Cleantech Forum **San Francisco**

San Francisco | January 22-24, 2018

Cleantech Forum
San Francisco

Company Showcase: Next Generation Innovations for Buildings

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MODERATED BY

YOACHIM HAYNES

Analyst, CTG

Company Showcase: Next Generation Innovations for Buildings
EXPERT REVIEWERS

CASSIE BOWE
Associate Vice President, Energy Impact Partners

ALFRED LAM
Vice President, Chrysalix

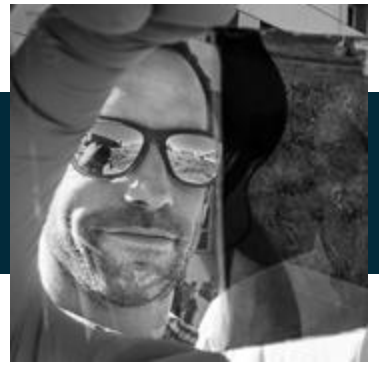
Company Showcase: Next Generation Innovations for Buildings

DIVYARAJ DESAI
Member of the Research Staff in The Energy Systems & Materials Group, PARC

PETER KOZODOY
Founder & CEO, Glint Photonics

MATT MILLER
CEO & Chief Engineer, Nativus

SERGEY VASYLYEV
CEO, Lucent Optics



LANCE WHEELER
Research Scientist, National Renewable Energy Laboratory

Company Showcase: Next Generation Innovations for Buildings

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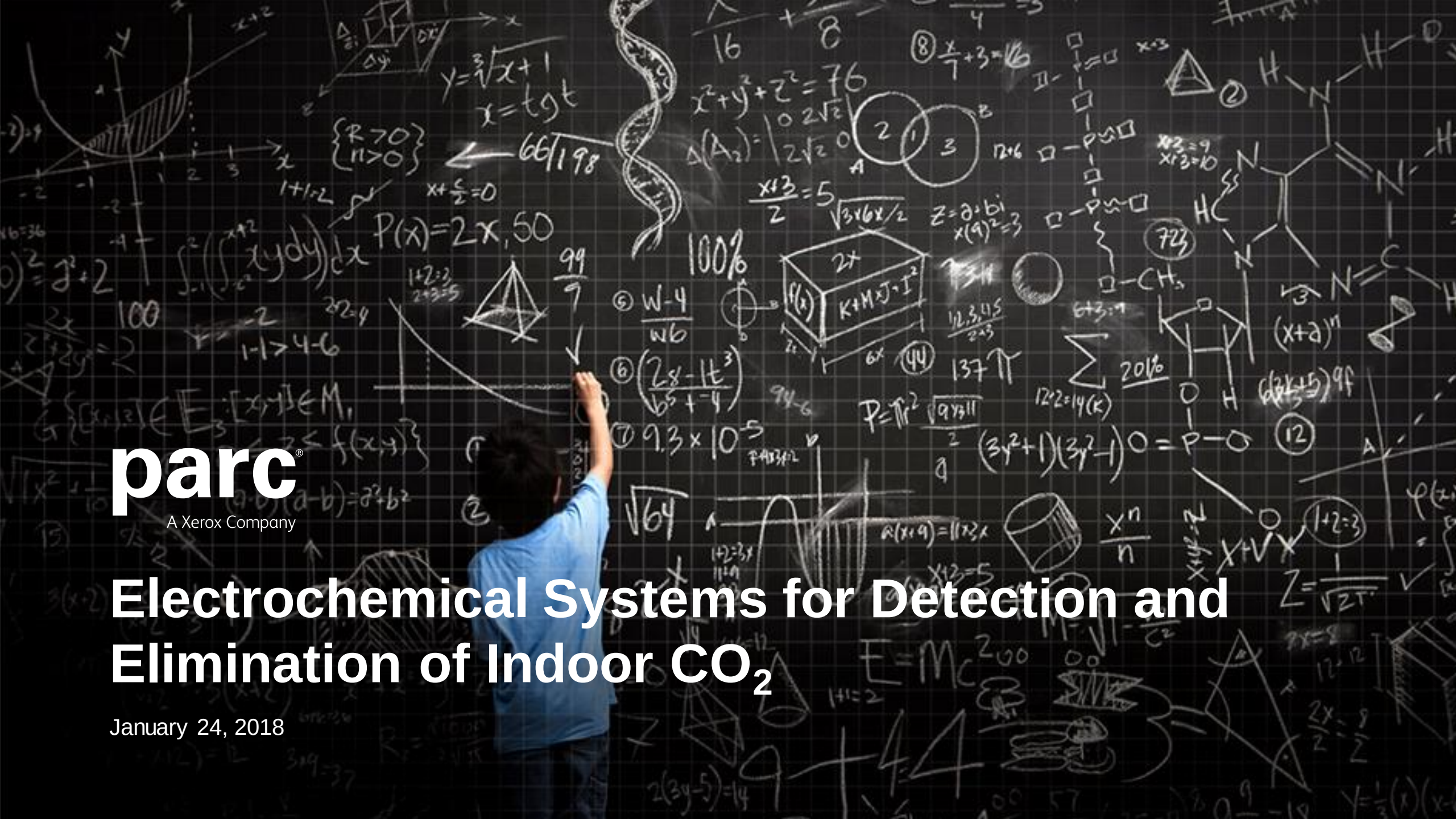

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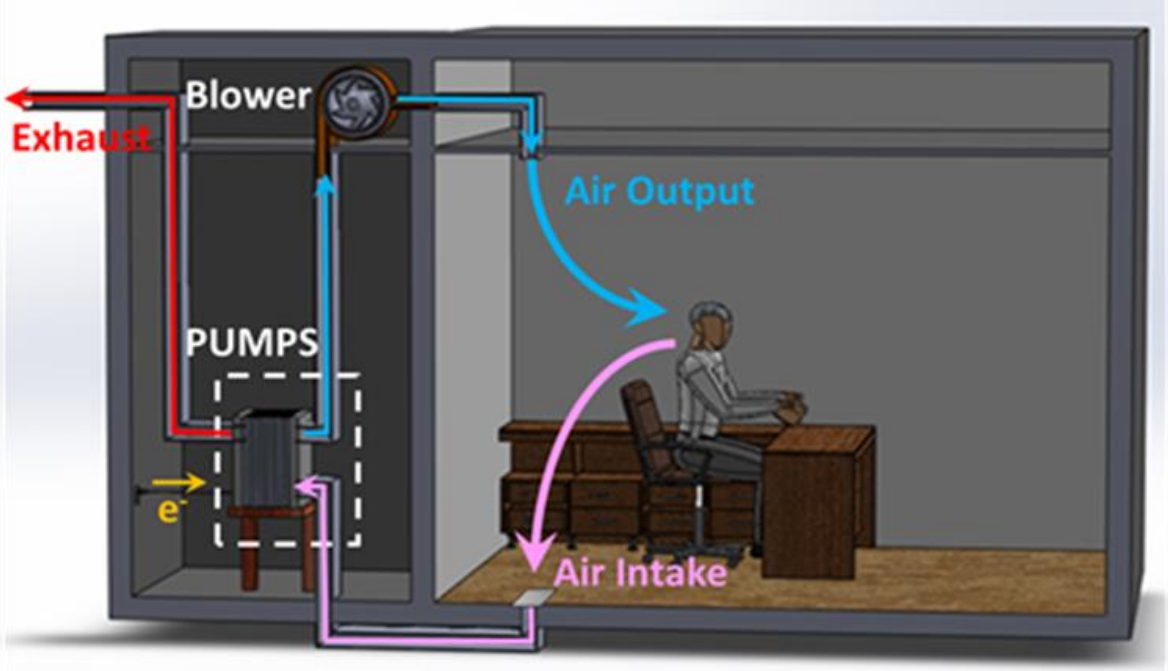
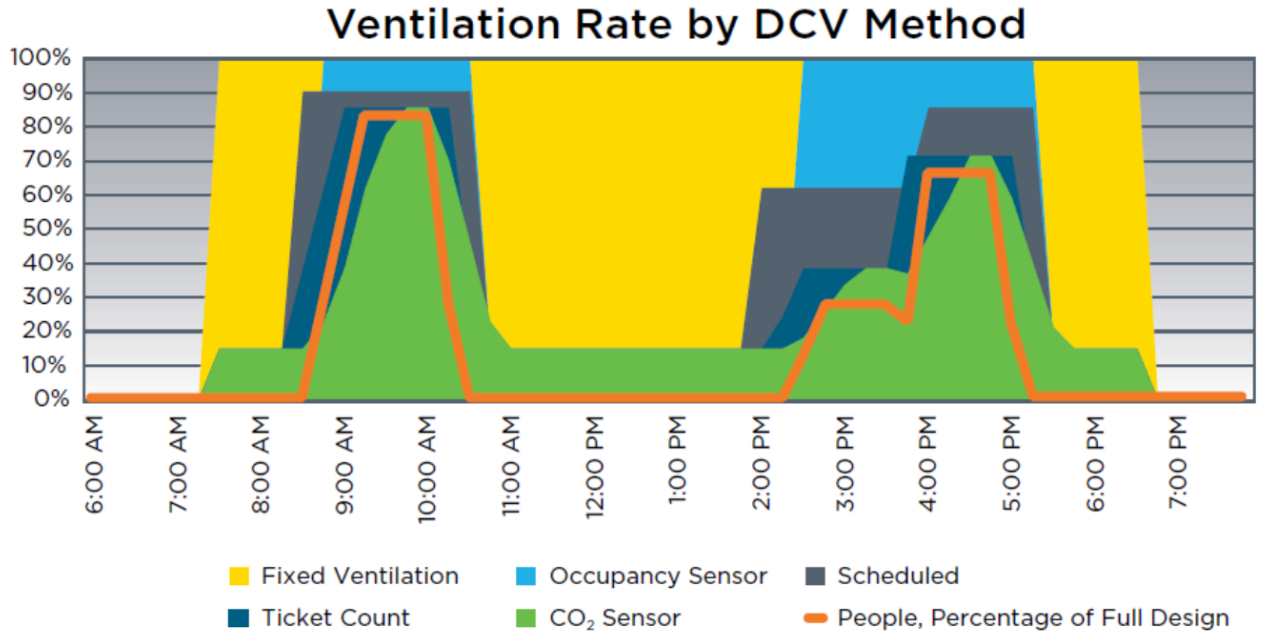
Electrochemical Systems for Detection and Elimination of Indoor CO_2

January 24, 2018

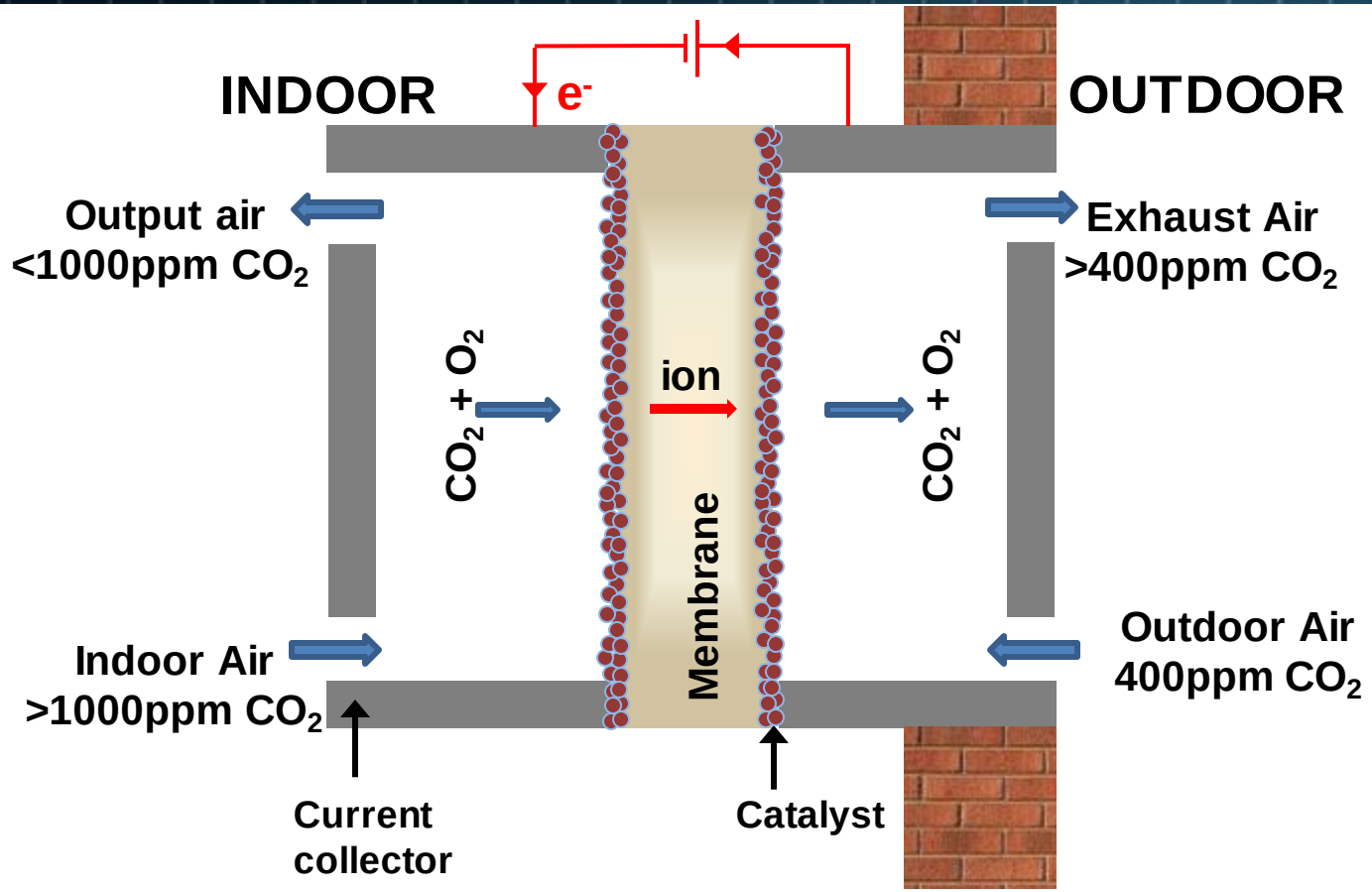
Technical Concept





- HVAC comprises 32% of the energy consumed by U.S. buildings. Direct removal of CO_2 reduces overall energy consumption by **1%**.
- CO_2-selective removal systems could result in greater energy savings than DCV (Mysen et al, Energy & Buildings, 2005).
- CO_2 removal is key to maintaining indoor air quality. Elevated CO_2 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 CO_2 Pump



- Electrochemical CO_2 pump is activated by electrochemical sensor feedback.
- Reversible 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.

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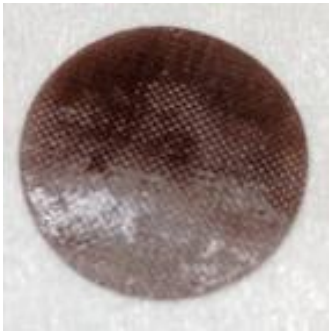
Performance Summary

MEA FABRICATION

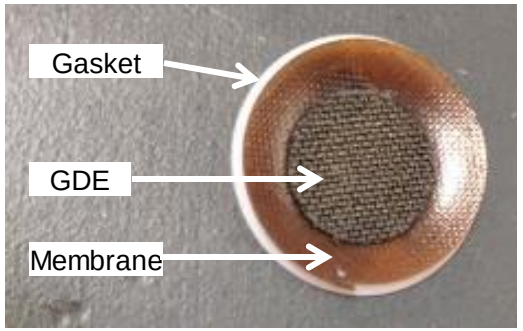
Membrane synthesis

Pristine Membrane

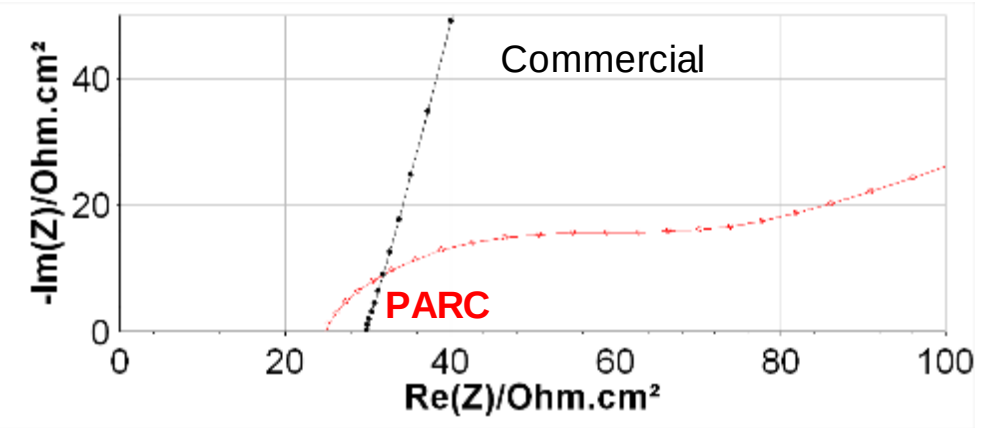
Functionalization



MEA fabrication

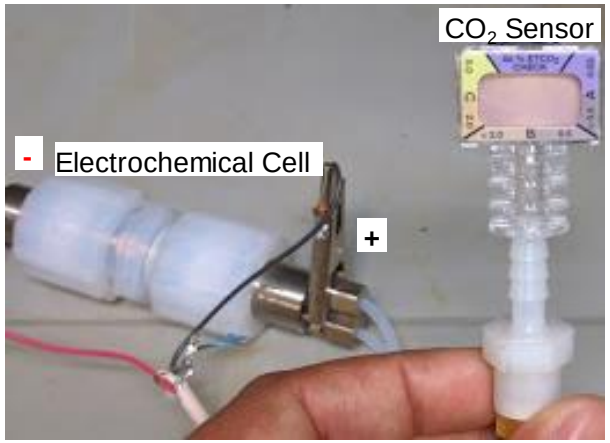


MEMBRANE CHARACTERIZATION (EIS)



CONCEPT VALIDATION

EXPERIMENTAL SETUP



- Custom-designed cell using ECR membrane
- Performance validated in pure CO_2 feed
- Sensor response determined using a colorimetric CO2 sensor

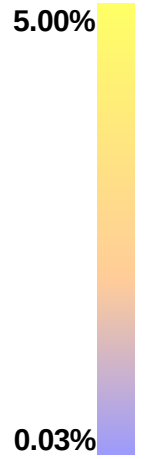
SYSTEM RESPONSE OF EXHAUST GAS (100% CO_2 Feed)

0 min

2 min

4 min

10 min



Benchmarks: Sorbents, plants and photobioreactors

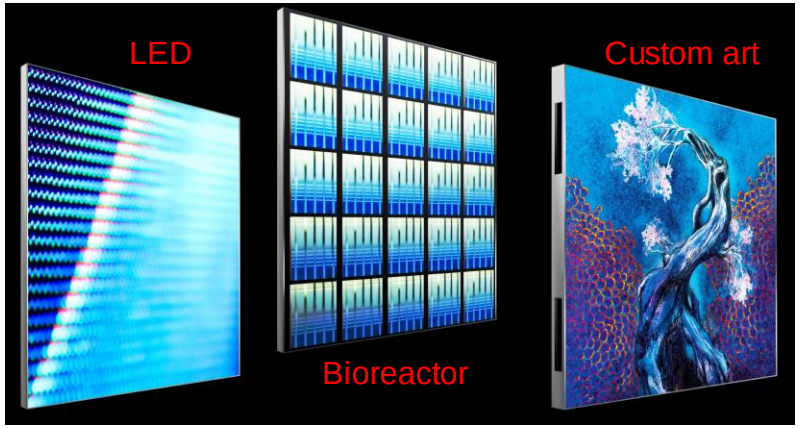
Solid CO_2 sorbent

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

Indoor plants

Poor CO2 removal rate
Source:Tarran, J et al, *Proceedings Of 6 th Internat. Conf. On Indoor Air Quality, Ventilation & Energy Conservation,-Sustainable Built Environment*. 2007.

Algal Photobioreactors



Need a continuous light source
Source: Artveoli microfluidic photobioreactor

- Adsorption air cleaning using CO_2 sorbents is the current state of the art (60% reduction in thermal load). However, sorbents have a high energy consumption (6 kWh/kg CO_2), which erodes the energy impact.
- Plants have been used for indoor CO_2 remediation and reduce HVAC load but have a poor CO_2 removal rate (<0.1 L/h/plant, Torpy et al, Urban Forestry & Urban Greening (2014), 13 (2), 227-233)

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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.

Metric	Value
Target Indoor gas concentration (ppm)	1,000
Operating temperature	ambient
Specific energy consumption (kJ mol^{-1})	100
CO_2 removal rate (LPH/person)	50
Power consumption (W/person)	60
Energy savings (kWh m^{-2} y^{-1})	48
Annual cost savings ($ m^{-2} y^{-1})	0.31
Installed cost ($/person), no PGM catalyst	52
Simple payback (y)	**2.8**

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THANK YOU

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Challenges

- Inexpensive catalysts
- Improve system reversibility
- Improve removal rate

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MATT MILLER

CEO & Chief Engineer, Nativus

NATIVUS

A Heating & Cooling Technology Platform

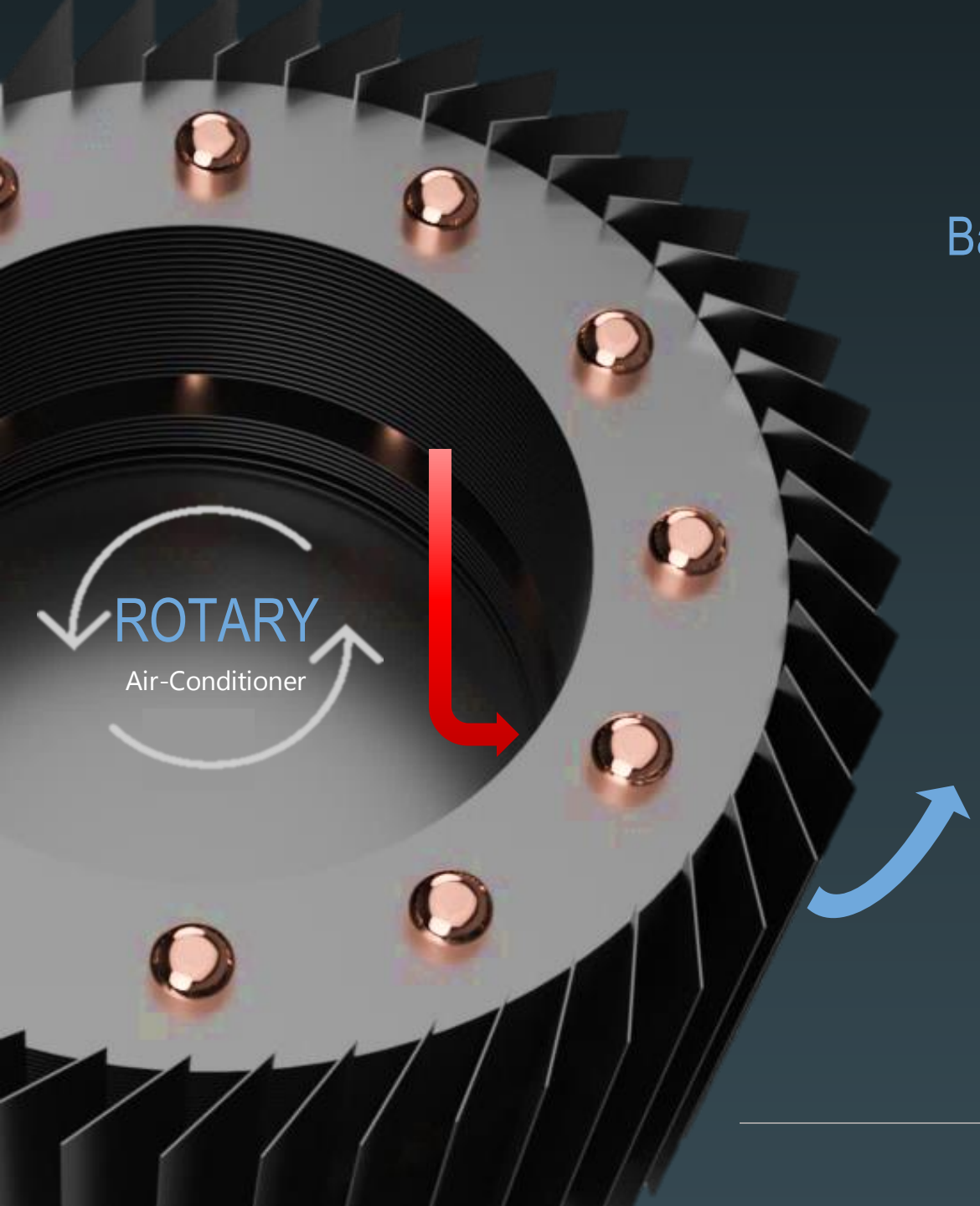
AUTODESK. Clean Tech Partner

CalSEED

FLOW rocket fund finalists

Veteran Owned Small Business VOSB cVE

nativuspower.com



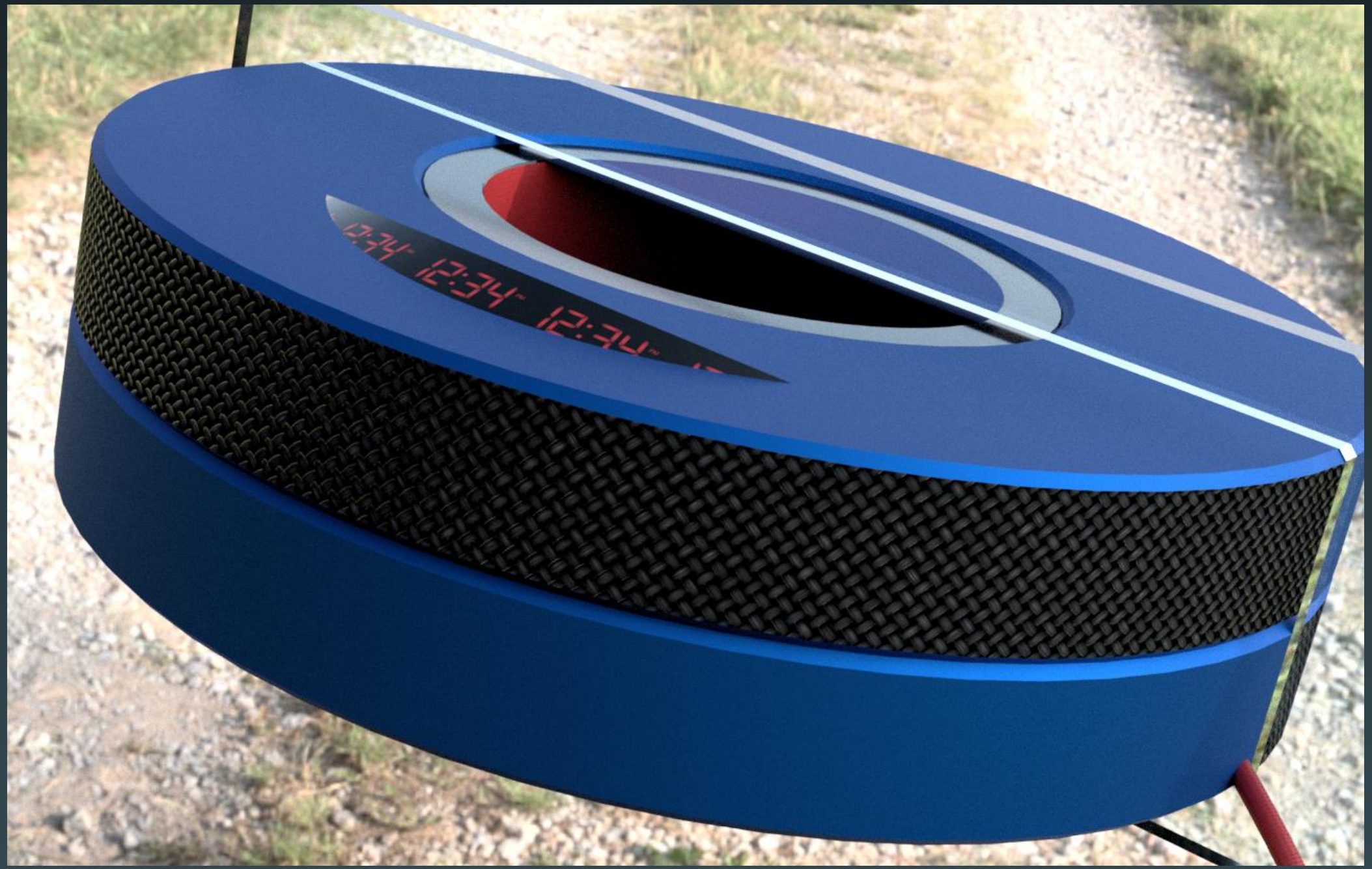
ARCHITECTURAL REDESIGN

Based on a patented heat exchanger platform that is 10x more efficient than current technology.

Fan + Heat Exchanger In One

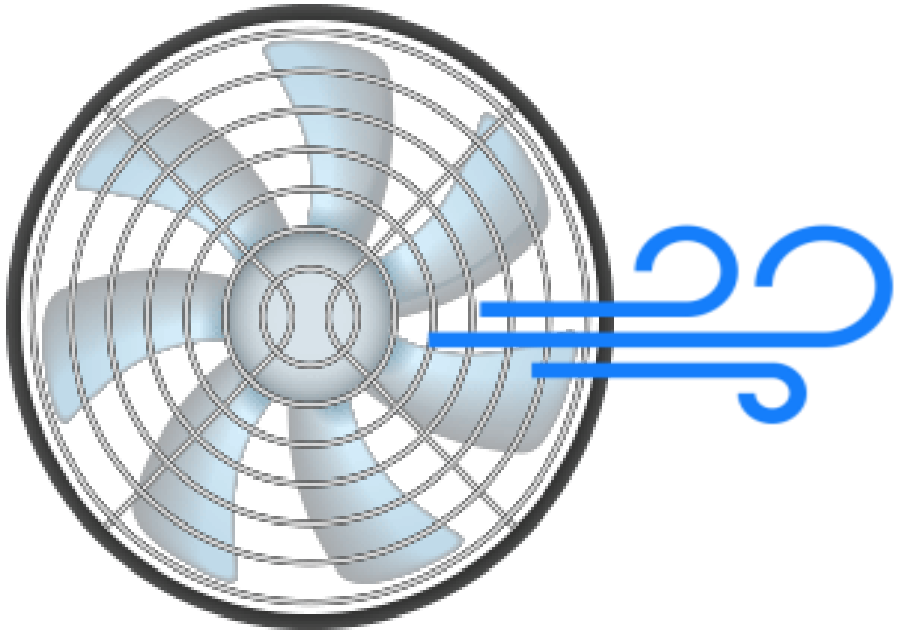
- Boundary Layer Sheared Away Via Centrifugal Force
- System Operates Standard Vapor-Compression Cycle
- Completely Sealed Refrigerant System

*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

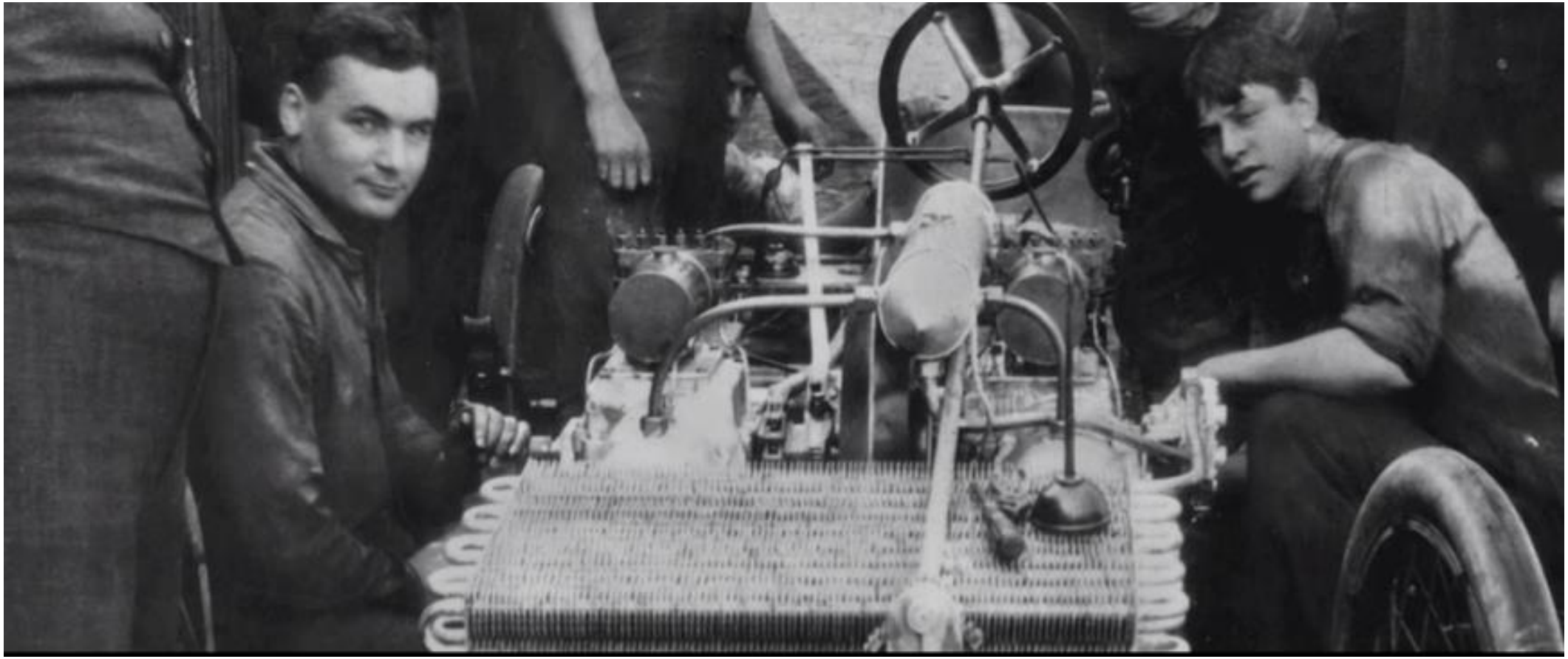
1. EIA. Assumes $.15 kWh Global COE Average.



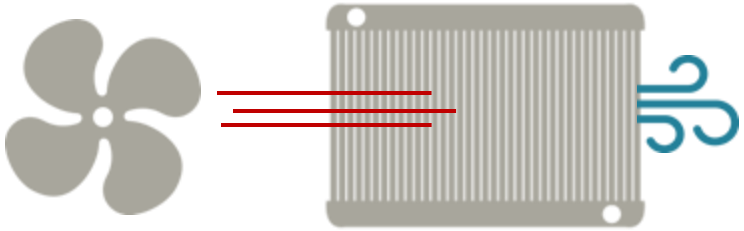
Stationary
‘Finned Tube + Fan’
Heat Exchanger

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.



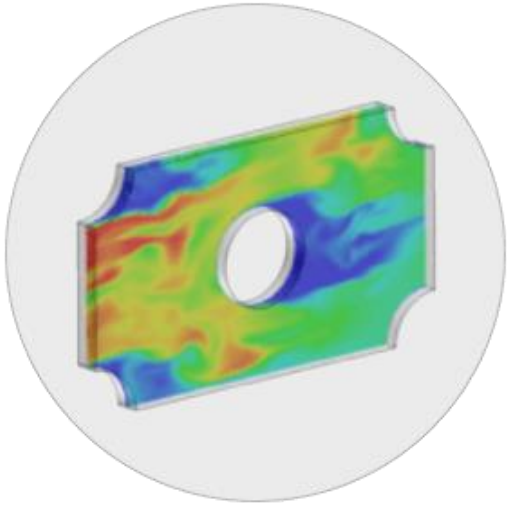
Problem: Poor Heat Exchange[1]



Fan

Heat Exchanger

Fouling

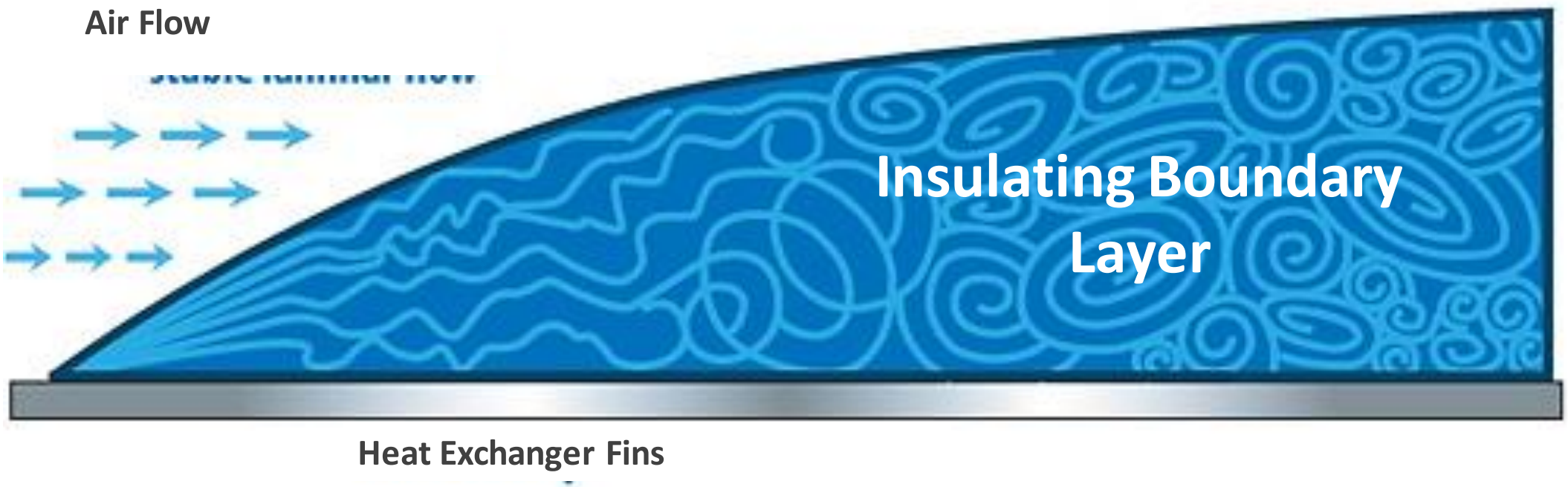


Boundary Layer

Condensate

[1] Lawrence Berkeley National Laboratory. *Fouling of HVAC Fin and Tube Heat Exchangers (White Paper)*. Berkeley, Sept. 2001.

The Boundary Layer



CRYO™ Air-Conditioner

Precision Climate-Control

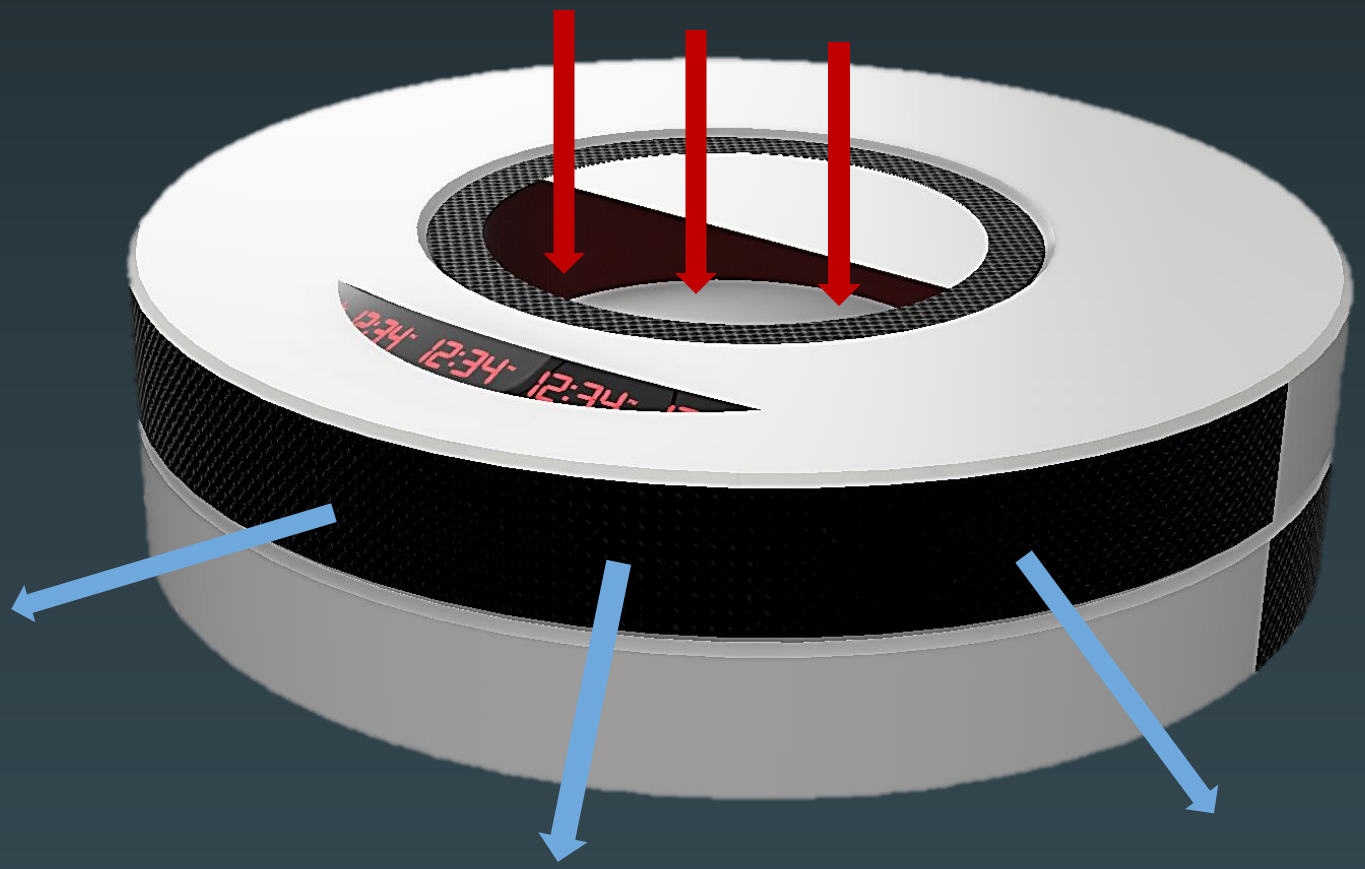
Lower
Operating Expense*

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 comprable capacity leading room air-conditioning system.
Initial estimates based on materials and components selected for manufacturing.

NATIVUS

Matt Miller | CEO
matt@nativuspower.com | 775.537.4611

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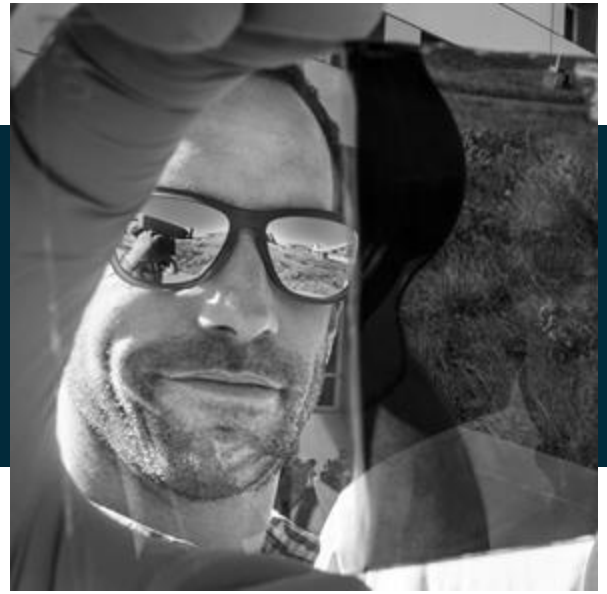


LANCE WHEELER

Research Scientist, National Renewable Energy Laboratory


SwitchGlaze

Good window OR Good solar panel: Why not both?

ENERGY I-CORPS
U.S. Department Of Energy

Dynamic windows

SageGlass®
view
suntuitive® by PLEOTINT
GENTEX CORPORATION

~20+ year ROI!
No energy generation

Solar windows

Transparent

ubiquitous energy

4% IR lab efficiency
2.5% UV theory efficiency

Semitransparent

The value of SwitchGlaze

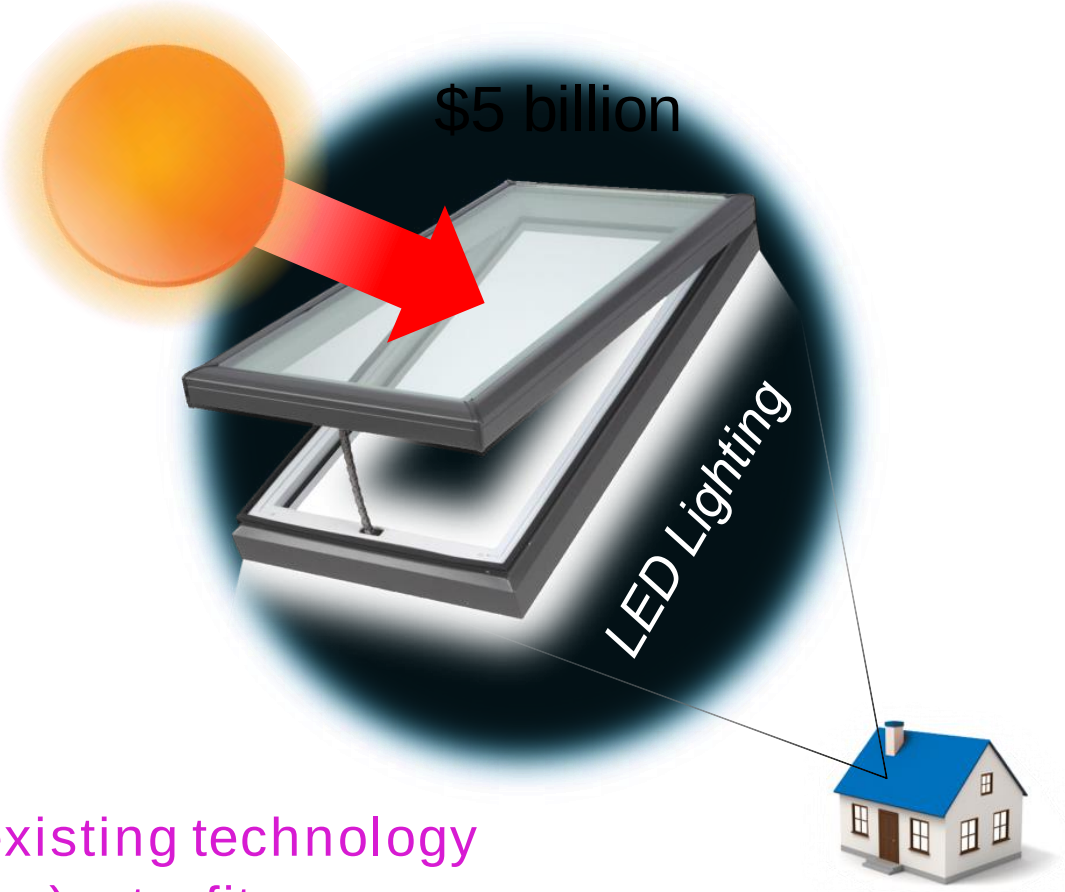
ENERGY I-CORPS
U.S. Department Of Energy

Commercial

Solar Mitigation
$3.90 / ft² / year

Solar Conversion
$2.38 / ft² / year

Residential



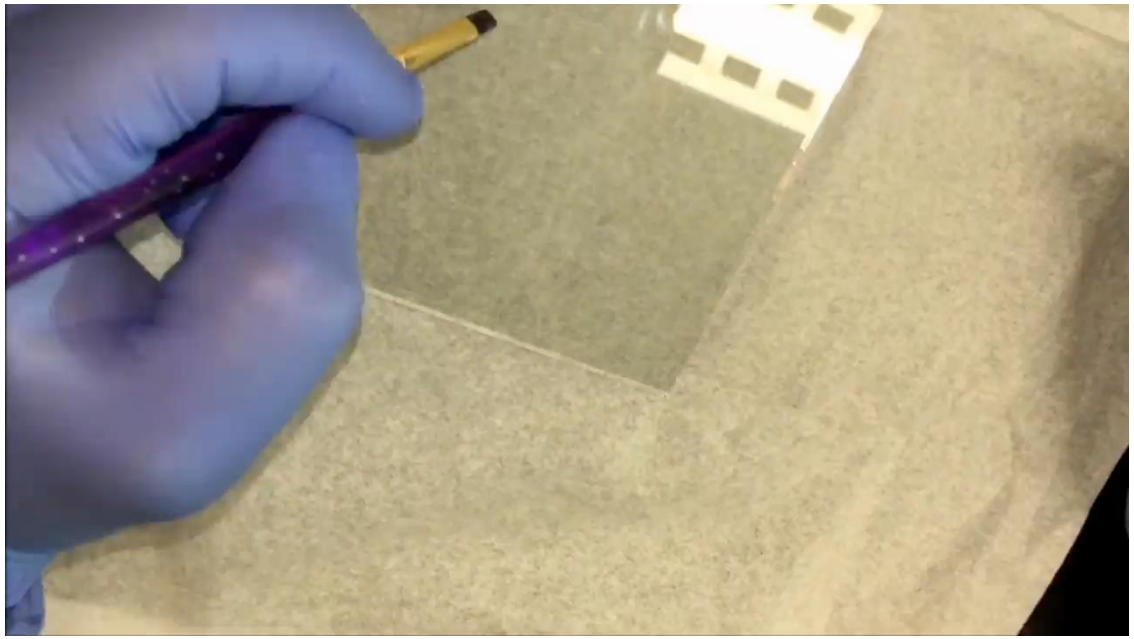
Efficiency higher than *any* existing technology
Drop-in (no destruction) retrofit

1-4 year ROI

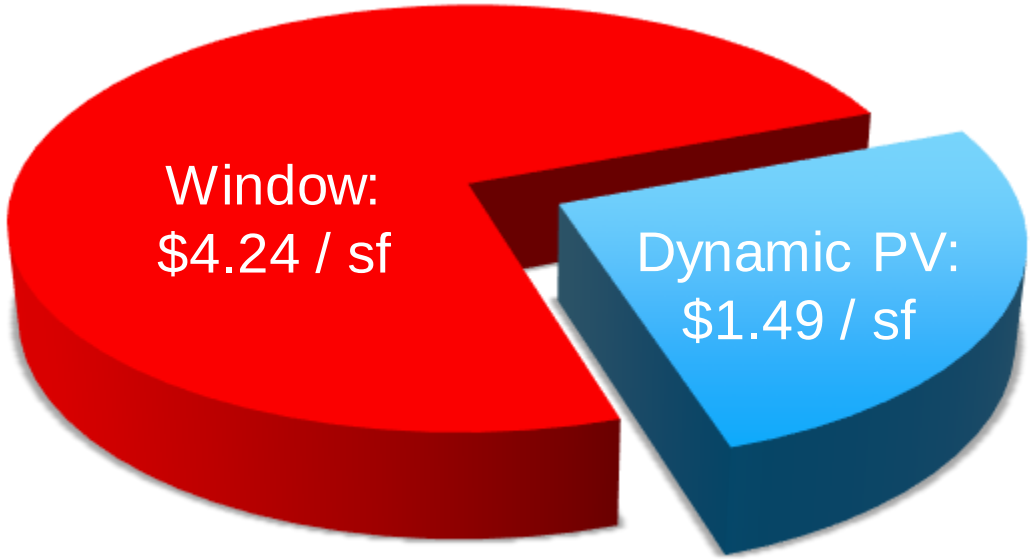
Incremental cost of SwitchGlaze

ENERGY I-CORPS
U.S. Department Of Energy

Roll-to-roll printing technology



Cost of a SwitchGlaze window

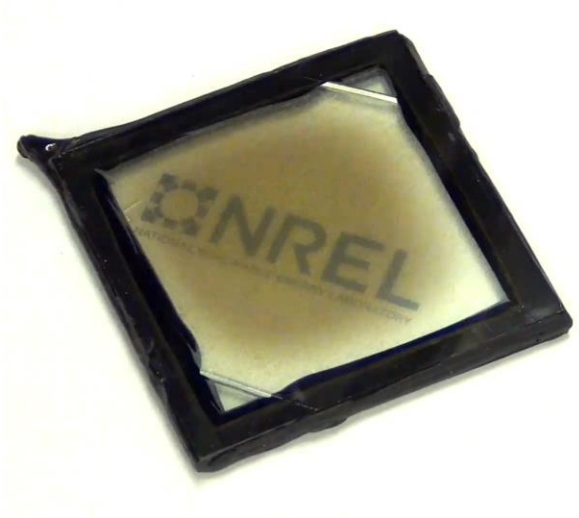


Bailie, C. et al. Preliminary Technoeconomic Analysis of Single-Junction Perovskites and Perovskites-on-Silicon. in (2015).

SwitchGlaze path to market and partnership needs

ENERGY I-CORPS
U.S. Department Of Energy

Proof of Concept



- *Multiple Non-prov. patents filed*
- *Large NREL portfolio*

Prototype

Investment needs:

- Research on Improved durability
- Scaling

Demo Installation

Product

$


SwitchGlaze