Company Showcase: Next Generation Innovations for Buildings
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Company Showcase: Next Generation Innovations for Buildings

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DIVYARAJ DESAI
Member of the Research Staff in The Energy Systems & Materials Group, PARC
Electrochemical Systems for Detection and Elimination of Indoor CO₂

January 24, 2018
HVAC comprises 32% of the energy consumed by U.S. buildings. Direct removal of CO₂ reduces overall energy consumption by 1%.

CO₂-selective removal systems could result in greater energy savings than DCV (Mysen et al, Energy & Buildings, 2005).

CO₂ removal is key to maintaining indoor air quality. Elevated CO₂ concentration affects human activity levels and cognitive function, especially in the key area of strategic thinking (Allen, JG et al, Environ Health Perspect (2016), 124 (6), 805-812)
Electrochemical $\text{CO}_2$ Pump

- Electrochemical $\text{CO}_2$ pump is activated by electrochemical sensor feedback.
- Reversible $\text{CO}_2$ electro-reduction at electrodes to form mobile ion that is transported across the membrane.
- Exhaust gas is rejected to surroundings, limiting the need for excessive outdoor ventilation.
Performance Summary

**Membrane synthesis**

- Pristine Membrane
- Functionalization
- MEA fabrication

**MEMBRANE CHARACTERIZATION (EIS)**

**SYSTEM RESPONSE OF EXHAUST GAS (100% CO\textsubscript{2} Feed)**

- Custom-designed cell using ECR membrane
- Performance validated in pure CO\textsubscript{2} feed
- Sensor response determined using a colorimetric CO\textsubscript{2} sensor

**EXPERIMENTAL SETUP**

- Electrochemical Cell
- CO\textsubscript{2} Sensor

- Commercial
- PARC

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>CO\textsubscript{2} Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.03%</td>
</tr>
<tr>
<td>2</td>
<td>5.00%</td>
</tr>
<tr>
<td>4</td>
<td>5.00%</td>
</tr>
<tr>
<td>10</td>
<td>0.03%</td>
</tr>
</tbody>
</table>
Benchmarks: Sorbents, plants and photobioreactors

Adsorption air cleaning using CO₂ sorbents is the current state of the art (60% reduction in thermal load). However, sorbents have a high energy consumption (6 kWh/kg CO₂), which erodes the energy impact.

Plants have been used for indoor CO₂ remediation and reduce HVAC load but have a poor CO₂ removal rate (<0.1 L/h/plant, Torpy et al, Urban Forestry & Urban Greening (2014), 13 (2), 227-233)

Solid CO₂ sorbent

High energy consumption (1 MJ/mol)
Source: DOI: 10.1039/C0EE00064G

Indoor plants

Poor CO₂ removal rate

Algal Photobioreactors

Need a continuous light source
Source: Artveoli microfluidic photobioreactor
Economic Assessment

- Designed to remove 50 L CO$_2$/h (1 person), and estimated to have an energy consumption of 75 W. Modular stack form factor and operates at a current density $>100$ mA/cm$^2$.

- Capital costs expected to scale similarly to an fuel cells, equivalent to $52$/occupant.

- Expected payback period would change based on energy savings/region of installation. We estimate a payback period of $<3$ years for an electrolyzer for the above scenario.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Indoor gas concentration (ppm)</td>
<td>1,000</td>
</tr>
<tr>
<td>Operating temperature</td>
<td>ambient</td>
</tr>
<tr>
<td>Specific energy consumption (kJ mol$^{-1}$)</td>
<td>100</td>
</tr>
<tr>
<td>CO$_2$ removal rate (LPH/person)</td>
<td>50</td>
</tr>
<tr>
<td>Power consumption (W/person)</td>
<td>60</td>
</tr>
<tr>
<td>Energy savings (kWh m$^{-2}$ y$^{-1}$)</td>
<td>48</td>
</tr>
<tr>
<td>Annual cost savings ($ m$^{-2}$ y$^{-1}$)</td>
<td>0.31</td>
</tr>
<tr>
<td>Installed cost ($/person), no PGM catalyst</td>
<td>52</td>
</tr>
<tr>
<td>Simple payback (y)</td>
<td>2.8</td>
</tr>
</tbody>
</table>
THANK YOU
Challenges

- Inexpensive catalysts
- Improve system reversibility
- Improve removal rate
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MATT MILLER
CEO & Chief Engineer, Nativus
ARCHITECTURAL REDESIGN
Based on a patented heat exchanger platform that is 10x more efficient than current technology.

Fan + Heat Exchanger In One

Boundary Layer Sheared Away Via Centrifugal Force
System Operates Standard Vapor-Compression Cycle
Completely Sealed Refrigerant System

*Energy Efficiency initial estimates based upon initial calculations, materials and components selected for manufacturing.
“World's Hottest Market: Air Conditioners For India And Hundreds Of New Electric Plants To Power Them”
- Forbes, May 2017
Global HVAC Energy Demand

$9T

12% Global GDP\(^1\)

1. EIA. Assumes $0.15/kWh Global COE Average.
Stationary ‘Finned Tube + Fan’ Heat Exchanger
We are long overdue for a system redesign...

In the foreground, a Finned-Tube Heat Exchanger (radiator) installed on an early car over a century ago.
Problem: Poor Heat Exchange

The Boundary Layer

Air Flow

Heat Exchanger Fins

Insulating Boundary Layer
CRYO™ Air-Conditioner

Precision Climate-Control

- **Lower**
  - Operating Expense

- **Light & Easy**
  - Single-Person Install

- **Single-Motor**
  - Quiet While in Operation

- **WiFi-Enabled**
  - Manage Usage

- **Air Filter**
  - Replaceable Filter for Cleaner Air

*Energy Savings based on a comparable capacity leading room air-conditioning system. Initial estimates based on materials and components selected for manufacturing.
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LANCE WHEELER
Research Scientist, National Renewable Energy Laboratory
Good window OR Good solar panel: Why not both?

**Dynamic windows**

- SageGlass
- view
- sunuitive by PLEOTINT

~20+ year ROI!
No energy generation

**Solar windows**

- Transparent
- Semitransparent

4% IR lab efficiency
2.5% UV theory efficiency

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It's encouraging to see the advancements in both window technology and solar panel technology. Dynamic windows and solar windows can work together to enhance energy efficiency and sustainability in buildings.
The value of SwitchGlaze

Commercial

Solar Conversion
$2.38 / ft² / year

Solar Mitigation
$3.90 / ft² / year

Efficiency higher than any existing technology
Drop-in (no destruction) retrofit
1-4 year ROI

Residential

LED Lighting

$5 billion
Incremental cost of SwitchGlaze

Roll-to-roll printing technology

Cost of a SwitchGlaze window

Window: $4.24 / sf
Dynamic PV: $1.49 / sf

SwitchGlaze path to market and partnership needs

Proof of Concept
- Multiple Non-prov. patents filed
- Large NREL portfolio

Prototype

Investment needs:
- Research on Improved durability
- Scaling

Demo Installation

Product

$
SwitchGlaze