. This would reduce SCT costs, and boost SCT demand, thereby creating ideal conditions to request better lines-of-credit from Financial Institutions for ESCOs.	SSSCC's Thermal Comfort for All Paper

Annex 2: Input data – Cost Benefit Analysis

Technology R290		Banking		Residential		Hospitality		Commercial (IT/BPO)	
		Conventional	R290	Conventional	R290	Conventional	R290	Conventional	R290
System price	INR/TR	25,946	39,150	25,946	39,150	25,946	39,150	25,946	39,150
Capacity (Tonnage of Refrigeration)	TR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Technology price	INR	25,946	39,150	25,946	39,150	25,946	39,150	25,946	39,150
Installation expenses	INR	-	-	-	-	-	-	-	-
COP		3.05	3.7	3.05	3.7	3.05	3.7	3.05	3.7
Equivalent Capacity	kW cooling	3.517	3.517	3.517	3.517	3.517	3.517	3.517	3.517
Power req per Ton of cooling	kW/TR	1.15	0.82	1.15	0.82	1.15	0.82	1.15	0.82
O&M expenses	INR/pa	2,640	1,400	2,640	1,400	2,640	1,400	2,640	1,400
Equipment lifetime (Usefule life)	hours	87,600	87,600	87,600	87,600	87,600	87,600	87,600	87,600
Operational duration	hours p.a.	3,288	3,288	3,294	3,294	8,736	8,736	2,976	2,976
	op. Hrs per day	12	12	12	12	24	24	12	12
	op. Days per week	5.5	5.5	7	7	7	7	5	5
	op. Weeks per yr	52	52	39.2	39.2	52	52	52	52
	off days per yr	12	12	-	-	-	-	12	12
Replacement system price	INR/TR	25,946	39,150	25,946	39,150	25,946	39,150	25,946	39,150

Replacement capacity	TR	-	-	-	-	-	-	-	-
Replacement cost	INR	-	-	-	-	-	-	-	-
Replacement year	yr	10	10	10	10	10	10	10	10
Diversity Factor		0.8	0.8	1	1	0.6	0.6	0.9	0.9
Energy Consumption	kWh	3,025	2,157	3,788	2,701	6,028	4,298	3,080	2,196
Tariff for end user	INR/kWh	13.5	13.5	9.5	9.5	13.5	13.5	13.5	13.5

Technology Solar VAM

		Banking		Residential		Hospitality		Commercial (IT/BPO)	
		Conventional	SVAM	Conventional	SVAM	Conventional	SVAM	Conventional	SVAM
System price	INR/TR	25,946	337,597	25,946	337,597	25,946	337,597	25,946	337,597
Capacity (Tonnage of Refrigeration)	TR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Technology price	INR	25,946	337,597	25,946	337,597	25,946	337,597	25,946	337,597
Installation expenses	INR	-	27,110.9	-	27,110.9	-	27,110.9	-	27,110.9
COP		3.05	0.63	3.05	0.63	3.05	0.63	3.05	0.63
Equivalent Capacity	kW cooling	3.517	3.517	3.517	3.517	3.517	3.517	3.517	3.517
Power req per Ton of cooling	kW/TR	1.15	0.0086	1.15	0.0086	1.15	0.0086	1.15	0.0086
O&M expenses	INR/pa	2,795	8,509	2,795	8,509	2,795	8,509	2,795	8,509
Equipment lifetime (Usefule life)	hours	87,600	87,600	87,600	87,600	87,600	87,600	87,600	87,600
Operational duration	hours p.a.	3,288	3,288	3,294	3,294	8,736	8,736	2,976	2,976
	op. Hrs per day	12	12	12	12	24	24	12	12
	op. Days per	5.5	5.5	7	7	7	7	5	5

	week								
	op. Weeks per yr	52	52	39.2	39.2	52	52	52	52
	off days per yr	12	12	-	-	-	-	12	12
Replacement system price	INR/TR	25,946	337,597	25,946	337,597	25,946	337,597	25,946	337,597
Replacement capacity	TR	-	-	-	-	-	-	-	-
Replacement cost	INR	-	-	-	-	-	-	-	-
Replacement year	yr	10	10	10	10	10	10	10	10
Diversity Factor		0.8	0.8	1	1	0.6	0.6	0.9	0.9
Energy Consumption	kWh	3,025	23	3,788	28	6,028	45	3,080	23
Tariff for end user	INR/kWh	13.5	13.5	9.5	9.5	13.5	13.5	13.5	13.5

Technology Radiant Cooling Hybrid System									
		Banking		Residential		Hospitality		Commercial (IT/BPO)	
		Conventional	RCS	Conventional	RCS	Conventional	RCS	Conventional	SVAM
System price	INR/TR	25,946	76,136	25,946	76,136	25,946	76,136	25,946	76,136
Capacity (Tonnage of Refrigeration)	TR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Technology price	INR	25,946	76,136	25,946	76,136	25,946	76,136	25,946	76,136
Installation expenses	INR	-	-	-	-	-	-	-	-
COP		3.05	3.97	3.05	3.97	3.05	3.97	3.05	3.97
Equivalent Capacity	kW cooling	3.517	3.517	3.517	3.517	3.517	3.517	3.517	3.517
Power req per Ton of cooling	kW/TR	1.15	0.88	1.15	0.88	1.15	0.88	1.15	0.88
O&M expenses	INR/pa	2,795	-	2,795	-	2,795	-	2,795	-

Equipment lifetime (Usefule life)	hours	87,600	87,600	87,600	87,600	87,600	87,600	87,600	87,600
Operational duration	hours p.a.	3,288	3,288	3,294	3,294	8,736	8,736	2,976	2,976
	op. Hrs per day	12	12	12	12	24	24	12	12
	op. Days per week	5.5	5.5	7	7	7	7	5	5
	op. Weeks per yr	52	52	39.2	39.2	52	52	52	52
	off days per yr	12	12	-	-	-	-	12	12
Replacement system price	INR/TR	25,946	76,136	25,946	76,136	25,946	76,136	25,946	76,136
Replacement capacity	TR	-	-	-	-	-	-	-	-
Replacement cost	INR	-	-	-	-	-	-	-	-
Replacement year	yr	10	10	10	10	10	10	10	10
Diversity Factor		0.8	0.8	1	1	0.6	0.6	0.9	0.9
Energy Consumption	kWh	3,025	2,315	3,788	2,899	6,028	4,613	3,080	2,357
Tariff for end user	INR/kWh	13.5	13.5	9.5	9.5	13.5	13.5	13.5	13.5

Technology Structure Cooling Hybrid System

		Banking		Residential		Hospitality		Commercial (IT/BPO)	
		Conventional	SCS	Conventional	SCS	Conventional	SCS	Conventional	SCS
System price	INR/TR	25,946	57,028	25,946	57,028	25,946	57,028	25,946	57,028
Capacity (Tonnage of Refrigeration)	TR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Technology price	INR	25,946	57,028	25,946	57,028	25,946	57,028	25,946	57,028
Installation	INR	-	-	-	-	-	-	-	-

expenses									
COP		3.05	3.93	3.05	3.93	3.05	3.93	3.05	3.93
Equivalent Capacity	kW cooling	3.517	3.517	3.517	3.517	3.517	3.517	3.517	3.517
Power req per Ton of cooling	kW/TR	1.15	0.89	1.15	0.89	1.15	0.89	1.15	0.89
O&M expenses	INR/pa	2,795	-	2,795	-	2,795	-	2,795	-
Equipment lifetime (Usefule life)	hours	87,600	87,600	87,600	87,600	87,600	87,600	87,600	87,600
Operational duration	hours p.a.	3,288	3,288	3,294	3,294	8,736	8,736	2,976	2,976
	op. Hrs per day	12	12	12	12	24	24	12	12
	op. Days per week	5.5	5.5	7	7	7	7	5	5
	op. Weeks per yr	52	52	39.2	39.2	52	52	52	52
	off days per yr	12	12	-	-	-	-	12	12
Replacement system price	INR/TR	25,946	57,028	25,946	57,028	25,946	57,028	25,946	57,028
Replacement capacity	TR	-	-	-	-	-	-	-	-
Replacement cost	INR	-	-	-	-	-	-	-	-
Replacement year	yr	10	10	10	10	10	10	10	10
Diversity Factor		0.8	0.8	1	1	0.6	0.6	0.9	0.9
Energy Consumption	kWh	3,025	2,341	3,788	2,932	6,028	4,665	3,080	2,384
Tariff for end user	INR/kWh	13.5	13.5	9.5	9.5	13.5	13.5	13.5	13.5

Technology Indirect-Direct Evaporative Cooling + DX Hybrid Cooling Systems								
	Banking		Residential		Hospitality		Commercial (IT/BPO)	
	Conventio	IDEC	Conventio	IDEC	Conventio	IDEC	Conventio	IDEC

		nal		nal		nal		nal	
System price	INR/TR	25,946	64,286	25,946	64,286	25,946	64,286	25,946	64,286
Capacity (Tonnage of Refrigeration)	TR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Technology price	INR	25,946	64,286	25,946	64,286	25,946	64,286	25,946	64,286
Installation expenses	INR	-	3,066.00	-	3,066.00	-	3,066.00	-	3,066.00
COP		3.05	4.62	3.05	4.62	3.05	4.62	3.05	4.62
Equivalent Capacity	kW cooling	3.517	3.517	3.517	3.517	3.517	3.517	3.517	3.517
Power req per Ton of cooling	kW/TR	1.15	0.76	1.15	0.76	1.15	0.76	1.15	0.76
O&M expenses	INR/pa	2,795	1,475	2,795	1,475	2,795	1,475	2,795	1,475
Equipment lifetime (Usefule life)	hours	87,600	87,600	87,600	87,600	87,600	87,600	87,600	87,600
Operational duration	hours p.a.	3,288	3,288	3,294	3,294	8,736	8,736	2,976	2,976
	op. Hrs per day	12	12	12	12	24	24	12	12
	op. Days per week	5.5	5.5	7	7	7	7	5	5
	op. Weeks per yr	52	52	39.2	39.2	52	52	52	52
	off days per yr	12	12	-	-	-	-	12	12
Replacement system price	INR/TR	25,946	64,286	25,946	64,286	25,946	64,286	25,946	64,286
Replacement capacity	TR	-	-	-	-	-	-	-	-
Replacement cost	INR	-	-	-	-	-	-	-	-
Replacement year	yr	10	10	10	10	10	10	10	10
Diversity Factor		0.8	0.8	1	1	0.6	0.6	0.9	0.9
Energy Consumption	kWh	3,025	1,999	3,788	2,503	6,028	3,984	3,080	2,036

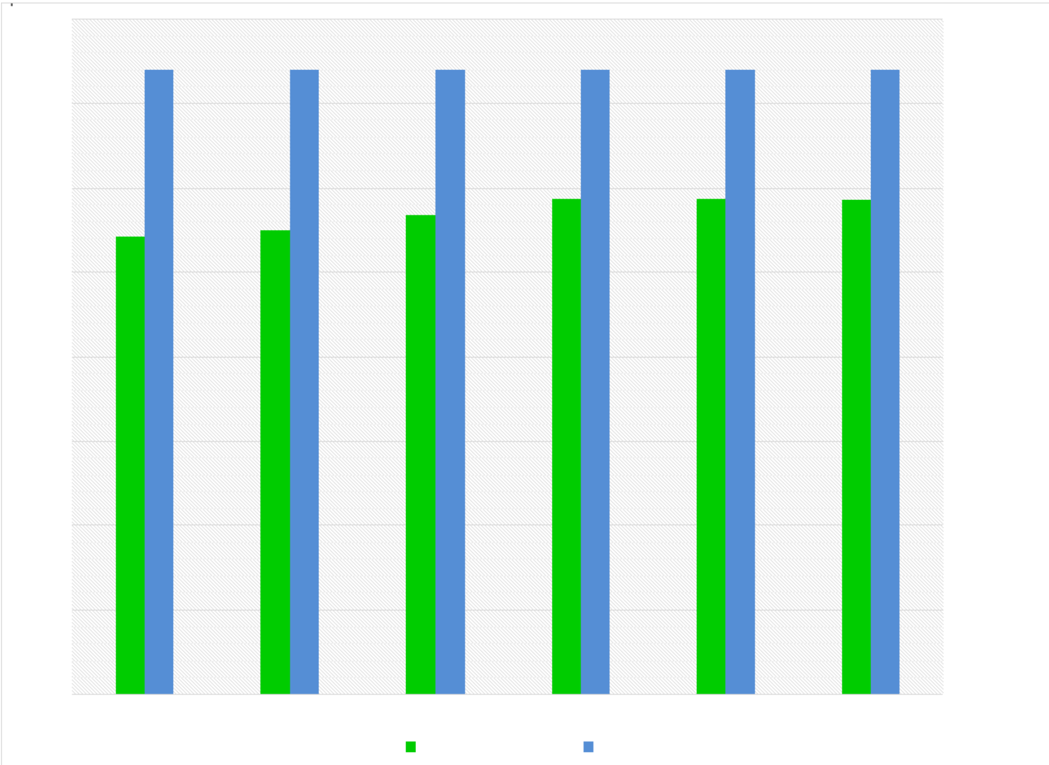
Tariff for end user	INR/kWh	13.5	13.5	9.5	9.5	13.5	13.5	13.5	13.5

Case Studies

Split Air-Conditioners using R290 (Propane) as a refrigerant

In 2012, Godrej & Boyce Inaugurated a new production line for the manufacturing of split and window type propane (R290) air conditioners. The new line is in the 1 & 1.5 TR split AC category, the most common air conditioner capacity segment in India. Moreover, the R290 models consume 21.2% less energy than the current top of line 5 star models across other brands (Godrej, Undated). In comparison to conventional 1 ton and 1.5 ton ACs the R290 ACs reflected a GHG saving percentage of 99.97% and an energy saving of 585 kWh/year/Unit for the 1 TR model and 877 kWh/year/Unit for the 1.5 TR model. Payback period of 3.8 years and 1.8 years was calculated for the 1 TR and 1.5 TR R290 ACs respectively. Lastly, even in the Energy Efficiency Ratio (EER) department, the R290 fares much better than the conventional refrigerant based ACs. The R290 has an EER of 3.7 of cooling/kW power for both 1 TR and 1.5 TR AC, while the conventional split ACs has an EER of 2.94 for both (*See Figure 2*).

Figure 2 | COP comparison of conventional ACs vs HC ACs



Source: cBalance Solutions Hub analysis

A comparative study carried out by Godrej & Boyce between R290 and R22 based ACs reveals that not only is R290 suitable for high ambient regions, variation in COP at high temperatures for HC-290 was the same as that of HCFC-22. Moreover, variation in capacity was also found to be the same and the flammability risk was found to be negligible (*See Table 1 to Table* 2 ,*Figure 3 to Figure* 5).

Table 1 | Comparison of R22 and R290 ACs – System Characteristics

Sr No	Characteristic	HCFC-22 air conditioner	HC-290 air conditioner
1	Nominal capacity (kW)	5.19	4.83
2	Nominal COP (cooling)	3.08	3.6
3	Evaporator type	Finned Tube	Finned Tube
4	Evaporator block volume (litres)	5.45	5.45
5	Evap no. tubes, circuits	32,3	32,3
6	Evaporator airflow rate (m3/h)	850	850
7	Condenser type	PFC	PFC
8	Condenser block volume (litres)	6.06	6.03
9	Condenser no. tubes	52	52
10	Compressor swept volume (m3/h)	5.27	5.39
11	Compressor rated COP	3.1	3.38
12	Cap tube length (m)	0.8	0.65
13	Cap tube OD (mm),	3	3.2
14	Refrigerant charge (kg)	0.75	0.36

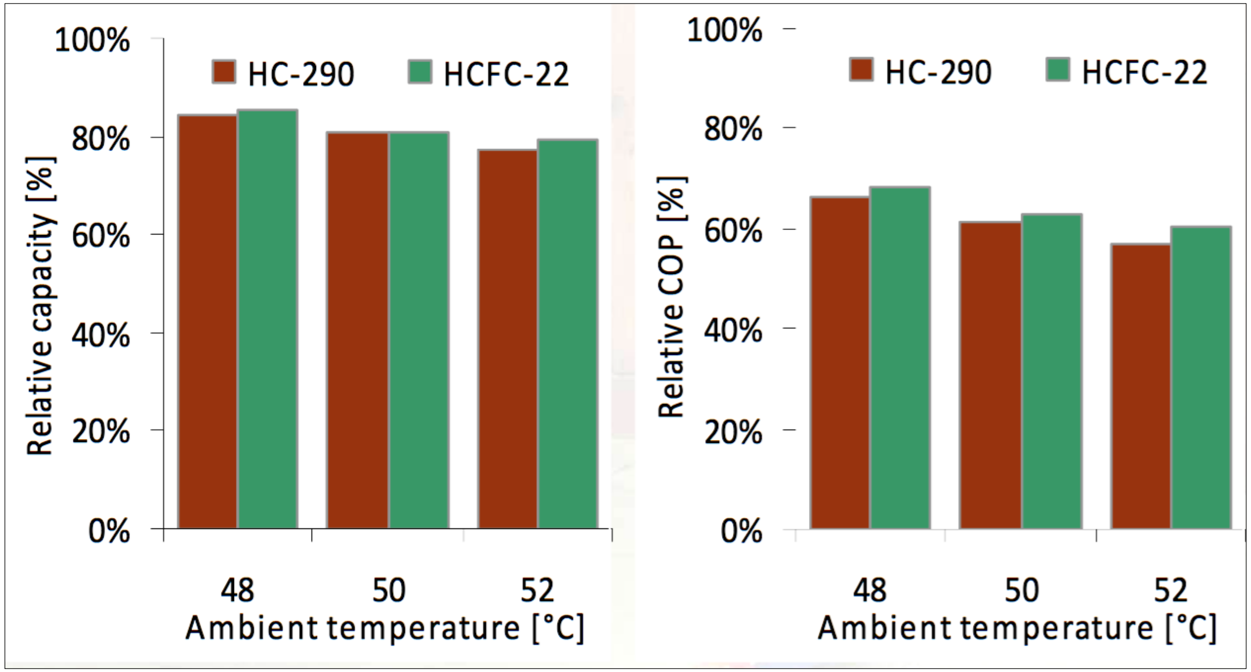
Source: Godrej and Boyce

Table 2 | Comparison of R22 and R290 ACs - Performance Parameters

Parameters	R22	R290
Volumetric Refrigerating Effect (KJ/m^3)	4359	3716
Relative to R22 (%)	0	-15
Discharge Temperature (Deg C)	95	77
Relative to R22 (Deg C)	0	-18
Coefficient of Performance (KW/KW)	4.23	4.28
Relative to R22 (%)	0	1

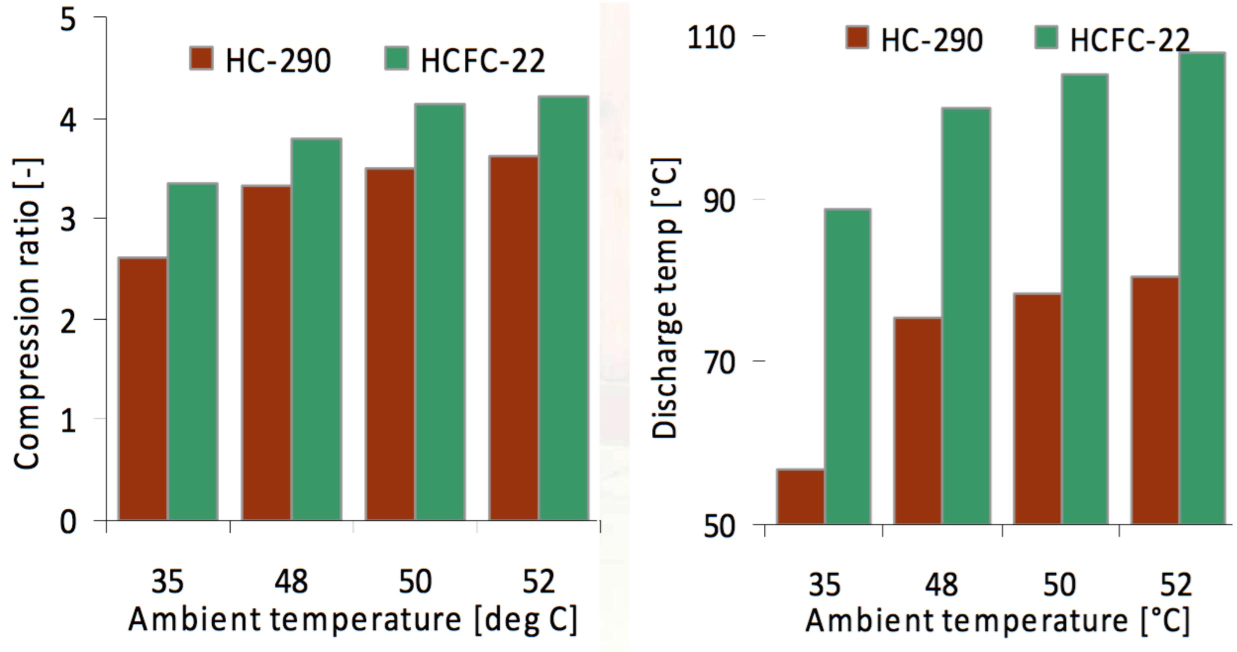
Source: cBalance Solutions Hub analysis

Figure 3 | Comparison of R22 and R290 ACs: I



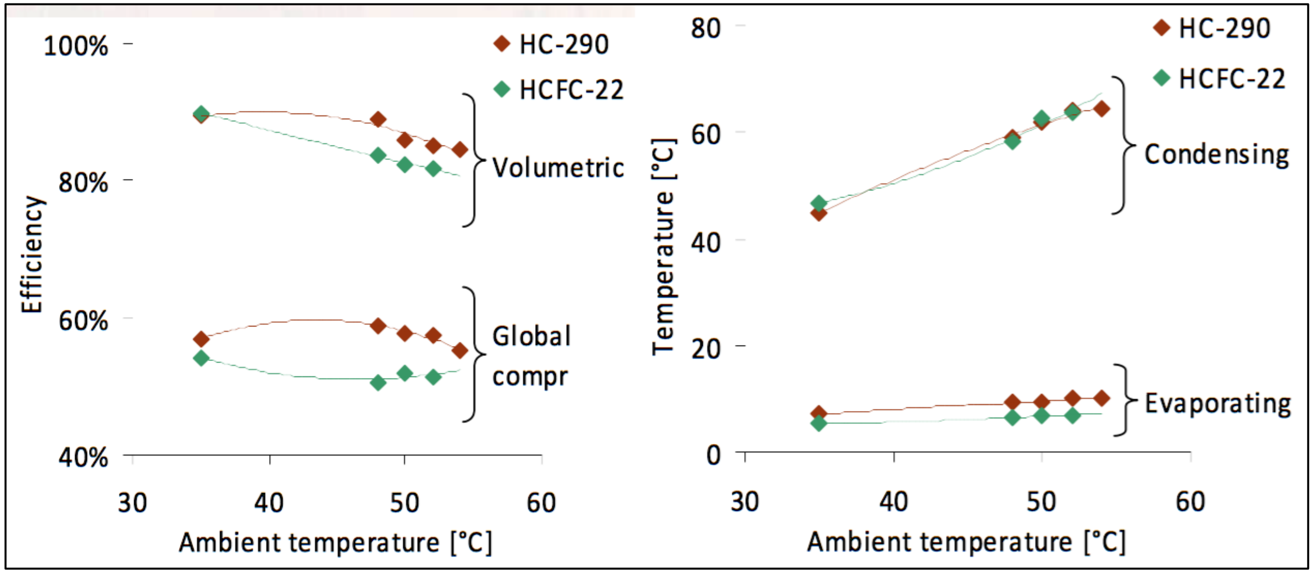
Source: Godrej & Boyce

Figure 4 | Comparison of R22 and R290 ACs: II



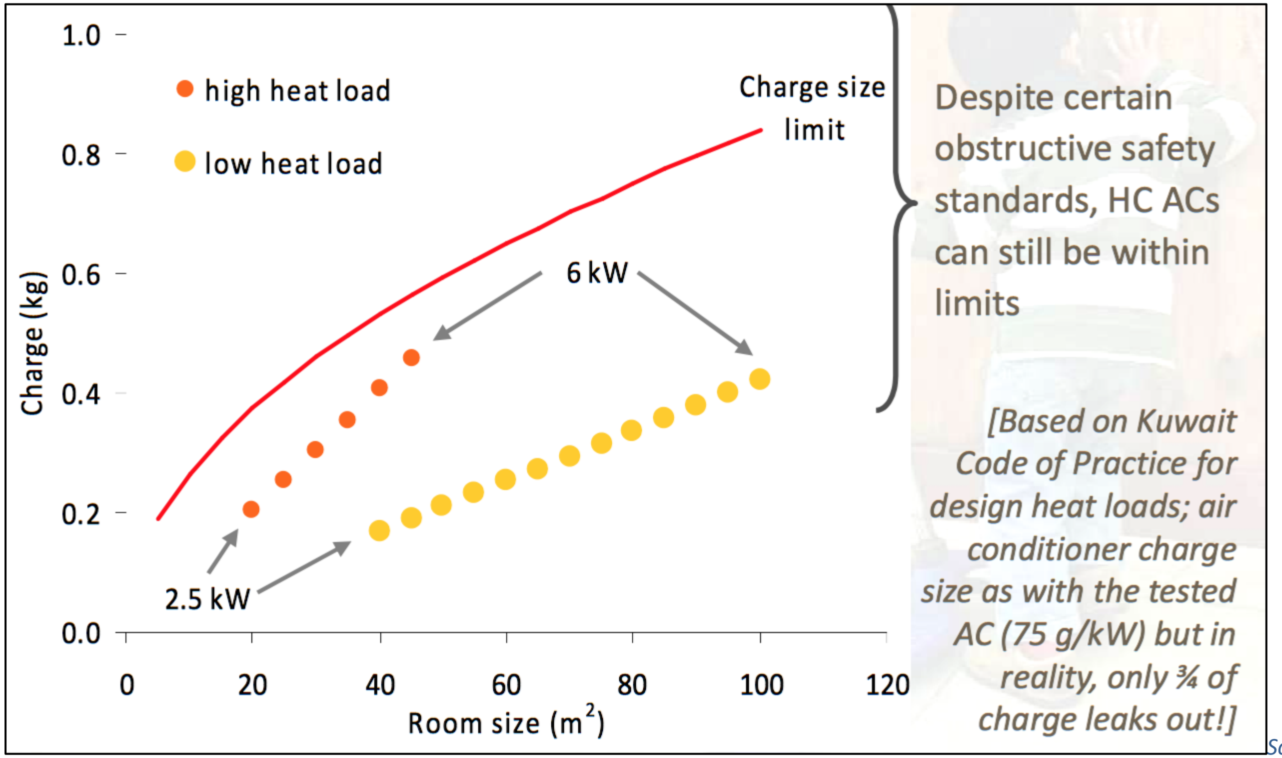
Source: Godrej & Boyce

Figure 5 | Comparison of R22 and R290 ACs: III



Source: Godrej & Boyce

Figure 6 | Charge size limit of R290



Source: Godrej & Boyce

Solar Vapour Absorption Machines (SVAM)

For this study, 10 TR & 75 TR SVAM by First Esco were considered and compared with conventional chiller systems of similar TR loads. For a 10 TR SVAM System, a solar field of approximately 160 Sq. meters is required to install the solar collectors. The resultant savings in energy and emissions would be 36,300 kWh/yr and 44 tons GHG emission/yr. The working principal is similar to that of a conventional Vapour Absorption Machine, however, the only and significant dissimilarity being the heat source of the generator. In the case of a SVAM, the solar collector directly heats the refrigerant through the help of collector tubes and then circulates it to achieve cooling. In other words, solar thermal energy is used to generate chilled water using Vapour Absorption Chillers.

Upon comparison, an energy saving of 84.62% and 43.75% for the 10 TR and 75 TR systems respectively were observed. Additionally, carbon reduced were observed at 44 Tons/yr and 506 Tons/yr as *shown in Table 3 toTable* 4 *and Figure 7 and Figure* 8.

Table 3 | Solar VAM - Specifications of System I under study

Specifications	Unit	Value
Nominal Capacity of Plant	TR	10
Cooling Load	Kcal/hr	30,000
Equivalent Electrical Load	kW	35
Chilled Water Circuit		
Chilled Water Flow Rate	CMH	6
Chilled Water Inlet Temp	Deg C	12
Chilled Water Outlet Temp	Deg C	7
Cooling Water Circuit		
Cooling Water Flow Rate	CMH	8.33
Cooling Water Inlet Temp	Deg C	32

Cooling Water Outlet Temp	Deg C	38
Thermic Fluid Circuit		
Thermic Fluid Flow Rate	CMH	9.33
Thermic Fluid Inlet Temp	Deg C	100
Thermic Fluid Outlet Temp	Deg C	90
Electrical Data		
Power Supply Voltage	V	415
Frequency	Hz	50
Connected Load	kW	15
Solar Field		
Solar Collector Area	Sq. m	80
Roof top/ Ground area for solar field	Sq. m	160
Energy Data -10 TR VCR AC plant		
Connected Load for Conventional AC plant (10 TR)	kW	13
Annual Operating Hours	Hrs/yr	3,300
Energy Consumption-Conventional AC Plant (10 TR)	kWh/yr	42,900
Operating hrs/yr on Solar Radiation	Hrs/yr	3,300
Operating Load with Solar	kW	2
Energy Consumption – Solar Mode	kWh/yr	6,600
Energy savings due to Solar AC Plant	kWh/yr	36,300
Savings Percentage	**%**	**84.62**
Carbon Emissions reduction due to Solar Hybrid Plant	**Tons/yr**	**44**

Source: FIRST ESCO India Pvt Ltd

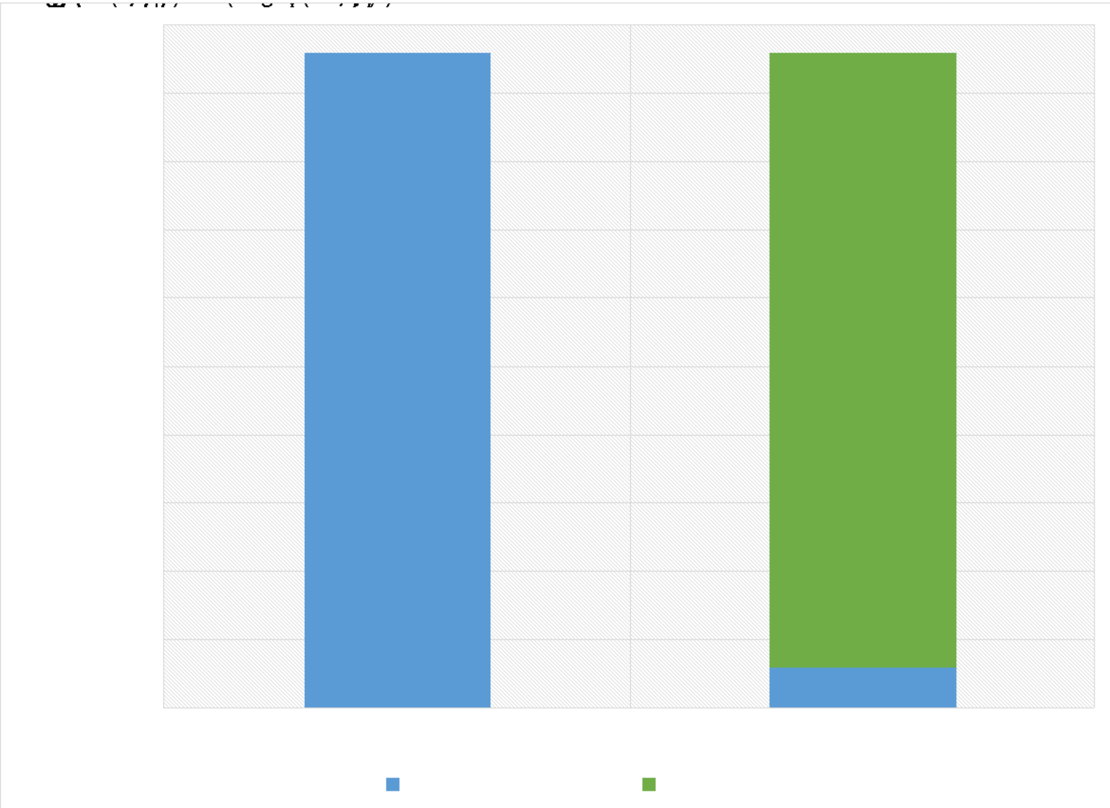
Table 4 | Solar VAM - Specifications of System II under study

Specifications	Unit	Value
Nominal Capacity of Plant	TR	75
Cooling Load	Kcal/hr	2,25,000
Equivalent Electrical Load	kW	262
Chilled Water Circuit		
Chilled Water Flow Rate	CMH	45
Chilled Water Inlet Temp	Deg C	12
Chilled Water Outlet Temp	Deg C	7
Cooling Water Circuit		
Cooling Water Flow Rate	CMH	62.5
Cooling Water Inlet Temp	Deg C	32
Cooling Water Outlet Temp	Deg C	38
Thermic Fluid Circuit		
Thermic Fluid Flow Rate	CMH	70
Thermic Fluid Inlet Temp	Deg C	100
Thermic Fluid Outlet Temp	Deg C	90
Electrical Data		
Power Supply Voltage	V	415
Frequency	Hz	50
Connected Load	kW	15
Solar Field		
Solar Collector Area	Sq. m	1,200
Roof top/ Ground area for solar field	Sq. m	2,400
Energy Data -75 TR VCR AC plant		
Connected Load for Conventional AC plant (75 TR)	kW	120
Annual Operating Hours	Hrs/yr	8,000
Energy Consumption-Conventional AC Plant (75 TR)	kWh/yr	9,60,000
Operating hrs/yr on Solar Radiation	Hrs/yr	4,000

Operating Load with Solar	kW	15
Energy Consumption – Solar Mode	kWh/yr	60,000
Energy savings due to Solar AC Plant	kWh/yr	4,20,000
Savings Percentage	**%**	**43.75**
Carbon Emissions reduction due to Solar Hybrid Plant	**Tons/yr**	**506**

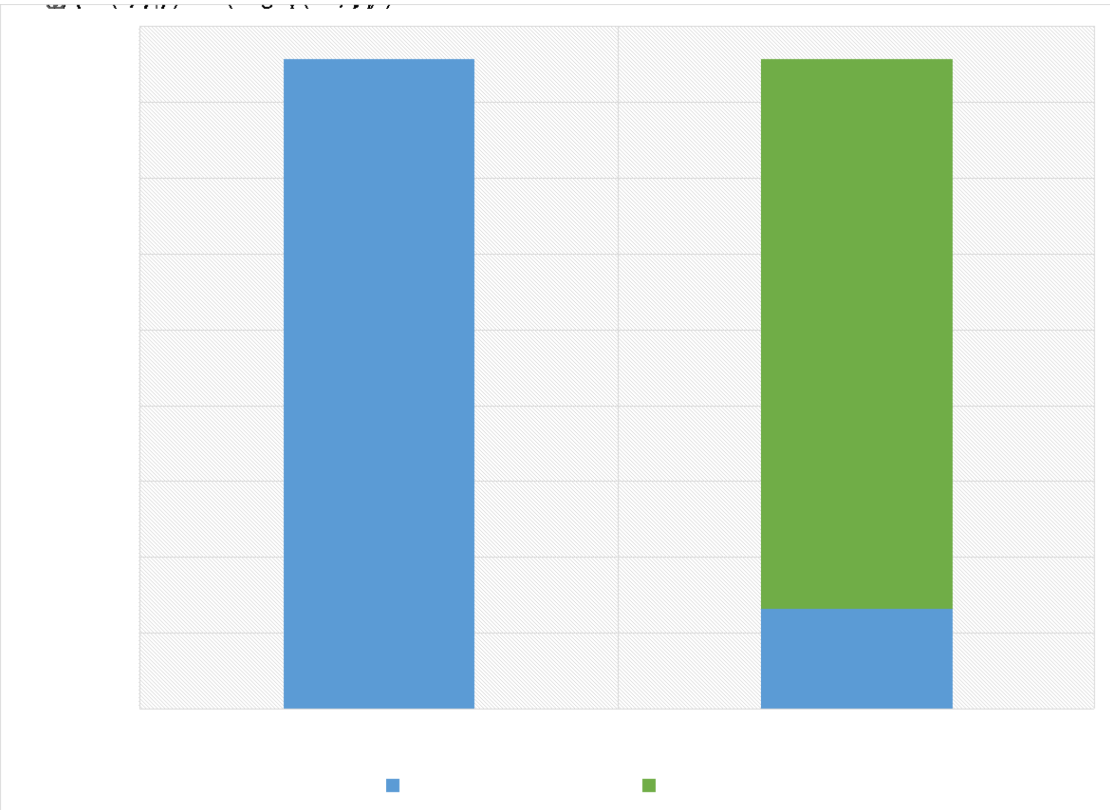
Source: FIRST ESCO India Pvt Ltd

Figure 7 | Energy Consumption and Savings – 75 TR system



Source: cBalance Solutions Hub analysis

Figure 8 | Energy Consumption and Savings – 10 TR System



Source: cBalance Solutions Hub analysis

- Thermax –VAM

While the GHG and Energy savings have been highlighted in the previous case study, this case focuses on providing the benefits on operational costs and savings. A 100 TR conventional chiller is compared with a 100 TR Thermax VAM chiller. As highlighted in *Table 5*, savings of almost INR 20 Lacs is observed per year. This finding suggests critical monetary benefits adding to the already realised energy savings and GHG emissions reduction.

Table 5 | Case Study analysis for Vapour Absorption Machine

DESCRIPTION	UNIT	Electrical	VAM
Chilling Output	TR	100	100
System type		Reciprocating	Steam fired
Power consumption	KW/hr	150	3
Power cost per unit	Rs/KWH	5	5
Power cost per hour	Rs/hr	675	14
Steam consumption	Kg/hr	NA	461
Steam cost per Kg	Rs/kg	NA	1
Steam cost per hour	Rs/hr	NA	415
Total Operational Cost per hour	Rs/hr	675	428
Operational Savings per hour	Rs/hr	-	247
Operational hours per year	Hrs	-	8,000
Operational Savings per year	**Rs/year**	**-**	**19,72,800**

Source: Thermax

Radiant Cooling

Uponor's Radiant Cooling Solutions, since 2009 has executed several radiant cooling system based projects in India. For this study, the Infosys MC1 installation is considered. Infosys is one of the global leaders in software development and is providing information technology solutions. The company is committed to sustainable growth and in pursuit of the same, they set up a team that implements sustainable solutions.

Table 1 | Radiant Cooling Case Study - Project Details

Location	Infosys
City	Hyderabad
Area	24000 Sq.m
Occupancy	2500
HVAC System Installed	Radiant Cooling System
% of area required cooling	85%

Source: Study by Infosys Green Initiatives

The MC1 building is a new facility of Infosys with 24,000 Sq.m of area. It is a project in which the slab had already been cast; as a result, slab cooling was not an option. A radiant cooling solution was installed, that provides higher thermal performance with cross-linked polyethylene pipes embedded in a layer of highly conductive material. These comfort panels, which are connected to a centralized chilling unit, that work at higher chilled water temperatures, thus resulting in a higher coefficient of performance (COP). The sensible cooling provided by the comfort panels had also reduced the amount of air to be circulated in the conditioned space, leading to a substantial reduction of the number of air handling units and in duct size. A reduction of energy consumption is another effect resulting out of the introduction of the radiant solution.

Upon comparing the installed radiant cooling system with a conventional system, an overall energy saving of 38.9% (1,71,000 kWh/yr) was observed (*see Table 3)*. Additionally, the system not only saved energy but also cost INR 292,300 less than the conventional system (*see Table 4*). A comparison of the system details is shown in *Table 2.*

Moreover, out of the 9 case studies reviewed, the minimum energy saving of 22.2% and maximum energy saving of 65% was observed, at an average of 36.4% across all 9 reviewed projects.

Table 2 | Infosys Case Study - System details comparison

System	Conventional AC System	Radiant
Cooled Area (Sq. m)	11,600	11,600
Supply Side Chilled Water Design Temp (Deg. C)	7.8	14
Return Side Chilled Water Design Temp (Deg. C)	15.6	17
Cooling Tower Approach (Deg. C)	2.2	2.2

Source: Study by Infosys Green Initiatives

Table 3 | Infosys Case Study – Energy Savings

Building	Conventional Building	Radiant Cooled Building
HVAC Annual Energy Index (kWh/sq.m)	38.7	25.7
Efficiency of Chiller Plant (kW/TR)	0.6	0.45
Energy Consumption (kWh/yr)	4,40,000	2,69,000

Reduction in Annual Energy Index (%)	**33.6%**
Energy Savings (kWh/yr)	**1,71,000**
Energy Savings (%)	**38.9%**

Source: Study by Infosys Green Initiatives

Table 4 | Infosys Case Study – Cost Savings

Buildings	**Conventional Building**	**Radiant Cooled Building**
Chiller (INR)	31,45,200	31,45,200
Cooling tower (INR)	13,06,400	13,06,400
HVAC low side works (INR)	2,28,39,000	1,53,10,000
AHUs, DOAS, HRW (INR)	51,18,200	28,78,900
Radiant piping, accessories, installation, etc. (INR)	Nil	90,75,800
Building Automation System (INR)	61,84,000	65,84,000
Total cost (INR)	**3,85,92,600**	**3,83,00,300**
INR/Sq.m	3,327	3,302

Source: Study by Infosys Green Initiatives

Structure Cooling

Panasia Engineers have executed several projects that involve cooling through structures. This study has reviewed the Veer Savarkar Rashtriya Smarak in Dadar, Mumbai (*see annexure for images*). A detailed study reveals that after installing the system, a reduction in cooling load of 10.8 TR was observed. This led to a total energy savings of 7.69 kWh/sq.ft/yr. Importantly, a 11.2 deg C reduction in surface temperature was also observed.

Slab B1 with a conventional cooling system reaches a peak temperature of 57 deg C, whereas Slab A1 with a structure cooling system reached 46 at the same given time. Thereby reducing load by 11 deg C. Percentage reduction in load was observed at 21%.

Across all five projects executed by Panasia Engineers, an average energy saving of 51% has been observed, with a minimum real world observed saving of 24% and a maximum of 75%.

Table 5 | Structure Cooling Case Study – Project details

Location	Veer Savarkar Smarak
City	Mumbai
Roof Area	554 Sq.m
HVAC System Installed	Structure Cooling System

Source: Panasia Engineers

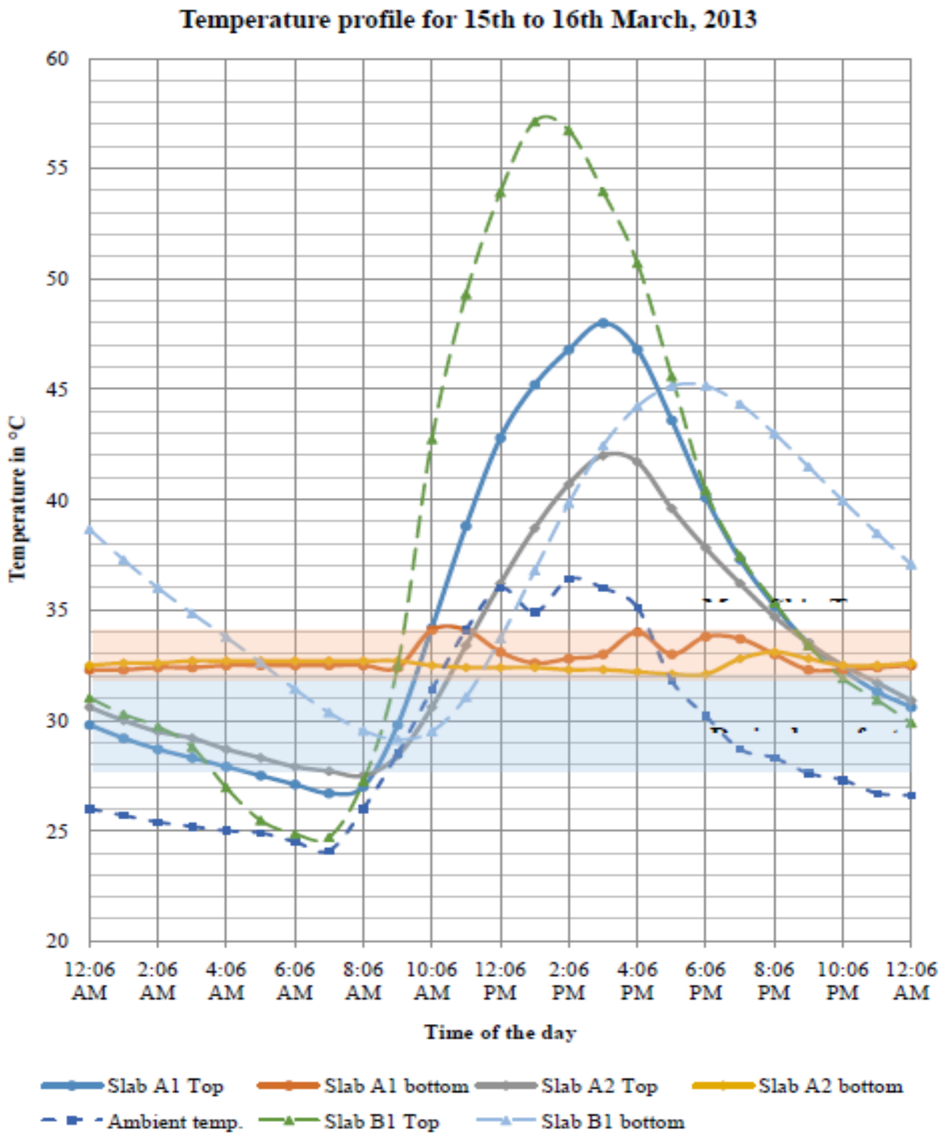
Table 6 | Structure Cooling Case Study – Savings Analysis

Systems	Conventional System	Structure Cooling System

Top Side Slab Temp (deg C)	57.1	48
Surface Temp (deg C)	45.2	34
HVAC System Tonnage (TR)	51.4	40.6
Energy Consumption (kWh/sq.ft/year)	10.8	3.1
Reduction in Surface Temp (deg C)		**11.2**
Reduction in HVAC System (TR)		**10.8**
Energy Savings (kWh/sq.ft/yr)		**7.69**

Source: Panasia Engineers

Figure 2 | Structure Cooling Case Study: Temperature Profile


Temperature profile for 15th to 16th March, 2013
Temperature in °C
60
55
50
45
40
35
30
25
20
12:06 AM
2:06 AM
4:06 AM
6:06 AM
8:06 AM
10:06 AM
12:06 PM
2:06 PM
4:06 PM
6:06 PM
8:06 PM
10:06 PM
12:06 AM
Time of the day
Slab A1 Top
Slab A1 bottom
Slab A2 Top
Slab A2 bottom
Ambient temp.
Slab B1 Top
Slab B1 bottom

Source: Panasia Engineers

Indirect/Direct Evaporation system (IDEC)

As highlighted in *Table 13 Table 15*, a comparison of the installed Indirect/Direct Evaporation system (IDEC) system with a conventional evaporative system reveals that there was a savings in net water addition during summers and monsoon season of 71% and 65% respectively. Moreover, the IDEC system also led an energy saving of INR 1,72,800/yr and 21,600 kWh/yr.

Table 12 | IDEC Case Study – Project Details

Location	Devi Gaurav Tech Park
City	Pune
Area	18,000 Sq.ft
Height	30 ft
Temp required	30 Deg C
HVAC System Installed	Indirect Direct Evaporative Cooling System
Fresh Air (%)	**100%**

Table 13 | IDEC Case Study – Savings Analysis

System	Evaporative Cooling System	IDEC System
Air Requirement(CFM)	1,20,000	80,000
Humidity in Space	High	70% Less
Summer - Net water addition in supply air (l/hr)	1750	500
Monsoon - Net water addition in supply air (l/hr)	650	225
Power consumption (kW/1,000 CFM)	54	48

Energy Consumption (kWh/yr)	1,94,400	1,72,800
Energy Cost (INR/yr)	15,55,200	13,82,400
Ducting Cost (INR)	42,00,000	28,00,000
Savings in net water addition during summers		**71%**
Savings in net water addition during monsoons		**65%**
Energy Savings (kWh/yr)		**21,600**
Energy Cost Savings (INR/yr)		**1,72,800**
Duct Installation Savings (INR)		**14,00,000**
Operation Cost Savings		**11.11%**

Source: HMX-ATE

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