ACADEMIC CURRICULA INTEGRATION PROJECT (ACIP)

SHAKTI
SUSTAINABLE ENERGY
FOUNDATION

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1 Executive Summary

This report explores the structure and backdrop for the inception of the Academic Curricula Integration Project (ACIP) in addition to the activities conducted during November 2015 - November 2016, and the learnings that emerged. The ACIP team conducted 12 workshops that were designed to significantly improve knowledge across tomorrow's architecture and building engineering graduates in the field of energy efficiency. The program further aims to realise energy efficiency being seamlessly integrated into the core curricula of architectural and engineering colleges across India, so as to enrich the upcoming Indian workforce with graduates by building capacity, to handle the responsibility in India's quest for an energy efficient, sustainable building growth. It further aims to provide a linkage between the sustainable energy industry and students or academia.

These workshops were conducted across 6 cities – Bengaluru, Chennai, Delhi, Mumbai, Pune and Jaipur. The ACIP team has successfully trained 79 architecture professors and 198 engineering students through workshops titled '*thoughtful cooling*' with focus on energy efficient building design. Memorandum of Understandings (MoU) have been signed with several colleges to affirm their intent to support curricula upgrade, by efforts from trained professors and through measuring the level of integration of sustainability in the minds of students through frequent assessments. Content for these workshops were developed by a collaboration between selected consultants and in-house expertise.

This report further includes an in-depth analysis of feedback received from participants and evaluation results from engineering students. Additionally, carbon footprint of the programme, primarily from the 12 workshops has been calculated along with strategies to offset the same have also been highlighted. Policy recommendations with respect to deep integration of sustainability into the architecture and engineering college curricula have also been state. The report concludes with the outlook for phase II of the ACIP.

2 Background

Our planet's oceans, vegetation, and soil can absorb 3 Gt of carbon emissions per year, a threshold first exceeded in 1968. In 2009, carbon emissions reached 6.6 Gt - more than double of what scientists agree the earth can hold. In the absence of action to counter this perilous trend, carbon emissions will rise to 14 Gt by 2050. For the planet and its inhabitants, our children and generations to come, this means accelerating desertification, more natural disasters, reduced crop yields, and serious public health implications such as heat-related infectious diseases.

It is expected that by 2030, India's building sector would grow at-least four to five times its current size, increasing the energy demand and emissions. This further implies that the cooling and refrigeration sectors would be the main drivers of energy demand in India. Less than 25% of Indian architecture colleges teach students how to design energy efficient or sustainable buildings. Only 3 to 4 courses out of the 72 courses offered at the bachelor's level, discuss the environmental impact of their building designs. Every year, students acquire diplomas after studying mainstream architecture and engineering curricula taught in universities courses are generally devoid of principles related to:

- Energy efficient building design
- Sustainable cooling technologies
- Building energy code

Less than 5% of the curricula of India's Architecture colleges deals with the environmental impact of their buildings. Scaling this number to the full magnitude of the number of students graduating from India's 423 registered Architecture Colleges leads to a startling conclusion: about 17,000 students graduate from India's architecture colleges with deficient skills to design environmentally responsible buildings.

Our research and field experience has shown that Architecture Professors are poorly trained in learning-centred teaching techniques and are largely oblivious to the spectrum of teaching methods now used by progressive academic institutions that have dismantled the traditional and failed method of unidimensional lecture teaching. Furthermore, professors in Architecture and Engineering colleges are left to grapple with a dearth of high-quality teaching aids: physical scale-models and virtual (animations etc.). Even the Professor's that have realized the disastrous lacunae that must be plugged if we are to transform the trajectory of energy consumption from India's relentless growing cities, are faced with unsurmountable administrative complacency from decision making executives in colleges and Academic regulatory bodies. There are no punitive consequences, financial incentives, or and peer-pressure amongst colleges to transform curricula. Training student's directly is also not sufficient. The magnitude is so vast that the Professor's of Colleges must be tooled

to deliver the required training on sustainable design principles and this effort must be institutionalized through curricula change.

The only way to address this magnitude of poorly trained and empowered students is by building capacity and deeply integrating sustainability and efficiency into architectural and HVAC-engineering higher education curricula, building capacity within India's Architecture and Engineering Colleges (those that teach HVAC design). Once capacity is built, students are endowed with an understanding of energy efficient building design, thereby developing buildings that have a reduced energy demand. Reduced energy consumption through energy efficiency adoption would eventually lead to increased supply in rural areas, strengthening energy access and security. Building capacity enables students to reduce emissions, increase India's energy security and thereby, combat climate change.

Additionally, the Energy Conservation Building Code (ECBC) and the Bureau of Energy Efficiency (BEE) Commercial Building Energy Performance Benchmarking Programme have established the concept of '*Benchmark Energy Performance Index*' values (kWh/m2/year) for various building usages and climatic conditions. However, these concepts have not yet transformed the Indian building energy consumption scenario due to a lack of awareness, skilled-capacity and insufficient emphasis on increasing uptake of these codes.

Today, even if the Energy Conservation Building Code (ECBC) were enforced by law, an adequately trained work force would be missing to implement it. Reduced uptake of efficient cooling technologies compounded by a rapid expansion of the artificially cooled built spaces in India with a lack of attention to bioclimatic architecture locks-in the current useless and toxic surge in energy consumption. This can be countered by the uptake of appropriate cooling technologies and basic bioclimatic design in buildings.

Moreover, developers will be constructing highly energy inefficient buildings, unfit for the Indian climate as they will be highly dependent on air conditioning in order to reach indoor thermal comfort, if this situation is left unchanged. NOE21, an independent association of public utility, founded in 2003 and based in Geneva, partnered with cBalance in order to identify, evaluate and promote solutions to climate change through a constructive approach. NOE21 informs that thermal refurbishing of buildings has a very long payback period, making retrofits most unlikely. Thus, there is an imperative need to sensitize the academic fraternity that shapes the attitude of architects and engineers that will design the 70% of built space that is yet to be built in India by 2030.

The ACIP team has embarked to address these vital lacunae that seeks to rectify the trajectory of energy consumption from India's buildings over the next 20 years.

3 Project Overview

3.1 Introduction to ACIP

Devised by Noe21 (Geneva) and cBalance Solutions Hub (Pune), this project aims to help countries in the tropical regions of the world address their cooling demand with the highest level of energy efficiency and lowest carbon emissions. June 2013 marked the beginning of this program, with the Pilot phase focusing on phasing out air conditioners using synthetic (fluorinated) refrigerants having very high global warming potential and phasing in energy efficient ACs that use natural refrigerants (propane), having low global warming potential.

The Academic Curricula Integration Project has been designed to enhance action-oriented understanding of sustainable cooling technologies (for the engineering students) and efficient building design centered around ECBC and other relevant sustainable design building guidelines (for architecture professors) through workshops designed to facilitate a two-way process of learning as well as syllabus integration of these programmes. These future professionals armed with up-to-date knowledge will be capable of integrating cooling load reduction strategies and sustainable cooling systems and energy efficiency principles in their practice.

ACIP aims at an ambitious but realistic objective: In 5 years from now, leading architecture and building engineering curricula located in the 5 biggest urban areas of India will have integrated energy efficiency in the substance of their existing curricula.

3.2 Project Objective

The ACIP team with support from key stakeholders: The Advisory Board and Shakti Sustainable Energy Foundation (Shakti), developed two distinct academically endorsed approaches for architecture and engineering programs with the goal of thematically expanding the breadth of knowledge imparted from a current two-dimensional focus of *'space'* and *'structure'*, to a three-dimensional realm wherein *'sustainability'* is legitimized and centralized as an equal third-axis that shapes the building design process. The project is not synonymous with increasing capacity to merely increase the stock of green-rated or ECBC-compliant buildings in India – the goal is not to reduce sustainably cooled interiors to a mere post-facto checklist approach. The project views green ratings as an outcome of an evolved design process where sustainability informs the very genesis and foundation of a design.

The overall objective of ACIP, in the area of cooling interiors, is to increase the energy efficiency (hereafter EE) of each kWh produced, thus reducing emissions of greenhouse gases compared to the expected emissions, facilitating the electrification of rural areas, and

reducing energy related bills. The project unfolded its activities in six major urban areas: Mumbai, Pune, Delhi, Jaipur, Chennai, and Bangalore.

The project established city-level curricula integration support groups for Architecture professors to handhold them and advise them on the process of engagement with management bodies of educational institutions to drive curricula change at the university level. This addresses a key-lacunae identified by prior programs with similar objectives (e.g. USAID's ECO3 program which is also conducted extensively for ToT's to build capacity to teach Building Physics in Architecture Colleges).

The Bureau of Energy Efficiency's (BEE) efforts towards simplifying the Energy Conservation Building Code (ECBC) code implementation through i) staged or tier-based implementation approaches, ii) enhancing uptake rates amongst new constructions through IT solutions for compliance checking, and iii) establishment of third-party assessment frameworks - have all led to an abundant pool of knowledge generated by the technical and institutional community. The existing symbiotic relationship shared between cBalance and the ECBC is being further reinforced through the project's (ACIP) deliberate effort to build on top of the ECBC program's aforementioned existing knowledge assets, thus avoiding duplication of effort and improving efficiency of resource allocation.

3.3 Structure of the Project

The ACIP deliberately avoids creation of '*additive*' curricula content (i.e. separate courses) for architecture colleges and instead works in an *'integrative'* manner. For architecture programmes, a training-of-trainer (ToT) workshop was created for professors. This format seeks to inform the entire five-year educational curricula spanning architectural theory, design and technical subjects.

For engineering programs, the project recognized the competing academic interests and professional opportunities available to students of mechanical engineering. Automotive engineering, industrial engineering, and robotics are other fields of professional interest that are reflected in the four-year curricula, while buildings and HVAC (heating, ventilation, and air conditioning) related courses form a modest fraction of the body of knowledge imparted. Therefore, the project conducted direct student-certification courses related to sustainable cooling technologies for specific students that were deeply interested in the subject and anticipate pursuing HVAC engineering as a profession.

3.4 Strategy

Methods of designing and building energy efficient buildings in India are widely available, but the problem lies in the implementation of these techniques to actual practice. This primarily happens because this knowledge is far from being transmitted to the next generation of Indian architects and engineers. Workshops conducted by the ACIP team brought a selection of specialised practitioners to share their knowledge with college staff and students. These specialists were either architects, consultants specialised in assisting architects with energy related issues, engineers specialised in indoor cooling, etc. They were handpicked by the ACIP team for their knowledge as well as their capacity to share their passion in a pedagogically effective manner. When one touches upon several fields of activity, it is difficult to teach new technologies and skills three-day and five-day sessions *(see detailed programme of events in Appendix A - Workshop Outline)*. However, they have proved to be sufficient to sensitize faculty and students on new skills and to motivate them towards an inner-academy process leading to new electives and renewed curricula content.

3.5 Steering Committee

During the initial phase of outreach with various universities, a steering committee was instituted comprising of professors, high-level decision making management from specific colleges, ACIP team, and select advisory board members from ACIP. The Steering committee helped develop specific curricula for the workshops, identified experts on technical subjects in order to carry out the training, and defined the venue and calendar of events. This committee further aided in localization and customization of the training content in order to align it with the existing curricula that colleges are affiliated with.

4 Project Activities

4.1 Training Module Development and Certification

Training content for the Engineering Student Certification program as well as for the Training-of- Trainer (ToT) program for Architecture professors was developed through collaboration between in-house expertise and select consultants:

- VK:e Environmental was contracted by cBalance to devise technical content for the Engineering Student Certification program.
- Environmental Design Solutions (EDS) was contracted for creating a massive open online course (MOOC) that is shared with participants prior to the workshops.
- Vernacular Architect Mr. Suresh Vaidya Rajan was contracted to develop the module on Physical Teaching Aids and additionally, for creating physical models that act as teaching aids (a detailed list of these can be found in section 4.2.6)

- Practicising Architect Ms. Prakriti Shukla helped create a module that dissects the current pedagogical lacunae in the teaching process practiced in lecture and studio courses and graduating to a higher understanding of the pedagogical craft required to embed sustainability into technical, humanities and design education. The modile looks at understanding the process of identifying relevant educational objectives (Bloom's taxonomy that spans the realm of remembering, understanding, applying, analysing, evaluating and creating) and integrating the spectrum of systems of learning (associative, indirect + interactive, experiential, co-operative, and project-based) into lesson plans and activities that encompass existing and augmented syllabus content.

The ACIP team has been constantly improving upon and upgrading the modules based on feedback by board members, the ACIP team, faculty and participants.

Additionaly, The ACIP team reached out to industry and academic bodies that reviewed, suggested relevant edits and certified the training modules. One such organisation, founded in 1981, is the Indian Society of Heating Refrigerating and Air Conditioning Engineers (**ISHRAE).** Secondly, another such organisation certified the content and is recognized by the Council for Opportunity in Education, Association for Equality and Excellence in Education, **AEEE** is one of the ten regional associations that is dedicated to provide equal educational access for the first-generation, low-income and disabled students.

List of all the modules (Architecture ToT training modules can be downloaded here, and Engineering Student Certification modules can be downloaded here) that have been certified by ISHRAE and AEEE are mentioned below:

4.1.1 Architecture Professor ToT Workshop

a. Active Cooling Principles
b. Natural Refrigeration Air-conditioning
c. Evaporative Cooling
d. Structure Cooling
e. Radiant Cooling

4.1.2 Engineering Student Certification Workshop

a. Active Cooling Principles
b. Building Physics Part 1
c. Building Physics Part 2
d. Direct-Indirect Evaporative Cooling Systems
e. Application of simulation in building energy efficiency and sustainable cooling

f. Methods for Comparative Assessment of Cooling Technologies
g. Natural Refrigerants ACs
h. Solar Vapour Absorption Machines (VAM)
i. Structure & Radiant Cooling
j. Thermal comfort and Indoor Air Quality

4.1.3 Development of Tools and Teaching Aids

The ACIP team approached Ar. Suresh Vaidya Rajan, an eminent, practicing architect and visiting faculty at select architectural schools in Delhi with a special interest and expertise in vernacular architecture and sustainable building constructing with locally available materials.

Following are a list of deliverables that have been developed by Ar. Suresh Vaidya Rajan:

a. **Physical model prototypes** - For pictorial and live demonstration of suggested physical teaching aids, for use by teachers as part of lesson plans for passive design, building physics, and sustainable cooling pedagogy including concepts of heat transfer, climatology, psychrometry, solar geometry, thermal mass, shading devices, building envelope design, ventilation, conventional refrigeration cycle, and sustainable cooling technologies.
b. **Do-it-Yourself (DIY)** - Created to a) infuse sustainability into the design consciousness and process of students, b) cultivate an instinctive visual, tactile and non-numerical understanding of technical subjects, c) breed familiarity with, and make less daunting, the engineering aspects of energy efficiency and cooling technologies, befriending numbers, and blurring the boundaries with HVAC engineering.
c. A **booklet/manual** supporting the usage of each of these tools.
d. A **design assignment/test paper** that will be used to understand the level of impact and understanding achieved by teachers post a ToT.

Prototype teaching aids for the following knowledge areas have been developed as part of the contract

THEME	Materials	Arch. Design	Climatology	Building Science and Services
TEACHING AIDS	Material bank/test cells	Shading devices	Psychrometry	Radiant cooling
	U-value measurement set	Form & Orientation	Bioclimatic Chart	Structure cooling
	Thermal mass	Window-Wall Ratios (WWR)	Solar chart plotter	Evaporative cooling
	Reflective Surfaces	Cross-ventilation	Solar protractor	Night sky cooling
	Heat Exchange/Transmittance		Climate calendar	Radiant heat transfer
	Insulation		Sun tracker	Conduction heat transfer
			Sun dial	

4.2 Workshop Proceedings

4.2.1 Workshop Outline

Outline for the 3-day Architecture ToT & 5-day Engineering Student Certification workshop can be found as *Appendix A.*

4.2.2 Workshop Plan

4.2.2.1 Architecture Professor ToT Workshop

Across each selected city, a renowned Architecture College - based on its progressive teaching methods and vibrant faculty - was selected and then approached, to act as the project HUB College. Comprising of the project team, professors and department heads from the HUB College, a steering committee was estabilished. Along with the HUB college, 4 other colleges were approached and a Memorandum of Understanding, MoU (*the template*

can be found as Appendix H) with each of them was signed, to affirm their intent to support the curricula upgrading by efforts of trained professors after the conclusion of the workshops. Each of the colleges identified a blend of the most suited professors for the workshop, which ensured that the entire educational spectrum of design related (3 professors) and technical courses (3 professors) were covered.

List of HUB and contributing colleges can be found in appendix D.

4.2.2.2 Engineering Student Certification Workshop

Similarly, a renowned Mechanical/Civil Engineering college from each of the selected cities – based on its progressive teaching methods and vibrant faculty - was selected to act as the HUB college. Comprising of the project team, professors and department heads from the HUB College, a steering committee was created. After being approached as the HUB College a Memorandum of Understanding, MoU (*the template can be found as Appendix H*) was signed, to affirm their intent to support the curricula upgrading and measuring the level of integration of sustainability in the minds of the students through frequent assessments. Students for this workshop were selected on the basis of their performance and primarily their interest towards the subject.

List of HUB colleges can be found in appendix D.

4.2.3 Pre-Workshop Knowledge Dissemination

4.2.3.1 Architecture Professor ToT Workshop

The following themes - Architectural Design, Climatology, Materials, Building Technologies, Building Science and Services and History & Theory of Design were identified in order to ensure that all the subjects were covered during the training. All the modules and sessions of the workshop were designed to encompass the aforementioned themes. Specialised practitioners consisting of architects, consultants specialised in energy efficient building design and modelling, engineers specialised in indoor cooling or sustainable cooling technologies, professors teaching in the field of sustainability and education were identified to be trainers for this workshop. They were selected by the advisory board and ACIP team to impart their knowledge in a pedagogically effective manner, to the participants.

Furthermore, trainers were provided with a brief (*can be found as Appendix B*), which included the guidelines, limitations and the basic agenda (*can be found as Appendix A*) of the workshop to ensure that the delivery was relevant and effective. A pre-requisite for attending the workshop is successful completion of an online course (a MOOC). The MOOC

is a 9-module online course that helps establish a thorough foundation in scientific and technical concepts that are related to Building Physics, Passive Design Strategies and Sustainable Cooling Technologies. It has benefited professors by acting as a platform to re-learn fundamental concepts, motivating and encouraging them to teach these concepts to the students in a simpler, yet effective manner. It is a pre-requisite since the ToT workshop will be intensely focusing on imparting pedagogy related training through the technical and design concepts discussed in the MOOC (*can be viewed here*).

4.2.3.2 Engineering Student Certification Workshop

Themes of sustainable cooling technologies, building physics, thermal comfort and energy modelling were covered during the workshop. All modules and sessions were designed to encompass the aforementioned themes. Thermal Comfort as stated in the ASHRAE 55 Std. Thermal Comfort Model is contextualized in this workshop. Bioclimatic design strategies that enable compliance with the Adaptive Standard, including use of shading, thermal mass, appropriate materials to reduce building envelope load, interior finishes (to reduce radiant temperatures), using climate responsive materials and construction assemblies etc. were discussed. Finally, sustainable cooling technologies such as active cooling, evaporative cooling, radiant cooling and structural cooling systems that help achieve thermal comfort, were studied elaborately.

Energy savings that could be achieved through changes in HVAC temperature settings were also discussed. This is also demonstrated through hands-on building energy modeling and simulation exercises on day 4 and 5. Design iterations were performed with changes in temperature settings, use of different building materials, shading devices, etc. to analyse and comprehend the respective effect of iterations on building energy consumption. Similar to the Architecture Professor ToT Workshop, specialised practitioners were selected by the advisory board and ACIP team to train the students. The trainers were provided with a brief (*can be found as Appendix B*), which included the guidelines, limitations and the basic agenda (*can be found as Appendix A*) of the workshop to ensure that the delivery was relevant and effective.

4.2.4 Workshop Activities

4.2.4.1 Architecture Professor ToT Workshop

The topics covered over the three days of the ToT workshop include a revision of the MOOC, followed by an introduction to Sustainable Cooling Technologies along with the different methods using which they can be integrated within the syllabus. The ToT workshop further encompassed devising and compiling of teaching aids (physical models, software tools,

testing and evaluation aids) and conduct training sessions that empowered, guided, and provided actionable-knowledge to professors who can then seamlessly embed syllabus content related to efficient and sustainable cooling strategies (design and technology) across courses covering climatology, building materials, building technologies, structural design, history and theory of design, architectural design and building science and services.

Day 3 constituted of a group activity titled '*Syllabus Renaissance'* where professors were divided into three groups, with each group representing one design, humanities and technical subject. Mentored by the ACIP team and trainers, each group developed a new lesson plans (*see Appendix C*) for their respective subjects, including passive design strategies, concepts of psychrometry, sustainable cooling technologies, teaching aids, and learning systems to effectively integrate sustainability into their curricula. Lastly, extensive feedback forms were provided to participants, to fathom the effectiveness of the workshops and how the ACIP team can improve both - organisational and content aspects of the workshop.

4.2.4.2 Engineering Student Certification Workshop

Topics covered over the five days of the Student Engineering Certificate workshop involved an introduction to Climate Justice and its coupling with our Built Space, followed by an introduction to the programme and the workshop objectives. Thereafter, students debated on topics of their personal position in mapping and articulating the context of Climate Change and Development. Topics covered during the first two days included Building Physics, Thermal Comfort and Indoor Air Quality, Active Cooling, Natural Refrigerant Air Conditioning, Solar Vapour Absorption Machines, Direct/Indirect Evaporative Cooling, Structure and Radiant Cooling.

On Day 3 students were taken to an identified site that showcased a practical application of one or more of the sustainable cooling technologies. The 4th and 5th day focused on introducing Energy efficiency modelling to students along with training them on the Smart Energy Tool. Lastly, students were evaluated, and on the basis of their performance were granted certificate of completion. Students that scored 50% and above, were given the certificate of completion. Extensive online feedback forms were also further with the participants, in order to analyse and comprehend their opinion on the organisational and content relevance of the workshop. This feedback is being absorbed to improve future workshops.

4.2.5 Post-Workshop Follow-Up

4.2.5.1 Architecture Training of Trainers Workshop

Post-workshop follow-ups involved the establishment of city-level support groups comprising of resource persons that can be contacted by the professors for any problems they face in their efforts to integrate the augmented syllabi in college curricula. These groups also involve the professors to be in touch with the ACIP team for any guidance or assistance in the implementation of a sustainability-integrated syllabus. Furthermore, teachers are provided access to the physical teaching aids post completion of the workshops. This is anticipated to take the shape of a '*climatology'* lab, which would store each of these aids, and be used as training material for the students, on fundamental concepts, across all partner colleges.

Several Half-Day Workshops (HDW) were conducted, which are critical follow up discussions conducted in collaboration with all participating architecture colleges individually. They are targeted towards formulating next steps that each participating college would need to take in order to effectively and seamlessly integrate energy efficiency and sustainable cooling within the existing curricula, and to understand the support that is required from the ACIP team for the integration to happen. Through the HDWs, the ACIP team in a collaborative effort along with participating colleges, further seeks to develop the lesson plans that need to be delivered towards final integration of sustainability.

4.2.5.2 Engineering Student Certification Workshop

Post successful completion of evaluations and distribution of certificates, students and their colleges are given one-year free license for using these tools developed by the Indian Society of Heating Refrigeration and Air Conditioning Engineers (ISHRAE). Post-workshop follow-ups further involve getting the student body in touch with our advisory board members and their respective organisations, with the prospect of providing them guidance and technical assistance in the field of sustainable cooling.

4.2.6 Curricula Integration

4.2.6.1 Half-day Roundtables/Workshops

Half day follow-up workshops were conducted across selected cities with partner colleges. The aim was to bring to the fore, innovative and experiential teaching practices specifically in the sustainable cooling sector. The individual subjects were identified by the colleges

from a pool of three subject areas – architecture design studio, technical and humanities. The emphasis was on integrating knowledge gathered through workshops and from different subjects while designing, and to maximize energy-efficiency and contribute to climate justice. Finally, to establish a roadmap for piloting curricula integration.

4.2.6.2 Syllabus Renaissance Output

As highlighted earlier, ToT workshops comprise of a group activity on day 3, where the professors embed different passive design strategies, concepts of psychrometry, sustainable cooling technologies, teaching aids, and learning systems to create new lesson plans for three subjects (one design, humanities and technical) from their syllabus, with the help of ACIP team and mentors. This reworked lesson plan acts as a starting point for the college to enable integration of sustainability into their core curricula in the next phase of ACIP.

All outputs from these sessions have been collated into one document, found as *Appendix C – Syllabus Renaissance Narratives*, all charts for the same can be found in *Appendix C – Syllabus Renaissance Charts*.

4.2.7 Workshop metrics

4.2.7.1 Trainers

A total of 23 trainers have been a part of all ACIP workshops, these are:

Table 1 | Trainer list

Trainer Name	Sessions Conducted	Designation
Aalok Deshmukh	Syllabus Renaissance	General Manager, Schneider Electric
Anubhav Saxena	Introduction to Energy Modelling, Smart Energy Tool – Modelling Sustainable Cooling Technologies	Sustainability Project Consultant, AECOM
Anuj Daga	Syllabus Renaissance	Architect
Deepa Parekh	MOOC Recap 1 & 2, Quiz	Project Manager, Environmental Design Solutions
Debashree Pal	Rethinking Pedagogy	Architect, Professor
Dominic Matthew	Workshop Objectives and Participant Expectations, Best Practices in Sustainable Architecture Curricula-Syllabus-Lesson Plans, Pedagogy, and Teaching Aids,	Architect

	Building a Sustainability-Integrated Curricula-Syllabus (Humanities, Technical and Design)	
Kushal Matai	Best Practices in Sustainable Architecture Curricula-Syllabus-Lesson Plans, Pedagogy, and Teaching Aids, Building a Sustainability-Integrated Curricula-Syllabus (Humanities, Technical and Design)	Architect
Mihir Shah	Case-Study Detailing	CEO, Halston Software
Milind Rane	Solar Vapor Absorption Machines	Institute Chair Professor, Mech. Engineering Dept., IIT Bombay
Nitin Deodhar	Active Cooling Principles	Chief Designer, NM Deodhar Consulting
Nitin Pasricha	Classroom Teaching Aids	Project Manager, ACIP, cBalance Solutions
Neeraj Kapoor	Active Cooling Principles, Sustainable Cooling Technologies – Evaporative Cooling	Founder, Kalpakrit
Pankaj Rathore	Sustainable Cooling Technologies – Radiant Cooling	Business Development Manager, Uponor
Prakriti Shukla	Rethinking Pedagogy	Architect
Ruchie Kothari	Best Practices in Sustainable Architecture Curricula-Syllabus-Lesson Plans, Pedagogy, and Teaching Aids, Building a Sustainability-Integrated Curricula-Syllabus (Humanities, Technical and Design)	Project Manager, BEMAP, cBalance Solutions
Shamakant Mirashi	Sustainable Cooling Technologies – Evaporative Cooling	Director, Arka Technologies
Shreya Mundhra	Virtual Teaching Aids	Project Assistant, ACIP, cBalance Solutions
Shrikant Kaduskar	Sustainable Cooling Technologies – Radiant Cooling	Owner, EMAC Services
Surendra Shah	Sustainable Cooling Technologies – Structure Cooling	Founder, PanAsia
Suresh Vaidya Rajan	Physical Teaching Aids	Architect, Professor

Udeet Methala	Virtual Teaching Aids	Consultant
Vrajlal Kanetkar	Active Cooling Prinicples, Sustainable Cooling Technologies – Evaporative Cooling	Engineer, Professor
Vivek Gilani	Warming Up, Climate Justice, Built Space and an Introduction to ACIP, Workshop Objectives and Participant Expectations, MOOC Recap 1 and 2, Natural Refrigerants, Radiant Cooling, Evaporative Cooling, Structure Cooling, Active Cooling, Solar VAM, Converting Knowledge into Action, What Next & Participant Feedback, Building Physics 1 & 2, Solar VAM, Thermal Comfort and IAQ	Managing Director, cBalance Solutions

4.2.7.2 Participants

A total of 79 architecture professors and 198 engineering students have been trained in the workshops conducted across 6 cities – Bengaluru, Chennai, Delhi, Jaipur, Mumbai and Pune during phase I.

4.2.7.3 Colleges & MoU

21 Architecture colleges and 7 Engineering colleges have been a part of all ACIP workshops conducted across 6 cities – Bengaluru, Chennai, Delhi, Jaipur, Mumbai and Pune in the past one year. MoUs have been shared with each of these colleges and currently a total of 9 colleges have signed the MoU, while others are in progress.

List of the colleges that have signed a MoU:

- Smt. K. L. Tiwari College of Architecture
- Sushant School of Art and Architecture
- Malaviya National Institute of Technology, Department of Architecture
- Kamala Raheja Vidyanidhi Institute of Architecture
- Rachana Sansad Institute of Environmental Architecture
- Sinhgad College of Engineering
- MESCOE
- MIT
- Rizvi College of Architecture

A list of all participants and colleges can be found as *Appendix D – Workshop Metrics.*

5 Learnings

5.1 Summary of feedback from participants

5.1.1 Architecture Professors

- Participants highlighted that they would prefer to spend more time on the MOOC, Passive Design Strategies, Teaching Aids, Pedagogy related sessions, Sustainable Cooling Technologies, Best Practices in Sustainable Architecture (*with additional examples*).
- Participants found the Physical Teaching Aids, Sustainable Cooling Technologies, Pedagogy related sessions and the MOOC to be outstanding.
- All participants agreed that the sessions were well spread out. They also suggested spending an entire day on the interactive sessions in order to fully comprehend all concepts and apply them to the reworking of the lesson plans.
- Some participants also suggested spreading the theory part of the workshop (MOOC and sustainable cooling technologies) over one and a half days, to give them a break and prevent saturation of concepts.
- Most of the participants wanted the workshop to be longer, having the sessions spread out, they suggested extending the workshop for 5 days.
- Participants were extremely satisfied with the structure of the workshop, and stated that they found the workshop to be extremely informative, inspiring and resourceful. They also stated that the workshop allowed them to introspect on their teaching methods, and how they could introduce and emphasize on the importance of each of these concepts of sustainability to their students and clients.
- Participants suggested that making the workshop less technical and more practical, by spending more time on the syllabus renaissance sessions and having more group discussions would be beneficial.
- They proposed creation of videos for each session, so its more easily accessible to them. Creating these videos would further help trainers understand how they can improve.
- Some participants also suggested conducting the same 3-day workshop, specifically for each college, to ensure that all faculty from that college is trained, easing the process of integration.
- Majority of participants voiced their concerns about starting the process of integration without coming from a technical background pertaining to the different sustainable cooling technologies. They further requested the ACIP team to develop a platform where they could get support from industry experts or the ACIP team itself, to help the process of implementing these technologies and teaching aids into their lesson plans. Networking with technical experts and industry members would help

the students to interact with them openly, further exposing them to a platform to discuss and understand these sustainable cooling technologies.

- The increasing class size (number of students) was identified to be another major concern, highlighting that most students come from different backgrounds, therefore, standardising the method of teaching is difficult.
- Participants also raised concerns with respect to getting the students more involved in sustainable building design, due to university regulations and how those policies need to change in order to effectively integrate sustainability into their syllabus.
- The time constraint with respect to meeting the university deadlines was identified to be another major concern, highlighting that the existing syllabus compels them to focus on the end-result more than ensuring a sufficient understanding of concepts. They further raised concerns as to how they could change their teaching style in compliance to the university regulations, so as to ensure that the thought-process of the students are developed to think sustainably when it comes to building design.
- Participants suggested that they should be informed about the syllabus renaissance session on day 1, to ensure that the discussion stays at a micro level and is more structured. Moreover, they suggested that participants should be given a list of subjects and intervention areas for the Syllabus Renaissance session, so that they are able to choose the areas they are better at and present on those areas, leading to a more productive discussion.
- All participants discussed improving the interaction midst the colleges, in order to compare how each of them are approaching the integration of sustainability into their curricula and learn from each other.

5.1.2 Engineering Students

- Majority of the students expressed their desire to spend more time on Sustainable Cooling Technologies – focusing on Radiant and Structure Cooling, Smart Energy, Carbon Footprinting, Building Physics and Psychrometry.
- Students found the presentations to be outstanding, especially, the sessions on sustainable cooling technologies.
- Students proposed spending more time on software training, so they could use the software to understand all aspects while modelling. They further added that the software sessions need to be more interactive.
- Students articulated that the workshop could be made more interactive - discussion and activity oriented, so that they are able to apply what they've learnt and more interactions would prevent saturation of these concepts.
- Students also proposed extending the duration of the workshop to make it a week-long workshop, suggesting that the duration of each session reduces, to prevent lapses in concentration.

- Students suggested spending more time on the impact and consequences of climate change, and adding a session on daily habits and its adverse effect on nature to the agenda.

The aforementioned feedback has been noted down and efforts to absorb and implement changes will be carried out by the ACIP team during the next phase of operations. Feedback forms for both can be found as *Appendix E*.

5.2 Evaluation results

To assess and provide certification to students, an evaluation was conducted by the ACIP team on the last day of workshops, which consists of 50 MCQ's including concepts of Building Physics, Thermal Comfort and Indoor Air Quality, Sustainable Cooling Technologies and Natural Refrigerants. Students were allowed to refer to all presentations and a concept book was shared with them. Students that score 50% and above were granted a certificate of completion. Upon analysing results from the 6 engineering student certification workshops, it was evident that certain questions (and concepts) require the trainers to improve the training to enhance greater understanding. Additionally, special attention will be given to ensure that students thoroughly understood the concept. The ACIP team has absorbed these learning and will strive to address this lacuna in phase II.

Table 2 | Questions that were answered incorrectly

Question	% of students who answered incorrectly
Choose among these the low-GWP natural refrigerants that have potential to replace currently used high-GWP refrigerants.	60.1%
Total Equivalent Warming Impact of ACs are a consequence of?	55.6%
India must 'leapfrog' to sustainable cooling because?	61.6%
Air-cavity walls and hollow concrete blocks are good insulators and resist heat better than conventional brick walls because?	51.0%
Insulation and thermal mass both mitigate the transfer of heat; but achieve it through different mechanisms; which of the following are true.	83.8%
The following statements are TRUE about the psychrometric/weather data chart presented below.	90.4%
Declination (i.e. tilt) of the earth's axis relative to the orbital plane causes all of the following, which leads to seasons, except?	53.5%
Which rating system is proposed to be 'mandatory' requirements to be followed by large commercial buildings in India in the next few years	64.6%
Solar VAM Systems employ all of the following processes except?	60.1%
A Radiant cooling system seeks to maintain an Operative Temperature of 22C. If it uses a chiller and radiant pipe network system that produces a Mean Radiant Temperature of 19C, what Air Temperature can it set for the air conditioning system to maintain comfort conditions?	55.6%
A structure cooling system employs all of the following processes except?	79.3%

Evaluation results can be found as *Appendix F*.

5.3 Key Outcomes

- Developed training content for '*Sustainable Cooling for Architecture/Engineering Education*'; Additionaly, a Massive Open Online Course (MOOC) was created and extensively used as a preparatory tool for training workshops.
- Certification from ISHRAE and AEEE for technical content was procured.
- India-specific Building-Energy-Modelling tool for optimum and efficient HVAC design (SmartEnergy), developed by ISHRAE, has been revived, refined and widely publicized. A 2-year unlimited-license-agreement was crafted for disseminating annual licenses to our engineering college network.
- Workshop format refined through feedback integration emerging from participants and other stakeholder interaction sessions (with advisory board members, academic experts etc.)
- Building-Energy simulation software training process refined through feedback integration from participants
- Nascent, informal city-wide networks of architecture colleges have begun emerging where organic interaction is detectable
- Creation of lesson plans to formally pilot curricula integration began across a few colleges in Delhi & Mumbai
- Connection established with Society of Building Science Educators (SBSE) – membership alternatives for Indian college professors are being explored
- Contours of Sustainable-Cooling Nomograph Research Project with 40 colleges across 8 cities crafted and concept note has received buy-in from KRVIA and Rachna Sansad (Mumbai), RV College (Bangalore), and SPA (Delhi) to serve a regional research anchors for 5400-BEM-simulation-based project
- Responsive advisory board of eminent building science professionals, sustainable architects, and academics has been constituted, response times have reduced and response rate have increased: includes Dr. Satish Kumar, Dr. Jyotirmay Mathur, Surendra Shah, Ashok Lall, Tanmay Tathagat, Roshni Udyavar, Vikram Murthy, Dr. Hariharan, KT Ravindran
- 1st Drafts of Sustainable-Cooling Enhanced Syllabi for 15 courses created.
  Re-working the structure and agenda of the workshops, resulting in conducting Deep-Dive workshops with each college, to ensure that all professors feel confident about teaching technical concepts to the students.

5.4 Lacunae identified

5.4.1 Deficient Tech-Support

- Technical training '*tech support*' for Architecture Professors post workshop required for: Climatology (Psychrometrics, Refrigeration Cycle, Sustainable Cooling

Technologies: Direct/Indirect Evaporative Cooling, Structure/Radiant Cooling, Solar Vapor Absorption, Comparative Life-Cycle GHG Emissions Assessment of Passive Design and Sustainable Cooling Technologies).

- Feedback from participant's highlight that more time to be spent on sustainable cooling technologies, current best practices in sustainable architecture, rethinking pedagogy, and building physics concepts, possibly extending the workshop from a 3-day format to a 4/5-day workshop
- Dearth of high-quality teaching aids (physical) and virtual (animations etc.) to convey building physics concepts and electro-mechanical processes of active cooling systems.
- No appropriate Sustainable Cooling Technology Modelling tool for Mechanical Engineering (RAC Course) Students; all tools for designing alternative systems are proprietary.

5.4.2 Administrative-Complacency

- No punitive consequences, incentives, or pressures – financial (taxation or increased revenue incentives), social (peers), market (competitors), or professional (regulatory bodies) in the academic ecosystem ensuring curricula is upgraded to integrate passive design and sustainable cooling across the spectrum of learning/teaching opportunities.
- Administrative and intellectual complacency in parent educational institutions of participating professors despite MOU's being signed and approved by senior management of educational institutions.
- Dis-interest amongst non-participating professors as a result from inadequate participation by colleges, in most cases does not translate to uptake of curricula integration.
- Tepid (National Institute of Advanced Studies in Architecture, NIASA), or inconsistent (Council of Architecture, COA) response from national capacity building and regulatory bodies in the context of training program certification, outreach support and mainstreaming. Diffuse, hierarchical nature in conjunction with significant flux of executive body members is not conducive to long-term engagement and delivery upon promises made.

5.4.3 Siloed Education

- Siloes of sustainable cooling knowledge libraries, well-documented performance-based case studies, capabilities and project opportunities in all 6 cities where the Program operates: tenuous or absent networks amongst Architecture and Engineering Academic Institutions, between practitioner's (Sustainable Design Architects and Sustainable HVAC Suppliers, Designers, Consultants) and professors/students.

5.5 Module-wise learning's/content upgrade

Across all workshops, programmatic and content specific upgrades were identified by participants, the ACIP team and partners. These upgrades vary from fixing errors, to adding elaborate definitions for certain concepts, adding animations and videos, address questions raised by participants, development of tools and teaching aids, software upgrades and overall program modifications with respect to organisation and management of the workshops. These upgrades have been absorbed by the ACIP team and upgrades will be applied before the next phase of operations.

A detailed list of these upgrades can be found as *Appendix G*.

6 Carbon footprint

6.1 Methodology

As per the ' *Standard GHG Protocol*', the ACIP team has calculated the footprint for 12 workshops conducted in the past year. The current footprint comprises of Accommodation and Travel (Air, Bus, Train and Taxi travel) related activities. Emissions are calculated using:

$$E_{CO2}e = Activity\ Data * Emission\ Factors$$

Where *E = Emissions* and CO_2e *= Carbon Dioxide Equivalent.*

6.2 Results

The overall estimated footprint from travel and accommodation was 12.9 tonnes of CO_2e (see table 3)

Table 3 | Activity Data & Emissions Summary

Sr No	Parameter	Activity	Data	Unit	GHG Emissions (Tonnes CO_2e)
1	Inter City Travel	Domestic Air Travel-Short Haul	**475**	Pass-kms	**0.1**
		Domestic Air Travel-Long Haul	**40,641**	Pass-kms	**4.2**
		Bus Travel-Intercity	**4,033**	Pass-kms	**0.1**
		Train Travel-Intercity	**21,938**	Pass-kms	**0.3**
2	Accomodation	4-star hotel in Hot & Dry region	**20**	Overnight stay	**2.2**
		3-star hotel in Hot & Dry region	**17**	Overnight stay	**1.4**
		3-star hotel in Warm & Humid Region	**44**	Overnight stay	**2.8**
		3-star hotel in Temperate Region	**14**	Overnight stay	**0.6**
3	City Travel	Car/Taxi Travel-City	**93,024**	Rupees	**1.4**
				TOTAL	**12.9**

6.3 Offset strategy

The ACIP plans to offset our emissions by partnering with Afforestation to plant '*Miyawaki*' style plantings. This rapid forest growth method works according to the principle of '*Potential Natural Vegetation*' and involves planting of native specifies in high density grids of 300 trees per 100 sq.m. It is estimated that this method could sequester approximately 7,500 tonnes of CO2/hectare during an assumed lifespan of 25 years.

7 Policy Recommendations

In compliance to the COP22 agreement, India has committed to bring about a 33-35% reduction in greenhouse gas emissions by the year 2030. This policy is now in preparation to implement this nationally adopted goal. In addition to this target, the Government of India (GoI) launched the '*Smart Cities Mission*' in July 2015, that is an urban renewal and retrofitting program to make cities across India, equipped with improved infrastructure and citizen friendly facilities, aiming to make them greatly sustainable. A total of 100 cities across all states of India have been identified to be developed into smart cities representing the identified smart features[1].

Furthermore, set up in 2007 by the Bureau of Energy Efficiency (BEE), the Energy Conservation Building Code was established by the GoI, in order to set minimum energy saving standards for new commercial buildings. 22 states across India, where a majority of building construction activities are occurring are already in the process of mandating this code. Uttar Pradesh, Kerala, Chhattisgarh, Gujarat, Bihar, Tamil Nadu, Haryana, Maharashtra and West Bengal are a few states that have currently mandated this code and are making amends to let it suit their regional and local climatic condition.[2] However, adopting building codes and legislation without enabling the workforce to put these codes into practice will fail to deliver results. The know-how gap in India's workforce is to be bridged by upgrading education. The purpose of this Policy recommendation file is to facilitate this.

Additionally, the Skill Development Mission of India aims to "*rapidly scale up skill development efforts through an end-to-end, outcome-focused implementation framework, which aligns demands of the employers for a well-trained skilled workforce with the aspirations of Indian citizens for sustainable livelihoods*." In order to achieve this, the mission aims "*to develop a network of highly skilled instructors, through the establishment of teacher training institutions and set up high-grade options for durable skilling to contribute to the creation of a highly skilled workforce*". [3] Organizations such as the All India Council of Technical Education, AICTE and Council of Architecture, CoA are currently conducting teacher training programs in India, to build and develop their skills across several aspects of pedagogy and architecture[4]. Moreover, the National Educational Policy formulated in 2016 states that prescribed text books should not be the only source of knowledge easily available to teachers and students. *"Examinations should be designed to test wider awareness, understanding and comprehension, and not merely ability to reproduce text book script. Curriculum should be broad based and aim for overall development of students in an increasingly technology driven environment."*[5]

[1] Ministry of Urban Development -http://smartcities.gov.in/writereaddata/SmartCityGuidelines.pdf
[2] ECBC - http://smartcities.gov.in/writereaddata/SmartCityGuidelines.pdf
[3] Ministry of Skill Development and Entrepreneurship – www.skilldevelopment.gov.in
[4] NIASA - http://www.niasa.org/new2/training-programs.aspx
[5] National Policy on Education 2016 – http://nuepa.org/New/download/NEP2016/ReportNEP.pdf

Finally, India's building sector is expected to grow four to five times its current size, thereby increasing the energy demand and emissions, implying that the cooling and refrigeration sectors would be two of the main drivers of energy demand. It is further identified with regret that the developers today are still highly dependent on air conditioning to reach indoor thermal comfort, which would increase the number of energy inefficient buildings. However, switching to sustainable cooling technologies, in the residential and commercial sector only, would save up to 60 GW of energy savings by 2030, thereby avoiding the construction of over 100 medium size coal power plants. Furthermore, this would save the emission of 3 major GHGs in the atmosphere (carbon dioxide, sulphur dioxide and nitrogen oxide) to a large extent.

Mainstreaming natural refrigerants and sustainable cooling technologies would further give way to opportunities in the refrigeration and air-conditioning industry and further address and align with the aforementioned policies. This would include research and development of energy efficient technologies, manufacturing of equipment, HVACR consulting, project management, and several support and maintenance services. The availability and easy accessibility of these technologies would further help in mitigating climate change, as well as reducing energy demand and increasing employability in this field.

Recommendations

1. Post identification of existing sustainability infused curricula gaps, the Ministry of Human Resource Development (MoHRD) and the Centre for Environment Education (CEE) are to be engaged to revise architecture and engineering college curricula, through inclusion of energy efficient buildings designing principles (architecture faculties) and the inclusion of sustainable cooling technologies (engineering faculties) and building energy modelling, along with complying with ECBC, to ensure energy efficient buildings are designed, with the aim to build capacity among the young builders. Furthermore, educational bodies such as Council of Architecture (COA) and CEE would need to monitor and evaluate this implementation, as capacity building needs to materialize on a national scale, if we are to successfully meet the agreement of reducing emissions by 33-35% by 2030, in order to mitigate global climate change.
2. Working with the Skill Development India mission and the Council of Architecture, to organize and conduct targeted teacher training programs, so as to train professors across architecture colleges and engineering students on energy efficiency through sustainable cooling technologies and passive design strategies. Capacity building is essential if India is to build thoughtfully cooled buildings in future, and to retrofit existing ones as well. To help develop these training of trainer institutions and ensure smooth capacity building, financial support to enable and further research on pedagogy and andragogy techniques, development and building of teaching aids, and execution of

capacity building programmes is required by University Grants Commission (UGC), Indian Society of Heating Refrigeration and Airconditioning Engineering (ISHRAE), and The Alliance for an Energy Efficient Economy (AEEE).

3. Revamping the education system by modifying the system of delivering knowledge, probing to ensure teachers focus on enabling critical thinkers, instead of encouraging rote-learning. Students not only need to understand the concepts but be critically empowered with knowledge on sustainable cooling to be able to question and apply the same in real world scenarios. This can be achieved in compliance with the recommendations presented by the National Educational Policy, 2016, through altering the delivery and evaluation processes, along with support from the Ministry of Human Resource Development and Centre for Environment Education (CEE), Ministry of Environment and Forestry and Climate Change (MoEFCC).
4. Establishing international knowledge exchange networks, to devise a platform of effective communication between professors in Indian universities and abroad. This would promote exchange of best practices, thereby strengthening capacity building and skill development. Furthermore, once established, these networks could be used by students to engage with skilled practitioners abroad, providing them scope for overseas employment and promoting sustainable livelihoods. This is to be facilitated by identifying government not-for-profit organizations, working in collaboration with colleges/universities.
5. Developing a structured roadmap for the integration of sustainability within architecture and engineering curricula to assist in a smooth transition within the next 5 years. Creating this roadmap could be devised through a collaborative effort from governmental and non-governmental organisations. Additionally, the steering committee would be required to monitor and evaluate the integration of the reworked curricula. Steering committee to include various stakeholders such as: architects, engineers, sustainability consultants, industry experts from the sustainable cooling technologies sector, HVACR experts, researchers in pedagogy, and organizations such as AICTE, COA, ISHRAE, AEEE, CEE etc.

8 Outlook & Objectives for ACIP Phase II

The ACIP seeks to accomplish seamless syllabus integration of sustainability and energy efficiency into official University-defined curricula by mainstreaming the three principles below into the academic curricula of architecture and mechanical engineering educational institutions:

- Energy efficient building design
- Sustainable cooling technologies
- Building energy code

8.1 Proposed Objectives for Phase II

8.1.1 Improved Tech-Support

- Deep '*Building Science and Sustainable Cooling Technology*' capacity building
- Enhanced '*sustainable cooling educator's kit*'
- Deep '*Curricula Integration*' in Architecture Colleges

8.1.2 Administrative-Fluency

- Formal support from national capacity building, regulatory bodies that prevail in architecture academia.
- Formal support, knowledge-partnerships with eminent architecture academic institutions in other nations.

8.2 Proposed Work Plan

8.2.1 Objective: Improved Tech Support

- An eminent partner architecture college, most suited for the pilot integration will be identified in each selected city, that is renowned for its progressive teaching methods and vibrant faculty. These institutions will be deemed/renewed as 'HUB Colleges'. Colleges in selected city sign/renew a MoU to affirm their intent to support curricula upgrading through efforts by trained professors' post-conclusion of workshops.

  The ACIP team will execute deep *'Building Science and Sustainable Cooling Technology*' capacity building: 4/5-day (4 cities, 1 workshop per city) deep-dive workshops that would primarily cater to Architecture Professors teaching '*Technical*' subjects for lecture support-mechanism. The college steering committee will identify

most suited professors, who will participate in the deep-dive workshop. Professors from other partner colleges would be invited to be a part of the workshop to maximise curricula integration.

This *deep-dive* workshop will include extensive training sessions that empower, guide, and provide technical actionable-knowledge to professors to seamlessly deliver and subsequently be empowered to embed syllabus-content related to sustainable cooling strategies across courses covering seven core themes: climatology, building materials, building technologies, structural design, and building services.

The workshop will be a 4/5-day journey for professors that starts with extensive training on fundamentals of building physics such as: heat transfer, psychrometry, adaptive thermal comfort, passive cooling design strategies, climate analysis, and solar geometry, followed by sustainable cooling technologies/techniques such as Structure Cooling, Radiant Cooling, Evaporative Cooling, and Natural Refrigerants where in principles behind the working of these technologies along with their applications are discussed.

Finally, the workshop would conclude with sharing relevant best practices in integrating sustainability within curricula, discusses engaging teaching aids (physical models, software tools, testing and evaluation aids), and empowering participants with hands-on syllabus modification to imbibe sustainability within the core of their teaching. The workshop will also enhance pedagogy skills and impart techniques for sustainability-integration in technical courses.

Over 12 months, 4 deep-dive '*Building Science and Sustainable Cooling Technology*' workshops will be conducted along with 2 semi-annual workshops across the 4 selected cities - which will catalyse architecture curricula integration within 4 institutes across India.

- Development of enhanced '*sustainable cooling educator's kit*' with augmented set of Physical and Virtual Aids: Commissioning creation of complete set of scale models for passive and active cooling strategies and associated DIY-manual for each program city; including scale models of sustainable cooling technology equipment such as Structure/Radiant Cooling Systems and Indirect Evaporative Cooling.

- To mainstream sustainable cooling technology modelling in Engineering Education, the SmartEnergy Tool will be upgraded by funding and managing process of software development to enhance the basic Heat-Load-Simulation tool to include scenario modelling for commercially available sustainable cooling technologies.

- The engineering academic intervention (workshops) will be distinguished from the architectural intervention in one primary manner. Instead of training trainers (professors), the program will continue to directly train mechanical and civil engineering students through this five-day certification workshops.

  Similar to the architectural intervention, the HUB and partner college approach is followed, but the primary stakeholders in this process are students, and not professors. The rationale for continuing to adopt this distinctly different approach is that Mechanical and Civil Engineering students are presented with multiple professional options beyond HVAC Engineering or Building Construction. Registration for these training courses will, therefore, be only open to third/final year engineering students across the selected cities who are largely certain about pursuing a career in HVAC engineering or building construction technologies.

  Participating engineering colleges can get involved by signing a Memorandum of Understanding (MoU) to affirm their intent enhance Mechanical/Civil Engineering course content related to Building Technologies, HVAC systems to embed principles of Building Physics, Building Energy Efficiency, Building Energy Simulation, Passive Cooling Techniques, and Sustainable Cooling Technologies.

  At the certification workshop, a rigorous hands-on training will be given to students to enable mastery of heat-load calculation and sustainable HVAC system modeling software. Post successful completion of evaluations and procurement of a certificate, students and their colleges are given one-year free licenses for using these tools developed by the Indian Society of Heating Refrigeration and Air Conditioning Engineers (ISHRAE).

  Over 12 months, 4 certification workshops will be conducted for at least 160 students from 8 colleges across the selected cities in India.

- The ACIP team will identify, establish and renew partnerships with architecture and engineering colleges for participation in the programme. To outline the partnership agreement, the ACIP will sign a Memorandum of Understanding (MoU) with (not limited to) 4 architecture institutes and 8 engineering institutes within the 12-month life-span of this project.

  For a detailed understanding of the partnership agreement with these institutes, please view the ACIP MoU as Appendix H.

- Executing Deep '*Curricula Integration*' in Architecture and Engineering Colleges: Pilot curricula-integration workshops, monitoring, and evaluation for 3 courses in at least

4 of the most activated and progressive architecture colleges identified from Phase 1 and 1 course (RAC) in at least 4 engineering colleges will be addressed through student certification workshops in Phase II.

- Half day follow-up workshops will be conducted across selected cities with partner colleges. The aim is to bring to the fore, innovative and experiential teaching practices specifically in the sustainable cooling sector.
- The ACIP team will assist partner colleges to develop lesson plans towards integration of sustainability within the curricula across 1 humanities, 1 design, and 1 technical subject as a pilot for one semester.
- A College Resource Kit (CRK) will be devised, that would include (not limited to):
    - Sustainability Handbook - This handbook would be a compilation of key concepts across existing subjects that can be used to get a better understanding of sustainable cooling techniques and technologies. This is not an exhaustive document and is to be used as only as a guide to comprehend the purpose of '*Thoughtful Cooling*' towards the '*Syllabus Renaissance*' exercise. The handbook would serve to be a repository of sustainability and energy efficiency fundamentals that could be delivered through a combination of recommended methods, tools and systems of learning (associative, experiential, etc.)
    - Training modules delivered during workshops
    - Other resources (videos, software's, articles, journals, Case studies, etc.)
    - Concept textbook
    - Trainer database
    - Physical teaching aids kit, which includes:
        - A Do-It-Yourself (DIY) kit that professors can use to replicate across their respective course delivery
        - A booklet/manual supporting the usage of these tools
        - A design assignment/test paper that will be used to understand the level of impact and understanding achieved by teachers post a ToT
        - Setup climatology labs across all Hub colleges (all 6 cities)

- Monitoring Curricula Integration
    - A tracker will be developed to monitor deliverables that the lesson plans would encompass for each of the three selected subjects, across all colleges.
    - Monthly review with each college to monitor the progress, and to address issues.
    - Semi-annual workshops to discuss and troubleshoot issues during pilot integration of sustainability and to further the scope of integration.

- Evaluating Curricula Integration
    - Framework (a formal assessment test and descriptive feedback form) to evaluate baseline 'capacity' amongst the test group and control groups will be developed; this framework will build on prior work already undertaken in other academic institutions across the globe and will avoid re-inventing 'capacity measurement' methodologies for surveying wherever possible.
    - Concurrently, a post-intervention assessment framework will be developed. The assessment will evaluate the test and control group group on their knowledge on the concepts being addressed in the lesson plans. While the pre-assessment evaluation is conducted at the start of the session / semester, the post-assessment is conducted prior to the final exams.
    - The pre/post evaluations would be analysed to highlight the effectiveness of the different methods of teaching, systems of learning, etc. against the sustainability concepts being addressed in the lesson plan for the respective subjects.
    - The feedback provided to the control group would be analyzed to understand the impact of the delivery methods and the new sustainability infused lesson plan
    - The analysis would help ACIP identify and bridge the gaps within the current process and plans.
- A descriptive feedback process will be administered to ascertain the impact of delivery methods and the upgraded content of the revised lesson plans. It will further identify gaps that will need to be addressed towards the implemented final integration strategy for phase 2.

8.2.2 Objective: Administrative-Fluency

Formal support from national capacity building, regulatory bodies that prevail in architecture academic:

- AICTE's Architecture Board (reconstituted in May 2016) will be propositioned, Door-opening strategy for NIASA, COA, IGBC will be re-evaluated and revised efforts will be undertaken through direct involvement with door-openers in the Advisory Board.
- Blending Engineering Student Certificate Program with activities of ISHRAE / IGBC Student Chapter's training activities.
- Academic Institutions in other countries with similar climate, indoor cooling challenges, and architectural contexts as India, and known for their academic pedigree in Architecture colleges, will be engaged with to develop formal knowledge-sharing partnerships through joint video-conference-linked workshop modules, mutual-recognition of certificates awarded, collaborative design projects and studios, and possibly student-exchange programs.

8.2.3 Objective: Ecosystem Integration

- Development of a Sustainable Cooling related '*Talent and Knowledge*' Freemarket technology and human-engagement platform to intensify ecosystem interactions and breed organic connectivity amongst the sustainable cooling ecosystem to enhance quality of architecture and engineering education.
- Promote '*vertically*' integrated design-studios through curricula change in Architecture colleges
- Create local-sustainable-architect network for each city, get colleges to formalize process of including local practicing architects as mentors for design studios based on real-world sustainable design briefs.

8.3 Project Activities and Responsibilities

8.3.1 Strengthen partnerships and operational framework at the institutional level

- Re-establish communication with architectural and engineering colleges engaged in Phase I of the project in the lead-up to city-specific engagements
- Formalize partnerships with 1 flagship/anchor Engineering and Architecture college by signing of MoUs reflecting deep-curricula integration processes that will commence post execution of kick-off workshops
- Establish College-level Steering Committees (CSCs) in colleges so identified as partners to look over project activities and monitor its progress

8.3.2 Develop training framework and conduct site visits

- Develop enhanced '*sustainable cooling educator's kit*' with augmented set of Physical and Virtual Aids. Provide free user licenses to participating institutions and students.
- Develop deep-dive Trainers for ToT (Training of Trainers) workshop module and finalize list of trainers and drawing from the cBalance pool of national resource persons (technical experts), advisory board members in addition to local experts identified in Phase 1.
- Execute and ensure smooth conduct of activities such as administration operations, hospitality & infrastructure management, training module implementation and training feedback module implementation, identified in Standard-Operating-Procedures (SOPs) developed in Phase 1
- Identify, engage with, and finalize execution of sustainable-technology demonstration site-visits with partners
- Identify, engage with, and finalize execution of sustainable-technology demonstration site-visits with partners

8.3.3 Develop curricula integration roadmap

- Collaborate with CSC to develop curricula integration roadmap (timelines, roles and responsibilities)
- Select pilot curricula-integration courses and conduct curricula-change design and planning sessions through web-meetings and in person group work-sessions

8.3.4 Post intervention activities

- Conduct post-intervention monitoring and evaluation activities.
- Document intervention activities and write progress reports for stakeholder communication

8.3.5 Key Support Activities

- Project Management for SmartEnergy Tool Upgrade.
- Project Management and execution for Sustainable Cooling 'Talent-and-Knowledge' Platform creation and maintenance.