INITIATIVE TO PROMOTE HABITAT ENERGY EFFICIENCY (I-PHEE)

(Clean Energy Research Initiative)

Department of Science & Technology
Government of India

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CONTENT

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PREAMBLE

Built habitat are seen as places of action on sustainable environment and climate change. India is one of the nations with an energy demand of 95.121 Billion kWh for sustaining its habitat. Globally, energy demand reduction and energy efficiency are recognized as the most effective interventions to meet the 2050 greenhouse gas reduction target, to mitigate climate change. Reducing energy demand also makes access to clean energy more affordable and improves energy security, thereby addressing all three aspects of the energy trilemma. The energy use building sector has almost doubled since the year 2000. Data from India Energy Outlook points that this energy demand will at the rate of 10% annually for the next 15 years. Though there has been commendable progress in the research on energy efficiency by various institutions, India's energy demand-supply gap and climate change remain a challenge. Concerned about the above factors, the Hon'ble Prime Minister tasked the Department of Science and Technology to form a committee to bring together a team of industry, environmental, and scientific leaders to develop deployable technologies to achieve environmental sustainability affordably. DST is hence leading the effort to deliver technologies and solutions towards habitat sustainability. DST is committed to our honorable Prime Minister's vision of accelerating the transformation of India's energy system to one that is smarter, cleaner, affordable and greener. To that end, DST has put in place some initiatives to work towards creating a more environmentally sustainable society. Our goal is to deliver clean energy technologies for the benefits of the world in the shortest possible time. DST is investing deeply in research and development across India to deliver this goal. DST took the responsibility to create an energy independent and sustainable India. DST created the *clean energy research initiative program* designed to save money, reduce energy use and safeguard the environment. The Clean Energy Research Initiative (CERI) hosts leading researchers who see this challenge as an opportunity to help future generations inherit a better world.

DST under 'Clean Energy Initiative' plans have established a program to support research and development in the area of habitat energy efficiency. The program is focused on improving the energy performance of buildings and cities. The program is geared to support the enhancement of knowledge and practice to save energy in design, construction, and operation of human habitat. We have continued to provide a platform to thousands of Indian academicians, scientists and researchers to benefit through our manifold programs and accelerate the development of all those great ideas into broadly accessible technology solutions. Our researchers are working closely with governments, industry and community groups to foster clean growth and low-carbon economic development. Providing safe, widespread, and equitable access to clean energy is one of the key challenges of our time. The DST has played a significant role in accelerating the transition to affordable, accessible and clean energy. The clean energy research initiative program is to promoted original, innovative ideas and superior research in the area of solar energy and building energy efficiency for new/improved energy materials, processes, devices, sub-systems, and systems. Hon'ble Minister, Science & Technology, and Earth Sciences pledged to double Government funded clean energy research and development over five years and enhance international engagement in programs on clean energy R&D.

One of the thrust areas under the CERI is Habitat Energy Efficiency; it is focused towards achieving self-sustainable habitats. DST floated a call for research proposals under the title "INITIATIVE TO PROMOTE HABITAT ENERGY EFFICIENCY (I-PHEE) in the year 2016. DST's priority is to support interdisciplinary research which is novel, transformative and eventually scalable and affordable. The Program is also geared to support the enhancement of knowledge and practice to save energy in design, construction, and operation of human habitats. Broad sub-themes of this program were designed based on extensive field visits and consultations with field officials, stakeholder consultation, and others, to ensure that they would indeed result in improved outcome based on the national needs. We have increasingly devoted our energies in developing a field deployment ready research outcome. Having established a strong reputation for the quality of research, we were keen to abstract projects that found practical solutions, whether within India or outside. We know the journey of capacity building is not always easy, but it is necessary if we are to fulfill our vision of "a world where everyone has a decent place to live." DST is fully committed to our aspiration to be a force for growth and prosperity in the communities where we live and serve.

DST received an overwhelming response from the academic research community, and a total of 115 proposals. Based on preliminary screening, detailed reviews and presentations by the research teams, thirty projects were approved for financial support under this program across the country. The financial outlay of I-PHEE is Rs.30.64 crore. The core essence of the program is that they work towards developing innovative solutions that are accessible, affordable and adaptable, meet the needs of the people of the country and benefit the world at large. The accepted proposals focused on translation research, converting existing knowledge or theory into design, processes or products. We envision that the outcomes of these projects will light up the sky by the year 2020. We bring together a summary of on-going research activities under the I-PHEE.

1. COMPARATIVE APPRAISAL OF THERMAL PERFORMANCE OF TRADITIONAL (ASSAM/IKRA TYPE) AND EMERGING HOUSING TYPOLOGIES AND UPGRADATION OF TRADITIONAL PROTOTYPES FOR IMPROVED THERMAL BEHAVIOUR IN DIFFERENT SUB-CLIMATIC ZONES OF NORTHEASTERN INDIA

Principal investigator: Souvanic Roy
Indian Institute of Engineering Science and Technology (IIEST), Shibpur

Background of Project

Climate, culture and materials and technology availability are the prime factors that greatly influence the buildings in a region and its sustainability. Since, climate varies from place to place, favourable design and technological solutions for the built environment are also region specific. Traditional construction in the north-eastern region consists mostly of typical bamboo houses, known locally as 'Ikra', and also known as Assam-type housing. These housing typologies are common throughout Northeast India with certain local variations depending on climate, altitude and material culture. Majority of such houses are used for residential purposes. Typically these houses are built with lightweight locally available material like bamboos, wooden planks, thatch etc. Review of national and international research reveals the need to develop a methodology for comparative evaluation of thermal performance and energy efficiency of small/ moderate size (500 to 750 sq ft.) non-engineered traditional/vernacular (Assam or Ikra Type) housing typologies constructed with local materials (bamboo, cane, wood, mud, brick/stone or composite and intermediate materials) using semi and unskilled construction techniques and emerging housing typologies using standard design criteria and modern materials (brick, concrete, glass etc.) in 3 sub-climatic zones of Northeastern India.

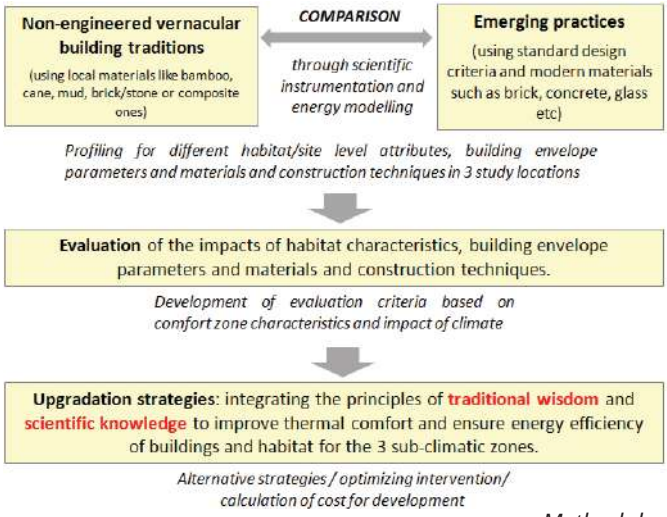
Aim

The research compares the thermal behaviour and energy performance of non-engineered vernacular building traditions (using local materials like bamboo, cane, mud, brick/stone or composite ones) and emerging building practices (using standard design criteria and modern materials such as brick, concrete, glass etc) in 3 predominant sub-climate zones of Northeastern India through scientific instrumentation and energy modeling and evaluates the impacts of habitat characteristics, building envelope parameters and materials and construction techniques. The research will suggest upgradation strategies for habitat/site level characteristics, building envelope specific design parameters and materials and construction techniques to achieve improved thermal performance and enhanced energy efficiency (embodied and operational) for traditional housing typologies and building practices for the 3 sub-climatic zones of Northeastern India. The research suggested a systems approach towards design and technology upgradation for small/moderate size traditional housing units to facilitate thermal comfort and energy conservation using locally available resource and materials with due consideration for the shortcomings of the prevalent approaches and scopes for possible improvements.

Methodology

The research will comprise of following steps:

a. **Literature review, procurement of equipments and appointment of manpower:** Literature review will facilitate refinement of research problem, methodology for evaluation of thermal performance and selection of energy simulation software based on the possible nature of data available for the project.
b. **Finalization of study areas and selection of outsourcing agency:** The study will be conducted in 3 sub-climatic zones namely Agartala (warm and humid), Jorhat (cool and humid) and Shillong (cold and cloudy). Selection of vernacular housing clusters (Assam or Ikra type) in 3 locations will be done based on field visits.
c. **Data collection:** Data will be collected in the selected housing typologies by installing sensors for recording temperature, humidity, wind velocity and intensity of day lighting. External climatic data will be collected from respective meteorological stations.



Methodology and mechanism

d. **Data Processing and Analysis:** Data collected shall be processed and analysed to assess thermal comfort levels of traditional and emerging housing typologies for 3 locations in comparison to acceptable comfort conditions defined by Corrected Effective Temperature (CET) values. This will be examined by using tools like Psychrometric Charts and ET (Effective Temperature) Nomogram. Appropriate energy modeling software (VE/ VE-Pro, Urbawind/Meteodyn) will be used to assess the performance of the building envelopes, habitat characteristics and prevalent materials and construction techniques in terms of energy consumption for heating, ventilation and space cooling.
e. **Design and Technology Upgradation for 3 sub-climatic zones:** Upgraded design and technology options for thermally comfortable and energy efficient housing prototypes and habitat/site characteristics for 3 locations based on energy modeling/simulation and study of good practices in similar contexts.

Expected Outcomes & Deliverables

a. **New/Upgraded Product:** Upgraded design and technology prototypes for location specific, thermally comfortable and energy efficient version of traditional housing typology for 3 sub-climate zones of Northeastern India in the range of 500 sqft. to 750 sqft. for urban/semi-urban locations.
b. **New/Upscaled Process:** Process of design and technology development for upgraded traditional housing prototypes is based on performance assessment of vernacular typologies through climatologically sensors, application of energy modeling software and adaptation of local materials and construction techniques
c. **New/Upgraded System:** Systems approach towards design and technology upgradation for small/moderate size traditional housing units to facilitate thermal comfort and energy conservation using locally available resource and materials.

d. **Performance Analysis:** Comparative performance appraisal of traditional Assam or Ikra type and modern housing typology in terms of thermal comfort and energy efficiency.
e. **Database Development and Documentation:** Bridges the knowledge gap about the link between habitat characteristics and features of building envelope and materials and construction techniques with thermal performance and energy consumption.
f. **Proof of new concepts at a device level:** Modification of existing concepts of simulation of different parameters (temperature, humidity and wind speed) related to thermal comfort and energy consumption based on nature and complexity of data collected through fieldwork.

About Institute & Previous Projects

The research group belongs to the Department of Architecture, Town and Regional Planning in Indian Institute of Engineering Science and Technology (IIEST), Shibpur, West Bengal. The group has an established legacy of applied research in the areas of climate responsiveness and energy efficiency in architecture and application of alternative technology in housing and architecture. PI with his research team conducted several sponsored research and consultancy projects on climate responsive, energy efficient, passive solar and green concept integrated residential, low income rural and urban housing and public building design projects.

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2. DESIGN AND DEVELOPMENT OF SOLAR AND AGRICULTURAL WASTE-BASED BUILDING COOLING SYSTEM

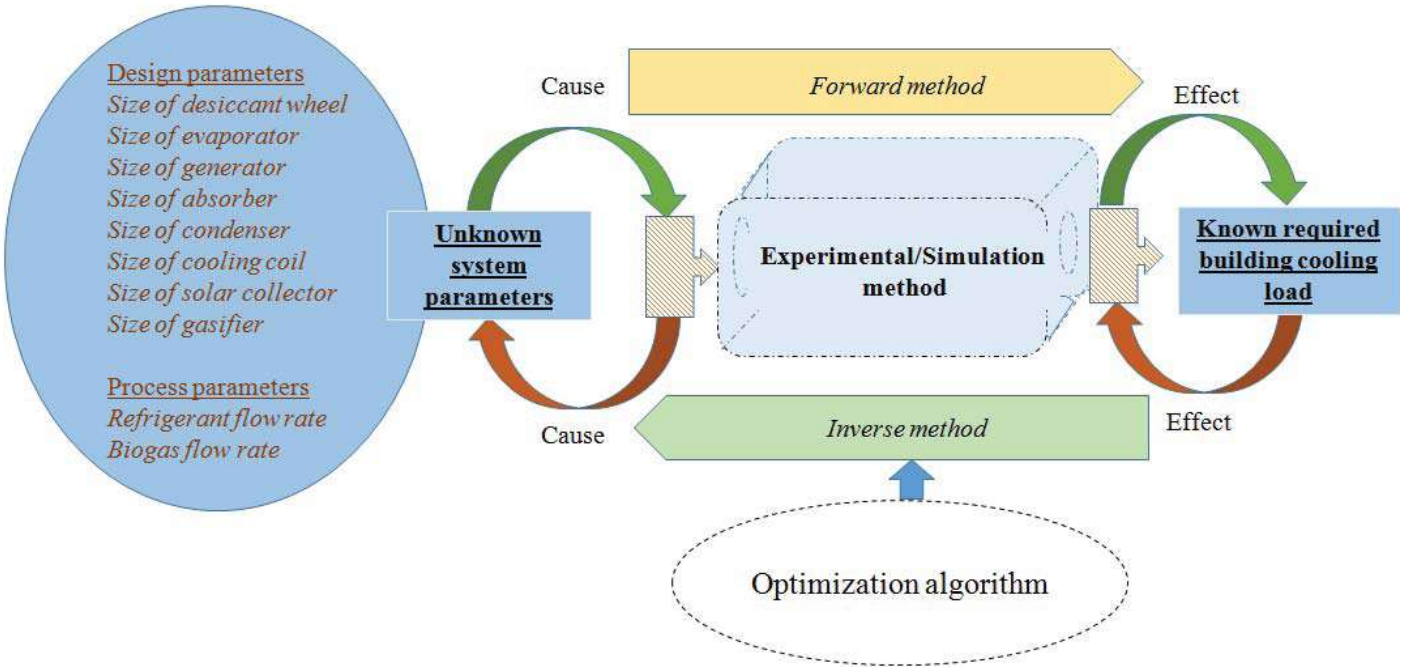
Principal investigator: Ranjan Das
Indian Institute of Technology Ropar

Background of Project

Since India is one of the leading developing nations in the world, so its air conditioning requirements are increasing day by day. At present, most of the energy for building cooling in India is obtained from coal-based thermal power plants, which is gradually escalating the pollution content. Therefore, considering the increasing energy demands of cooling and significant pollution, the need of an air-conditioning system arises that works on the energy extracted from renewable energy resources. The present building cooling system is based on the principle of vapour absorption system involving suitable desiccant that is powered by utilizing the energy supplied by solar collector and agriculture waste. The agricultural waste will be gasified in a gasifier to reduce the emission of SO2 and NOx. Considering the variation of cooling load depending upon the application, a building cooling system (between 1 ton to 3 tons of refrigeration), the optimum sizing of the system components shall be decided on the basis of building size and heat loads. Thereafter, a general model will be required that can be used to decide the size of individual components that enables the designer to decide the optimum size of individual component in order to meet diverse building cooling applications. Based on the final design of the air-conditioner, the actual prototype of the system will be fabricated. Finally, the experimental validation of the optimized model will be performed for a given building cooling load using actual installation in line with residential/small commercial loads.

Aim

- Investigation of hybrid renewable energy-based building cooling systems operating on vapour absorption system to identify their potential to work with solar collector and agriculture waste (particularly paddy/wheat straw) for domestic air-conditioning applications (between 1 ton to 3 tons). The usage of agricultural waste-derived gasifier also addresses the problem of paddy /wheat straw burning issue presently practiced in the northern India.
- Based upon the feasibility study, design and develop the optimized building cooling system operated with solar collector and agriculture waste.
- Comparison of designed air-conditioning system with conventional and different thermal building cooling systems based upon the performance, emissions and cost.
- Experimentally investigate the performance, emission and cost characteristics of designed air-conditioning system under varying cooling load and environmental conditions.
- Formulation of general inverse optimization-based model to decide the optimum size of different components of the designed air-conditioner for diverse cooling load requirements/applications (1 ton to 3 tons).
- Using fins under wet condition to improve the heat transfer rate from the space to be cooled, thereby reducing the energy requirement.
- Experimental validation of optimized air-conditioning system design obtained using inverse model in order to meet the given cooling requirement.
- Possible commercialization of the proposed building cooling/air-conditioning system powered by solar collector and agricultural waste derived gasifier would lead to significant energy saving and environmental impact.

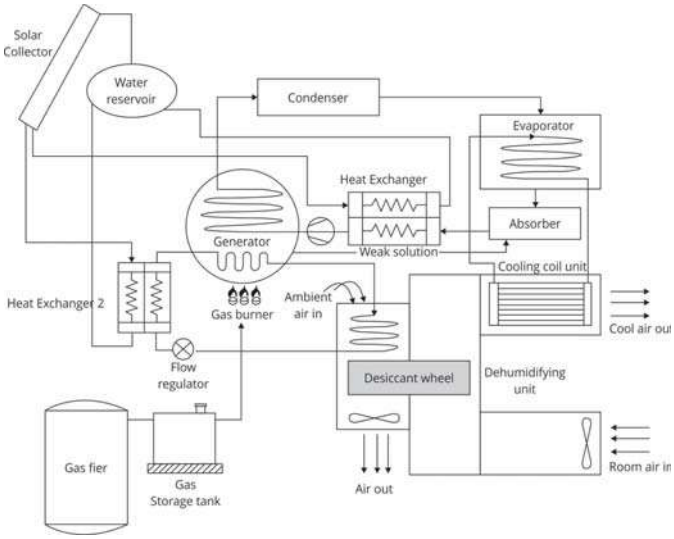


Methodology

This project involves the design and development of hybrid renewable energy-based vapour absorption cooling system powered by solar collector and agricultural waste-based biogas. The cooling system to be designed will involve generator, condenser, evaporator, absorber, heat exchangers and cooling coil unit where the dehumidification of the air is carried out by a desiccant wheel. The use of gasifier makes the process efficient and eco-friendly due to less emission of harmful gases like SO2 and NOx. Then, the comparison of designed optimized air-conditioning system with existing ones will be carried out for diverse building cooling applications using numerical simulation. The basis of comparison will be performance, emission and cost. After obtaining the final design of the air-conditioner, the actual prototype of the system will be fabricated. The experimental investigations on the fabricated system will be done under actual cooling conditions for diverse building cooling applications (Range 1 ton to 3 tons). All experimental data will be acquired by using Labview based data acquisition system (DAQ). Emissions data will be measured by emissions analyser. Finally, the experimental validation of the optimized model will be performed for a given building cooling load (using actual installation in line with residential/small commercial load).

Expected Outcomes & Deliverables

This project deals with the design and development of hybrid renewable energy-based building cooling system operated by solar collector and biogas that is aimed at addressing the problem of paddy /wheat straw burning issue practiced in the northern India. The energy from agricultural stubble and solar collector will be utilized in a vapour absorption-based air-conditioning system. The system will meet a cooling load between 1 ton to 3 tons. The deliverables have been itemized below,



Schematic of proposed design of hybrid air-conditioning system

- A renewable energy-based hybrid building cooling (air-conditioning) system utilizing energy from agriculture waste and solar collector to tackle the problem of paddy and wheat straw disposal which is particularly increasing the pollution in the north India.
- Optimized design of air-conditioning system operated with agriculture waste and solar collector supplied energy to decide the optimum size of each component based upon the given building heat load requirement.
- Performance, emission and cost analysis of the presently-proposed vapour absorption will be carried out against the conventional vapour compression-based air conditioning system.
- Possible commercialization of the air-conditioning system would lead to significant energy saving and environmental impact. Further, the proposed cooling system will reduce the dependency on conventional grids.

About Institute & Previous Projects

Indian Institute of Technology, Ropar is one of the eight new IITs set up by the Ministry of Human Resource Development (MHRD), Government of India, to expand the reach and enhance the quality of technical education in the country. This institute is committed to providing state-of-the-art technical education in a variety of fields and also for facilitating transmission of knowledge in keeping with latest developments in pedagogy.

1. Inverse Analysis and Unknown Parameter Estimation in Natural and Forced Draught Cooling Towers. (Funded by: IIT Ropar): This project used forced and induced draught cooling towers to experimentally study heat transfer characteristics and developing new correlations.

2. Design and Development of a Solar Pond and Biomass Driven Thermoelectric Unit for Domestic Power Generation using Inverse Method. (Submitted to SERB-DST): This project aims at generating electricity through thermo-electric power derived from solar pond and biomass for meeting a household requirement. A series of thermo-electric cells powered by solar pond driven thermo-syphon will be used.

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3. DEVELOPING ALKALI-ACTIVATED LOW CARBON BRICKS USING CONSTRUCTION AND DEMOLITION WASTES FOR ENERGY EFFICIENT WALLING ENVELOPES

Principal investigator: B. V. Venkatarama Reddy
Indian Institute of Science Bangalore

Background of Project

Bulk of the buildings in India use masonry walls for the external building envelope. Burnt clay bricks, concrete blocks and natural stones represent some of the commonly used materials for the masonry wall construction. Soil (clay), aggregates (coarse and fine), Portland cement and lime form the basic raw materials for the manufacture of walling materials apart from the energy expenditure.

The literature reveals that there are varieties of non-organic solid wastes and are produced due to industrial and mining activities in considerable quantities in India and elsewhere. There are attempts to derive construction products from C&D wastes. Majority of the investigations on C&D wastes attempted to recycle the coarse aggregates in concrete. There are limited investigations in utilising the C&D wastes for the production of masonry units such as bricks and blocks.

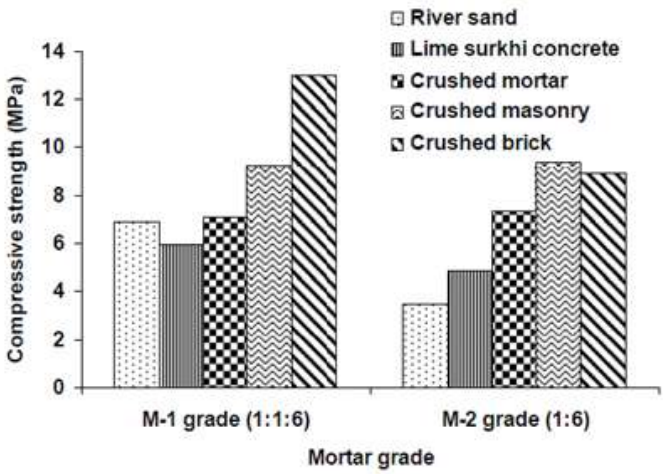
There is a need for Low-C bricks and utilising non-organic solid wastes. This will also mitigate the shortage of mined raw materials being used for the production of construction materials. Finding alternative solutions for the production of masonry units without firing and without using OPC is essential for sustainable construction practices. Developing technologies utilising C&D wastes for the production of masonry units through alkali activation of pozzolana binders and geopolymer route are the technical challenges.

One part of the proposed R & D is to develop and standardise the production of masonry units using C&D wastes, GGBS, lime and geopolymers. Further on characterising the properties of cement free bricks/blocks, understanding the structural behaviour of masonry using such units, and examining the thermal characteristics and thermal performance.

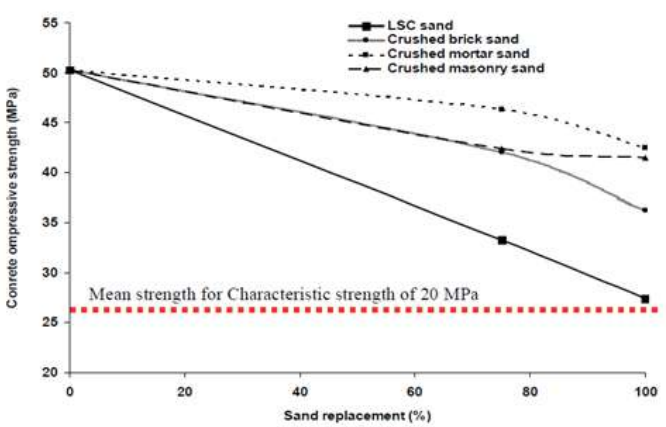
Aim

The main objective of the project is developing processes for the manufacture of Low-C bricks from C&D wastes (without firing and without using OPC) and characterising the structural, durability and thermal properties of Low-C bricks and their walls. The specific objectives are as follows.

a. Developing low embodied carbon (Low-C) bricks from C&D wastes through alkali activation process using fly ash and GGBS
b. Characterising structural and durability characteristics of Low-C bricks and their masonry
c. Evaluating the thermal characteristics of Low-C bricks and walling systems
d. Analysis of energy and embodied carbon in Low-C brick walling systems



28 day compressive strength of mortars with different types of fine aggregates



Strength versus sand replacement by C&D crushed sand for concrete

Methodology

Heterogeneous mixture of C&D wastes will be crushed using a jaw crusher and will be passed through 10 mm mesh. The crushed materials will be used in the experiments and for the preparation of bricks.

Grain size distribution, bulk density and specific gravity of the processed material will be carried out. The particle size and shape will be evaluated using SEM image analysis. Static compaction tests will be performed on crushed mixture of C&D wastes at OMC for establishing force-stroke relationships which will reveal the maximum force and compaction pressure required to produce compacted stabilised bricks.

Optimum binder content: Two types of binders will be examined: (a) GGBS-lime mixtures (b) fly ash based geopolymer. The optimum binder content will be established through a parametric study. Two types of curing methods will be explored (a) normal water curing at ambient temperatures and (b) low temperature steam curing. The parametric studies will reveal the optimum proportions of GGBS-lime binder and the fly ash-silica-alkali proportions.

Characteristics of compacted bricks and masonry: Based on the optimum binder proportions, the compacted bricks will be manufactured and the bricks will be examined for compressive strength, water absorption, stress-strain characteristics, surface porosity and pore-size distribution, liner expansion on saturation, drying shrinkage and mass loss in accelerated durability test.

The following properties of the masonry using Low-C bricks will be evaluated.

a. Masonry prism compressive strength
b. Stress-strain characteristics
c. Flexure bond strength

Thermal characteristics and embodied energy: Thermal characteristics of Low-C bricks will include: (a) thermal conductivity values and (b) determining the heat flow through Low-C brick masonry elements. Embodied energy analysis of Low-C bricks and their masonry will be carried out.

Expected Outcomes & Deliverables

New Product:
The main target of the proposed project is to develop technologies for energy and carbon savings in external wall envelope materials for the buildings to reduce carbon emissions in the construction sector. Also, to reduce burden on the natural resources consumption in the construction sector by utilising solid wastes such as C&D wastes. The deliverables from the project include:

a. Technology of Low-C Bricks from C&D wastes without using Portland cement and without firing
b. Thermal performance of Low-C brick walls
c. Embodied energy and embodied carbon analysis of the new Low-C bricks

About Institute & Previous Projects

The Indian Institute of Science (IISc, or just 'The Institute') was established in 1909 by a visionary partnership between the industrialist Jamsetji Nusserwanji Tata, the Maharaja of Mysore, and the Government of India. Over the 108 years since its establishment, IISc has become the premier institute for advanced scientific and technological research and education in India. Since its inception, the Institute has laid a balanced emphasis on the pursuit of basic knowledge in science and engineering, as well as on the application of its research findings for industrial and social benefit. The Institute has carried hundreds of DST sponsored research projects.

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4. SUSTAINABLE ENGINEERED CELLULAR GEOPOLYMER MASONRY FOR IMPROVED BUILDING ENVELOPE PERFORMANCE

Principal investigator: K.V.L. Subramaniam
The Indian Institute of Technology Hyderabad

भारतीय प्रौद्योगिकी संस्थान हैदराबाद
Indian Institute of Technology Hyderabad

Background of Project

In urban environment, bulk of the building envelope consists of non-structural infill. The infill provides a physical separation between the internal and the external environments. In buildings, there is a very large volume requirement for the infill material. Typical infill used in buildings is masonry made of brick units. The brick units are associated with a large embodied energy. Improvements to the building envelope using infill made with cellular geoplymer masonry blocks is proposed.

It is proposed to develop infill material consisting of cellular geoplymer masonry blocks. The geopolymer for making the masonry block will be produced using fly ash, with minimal processing energy. The use of fly ash as the only precursor raw material for producing infill material offers environmental beneficiation through the large-scale effective use of waste material from industrial and post-consumer utilization, disposal of which has become a challenge. Additionally, the inherent benefits of enhanced thermal comfort and internal environment through superior attenuation of noise make it suitable for use as a building material. The potential benefits of the proposed cellular geopolymer masonry blocks used as a construction material include:

Reduction of Energy Demand: Increasing urbanization and economic growth in India has led to a very rapid increase in the energy demand in urban centers. The low thermal conductivity of cellular masonry blocks would provide enhanced thermal comfort resulting in operational energy savings.

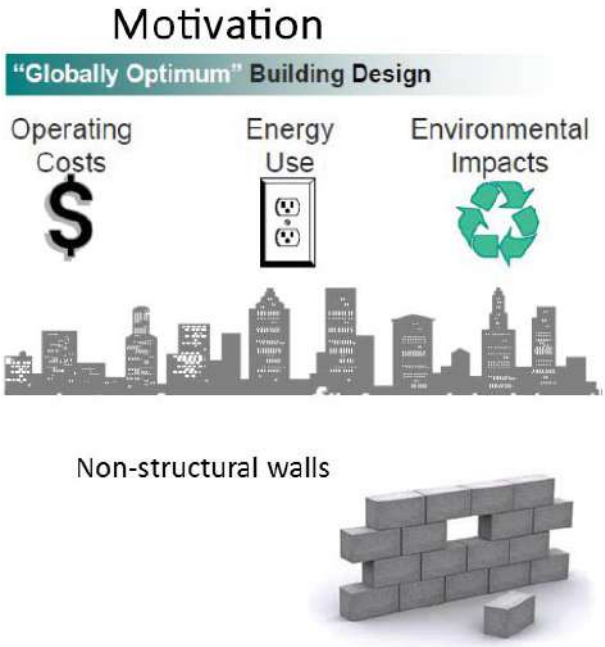
Waste utilization: Fly ash generation in India is currently 220 million tons per anum, with 55% utilization. The ash production likely to increase to 260 million tons by 2020. The proposed masonry blocks provide a solution for potential disposal problem associated with the large quantities of unutilized fly ash.

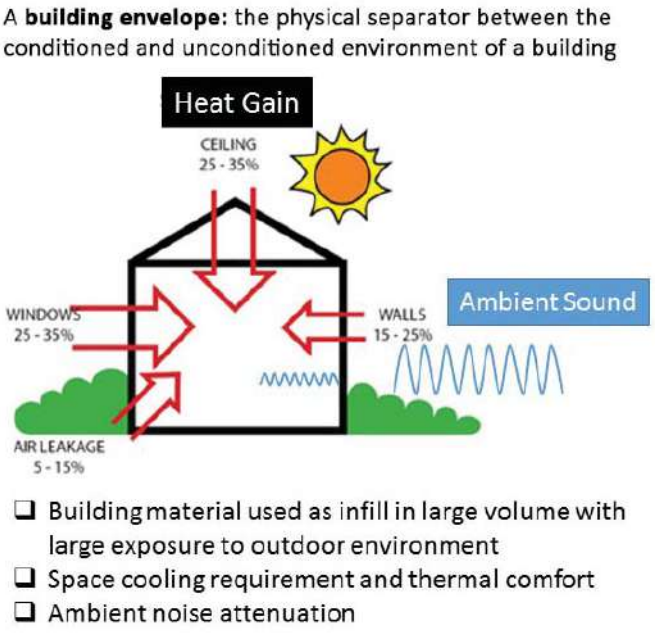
Reduction in embodied energy: The processing temperature 60 deg C, which is lower than requirement for autoclaving (135 to 190 C), providing energy saving in manufacture.
Cost savings: Considering the large volume of construction material required to meet the projected demand of housing, major cost savings will be achieved.

Aim

The central idea of this proposal is to produce, evaluate and test the deployability of low-weight, cellular geopolymer masonry units made entirely of activated fly ash geopolymers. In addition to weight saving, these units have the potential for providing energy savings because of low energy cost in manufacture compared with conventional AAC blocks and provide savings in operational energy because of the enhanced thermal comfort achieved because of low thermal conductivity. The different aspects of research work proposed here include:

- Production of cellular geopolymer masonry blocks through incorporation of metastable foams within a geopolymer matrix achieved using only fly ash.
- Evaluation of the thermal properties of the new material for thermal comfort of the built environment.
- Comparative assessment of energy performance of new building material with conventional building materials through energy simulation in different climatic zones of India.
- Field evaluation of the cellular geopolymer masonry.





Methodology

The cellular geopolymer masonry blocks for use as infill consisting of large entrained porosity in the form of uniformly distributed air cells will be developed and evaluated. The overall methodology adopted includes the following:

- Development of a systematic procedure for using the appropriate activator for achieving geopolymers of sufficient compressive strength using low calcium fly ash and slag combination.
- Development of production procedures for achieving cellular geopolymer with the desired level of end porosity for optimized thermal performance and strength.
- Evaluation of material properties of relevance to performing energy simulations for built environment using the new material.
- Development of calibrated building energy model for including the use of cellular geopolymer masonry in construction

Expected Outcomes & Deliverables

The outcome of this research will produce an advancement in the processing technology which will lead to better design of cellular geopolymer concrete mixes using low-calcium fly-ash. Currently there is an apprehension about the use of geopolymers due to concerns of producing the material of required strength consistently using fly ash as the raw material feed, which is of a variable nature. Systematic procedures for producing Geopolymers of consistent properties will be developed. The engineered cellular structure produced will be optimized for achieving the desired level of thermal conductivity while ensuring adequate strength for use in infill walls. The final output is the development of guidelines for use of fly ash in low temperature geopolymers for use in cellular masonry blocks.

The final outcome of this work is the development of technology to produce cellular geopolymer blocks, assess the potential for production, evaluate the product in field application, and evaluate the improvements to the building envelope achieved through thermal benefits. The outcome of this project will be the development of technology which will be ready for commercialization. The outcome will be suitable for adoption by small and medium scale manufacturers. To make the technology ready for commercialization the following will be achieved:

1. Optimization of the production process: Process variables for producing bricks of consistent quality will be optimized. Ready to use guidelines for mass production of the cellular geopolymer bricks will be developed.
2. Evaluate and quantify the environmental benefits: The energy savings and enhancement to building envelope with enhanced thermal comfort achieved will be evaluated within a framework provided by GRIHA.
3. Costing: The cost involved in setting up a production facility for the cellular geopolymer brick unit will be evaluated.

About Institute & Previous Projects

I.I.T. Hyderabad has an established track record of delivering on funded research projects leading to technology development. Currently work is on-going in the Center for Sustainable Urban Development I.I.T. Hyderabad, on the following related project

"Development of Sustainable Fiber Reinforced Masonry Systems for Rural India" through funding under Centres of Excellence for Training and Research in Frontier Areas of Science and Technology (FAST), MHRD.

Completed projects in related areas at I.I.T. Hyderabad

"Development and evaluation of self-curing, user friendly geopolymers for structural applications" Dr. K.V.L Subramaniam (PI), 2012-15, Fly ash Mission, DST.

Industry Partner

The outcome of this project will be the development of technology which will be ready for commercialization. The aspects of production and economics will be evaluated in collaboration with the industry partner, Aarush Building Materials Pvt. Ltd. Aarush is currently engaged in the manufacture of aerated autoclaved concrete (AAC) blocks using fly ash. The cellular geopolymer brick unit will be particularly suitable for use in low-cost housing schemes. To this end, we have an agreement with Nova Build Design for exploring the use of the bricks within an integral precast slab system for mass housing schemes.

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5. DEVELOPMENT OF HIGH VOLUME FLYASH FOAM CONCRETE WALL PANEL USING RICE STRAW AS THERMAL INSULATION MATERIAL

Principal investigator: K.M.Mini
Amrita Vishwa Vidyapeetham

Background of Project

One of the important challenges of future buildings is the reduction of energy consumptions, from construction to demolition. As a tropical country India faces serious issues of temperature rise and fall in most of the parts, which demands the need for a thermal insulation in existing buildings. Insulation is a key component of sustainable building design. A well-insulated home reduces energy bills by keeping warm in the winter and cool in the summer, and this in turn cuts down carbon emissions linked to global climate change. In terms of energy efficiency, investing in high levels of insulation materials is more cost-effective than investing in expensive heating technologies. Insulation materials are used in roofs, walls and floors. The introduction of the concept of "sustainability" in building design process encouraged researches aimed at developing thermal and acoustic insulating materials using natural or recycled materials. Some of them, such as kenaf or wood fiber, are already commercialized but their diffusion could be further improved since their performance is similar to the synthetic ones. So the present trend is to go for a sustainable construction, green construction, using green materials like straw, corn cob etc. The goal of the present proposal is to develop a state of the art of green building insulation product for existing buildings made of natural materials.

Aim

- Development of a cost effective high volume flyash foam concrete insulated wall panel for existing buildings using green materials like rice straw under different proportions.
- Testing the various properties of fabricated insulated panel in terms of thermal insulation capacity, mechanical strength, noise absorption, moisture absorption and fire resistance.
- Understanding the best proportion of straw that can be used for better thermal insulation in terms of test results and modeling techniques.
- Development of parametric study of heat transfer across the insulated panel by numerical simulation and to develop an empirical model to predict the heat transfer characteristics of wall panel.

Methodology

- **Preparation of fibers:** Collection, chopping into required sizes, drying in sunlight, application of additives to make it water resistant.
- Homogenization of fibers mix and formation of approximately equal size of fibers.
- Pressing down of treated fibres under increased pressure and temperature to reduce the hollow nature of straw using hot pressing.
- Preparation of foam concrete mix to required density that can offer high thermal resistance
- Addition of treated fibres to the foam concrete in varying proportions
- Use of hot plate guarded apparatus to evaluate the thermal resistance for the composite panel.
- Use of cone calorimeter to find the fire resistance for the composite panel.
- Checking the water absorption for the composite panel.
- Use of impedance tube method to assess the sound absorption coefficient.
- Evaluation of various strength properties using compression testing machine, universal testing machine and fabricated test set-up.
- Comparison of the properties of panel with the commercially available insulating panels.
- Use of analytical and numerical models to assess and check the optimum amount of straw in concrete.
- Development of parametric study of heat transfer across the insulated panel by numerical simulation and to develop an empirical model to predict the heat transfer characteristics of straw

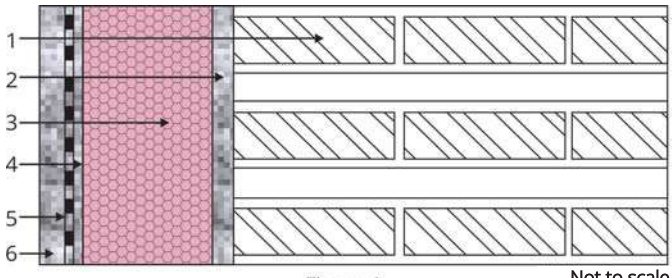
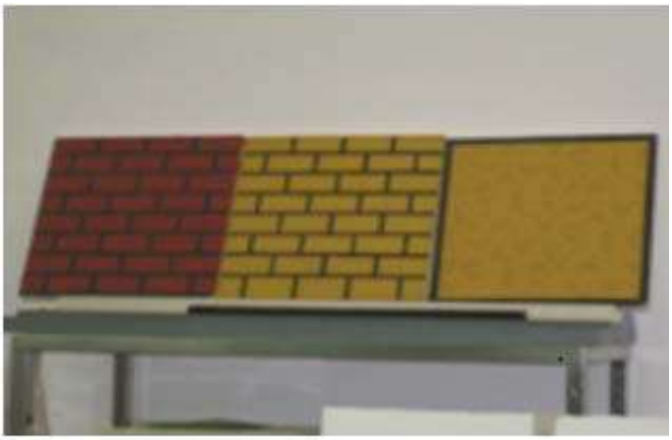


Figure 1 Not to scale

Exterior Wall Insulation

Insulation on the exterior
1. Brick work
2. Plaster
3. Insulation
4. Polymerised mortar, 2 coats
5. Reinforced fibre
6. Elastomeric coat



Expected Outcomes & Deliverables

New/Upgraded Product: Proposal focus on use of rice straw, a waste material of cultivation from paddy field and use of flyash, by-product of thermal power plant, for preparation of foam concrete wall panel. The rice straw can be directly purchased from the farmers, which will provide an extra income to the farmers.

New/ Upgraded System: A way of sustainable construction. Performance analysis: Analysis can be done on a commercial scale in terms of thermal comfort compared to existing ones and also on a financial scale.

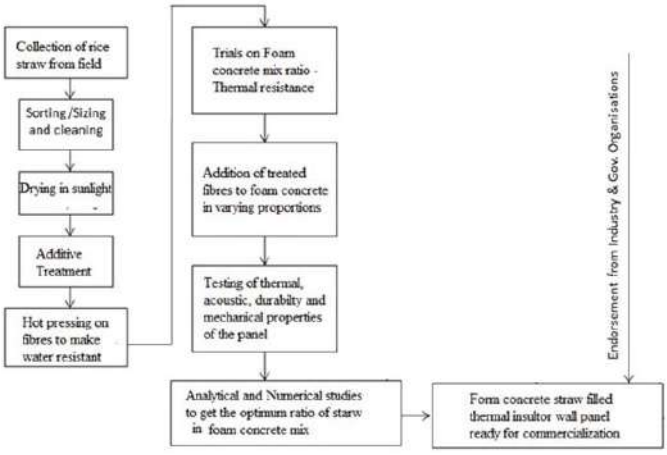
Feasibility analysis: Checking feasibility of proposed model with the support of engineers and contractors working in construction.

Technological Capability: The proposed model will enhance sustainable way of construction

Achieving State of art performance: The efficiency of the proposed model will compare with the existing technologies available in the market and if modification required, can be done on a later stage.

Upon completion of the project following Novel Technological Developments are expected:

- An environmentally friendly wall panel to induce thermal comfort in existing buildings without disturbing the system.
- An entirely new class of green wall panel mostly incorporating the waste materials, thus to facilitate the sustainable way of construction without disturbing the nature.



Different steps involved in the proposed plan of development of thermal resistant green wall panel

About Institute & Previous Projects

Amrita School of Engineering, Amrita Vishwa Vidyapeetham is a multi-campus, multi-disciplinary research university that is accredited 'A' by NAAC and is ranked as one of the best research universities in India. Amrita Vishwa Vidyapeetham has been ranked and placed in Category A in the Ivy League of Indian universities in the 2009 review of Deemed Universities constituted by the MHRD. The university is spread across five campuses in three states of India - Kerala, Tamil Nadu and Karnataka, with the University headquarters at Coimbatore, Tamil Nadu. As per the recent NATIONAL INSTITUTE RANKING FRAMEWORK (NIRF) released by MHRD, Amrita Vishwa Vidyapeetham ranked as No.1 private University in India.

Amrita Vishwa Vidyapeetham has always given paramount importance to research. Amrita is a partner in various international bilateral governmental research programmes and initiatives. These research initiatives have the support of major national laboratories, industry leaders and agencies like DST, TIFAC, ISRO, DIT, DRDO, Microsoft etc. The investigators are undertaken various funded projects in materials, sustainable construction and enhancement in durability of structures with the support of DST, AICTE, Institution of Engineers etc. Investigation of Compatibility between Portland Pozzolana Cement and Admixtures in High Performance Concrete (DST), Development and scale_up of plunging hollow jet, venturi and sudden expansion type aerators (AICTE) and Neural network modelling for stability analysis of fibre reinforced composite laminate plates (Institution of Engineers, India) etc. are a few among them.

Industry Partner and Team Member

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6. ENERGY EFFICIENCY AND OCCUPANT COMFORT MANAGEMENT IN THE BUILT ENVIRONMENT

Principal investigator: Seshan Srirangarajan
The Indian Institute of Technology Delhi

Background of Project

Buildings are one of the largest end users of energy. Most modern buildings are designed keeping in mind the energy efficiency in its operation and the occupants' comfort. Many modern buildings have a building management system (BMS) integrated in its operation and maintenance. However the various subsystems of the building do not talk to each other. The sub-systems may be very efficient individually but as an integrated system they operate sub-optimally. Furthermore, the performance of various equipment deteriorates over a period of time which is not taken into account at the time of design of control loops in the BMS.

The use of relatively simple sensor technology and control algorithms limits the effectiveness of the energy management and security systems. There is a lack of good quality, high resolution data due to several reasons such as the non-availability of adequate number of accurate and cheap sensors, and the sensors not being calibrated at regular intervals. In addition, the data that is acquired is not used to systematically analyse/predict/prevent faults or learn demand patterns over a period of time. Due to all these reasons, the actual energy performance index of a building is very different from its designed value.

Most of the energy in buildings is consumed in the heating, ventilation, and air conditioning (HVAC), and the lighting systems. The parameters that are typically considered as part of occupant comfort include indoor lighting, air quality, and thermal comfort. In this project we will address each of the above mentioned facets of energy consumption/efficiency and occupant comfort in buildings.

Aim

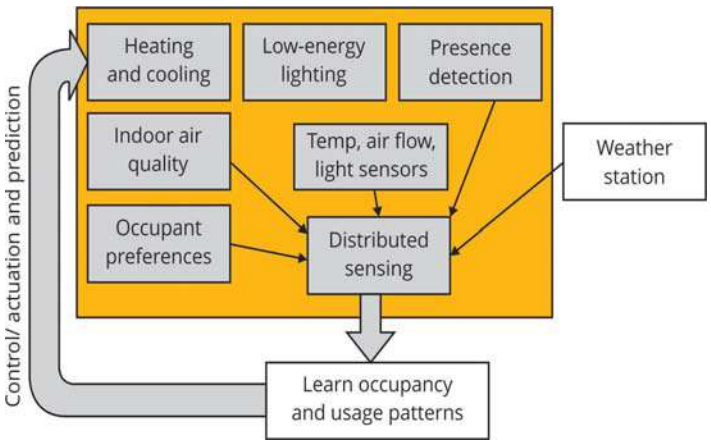
The main aims or objectives of the project are the following:

1. **Indoor lighting:** Development of low-energy consumption and large area (10 cm x 10 cm) lighting suitable for a built environment.
2. **Indoor air quality:** Design and development of low-cost photo-ionization detectors (PID) for volatile organic compounds (VOC) analysis.
3. **Variable frequency drives:** Understand and address the drawbacks of variable frequency drives (VFDs) in building HVAC systems for energy efficient operation.
4. **Power quality issues:** Study power quality problems due to the large-scale use of CFL and LED lighting solutions in buildings, and develop solutions to address some of these problems.
5. **Building modelling:** Modelling of building zone(s) in an energy estimating software and evolving control strategies for efficient and healthier operation of buildings.
6. **Post-occupancy evaluation:** Performance monitoring and evaluation, and study of indoor air quality of an existing building. This would involve developing methodology for data fusion and analysis from multiple sensors/sources, performing presence detection, and automatically learning occupancy patterns.

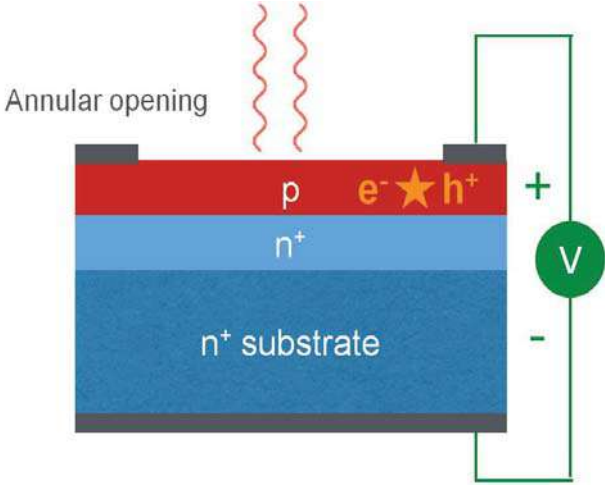
Methodology

Here we describe the methodology that will be followed in order to achieve the stated objectives of the project.

1. **Indoor lighting:** We will use low-temperature printing for large-area devices with new organic materials, lower intrinsic brightness to improve lifetime, and deposition method for rapid industrial uptake. Polymeric materials based on truxene and extended truxene cores, which have shown a lot of promise, will be developed.
2. **Indoor air quality:** We will develop a PID system using low-cost printed technology. These devices will utilize a printed magnesium fluoride (MgF) capsule which will be packaged



System-level block diagram



Epitaxial Inorganic LED Structure

with nobel gas having the required characteristics. RF Plasma will be excited by printed electrodes which will be integrated. PID performance will be calibrated, and finished devices will be used for monitoring of VOC in buildings.

3. **Variable frequency drives:** We will study, measure and analyse the problems with VFDs in HVAC system. We will develop laboratory prototype for VFDs to demonstrate the performance of the proposed solutions.
4. **Power quality issues:** We will develop a laboratory prototype to demonstrate the performance of the proposed solutions to the power quality problems due to the large scale use of CFL and LED lighting.
5. **Building modelling:** We plan to monitor a local building (with a focus on 1 or 2 zones) through various existing sensors and new sensors will be added to collect data related to occupancy, energy consumption, indoor air quality etc. We will also integrate temperature, ambient light, and air flow sensors to provide light level and temperature information which can be used for thermal modelling.
6. **Post-occupancy evaluation:** Using data from distributed sensors and thermal modelling of the building we will demonstrate an intelligent decision support system for energy savings and comfort management in a building. We envisage testing the new control strategies in one or two zones of an office building to demonstrate the efficacy of the intelligent decision support system in managing the trade-off between energy efficiency/savings and occupant comfort.

Expected Outcomes & Deliverables

1. **Indoor lighting:** High brightness (~5,000 Cd/m2) large-area devices (10 cm x 10 cm) at luminous efficacy of 15 lm/W and a lifetime (L70) of 10,000 hrs.
2. **Indoor air quality:** A laboratory prototype PID sensor will be developed for analysis of VOCs.
3. **Variable frequency drives:** Design modifications in VFDs for improving energy efficiency in HVAC systems with a laboratory prototype.
4. **Power quality issues:** Steps for power quality corrections due to the large scale use of CFL and LED lighting with a laboratory prototype.
5. **Post-occupancy evaluation:** We will demonstrate and test new control strategies for managing the trade-off between energy savings and occupant comfort in a building.

About Institute & Previous Projects

The lead organisation for this project is the Indian Institute of Technology Delhi (IIT Delhi). IIT Delhi was set up with the vision to contribute to India and the world through excellence in scientific and technical education and research; and to serve as a valuable resource for industry and society. The Institute lays a strong emphasis on sponsored research and industrial interaction, and has set up many modern laboratories.

Industry Partner and Team Members

The team implementing this project, including the industrial partners, has extensive experience in the entire spectrum of expertise needed – material design and synthesis, device fabrication over large areas, packaging, power circuit design, low cost cooling design, control systems, machine learning, sensor data analytics, and building standards and management. The two collaborators from industry include (a) Mr. G. C. Modgil, Sterling India Consulting Engineers, a very prominent consultant involved with formulation of standards like ASHRAE and ECBC, b) Mr. Amrish Chopra, Anergy Instruments Pvt. Ltd., an industrialist specializing in building control systems, sensors and lighting. Our industrial collaborators have designed and worked with several prominent Indian buildings, such as the India Habitat Center, which will be taken up for study, using their unique insights into the design of those buildings.

The PI, Seshan Srirangarajan, has worked extensively in the area of wireless sensor networks. Srirangarajan has also worked on sensor fusion techniques and machine learning for various applications including building energy management. Among the co-PIs, Sanjeev Jain is an expert in solar cooling, natural refrigerants, microscale and decentralized energy systems. Madhusudan Singh has worked with ultra-bright organic light emitting diodes (OLEDs) using printed devices. Josemon Jacob has extensively developed the synthesis of truxene-based blue emitting materials. Amit Jain is an expert in power electronics, drives and circuits. Dr. Mitra is an expert in MEMS devices and microfabrication. His work has focussed on uPlasma ionisation detector and application to VOC sensing in ambient air.

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New Delhi

Sanjeev Jain
Professor
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New Delhi

7. GREEN BUILDINGS AND ENERGY EFFICIENT COOLING SYSTEM FOR SUSTAINABLE BUILDINGS IN INDIA

Principal investigator: S. Kalaiselvam
Anna University

Background of Project

The latent thermal energy storage (LTES) systems using phase change materials (PCM) has been recognized as one of the effective measures to redistribute and enhance energy efficiency in thermal systems. This research project is focused onto explore the underlying thermo-kinetic behaviour of variety of PCMs suitable for Building energy conservation applications. The important parameter that influences the heat transfer between the bricks and PCM will be experimentally determined using the proposed system. This work study the heat transfer characteristics of micro/nano encapsulated PCM bricks and PCM window curtains for latent-heat energy storage. The influence of external factors like natural convection and outdoor temperature on the phase change behaviour and energy storage will also be discussed.

The project also provides detailed data for benchmarking and validation of analytical models, and to discuss the newly synthesised Nano encapsulated PCMs. The energy saving achieved due to reduced wall gain heat load by impregnating PCM in Bricks will be compared with the normal bricks used for constructions. Further energy saving by impregnating the PCM in curtains to reduce the solar heat gain will be discussed.

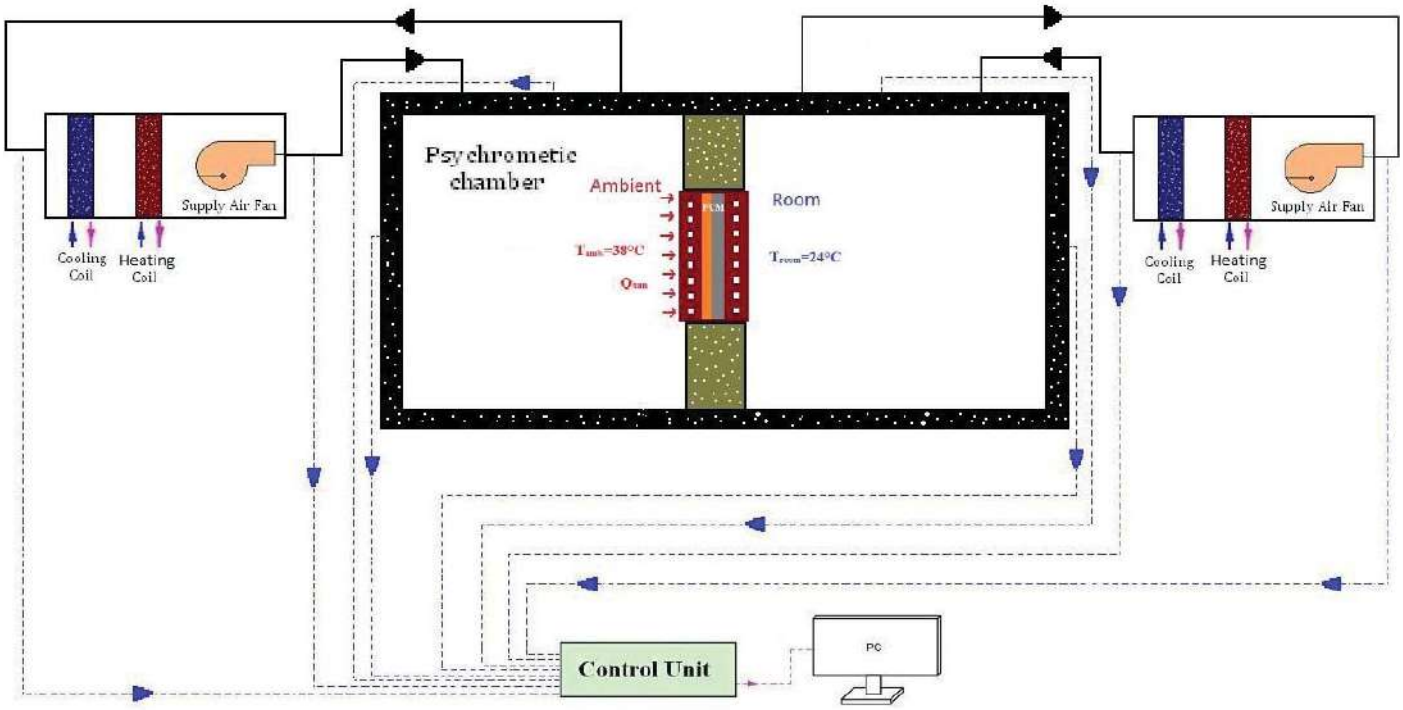
Aim

- Sustainable buildings uses the renewable energy sources and to develop new passive cooling techniques to utilize the natural available energy towards the building energy conservation.
- Latent heat thermal energy storage materials have higher potential to store and release energy.
- This project study the thermal properties of micro and nano encapsulated PCM that influences the energy conservation in buildings.
- Owing to their heat storage capacity, LHTES materials stored in the building construction materials has a capacity to eliminate heat penetrated to buildings by means of wall gain heat load.
- Heat transfer enhancement in the PCM made by encapsulating the PCM in micro and Nano size.
- Higher heat transfer in the PCM increases the human comfort by decreasing the thermal swing and sustaining the Indoor temperature for prolonged time.
- To evaluate the heat transfer through thermal energy storage (TES) units filled with different microencapsulated phase change materials (PCMs).
- This Project identify a suitable parameter in optimizing the phase change temperature of the PCM for specific ambient conditions.
- To study the Phase change behavior of the PCM impregnated in building materials under the influence of natural convection.
- To calculate the energy saving of buildings using PCM impregnating wall materials.

Methodology

This project is structured into the following main steps:

- Climatic conditions and definitions of material properties;
- Synthesis of new micro/nano encapsulated PCMs;



Experimental setup

- Wall and window blinds specimen construction and experimental testing;
- Numerical modeling and validation.

Work Methodology

This project focuses towards developing the sustainable buildings using latent thermal energy storage materials for building energy conservation. The work flow starts with the survey of literatures to clearly understand recent trends in PCM based buildings, difficulties in impregnating the PCM, energy saving achieved in existing Green buildings. After consolidating the literature, the data's required for the numerical analysis of the PCM impregnated building materials are to be collected, which includes the climatic data's of the specific region. The suitable phase change materials and optimum wall thickness that suits to the ambient temperature are finalized from the numerical analysis. Next the synthesis procedure for Micro/ Nano encapsulated PCM is started. The experimentation starts with the testing of hollow bricks used in the building construction for the climatic conditions throughout the day. The suitable impregnation procedure are implemented and the Nano encapsulated PCMs are integrated into the wall materials, which are tested in the Psychometric chamber for all climatic conditions. The experimental data's of both hollow and PCM impregnated bricks are compared based on the heat transfer calculations. In addition to that the solar gain heat load is restricted by implementing the PCM filled curtains. The energy saving of the Nano encapsulated PCM in wall materials are properly inferred.

Expected Outcomes & Deliverables

Expected out-come
Material development

- MPCM - 5
- MPCM bricks
- PCM-window blinds

Prototype development

- Psychrometric chamber
- Energy output
  - Expected annual energy savings around 45-50%

Research Papers/ Technical Documents/ Reports

- Patents - 4
- International journal publication – 5

Training, Awareness Camps and Ph.D. / M.Tech.

- No. of Ph.D.: 01
- No. of M. Tech.: 03
- Awareness Camps: 01 – By conducting workshop on sustainable buildings

Deliverables

- Selection procedure of the PCM: The parameters that govern the selection of Phase change materials will be explained. The thermo-physical properties that influence the phase change behavior of the PCM will be elaborated.
- New/upgraded products- micro/nano encapsulated PCMs: Techniques for encapsulating the PCM are finalized and the Micro/Nano encapsulated PCM will be synthesized.
- Nano encapsulated PCM impregnated bricks: The PCM impregnated bricks, normal bricks and the PCM impregnated curtains are experimentally analyzed in the controlled Psychrometric environment for all climatic conditions.
- New/upgraded system - energy efficient passive cooling system: This project will help to implement the latent thermal energy storage materials for sustainable buildings in India.

About Institute & Previous Projects

Anna University is one of leading technical University in the world. Anna University has been ranked number 6th among all universities in India on National Institutional ranking framework conducted by Ministry of Human Resources Development, Government of India.

Previous projects

The previous research projects were focused towards study of thermo-physical property analysis of PCM to utilize the renewable energy sources in various applications like hybrid solar systems and Building by using Nano structured Phase change materials. More than 20 research papers were published in well reputed International Journals and an Indian Patent were also filled.

Industry Partner

Ms. Shree Sharathaa constructions are one of the known builders in Chennai. They are impressed by the project and ready to implement Green building techniques to reduce the global warming and test the PCM bricks in onsite.

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8. USER FRIENDLY FUNCTIONAL SIMULATION TOOL DEVELOPMENT THROUGH EXPERIMENTAL VALIDATION FOR INTEGRATION OF PCM IN ENERGY EFFICIENT BUILDINGS FOR THERMAL MANAGEMENT

Principal investigator: R. Velraj (Lead), V. Antony Aroul Raj, N.B. Geetha
Anna University

Background of Project

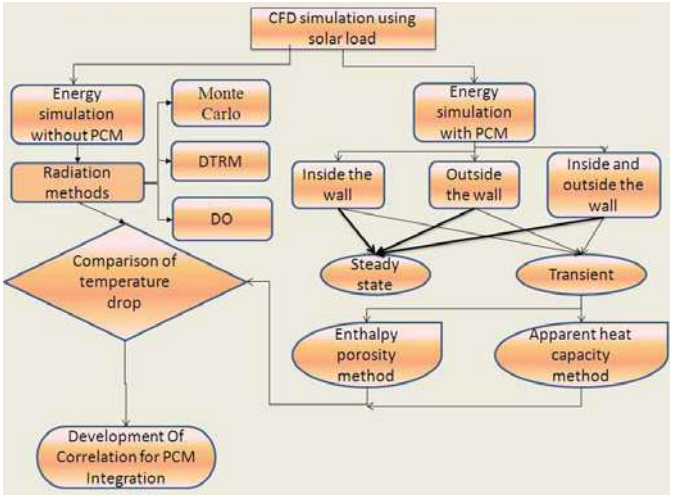
- Buildings are highly energy intensive sectors due to the rapid urbanization in our country.
- Buildings consumes nearly 40% of the energy generated in any country. Out of this, 60% energy (i.e. 24 % of the total energy generated) is spending for building cooling/ heating.
- The present light weight buildings have very low heat storage capacity and hence the peak shaving could not be accommodated by the building wall elements.
- Instead of massive building, introduction of PCM is considered as the best option.
- There is a resistance among the Architects and consultant for using PCM in the buildings due to difficulty in analyzing the performance of the PCM in the buildings at various seasons of the year.
- The phase change problem being a transient phenomenon during the entire charging and discharging period the modeling and solving is complex and further the thermal problems are new for building engineers.
- Creating a simple model from complex simulation will reduce the burden of new users to implement PCM in the buildings.
- This proposal is initiated towards the objective of introducing PCM in the buildings of the future and to provide user friendly analysis tool for the building designers.
- The novelty of the present work is developing a simulation tool towards designing the PCM integration in building using building simulation software in a simple way.

Aim

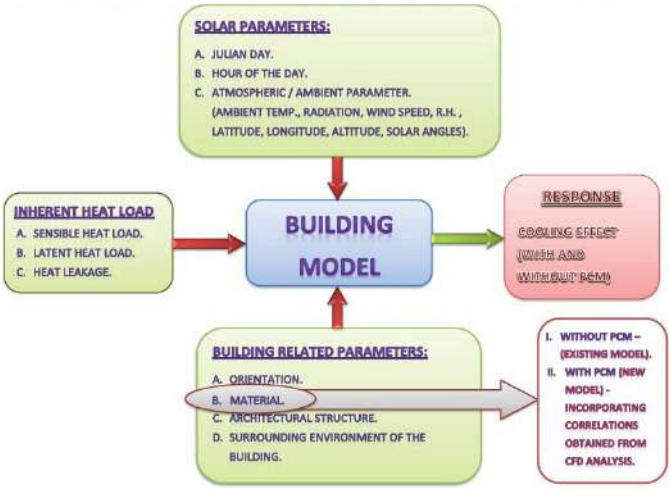
- To study the literature for various concepts being adopted by the researchers towards the integration of Phase Change Material (PCM) in buildings for energy efficient thermal management.
- To investigate the structural and year round thermal performance of the PCM integrated buildings using Finite Element Analysis (FEA) and Computational Fluid Dynamics (CFD) software by considering various input factors that influences the performance of the building.
- To identify suitable PCM to be integrated with building elements based on the site specific conditions for year round thermal management.
- To carry out experimental investigation with and without PCM integration in building. Validation of CFD results with the results of experimental investigation
- To develop an analytical expression based on extensive numerical analysis.
- To carry out experimental analysis and validate the developed correlation.
- To incorporate the analytical expression in the building system simulation software.
- To perform the simulation using the building system simulation software and compare the results.
- To disseminate the knowledge gained through publications, conduct of seminar and collaboration with industries for commercial promotion.

Methodology

- Performing a detailed study to analyze the merits and demerits of various methods of incorporating the PCM integration in the buildings.
- A best configuration will be selected that suits the maximum percentage of Indian weather conditions for the integration of PCM in the buildings.
- Development of a physical model for the selected configuration and CFD analysis will be performed for the practical range of values of the selected parameters.
- Developing correlations based on the extensive results obtained from the CFD analysis.
- Construction of the Experimental buildings with and without PCM integration.



Flow diagram for CFD simulation and development of correlation



Analysis and model up-gradation in building simulation software

- Conduct of experiments and validate the results obtained from the CFD analysis.
- Incorporating the analytical expression in the building system simulation software.
- Simulating the thermal performance of the building using the building system simulation software and compare the results.
- Developing user friendly functional Simulation tool using simple correlations which will be useful for designers using PCM in buildings and validating those correlations.

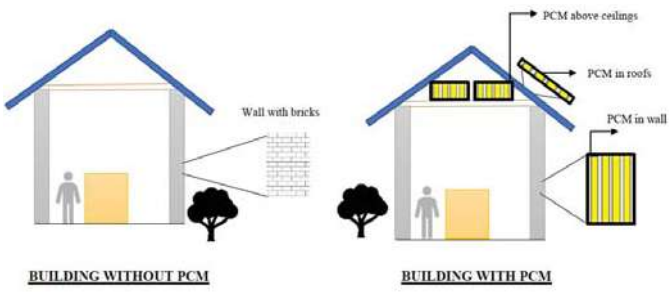
The work will be executed by forming three different sub groups namely CAE analysis group, Experimentation group and Building simulation group. Finally the consolidation of the report and dissemination of results will be carried out jointly by all the three groups.

Expected Outcomes & Deliverables

Upgraded software Product for the analysis of PCM integration in building which is validated with the experiments will be made available. The international energy agency is trying to bring norms and standards for the PCM integration in buildings of the future. At this juncture, this kind of software, which is not available at present in the national and international scenario will become very significant.

Deliverables

- An experimental building to validate the theoretical results obtained from the CFD analysis.
- Validated Correlations for the analysis of PCM integration in buildings
- Software tool for the analysis of PCM integration in building sector which is not presently available nationally and internationally.
- Publishing few journal articles in the field of incorporation of PCM integration in buildings.
- IPR for the software tool to be developed for PCM integration in buildings.
- Target Users will be Consultants/ Designers/ Architects in the Building sectors for effective thermal load management to achieve passive cooling or to reduce the energy consumption by the HVAC system through integration of PCM in the building elements.



Schematic representation of the proposed building for experimentation

About Institute & Previous Projects

Three institutes are involved in this project namely Institute for Energy Studies (IES - Anna University), Easwari Engineering College (EEC), Meenakshi Engineering College (MEC). Anna University was established on 4th September 1978 as a unitary type of University. It offers higher education in Engineering, Technology, and allied Sciences relevant to the current and projected needs of the society. Easwari Engineering College was established in 1996-1997 with a vision for women empowerment through Higher education in Engineering and Technology. Meenakshi College of Engineering was established in the year 2001 and accredited by AICTE and affiliated with Anna University.

Anna University has executed more than 400 research projects in various field of Engineering and Technology funded by SERB, DST, UGC, CSIR, BRNS, ICMR, MoEF, MNRE, DBT, CVRDE, DRDO, DRDE, SPC, TNPCB, AERB, NIOT, ISRO, INCOIS, and IGCAR. Institute for Energy Studies, Anna University Chennai presently has completed more than 15 research projects funded by DST, MNRE, DRDO and UGC.

Team Members

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9. DESIGN & PROTOTYPE DEMONSTRATION OF A CHCP SYSTEM FOR SCALABLE BUILDING ENERGY USE BASED ON METHANOL POWERED FUEL CELL SYSTEM

Principal investigator: Atul Bhargav
Indian Institute of Technology Gandhinagar

Background of Project

A significant component of energy consumption by sector is building energy. A typical commercial building in India consumes around 200 to 400 kWh of power for every square meter of space in a year. Generally, this energy is supplied through the grid, or by diesel generators that are used for auxiliary/ backup power. While the grid suffers from unreliability, lack of capacity and voltage fluctuations, the diesel generators are inefficient, polluting, and subject to fuel pilferage. Hydrocarbon based fuel cell systems have the potential to mitigate the usage of imported petroleum and reduce greenhouse gas emissions by acting as a combined heating-cooling-power source. India's five year plan for chemical sector from 2012-2017 and FICCI's 2012 report on the Indian Chemical and Petrochemical Industry list methanol as a chemical with a rapidly increasing demand and an increase in production. While indigenous capabilities in individual subsystems exist, a collective effort to functionalize an integrated FPS-FC system has not been developed in India. Methanol offers certain advantages when compared to other fuels, the chief being large production capacities and ease of reforming. Coupled with efficient heat recovery system and control strategies, steam reforming can deliver higher hydrogen yield and increase system efficiencies. Further, with the aid of simulations, the balance CHCP system will be designed. The proposed research work will greatly help in commercializing the methanol based fuel processing - fuel cell systems that can act as a scalable CHCP source.

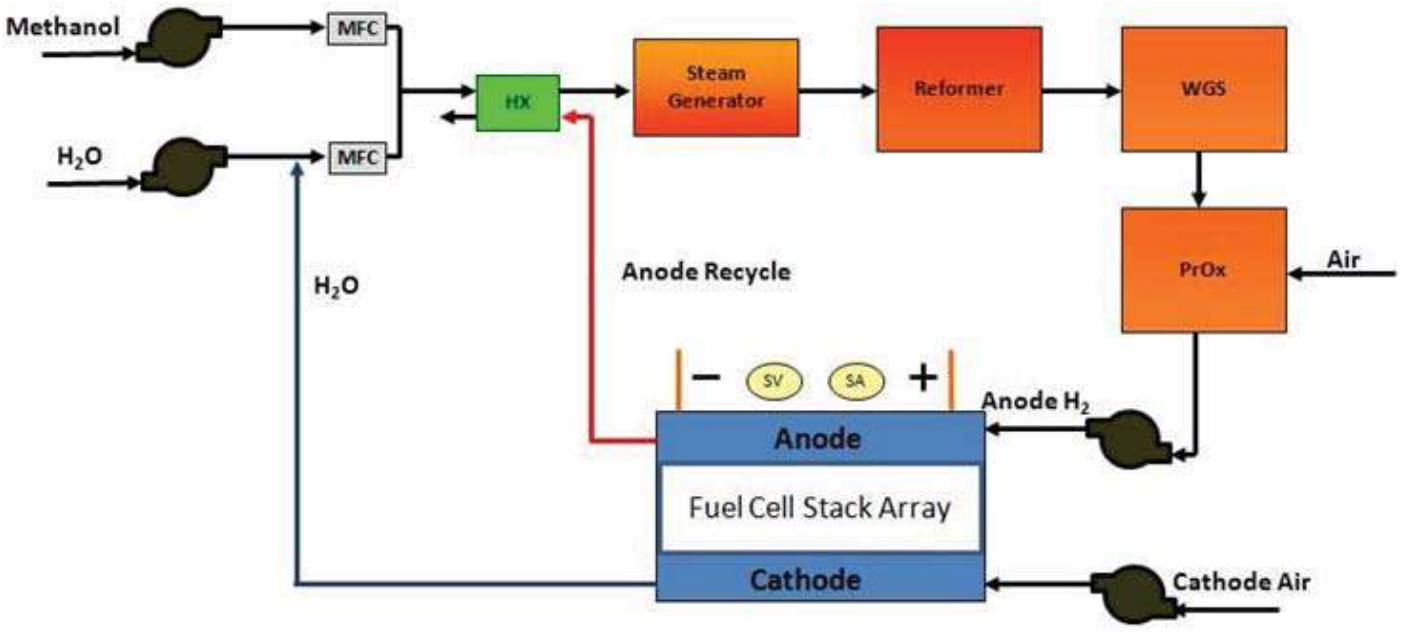
Aim

This study aims to develop a prototype of a methanol fuel processor based FPS-FC system that can be scaled to work with a wide range of building energy requirements. The project further aims to design a modular system ensuring scalability and ensure robustness of the reformer system through detailed thermal integration of the reformer system. Control systems will be developed that enable efficient working of the FPS-FC system at all load conditions and ensure higher efficiencies. The main objectives of the proposed research work are:

- To design and develop an indigenous methanol fuel processor with integrated heat recovery, reforming, water-gas shift and hydrogen cleanup steps.
- To couple the methanol fuel processor with a commercial PEM fuel cell stack and balance-of-plant
- To develop the ancillary systems to enable the use of the said system as a CHCP source for building energy

Methodology

- Design, test and individually characterize various reactors in the fuel processor: reformer, water-gas shift and preferential oxidation
- Understand the tradeoffs involved in the design of a thermally integrated CHCP system; identification and development of balance of plant components
- Long term tests to understand the effect of impurities in the fuel/ methanol-water mixture



Expected Outcomes & Deliverables

New System and Performance analysis: The results of the proposed work will deliver a state-of-the-art methanol based fuel processor that is efficient, scalable and robust for CHCP solutions for building energy use.

About Institute & Previous Projects

The Indian Institute of Technology Gandhinagar strives to offer the best undergraduate and graduate education in India with unmatched innovations in curriculum. The institute promotes critical thinking and an appreciation of the interdisciplinary character of knowledge, with an emphasis on the liberal arts, project oriented learning, compulsory courses in design and the life sciences, diversity and globalization.

In order to enable testing of hydrocarbon based fuel cell systems and system components, a safety laboratory for Hydrogen, Carbon Monoxide and Hydrocarbon has been designed, built and commissioned at IIT Gandhinagar. The principal investigator (PI) has successfully completed a DST-sponsored project to develop ethanol based autothermal reformer. The PI also is working on a NMRL sponsored project on diesel autothermal reforming. The PI has experience in building two generations of complete diesel-based PEM fuel cell systems, and has participated in the design for the third generation at the University of Maryland (UMD), in partnership with Ballard Power Systems.

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10. DESIGN AND DEVELOPMENT OF SOLAR PHOTOVOLTAIC POWERED COLD STORAGE SYSTEM

Principal investigator: M. Jaya Bharata Reddy
National Institute of Technology Tiruchirapalli

Background of Project

India is the second largest producer of horticultural commodities in the world wherein 88.977 million metric tonnes of fruits and 162.887 million metric tonnes of vegetables were produced during the year 2013–14 (Indian Horticultural Database 2014). Perishables worth Rs.133 billon are wasted every year because of lack of cold storage. Cold chain means temperature controlled logistics system that maintains ideal storage conditions (temperature - 0°C and 15°C) for perishables from origin to consumption.

Electrical energy expenses account for about 28–30% of total expenses in cold storage in India. As number of companies uses old equipment consuming huge electricity; power saving cold storage equipment's market is seeing an uptrend. Cold chain is priority to government and incentives are offered by government to attract private and foreign investments. But challenges faced for cold storages are; Unreliable power supply and cost, ongoing maintenance, lack of vertical integration, uneven distribution of cold storage, low awareness amongst industry about practices and lack of trained manpower.

Renewable solar energy potential in India is about 100 GW which is economically sound alternative to grid power. Running cost of cold storage system can be reduced with solar power. Solar based refrigeration system is appropriate for India as solar power is available throughout the year.

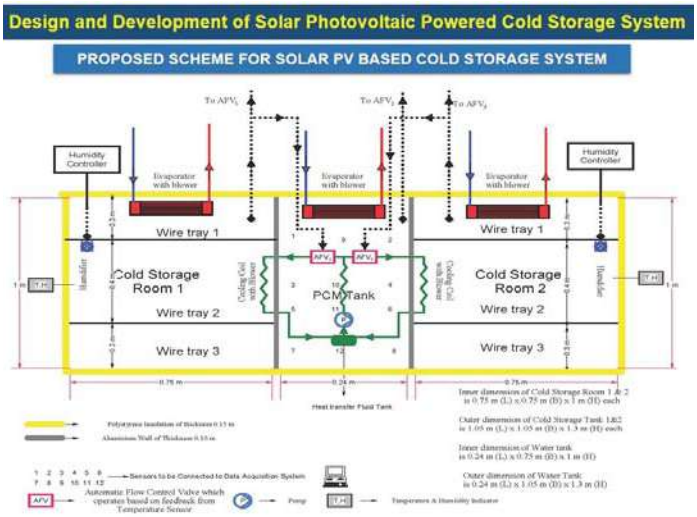
In this project, an energy efficient Multi commodity Solar PV based cold storage system for fruits and vegetables using low melting temperature phase change material (PCM) will be designed and developed to solve the challenges and to store excess thermal energy generated.

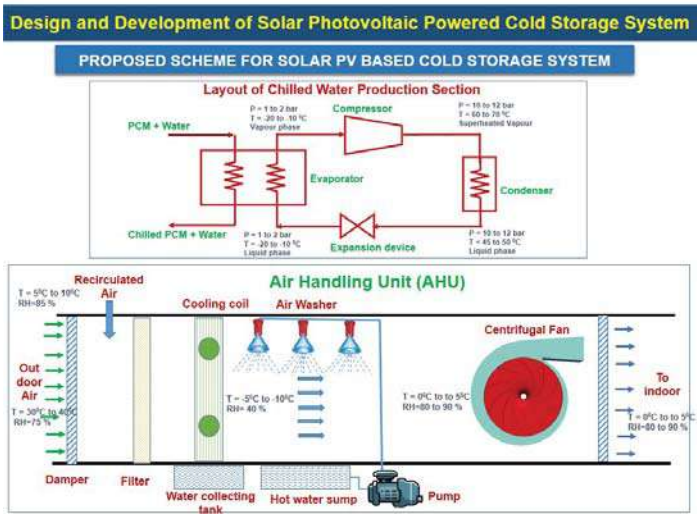
Aim

The objectives of the project is to Design and develop an energy efficient solar powered cold storage system with different temperature and humidity for various fruits and vegetables under different operating conditions, testing and demonstration of the system for farmers and industries. The uniqueness of the project is using the Low Melting Temperature Phase Change Material (PCM) to store and circulate in the cold storage rooms in addition to the direct evaporation of refrigerant. The excess cold energy can be stored in the PCM and is utilized when the absence of solar energy and Grid power. This is an energy saving and cost effective system when compared to the Battery Energy Storage (BES). The collaborative institutes (National Institute of Technology (NIT), Tiruchirappalli and Indian Institute of Food Processing Technology (IIFPT), Thanjavur) will develop an Engineered PCM based 3 TR prototype solar PV based cold storage system for fruits and vegetables and deliver to the society through demonstrations, workshops, seminars and trainings for farmers, academicians and stakeholders. The awareness will also be created among farmers and food processing industries regarding the importance of PV based cold storage system.

Methodology

System is designed for 3 TR capacity chiller in that 1TR cold energy is stored in phase change material (PCM) and 2 TR energy is utilized for the cold storage application. The method of operation of refrigeration adopted here is vapour compression refrigeration (VCR) system. Performance is measured as coefficient of performance (COP) - defined as ratio of cooling capacity to compressor work input and for the practical applications, the COP is taken as 1.5. Total electrical energy consumption would be 402.6 MJ/day. If solar panels receive 7 hours of daylight per day, 117.4 MJ/day of energy will be saved. In addition to the energy savings, the chillers can be operated with the absence of grid power and solar power for a maximum period of 2 hours using the stored energy available





in the PCM for every 4 hours of charging the PCM. Based on economic and optimum chiller design analyses, the chiller capacity is oversized by 50% of required capacity i.e. for the 2 TR cold storage application 3 TR chiller is selected. As PCM is added to water, its freezing temperature is reduced to -25 °C which supplies energy even when chiller is at off condition. This system is highly useful to farmers and stakeholders by reducing wastage of perishables and reducing power consumption. Project concludes:

- Successful PCM based Solar PV cold storage system will meet at 10% of India's cold storage requirement from field to industry (Requirement is 520 lakh MT - NCCB, 2015).
- PCM based Solar PV cold storage system will run even during absence of solar energy which saves at least 10% of the post-harvest loss in fruits and vegetables

Expected Outcomes & Deliverables

- Engineered PCM based 3TR proto model of a cold storage system suitable for a solar PV generation system for controlling storage temperature, RH combinations for different fruits and vegetables under Indian climatic conditions.
- Total technical document for easy transfer of technology
- Development of product for demonstration and downstream arrangements
- Training by conducting workshops for professionals.
- Skilled man power for food industries and academic/ research institutes
- Awareness creation among public regarding the importance of food safety and quality
- Preparation of research papers and patents

About Institute & Previous Projects

National Institute of Technology (NIT), Tiruchirappalli

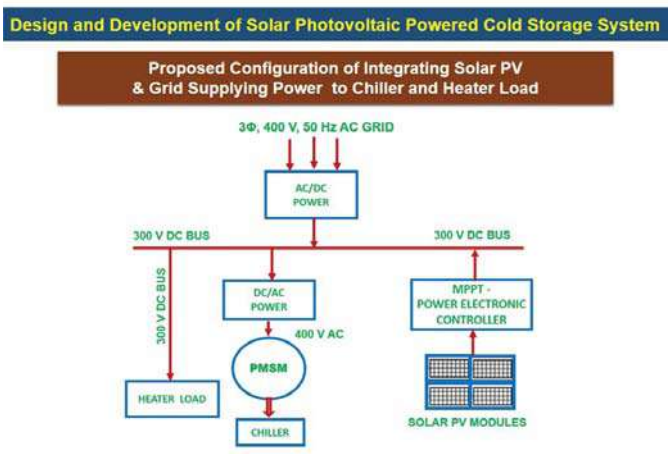
National Institute of Technology (formerly-Regional Engineering College) was started as jointly by Indian Govt. and Tamilnadu Govt. in 1964 and registered under Societies Registration Act XXVII, 1975. NIT bestowed as autonomous in finance and administration, hence granted Deemed University Status by UGC/AICTE and Indian Govt. in 2003. Institute offers 10 UG courses, 21 PG courses in Science, Engineering & Technology besides M.S and Ph.D (about 200scholars) in all departments. R&D activities funded by consultancies, DST, CSIR, ISRO, DRDO, DEITY, UGC and AICTE reached exponential growth.

Indian Institute of Food Processing Technology (IIFPT), Thanjavur

Indian Institute of Food Processing Technology (IIFPT) is a pioneer R&D Institute food processing, new process and product development under Ministry of Food Processing Industries (MoFPI), Government of India. Institute was founded by Dr.V. Subrahmanyan, (eminent scientist, CFTRI Mysore) as PPRC in 1967 at Tiruvarur, moved to Thanjavur in 1984, renamed as Indian Institute of Food Processing Technology in 2008 and renamed as IIFPT in 2017. Food Safety and Quality Testing Laboratory is NABL accredited. Incubation centre offers Hands-on-training on food processing technologies. IIFPT offers B.Tech., M.Tech. and Ph.D. programs in Food Process Engineering, M.Tech. programs in Food Science and Technology.R&D activities funded by DST,DBT,CSIR,ICAR,MFOPI, UGC and consultancies (from food processing industries) reached exponential growth.

Team Members

- M. Jaya Bharata Reddy (PI,NITT)
- V. Mariappan (Co PI,NITT)
- S.Senthil Kumar (Co PI,NITT)
- G.Saravana Ilango (Co PI,NITT)
- N. Sivakumaran (Co PI,NITT)
- M. Loganathan (Co PI, IIFPT)
- Sinija V R (Co PI, IIFPT)



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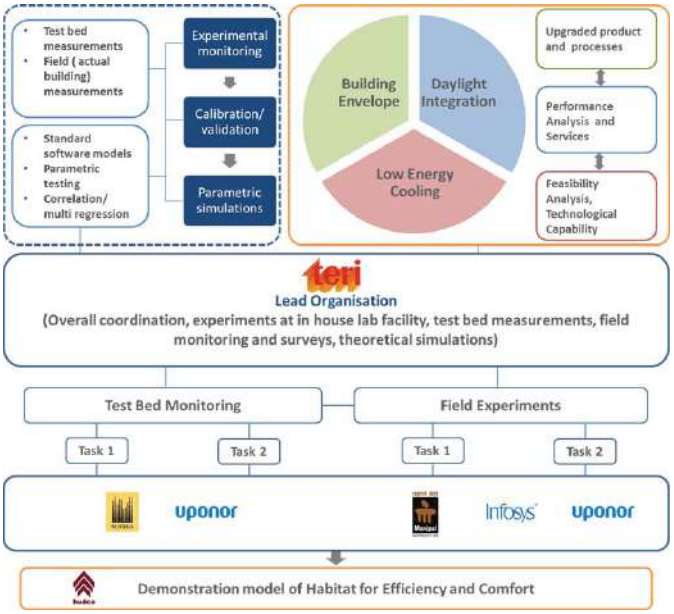
11. HABITAT MODEL FOR EFFICIENCY AND COMFORT (HMEC)

Principal investigator: Minni Sastry
The Energy and Resources Institute

Background of Project

Currently, the percentage of energy efficient or green buildings out of the new buildings being constructed in the country is only about 2-3% or even less (IGBC, TERI, 2015). One of the reasons for this is- efficient products and equipment, available in the market, are imported or are being produced by international companies and hence are not affordable and replicable on large scale. This case, is applicable for movable external shading device as well, though they contribute in reducing more than 10% of cooling load in a building, these are not integrated by developers, as they are very expensive. It is a need of the hour to manufacture and commercialize building products for India specific climatic conditions, in the proposed project it will be carried out for movable external shading devices.

Since artificial lighting and HVAC are responsible for significant percentage (60-75%) of electricity consumption, studies on innovative low energy cooling solutions are also proposed in the study. Low energy cooling strategies, such as the radiant slab cooling, it is monitored and quantified that more than 30% energy savings are possible when compared to conventional all-air system. Radiant cooling has a great potential to provide cooling at local level and more uniformly thus improving the occupant thermal comfort compared to convective cooling. However, there are no standards in India to define human/ occupant thermal comfort conditions for radiant cooled buildings, also there are no operational conditions established for radiant cooled buildings in India. The project will establish these and also investigate the potential of natural heat sinks in minimizing chiller requirement for chilled water generation, in radiant cooled buildings.



Outline and consortium structure of the proposal

Aim

The proposed research aims to focus on application orientated outcome, minimizing barriers to use innovative and cost effective building envelope solutions like "Shade smart", and low energy based radiant slab cooling to improve overall energy efficiency of the buildings in dense urban locations. Also, it is aimed to construct a demonstration model energy efficient habitat with solutions of -efficient building envelope, and low energy cooling.

Specific Objectives:
Task 1 - To provide economically viable and large scale replicable external shading device solutions for Indian building industry. The device will be able to minimize direct solar heat gains by 75%, while allowing diffuse natural daylight.

Task 2 - To design and demonstrate potential of low energy radiant slab cooling, integrated with natural heat sinks and establish benchmark for optimum operating condition for energy efficiency and thermal comfort.

Methodology

Task 1: Building envelope
Cost effective external movable window shading device (Residential & Commercial Buildings)
The shading system named as "Shade Smart" was developed by TERI as a cost effective solution for shading external windows in residential buildings. Under this subtask, it is proposed to upgrade the "Shade Smart" design for large scale replication in residential and commercial buildings, for both existing and new buildings.

For commercialization of Shade Smart, first step is to evaluate and establish the performance of designed and manufactured shading devices. It is proposed to install 2test beds, for monitoring performance of Shade Smart in North India latitude and South India latitude.

Image showing proposed demo habitat under the project with two innovative solutions

Along with industry partners, performance of "Shade Smart" will be evaluated in existing buildings.

As part of this task, a tool will be developed for stakeholders, to provide technical assistance in designing shading devices. Commercialization plan for Shade Smart will be worked together with industry partner Sobha Glazing.

Task 2 Low energy cooling systems
2a: Potential of radiant slab cooling coupled with geo exchange system
2b. Operative temperature based thermostat set points and evaluation of low energy slab cooled buildings

About ten existing radiant cooled buildings across the country will be studied for their thermal comfort performance. After analyzing surveyed data, operational conditions and thermostat set points for radiant cooled buildings in India will be proposed.Since in radiant cooled buildings, building envelope plays a key role, software simulations will be used to establish ideal envelope conditions for radiant cooled buildings in different climate zones.

Empirical analysis and simulations to test feasibility of natural heat sinks for generating chilled water for radiant slabs will be the next activity.The final activity will be design and demonstration of model energy efficient building integrated with radiant slab cooling and efficient envelope that will be monitored for its performance for a time of one year.

Expected Outcomes & Deliverables

a. **New/Upgraded Product:** "Shade Smart"- A novel and cost effective movable external shading device.
b. **New/Upscaled Process:** Thermal performance indicator for shading requirement in non-air conditioned, air conditioned and mixed mode buildings **Performance Analysis:** Establishment of test protocols for evaluation of performance methods for complex fenestration in Indian Conditions.
c. **Feasibility analysis:** Integration of natural heat sinks for radiant slab cooling technology
d. **Technological Capability:** Control mechanism for optimized thermal comfort performance in radiant slab cooled buildings
e. **Achieving State of art performance in a chosen device/system:** Design, demonstration of energy efficient, comfortable habitat integrated with hybrid radiant slab cooling and efficient windows.

About Institute & Previous Projects

The Energy and Resources Institute (TERI) is a leading think tank dedicated to conducting research for sustainable development of India and the Global South.TERI was established in 1974 as an information centre on energy issues. However, over the following decades, it made a mark as a research institute, whose policy and technology solutions transformed people's lives and the environment.TERI is registered under societies registration act 1860 (Punjab Amendment) Act, 1957 as applicable in Delhi.Centre for Research on Sustainable Building Science (CRSBS), under TERI, has been set up to facilitate development and mainstreaming of sustainable buildings, to improve performance levels of existing buildings, and raise awareness on sustainable buildings.

Some key projects of the Centre include High Performance Commercial Buildings in India, under APP partnership, which was carried out along with BEE to mainstream ECBC 2007. Another Research project has been with UNEP on developing framework for Sustainability Index of construction materials based on the concept of Sustainable Consumption and Production. The Centre has worked with IFC on feasibility of climate resilient affordable housing solutions. Centre has also been working with industry partners to evaluate performance of many efficient building materials.

Industry Partner and Team Members

Industry Partner: Manipal University (Academic and Research institute), Infosys (Information Technology industry), Sobha Galzing (Manufacturing and marketing window and glazing systems), Uponor (Indoor climate solutions, plumbing solutions) and HUDCO (Techno financing for Low cost housing and urban development) have been acting as the collaborators/ consortium partners.

Team member:
- Minni Sastry (Principal Investigator)
- Hara Varma (Co-PI)
- Sanjay Seth (Senior Advisor)
- Kiriti Sahoo
- Vini Halve
- Siva Ramakrishna Evani

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Hara Varma
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12. DEVELOPMENT OF A SOLAR BASED HUMIDIFIER-DEHUMIDIFIER LINKED WITH GROUND WATER

Principal investigator: Ajay Kumar Yadav
National Institute of Technology Karnataka

Background of Project

Due to environmental problems caused by synthetic refrigerants, there has been an upswing in the use of eco-friendly air conditioning system. Air cooling using ground water evaporation method offers an interesting and eco-friendly alternative to the conventional vapor compression air conditioning system. Basic evaporative cooling systems (humidifiers) are available in the market but a solar based evaporative system, using ground water, is not used in the Indian scenario. The temperature of ground water (at a depth of 7-10 m) is approximately 23°C which is much closer to human comfort as per ASHRAE standards (23.5-25.5 °C). Since the ground water temperature is invariant with the ambient conditions, this can be used for cooling/heating of a room air in summer/winter respectively.

Present day evaporative coolers (humidifier) provide less cooling comfort in the coastal areas (hot and humid climate). Solar assisted desiccant air conditioning is particularly useful where there are abundant solar resources with high temperature and humidity levels. The proposed cooling system uses a desiccant which can control the moisture content in the air. A solar heater will be used to regenerate the desiccant periodically. Dry and clean air produced from desiccant has various industrial applications.

Aim

This project is envisaged to develop a prototype of solar based sustainable low energy evaporative cooling/heating system using ground water for household applications. Whereas for industrial use, it is intended to develop a novel solar based dehumidifier using solid desiccants. An optimum geometrical and operating parameters for the desiccants will be determined through CFD study. An experimental test rig will be developed based on the optimum geometrical parameters obtained from CFD analysis. Developed evaporative cooler will also be tested in Bundelkhand (U.P.) region for its performance.
Main objectives are:

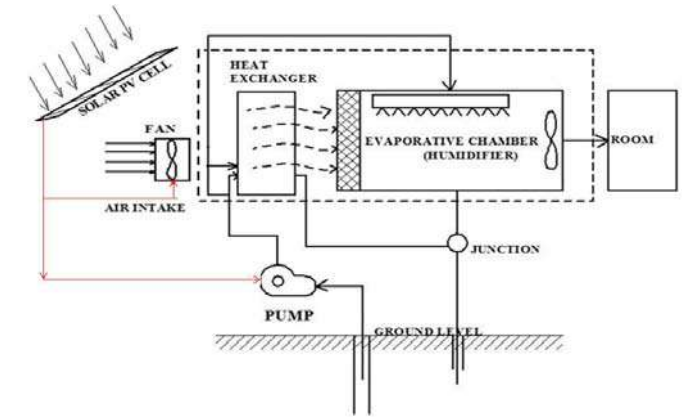
- To develop a prototype of solar based sustainable low energy evaporative cooling system (humidifier) using ground water.
- Development of a novel solar based dehumidifier using solid desiccants for industrial applications.

Methodology

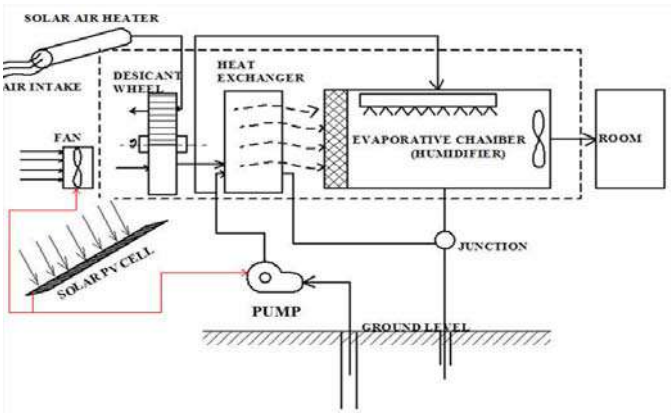
The project will be implemented in two phases; theoretical as well as experimental. The theoretical study will be focusing on the optimal design of each component. A schematic diagram of the evaporative air cooling system for hot-humid condition is shown in Figure (attached). It consists of one desiccant wheel (DW), one heat exchanger (H.E.), one humidifier (HU), one solar air heater, and two blowers. As ambient air passes through desiccant wheel it gets dehumidified and heated. This hot and dry air goes to heat exchanger where air gets sensibly cooled. Cool and dry air goes to humidifier where air gets evaporatively cooled. Enthalpy of air remains constant throughout the humidifier. Room is at constant temperature and humidity. As input parameters vary enthalpy of air at room inlet varies. Hence, cooling capacity of the system can be calculated for each and every inlet parameter. For hot-dry climate the desiccant wheel and solar air heater will be absent. The theoretical study will be focusing on the following:

1. A thermodynamic/psychometric analysis of the system.
2. Numerical modelling of the Dehumidifier to optimize the geometrical parameters.
3. Numerical modelling of the solar collector.
4. Study the effect of ground water temperature on the cooling effect of evaporative cooler.

Based on the optimal parameters obtained from the theoretical studies, experimental setup will be designed and fabricated. The performance of the system will be assessed under different operating conditions.



Schematic of proposed system for hot and dry climate



Schematic of proposed system for hot and humid climate

Expected Outcomes & Deliverables

An efficient, eco-friendly low energy evaporative cooling system (humidifier) will be developed for all climatic conditions. Additionally, an efficient desiccant based dehumidifier with solar assisted regenerative system will be developed. The proposed dehumidifier will be greatly useful in process & textile industries. As the system uses solar energy, the running cost of the product is nil but the initial cost may be slightly higher than the existing system. Cooling effect of evaporative cooler will be more as the system uses ground water.

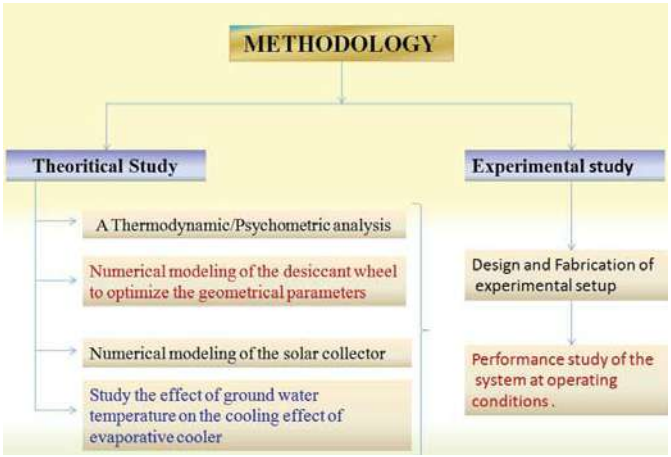
This is a clean energy, sustainable and advanced evaporative cooling system which can be used as an alternative to air conditioner as well as heat pump for all climatic conditions. This will be equally useful for the people staying in the remote villages as well as in the urban areas. Unlike vapor compression refrigeration system, very good indoor air quality (100%) can be maintained with low energy consumption.

About Institute & Previous Projects

About Institute: Since its inception in 1960, the National Institute of Technology Karnataka (NITK), Surathkal has established itself as a premier Institution engaged in imparting quality technological education and providing support to research and development activities. NITK is conferred the status of an Institution of National Importance vide NIT Act No.29 of 2007 by Govt. of India and is involved mainly in teaching and research. Presently, NITK offers 9 Bachelors, 28 Master's and Doctoral Degree programmes.

Previous Projects

1. Numerical and experimental studies on two phase carbon dioxide based natural circulation loops sanctioned by DST, SERB, New Delhi - 2014-17
   PI: Dr. Ajay Kumar Yadav
2. An investigation into the aerodynamic and aeroelastic behaviour of compressor cascade in a droplet laden flow sanctioned by DST, SERB, New Delhi - 2016-19
   PI: Dr. Anish S.



Industry Partner

Siskin Instruments Co. (P) Ltd. Bangalore is a 32 years old time tested enterprise engaged in laboratory Instrumentation used in research and quality control needs of process & product development. They do application based services of selected group of products like thermostatic bath, circulators, Membrane pumps, Ultrasonic cleaner, Homogenizer, Visco Systems & Glass Reactor.

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Anish S
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13. SMART ENERGY MANAGEMENT IN BUILDINGS

Principal investigator: Krithivasan Ramamritham
Indian Institute of Technology Bombay

Background of Project

The modernization of the electric grid is an ongoing effort in many countries. In Europe and the US, the current electric grid is based on older technologies that have evolved over decades. Evolving the current grid into a smart grid will require adopting and integrating multiple technologies for net/smart-metering, demand-response, real-time data monitoring, and variable pricing [DOE 2008, ISO-NE 2009]. Presently, US deployment of smart meters is further along than other smart grid technologies such as real-time demand response. As in the US, the grid in India is based on older technologies and is fragmented. In recent years Indian government agencies, like their counterparts elsewhere, have begun formulating policies and guidelines for adopting smart grid technologies (see [India SmartGrid 2010] for a discussion of policy issues). An additional problem that plagues the Indian grid is the gap between supply and demand - due to rapid economic growth, demand for electricity has risen rapidly and electricity generation has struggled to keep up. As a result, load shedding and rolling blackouts are common during peak usage periods, when supply falls short of demand. Consequently, Indian homes and businesses frequently rely on backup sources such as battery-based home UPS or portable diesel generators - an aspect that we will exploit in our proposed research on smart buildings and homes.

Aim

Knowing that the world is moving towards energy crisis, and the fact that around 40% of total energy in developed countries is contributed by buildings, we propose "Smart Energy Management in Buildings" that can reduce the energy consumption by gaining various insights into a building's behaviour while using minimum number of sensors.

- Develop a Smart Building Management System (BMS) that provides deeper insights about a building.
- The Smart BMS will provide a holistic view of a building using minimum number of physical sensors.
- The BMS will be designed to take actions in a timely manner based on sophisticated analytics.
- We will endeavor to demonstrate substantial savings in energy, to the tune of 50%, attributable to the proposed enhancements.
- Our proposal aims at achieving a multi-level view of a building, which can enable building managers to get deeper insights about the building's behavior.
- One way we will aim to reduce energy consumption is by exploiting louvre, "a set of angled slats fixed or hung at regular intervals in a door, shutter, or screen to allow air or light to pass through whose controlled deployment will allow the use of natural air and light to improve the quality of light and environment inside buildings while also reducing energy costs.

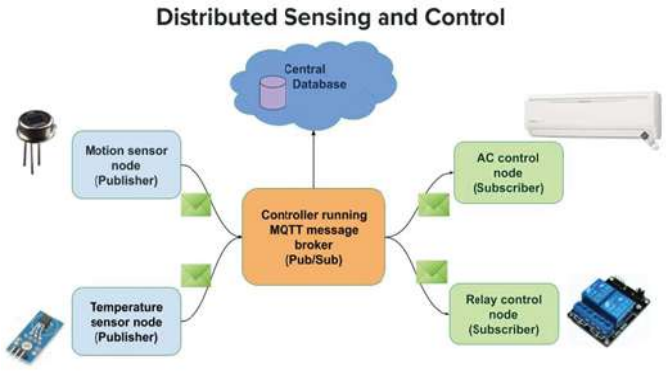
Methodology

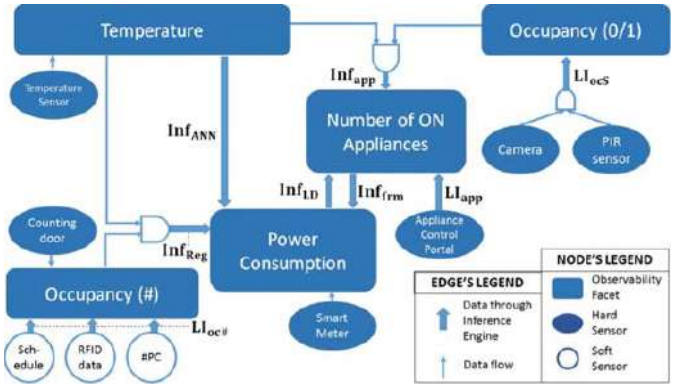
Smart Energy Management In Buildings that systematically uses the different approaches to achieve the aim of reducing energy consumption using minimal number of sensors. For achieving this goal, we define the fundamental blocks of smart energy management in buildings:

Sense Meaningfully, Analyse and Respond Timely (SMART) Cycle: After careful examination of how sensor works in an application, it was deduced that all the sensors follow the SMART cycle, where the sensor has to meaningfully sense the parameter it is designed to sense, analyse the sensed value (might even perform computation) to help in decision making and finally outputs a timely response, which can be decision or a value.

Facet-Sensor Relationship Graph: By analysing the input and output of different sensors, we claim that the output of one sensor can be used to predict the output of other sensors.

Aggregation to combine and propagate the data: With large number of sensors, it becomes important to use the data, generated by them, in a meaningful way. This can be achieved by combining the data from various sensors using an Aggregation Module. These values mainly help us to determine the state of the building and access to real time and archival data for performing analytics or inference.





Expected Outcomes & Deliverables

A Smart BMS, which performs tasks like tracking and controlling available energy, reducing and optimizing power consumption (PC), monitoring the status and health of the appliances in the building, requires the sensing of various facets, like power consumption, temperature, humidity and occupancy status. A straightforward approach is to deploy a network of sensors to sense these values in all parts of the building.

- Replace hard/physical sensors (PS) with soft sensors
- Use building structure to reduce the number of sensors
- Use correlation between different facets observed and sensors available

By capturing such relationships, we can further reduce the number of sensors and yet be able to observe more facets with less sensors, while keeping a check on accuracy constraints.

This project will be a building management framework which can be deployed in any building. The framework will indicate the type, location and minimum number of sensors required to obtain insights about a building. Research papers presenting our results will be published at premier conferences and journals. Sensor datasets from our deployments and source code from our prototypes will be released to researchers for further experimentation.
We will endeavour to demonstrate substantial savings in energy, to the tune of 50%, attributable to the proposed enhancements to energy management being applied, in various scenarios on campus.

About Institute & Previous Projects

Established in 1958, the second of its kind, IIT Bombay was the first to be set up with foreign assistance. In 1961 Parliament decreed the IITs as 'Institutes of National Importance'.

The institute is recognised worldwide as a leader in the field of engineering education and research. Reputed for the outstanding calibre of students graduating from its undergraduate and postgraduate programmes, the institute attracts the best students from the country for its bachelor's, master's and doctoral programmes. Research and academic programmes at IIT Bombay are driven by an outstanding faculty, many of whom are reputed for their research contributions internationally.

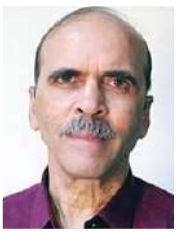
IIT Bombay also builds links with peer universities and institutes, both at the national and the international levels, to enhance research and enrich its educational programmes. The alumni have distinguished themselves through their achievements in and contributions to industry, academics, research, business, government and social domains. The institute continues to work closely with the alumni to enhance its activities through interactions in academic and research programmes as well as to mobilise financial support.

Previous Projects

- Establishment of Centre of Excellence for Training and Research in Frontier areas of Science and Technology sponsered by MHRD - Year 2014-18
- Designing Immersive virtual environments (IVEs) to promote environmental attitudes and pro-environmental behaviour (PEBs) in educational campus sponsered by MHRD - Year 2014-17
- Optimizing location and capacity of emergency response infrastructure for megacities sponsered by MHRD - Year 2014-17
- Towards an affordable and socially inclusive privatized healthcare: Learning from implementing and assessing a Swasth India project in Mumbai sponsered by MHRD - Year 2014-17
- Empowering citizens to plan and monitoring urban spaces sponsered by MHRD - Year 2014-17
- Smart and safe Electric power management for homes and buildings sponsered by TCS - Year 2013-16
- Designing a Smarter and Greener Electric Grid: A Sensor data Driven Approach sponsered by DEITY, Ministry of Information Technology - Year 2012-15

Industry Partner

Ever since we began work on Smart Energy Informatics, TCS has stood by our side providing both monetary as well as technical help. TCS has stationed one of its researchers in our lab to enable the collaboration. This new project offers a natural extension (and a new avenue) for the ongoing IITB-TCS collaborations.



Krithivasan Ramamritham
Center for Urban Science and Engineering
Indian Institute of Technology Bombay
Mumbai

Ronita Bardhan
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Indian Institute of Technology Bombay
Mumbai

14. DRIVING EFFICIENT LOW ENERGY COOLING TECHNOLOGIES - ASSESSMENT TO TECHNOLOGY TECH-TRANSFER (DELTA-T)

Principal investigator: N K Bansal
CEPT University

Background of Project

India, with population nearly 1.2 billion, is world's third largest greenhouse gas emitter. It has pledged to reduce carbon emission per unit of gross domestic product up to 35% by 2030 from 2005 level. The building sector is experiencing unprecedented growth leading to higher energy consumption(Govt of India,2015). India's electricity demand is expected to rise from 775 TWh in 2012 to 2499 TWh by 2030. Estimates by National Institution for Transforming India (NITI Aayog) indicates that the mitigation activities for moderate low carbon development would cost India around USD 834 billion till 2030 at 2011 prices(de Dear, Leow, & Foo, 1991). With an increase in affordability and power supply, the future shall a see a steep rise in demand for airconditioning. By 2030, 60% of commercial space and 40% of residential households in India are expected to be air conditioned. The space cooling systems adopted in developing nations like India have a great impact on the economy as well green-house gas emissions.

The ISO and ASHRAE thermal comfort standards are used to design space conditioning systems, where the systems operate at 22.5 ± 1°C. The ASHRAE 55-2010 standard includes an adaptive thermal comfort model to differentiate the thermal response of occupants in air conditioned and naturally ventilated buildings. However, until now there has been a lack of a contextual model for adaptive thermal comfort for India, even though a large proportion of existing as well as new buildings are either fully naturally ventilated or use natural ventilation for most part of the year, supplemented by air-conditioning.

Aim

The aim of the project is to

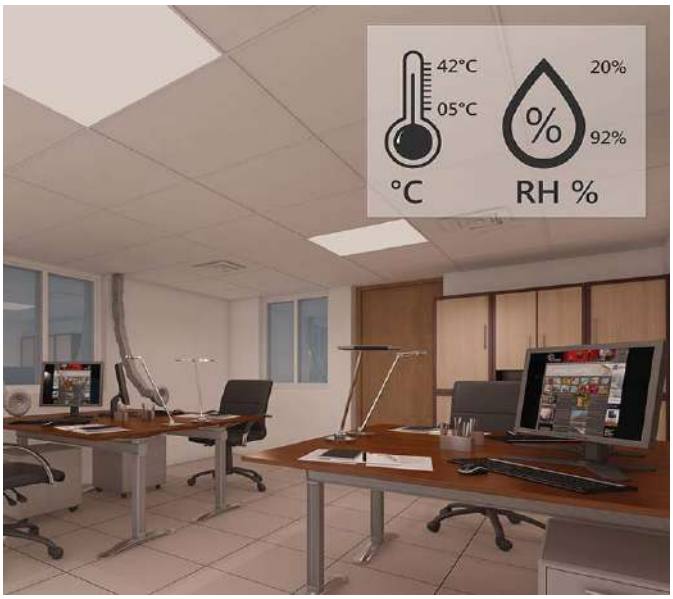
- Quantify energy saving potential of smart low energy cooling systems.
- Identify opportunities and develop cost effective scalable energy & environment monitoring sensing and controls systems to integrate with low energy cooling system to enhance performance of low energy cooling systems.
- Develop effective communication tool to work with existing energy models for low energy cooling system design development.

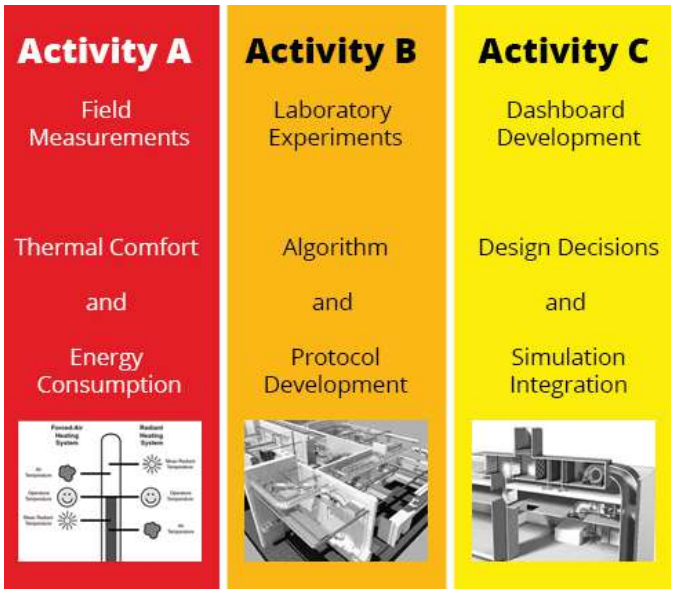
Methodology

Project has been envisaged to work in three distinct but symbiotic activities. Activity A will focus on field studies. Activity B will focus on laboratory experiments to develop operational protocol and algorithm for smart low energy cooling based on affordable sensors and controls and Activity C will deal with design decision making support and educational tool.

Activity A (Field measurements):
To evaluate energy and thermal comfort performance of low energy cooled buildings, a year round monitoring will be conducted. Total six commercial buildings, two each in Hot-Dry, Warm-Humid and Composite climate zone will be selected based on selection criteria.

Activity B (Laboratory experiments):
This activity will develop operational protocol and algorithm for low energy cooling using laboratory experiments. It will use thermal comfort experiments using thermal manikin and low energy cooling tested to investigate interdependency between cooling and comfort. During the process of developing protocol, in association with industry partners, researchers will





develop affordable sensors and control systems to increase effectiveness of low energy cooling systems.

The protocols and algorithm will be developed based on the research experiments to suggest smart cost-effective controls that will enhance performance of low energy cooling systems. The learning of the research experiments especially on cost-effective smart controls will also be applicable to residential low energy cooling systems once algorithms and operational protocols are established.

Activity C (Dashboard development):
This activity will develop a visualization and education tool to help architects and engineers take decisions regarding performance of low energy cooling system. The tool will read key design inputs from the users and will output visualization and performance information of low energy cooling system.

Expected Outcomes & Deliverables

The study will provide following outcomes:
Activity A (To evaluate energy and thermal comfort performance of low energy cooled buildings):

1. Building energy and thermal comfort performance report: A detailed report will be prepared outlining performance of low energy cooling systems in the buildings monitored. Report will also act as a best practice guide for monitoring and operating low energy cooling systems in two separate sections.
2. Development of Performance Baseline for Low Energy Cooling Systems: Extensive monitoring (indoor, outdoor, systems, and energy) of six buildings throughout the year will provide unique set of performance baseline for designers and operators to compare.

Activity B (Establishment of low energy cooling test bed and deriving protocols):

1. Establishment of Protocols for Low Energy Cooling System Performance Measurement: While measurement protocols are available for few low energy cooling systems at peak capacity, the multi-point measurements will be developed as part of the research project.
2. Understanding thermal comfort of Occupants in Low Energy Cooling Systems (Non-compressor based) Spaces: The study will provide extensive understanding of comfort expectations for low energy cooling systems. Quantifying thermal comfort of humans using thermal manikin will provide detailed understanding for conditions delivered by low energy cooling systems.

Activity C (Developing Low Energy Cooling Tool):
One of the key barriers in implementing low energy cooling systems is less understanding of system limitations. This tool is designed to make designers more aware of system operation and expected performance (when will the system work and when it will fail) to design appropriate low energy cooling systems in the building.

About Institute & Previous Projects

CEPT University Established by Act No 24 of 2005 of State Government of Gujarat and notified through the State Gazette vide Notification Number GH/ISH/5/CEP/2004/3402/Pt-I/KH-1 of 2005 dated 11th April 2005. Included in the list of Universities maintained by UGC under Section -2(f) of the UGC Act 1956.
The previous/ongoing projects of the institute are as follows:

- US-India Joint Center for Building Energy Research and Development (CBERD) funded by The U.S. Department of Energy (DOE) and the Department of Science and Technology (DST), GOI
- Set up Centre for Excellence in area of Solar Passive Architecture and Green Building Technologies funded by Ministry of New and Renewable Energy (MNRE), GOI

Industry Partners

CEPT University have signed Non-Disclosure Agreement (NDA) to following four industry partners for the purpose of proposal development. CEPT University will sign Intellectual Property Agreement (IP agreement) in case of successful evaluation of proposal and in case of award of research project to CEPT University.

1. Bry Air (Asia) Pvt. Ltd: Bry-Air prodeces state of art air and humidity management system.
2. Schneider Electric India: Schneider Electric India (SEI) develops connected technologies and solution to manage energy and process in ways that are safe.
3. ContraVolts Infotech Pvt. Ltd: ContraVolts is Bangalore based start-up firm offering a complete range of high class engineering simulation services and technical solution in area of computational fluid dynamics.
4. PiRhoAlpha Research Pvt. Ltd: PiRhoAlpha is Mumbai based startup organization involved in development of affordable sensor technologies to monitor indoor environmental conditions.

Dr. N K. Bansal
Professor Emeritus
SINTEX Professor Chair

Rajan U Rawal
Asst. Professor Faculty of Design
Executive Director of Centre for Advanced Research in Building Science and Energy
CEPT University

15. ENERGY EFFICIENT LIGHTING WITH VISIBLE LIGHT BASED COMMUNICATION AND POWER LINE COMMUNICATIONS

Principal investigator: Abhinav Kumar
Indian Institute of Technology Hyderabad

Background of Project

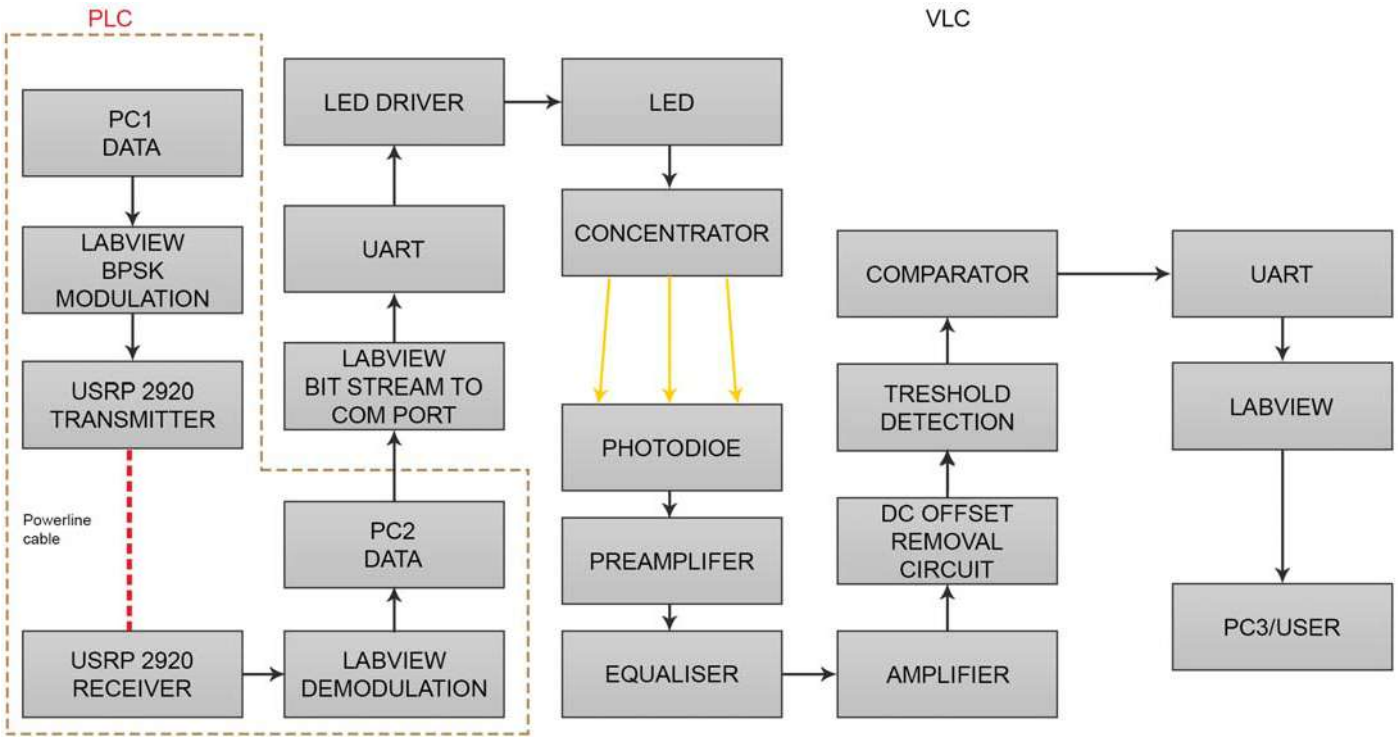
The brisk growth of communication systems in the recent time are making the existing communication channels crowded. A lot of research is being put into new communication channels that are reliable and support high data rates. Developments in digital modulation schemes allow high speed communication even in hostile mediums. With the recent improvement in Light Emitting Diode (LED) illumination technologies Visible Light Communication (VLC) has turned out to be great option for indoor communications. VLC can work in parallel with existing radio frequency (RF) systems to provide a better Quality of service(QOS) to the users. Currently LEDs are increasing exponentially due to their long lifetime, higher reliability, low power consumption as compared to fluorescent and incandescent illumination sources. This is a retro fit system to fulfil the illumination purpose while capable of providing high data rate communication. With properties like license-free bandwidth (BW), non-hazards and non-interference with existing RF communication systems VLC can provide Internet of Things (IOT) and 5G communication systems for indoor down-link scenario. The other communication channel that can be used is, power line channel. Power line transmission is everywhere. Also, indoor power outlets make Power Line Communication (PLC) one of the best source for implementing smart home networking. Integrated PLC and VLC system can be compared with 'Ethernet and Wi-Fi' system, where the wired communication part is played by PLC and wireless communication part is played by VLC.

Aim

In this project, we will design optimal LED placement algorithms with sensing and dimming schemes for energy efficient operations of lighting. We will design and analyze the performance of visible light based communication (VLC) system using the LEDs. Further, we will design and analyze the performance of broadband power line based communication (PLC) system over existing wiring till LED. We will also develop a prototype of a working energy efficient VLC+PLC link used for both communications and lighting.

Methodology

The research group at IIT Hyderabad has significant past experience in the domain of wireless communications. That includes cellular, wifi, mmwave, LTE-U, Zigbee based communications among others. Hence, the team at IIT Hyderabad will focus on the VLC. Further, the team at IIT Hyderabad is already working on optimal base station placement, base station switching off/on, and base station cooperation in the context of energy efficient cellular networks. A similar approach is required to solve the problem of optimal LED placement and for designing appropriate switching on/off plus dimming algorithms for energy efficient VLC. The team at NIT Goa has excellent past experience in designing narrow band PLC systems. This will be a great asset in designing the broadband PLC based controller to LED communication link. Each team will initially procure several existing standalone VLC



Integrated system block diagram

and PLC systems to perform thorough performance analysis of their respective systems. This will also help in proposing better schemes for both VLC and PLC. The VLC system will also be used to design optimal LED placement schemes that result in joint data rate and light intensity maximization at the least possible energy consumption. Finally, the two systems will combined to create the novel VLC+PLC prototype. The PLC based controller will also be designed as part of the project.

Expected Outcomes & Deliverables

Outcomes:

- Energy efficient scheduling schemes for LEDs/lighting
- New VLC+PLC prototype as a proof of concept
- Performance analysis of existing PLC and VLC systems.

Deliverables

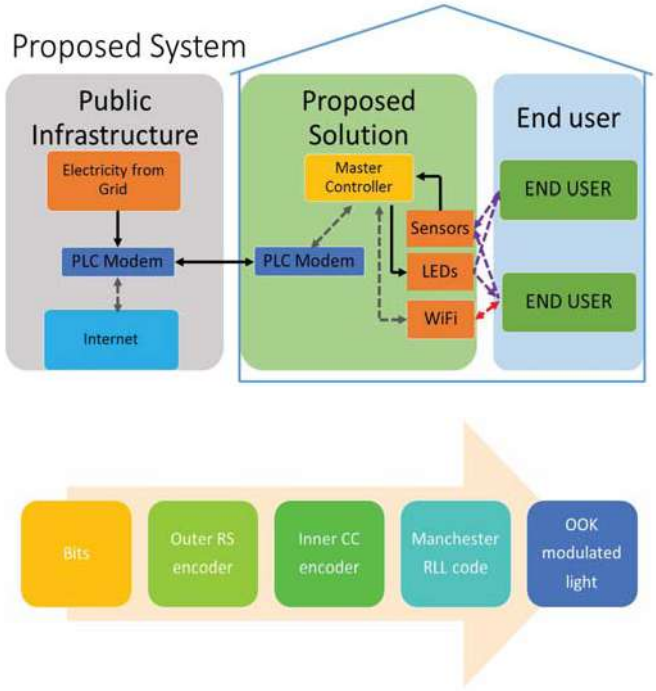
- Publication of the new results in conferences and journals
- In case the developed schemes are patentable file suitable IPR application

About Institute & Previous Projects

Indian Institute of Technology (IIT) Hyderabad is an institute of national importance setup in 2008. Already with 180+ faculty and 2000 students, it is amongst the fastest growing research institute in India. More than 50% of the 2000 students are graduates, heavily involved in research and development activities. The PI's have existing or completed projects in the area of LTE's operation in unlicensed spectrum, intelligent transport systems for smart mobility, and self-powered wireless chipset for building to building communications.

The previous/ongoing projects of the PI/Co-PIs are as follows:
DST funded "Performance evaluation of cellular networks in unlicensed spectrum co-existing with WiFi" 2016-2019 as YSS for Dr. Abhinav Kumar

DEITY funded "Self powered wireless chipset for building to building communications", 2013-2016. For Dr. GVV Sharma



Sample OOK transmitter block diagram for VLC

Abhinav Kumar
Assistant Professor
Indian Institute of Technology
Hyderabad

G V V Sharma
Assistant Professor
Indian Institute of Technology
Hyderabad

16. DESIGN AND DEVELOPMENT OF A LOW COST AND EFFICIENT STANDALONE PHOTOVOLTAIC SYSTEM WITH THREE PORT CONVERTER

Principal investigator: Susovon Samanta
National Institute of Technology Rourkela

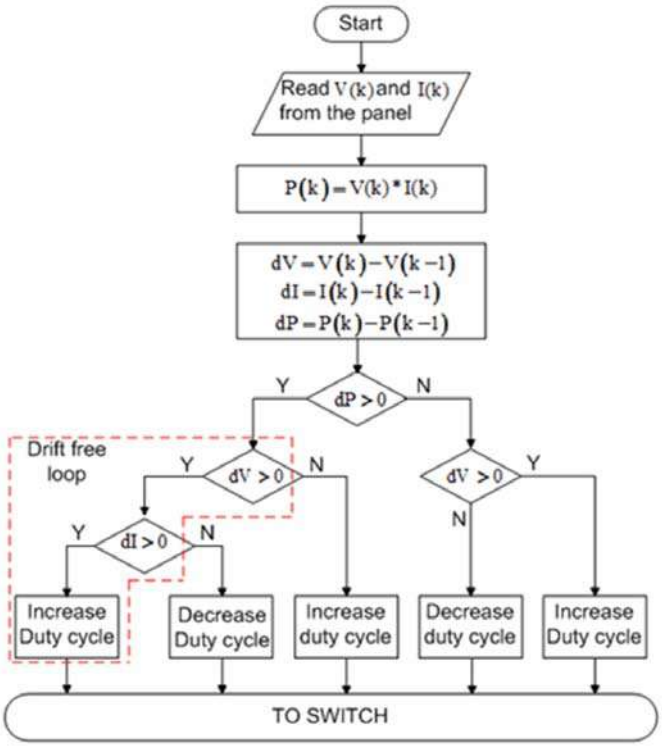
Background of Project

Many types of photovoltaic (PV) power conversion systems have been developed including the grid-connected system for reducing the power from the utility and the standalone system for providing load power without utility. The standalone system requires battery for energy storage to supply the load power during the period without or shortage of solar radiation. To provide a specific voltage level for load and control power flow between input sources, a dc-dc converter is needed for each input sources. Usage of a dc-dc converter for each input sources effectively increases the price, mass and loss of the overall system. A three-port converter (TPC), which contains an input port connected to an input source, an output port connected to a load, and a bi-directional port connected to a battery, is a good candidate for a standalone PV system which interfaces a renewable source with a load along with an energy storage element. The household appliances in India generally require a single phase 230-V, 50 Hz supply. A standalone PV system is mostly designed with low voltage levels for the PV array and battery in the range of 24-36 V. So, for a stand-alone AC system boost-TPC is suitable, because the load voltage is higher than the input voltage. Other option will be to use a transformer after the H-bridge inverter to boost up the voltage. So, this proposal will address different issues related to the three-port dc/dc converter in integrating a PV system to battery and load (both AC & DC loads).

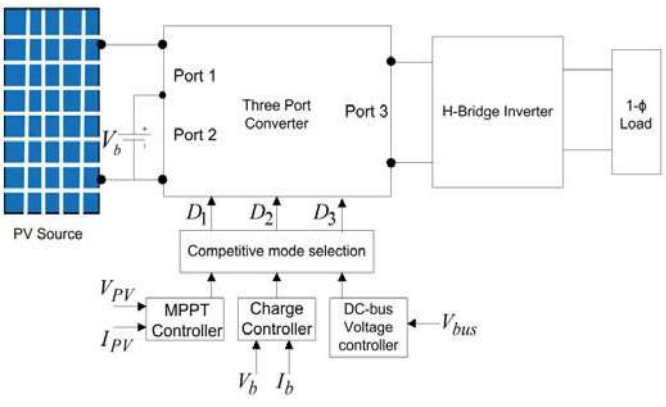
Aim

The main objective of the proposal is to build a cost effective and marketable low power PV based standalone system prototype inside NIT premise for household and industrial application located in remote places. Fabrication and shaping the prototype to a product will be done with the active help of the industry partner M/s Hertz Power Control, Kolkata. So based on this following are the objectives of the proposal.

1. Design and Development of a suitable TPC topology for standalone PV system.
2. Evaluation of tracking performance of most popular MPPT techniques for stand-alone PV systems with TPC.
3. Design of three port converter and it's small signal analysis for the implementation of low cost single voltage sensor based maximum power point tracking algorithm.
4. The peak power tracking performance (i.e., steady state behavior and drift analysis) of the PV system with TPC, in case of fast change in weather conditions will be addressed.
5. Design and development of an efficient and low cost power management strategy (i.e., peak power tracking, battery charge controller and load management).
6. Design and development of H-bridge Inverter and integration with TPC



Flowchart of Proposed Modified P&O MPPT algorithm to be implemented in TPC



Proposed schematic for development of PV based standalone system with Power Management algorithm

Methodology

The uniqueness of the proposal is to design and develop a cost effective and marketable low power PV based standalone system prototype. The overall system will consist of a three port dc/dc converter, H-bridge inverter and power management algorithm. Brief methodology is as following:

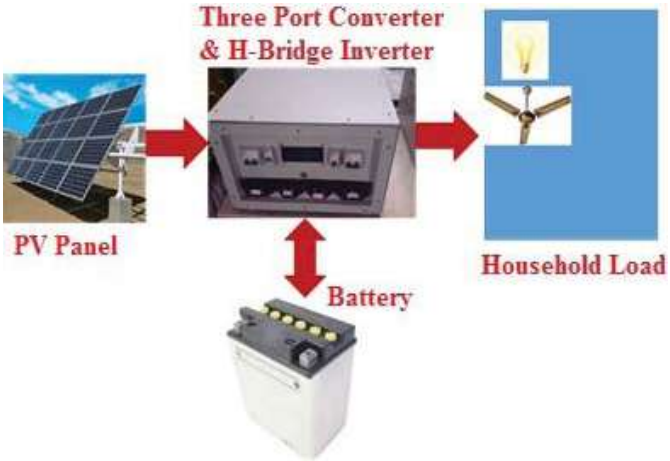
i. Review and simulation of existing PV-based standalone topologies
ii. Review of three port converter topologies suitable for the present design
iii. Evaluation of Solar PV tracking performances of most popular MPPT techniques for three port converters
iv. Development of an efficient and low cost power & battery management strategy for standalone PV converter system
v. Integration of H-bridge Inverter with the three port converter
vi. Prototype hardware development that is marketable for low power household application.

Expected Outcomes & Deliverables

i. New/Upgraded Product: PV-based standalone system will be developed which will consist of three port converter and H-bridge Inverter. Efficient and low cost power management algorithms will be developed.
ii. Performance analysis: Performance analysis will be done on existing standalone PV-based topologies and algorithms. (Scientific data generation, analysis and evaluation)

The outcome of the project includes

a. Development of a PV-based standalone system suitable for low power home application.
b. Patent/Publications (SCI) are the expected scientific output from the proposal of the project.



Overview of the proposed scheme of the PV based standalone system

About Institute & Previous Projects

NIT Rourkela is one of the premier national level institutions for technical education in the country and is funded by the Government of India. Government of India has elevated the Regional Engineering College, Rourkela to a deemed university under the name of National Institute of Technology, Rourkela. In the recent ranking by MHRD, NIT Rourkela ranked 12th among engineering colleges across the country.

Prof. Samanta (PI) of this proposal is working for several years on different aspects of DC-DC converter. He is currently handling 3 other sponsored projects the details of which are given below.

Previous Projects:

1. Design & Development of a Bidirectional DC-DC Converter with Power & Energy Management of Battery and Ultracapacitor for an Electric Bike with Regenerative Braking, SERB-DST, March 2015-March 2018 (Ongoing)
2. Modeling and Controller Design for Active Clamp Forward Converter with Multiple Outputs used as Electronic Power Conditioner (EPC), ISRO, April 2015-April 2017 (Ongoing)
3. Hybrid Optimization Based Fractional Order Fuel Cell Modeling and Online Parameter Estimation with Design of Adaptive Controller for Integrated Power Converters, NRB, DRDO, May 2015—May 2018 (Ongoing)

Industry Partner

Industry partner of this project is M/s Hertz Power Control, Kolkata. They have been engaged in developing various power electronics equipment mainly used for research and development activities in various IITs and Government funded institutes.

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Assistant Professor
Department of Electrical and Electronics
National Institute of Technology
Rourkela

Gopalakrishna S
Assistant Professor
Department of Electrical Engineering
National Institute of Technology
Rourkela

17. STANDALONE EVAPORATIVE AIR COOLER PUMP FLOW AND FAN SPEED CONTROLLER USING SOLAR ENERGY

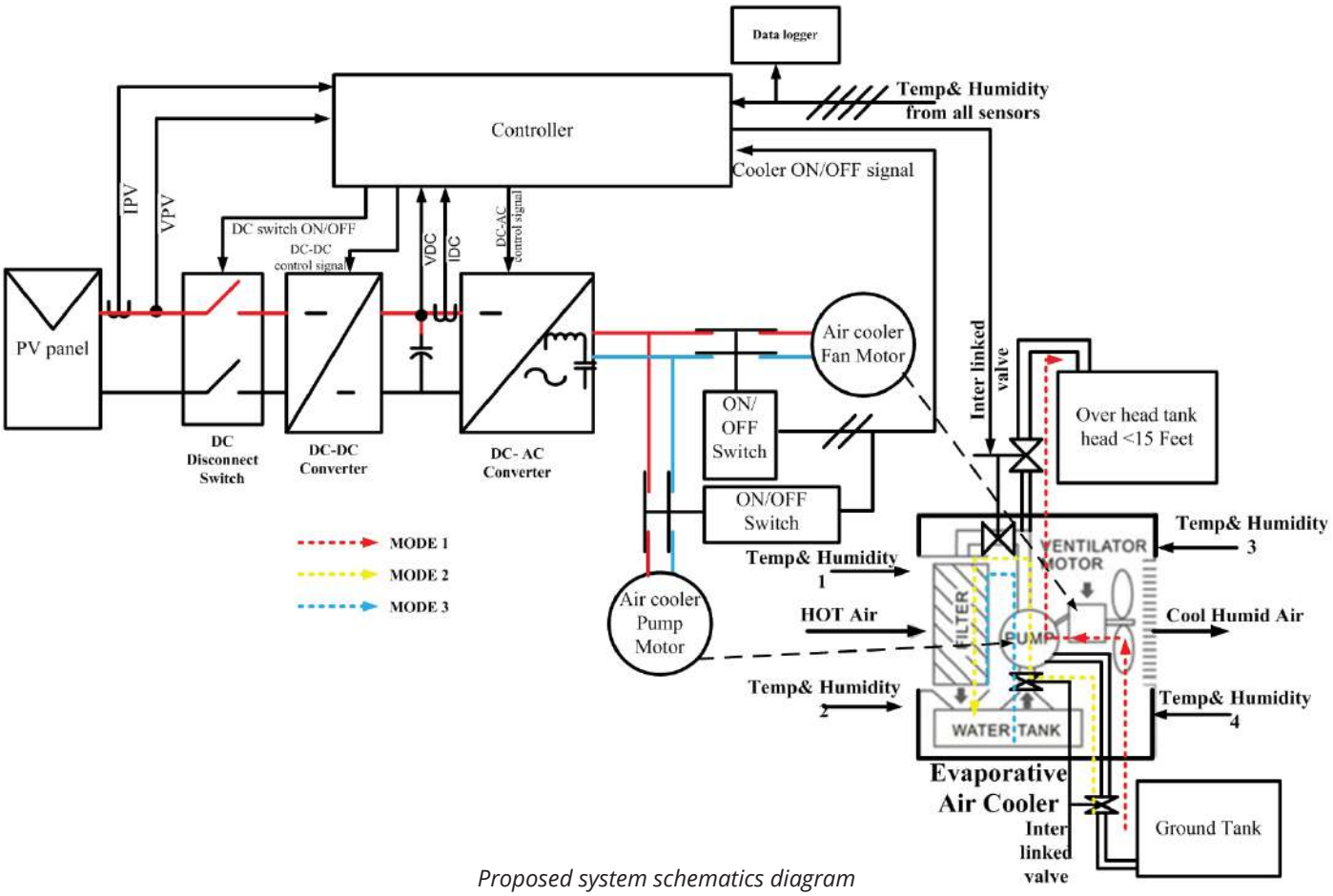
Principal investigator: B. Venaktesa Perumal
National Institute of Technology Karnataka

Background of Project

In India the per capita income is around Rs.1.00 lakh per year. During summer, the temperature in most of the places reaches about 45º C. And also the load shedding is frequent everywhere in India. Affordability to avail an air conditioner with the per capita income is highly impossible. To overcome these issues the proposed solution provides the thermal comfort for a small room. This product will be sell through the distributors of the solar water pumping systems to reach the every village in India. Due to the advancement in the solar panel manufacturing technology the cost the proposed product will reduce which will increase the volume of the product. The proposed solution can be used during summer and winter, during the summer it can act as a cooler and also used to pump the water from sump to overhead tank within 15 feet height. During winter it can be used as a water pump. This option provides high return on investment to the customer apart from the zero electricity bill (cooler power consumption). The reliability of the product is high due to the absence of the energy storage element (battery less).

Aim

To design and develop a solar driven evaporative air cooler for rural application. High efficient and effective converter need to be identified, to operate cooler pump and fan motor in the proposed evaporative air cooling system. Proposed converter behavior needs to be verified and validated in both simulation environment and hardware. Also behavior of the system needs to be studied for different environmental conditions like variation in ambient temperature and humidity to optimize the solar panel requirement. To enhance the performance of the proposed system, study has to be made on cooler pump to operate as normal water pump (pump the water within 15 feet head) when the air cooler is not in use. The proposed system is off grid based system to minimize the grid power usage during the summer especially in India.



Proposed system schematics diagram

Methodology

Fig. 1 shows the system diagram. The evaporative cooler is fed from the PV through power electronics converters. The dc-dc converter will be used to convert the PV generated power to electrical power by using perturb and observe based MPPT algorithm technique. The generated DC electric power can be used either directly or by one more conversion. The DC power is converted into AC by using DC to AC converter as shown in Fig. 1. This AC power is fed to pump and fan in the evaporative air cooler. In other way directly the generated DC power can be fed to DC motor of the pump and fan in the evaporative air cooler. Performance of both the configurations will be verified and validated. Environmental condition based study will be done on the system using thermal and humidity sensor to optimize the panel sizing based on the thermal lag effect. Additional pipe arrangement is made to pump the water (below 15 feet head), when the air cooler is not in use. The entire solar generated power is utilized effectively without using battery. Out of these the cost effective best performance configuration will be suggested. Reliability of the proposed system is increased due to the absence of battery and associated charging circuit. Fig.2 shows the irradiance variation over a normal day (during summer). This shows the temperature variation inside the room with thermal lag. The thermal lag will be taken care by the appropriate selection of the solar PV size. The PV power generation profile will also be similar to irradiance variation. By using the PV the solar energy is extracted and processed by the power converters to operate the evaporative cooler.

Expected Outcomes & Deliverables

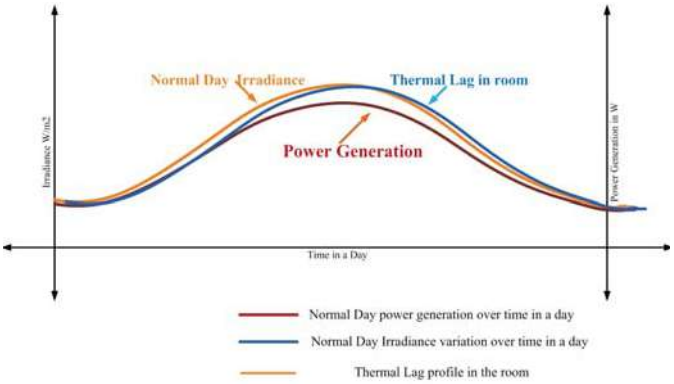
- Effective utilization of solar energy to produce the thermal comfort in rural areas (one small room or shop). During summer the temperature shoots upto 45⁰ C. in India. Using air conditioner to get thermal comfortness increases the grid demand also the grid reliability is also questionable. With the proposed solution it is possible to minimize the utilization of the grid.
- The proposed evaporative air cooler is automatically controlled according to sun light variations. The power generated from the solar panel changes according to the irradiance and temperature. No separate control is need for the thermal impact. The variation in the irradiance takes care of the temperature. The mechanical design of the water sprayer inside the coir mat is controlled according to the sunlight without separate control mechanism.
- Cost effective solution to get a thermal comfort. It does not consume the grid power and battery less system. The system will be utilized throughout the year, either as a cooler or pump.
- Solar power is utilized to pump the water (within 15 feet head) when the cooler is off. This enables the fresh water circulation in the air cooler provides healthy solution.
- Product works on off grid without battery. Solar panel is the only source for the proposed air cooler. Panel maintenance is easier.

About Institute & Previous Projects

NITK Surathkal is a premier Institution engaged in imparting quality technological education and providing support to research and development activities. NITK has carved a niche for itself among the best technical institutes in India. NITK offers 9 UG, 26 PG programs and PhD programs. Research at NITK Surathkal is an integral part of curriculum and thus the essential component in teaching-learning process. It is a success story at NITK. During 2015-2016, total of 74 on-going sponsored research projects were being carried out across all departments and the funding is INR 36 crores.

Industry Partner

Bruhat Energy solutions and Technologies pvt ltd. is incorporated in Mangalore and is engaged in the manufacturing and trading of solar products esp. solar inverters for rooftop systems (500 W to 10 kW), Charge regulators and lamps/lights. They are intending to engage in the research of novel solar based products.



Irradiance variation and PV power generation variation over normal day

B. Venaktesa Perumal
Department of Electrical and Electronics
National Institute of Technology
Karnataka, Mangalore

18. DEVELOPING ENERGY EFFICIENT AND ECBC COMPLIANT OPAQUE WALL ASSEMBLY UNIT FOR WARM & HUMID CLIMATE AS WELL AS HOT & DRY CLIMATE

Principal investigator: Roshni Udyavar Yehuda
Science & Technology Park

Background of Project

Opaque wall assembly comprises a major component of building envelope that is directly related to building heating and cooling and to the thermal comfort of occupants. A CMIE study conducted in 2001 indicated that nearly 34% of energy consumption in residential buildings in India is attributed to fans while in the commercial sector nearly 60% is attributed to HVAC. This clearly indicates lack of thermal comfort in the summer months and the resulting use of fans and AC for providing thermal comfort. This is mainly due to poor design of building envelope.

While the Energy Conservation Building Codes (ECBC) launched by the Bureau of Energy Efficiency (BEE), Ministry of Power, Govt. of India in 2007 provides U-values for opaque wall assemblies, roofs and fenestrations of the building envelope, it is presently applicable only for commercial buildings and is yet to be mandated by all States in India. Attempts to work on pilot projects compliant with ECBC have shown that very few options are available in the market for walling materials.

With technological advancement, people failed to continue the tradition of maintaining harmonious balance between buildings, climate and their lifestyle. Modern architecture has become a "conquest" of nature in the sense that, environmental conditions notwithstanding, a building could be given a sleek, clean and well proportioned exterior façade, and the interior made as comfortable as required with the help of artificial devices. However, the drawback is that, such buildings consume an enormous amount of energy.

Aim

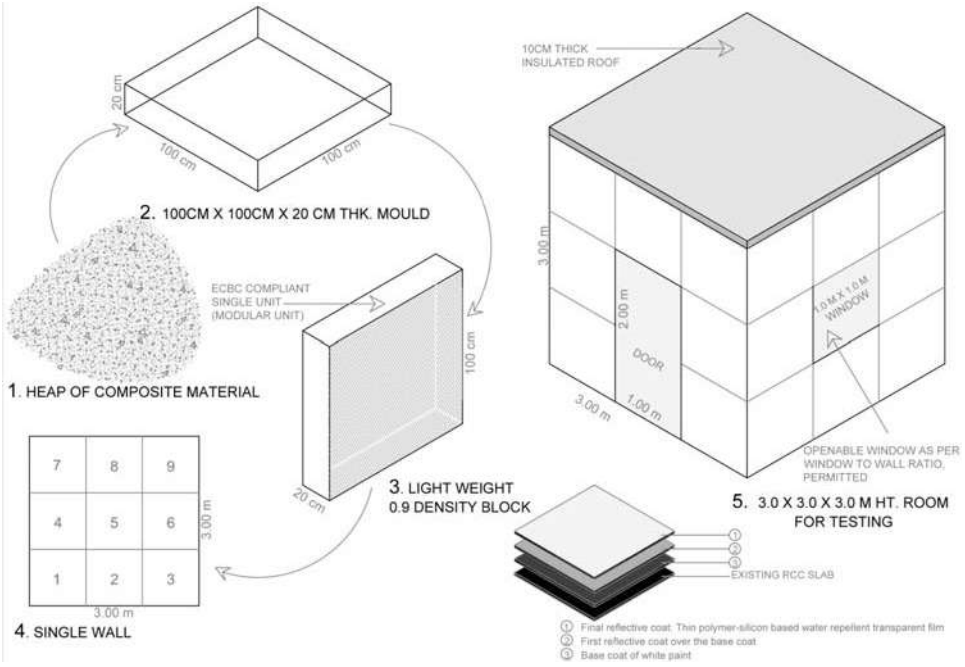
The aim of the project is to develop alternative energy efficient opaque walling assembly materials that are sustainable in the Indian context. The objectives are:

1. To review existing walling materials used in building envelopes in warm-humid and hot-dry climates for thermal behavior and energy performance
2. To develop a theoretical framework for assessment of thermal and physical / structural properties of opaque wall assembly and set benchmarks with respect to sustainability
3. To develop modular units of suitable sizes that could be assembled into an opaque wall assembly
4. To develop opaque wall assembly with following characteristics:
    a. Low embodied energy – process and transport energy
    b. Modular - which provides flexibility and ease of assembly
    c. Self-cooling – natural breathing material
    d. Provides thermal comfort in warm-humid and hot-dry climates
    e. ECBC compliant
    f. Economical

Methodology

The methodology for the research is described below:

1. Review of existing walling materials, their thermal properties and behavior – study through review of literature and experimentation;
2. Develop a theoretical framework in collaboration with industry partners and collaborators for assessment of



Flow chart and Diagram of experiment working

thermal and physical / structural properties of opaque wall assembly and set benchmarks with respect to sustainability and thermal behavior
3. Benchmarking material properties with respect to compliance with ECBC and sustainability
4. Study of raw materials, technology update – market survey, literature review and experimentation
5. Advantages and shortcomings of existing walling materials
6. Develop sustainable modular units of opaque wall assembly with following characteristics:
   a. Low embodied energy
   b. Modular - which provides flexibility and ease of assembly
   c. Self-cooling
   d. Provides thermal comfort in warm-humid and hot-dry climates
   e. ECBC compliant
   f. Economical
7. Develop three to five different prototypes for 2 climate zones
8. Testing of prototypes for their performance with respect to sustainability, self-cooling abilities (optimized thermal performance) for warm-humid and hot-dry climates
9. Construction of life size test unit for performance evaluation

Expected Outcomes & Deliverables

Deliverables will be in the form of a new product(s) for opaque wall assembly for any type of building (residential, commercial or industrial) which will be self-cooling, modular and sustainable (characteristics identified in objectives) and the cost of which will be below the standard costs for a conventional wall.

To assess the success of the deliverables of the project - Modular Opaque Wall Assembly for warm-humid and hot-dry climate, an index will be developed which will include the following criteria:

1. Workability/ Suitability for building construction work – this will include aspects such as construction time, labor requirement, mechanical equipment requirement, local resources
2. Assessment with respect to thermal behavior – this will include comparison with thermal transmittance values given in ECBC envelope performance factor and other such standards.
3. Cost benefit analysis in comparison with conventional walls – this will include initial cost, running cost, energy savings and payback period
4. Scale up for manufacture at large scale – this will include market availability, ease of construction, cost and technological feasibility
5. Sustainability – this will include aspects such as embodied energy, pollution, recyclability, reusability, longevity and renewability

The above criteria will be developed statistically with weightage assigned to each aspect.

About Institute & Previous Projects

Science and Technology Park is an autonomous not-for-profit institute established in 1986 supported by National Science and Technology Entrepreneurship Development Board (NSTEDB) of Department of Science and Technology, Government of India. It provides advisory and policy services to the government departments, industries and public funded institutes. The Park is well recognised for its support in e-governance, environment and sustainable development services, business incubation, energy efficiency and nonconventional energy advisory services, funding innovation, social and rural incubation. The Park has brought into the market several innovative products and many of those are in sustainable buildings.

Pune Municipal Corporation is the first Urban Local Body in the Country to take up implementation of Eco – housing Programme developed by Science and Technology Park. Scitech Park has developed climate responsive Eco housing criteria version I and II which was funded by United States Agency for International Development (USAID) along with its technical partner International Institute for Energy Conservation (IIEC). Scitech Park has also developed Eco housing criteria for retrofit construction for Municipal Corporation of Greater Mumbai in partnership with USAID and IIEC.

Industry Partners

The industry partners for the project are Panasia Engineers and Godrej Construction. Panasia Engineers Pvt. Ltd. have been in the business of natural cooling since 1970. They designed the cooling tower for the CII Godrej Green Building Centre, India's first Platinum rated green building. Godrej Construction is part of the Godrej & Boyce Manufacturing Ltd. (est. 1897)- Construction Division (est. 1997), Mumbai is involved in manufacture of TUFF blocks and providing turn-key construction for medium and large scale projects in India; has in-house advance R&D facilities.

Roshni Udyavar Yehuda
Advisor
Environment & Sustainability
Science & Technology Park
Pune

Vikram Saraph
Group Director
Architect and Planner
Science & Technology Park
Pune

19. INNOVATIVE APPROACH TO ENERGY SAVINGS IN NEW AND EXISTING INDIAN HABITATS: MULTILAYER SYSTEM FOR ENERGY EFFICIENCY USING PHASE CHANGE MATERIALS

Principal investigator: Ghanshyam Pal
SRM University

Background of Project

Due to long and hot summer season in India, cooling and heating (during winter) of these buildings has a huge energy footprint and, hence, consumes large amount of electricity. The solution involves reducing the electricity consumption in residential and commercial buildings by increasing the energy efficiency of these structures. Incorporation of phase change materials (PCM) in buildings could reduce the electricity consumption in heating and cooling of these buildings. The proposed PCM system can be easily integrated in to new or existing residential/commercial buildings. The system can also be used to improve thermal comfort of habitats which does not have air-conditioning.

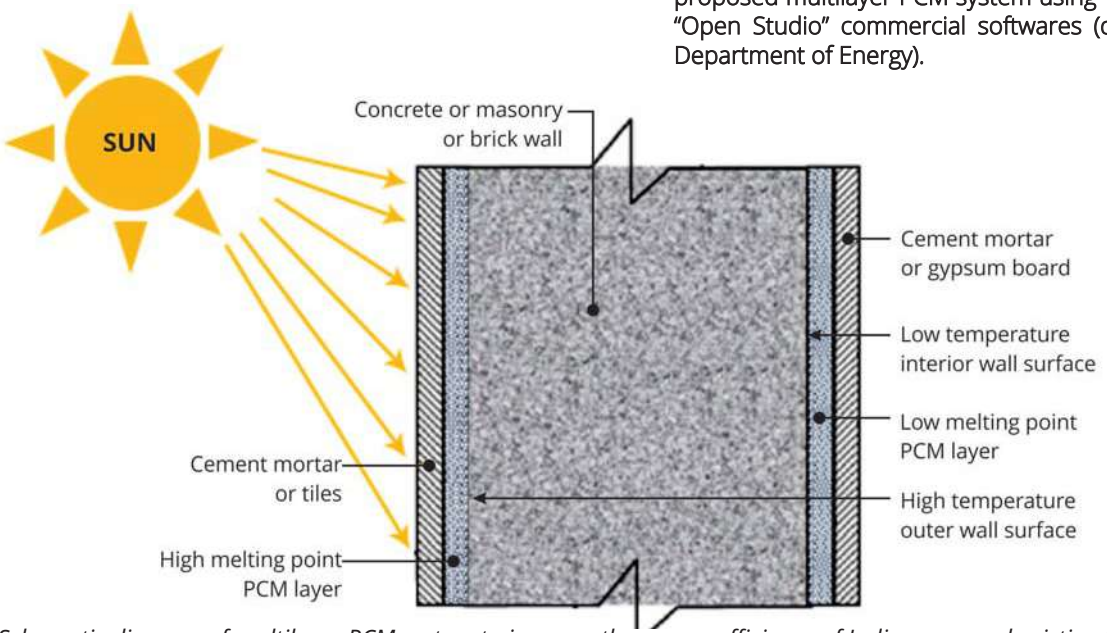
The building envelope heats up due to solar radiation. During the day time, there exists a negative thermal gradient across the thickness of the building wall. The multilayer PCM system proposed in this project consists of two layers of microencapsulated or form stabilized PCM material, one layer PCM for each outer and inner surface of the building wall.

As the day starts, the outer surface of the wall starts heating up. When the wall outer surface temperature reaches melting point (phase change point) of PCM, the heat energy is absorbed as latent heat by PCM. Since, melting is an isothermal process, a part of solar energy incident on the wall outer surface is utilized in melting the PCM which limits the heating of the wall. Concrete is bad conductor of heat and therefore the inner surface of the same concrete wall remains at relatively lower temperature than the outer surface. A second layer consisting of low melting point PCM material is placed on the inner surface of the wall. The inner PCM system layer functions in the same way as the outer surface PCM layer and utilizes the heat energy reaching the inner wall surface as latent heat for PCM melting but at lower temperature. Therefore, a significant part of energy reaching inner wall surface is getting consumed by the inner PCM layer in an isothermal process (melting of low temperature PCM) and not contributing to rise in room temperature. It has been shown that in use of PCM in residential and commercial structures reduces the energy demands of air-conditioning systems and can improve the energy efficiency of the entire building.

Aim

The aim of the project is

- Characterization of organic and inorganic PCM based on material properties, namely, PCM latent heat, PCM melting temperature, volatile organic content (VOC) level during phase change cycling, thermal stability and local availability in India.
- Microencapsulation of PCM material and form stabilization of PCM using silica fumes, kaolinite clay, waste glass powder and granulated blast furnace slag.
- Investigation of the polymeric coated and form stabilized PCM in terms of thermal conductivity, heat transfer/ absorption capacity, thermo-chemical stability and compatibility with construction material.
- Enhancing the heat transfer rate (thermal conductivity) of polymeric PCM coating by adding carbon nanotubes and expanded graphite.
- Development of multilayer PCM system for new and existing habitats in conjunction with construction materials such as cement mortar, tiles and gypsum boards.
- Field study of thermo-chemical durability of prototype fitted with multilayer PCM system with improved thermal inertia in term of inside temperature, inside thermal fluctuations, air quality (VOC) and energy efficiency.
- Numerical modelling of full scale building fitted with proposed multilayer PCM system using "Energy Plus" and "Open Studio" commercial softwares (developed by US Department of Energy).



Schematic diagram of multilayer PCM system to improve the energy efficiency of Indian new and existing habitats

Methodology

The work proposed herein involves raw material characterization, characterization of proposed multilayer system, testing of the pilot system and computer modelling of energy efficiency of full scale habitats. The project can be divided in to three phases

Phase I: Characterization of encapsulated / form stabilized PCM materials
The issue of low thermal conductivity of polymer coating or form stabilizing coating shall be alleviated by adding multiwall carbon nanotube or expanded graphite. Therefore, in the first phase the range of phase change temperature, baseline and enhanced thermal conductivity and heat transfer capacity of the resultant encapsulated / form stabilized PCM system will be studied as function of PCM loading, nature of coating / form stabilizing material and coating thickness using laser flash analysis, differential scanning calorimeter and thermos-gravimetric analysis. The base line chemical composition of encapsulated / form stabilized PCM materials layers will be determined in this phase using FT-IR spectroscope.

Phase II: Field test of rate of heat transfer and energy capacity of multilayer PCM system
The data acquired will be used to determine the efficiency of each type of multilayer PCM system. Following the field tests, the encapsulated / form stabilized PCM layers will be subject FT-IR analysis to study the effects of field exposure on the chemical makeup of these layers. The FT-IR analysis coupled with temperature data will help in studying the durability and reliability of the encapsulated / form stabilized PCM layers designed to improve the energy efficiency of Indian habitat.

Phase III: Numerical modelling of energy efficiency for a Full Scale Building using the data collected in Phase II
The numerical simulation of energy consumption in the heating and cooling of a full scale residential building without and with multilayer PCM panels will be carried out using the data collected in Phase II and using commercial level building energy analysis softwares "Energy Plus" and "Open Studio", developed by US Department of Energy. The results obtained will establish the effectiveness of multilayer PCM panels in improving the energy efficiency in Indian habitats.

Expected Outcomes & Deliverables

a. New/Upgraded Product
b. Performance analysis (Scientific data generation for different applications)
c. Feasibility analysis

Our deliverables are engineered specific phase change material (PCM) system for various applications such as to improve the thermal comfort of a new or existing residential/commercial buildings for Indian environment conditions. As per literature, we have found that there exist no PCM system specifically designed and optimized for Indian weather conditions.

About Institute & Previous Projects

SRM University is a multi-stream deemed university under section 3 of UGC Act 1956. The University is accredited by NAAC with 'A' grade and CGPA of 3.5 out of 4. The University offers UG, PG and PhD programs under the faculties of Engineering & Technology, Medicine & Health Sciences, Science & Humanities, Management and Law.

During last decade, SRM University has received 148 funded projects from various Indian Government Ministries and international organizations. Department of Biotechnology (DBT) has recognized SRM University as partner through "SRM-DBT Partnership Platform for Contemporary Research, Services and Skill Development in Advanced Life Sciences Technologies".

Industry Partner

Cera-Chem Private Limited, the industrial collaborators / consortium partners on the project, is India's leading construction chemicals manufacturer from Chennai, India. During the past two decades, Cera-Chem has evolved and expanded from a single manufacturing unit at Chennai to multi-point manufacturing units logistically placed at Hyderabad and Baroda to effectively cater the market demands. The range of Cera-Chem products comprises of concrete admixtures, water proofing systems, industrial grouts, anti-corrosive coatings, protective and decorative coatings, concrete repair products, industrial floorings, concrete surface treatments, tile adhesives and joint fillers, joint sealant and vibration pad and a range of epoxy flooring systems.

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20. DEVELOPMENT AND PERFORMANCE ANALYSIS OF DOUBLE PANE SEMI-TRANSPARENT SOLAR PHOTOVOLTAIC WINDOW/FACADE SYSTEM

Principal investigator: Sanjay Mathur
Malaviya National Institute of Technology Jaipur

Background of Project

Worldwide, the building sector accounts for about 40% of global energy. In India, the building sector consume 35 % of the total energy usage. With the growth of economy, it can be envisaged that the demand of energy in the building sector is going to increase rapidly.

Window is an integral part of buildings. Semi-transparent solar photovoltaic (STPV) module based window system is emerging as an attractive technology in BIPV category towards achieving the goal of net zero energy building. However, there are several issues associated with STPV based window system. Performance of SPV module is location dependent. Like any other SPV technology the output of STPV module is also affected by module temperature and other operating conditions. Absorption of unwanted part of solar spectrum may aggravated the building cooling load in a climatic region like India's. Moreover, the transmission of less or more daylight inside the occupant area may indirectly lead to increase in energy demand of a building. The non-uniformity of daylight inside the occupant area is another problem associated with STPV based window system.

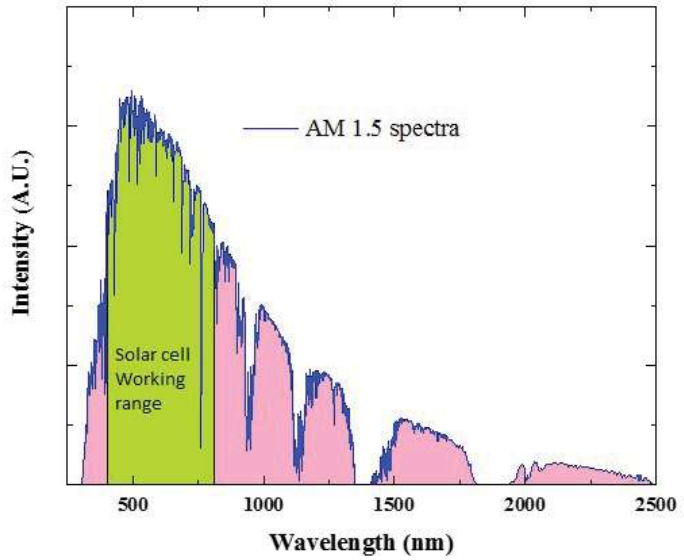
Both electric power generation and SHGC are affected by angle of incident on SPV module. The angle of incidence is location dependent. In general, the power generation of SPV module decrease with increase in angle of incident. With increase in incident angle the SHGC is also decreases for a window which is a positive effect for a hot country like India. Here, most of the time the angle of incident, for a south facing window in the northern part of the country, is higher than 40 degrees, especially during the summer month. So the angle of incident is a curial parameter in determining the overall energy performance of a STPV window system in Indian climatic conditions.

Aim

- Development of Window/Façade system using spectrally selective glass and Semi-Transparent Solar Photovoltaic Module.
- Performance evaluation of the proposed window/façade system under various design and operating conditions. The proposed variations are mentioned bellow

  i. Position of low-e and PV surfaces
  ii. Strategy for operating vent for air cavity
  iii. Variation in SPV module characteristic: Change in Module Transparency
  iv. Location and orientation
  v. Angle of incidence
  vi. Variation in window to wall ratio (WWR)

- Performance evaluation of the proposed system under impact of various blinds (both external, internal and inline systems).
- Development of control algorithms for external/internal blinds that optimise the performance of the proposed new system and at the same time utilize maximum daylighting and minimizing energy consumption of the internal task lighting; essentially a Multi-Objective Optimization Problem (MOOP).
- Integrate the new controllers with transactional network system, VOLTTRONTM.



Spectrum of solar radiation and solar photovoltaic cell's response

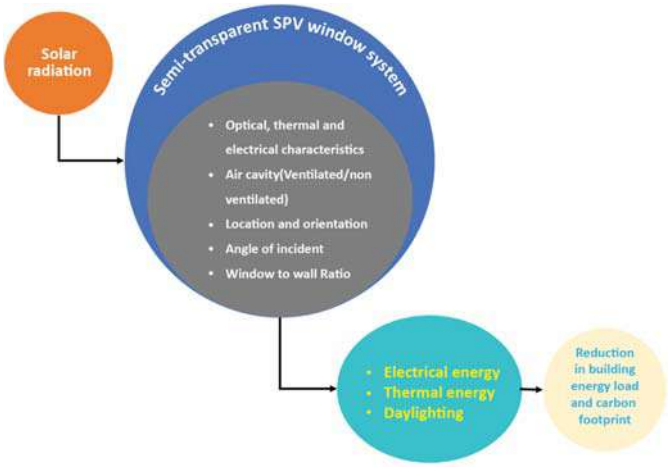
Schematic diagram of the experimental setup

Methodology

The methodology is composed of both experimental and simulation works. In the first step, thermal, optical and electrical characteristics of the STPV module and glass will be experimentally determined in the required wavelength ranges. After the opto-thermal properties are acquired the basic simulations will be carried to determine the necessary air gap between the STPV module and glass. In finding the air gap the energy performance determining factors such as U-values, SHGC and VLT will be used for the reference. In the next step, the proposed system will be developed as per the required specifications. Long-term experimental investigation will be carried to find the system performance in real operating conditions. To observed the effects of different designed and operating variables, model of the system will be developed in an appropriate simulation software. The simulation data will then be processed to find various performance determining parameters. In the next step, the simulation based results will be compared with the experimental findings. If required, the simulation model will be calibrated before performing further simulations. At the end, the product will be further experimental investigated with the best design and operating conditions.

Expected Outcomes & Deliverables

The prime objective of the proposed project is the development of a new STPV and spectrally selective glass integrated double pane window/façade system. In order to check the optimal working of the developed system under varying climatic and operation conditions, performance analysis and evaluation are other important deliverables of the project. At the end of the project it is expected found the optimal specifications of a STPV integrated window system as per the working environment.



Schematic diagram of usefulness of the proposed project

About Institute & Previous Projects

MNITJ is fully funded by Ministry of Human Resource Development (MHRD), Government of India. The Centre of Energy and Environment (CEE) of MNITJ is at the cutting-edge in northwest India when it comes to research in renewable energy systems. IIIT-H is an autonomous university founded in 1998. It was set up as a not-for-profit public private partnership (N-PPP) and is the first IIIT to be set up under this model in India.

Both CEE of MNITJ and Centre for IT in Building science of IIIT-H are part of the prestigious 5-year project for promoting R & D in 'Energy Efficiency in Buildings' that has been awarded by Indo-US Science and Technology Forum, Govt. of India, and Department of Energy, USA to a consortium of Indian and US institutes.

CEE, MNITJ and CBS, IIITH has recently completed a project on “Development of weather file and weather data book for 62 Indian cities”. These files are being used for simulation of building energy efficiency and design of solar photo-voltaic systems. The project was funded by ISHRE.

Industry Partner and Team Members

The industrial partner, Dhabariya Polywood LTD, Jaipur has long-standing experience in the field of PVC/ UPVC door, window. Both Sanjay Mathur and Jyotirmay Mathur have rich experience on research and project management in different capacities, while Amartya Chowdhury is a solar photovoltaic material specialist. Further, Vishal Garg and Sachin Chaudhari from IIITH would bring in their expertise in Building Automation and Controls, and Illumination Engineering.

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21. SMART PERFORMANCE ROADMAP FOR AIRPORT TERMINAL BUILDINGS IN INDIA

Principal investigator: E. Rajasekar
Indian Institute of Technology Roorkee

Background of Project

Airports operate as businesses and therefore need to make a business case for capital expenditures. These types of decisions include investments in energy consuming equipment or energy efficiency measures. To calculate an expected return on investment (ROI) the anticipated energy end use costs must be known or reasonably estimated. When it comes to terminal energy usage it is not effective or practical for an individual airport to gather benchmark data for similar facilities. Energy benchmark methodologies for commercial buildings is already being widely researched in Indian context. However, such studies for airports remain largely unaddressed.

Airports are seen as the gateway of modernization for any urban center. Airports, in general, have high-energy consumption. Influenced by many factors, the characteristics of airport energy consumption are stochastic, nonlinear and dynamic. In recent years, airport managers have made huge efforts to harmonize airport operation with environmental sustainability by minimizing the environmental impact, with energy conservation and energy efficiency as one of their pillars. Variations amongst airports make it difficult to compare terminal energy end uses. Since there has been little tracking of energy end uses for airport terminals, there hasn't been an effective way to benchmark the data that airports can use to help justify, prioritize, and determine replacement or retrofitting decisions. Gathering the energy end use data will aid in the development of the benchmarks and is only the first step. As airports become more mature in their collection and/or modeling of their terminal energy end uses and data becomes more widely available, benchmarking then can become more precise in assisting airports in properly allocating costs and in making decisions regarding retrofitting or replacing terminal systems and equipment. Research is needed to provide the initial data and benchmarks to allow airports to have a frame of reference for their terminal energy end uses.

Aim

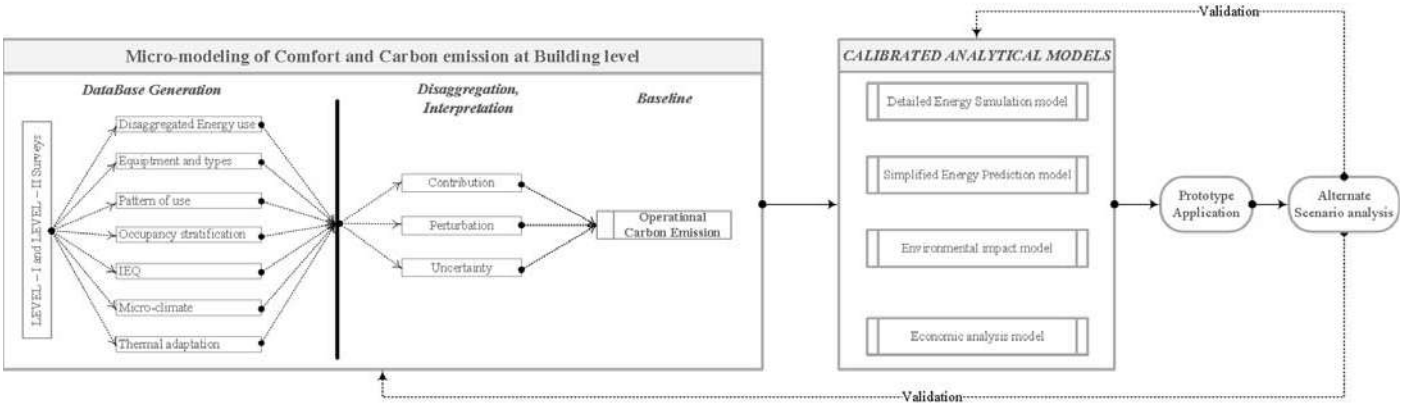
The present study intends to carryout real-time performance data monitoring and baseline development for (existing) buildings. Using calibrated simulations, intervention scenarios will be developed along with cost and implementation models. In order to ensure performance effectiveness and awareness, a prototypical-national data-networking platform will be developed through this study. Data related to energy and IEQ performance of terminal buildings will be monitored and collected at a centralized nodal platform adapting standard measurement protocols. Usage pattern and subjective comfort assessment will be carried out through physical field studies. Through a series of data mining and analysis, the energy and IEQ will be characterized and a base line performance benchmark developed. Using the data collected, key performance indicators (KPIs) will be identified. The study will adopt top-down and bottom-up approaches appropriate to the candidate buildings and respective sampling frequencies. The study will adopt the tier-wise arrangement of KPIs proposed by CASCADE methodology.

Methodology

The project is visualized in three phases comprising a total of twelve sub-tasks. In Phase-I, the consortium will conduct a pilot field study and evolve a selection criteria based on which representative building samples will be identified. The institutional members will carry out physical documentation and load profiling of the selected buildings. Sensor selection/ fabrication, deployment, monitoring, data collection and documentation will be carried out. Subjective field surveys will be taken up through which IEQ perception of the occupants and behavioral pattern will be studied.

Phase – II of the study will deal with data mining, characterization and benchmarking with respect to the energy and IEQ indicators. A comparative analysis of buildings across climate zones will be carried out based on which performance baselines and benchmarks will be evolved. Through calibrated simulations, performance effectiveness of various energy efficiency strategies will be analyzed. Based on a feasibility study, the strategies will be grouped into intervention scenarios in order to achieve a set of performance targets.

Phase – III of the study will focus on preparing a performance efficiency roadmap for transport terminal buildings based

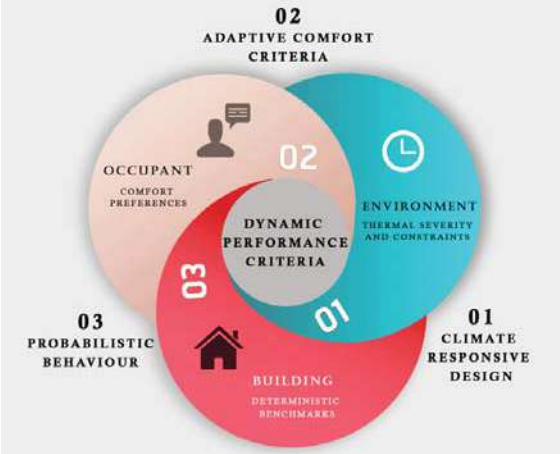


on the above results. The roadmap will include a set of M&V procedures and associated tools and milestones to achieve exemplary performance. To pave way for further research and to ensure performance effectiveness a data-networking platform will be developed. This is intended to serve as a prototypical portal in which real-time performance feeds of terminal buildings will be made available.

Expected Outcomes & Deliverables

Deliverables from the projects will include building Space utilization and Energy use characterisation (plug/power), Performance Monitoring Protocol for Airport Terminals which includes Survey methods, Instrumentation, Data processing and reporting structures in Phase I. Deliverables in Phase II includes Baseline Performance benchmarks such as energy and indoor environmental quality for airport terminals. Deliverables in phase III includes Energy efficient strategies and implementation potential including cost-benefit assessments and guidelines for Energy Efficiency in New and Existing airport terminals.

Objectives	Outcome	Deliverables
1. Develop a Research Framework and performance monitoring protocol for Energy and IEQ evaluation in airport terminal buildings of India	Building Space utilization and Energy use characterisation (plug/power) Base data on building Envelope, Electrical and Mechanical system; on-site electricity generation Protocol for "Data Monitoring" - parameters, standards, format for data collection	Performance Monitoring Protocol for Airport Terminals which includes 1. Survey methods 2. Instrumentation 3. Data processing and reporting structures
2. Characterize real-time energy consumption and IEQ in representative terminal buildings and develop base-line performance Benchmarks	Data Collection as per PROTOCOL: Pilot and main survey Load Consumption pattern Analysis Development of Energy Performance Benchmarks Research Publication	Baseline Performance benchmarks for airport terminals
Interim Report		
3. Building and System level Interventions, Alternate Scenario Analysis through Calibrated Simulations; Develop cost and implementation model	Identification of Energy efficient strategies Performance Evaluation of Alternate Scenario through simulation and analysis Cost-benefit assessment Stakeholders' meet (implementation potential)	Energy efficient strategies and implementation potential for airport terminals
4. Develop Efficiency Road map and M&V protocol for exemplary performance; Data Networking platform for Smart monitoring and control	Development of Implementation roadmap M&V protocol for facility managers Development of Smart data networking platform Research Publication Stakeholder workshop for capacity building	Guidelines for Energy Efficiency in New and Existing airport terminals A portal for streaming and analysing energy use in airports
Final Report		



Framework for integrated performance guidlines

About Institute & Previous Projects

IIT Roorkee: Indian Institute of Technology - Roorkee is an institute of national importance in higher technological education and in engineering, basic and applied research.
On-going research projects of the team, relevant to this context include geo-spatial mapping and assessment of carbon footprint in neighborhoods, IUSSTF sponsored project on Improving Building Energy Efficiency and Climate chamber based assessment of thermal comfort for Indian people.

C-DAC: C-DAC is the premier R&D organization of the Ministry of Electronics and Information Technology for carrying out R&D in IT, Electronics and associated areas.
On-going research projects of the team, relevant to this context include development of ICT Technologies for Smart Buildings with Low Carbon Emissions, Development of Security Solutions for SCADA Systems and Cloud computing.

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22. ENERGY EFFICIENCY IN GREEN BUILDINGS USING GEOTHERMAL PILE FOR COOLING

Principal investigator: Tanusree Chakraborty, Rajni Saggu
The Indian Institutes of Technology Delhi

Background of Project

In 2015, in the United Nations Climate Change Conference, India has agreed to voluntarily reduce carbon emissions, and therefore to develop clean, renewable energy technologies that are cost effective, and sustainable. Shallow geothermal energy is a renewable energy source that can be harvested through building foundations in a cost-effective manner. Geothermal energy pile foundations serve the dual role of supporting the building loads and transmitting thermal energy between the building and the ground underneath. It may be noted that tall multi-story buildings are an integral part of the modern smart cities, and pile foundations are usually built to support these tall buildings. These pile foundations can be effectively used to harvest geothermal energy in a cost-effective manner. Although geothermal energy piles have been used in some western European countries for heating in winter, their use in India pose unique challenges. Due to minor seasonal variations, the cooling requirements in India being significantly greater and therefore these systems become less effective. Hence, an engineering analysis is needed to determine the geothermal heating and cooling potential of the location through geotechnical investigation and to determine the geotechnical capacity of geothermal energy piles while subjected to heating and cooling. The proposed work will establish a pioneering framework for the design of structural piles as heat exchange piles. As the profession recognizes the value of the research, the framework will be adopted, extended and used for different site conditions in India. This will lead to increased popularity of the use of geothermal energy through structural piles, which will reduce the use of fossil fuels resulting in cost savings and a cleaner environment. Clearly, this research will contribute to the sustainable development of urban infrastructure.

Aim

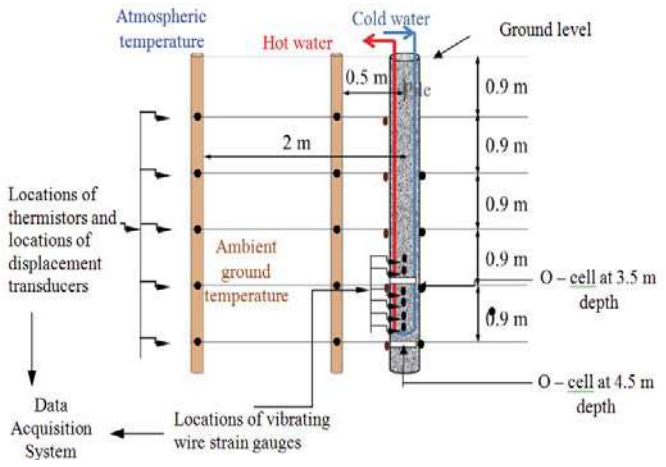
The aim of the research is covered by the following objectives:

1. To fabricate model geothermal energy pile in IIT Delhi,
2. To investigate the load transfer mechanism of energy piles in a group for application in green building design,
3. To investigate the effect of pile spacing and the soil conditions on the pile capacity,
4. To understand group efficiency of energy piles under repeated cooling cycles and to evaluate the pile capacity over time due to prolonged use of heat exchanger piles,
5. To identify the key design parameters for design of energy piles in a group,
6. To perform numerical simulation of energy pile group for different building configurations and cooling requirements,
7. To perform cost-benefit analysis of geothermal energy piles in comparison to conventional air conditioning system,
8. To check the final design along with TERI university.

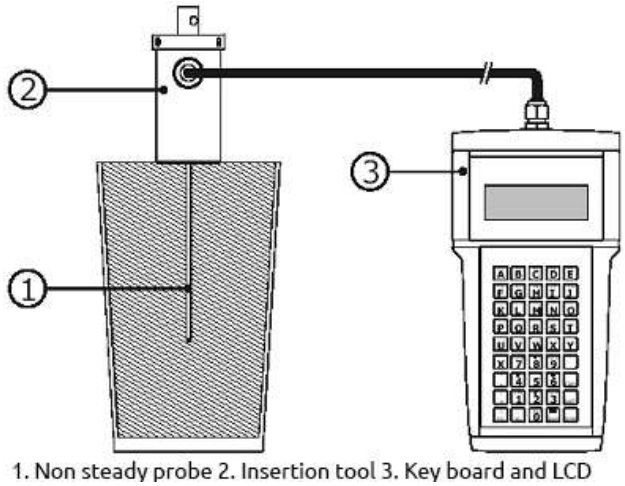
Methodology

1. Set up of a Model Geothermal Energy Pile at IIT Delhi:
   i. The geothermal energy pile of 100 mm diameter and 5 m length will be installed in the premises of IIT Delhi.
   ii. Two levels of Osterberg cells (O-cells) will be installed at 3.5 m and 4.5 m depth for an accurate independent measurement for the material within the intermediate sections of the pile by observing the reaction of the relevant strain and displacement gauges with or without thermal loading.
   iii. The thermo-mechanical behavior of geothermal energy pile will be investigated under repeated thermal cycles over a period of 18 months.

Experimental investigation of soil thermal conductivity and diffusivity will be performed over a wide temperature range, for various water contents and different soil types from some parts of North of India



Schematic diagram of model geothermal pile investigation setup



1. Non steady probe 2. Insertion tool 3. Key board and LCD

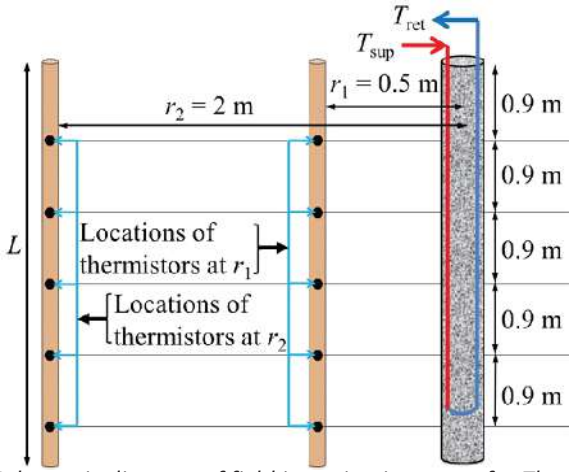
Schematic diagram Soil Sample Collection

2. Numerical Investigation of Geothermal Energy Pile Groups:
   i. Validation of numerical analysis results for a single geothermal pile with experimental analysis results for the model geothermal pile,
   ii. Investigation of load transfers mechanism of geothermal energy piles in a group of 4 piles,
   iii. Analysis of group efficiency of energy piles under multiple cycles of heating and cooling and evaluation of pile capacity over time due to prolonged use of these heat exchanger piles.

Expected Outcomes & Deliverables

1. **Expected Outcomes**
   i. Identification of key design parameters for the geothermal energy piles,
   ii. Evaluation of heat exchange capacity of the geothermal energy piles
   iii. Evaluation of long term performance of geothermal energy pile group and associated soil- structure interaction
2. **Deliverables**
   i. Laboratory scale geothermal energy pile set up,
   ii. Database on soil thermal properties for different soil types,
   iii. Feasibility check for usage of geothermal energy piles in Indian climate.
   iv. Thermo-mechanical performance evaluation of geothermal energy piles for cooling dominated environment through experimental and numerical investigation,
   v. A benchmark for the feasibility analysis of geothermal energy piles in Indian climatic and soil conditions
   vi. Implementation of the new technology of geothermal energy piles for heating and cooling of the buildings in green building construction.

The feasibility study of geothermal energy piles in Indian soil and climate conditions will be immense help for pile designers to implement the relatively new concept of geothermal energy piles for the green buildings in India.



Schematic diagram of field investigation setup for Thermal Conductivity and Diffusivity

About Institute & Previous Projects

The Indian Institutes of Technology Delhi is among the foremost of institutes of national importance established through an Act of Parliament for fostering excellence in education.It is an autonomous statutory organization functioning in terms of the Institutes of Technology Act, 1961, amended vide the Institute of Technology (Amendment) Act, 1963 and the statutes framed there under. The vision of this premium institute is to the contribute India and the world through excellence scientific and technical education and research and serve as a valuable resources for industry and society.

Industry Partner

TERI University

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Rajni Saggu
Assistant Professor
Amity University
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Bishwajit Bhattacharjee
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Manoj Datta
Professor & Head
The Indian Institutes of Technology Delhi

23. BIOMASS DERIVED NANOSTRUCTURED CELLULOSE AEROGEL MATERIALS FOR THERMAL INSULATION IN ENERGY EFFICIENT SMART BUILDINGS

Principal investigator: Kamalakannan Kailasam
Institute of Nano Science and Technology, Mohali

Background of Project

Buildings are one of the most energy consuming areas which spend more than 30% of the total energy of India being used. A major part of the energy is used only for heating/ cooling the building. A recent survey suggested that India's occupied-building area will skyrocket from 8 billion square meters in 2005 to 41 billion in 2030. To overcome the energy management for sustainable living, there is an urgent need to build smart houses with all modern facilities and comfort, which also involves a very good energy management to reduce the electrical energy consumption in household. Another common factor globally is the increasing energy usage due to the global warming is most alarming which can't be ignored and our efforts to compensate such energy loss also add to this energy vows in this current scenario. In most of the world currently petroleum based polymer is mainly used for thermal insulation to prevent energy loss.

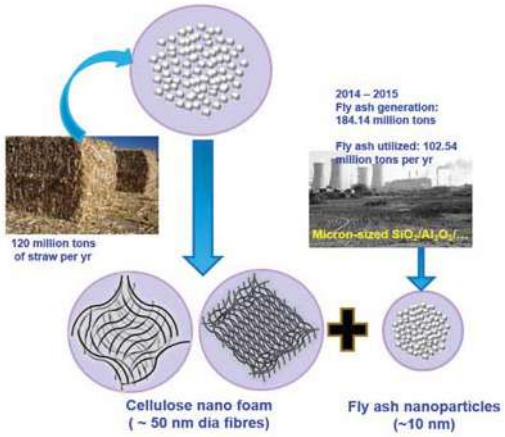
In India we are commonly using polystyrene based materials, glass wools or fly ash bricks, etc. for building wall insulation. All these materials have low insulation properties and save only 3-8% energy consumption. To address the above issues, the cellulose aerogel-fly ash composite with high thermal insulation property will make a huge difference in saving energy for the power sector. Additionally, this nanocomposite/foam provides an alternative and attractive optional building material to the existing one which is sustainable, abundant and low-cost for thermal insulation applications.

Aim

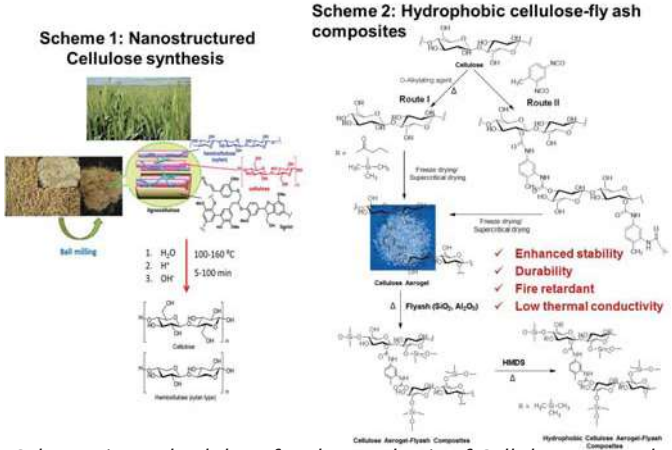
a. Design and development of low-cost biomass derived hydrophobic cellulose aerogels and their nanocomposites with fly ash. Target is to achieve exceptional low thermal conducting material (below 10mW/m-K) for energy efficient building with very good climate aging durability.
b. Accurate measurement of moisture adsorption by water vapor physisorption, contact angle studies for probing the hydrophilicity/ hydrophobicity, rheology studies for determining mechanical strength and young's modulus measurements for compressibility studies of aerogel nanocomposites.
c. Developing transient 3 omega method for the solid materials and measuring the thermal conductivity of the aerogel nanocomposites.
d. Deliverables & Technology Transfer: Biomass derived low-cost cellulose aerogel nanocomposites as ultra-low thermal conducting material (below 10mW/mK) and subsequent technology transfer to industries. Ingersoll Rand is our industrial partner to expand the lab-scale to industrial-scale synthesis, testing the performance, patent the products and further exploring of commercial options. We want to achieve the thermal insulation efficiency and projected cost: 40-60% & < Rs.100 per Kg (Current polymers-3-8% & > Rs. 200 per Kg).

Methodology

a. Development of nanostructured cellulose aerogels using biomass derived cellulose pulps and their nanocomposites by,
   i. from derivatized and non-derivatized cellulose pulps
   ii. crosslinking with agents like tolylene-2,4-diisocyanate
   iii. freeze drying and supercritical cooling methods to aerogels
   iv. formulation of cellulose aerogel composites with fly ash to attain building insulation material
   v. surface modification of the nanocomposites with hydrophobic agents like HMDS if necessary
   vi. accessing the durability of nanocomposites in different climate conditions
b. Characterization and optimization of cellulose aerogels and their composites by, *Water vapor physisorption:* Degree of hydrophilicity/ hydrophobicity from water adsorption-desorption studies at different temperatures. *N2 physisorption:* Surface area, pore size & pore volume datas which provides the porosity features of the samples. *Microscopy:* Microscopic (SEM and TEM) analysis for the



New nanocomposites from waste sources for thermal insulation: abundant biomass-derived cellulose and fly ash



Schematic methodology for the synthesis of Cellulose aerogel-fly ash nanocomposites

determination of the morphology and porous features. *Rheology:* Mechanical strength of the cellulose aerogels and their nanocomposites will be provided. *Young's modulus:* Compressibility data will be provided for the composites *Thermal conductivity measurements:* Transient 3 omega method to measure heat transfer and thermal conductivity properties will be provided. *Durability:* Cellulose-aerogel nanocomposites will be subjected to various Indian weather conditions. After this exposure, the nanocomposites will be characterized with different techniques like FTIR-ATR and Solid-state NMR, etc.

Expected Outcomes & Deliverables

a. New/Upgraded Product: Cellulose aerogel-fly ash nanocomposite based insulation materials from biomass derived cellulose pulp/ agricultural crop wastes and thermal power plant wastes (fly ash).

b. New/Upscaled Process: 1 Kilogram scale cellulose aerogel-fly ash nanocomposites from a single process.

c. Technological Capability and Proof of New Concepts at a Device level:

i. New generation thermal insulation cellulose aerogel nanocomposite as heat insulation material with ultra-low thermal conductivity (below 10 mW/m-K) where the commercially available thermal insulators have conductivity around 30-40 mW/m-K.

ii. Developing transient 3 omega method for high accuracy measurement of thermal conductivity for solid materials which will be developed for the first time in India.

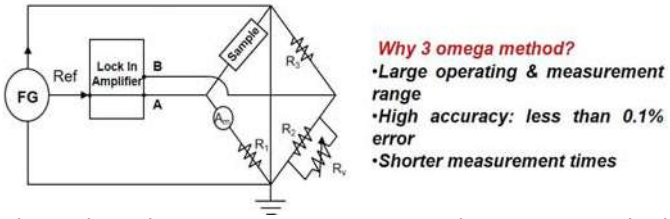
d. Deliverables for Practical Applications:

i. Low-cost biomass derived cellulose aerogel-fly ash nanocomposites.

ii. Our target is to achieve very high thermal insulation efficiency of the proposed nanocomposite in the range of 30-60%.

iii. Projected cost of the proposed nanocomposite will be less than Rs. 100 per Kg while the current market price of expanded polystyrene is above Rs. 200 per Kg

e. Industrial Partnership: Effective collaboration with Ingersoll Rand for large-scale production, testing the materials towards energy efficiency in building material formulation, patenting and commercialization of the cellulose aerogel-fly ash nanocomposites.



Thermal Conductivity measurement circuit by 3 omega method

About Institute & Previous Projects

Institute of Nano Science and Technology, Mohali is working on different areas of nanotechnology where energy and environment research is of prime focus to address the emerging energy needs.

Previous Projects

1. Photocatalytic-driven Hydrogen Generation and Cellulosic-Biomass Conversion using Mesoporous Carbon Nitrides supported by DST-SERB-ECR.
2. Prototype Large-Scale Reactor for Simultaneous Production of H2 and Fine Chemicals under Natural Sunlight supported by DST-Nanomission-NATAG.
3. Method development for measurement of thermal properties (especially thermal conductivity) for heat transfer materials at higher temperature supported by IOCL R&D.

Industry Partner

Collaboration with Ingersoll Rand for large-scale production, testing materials towards energy efficient in building formulations, patenting and commercialization of cellulose-fly ash nanocomposites.

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24. TEST WORKBENCH AND PROOF OF CONCEPT PROTOTYPE FOR BUILDING ENERGY EFFICIENCY SOLUTIONS

Principal investigator: Ciji Pearl Kurian
Manipal University

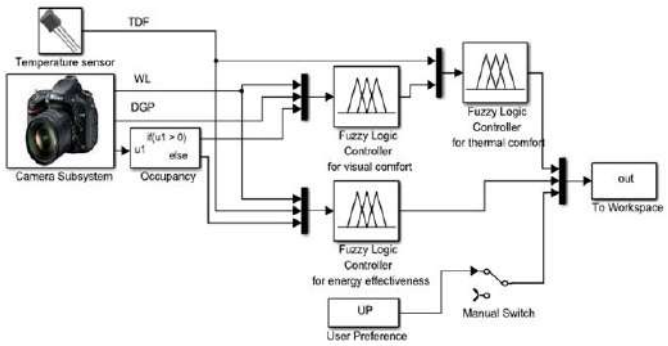
Background of Project

The Indian Government's inspiration on growth through sustainable development is motivating the research in the field of Building Automation and Control (BACS). According to the green building rating systems, American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) and Leadership in Energy, and environmental design (LEED) certifications, Lighting and HVAC controls are critical components for saving energy in buildings. The latest version of LEED accreditation system (LEED v4) introduces the use of climate-based daylight metric, spatial daylight autonomy, as a simulation based compliance path for the daylighting credit. Use of shading devices to provide optimum visual comfort, thermal comfort is also carried out by many researchers worldwide. Many of the researchers proposed occupancy sensors, daylight-adaptive lighting system, wireless sensors and networking for energy efficiency of buildings. Current energy policy of the European Union promotes energy certification for buildings. High dynamic range image sensors for lighting measurement and control application is also widely demonstrated by various researchers. The latest research in this direction proposed luminance gradient as a metric for evaluating the luminous environment in which they have used a camera based measurement system. Among building energy efficiency measures, window blinds and shading plays a major role in reducing building lighting and cooling load. The introduction of Building Analytics is also a boon for the domain as it converts big data from sensors into actionable intelligence which improves functionality.

Aim

To develop a test workbench for optimizing energy efficiency in daylight-artificial light integrated scheme.

- Contribute to the development of the intelligent building control scheme.
- Developing the control strategy that optimizes energy consumption and occupant comfort in the building interior.
- Development of image based, photometric measurement and analysis focussing on calibration methodology/ machine learning methods to use camera as a sensor for replacing photo sensor and occupancy sensor.



Simulink model for window blind control

- To integrate data analytics model for adaptive predictive control.
- Establishing a single platform, for the calibration, measurement, control, and analysis.

To integrate the algorithms and modules developed, with building information modelling (BIM) for sustainable building design.

- Demonstrate the prototype in a test room and compare the performance of camera-based sensors and adaptive control scheme based on data analytics models with baseline models.

Methodology

Phase I

- Use the available Energy simulators to assess the design stage performance of buildings.
- Use simulation tools for collecting data to derive data analytics model, do the sensitivity analysis, train the data for control and analysis.
- Develop room energy efficiency engine simulation models (EEESM)and interfacing modules to analyze the effect of various sensors, lighting system, communication protocols, networking , window shading system and control algorithms.
- Calibrate and use camera based sensors for lighting control as well as for the measurement of spatial uniformity and glare.
- Compare adaptive lighting and HVAC control schemes with baseline/ ASHRAE reference models.

Phase II

- Develop a test room facility and analyze the performance of window blinds and dimming of LED luminaries with embedded controllers developed. Test room allows real time emulation of energy performance based on climate data and sensor data.
- Study of energy implications, and analyze the performance of the building towards Positive net energy and suitability for Leadership in Energy and Environmental design (LEED) certification. This phase includes Rooftop PV design and implementation also.
- Develop necessary software modules for visualization and monitoring.

Expected Outcomes & Deliverables

- Demonstrate a test workbench for the design and deployment of reconfigurable adaptive controllers and calibrated camera based luminance sensors integrated with building information modeling for the robust control of lighting and window blinds for minimizing electrical energy consumption with improved visual and thermal comfort of a building interior in any ecological zone.
- Validate the proof of concept prototype model at institution test room facility by implementing the controllers, sensors, and actuators with innovative wireless control and

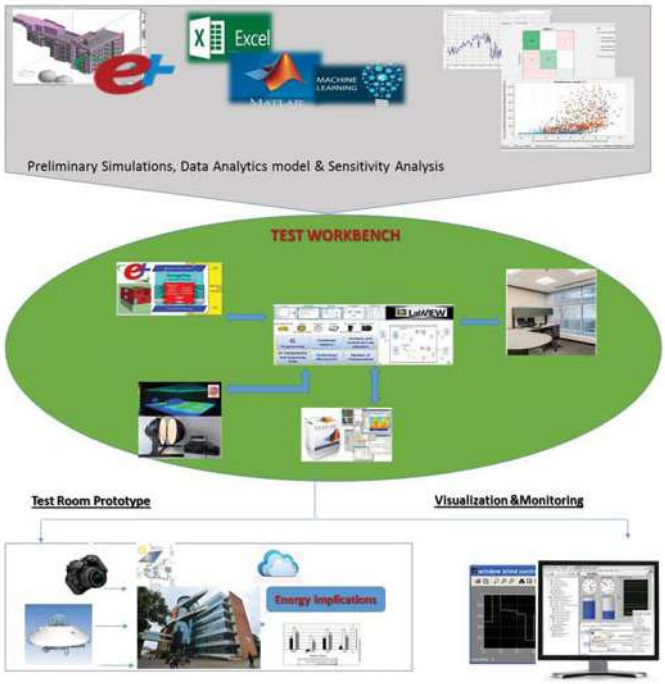
networking towards the attainment of zero net energy / positive net energy building for a specific climate type.
- A software tool for the study of energy implications in daylight- artificial light integrated scheme for the benefit of researchers and industry in this field.
- An embedded system for improving building energy efficiency, commercialize with the support of industry collaborator Philips India Ltd., Bangalore.
- Uphold an enhanced investigation and test facility at the institute in the area of Building Energy Management and Photometric Testing to enable continuous research contributions.
- Develop a Data Analytics model for predicting/analyzing energy performance of a building, leading to efficient pre-emptive control.
- Publishing research articles in high impact factor journal and conference on the technology development, case studies and report of comparison with baseline standards.

About Institute & Previous Projects

Manipal University is known for Lighting and Energy Management studies. University offers postgraduate and research programs in this area.

The following Research projects are specifically in the field of this funding project.

1. Optimization and robust control of energy consumption in daylight – artificial light integrated schemes (PI)
2. Adaptive Predictive lighting controllers for daylight Artificial light integrated schemes (DST funded, guided by PI) with invention award (invention ID: IN-814205) is DST funded project (SR/WOS-A/ET-06/2008dated June 2009).
3. High Dynamic Range Imaging for evaluating quality of daylight-Artificial light integrated scheme(Co-PI)
4. Image based Wireless Networked Lighting Control for Daylight-Artificial light Integrated Scheme(Co-PI, on-going)
5. Embedded model predictive control based on data analytics for building energy efficiency and comfort (PI, Guiding by PI)



schematic diagram of methodology

Industry Partner

Collaborating Industry is Philips Lighting India Ltd., a proven standing, and R&D capability and has the potential to commercialize the products. Dr. Narendranath Udupa, Head, Philips Lighting is the team member. They provide the following

- Reserving the efforts of one senior researcher in this area, this would be approximately considered 80K Euros.
- Sponsoring two interns every year by paying them a stipend of 20000 INR per month.
- Technical solutions for the development of embedded system
- Help to provide industry standards and to commercialize the product

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Susan G Varghese
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25. CHARACTERIZATION STUDIES OF NANO-ENHANCED PHASE CHANGE MATERIAL (NEPCM) IN THERMAL STORAGE DEVICES FOR SUSTAINABLE BUILDING DESIGNS IN INDIA

Principal investigator: Dibakar Rakshit
Indian Institute of Technology Delhi

Background of Project

With dwindling energy resources which earth is having in the form of fossil fuels, today there is a scrupulous requirement of venturing alternative avenues, which can eventually share the ever increasing energy demand. These alternative avenues encompass all renewable energy resources which earth is having. These large energy resources or basins which earth is encompassed with include solar, hydro, wind, biomass, ocean and geothermal energy. Through the application of the human ideologies and emerging technologies, tapping the energy from these reserves in an efficient manner has always been a paramount task. In any case, the principal aim is the reduction/ cessation of fossil fuel based energy production through enhanced utilization of the aforementioned resources.

The component of vital importance in alternative energy applications is the Energy Storage (ES). Energy storage enables storing of some form of energy so it can be drawn upon at a later time on demand. There is a large variety of ES systems such as mechanical, chemical, biological, and magnetic energy storages. However, in many applications, the renewable energy manifests itself as thermal energy. Therefore, Thermal Energy Storage (TES) is amongst the most important ES types. One of the most efficient means of TES implementation is through the use of Phase Change Materials (PCMs). PCMs are able to absorb/release large amounts of heat (latent heat) during the phase change which can be solid-solid, solid-liquid, and liquid-gas takes place in almost isothermal conditions or in a very narrow temperature range.

The isothermal phase change process enables the usage of these materials for temperature control so the application areas of PCMs are numerous including transport, general storage and medical applications. Meanwhile, high latent heat content enables utilization of PCMs for TES applications (predominantly in buildings). Nowadays, thermal energy storage (TES) systems could be used to reduce buildings' dependency on fossil fuels. TES can be employed as efficient, environment friendly and reliable supplier of heat energy where sustainability is the prime criteria. The main advantage of using TES is that it can contribute to match supply and demand of energy when they do not coincide in time16. The development of efficient PCM based TES system is a challenging task which significantly includes their characterization. Characterization basically involves determination of important material properties thereby leading to design and modelling, and finally the implementation of such system. Usually the design and modelling stage requires the solution of transient heat transfer problems involving phase change which is a relatively complicated task in itself. Nevertheless, according to Mehling and Cabeza15, one of the major limiting factors for both modelling and implementation of efficient PCM based TES systems is the inaccuracy/lack of the experimentally determined material data especially in terms of phase change temperature/range, enthalpy and thermal conductivity. This poses a serious problem since the accurate knowledge of thermophysical material properties of PCMs is a prerequisite for more optimal and efficient design and implementation of PCM based TES units and the prediction of long-term behavior of such systems. Moreover, more reliable determination of thermophysical properties of existing PCMs should provide better understanding of the limitations of those materials and induce novel ideas to help the research activities regarding the development of new phase change materials.

Aim

The aim of the project is

- Identification of potential PCM as thermal storage for Indian climatic conditions.
- To establish the characterization procedure for characterizing well established PCM.
- Identification of potential additives/nanoparticles for the properties enhancement of the PCM.
- Quantification of thermophysical properties of the NEPCM
- Reinforcing PCMs into a composite tile as sustainable building material and thereby measure its strength and its compliance to the standards

Methodology

- Mapping of PCM to the Indian climate condition and assessing its thermophysical properties so as to test its suitability for Indian climatic condition (basically Delhi) and their application to buildings and houses to achieve thermal comfort and lowering of inside room temperatures.
- Enhancement of the PCMs characterized in step one by dispersing high conductivity nanoparticles within the PCM matrix and characterizing NEPCMs.
- To develop a tile incorporating characterized PCM and evaluate the physical (viz., water absorption, porosity, bulk density) and mechanical properties (viz., modulus of rupture, breaking strength, impact resistance) of the developed thermally insulated ceramic tiles and verify the obtained results whether complied with standard values specified by various codes.

Expected Outcomes & Deliverables

- Comprehensive review of various PCM technologies suited for building applications by considering their technological capabilities to improve indoor environment, increase thermal inertia and decrease energy consumption for building operation in Indian climatic conditions.
- Identification of candidate Phase Change Material (PCM) for efficient utilization in Latent Heat Thermal Energy Systems for green buildings in India.
- Increase the thermal conductivity (by 3 times) and thereby increasing the heat transfer rate by nanoparticle induction to the PCM matrix (testing will be done, provided the thermal conductivity meter being procured from other submitted proposal, is available)

- Development of a robust, economical and scalable method for the characterization of the nanoenhanced PCM.
- Manufacturing of tile incorporating the PCM so as to be thermally insulated as well as complying the building standards in terms of strength.

About Institute & Previous Projects

IIT Delhi is a premier institute in the country working with an aim to generate new knowledge by engaging in cutting-edge research and to promote academic growth by offering state-of-the-art undergraduate, postgraduate and doctoral programmes. The institute's constant endeavour is to undertake collaborative projects which offer opportunities for long-term interaction with academia and industry.

Funded research projects being led/participated by Dr Dibakar Rakshit include:

- **Sustainable Technologies for Rural development (STAR)** funded by Department of Science & Technology (DST)
- **Energy Efficient Buildings** funded by Department of Science & Technology (DST)
- **PCM based heat exchanger** funded by DRDO

Industry Partner and Team Members

IIT Bhubaneswar has been acting as a collaborator/consortium partner.

Team members

- B. Hanumantha Rao (Collaborator) (IIT Bhubaneswar)
- Sanjeev Jain (Co-PI) (Professor, IIT Delhi)
- S.C. Kaushik (Co-PI) (Professor, IIT Delhi)

Dibakar Rakshit
Centre for energy studies
Indian Institute of Technology
New Delhi

Sanjeev Jain
Professor
Department of Mechanical Engineering
Indian Institute of Technology Delhi
New Delhi

26. ENERGY SAVING THROUGH IOT BASED BUILDING AUTOMATION AND NON-LINEAR PREDICTIVE CONTROLLER

Principal investigator: D. Devaraj
Kalasalingam University

Background of Project

In India buildings consume about 21.98 % of total energy (170,034 GWh) which is the second highest energy consuming sector after industrial sector. The electricity consumption per capita in residential sector is 0.63 MWh producing a total of 1710.3 million metric ton of CO2 emission which is third highest after china and USA. The average energy consumption for various activities in India is 38% for cooling, 28% for lighting, 13% for refrigeration, and 7% for air conditioning. The overall energy conservation potential in India is about 23% and overall saving potential in domestic sector is 32% wherein households of rural and urban India have a saving potential of 40– 50% and 15–20% respectively. More than 60% of such energy is consumed in building heating, ventilation and air-conditioning systems. Another problem confronted by India's energy sector is the peak-demand faced by the Indian grid. The peak-to-average ratio (PAR) of the Indian grid is high compared to most of the countries and is therefore one of the pressing problems faced by the grid. The role of buildings in mitigating peak-demand in the grid by optimizing energy consumption in HVAC systems is vital for reducing PAR. Hence, the reduction of primary energy consumption of domestic building is important for the overall energy chain in India. Under this scenario undertaking a project on "IoT based building automation" assumes great significance.

Aim

The aims of this project are:

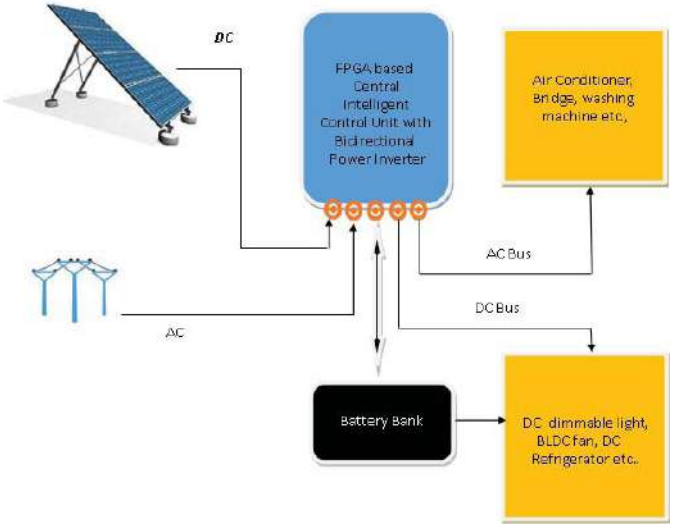
- To develop a multi-objective optimization based energy efficiency measures that aims to minimize energy consumption, investment and operational cost, minimization of carbon footprint, and to maximize consumer comfort.
- Development of higher-level controller with MEMS processor based devices and wireless sensors for monitoring and control of electrical appliances in the building.
- To develop non-linear model predictive controller for building heating, ventilation and air-conditioning systems exploiting the feedback linearization property that leads to global linear models.
- Development of lower-level controller based on embedded platform (Beaglebone Black or Intel Gallielo) that uses the predictive information on climate, occupancy, and other ambient conditions to reduce the energy consumption. The sensors are both hard-wired/wireless.
- Demonstration of the hierarchical controller in a building having a reasonable scale.

Methodology

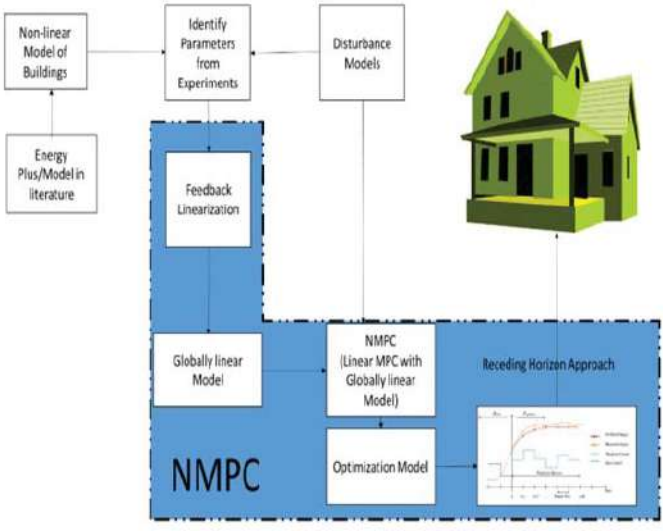
The project works in three phases: 1) Higher level optimization and development of controller, 2) Development of lower level controller, and 3) Pilot demonstration.

a. **Higher level optimization and control:** The energy efficiency measures will be formulated as a multi-objective optimization (MOP) problem with the objectives to reduce energy consumption, minimize investment and operational cost, carbon foot-print reduction, and maximization of consumer comfort.

An IoT based web architecture will be developed for automatic control and monitoring of all loads using MEMS technology (MICA processors) and wireless sensors. MEMS processors will implement the decision making mechanisms that promote energy efficient operation of electrical appliance, CO2 emission reduction. A fuzzy controller will be developed for processor decision making.



DC Micro grid with Intelligent FPGA Power Converter Controller



Schematic of the Nonlinear Model Predictive Controller for Building HVAC control

An Intelligent control system for solar panels in buildings will be developed in FPGA platform for cost effective battery charging, optimal use of solar panels, and grid power to the loads

b. **Lower-level optimization:** The methodology adapted can be described in the following six steps: **Step 1:** Use first principle models in literature and Energy Plus software to model the building to obtain an initial first principle model of the building. **Step 2:** Obtain the parameters of the model from experiments. Model the disturbances using function approximation technique. **Step 3:** Using the parameters obtained in step 2, obtain the building model with the actual parameters and simulate the building dynamics. **Step 4:** Obtain the climate forecasts (from internet), occupancy (modelled using Hidden Markov Model), and heating due to occupancy modeled using function approximation techniques. **Step 5:** Exploit the differential flatness property of the model to build globally linear models (i.e. models that are linear at all operating points) using dynamic feedback linearization.

The hardware implementation of the field level controller for HVAC systems will be developed in BeagleBone Black (embedded controller) by using CVX_PY solver (exploiting the linear Model Predictive Controller (MPC) or using Sequential Quadratic Programming). Demonstrate the capability of Nonlinear Model Predictive Control (NMPC) using NI cRIO controller in the laboratory

c. **Pilot Demonstration**
   - Implement the proposed methodology in a building of suitable scale.
   - Develop a Provide a pre-commercial prototype of the NMPC

Expected Outcomes & Deliverables

The expected outcome of this project are,
- Energy savings up to 20%
- Peak-demand reduction by 30%

The expected deliverables of this project are,
- Building Energy Management system: Prototype of a building automation system with necessary control units and intelligent solar control unit for energy efficient operation.
- A pre-commercial version of the NMPC in an embedded board suitable for commercialization by the Industrial partner.

About Institute & Previous Projects

About the University
Kalasalingam University, located in Virudhunagar District formerly known as Arulmigu Kalasalingam College of Engineering (AKCE) was started in 1984. The Ministry of Human Resources Development, Government of India, New Delhi has granted University status (Under section 3 of UGC Act 1956) wide notification No. F.9-2/2002/U.3 dated 20th October 2006 to AKCE. It started functioning from the academic year 2007-08.

TIFAC-CORE in Network Engineering and National centre for Advanced Research in Discrete Mathematics (n-CARDMATH) has been set up with the financial support of DST, Government of India to promote research. The International Research Centre (IRC) at KLU is a testament to the vision of the founder to create a true hub of research that goes beyond the boundaries of the country.

Project Details:
Kalasalingam University has received funds for undertaking projects from various funding agencies such as DST, BRNS, ICSSR, ICMR, AICTE, CSIR, DBT, IIMA, IIPA. So far, the faculty members of Kalasalingam University have completed 29 funded projects with the total sanctioned amount of Rs. 5,13,82,979 and at present there are 17 ongoing projects with the total sanctioned amount of Rs. 4,26,88,675.

Industry Partner and Team Members

Industry Partner: Mr. Ravi Rengasamy, Thermaguard Technologies Pvt Ltd

Team Members
- Seshadhri Srinivasan (Co- PI)
- B. Subathra (Co- PI)
- M. Karuppasamypandiyan (Co- PI)

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27. DEVELOPMENT OF ENERGY SAVING AND ENERGY GENERATING SMART WINDOWS

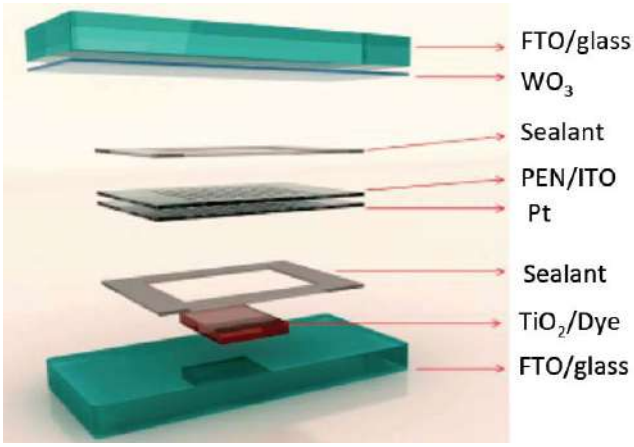
Principal investigator: Aswani Yella
Indian Institute of Technology Bombay

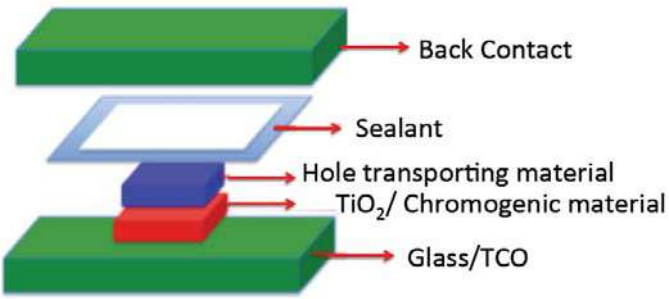
Background of Project

Smart windows are an emerging dynamic window technology that actively controls the transmittance of light upon application of a external stimuli. So far the existing technology for chromogenic smart windows (including electro, photo and thermo-chromic) utilizes external stimuli (like electric field, light or heat) to save the energy by reducing the cooling costs. While these types of simple smart windows have great potential for energy savings from heating and cooling in buildings, automobiles, aircrafts, etc. the rejected energy is simply lost to the environment without any further purpose. If the rejected light energy can be harvested using photovoltaic devices, their energy generating function is ideal for energy conservation. Self-powered smart windows have been made previously to utilize the rejected energy. But, these self-powered smart windows utilizes two different kinds of materials (absorber and chromogenic materials) because of which the optical transmittance of the windows is reduced. The current proposal deals with developing materials, which can be simultaneously used as both chromogenic as well as absorber materials, so that the optical transmittancy is retained as well as the same material can be also used for energy generating option.

Aim

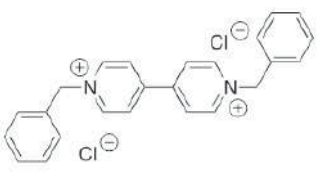
The project aims at developing smart windows using organic-inorganic hybrid chromogenic materials, which can be switched between the bleached and colored states using external stimuli, like temperature or UV-light. The ability to combine, in a single material, organic and inorganic components at molecular level represents a great step in material science with extraordinary implications for developing novel multifunctional materials. Organic–inorganic hybrids have the advantages of both organic (light weight, flexibility, versatility, etc.) and inorganic materials (high thermal and mechanical resistance), which make them ideal candidates for these applications. Chromogenic hybrid materials (switched using temperature, light or external voltage bias) will be developed as a part of the current proposal. We have found that the viologen based organic inorganic hybrids exhibit electrochromism which can be switched by the external voltage from colorless state to coloured state and methyl ammonium based organoplumbates to exhibit thermochromism from colorless state at room temperature to colored state at 60°C. The colored state will be employed as the absorber for the photovoltaic devices and the bleached state will be completely transparent under the normal conditions without any external stimuli. The aim is to develop completely transparent devices at room temperature and upon application of external stimuli results in the energy generating and energy saving smart windows.

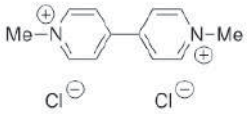




Glass/FTO
Chromogenic material
Sealant
PEN/ITO/Pt
Sealant
TiO_2/dye/Electrolyte
Glass/FTO

Glass/FTO
HTL
Chromogenic material
ETL
Glass/FTO





Schematic diagram of methodology

Methodology

Optically switchable materials have broad applications in the building architectures, vehicle windows, aircrafts, and sunroofs, because they not only reduce cooling/heating costs and ventilation loads, but also enhance the thermal and visual comfort for indoor users. Therefore, the smart windows with electrochromic (EC), photoelectrochromic (PECC), and photovoltachromic cell (PVCC) have received increasing attention, where the optical transmittance change can be stimulated and reversed in response to an external stimuli. The proposal deals with developing chromogenic organic-inorganic hybrid materials which can be optically switched by using external stimuli. These optically switchable materials will be developed in such a way that under normal conditions the material has to be transparent and upon applying external stimuli like temperature, UV-light, etc results in a material with red absorption. The externally switched smart material will be used as an absorber in photovoltaic applications so that energy can be generated by the same material. We have found that the viologen based organic inorganic hybrids exhibit electrochromism which can be switched by the external voltage from colorless state to coloured state and methyl ammonium based organoplumbates to exhibit thermochromism from colorless state at room temperature to colored state at 60°C. The colored state will be employed as the absorber for the photovoltaic devices and the bleached state will be completely transparent under the normal conditions without any external stimuli.

Expected Outcomes & Deliverables

a. Viologen, ammonium iodide based organic moeities and metal halide based inorganic moieties will be used to develop chromogenic organic – inorganic hybrid materials will developed. The developed materials will be completely transparent at room temperature and colored upon application of external stimuli.
b. Fabricate the devices using the newly developed materials and optimize the processing parameters to achieve high-energy savings and energy generation.
c. Prototype smart window device with the proposed device concept will be shown. The device concept employs making smart window devices with two transparent conducting materials so that the complete device will be transparent at room temperature.
d. The targeted power conversion efficiencies are 4-5% over an active area of 100cm2 for the chromogenic materials that can be optically switched by external stimuli.

About Institute & Previous Projects

Indian Institute of Technology-Bombay is recognised worldwide as a leader in the field of engineering education and research. Established in 1958, the second of its kind, IIT Bombay was the first to be set up with foreign assistance. Research and academic programmes at IIT Bombay are driven by an outstanding faculty, many of whom are reputed for their research contributions internationally.

The following are the projects that are ongoing in PI laboratory.

- Sensitized mesoscopic solar energy conversion systems DST INSPIRE FACULTY AWARD Indian Institute of Technology – Bombay – 35 Lakhs, duration: 5 years
- Development of metal organic materials for optoelectronic and photovoltaic applications - IIT-Bombay Seed grant – 20 lakhs duration: 3 years
- Development of stable organic-inorganic hybrid perovskite solar cells - DST SERB ECR – 55 lakhs, duration: 3 years
- Lead free perovskites for stable and efficient photovoltaic devices - DST SERI – 60 lakhs, duration: 3 years.

The following projects are ongoing in the Co-PIs laboratory

- Development of multicomponent reactions for the synthesis of chiral heterocycles: Application in the synthesis of natural products. IITB seed grant -20 lakhs, Duration: 3 years
- Chiral Rhodium catalyst preparation and applications: Synthesis and catalytic applications for asymmetric transformations. DST Fast track grant -33 lakhs, Duration: 3 years
- Rhodium catalyzed asymmetric C-H functionalization: development of novel methodologies for stereoselective synthesis of oxepine and azepine derivatives. DST EMR grant – 44.9 lakhs, Duration: 3 years

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28. ENERGY EFFICIENT BUILDINGS: TECHNOLOGY WITH INTELLIGENCE

Principal investigator: Bijaya Ketan Panigrahi
Indian Institute of Technology Delhi

Background of Project

Building is a major consumer of energy and envelop acts like a filter allowing favourable energy inputs such as day light and absorption of favourable heat in winter, while ensuring rejection of thermal energy in summer. The passive design of building envelop is one of the important aspects of energy efficient building design. The decision variables in this context are numerous including orientation, shape and construction materials etc. While passive design can reduce the energy load, complete control can only be achieved through mechanical, electrical and thermal systems. Full control however requires ICT based management and close loop control. Energy efficiency and energy saving, deployment of renewable energy sources are the key factors for sustainable energy development. When all these factors are handled together clustered with the advancement of communication technology, they may give the comprehensive solution for integrated energy management. The energy efficiency should be seen in both forms: electrical efficiency as well as thermal efficiency. Many efforts are available highlighting these technological advances individually. But the need for integrated energy management still remains. In view of this the purpose of this project is to develop an integrated energy efficient solution to support a building such that the dependency on fossil fuels is reduced by the optimum utilization of renewable energy sources, demand response and energy reductions.

Aim

The overall aim of this work is to develop a complete software package for design of intelligent smart energy efficient and green building and its operational management through smart system involving sensors, actuator and computer control feedback loop system. The specifics would involve

- Development of the frame work for hybrid optimization tool using evolutionary algorithm such GA, PSO, DE and pattern search etc. to design the envelope of energy efficient building.
- Formulation of component of objective function dealing with optimization of electrical and mechanical building services system relevant to energy efficiency and GHG emissions.
- Required thermal properties and performance tests for components of recently (globally) introduced elements such as PCM (imported or indigenously developed) incorporated wall or roof elements, Building integrated Photo-voltaic system such as solar tiles, panels and PZT energy harvesting devices etc.
- Design of smart energy management system for the building using modern ICT and AI based optimal dispatch controller for integrating the same with building service system to make it intelligent.

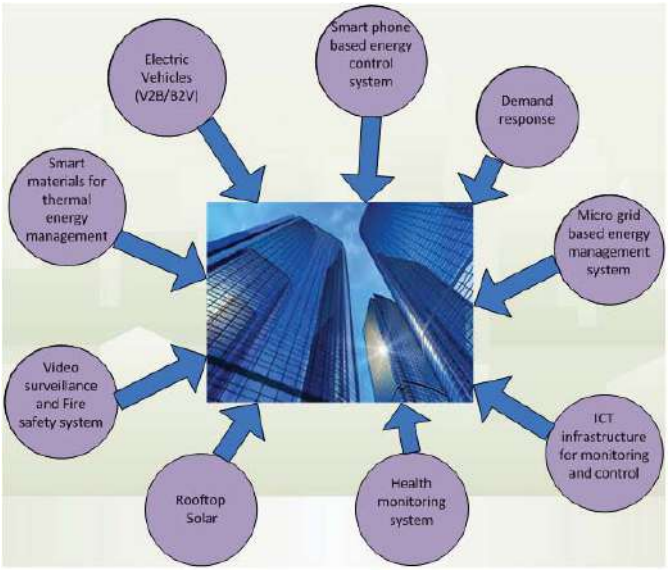
Methodology

The smart building energy management system (SBMS) is the key to energy efficiency. This deals with optimizing the available resources and demand using ICT based infrastructure. Due to environment concerns, the emphasis is to increase the utilization of renewable energy sources and improved materials to reduce the energy needs of an establishment/ building. The ability to monitor and control building operations is essential to achieve energy efficiency. Keeping this in mind the following work packages are designed.

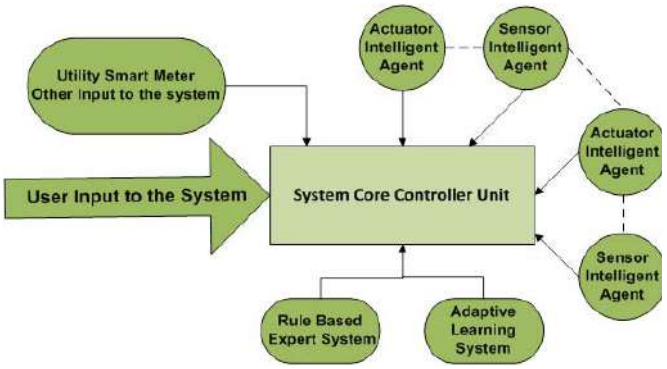
Work Package 1: Identification of the decision variables related to envelop for minimizing energy load including lighting, heating, cooling etc. Estimation of load profiles, building integrated photovoltaics.

Work Package 2: The optimal size of the RE generation system, battery and other resources will be calculated with the aim of reducing dependency on grid. Development of advanced BEMS that integrates both AC and DC demand and generation will be attempted.

Work Package 3: ICT will be used in achieving more efficient utilization of energy through simulation, modelling, analysis,



Architecture for Efficient energy Building



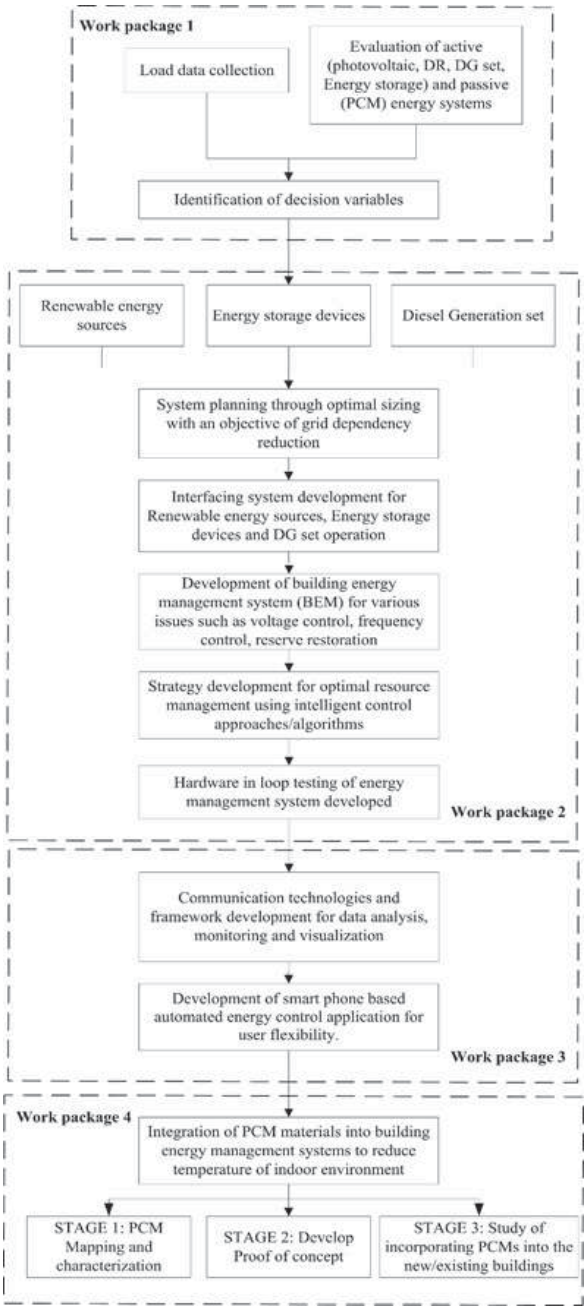
Architecture of hybrid intelligent system for smart micro grid

monitoring and visualisation tools that are needed to facilitate a "whole building approach" to both design and operate buildings.

Work Package 4: Evaluation of the PCM materials and characterization to reduce the energy needs of the building.

Expected Outcomes & Deliverables

- Design methodology for integrated (Electrical, Thermal and Envelop) energy efficient building including smart building management system [design Phase].



Flow chart of project methodology

- Electrical energy management system for SBEM through the use of ICT, energy efficient appliances, AC/DC microgrids, demand response [operational phase].

About Institute & Previous Projects

IIT Delhi: IIT Delhi is a premier institute in the country working with an aim to generate new knowledge by engaging in cutting-edge research and to promote academic growth by offering state-of-the-art undergraduate, postgraduate and doctoral programmes. The institute's constant endeavour is to undertake collaborative projects which offer opportunities for long-term interaction with academia and industry.

Previous projects: Some of the previous projects handled include: charge discharge scheduling of electric vehicle with vehicle to grid (V2G) and grid to vehicle (G2V) operation in micro grid, demand response scheduling in smart cyber-physical distribution system (SCPDS) considering the customer satisfaction through incentive schemes.

Industry Partner and Team Members

Industry partners: CPWD, NBCC, Sunsure

Team Members: B K Panigrahi, Bhim Singh, S C Kaushik, B. Bhattacharjee, Kolin Paul, AshuVerma, Suresh Bhalla, Dibakar Raksit, Sunil Jha

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29. DEVELOPMENT OF NOVEL PHASE CHANGE MATERIAL BASED COLD THERMAL ENERGY STORAGE SYSTEM FOR ENERGY EFFICIENCY AND THERMAL COMFORT OF BUILDINGS

Principal investigator: A. Sreekumar
Pondicherry University

Background of Project

Buildings are responsible for 40% of the total world annual energy consumption and also responsible for one-third of greenhouse gas emissions around the world. A significant portion of this energy is used for air conditioning purpose in buildings. Increasing awareness of the environmental impact of greenhouse gas emissions and CFCs triggered a renewed interest in environmentally friendly cooling, and heating technologies for buildings. Phase change material based cold thermal storage system is an alternate to other conventional air conditioning systems used in the buildings. In PCM based cold thermal storage system, the cold energy is stored in a storage material by running chillers or air-conditioning system when the electricity is available cheap or during off-peak hours and extracted when the demand is high ie., during peak hours. Latent heat storage using phase change materials (PCMs) can be used for free-cooling purposes due to their high storage density. And also the cold air during night hours is used to solidify the PCM and the accumulated cold is extracted during the warm hours of the day in free cooling. This is known as free cooling or night ventilation. Free cooling or ventilation cooling is truly a green concept and it also ensures that a good indoor air quality is maintained in the building. The aim of the use of PCM-products is to reduce the energy needed for cooling the building where there is overproduction of heat.

Aim

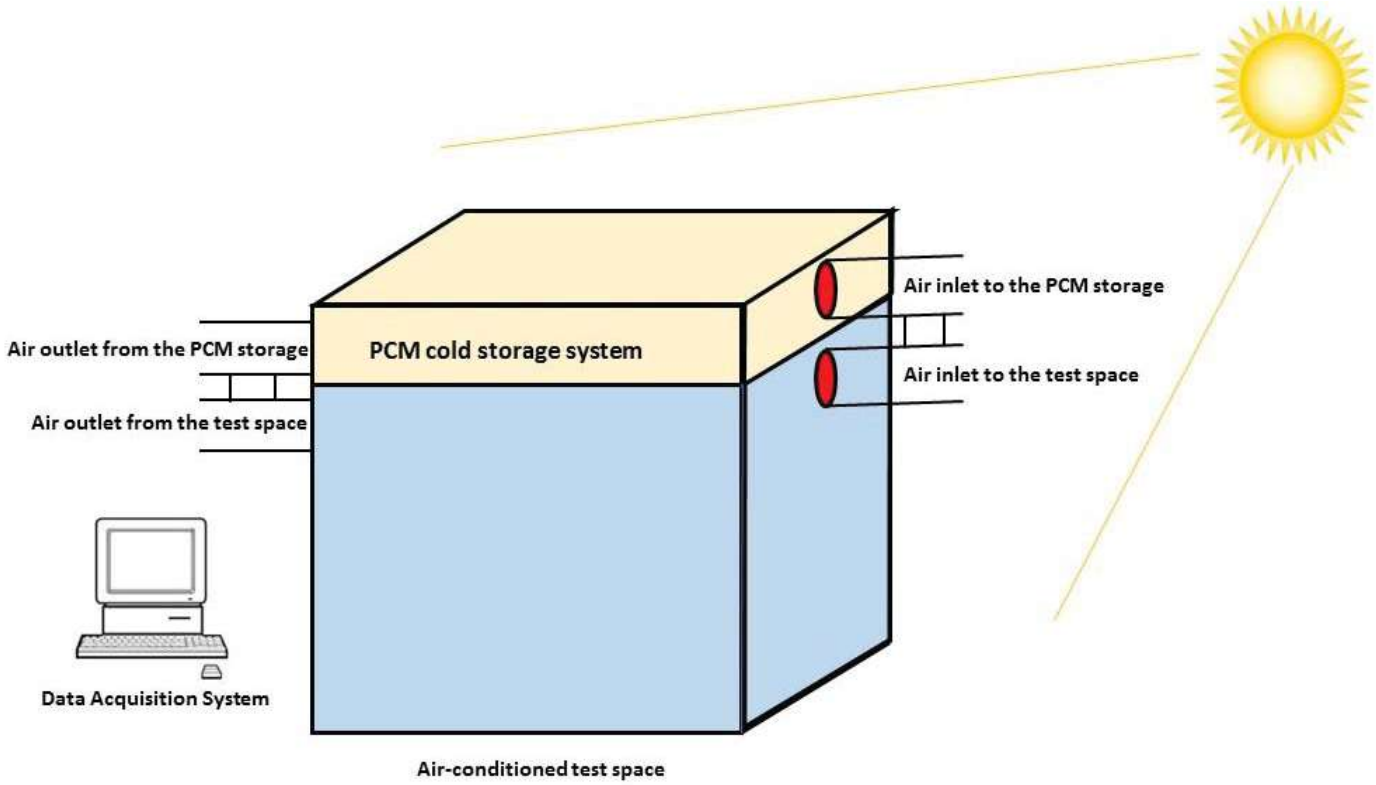
The aim of the proposed project are as follows,

1. Identification of the phase change material which can be used for low temperature applications
2. Studies on thermo-physical properties and performance improvement techniques on identified PCM.
3. Design and development of an efficient PCM integrated Cold Thermal Energy storage test space for indoor thermal comfort
4. Techno-economic analysis and performance evaluation of the complete system
5. Documentation and report submission

Methodology

Phase I

Initially, a low temperature phase change material with melting point less than atmospheric temperature is selected and its various thermo-physical properties will be analysed. To upgrade the performance of the phase change material various techniques like composite PCM and other methods such as thermal conductivity improvement and encapsulation has to be performed.



Experimental prototype of building integrated PCM test space

Phase II
An efficient PCM based cold thermal storage system for indoor thermal comfort of building will be designed. Materials for the system and other important components are selected by studying the thermo-physical properties of the materials. Based on the study, materials for the fabrication will be selected. The necessary instruments have to be procured in the mean time for analyzing the performance of the system.
Once the design is finalized, which will be tested using CFD software for optimising the parameters like temperature, air velocity, humidity, etc. After optimizing the design parameters, the PCM based cold thermal storage system will be fabricated.

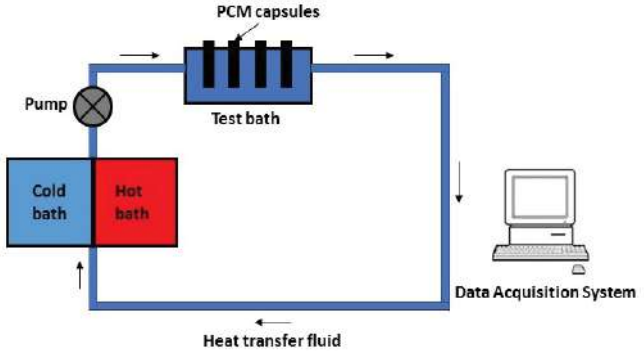
Phase III
The flow through the system has to be clearly controlled to know the temperature variations with different air flow velocities. This has to be done by measuring output velocity and temperature of air for different input flow rate. A control system will be made to provide optimum air velocity for the required temperature. Based on the optimized parameters, the efficiency of the system will be calculated.

Expected Outcomes & Deliverables

Identification of suitable PCM with required thermo-physical properties and the development of advanced PCM heat exchanger are the determining factors towards achieving final goal of the project.

It is envisaged that upon successful completion of this project, energy efficient PCM based cold thermal storage system in buildings for the application of thermal comfort will be developed based on the designed and optimised data available. The developed system will be a solution to bring down the cold energy generation cost. Following are the integral components towards the successful completion of the project.

1. Development of Eutectic PCM with desired freezing point for human thermal comfort
2. Investigation of Thermo-physical properties of the developed PCM to determine the compatibility of the material
3. Development of PCM heat exchanger with adequate heat transfer facility and integration with air conditioning test set up.



Lab scale PCM test setup

About Institute & Previous Projects

The Pondicherry University was established by the Government of India through as Act of the parliament. Since its inception in 1985, University continues to be a leading University situated in the southern part of the country and focused on both quality teaching and innovative research of high standards in a wide range of disciplines. The Centre for Green Energy Technology (C-GET) in Pondicherry University was established in 2010 under the aegis of Madanjeet School of Green Energy Technologies with a vision to promote education and research in environmentally clean methods of energy production, conservation and utilization. The centre offers M. Tech. in Green Energy Technology which is partly supported by South Asia Foundation (SAF). The Ministry of New and Renewable Energy has recognized and approved the centre as a Centre of Excellence. The centre also promotes research in the fields of all clean sources of energy production, conversion and utilization like solar photovoltaic, solar thermal, energy storage, fuel cells, bio-fuels, wind energy, ocean energy, chemical energy, applications of nanotechnology for energy conversion, etc.

The principal investigator of this project successfully completed a project entitled 'Development of Matrix Solar Air Heaters for Medium Temperature Applications in Agriculture and Industrial Sectors' for a budget of Rs. 6,00,000/- funded by UGC-BSR. Currently, PI is handling a project entitled 'Development of Porous Bed Solar Air Heaters with Latent Heat Thermal Energy Storage' for a budget of Rs. 26,62,903/- funded by SERB-DST.

Industry Partners

Two industrial firms namely, Kraftwork Solar Pvt Ltd, Kerala and Matri Instruments, Pondicherry have kindly agreed to facilitate the fabrication work, as and when it is required.

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30. TRANSLATING URBAN SPACES AS STRATEGIC ENERGY AND WATER SECURITY MEASURE

Principal investigator: Mahua Mukherjee
Indian Instituite of Technology Roorkee

Background of Project

Promising urban areas are attracting population and settlements are turning into urban from rural. Well-maintained engineered infrastructure is important to make cities attractive place. Increase of risks is putting urban economy and socio-environment on edge (World Bank, 2010). The green urban space (GUS) has potential to play multiple roles to curb limitations of engineered infrastructure; responsible utilisation of urban public spaces and surfaces can help any city in a long way.

Urban spaces have varied degree of surface characteristics, which influences natural processes like heat and water balance in urban areas. Urban morphology coupled with surface reflectivity and permeability controls/ creates urban heat and water imbalance. GUS with its soil, active vegetation and water components duly designed, can take care of urban ills efficiently. State of the Art review identifies limited implementation of GUS deprives cities from using a major resiliency tool for energy and water security. A thorough scientific investigation into limited application of GUS will be an important step forward. Potential GUS elements' presence and accessibility will influence the mitigation.

To enumerate real world scenario better, the Living lab research philosophy has edges over other methodologies; in this, user-centric research methodology for scoping, prototyping, validating and solving complex solutions in dynamic real life contexts are studied.

The GUS is scarce in India, and mostly availability does not conform to WHO norms of 9 sq.m/person. Best practices conform to the fact that to implement GUS as a resiliency infrastructure, policy, missions and action plans of government and others are critical.

Aim

Establishing GUS potential as sustainable intervention to restore declining City-Nature connect and moreover as urban-Risk Resiliency tool is the aim of the study. 4 objectives are set to explore, create scenario and develop design strategy and implementation policy for the GUS.

First Objective is establishing GUS potential as an opportune measure for Energy and Water security in India, and reviewing challenges for its wider application. The Living Lab experiences coupled with rapid visual survey, secondary sourced qualitative and quantitative data search for GUS potential, and challenges; and Key informants' interview will accomplish the first objective. Local and micro-scale GUS elements in the Delhi NCR will be the scope of investigation.

Exploring Design Strategies for GUS Defragmentation and efficiency improvement employing Green Resilient Infrastructure (GRI) is the second objective. Effective selection of design strategies to network GUS for improved ecosystem and resiliency services is the intent for the same.

Assessment framework development for GRIs on GUS through interactive tool, with the intention for ease in assessing the GUS elements potential as water and energy security measure in urban areas is the Third objective.

The Fourth objective is re/delineating scope of GUS to decrease water and thermal stress in urban areas into identified urban development schemes of government; and it intends to expedite wider application of GUS as a resiliency measure through government schemes/ missions.

Green Urban Spaces (GUS)

Instrumentation

Methodology

Objective I: Establishing Green Urban Space (GUS) potential as an opportune measure for Energy and Water security in India, and reviewing challenges for its wider application.
(1) Best Practice Data Base (2) Exploring Policy Initiatives (3) Living Laboratory (4) Reporting and Peer-reviewed meeting

Objective II: Exploring Design Strategies for GUS Defragmentation and Efficiency improvement employing Green Resilient Infrastructure (GRI)
(1) Defragging GUS (2) Efficiency appraisal for GRI of GUS (3)Living Laboratory (4) Reporting and peer reviewed meeting

Objective III: Developing Assessment framework for GRIs on GUS through interactive tool
(1) Database Development (2) Characterization of solutions (3) Algorithm development (4) Tool development (5) Validation

Objective IV: Re/delineating scope of GUS to decrease water and thermal stress in urban areas into identified urban development schemes of government
(1) Gap identification in govt schemes (2) Re/delineating scope of GUS in planning mandates (3) Formulate decision model for GUS application (4) Report

Expected Outcomes & Deliverables

GUS is multifaceted opportunity for Eco-system services and Risk resiliency measure for Energy and water security; yet finds limited application. The present study focuses on bringing out application potential and challenges, best practices' lessons and stakeholders' role. Identification of scope for GUS intervention through relevant policy/ legal mandates, Key Performance Indicators (KPIs), Survey/ monitoring Techniques will help in developing intervention strategy formulation for GUS, as an alternative or complementary urban Infrastructure service.

Implementability scope finding in Government schemes/ missions, Interactive assessment framework and Handholding Planning kit, Planning and design data collection, analysis and evaluation for selected GUS as the Living Laboratory will strengthen feasibility analysis within Government schemes and mission relevant for GUS.

Research capability through scholar-driven work programme, and peer networking are significant outcome of the proposed study.

Deliverables:

- Interactive assessment tool for GUS strategies' efficiency.
- Kit for Planning Decisions
- GUS (selected) performances documentation, monitoring and evaluation based on appropriate protocol after review of existing national and international ones.
- Customized lessons learnt from global best management practices on GUS for local application. Emphasis is on way-finder in translating under-utilized urban-space into strategic resiliency tool.
- Research publications.

About Institute & Previous Projects

IIT Roorkee team has strong research experience in the field of sustainable habitat, energy efficiency, outdoor and indoor thermal comfort, urban planning, risk resiliency, instrumented field monitoring and performance assessment, alternative scenario generation, simulation and data analysis.

Relevant Projects:

1. Surface transformation due to Urban dynamics in Institutional campuses and its Environmental impact: UCOST, M Mukherjee
2. Energy efficiency and design optimization of CTS, Pune: CTS, E Rajasekar
3. Process Standardisation for Inclusive Urban Planning: IIT Roorkee, U K Roy

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