BUILDINGS ENERGY EFFICIENCY CONSORTIUM

U.S. - CHINA CLEAN ENERGY RESEARCH CENTER (CERC-BEE)

YEAR 4 JOINT ANNUAL MEETING

Berkeley California

Hybrid ventilation optimization and control – R&D

U.S. Research Lead: Leon Glicksman (MIT)

China Research Leads: Hongwei Tan (Tongji University)Baizhan Li (Chongqing University),

China Industry Partner(s): Zhuhai Singyes Green Building Technology Co. Ltd Chongqing Fu Tai Construction Group Heishishan Integrated Tourism development LLC,

Alonso Domínguez

Massachusetts Institute of Technology

August 25th, 2014

Purpose and Objectives

- Research purposes
  - Determine the potential of natural ventilation
    - To provide comfortable indoor conditions
    - To reduce the need for air conditioning and cooling season energy consumption
    - Over the important climatic zones in China and the United States
  - Promote widespread application of natural ventilation
  - Propose guidelines for the optimum operation and control of these buildings
- Research objectives
  - Develop fast but accurate design tools that can be confidently used in new or retrofit designs of naturally ventilated buildings

Purpose and Objectives

- Research objectives (cont'd)
  - Define ventilation strategies in demonstration buildings in China and the US
    - Insure that workable and efficient natural ventilation designs are selected
    - Monitor demonstration buildings
  - Publish monitoring results and validation of CoolVent with monitoring data from real buildings in the US and China in a research journal
  - Use results in workshops, seminars and the International Energy Agency (IEA) Annex 62 program to demonstrate to potential users the value of natural ventilation.

Progress and accomplishments on Year 4

- Improvement of MIT's design tool, CoolVent
  - CoolVent and MIT Design Advisor were merged to increase the options available to simulate a building
  - Current lack of optimized controls in natural ventilation building operations. New optimized control strategies are being developed based on:
    - Simple rules extracted from optimized control strategies for a room with thermal mass
    - Predictor that keeps track of the thermal mass temperature, as this cannot be measured in actual buildings

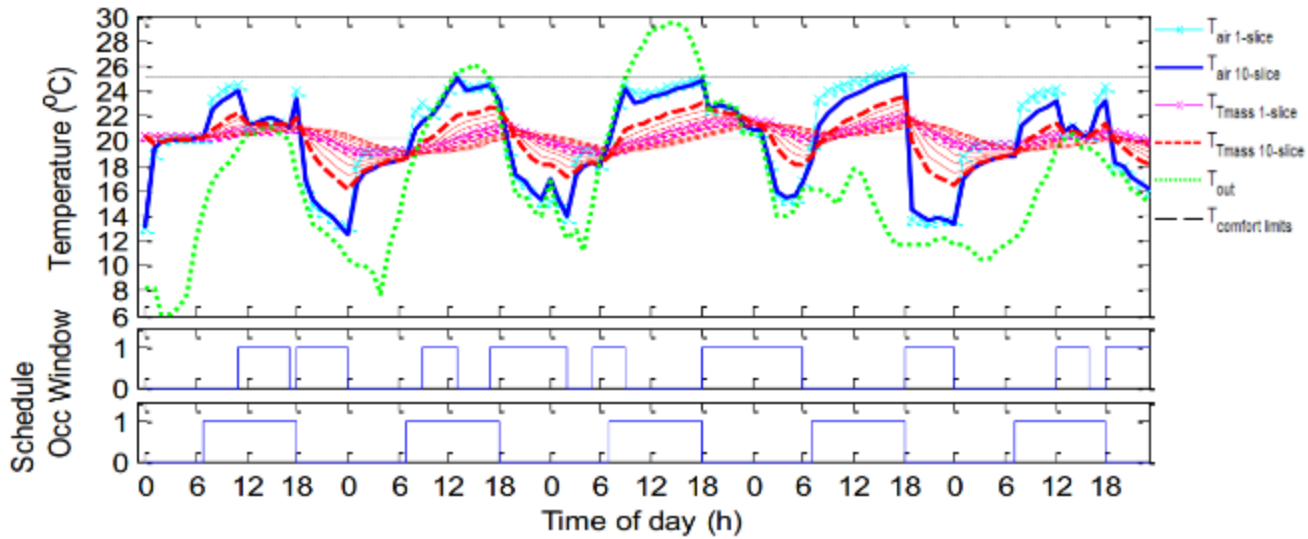
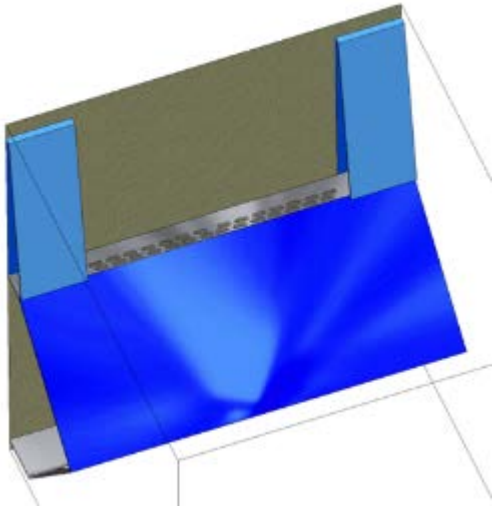
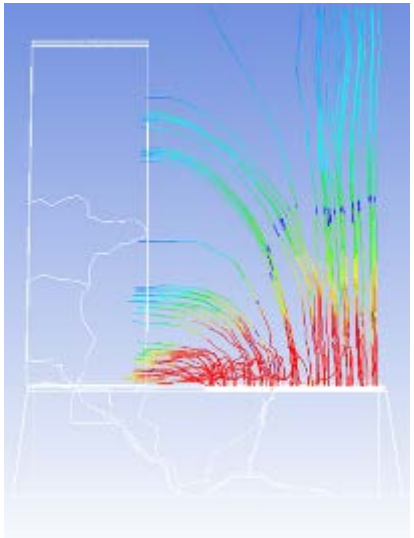


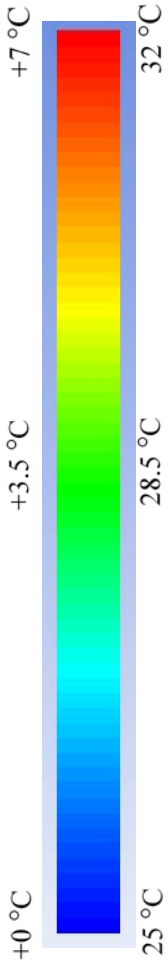
Figure 6-16: Testing the effectiveness of effective 1-slice model for Madison weather, May 15-19. Parameters used: low heat gain, q=15W/m^2; normal thermal mass heat capacity c=880 J/kgK.

Progress and accomplishments on Year 4

- Demonstration projects in China
  - Submitted three reports to Singyes, developers of the demonstration building in Zhuhai
    1. Determined worst-case scenario for impact of photovoltaic panels on the performance of natural ventilation
    2. Evaluation of ventilation strategies: including exhaust fan at the outlet of the ventilation shaft and night ventilation. Assessed impact of the photovoltaic panels on the percentage of time that air conditioning is needed in the building.
    3. Analyzed the impact of the geometry of the photovoltaic mounting frame on performance of natural ventilation

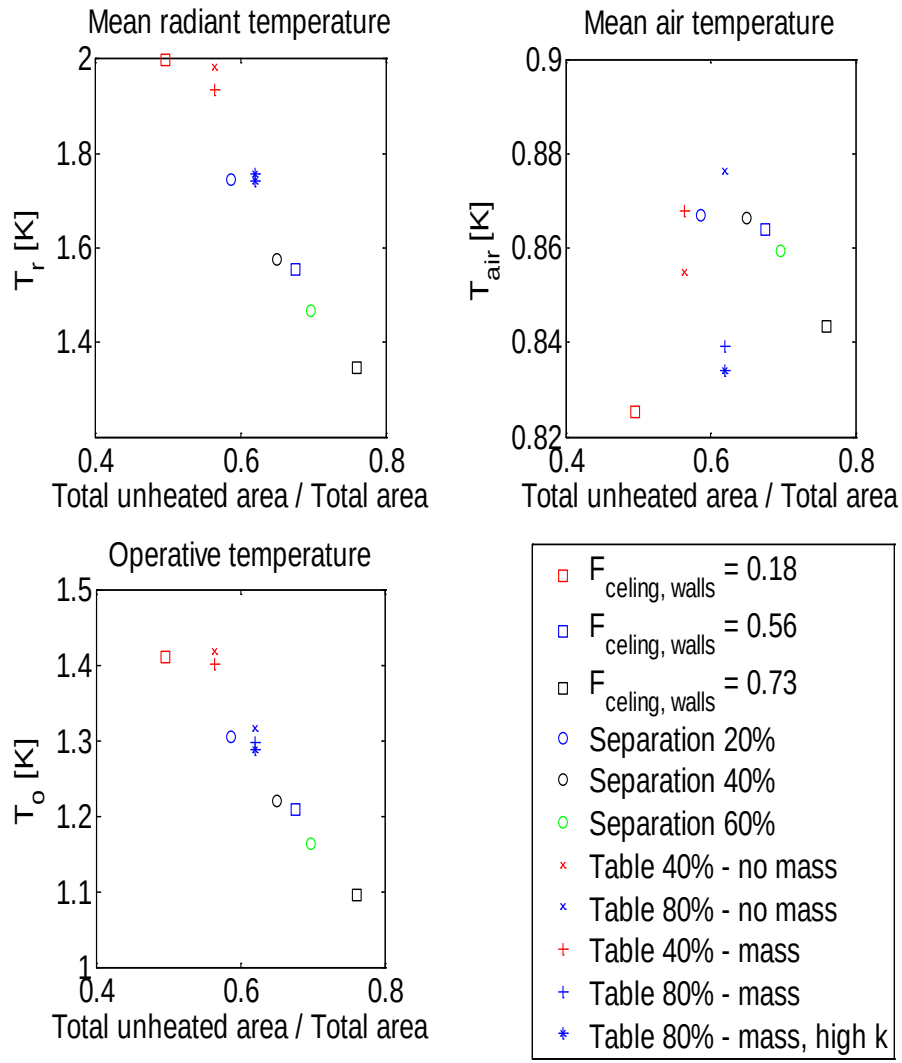






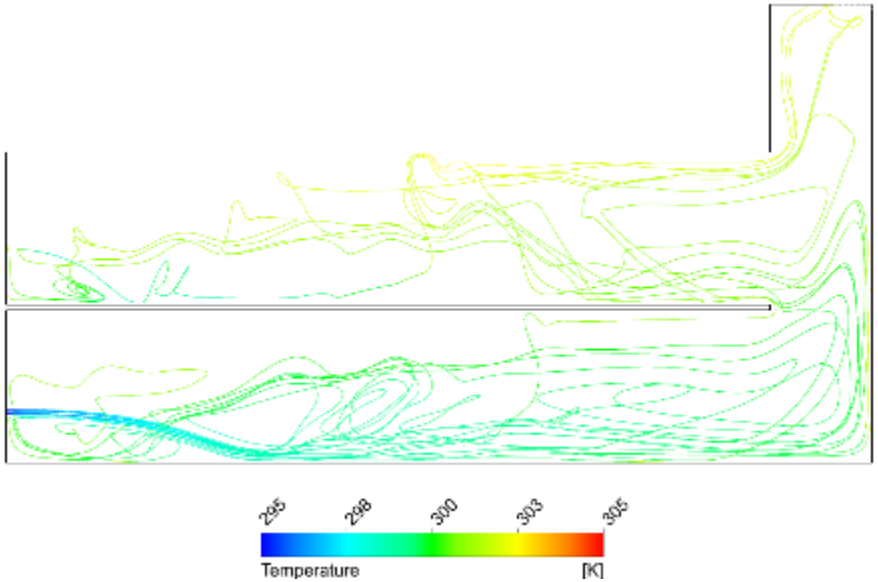
Progress and accomplishments on Year 4

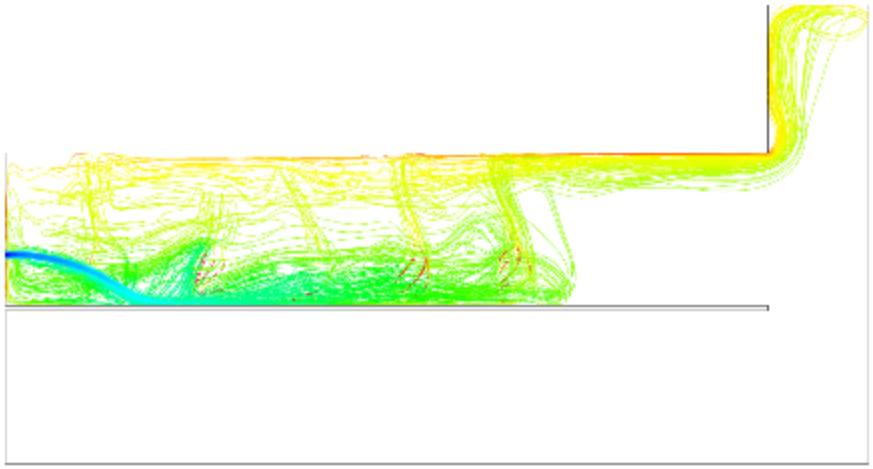
- Improvement of thermal stratification model
  - Operative temperature was calculated for many room configurations, which include tables, vertical separations and different lighting configurations
  - Mean air temperature at occupant level was found to be similar for all these cases (and generally below the exhaust – or well-mixed – temperature).
    - Therefore, software relying on the well-mixed temperature to calculate natural ventilation potential, underestimates its potential.
  - Operative temperature follows a linear trend in the dimensionless temperature vs dimensionless convection area plane (for example, interior vertical partitions). In all the cases the operative temperature was found to be higher than the exhaust temperature.



Progress and accomplishments on Year 4

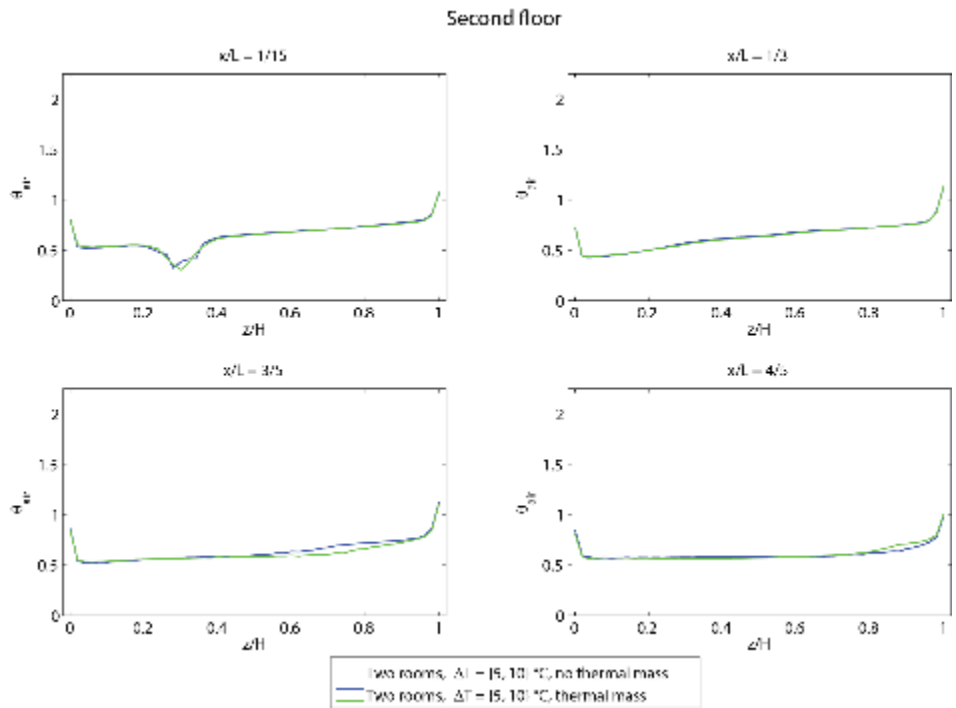
- Improvement of thermal stratification model (cont'd)
  - Effect of a second floor, connected through a ventilation chimney with a large opening, on the thermal stratification of the spaces was investigated.
    - When the temperature rise in the second floor is higher than in the first floor, it was found that virtually all of the air from the first floor enters the second floor.
    - The temperature profile in the first floor is also different than in the single-floor case. However, the mechanism by which the temperature stratification changes in the first floor was found to be heat transfer in the ventilation chimney, given that no air from the second floor reaches the first floor.





Progress and accomplishments on Year 4

- Improvement of thermal stratification model (cont'd)
  - The temperature stratification of the second floor was found to be independent of the stratification of the first floor, except for the well-mixed temperature of the first floor.
  - The effect of thermal mass on the stratification in both floors was assessed. It was found that in steady state, the stratification in the rooms, as well as the temperatures in the floor and the ceiling of both floors, was not significantly altered by the presence of the thermal mass.



Progress and accomplishments on Year 4

- Organized natural ventilation workshop at the MIT campus on August 20th
  - Day-long workshop features speakers from SOM, Payette, Transsolar and MIT, and a hands-on workshop on CoolVent
  - Intended for architects, designers and engineers as well as educators; its goal is to disseminate our work on natural ventilation and to reach new CoolVent users to promote the use of natural ventilation that will reduce energy use for cooling

Progress and accomplishments on Year 4

- Organized natural ventilation workshop at the MIT campus on August 20th
  - Professional firms:
    - Arup
    - Vanderweil Engineers
    - Environmental Design Solutions
    - AKF Group
    - Sustainable IQ
    - FirstFuel
    - Sasaki Associates
    - Duo-Gard
    - Bard, Rao + Athanas Consulting Engineers (BR+A)
    - KAO Design Group

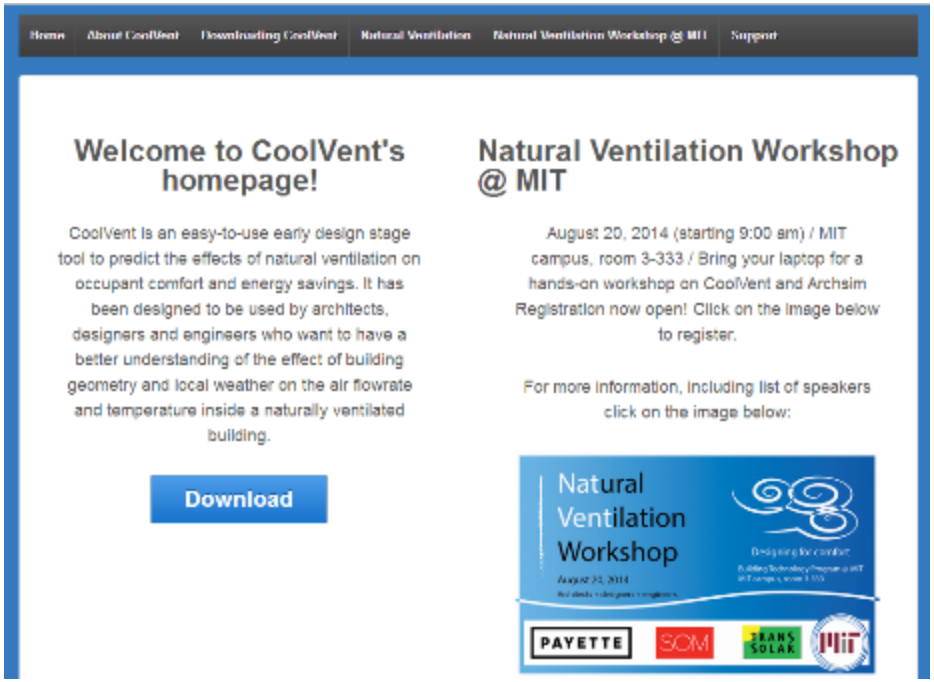
Progress and accomplishments on Year 4

- Organized natural ventilation workshop at the MIT campus on August 20th
  - Universities:
    - MIT
    - Harvard
    - Virginia Tech
    - Iowa State University
    - Politecnico di Torino
    - University of Hawaii*
    - University Politehnica of Bucharest*

*Through web streaming

Progress and accomplishments on Year 4

- Improved dissemination
  - New web site on line: coolvent.mit.edu
  - CoolVent now used at Harvard, MIT and planned for Berkeley
  - ASHRAE presentations (latest: ASHRAE Winter Meeting 2014)
  - Conferences
    - Latest: CISBAT 2013, Lausanne, Switzerland
    - IEA annex 62, April 2014



CISBAT 2013

venticool
the international platform for ventilative cooling

IEA EBC
Annex 62
The IEA project
on ventilative cooling
EBC

OCTOBER, 19th-22nd, 2014. São Paulo, Brazil
ROOMVENT 2014

Estimated CO_2 and energy savings

- In 2025:
  - In the US:
    - Domestic: Retrofit will save 56×10^9 kWh of electricity and 30 MTc/yr of CO_2. New naturally ventilated houses will save 4×10^9 kWh of electricity and 2 MTc/yr of CO_2.
    - Commercial: Savings of 11 kWh/m^2 for all new buildings. This results in a yearly electricity savings in 2035 of 3.5×10^9 kWh or 2.1 MTc/yr of CO_2.
  - In China:
    - Around 3.3×10^{11} kWh or 258 MTc/y of CO_2.

Schedule of completion for remaining (unmodified) Year 4 Milestones

- MIT: 11% of unspent DOE funds
  - Third quarter of 2014
    - Extend air thermal stratification in naturally ventilated office:
      - Generalize results of thermal stratification model to include not only additional surfaces (which participate through radiation with the rest of the room, thereby changing the temperature of the ceiling and the floor), but also include transient effects related to thermal mass in the building
    - Improvement of design tool, CoolVent
      - Continue with implementation of control strategies for hybrid ventilated systems
    - Collaboration in IAE Annex 62
  - Fourth quarter of 2014
    - Improvement of design tool, CoolVent (cont'd)
      - Implement improved thermal stratification performance and begin integration of this model with thermal comfort conditions to improve control model (thermal comfort is a metric to optimize the control of the ventilation system)

Schedule of completion for remaining (unmodified) Year 4 Milestones

- Zhuhai: experimental setup (mockup)

	US research team
Experiments (Nov. 2014)	• Propose experiment methodology (data to be recorded, etc.) • Assess the experiment results

	China research team	**China developer**
Experiments (Nov. 2014)	• Evaluate and modify the experiment plan • Participated in experiments. • Assess results	• Evaluate and modify the experiment plan • Implement experiment • Manage and record data • Assess results

Project plan and schedule

- MIT
  - Second half of 2014 follows schedule as shown before
  - First quarter of 2015
    - Continue working towards optimization of control algorithms in CoolVent.
    - Create design guidelines: finish analyzing aggregate of data from China and US to identify key design features of successful naturally ventilated buildings.
    - Continue collaboration in IAE Annex 62
  - Second quarter of 2015
    - Create control guidelines: finish analyzing aggregate of data from China and US to identify best practices in operating naturally ventilated buildings
    - Write and publish journal papers related to the research
    - Workshops for designers will be held in the US and China on natural ventilation design and control

Project plan and schedule

- Zhuhai: real building monitoring

	US research team
Real building validation (Aug. 2015)	• Propose experiment plan (what ventilation strategy should be applied?, etc.) • Assess experimental results
Summarizing design principles (Nov. 2015)	• Three organizations summarizes the study separately. • Participate in meeting with all institutions to help SYE preparing final report

	China research team	China developer
Real building validation (Aug. 2015)	• Evaluate and modify the experiment plan • Participated in the experiments. • Assess experiment results	• Evaluate and modify the experiment plan • Carry out experiments • Share experiment data collected in the study in the research group • Assess experiment results
Summarizing design principles (Nov. 2015)	• Three organizations summarizes the study separately. • Participate in meeting with all institutions to help SYE preparing final report	

Issues/risks and abatement plans

- Sporadic communication with Chinese research team and developer
  - Proposed conference call with Chinese team
- Access to demonstration buildings to carry out monitoring experiments
- Project develops a technology, not a new product
  - No industrial partner
  - Market potential for building control and management system providers
- Need for additional researcher for the US team
- Wrong perception regarding natural ventilation
  - Increasingly important part of new high performance buildings
  - Difficult to control – several naturally ventilated buildings do not achieve their savings potential due to operation issues
  - Further research is necessary

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Concept Proposal for Project Continuation

- Improve design tool by including better assessment of comfort and optimum controls for night ventilation, fan assisted ventilation and joint air conditioned / natural ventilated buildings
- Disseminate results as design guidelines and standards for natural / hybrid ventilation systems. Make our design tool available to architects designers.
- Ground up method of dissemination: architectural and architectural-engineering schools along with young design practioners
- Continue participation in IEA Annex 62: Ventilation Cooling program to propose new natural ventilation standards
- Using CoolVent simulate different ventilation options for the demonstration projects to evaluate and define best design and operating strategies
- Set up monitoring experiments in buildings in both the US and China
- Using the data from the monitoring experiment in China, as well as data from previous monitoring experiment in the US, validate design tool and publish results in relevant research journal

Concept Proposal for Project Continuation – Outcomes

- Development of validated design process for natural ventilated and dual mode buildings that will allow designers and developers to confidently plan for commercial and residential buildings in the US and China
- Advanced natural ventilation building designs and control systems for optimum operation of buildings
  - Control algorithms based on simple rules that can be implemented in existing building manager systems, extracted from optimization schemes
- Performance data from monitored buildings in the US and China to substantiate energy savings and comfort levels

Concept Proposal for Project Continuation – Outcomes

- A design tool to produce building design parameters to achieve comfortable energy efficient building especially in cooling dominated regions
  - Include air flow, fans, design exhaust and inlet geometries, controls, optimization of operation including use of thermal mass, night cooling, individual flow control, joint natural ventilation and air-conditioning systems
- Publish reports regarding ventilation system proposed design and expected performance and comparison with data from the actual buildings
- Develop suggestions to improve performance of the ventilation system (metrics: energy consumption and percentage of time under comfortable conditions)
- Dissemination of natural ventilation know-how through web site and IEA reports
- Carry out workshops in US (planning next workshop in Chicago, IL) and China

Annual U.S. and China (estimated) project budget, spending, and cost-share by source (past, current, planned)

- MIT is the Source for all cost sharing associated to this project and the costs to date are as follows:
  - Total cost sharing: $253,673.24

Project plan and schedule (Qtly)

Project Schedule					
	FY2014	FY2015			
Task	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
2014 Q4 Milestone: Begin second phase of individual zone control: Optimize individual control of zones to improve general energy consumption performance of the building (not just of the zone)	■	■			
2015 Q1 Milestone: Once new control systems have been optimized in CoolVent, determine the impact of these on the potential savings for naturally ventilated buildings		■	■		
2014 Q4 Milestone: Generalize results of thermal stratification model to include not only additional surfaces (which participate through radiation with the rest of the room, thereby changing the temperature of the ceiling and the floor), but also include transient effects related to thermal mass in the building)	■				
2014 Q4 Milestone: Continue with implementation of control strategies for hybrid ventilated systems	■	■	■		
2015 Q1 Milestone: Implement improved thermal stratification performance and begin integration of this model with thermal comfort conditions to improve control model (thermal comfort is a metric to optimize the control of the ventilation system)		■			
2015 Q2 Milestone: Finish analyzing aggregate of data from China and US to identify key design features of successful naturally ventilated buildings		■	■		
2015 Q4: Write and publish journal papers related to the research, particularly the results of surveys of monitoring buildings, as well as the design and operational guidelines. Workshops for designers will be held in the US and China on natural ventilation design and control.	■	■	■	■	■