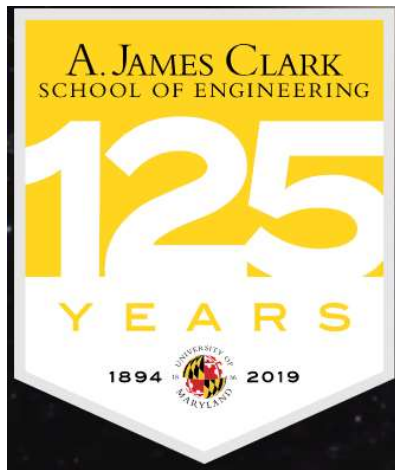


Energy (and) Innovation at the University of Maryland



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Minta Martin Professor, Director CEEE

University of Maryland

Department of Mechanical Engineering

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Appalachian Mountains, WV

Before...



Photo courtesy Vivian Stockman / www.ohvec.org.
Flyover courtesy SouthWings.org

...after Mountaintop Removal Coal Mining



More Environmental Impact

Energy Source	Mortality per PWh elec.
Coal	10,000 – 170,000
Oil	36,000
Gas	4,000
Biomass	24,000
Solar Rooftop	440
Wind	150
Hydro	1400
Nuclear	90

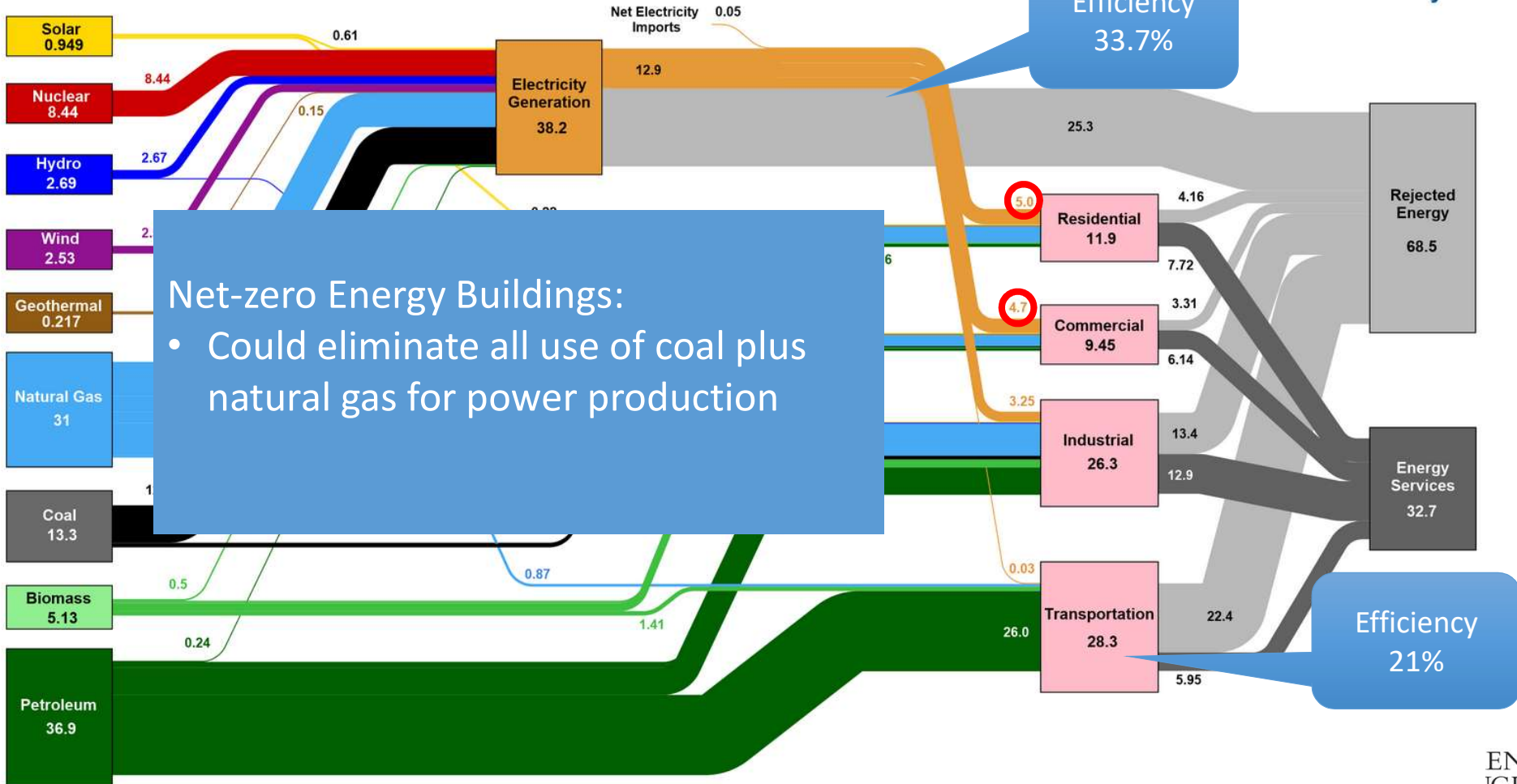
<http://iopscience.iop.org/article/10.1088/1748-9326/8/3/034005>

https://en.wikipedia.org/wiki/Energy_accidents

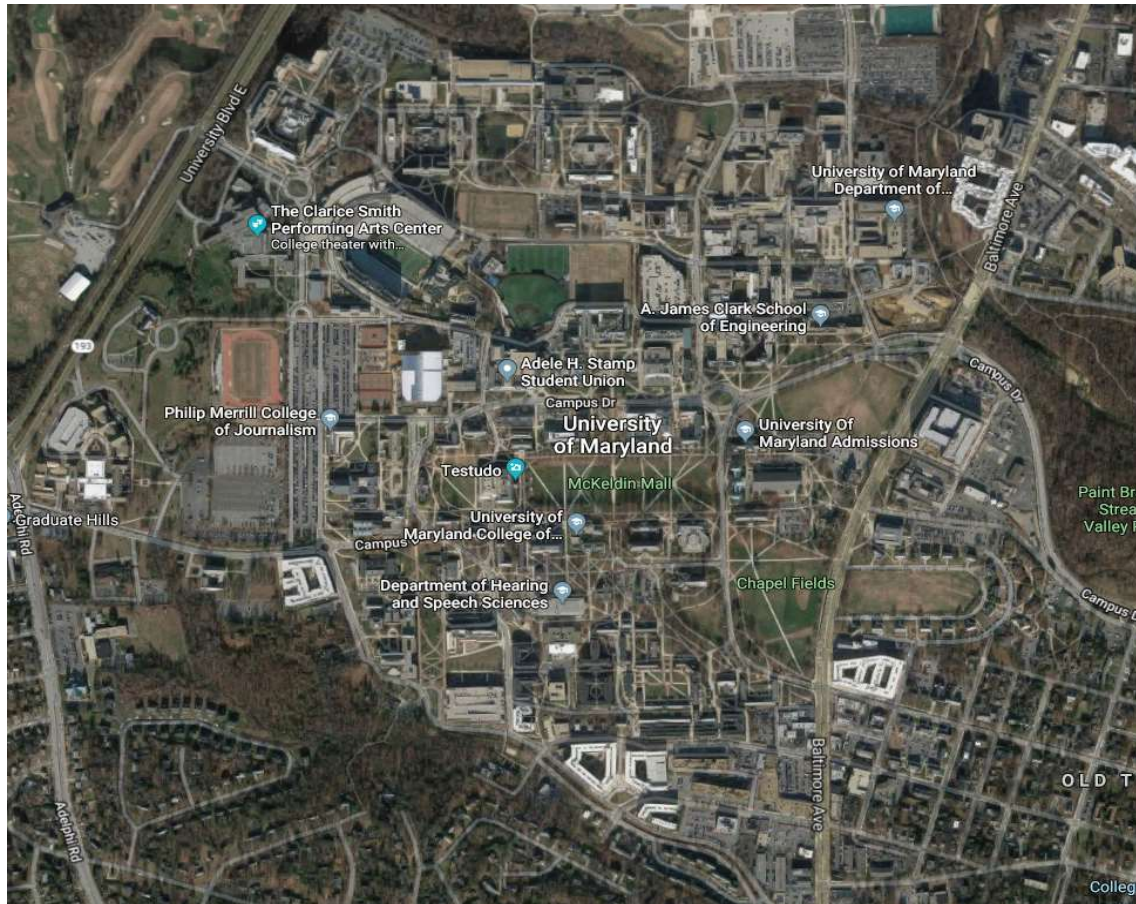
NZEB Energy Savings Potential

Estimated U.S. Energy Consumption in 2018: 101.2 Quads

Lawrence Livermore
National Laboratory



Heat Pump Application Opportunity



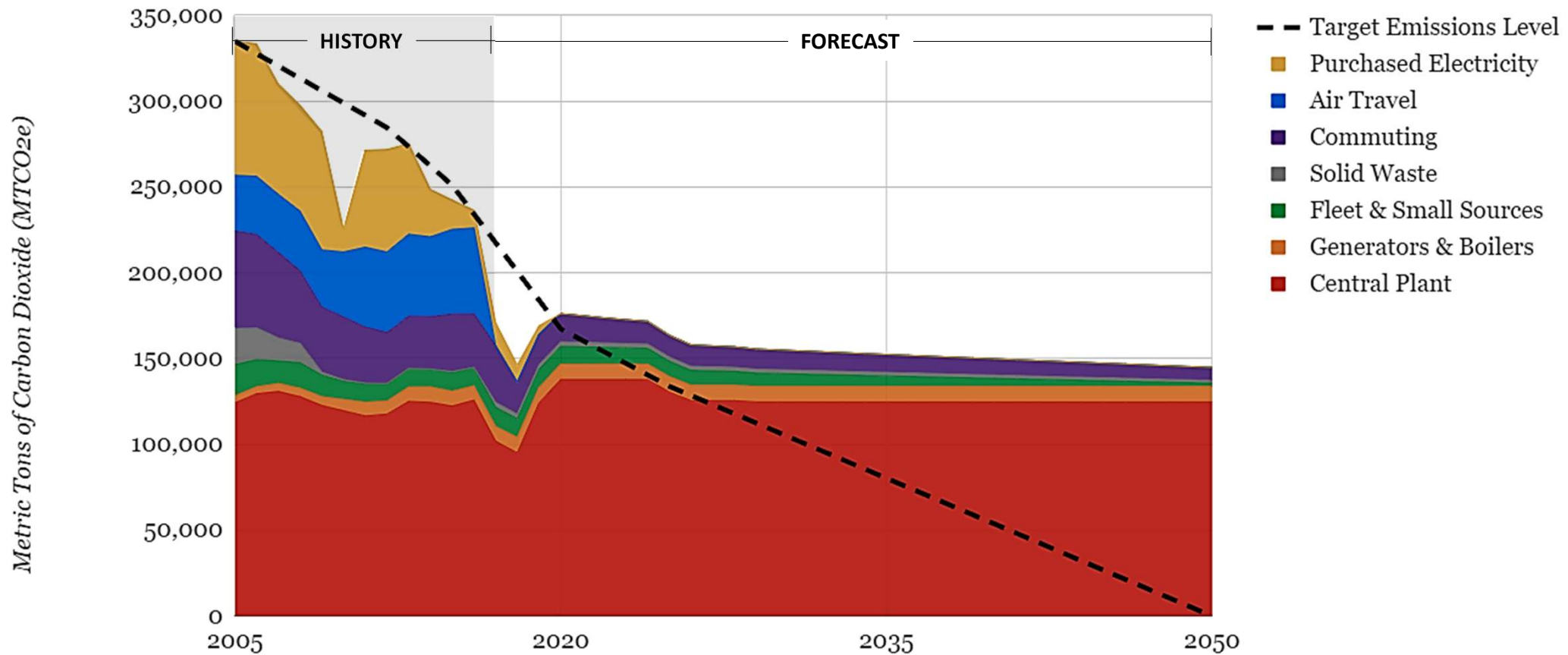
University of Maryland
College Park, MD

~260 Steam Heated Bldgs

Commitment to be zero-carbon campus by 2050

How?

UMD's GHG Emissions – History and Potential Future



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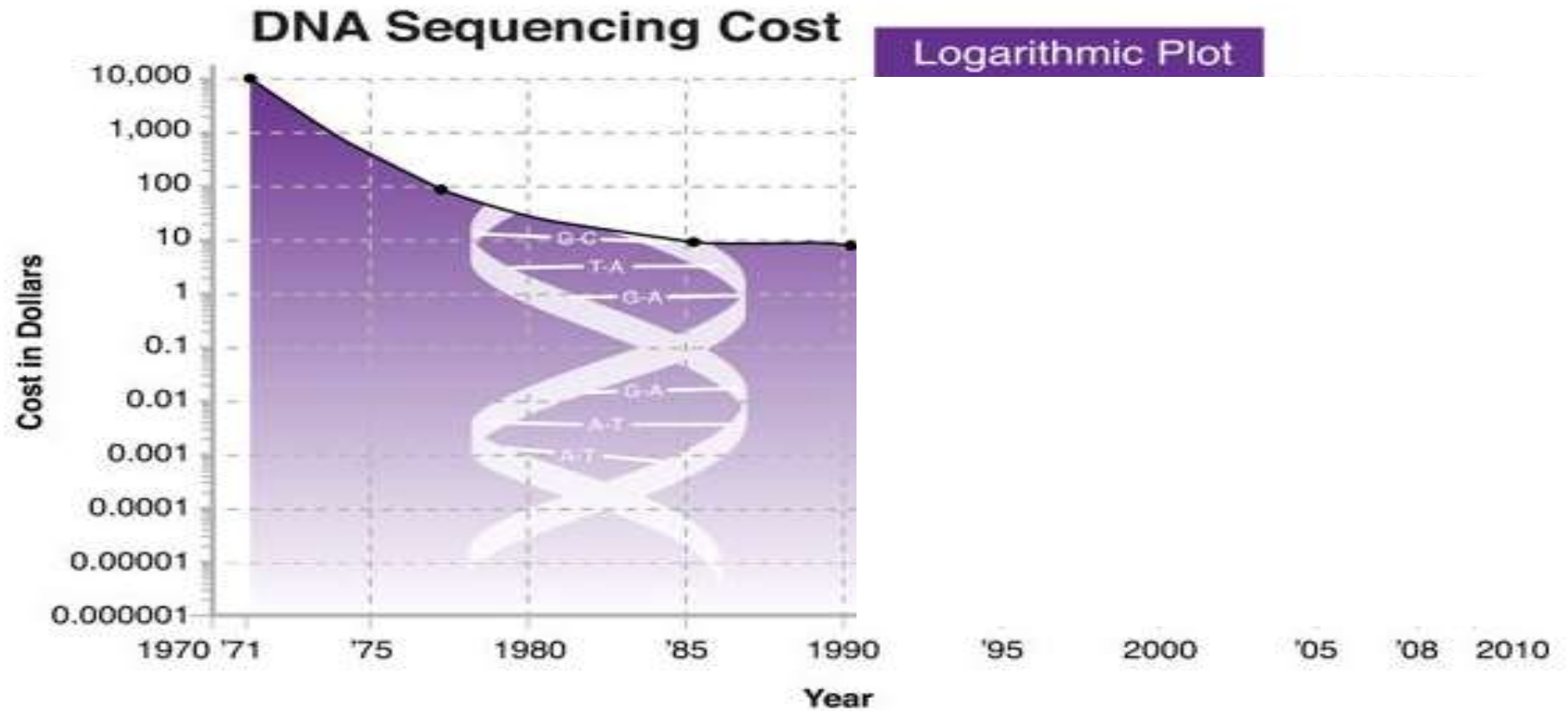
Energy Innovation at Maryland



Highly focused, highly collaborative

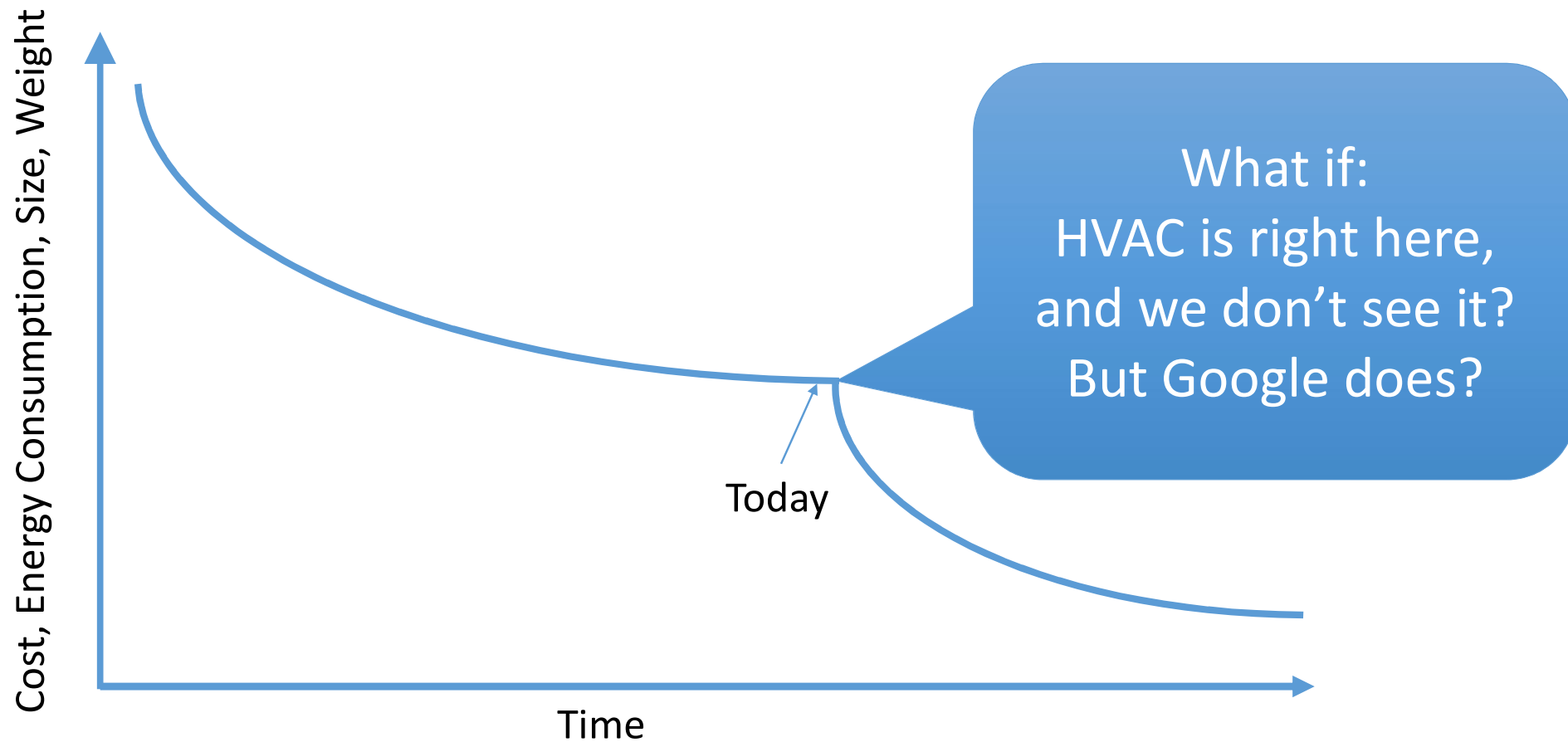
- Center for Research in Extreme Batteries
- Center for Environmental Energy Engineering
- Nanostructures for Electrical Energy Storage
- Maryland Transportation Institute
- Center for Sustainability in the Built Environment

For Inspiration...

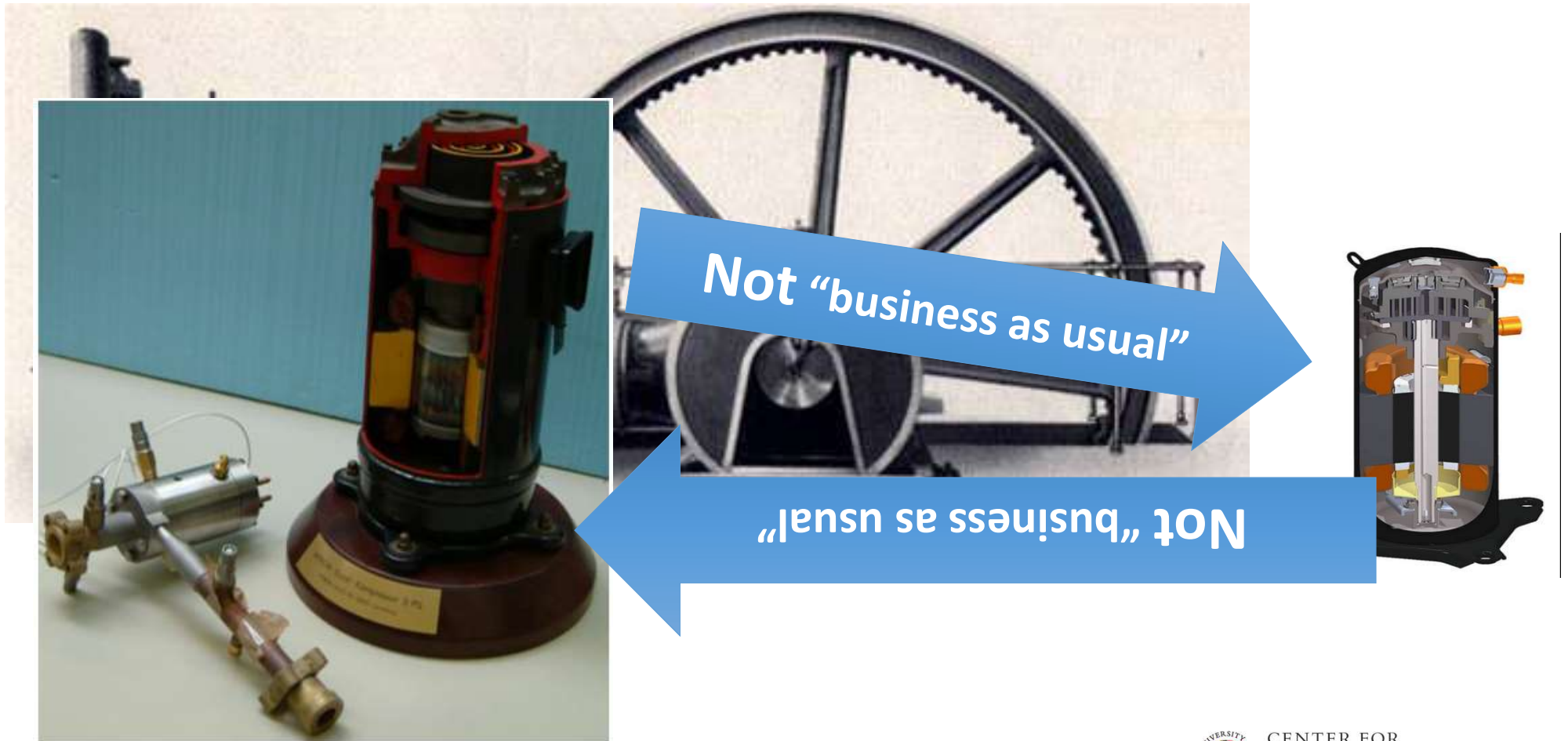


Diamandis, Peter H.; Kotler, Steven (2012-02-21). Abundance: The Future Is Better Than You Think (Kindle Locations 4226-4228). Free Press. Kindle Edition

The Future of HVAC&R: A New Perspective



Historical Compressor Development



Electrochemical Compression of NH_3 , CO_2

Researcher: Joe Baker, **PI:** Yunho Hwang, Chunsheng Wang

Duration: Jul. 2018 to Jul. 2022, **Type:** Long-term

Sponsor: ARPA-E with CEEE cost-share

Key Idea

- Develop an electrochemical compression device for ammonia gas for use in air-conditioning as well as power-to-gas energy storage

Technology Summary

- A vapor compression device that uses electrochemical reactions instead of moving mechanical parts
- Compression of ammonia and hydrogen gas mixtures using ion exchange membrane
- Useful for air conditioners or as fuel for ammonia diesel internal combustion engines

Technology Impact

- Reduce noise and energy consumption in residential air conditioners and ammonia energy storage

Contribute 2.5% of DOE BTO's 20 quad energy saving target by 2030

Proposed Targets

Metric	State of the Art	Proposed
Compression mechanism	Mechanical	Electrochemical
Lubrication	Required	Not required
Efficiency	65%	70%

Supporting Figures, Tables, & Illustrations

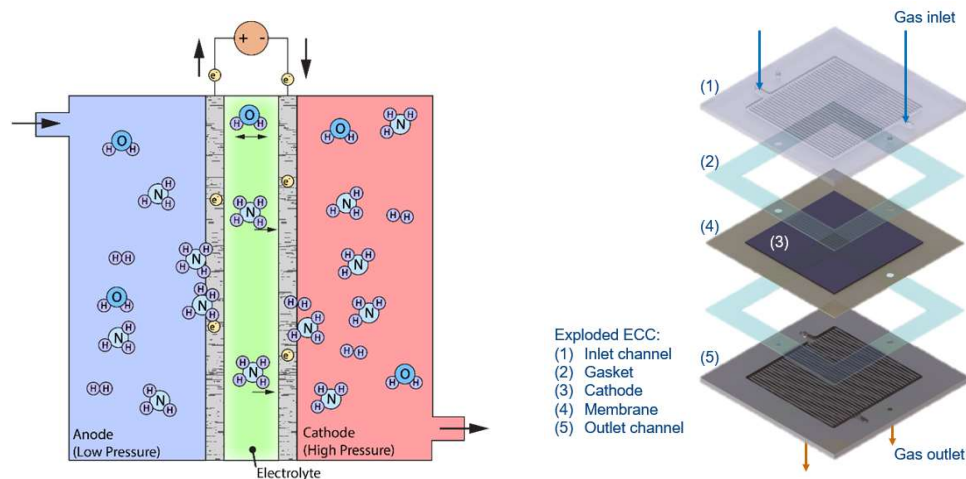


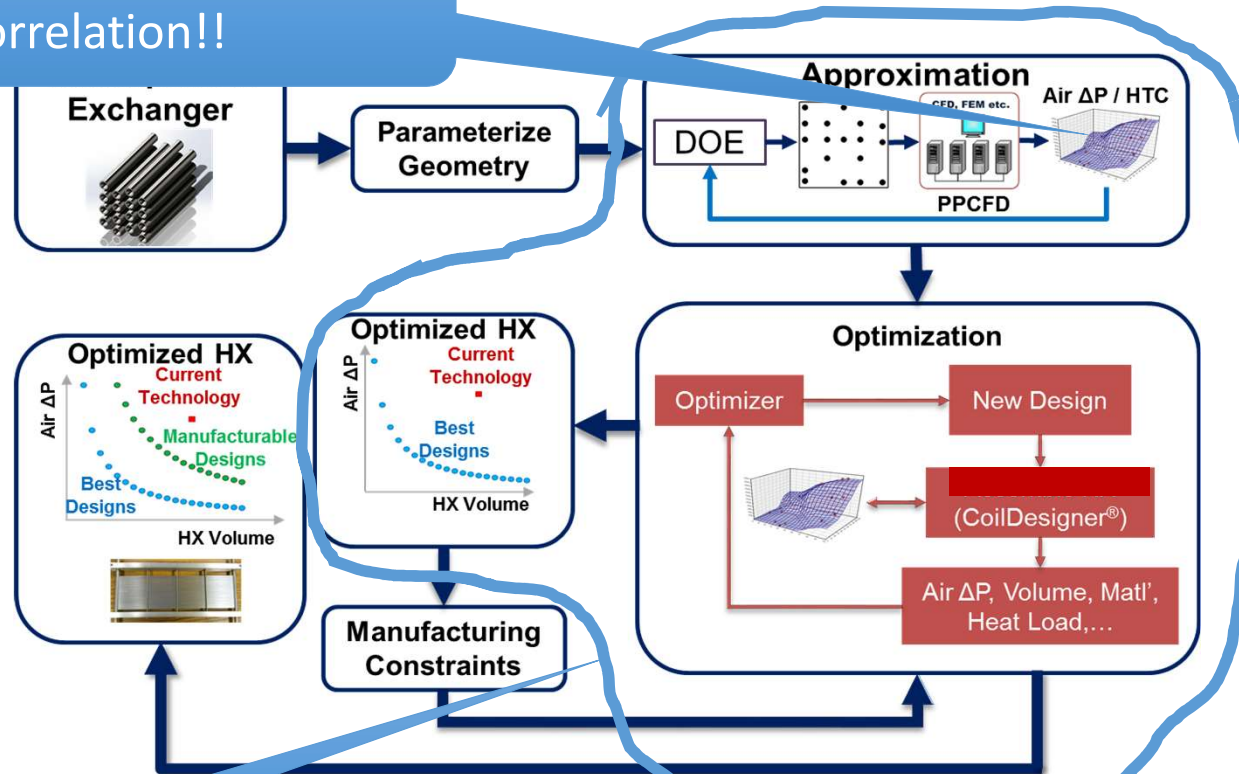
Figure: Diagram of working principle (left) schematic drawing of compression cell (right)

Optimization Framework

Metamodel = New HT and dP Correlation!!

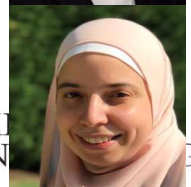


20%+
Better

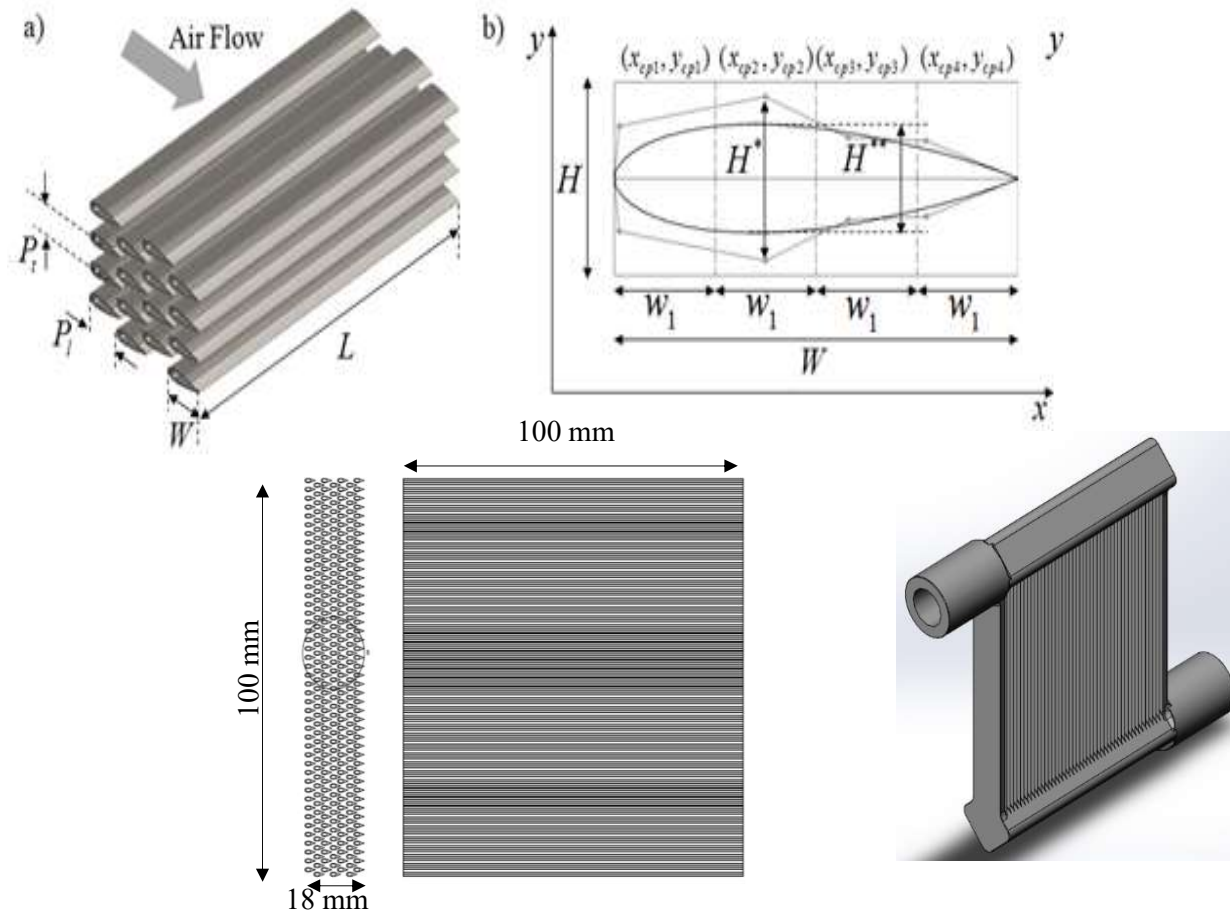


Automated!

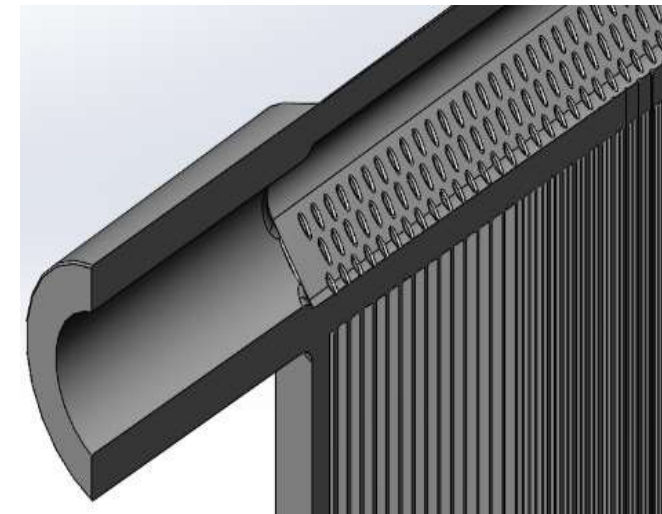
Abdelaziz, O., Aute V., Azarm S., and Radermacher R., 2019, "Approximation Assisted Optimization For Novel Compact Heat Exchanger Designs, HVAC&R Research, vol 16 , No. 5, pp. 707-728.



Tube Shape Optimization

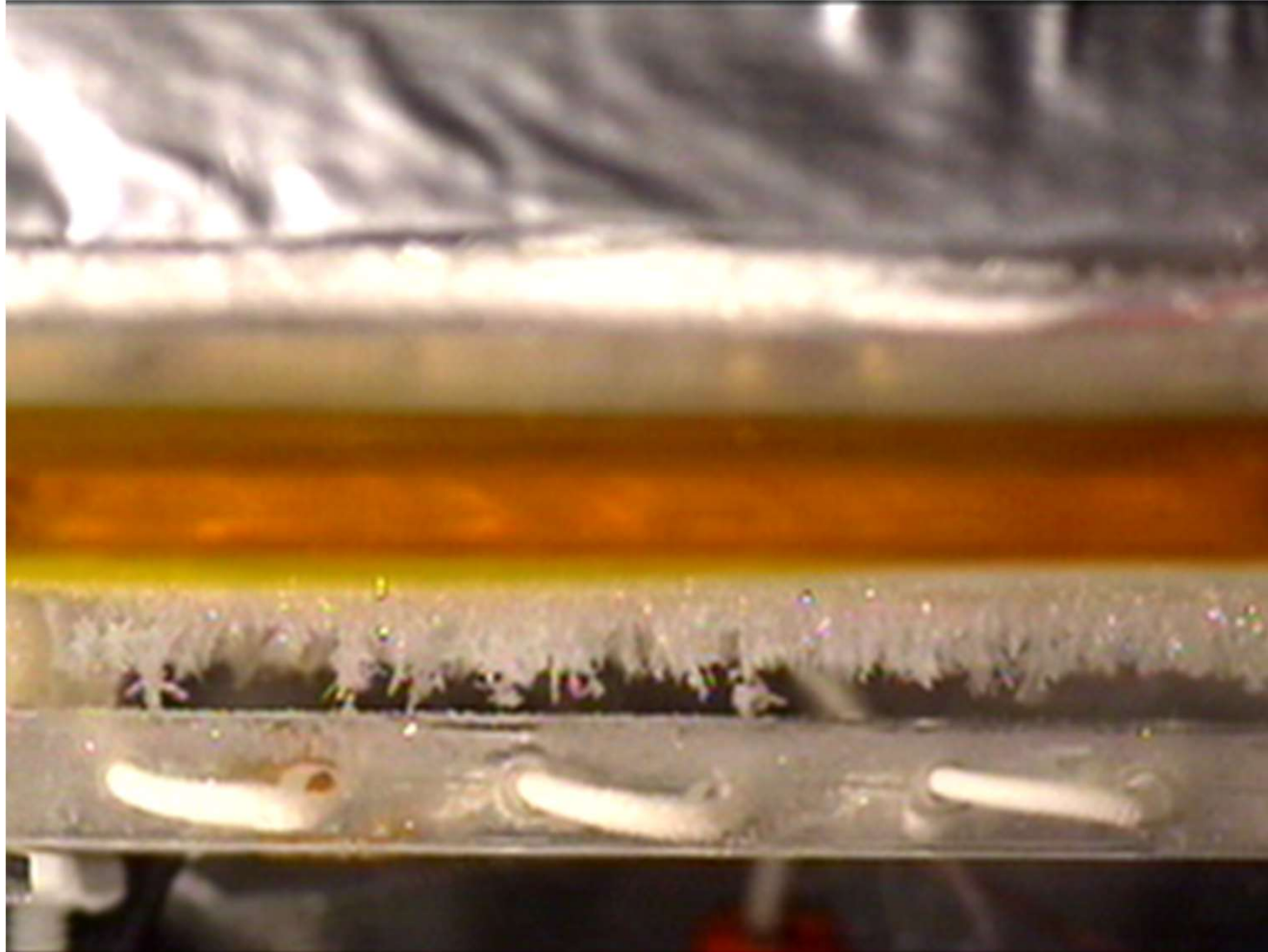


Geometry and Topology
Optimized in 2 Dimensions!



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EHD-Enhanced Frost Control



Half the Volume, Third of the Weight...



Personal Cooling

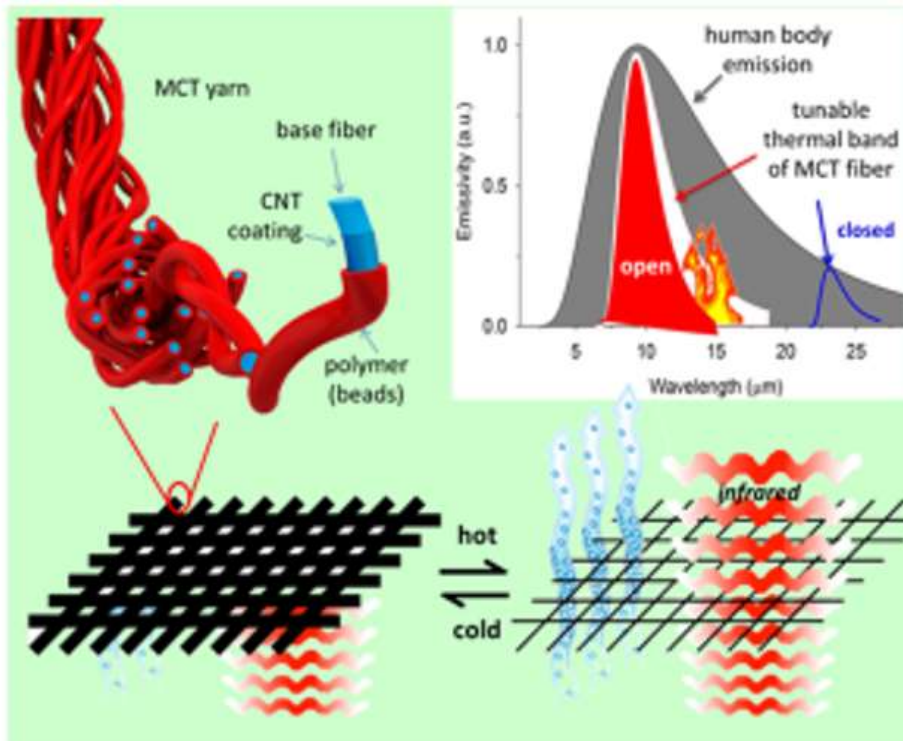
**Why cool entire buildings,
when only the occupants
want to be cool?**



Perfect individual comfort for higher
productivity!
Mobile Comfort Inc.



Smart Meta Clothing

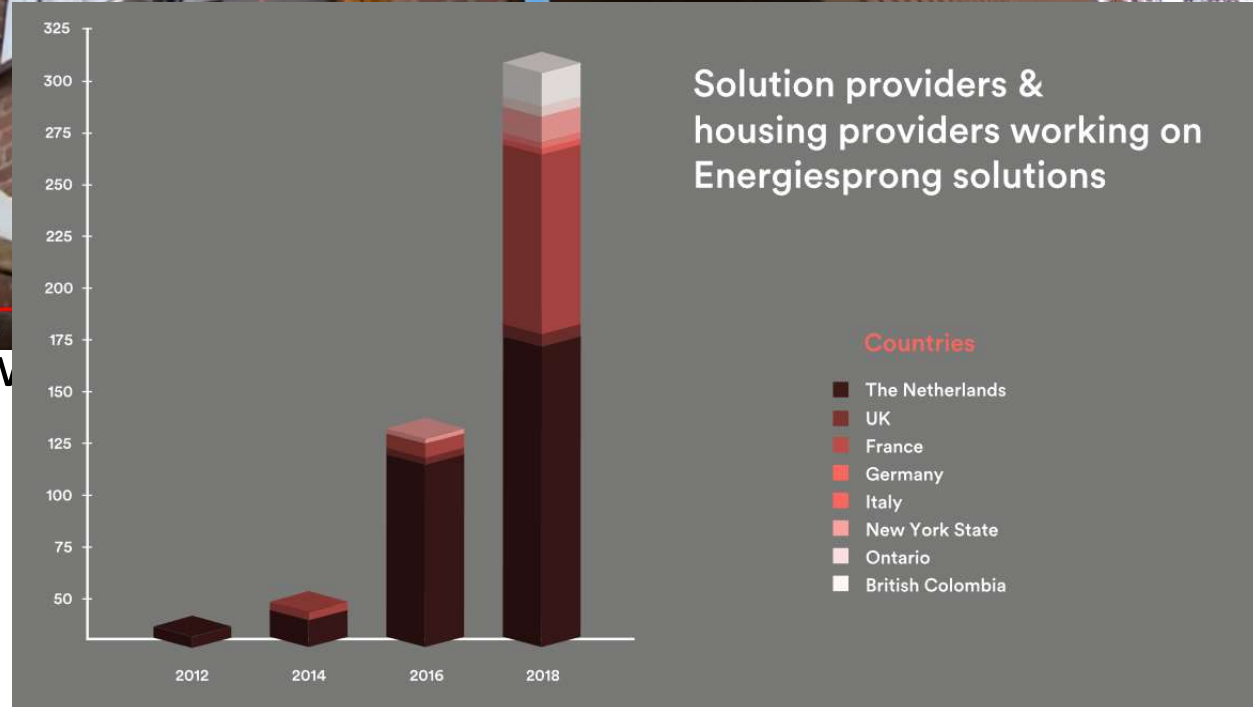


ARPA-E: Meta-Cooling Textile with Synergetic Infrared Radiation and Air Convection for Bidirectional Thermoregulation; PI: PI: YuHuang Wang (Chemistry), Co-PI: Bao Yang, Min Ouyang, Bing Hu, Jane Hunter; 03/2015-02/2018

Energiesprong

- Netherlands: 20,000 units to be rehabilitated to NZE
- \$165K for first unit
- Now \$65K
- Goal \$45K, same as conventional rehabilitation

Jobs that cannot
be exported!

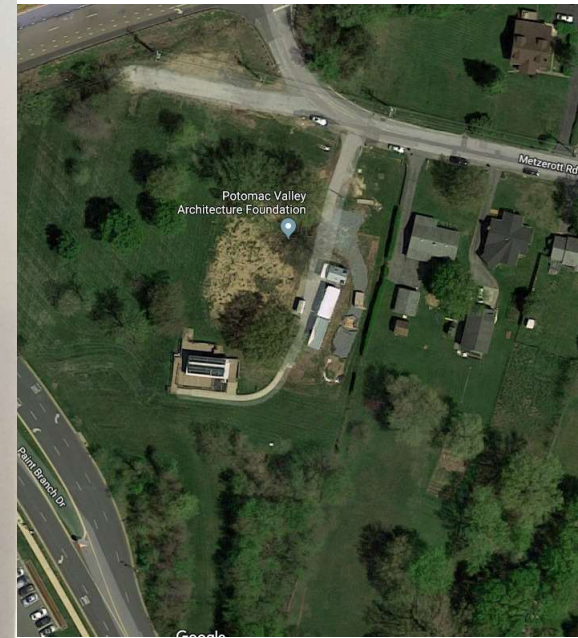


bility Park



[Vision](#) [Faculty](#) [Organization](#) [Members](#) [Benefits](#) [EEHP](#) [MOC](#) [AHX](#)

CALVERT HILLS



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Putting it all together...

**Let's Collaborate:
Conducting Energy Research
To propel an Entire Industry to
Manufacture Equipment**

**Much smaller,
Much less resource-intensive than today and
Operates in buildings with no net energy use!**

