Project Summary

**Timeline:**
- Start date: October, 2012
- Planned end date: August, 2014

**Key Milestones**
- Mid- & Full-scale Lab Tests; June, 2013
- Full-scale Demo; January, 2014
- System Documentation; July, 2014

**Budget:**
- Total DOE $ to date: $1,037,812
- Total future DOE $: $0 (committed to date)

**Target Market/Audience:**
Owners, developers, and operators of medium-large scale commercial, institutional & multi-use buildings in warm, humid climates.

**Key Partners:**
- Lawrence Berkeley National Laboratory
- dPoint Technologies, Inc.
- Arup
- ETH Zurich
- Membrane Technology & Research, Inc.

**Project Goal:**
Design & demonstrate at increasing scales the energy benefits of large-scale, wall-integrated heat & moisture exchangers. Characterize both the ventilation energy benefit as well as the insulation benefit of this hybrid envelope/hvac technology.
Purpose and Objectives

Problem Statement:

State-of-the-industry energy recovery ventilators (ERV’s) offer low humidity exchange ($\varepsilon_{\text{latent}} = 0.45-0.65$) with high attendant pressure penalties (200-350 Pa), resulting in low market penetration and limited impact.

Integrated ERV solutions could leverage multiple advantages to produce better a better ROI and reap more of the nearly 3 quads of potential US savings available annually.

Target Market and Audience:

The target market for AirFlow Panels™ includes developers, owners, and operators of commercial and multi-family residential buildings.

<table>
<thead>
<tr>
<th></th>
<th>Square Footage</th>
<th>Energy Savings Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Construction</td>
<td>108 B</td>
<td>0.72 Quads</td>
</tr>
<tr>
<td>Renovation</td>
<td>257 B</td>
<td>1.88 Quads</td>
</tr>
</tbody>
</table>

2013 US Market Size  (maximum adoption potential)
Purpose and Objectives

Impact of Project:

The key to achieving significant impact in energy savings is to overcome the resistance to adoption of *decentralized outdoor air paths* (as opposed to conventionally centralized) and *combined hvac and envelope functions* (as opposed to segregated).

Toward this goal, project deliverables include:

1. validated testing at various scales
2. operational installation demonstrating the benefits

Impact Trajectory

- **Near term**
  - 3 pilot installations
  - build awareness
  - certifications (ahri)
  - industry collaboration

- **Intermediate term**
  - 15 installations
  - sales partnership
  - manufacturing
  - supply chain

- **Long term**
  - 150+ installations
  - strategic partner
  - International sales
  - scale up manuf.
**Approach:**

The technology is a hybrid of two building system functions—HVAC and building envelope—integrated into a unified whole to achieve lower energy use at better economic returns.

**Distinctive Characteristics:**
- Large-scale air-air exchanger
- Polymeric membrane-based
- Higher transfer surface area
- Lower face velocity & pressure loss
- Manufactured in a panelized form
- Integrated into modular wall panels
- Simultaneous improvements to ventilation & envelope performance
Progress and Accomplishments

Key Issues:

I. Validating the coupled ventilation/envelope heat & moisture exchange

II. Assessing the feasibility of achieving theoretically predicted performance in practice.

III. Identifying and resolving pragmatic design & operation issues, including:

a. balance of system design (e.g. fans, filters, dampers, etc.)
b. code/regulatory issues (e.g. intake/outlet separation distances)
c. manufacturing methods (e.g. cross-leakage, filter access, etc.)
<table>
<thead>
<tr>
<th>MILESTONE</th>
<th>PROPOSED</th>
<th>ACTUAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Medium-scale laboratory test (Berkeley)</td>
<td>Dimensions: 3'-3&quot; x 5'-3&quot; x 3&quot;</td>
<td>3'-0&quot; x 4'-0&quot; x 10&quot;</td>
</tr>
<tr>
<td>AirFlow Rate</td>
<td>22 cfm</td>
<td>40-90 cfm</td>
</tr>
<tr>
<td>Supply Inlet</td>
<td>90 F</td>
<td>90% RH</td>
</tr>
<tr>
<td>Exhaust Inlet</td>
<td>72 F</td>
<td>50% RH</td>
</tr>
<tr>
<td>$\varepsilon_{\text{sens}}$</td>
<td>&gt; 0.88</td>
<td>0.97-0.99</td>
</tr>
<tr>
<td>$\varepsilon_{\text{latent}}$</td>
<td>&gt; 0.82</td>
<td>0.76-0.88</td>
</tr>
<tr>
<td>$\Delta P$</td>
<td>&lt; 80 Pa</td>
<td>53-113 Pa</td>
</tr>
<tr>
<td>$U_{\text{eff}}$</td>
<td>= 0.85 $U_{\text{actual}}$</td>
<td>0.75-1.1 $U_{\text{actual}}$</td>
</tr>
<tr>
<td>2 Full-scale laboratory test (Berkeley)</td>
<td>Dimensions: 3'-3&quot; x 5'-3&quot; x 3&quot;</td>
<td>5'-3&quot; x 6'-6&quot; x 3&quot;</td>
</tr>
<tr>
<td>AirFlow Rate</td>
<td>22-44 cfm</td>
<td><strong>Data measurements complete (April, 2014)</strong></td>
</tr>
<tr>
<td>Supply Inlet</td>
<td>90 F</td>
<td>90% RH</td>
</tr>
<tr>
<td>Exhaust Inlet</td>
<td>72 F</td>
<td>50% RH</td>
</tr>
<tr>
<td>$\varepsilon_{\text{sens}}$</td>
<td>&gt; 0.88</td>
<td></td>
</tr>
<tr>
<td>$\varepsilon_{\text{latent}}$</td>
<td>&gt; 0.82</td>
<td></td>
</tr>
<tr>
<td>$\Delta P$</td>
<td>&lt; 80 Pa</td>
<td></td>
</tr>
<tr>
<td>$U_{\text{eff}}$</td>
<td>= 0.85 $U_{\text{actual}}$</td>
<td></td>
</tr>
<tr>
<td>3 Full-scale operational demonstration (Singapore)</td>
<td>Dimensions: 3'-3&quot; x 12'-0&quot; x 3&quot;</td>
<td>5'-3&quot; x 12'-0&quot; x 3&quot;</td>
</tr>
<tr>
<td>AirFlow Rate</td>
<td>22-44 cfm</td>
<td><strong>Data measurements in progress.</strong></td>
</tr>
<tr>
<td>Supply Inlet</td>
<td>90 F</td>
<td>90% RH</td>
</tr>
<tr>
<td>Exhaust Inlet</td>
<td>72 F</td>
<td>50% RH</td>
</tr>
<tr>
<td>Fan Energy Reduction</td>
<td>&gt; 0.88</td>
<td></td>
</tr>
<tr>
<td>Cooling Energy Reduction</td>
<td>&gt; 0.82</td>
<td></td>
</tr>
</tbody>
</table>
Progress and Accomplishments

**Accomplishments: MILESTONE 1**

**Measured Performance:**

- $0.76 < \varepsilon_{\text{latent}} < 0.88$
- $53 < \Delta P < 113$ Pa
- $U_{\text{eff}}$ improved 4-25% when $\Delta T > 12$ C
Progress and Accomplishments

Accomplishments: MILESTONE 2

Full-scale Lab Test

Measured Air Temperature Differentials – currently processing raw data

Measured Envelope Temperature Differentials – currently processing raw data
Progress and Accomplishments

Accomplishments: MILESTONE 3

Full-scale Demonstration

ETH Zurich, Singapore—currently collecting raw data
Progress and Accomplishments

Accomplishments: COMMERCIALIZATION

Conventional Air Con

[high condensation]

AirFlow Panels™

[low condensation]

Indoor Concentration of Airborne Mold

Source: Harvard School of Public Health, 2001

[1,000m² in 45-floor office]

Increased Leasable Floor Area

Source: Hudson Yards, New York
Progress and Accomplishments

Accomplishments: COMMERCIALIZATION

Pilot-scale Manufacturing Plan:

- bills of materials
- labor
- equipment
- cost targets

for manufacturing 5-100 units.

<table>
<thead>
<tr>
<th>ORDER QUANTITY:</th>
<th>START-UP</th>
<th>PER ORDER</th>
<th>FIXED/MONTH</th>
<th>VARIABLE/UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>LABOR</td>
<td>$9,415</td>
<td>$8,209</td>
<td>$3,377</td>
<td>$406</td>
</tr>
<tr>
<td>MATERIAL</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A $8,667</td>
<td></td>
</tr>
<tr>
<td>EQUIPMENT</td>
<td>$4,618</td>
<td>N/A</td>
<td>N/A $406</td>
<td></td>
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<tr>
<td>OVERHEAD</td>
<td>$3,450</td>
<td>N/A</td>
<td>$2,841</td>
<td>N/A</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$17,483</td>
<td>$8,209</td>
<td>$6,218 $9,073</td>
<td></td>
</tr>
</tbody>
</table>
Progress and Accomplishments

Accomplishments: SPIN-OFF PRODUCT
### Progress and Accomplishments

#### Market Impact:

<table>
<thead>
<tr>
<th>Zone</th>
<th>City</th>
<th>Office</th>
<th>School</th>
<th>Hospital</th>
<th>Residence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Miami</td>
<td>25.12</td>
<td>55.03</td>
<td>89.26</td>
<td>26.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22.4%</td>
<td>38.0%</td>
<td>27.5%</td>
<td>15.6%</td>
</tr>
<tr>
<td>2</td>
<td>Atlanta</td>
<td>32.37</td>
<td>58.46</td>
<td>94.12</td>
<td>47.84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>27.7%</td>
<td>42.8%</td>
<td>32.1%</td>
<td>20.0%</td>
</tr>
<tr>
<td>4</td>
<td>DC</td>
<td>37.38</td>
<td>74.76</td>
<td>128.28</td>
<td>49.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24.3%</td>
<td>41.1%</td>
<td>36.0%</td>
<td>14.4%</td>
</tr>
<tr>
<td>7</td>
<td>Minneapolis</td>
<td>39.84</td>
<td>91.81</td>
<td>167.76</td>
<td>54.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>31.0%</td>
<td>50.1%</td>
<td>48.5%</td>
<td>16.0%</td>
</tr>
</tbody>
</table>

**Projected annual savings**

\[
\text{[KWh/m}^2\text{ (% below baseline)}
\]

### Potential Annual US Savings

- **Projected annual savings**
- **Potential Annual US Savings = 2.72 Quads**

### Impact Trajectory

**Near Term**
- 4 pilot installation discussions
- Strategic industry partner discussions

**Intermediate Term**
- Manufacture study built into supply chain
- Sales partnership discussions

**Long Term**
- International sales partnership
- Scale up manufacture

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**EnergyPlus simulation output**

**Temperature Profile: Summer Time Miami - Office**

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**Figure:**

- Graph showing temperature profile with various labels and data points.
Project Integration and Collaboration

Project Integration:
• work with advanced building design teams (e.g. Rocky Mountain Inst.)
• collaborate with major building component manufacturers (confidential)
• participate in industry & regulatory road-mapping/planning
• Present in major industry forums (e.g. International Green Building Conf.)

Partners, Subcontractors, and Collaborators:

STTR Research Partner:
Lawrence Berkeley National Laboratory
• Theoretical Support
• Testing & Validation Lead
• Whole Building Simulation

Consultants:
dPoint Technologies
• Membrane Engineering

ARUP
• Envelope Engineering
• HVAC Engineering

Portland Ten
• Commercialization
Next Steps and Future Plans

Communications:
• Façade Tectonics Conference, University of Southern California, 2011
• International Green Building Conference, Singapore, 2012
• Eco-Expo Asia, Hong Kong, 2012

Awards/Recognition:
• NOVA/Saint-Gobain Innovation Competition-finalist, 2012
• Defense Energy Technology Challenge-finalist, 2012
• Asia Pacific Clean Energy Challenge, finalist, 2012

Next Steps and Future Plans:
• Pilot project installations (goal = 3 installs in the coming year)
• Build sales pipeline
• Develop low-cost/high performance manufacturing methods
• Execute manufacturing strategy (2013 pilot study forms the basis)
REFERENCE SLIDES
**Project Budget**

<table>
<thead>
<tr>
<th>Project Budget:</th>
<th>DOE</th>
<th>Cost Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total:</td>
<td>$1,037,812</td>
<td>$202,120</td>
</tr>
<tr>
<td>STTR Ph.1:</td>
<td>$ 99,979</td>
<td>$ 0</td>
</tr>
<tr>
<td>STTR Ph.2:</td>
<td>$ 937,833</td>
<td>$202,120</td>
</tr>
</tbody>
</table>

**Variances:**
STTR Ph. 2 Budget Period 1 (first year) was re-budgeted due to membrane manufacturing costs incurred earlier than anticipated.

**Cost to Date:**
DOE: $907,900 (87%)  
Cost Share: $232,700 (115%)

**Additional Funding:** Currently sought (US DoD, US DOE, private investment, sales)

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**Budget History**

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>DOE $562,407</td>
<td>DOE $475,405</td>
<td>DOE tbd</td>
</tr>
<tr>
<td>Cost-share $140,393</td>
<td>Cost-share $92,307</td>
<td>Cost-share tbd</td>
</tr>
</tbody>
</table>
Project Plan and Schedule

7 Quarter (21 month) Project Currently Funded
“GO” Decision Made at Quarter 4

Milestones:

1. Medium-scale prototype – 2-month delay due to design/fabrication complications
2. Large-scale prototype – 3-month delay in membrane care fabrication
3. Full-scale demonstration – 5 months early due to host site schedule coordination
4. System documentation – Ongoing development/refinement throughout project.

<table>
<thead>
<tr>
<th>Task</th>
<th>FY2013</th>
<th>FY2014</th>
<th>FY2015</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q1 (Oct-Dec)</td>
<td>Q2 (Jan-Mar)</td>
<td>Q3 (Apr-Jun)</td>
</tr>
<tr>
<td>Past Work</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q3 2013 Milestone: Medium-scale Laboratory Test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q2 2014 Milestone: Full-Scale Laboratory Test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q3 2014 Milestone: Full-scale Demonstration</td>
<td></td>
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<td></td>
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<tr>
<td>Q4 Milestone: Example 4</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Current/Future Work</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q4 2014 Milestone: System Documentation (Design/Cost)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q2 2015 Milestone: Manufacturing Process/Plan</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q2 2015 Milestone: Two Pilot Projects Installed</td>
<td></td>
<td></td>
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</tbody>
</table>