Hybrid ventilation optimization and control research and development
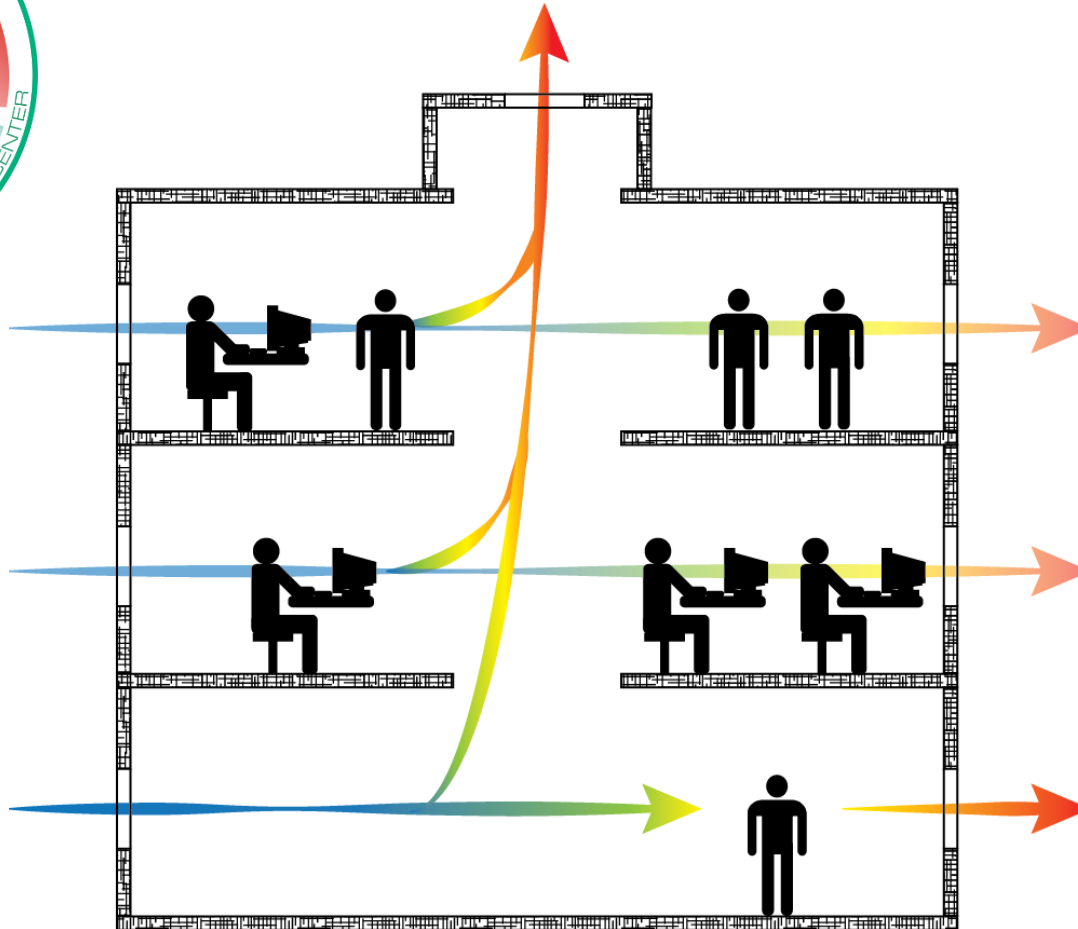
2014 Building Technologies Office Peer Review

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Massachusetts Institute of Technology

Project Summary

Timeline:

Start date: August 2011

Planned end date: September 2015

Key Milestones

1. Enhanced CoolVent to simulate joint natural ventilation and air conditioning: illustrated energy savings for different US climates, building types (ASHRAE Winter Meeting 2014)
2. Obtained monitoring results for several buildings in US, Japan
3. Began work on Chinese demonstration (Zhuhai

Budget:

Total DOE $ to date: $186,627

Total future DOE $: $115,149

Target Market/Audience:

This program is technology driven rather than product centered

Reach a USD$1.6 billion market that includes design and architecture firms, hybrid ventilation equipment companies, building operators and managers

Key Partners:

Baizhan Li, Chongqing University
Hongwei Tan, Tongji University
Zhu Neng, Tianjin University
Zou Wei, Chongqing Fu Tai Construction Group Heishishan integrated tourism development
Xin Deng, Zhuhai Singyes Green Building Technology

Project Goal:

- To promote the widespread application of natural ventilation to provide comfortable conditions that will reduce or eliminate the need for air conditioning over the important climatic zones in China and the US.
- To develop fast and accurate design tools, control algorithms that can be confidently used in new or retrofit designs of naturally ventilated buildings.

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Purpose and Objectives

- Project part of the US-China Clean Energy Research Center Building Energy Efficiency Consortium (CERC-BEE)
  - Joint program between US and China to increase building energy efficiency

Problem Statement:
- Performance of natural ventilation dependents on building's shape, orientation and operation
- Lack of simple, fast and accurate models to test different shapes, orientations and ventilation strategies at early design stage
  - Existing computer programs are difficult to learn and use; require advanced technical training, do not include key factors
- Lack of robust control algorithms for hybrid system

Target Market and Audience:
- Architects and designers in new or retrofit projects
  - Especially–but not limited to–relevant weather regions in China and US
- Hybrid ventilation system providers; building managers and operators
- Academic community, including students

This program is technology driven rather than product centered

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Purpose and Objectives

Impact of Project:

- Estimated market size of USD$1.6 billion
- Reduction of energy consumption and CO_2 emissions in commercial buildings (estimated):

	China	US
Annual energy savings [kWh]	2.20×10^{11}	2.9×10^{10}
Annual CO_2 abatement [kg]	1.72×10^{11}	1.6×10^{11}

- New standards and guidelines for naturally ventilated buildings
  - Participation in IAE Annex 62 Ventilation Cooling program to develop codes and standards; design methods and tools

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Purpose and Objectives

- Impact path:

Near term

- Natural ventilation is key technology in new buildings
- Use of CoolVent in new demonstration buildings in China, the US
- Use of CoolVent in design firms, universities

Intermediate term

- New standards and guidelines energizes application of natural ventilation in new and retrofit projects
- Extensive use of optimized natural ventilation controls, algorithms

Long term

- Widespread application of natural ventilation in commercial buildings
- Substantial savings derived from natural ventilation
- Results from present research used in design of new buildings

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Approach

Approach:

- Surveys of successful application of natural ventilation in China, the US and other countries – demonstration buildings (Boston, Tokyo)

- Development of fast but accurate design tools that can be confidently used in new or retrofit designs of naturally ventilated buildings

- Development of innovative control algorithms to be used in hybrid ventilation systems (building in Tokyo)

Demonstration buildings in Boston and Tokyo
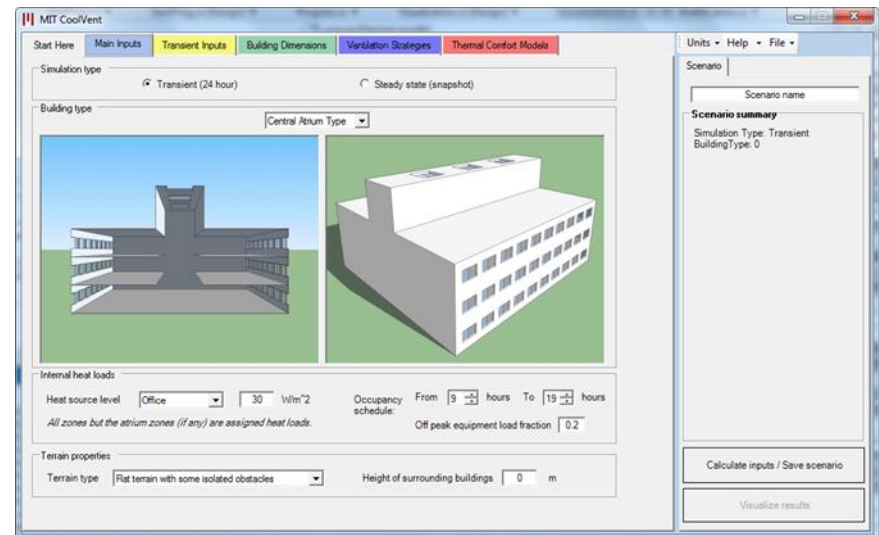
CooVent: a design and control tool for hybrid ventilation

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Approach

- Work with Chinese universities and developers in three projects: Zhuhai, Wuhan and Chongqing

- Work with US developer: new net zero energy office building in Massachusetts

- Participation in new IEA annex 62 Ventilation Cooling program to develop codes and standards, design methods and tools

- Development of innovative control algorithms to be used in hybrid ventilation systems

nizing workshop in MIT (Skidmore, ...erra, IBPSA)

Net zero energy office building, Massachusetts

Projects in China: Chongqing and Zhuhai

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Approach

Key Issues:
- Need to optimize control of ventilation elements
  - Implemented new hybrid ventilation systems
  - Exploring optimization techniques
- Current thermal stratification model incorrectly predicts high temperature close to walls, ceiling and floor, underestimating natural ventilation potential and comfort conditions
  - Extending model to account for radiation exchange between walls, ceiling and floor, and also with other surfaces (furniture)
- Zhuhai façade heating: interference with natural ventilation
  - Ran CFD simulations to establish possible interference mechanisms. Chinese colleagues are preparing experimental setup

Distinctive Characteristics:
- This program is technology driven rather than product centered
- This is the only natural ventilation research program sponsored by DOE
- Potential to achieve substantial energy savings with little capital cost

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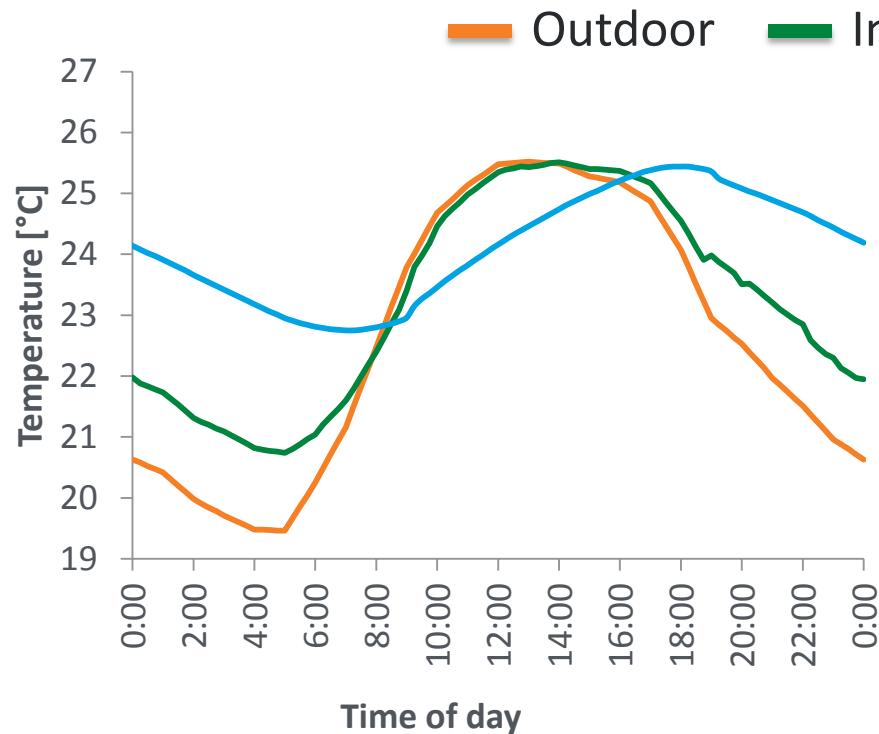
Progress and Accomplishments

Accomplishments:

- Enhanced CoolVent to simulate joint natural ventilation and air conditioning
  - Illustrated energy savings for different US climates, building types (ASHRAE Winter Meeting 2014)
  - Began work on advanced controls CoolVent
    - New control for hybrid ventilation for buildings with low thermal mass included in CoolVent
    - Individual control of each zone in the building
- Obtained monitoring results for several buildings in US, Japan
- Began work on Chinese demonstration (Zhuhai)
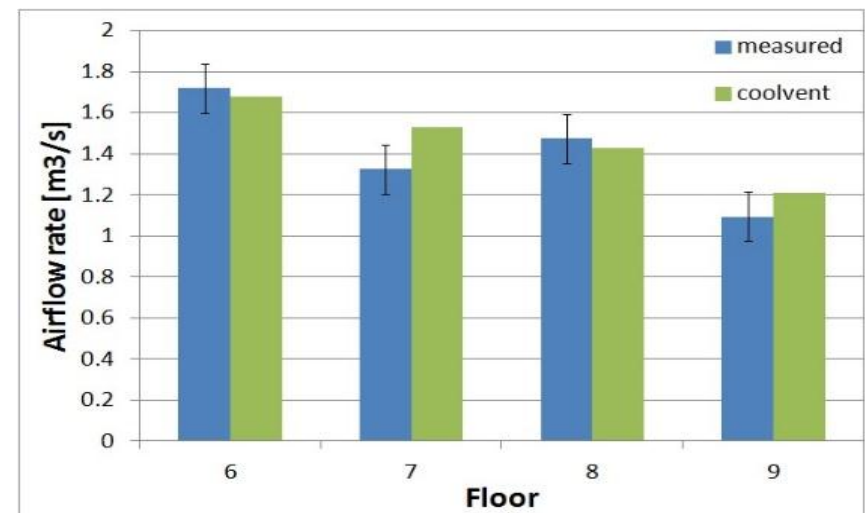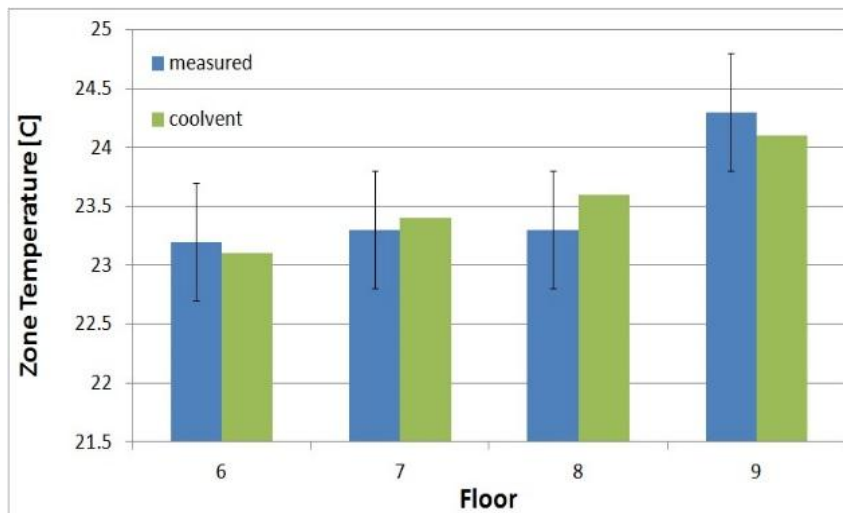
Progress and Accomplishments

- Control algorithms:
  - Decision to close windows and turn on AC based on thermal model of future temperature– reduced total amount of AC usage by approximately two hours every day during the cooling season compared to hour by hour temperature control only.
  - In progress: optimization of night ventilation with thermal mass

Window control: fixed time

Predictive control

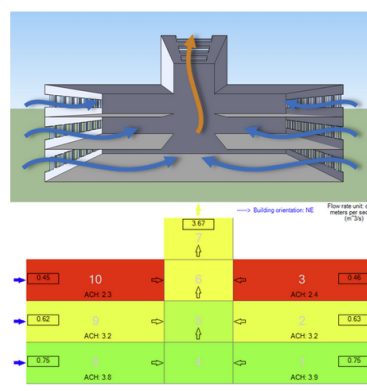U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy
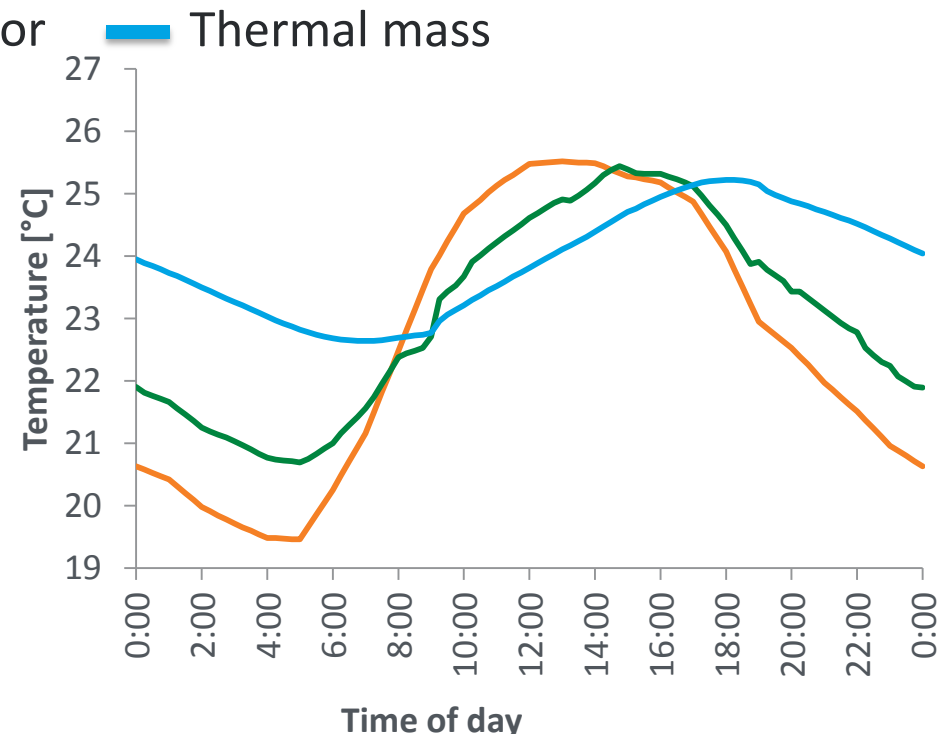
Progress and Accomplishments

- Improved dissemination
  - New web site on line: coolvent.mit.edu
  - ASHRAE presentations (latest: ASHRAE Winter Meeting 2014)
  - Conferences
    - Latest: CISBAT 2013, Lausanne, Switzerland
    - IEA annex 62, April 2014
    - Next participation: Two papers in ROOMVENT 2014, Sao Paulo, Brazil
  - Program being used at:
    - MIT
    - Harvard
    - University of California, Berkeley
    - Japanese design firm
    - SOM, Payette
    - European universities

Project Integration and Collaboration

Project Integration: MIT participates in two demonstration projects in China: Zhuhai and Chongqing. Possible collaboration in the Wuhan project. Additionally, communication with WindowMaster, SOM

Partners, Subcontractors, and Collaborators:

Name	Affiliation	Roles
Dan Arons	Architerra	Designer of new Massachusetts zero energy office building
Baizhan Li	Chongqing University	China research lead
Hongwei Tan	Tongji University	China research lead
Zhi Zhuang	Tongji University	China research lead
Wang Xuesong	Chongqing University	Designer of the Chongqing project
Zou Wei	Chongqing Fu Tai Construction Group	Chongqing developer
Zhu Neng	Tianjin University	China research lead, Chongqing
Luo Duo	Zhuhai Singyes Green Building Technology Co.Ltd	Chief engineer (Zhuhai developer)
Deng Xin	Zhuhai Singyes Green Building Technology Co.Ltd	(Zhuhai developer)

Next Steps and Future Plans

Next Steps and Future Plans:
- Continue development of CoolVent as a free, easy to use stand-alone program for early stage design of natural ventilation systems (improved thermal comfort model, controls)
    - Demonstrate its use working with Chinese developers (at least one in the first year) and monitoring of natural ventilated buildings
- Participation in real building designs and detailed monitoring results for several representative buildings to establish credibility in natural ventilation concepts
- Plan for broad use to access architects around the world though architectural student use, workshops, seminars, papers (bottom-up approach)

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Next Steps and Future Plans

Next Steps and Future Plans:
- Natural ventilation workshop to be held at MIT:
  - Payette
  - SOM
  - Architerra
  - Harvard University
- Publish several papers, presentations at ASHRAE and conferences
- Explore link of CoolVent with DeST
- Publication of the results in a design handbook
- Control algorithms to optimize efficiency and comfort in dual mode buildings with multiple zones

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Next Steps and Future Plans

Next Steps and Future Plans:

- 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)

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REFERENCE SLIDES

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A Project of CERC-BEE (US-China Clean Energy Research Center Building Energy Efficiency Consortium)

BERKELEY LAB | OAK RIDGE National Laboratory | MiT | ICF INTERNATIONAL | NRDC The Earth's Best Defense | UC DAVIS UNIVERSITY OF CALIFORNIA | Dow | ENERGY FOUNDATION | SAINT-GOBAIN | Bentley | CLIMATEMASTER | C3 Energy | 3M | LUTRON

U.S. Research Leads | **U.S. Industrial Partners** *(Funding +40% Annual Average Growth Rate)*

Research Strategy → Huge Impact:
- U.S./China construction market ~ 2B m2
- CO_2 savings ~ 100Mt/year by 2025

Technologies, Software

↓

New Patent Applications

Demonstration Buildings, Commercial Impact, Tools and Guidebooks

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Market

Wide Adoption Very Low Energy Buildings

↓

Policy

ABOUT: CERC-BEE is a five year, $50M program created by the U.S. Department of Energy and Chinese Ministry of Science and Technology.

R&D TEAMS: U.S. national laboratories, and U.S. and Chinese universities, and research institutes team up with industry partners to accelerate innovation and deployment.

SELECTED RESEARCH OUTCOMES:
- Launched eight new products and developed two software tools (e.g. Cloud tool for microgrids, 40 new users from China)
- Won R&D Top 100 Award for GSHP by Climate Master
- Exceeded IP goals: ~ 25 patents filed, 4 approved; inventions disclosed and more in process (e.g. sprayable liquid flashing, cool roof materials)
- Developed 20 standards (e.g. LBNL involved in new Chinese commercial building code revision)
- Published 135 Chinese and 54+ US academic research papers

Website: cercbee.lbl.gov

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Building Design
Whole Building
Policy & Market Promotion
Building Envelope
Microgrid & Renewable Energy
Building Equipment

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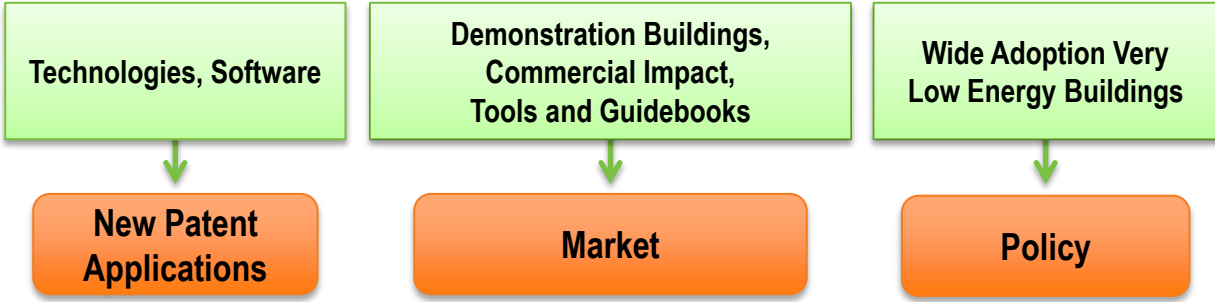
Project Budget

Budget History					
CY2013 (past)		CY2014 (current)		CY2015 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$135,000	$93,529	$112,715	$51,627	$115,149	$53,514

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Project Plan and Schedule

Project Schedule														
Project Start: August 2011		▇ (blue)	Completed Work											
Projected End: September 2015		▇ (dark)	Active Task (in progress work)											
		◆ (red)	Milestone/Deliverable (Originally Planned)											
		◆ (black)	Milestone/Deliverable (Actual)											
		FY2013				FY2014				FY2015				
Task		Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	
Past Work														
Q2 Milestone: Finish monitoring report of the Artists for Humanity EpiCenter, including comparison between measurements and simulation results using CoolVent.		▇	▇	◆										
Q2 Milestone: Once CoolVent has been validated, continue with the assessment of potential energy savings in the US		▇	▇	◆	◆									