Technology and Future Energy Systems: Lessons from arpa·e

CHANGING WHAT'S POSSIBLE

Emerging Technologies Summit
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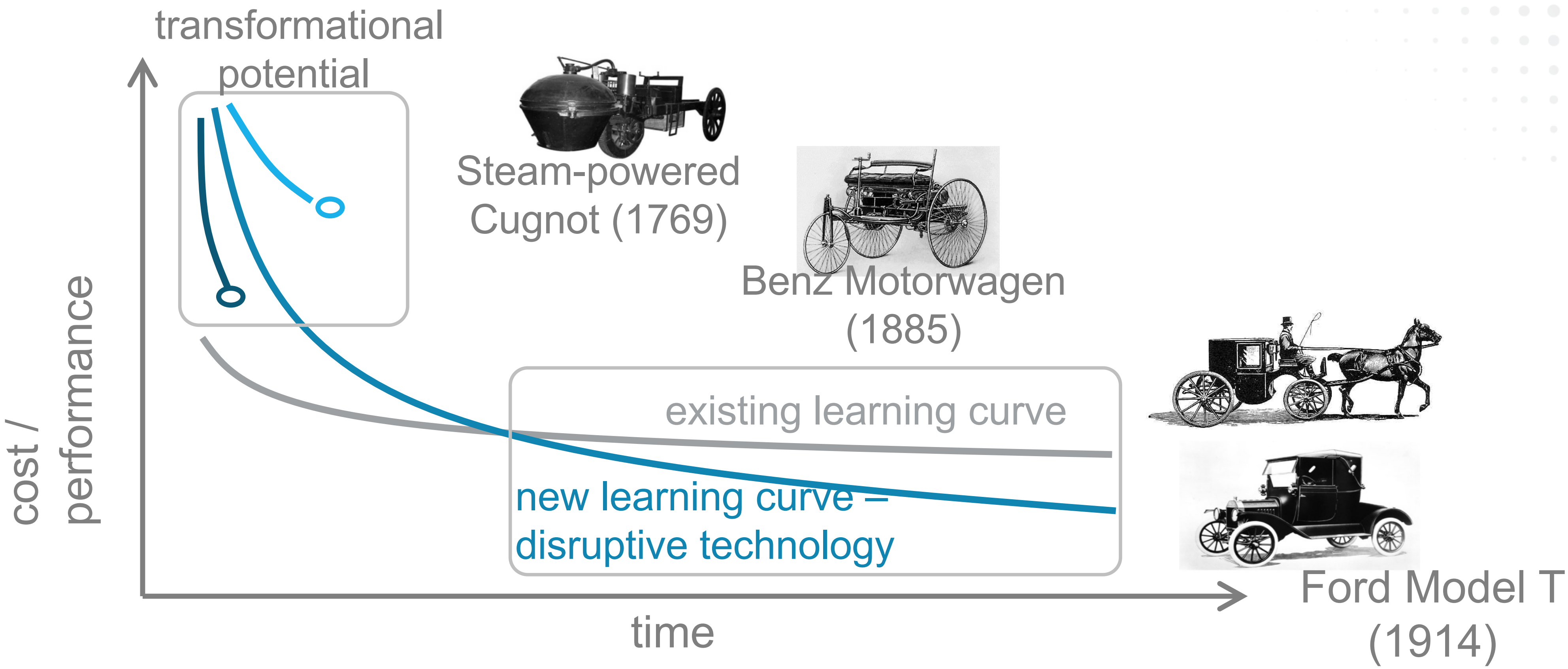
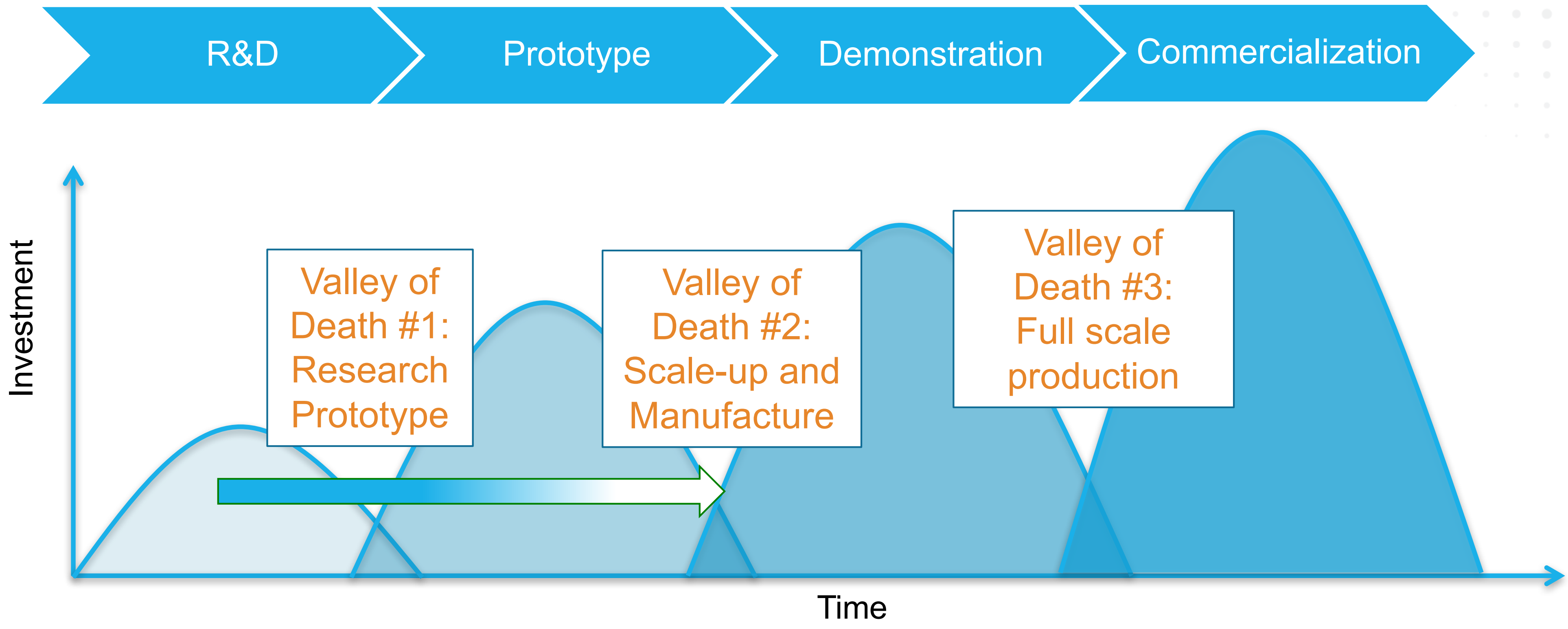
Former Director of ARPA-E

Learning Curves and Incumbent Technologies



Transitions Toward Market Adoption



Lessons from ARPA-E:

Goal-oriented R&D Management

Expert, Empowered Program Directors

Limited-term funding under Cooperative Research Agreements

Project management for both technical and commercial goals

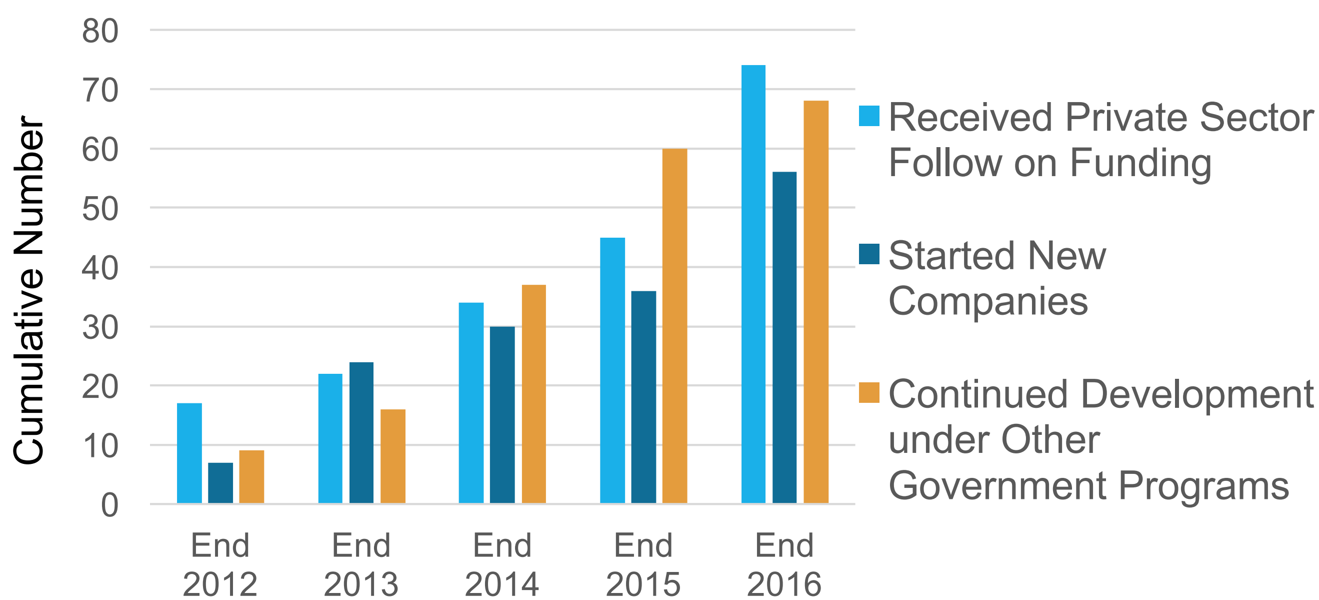
Projects cancelled if progress can't be demonstrated

Mentoring in finding post-ARPA-E development funds

Metrics for Goal-oriented R&D

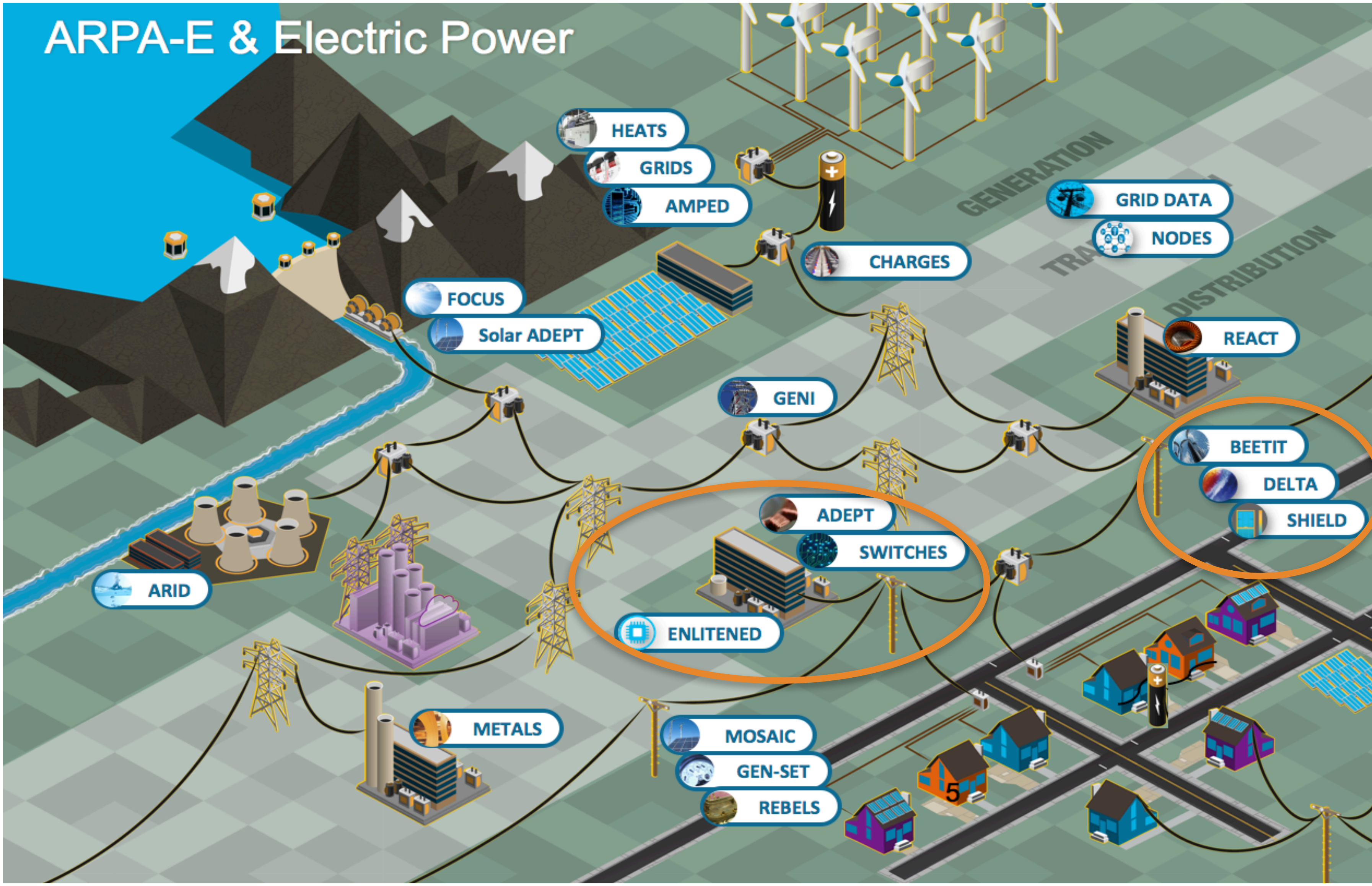
Since 2009 ARPA-E has invested approximately $1.5 billion across more than 580 projects, of which 262 have completed their ARPA-E support as of Feb 2017.

74 ARPA-E projects have cumulatively attracted more than $1.8 billion in private-sector follow-on funding (as of Feb 2017).



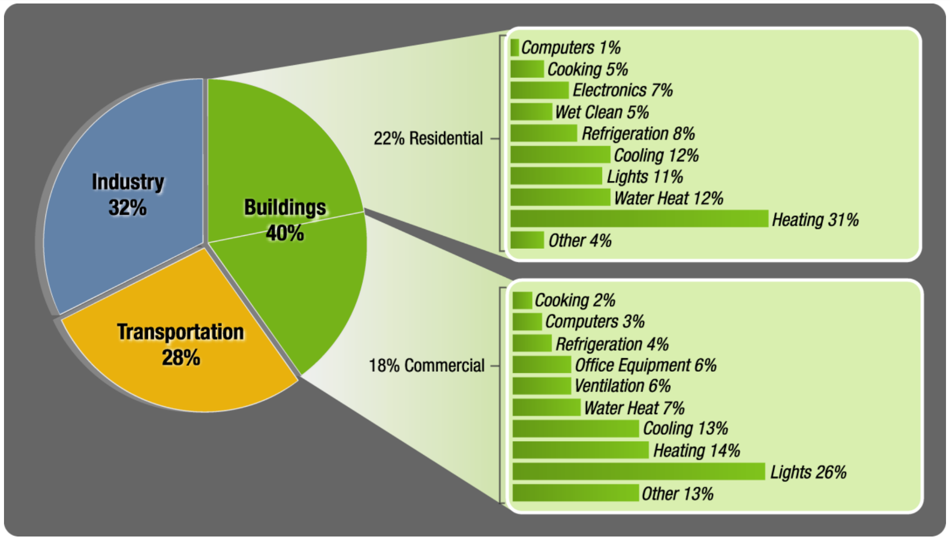
Deputy Director of Commercialization: David.Henshall@Hq.Doe.Gov

ARPA-E & Electric Power



End use efficiency

Buildings use 72% of U.S. electricity and 55% of its natural gas



By 2030, Business as usual:

16% growth in electricity demand and additional 200 GW of electricity ($25-50 Billion/yr)

Source: LBNL Environmental Energy Technologies Division, 2009

BEETIT - 2010

Building Energy Efficiency Through Innovative Thermodevices

Lower energy approaches to heating, ventilation and air conditioning (HVAC).

DELTA - 2014

Delivering Efficient Local Thermal Amenities

Local thermal management for individual comfort, goal to reduce overall AC costs by allowing less stringent building-wide AC

Shield - 2016

Single-Pane Highly Insulating Efficient Lucid Designs

Insulating, anti-condensation window materials with excellent optical quality, for cost-effective retrofits or replacements

SENSOR – 2017 foa

Saving Energy in Structures with Occupancy Recognition

Reducing HVAC energy demand by accurately sensing building occupancy, allowing demand-based heating, cooling, ventilation

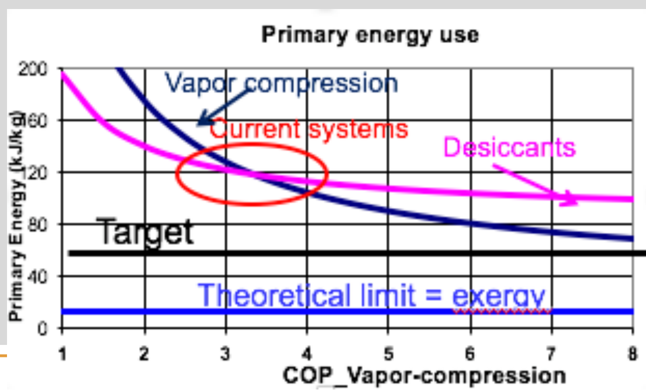
BEETIT

Building Energy Efficiency Through Innovative Thermodevices

Goals

- Improve energy efficiency of HVAC systems by 50%
- Cost-competitive with conventional systems

Challenge



Portfolio

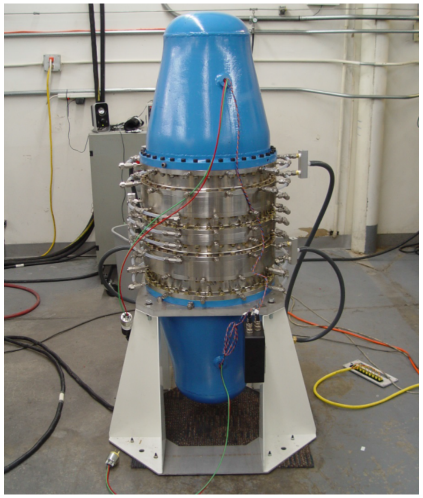
- 15 Project teams
- Opportunity areas:
  - Gas Cycles
  - Solid State Cooling
  - Absorption/Adsorption Cooling

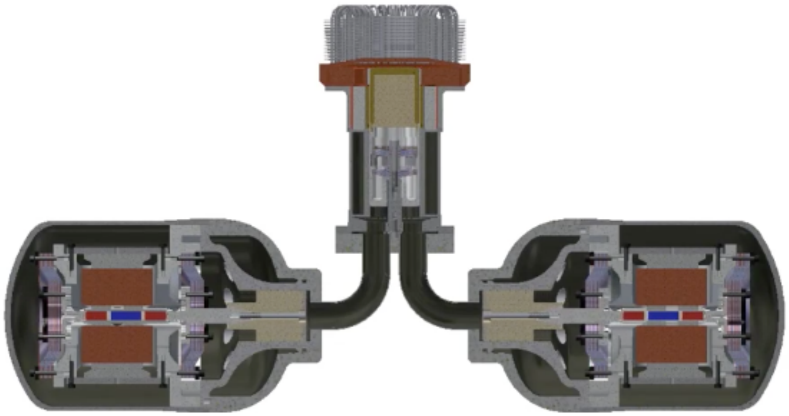
Pathway to Impact

- Collaboration with Navy for expeditionary needs
- Commercial first markets

Project Example: Infinia Technology Corporation

- Heat pump that uses a Stirling cycle
- Heats and cools more efficiently than conventional vapor compression systems
- Cost-effective thermosiphon to enable the Stirling cycle at air conditioning temperatures



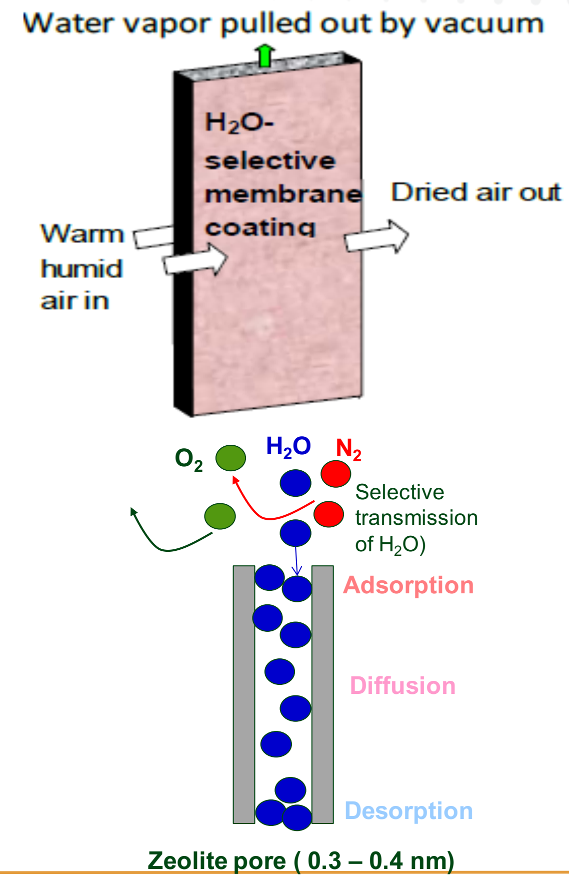


Products in development for both Military & Commercial Applications

Direct replacement for existing units, using at least 33% less energy

Pacific Northwest National Lab / Texas A&M Univ

- Dehumidification using zeolite coated membranes that selectively allow water vapor to pass, but not air
- Potential Products:
  - Humidity removal add-on, reducing fuel use by 10%
  - Evaporative coolers that work in all climates, reducing fuel use by 33% (tropical) to 90% (arid)
- Future Plans
  - Scale-up underway: joint funding by ARPA-E / Pentagon / Military Sealift Command
  - Performance tests planned for both commercial and military applications



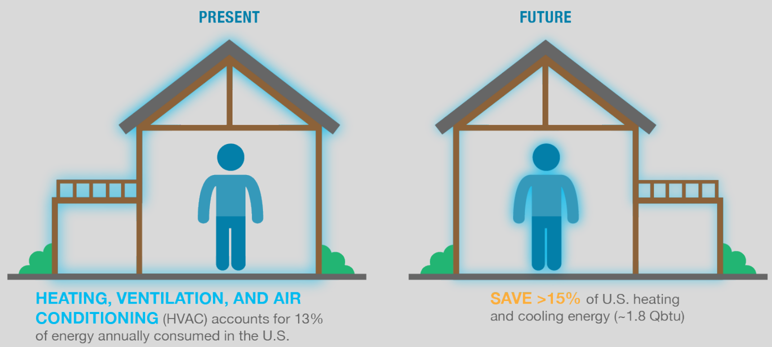
DELTA

Delivering Efficient Local Thermal Amenities

Goals

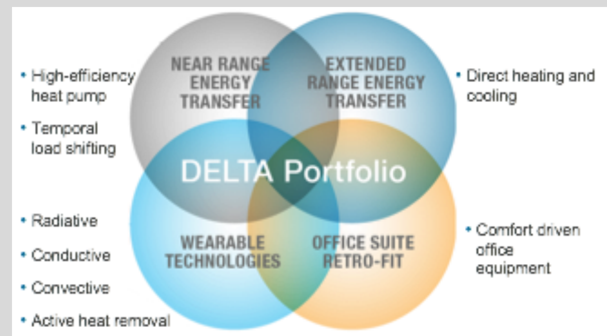
- Local temperature for occupants that enables reductions of Heating Ventilation and Air Conditioning (HVAC) energy consumption by at least 15%
- Enable radical and sustainable architecture in next generation energy-efficient building design

Concept:



Portfolio

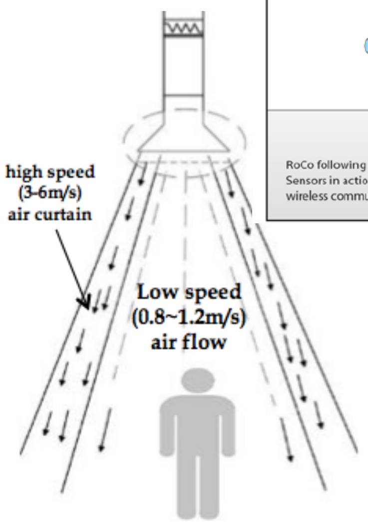
- 11 Project teams

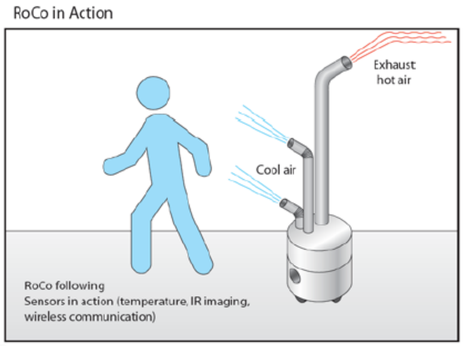


- Four categories
  - Extended range, Close proximity, Thermal physiology, System combinations

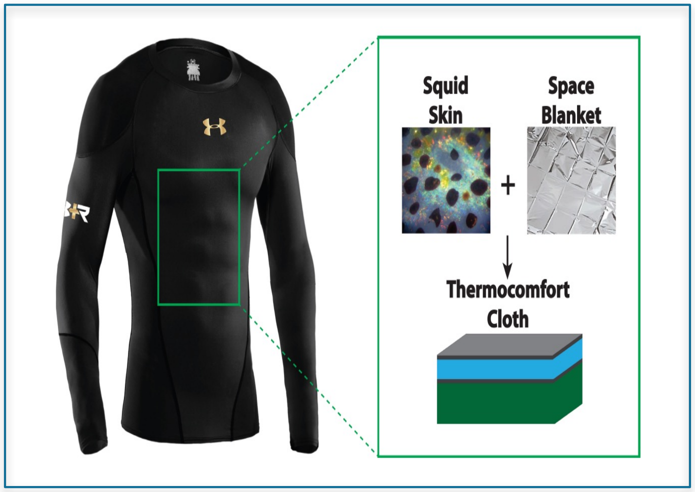
Personal heating and cooling

Ventilation comes to you



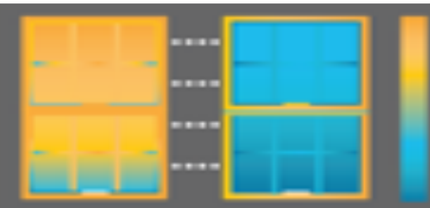


Comfort control through clothing



SHIELD

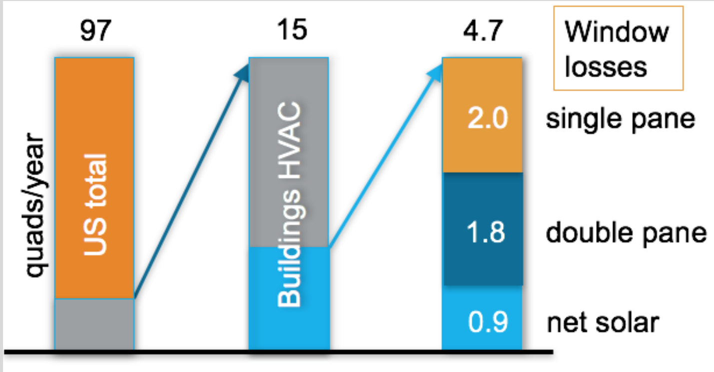
Single-Pane Highly Insulating Efficient Lucid Designs



Goals

- Halve the heat lost through single-pane windows
- Produce secondary benefits, such as improved soundproofing, reduced cold weather condensation, that will make retrofits more desirable

Context



Challenge

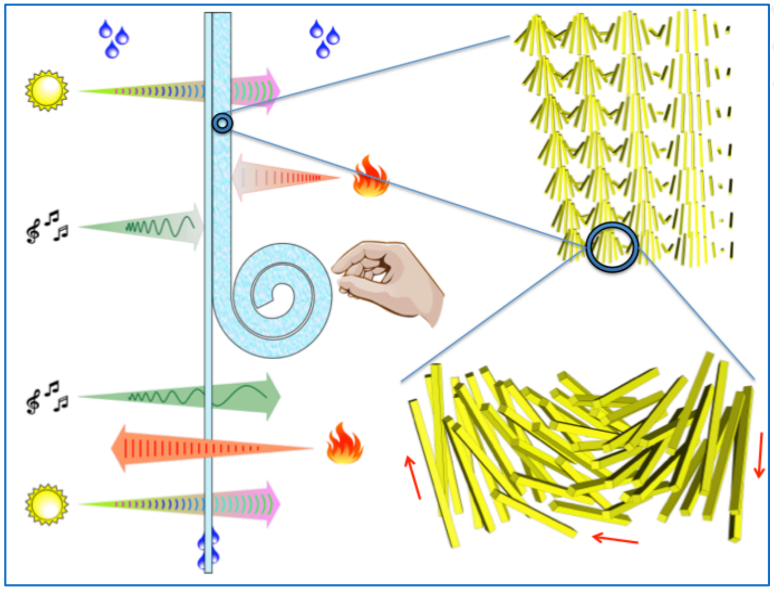
Portfolio

- 14 projects
- Opportunity Areas
  - Controlled nanostructures
  - Phononic engineering
  - Composite materials

Project Spotlight: University of Colorado Boulder

University of Colorado **Boulder**

Goal: A flexible, transparent window film for application onto single-pane windows.
Approach: Liquid crystalline phases of nano-cellulose aerogel that has low-emissivity properties.
Cost factor: Fabrication from low-cost cellulose nano-rods from food industry waste.



Project Spotlight: IR Dynamics, LLC

IR Dynamics

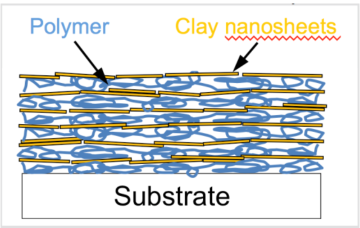
Location: Santa Fe, NM

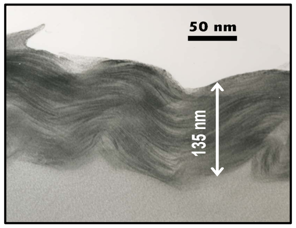
Goal: flexible window films that improve thermal insulation.

Approach: Composite of polymer-films with two embedded nanophase materials: transparent clay materials that act as a thermal barrier and IR thermochromic vanadium dioxide-based nanomaterials.

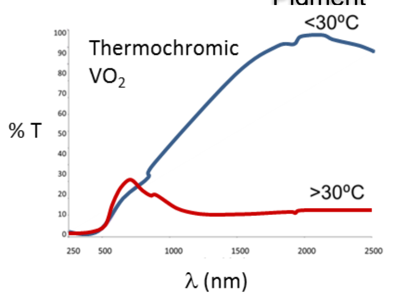
Window films that combine two nanotechnologies

Lower U-Value with Transparent Clay Nanosheets

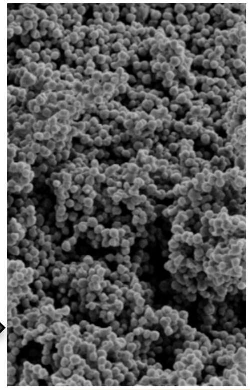




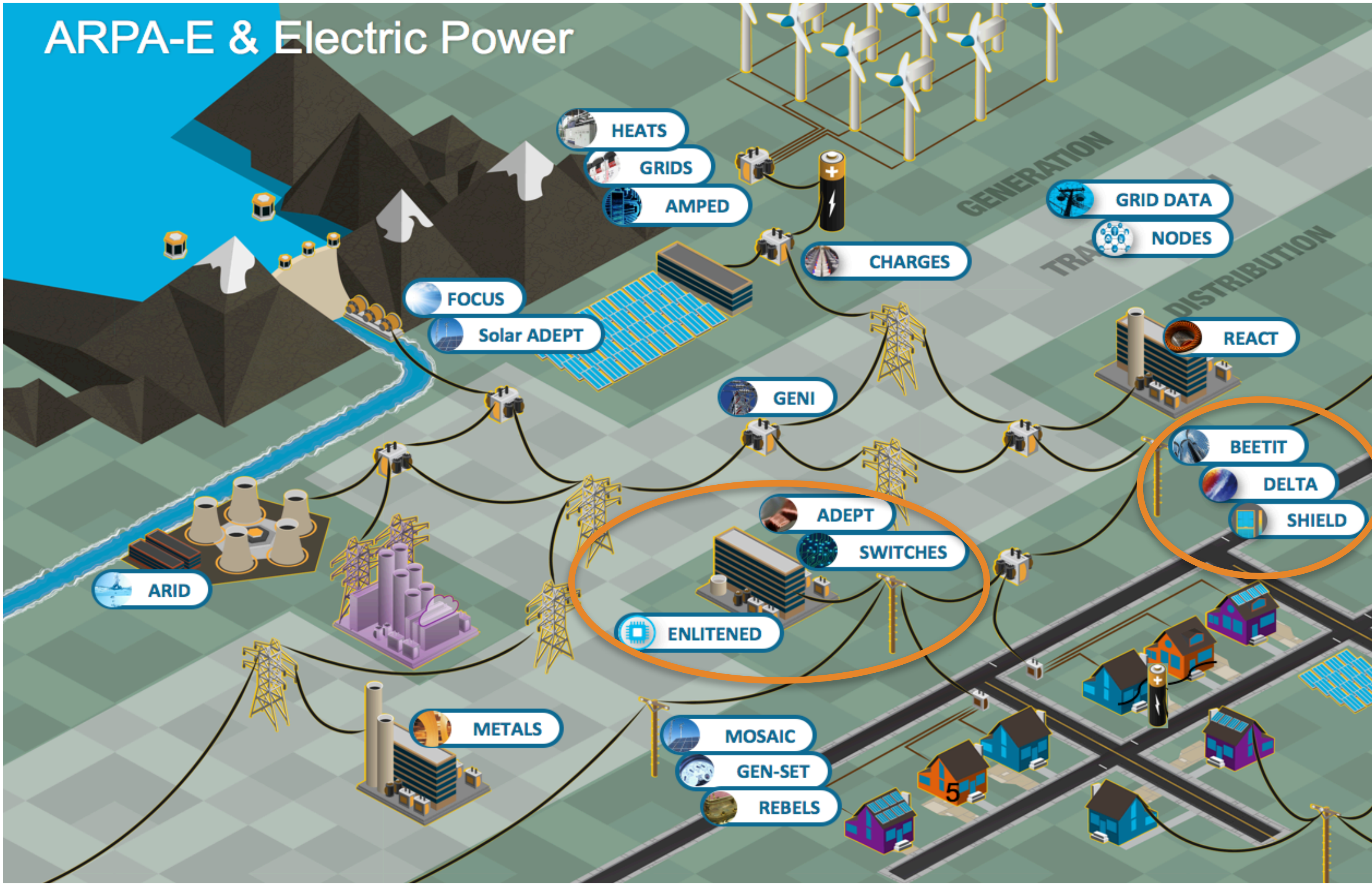
Smart Infrared Control with Transparent VO_2 Based Pigment



50nm Thermochromic Particles

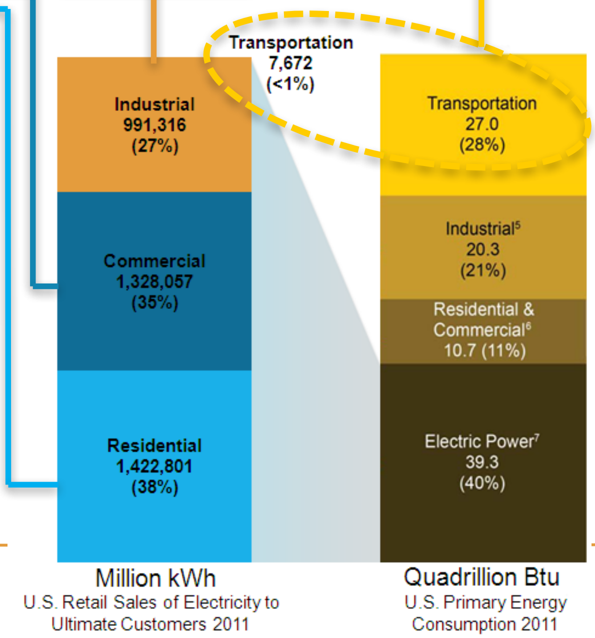


ARPA-E & Electric Power



High Growth Applications Need Converters

- **Motor Drives**
  - Motors: 50% of all U.S. electrical energy usage.
  - Hybrid Electric Vehicles: Power Electronics are 20% of material cost.
- **Electronic Ballasts/LED**
  - Lighting consumes 12% of U.S. electricity.
  - Dimmable controls: Power electronics 30-50% of cost
- **Information Technology**
  - Computing technology: 5-10% of U.S. electricity.
  - Datacenters alone: ~2-3%.



EIA, Retail sales of electricity to ultimate customers, January 30, 2013.
EIA, Annual Energy Review DOE/EIA-0384(2011), September 2012
NXP Semiconductors, Analyst Day , September 2012.

ADEPT - 2010

Agile delivery of electric power technology

Power Conversion Efficiency: Wide band-gap semiconductors for high-power, high-current applications

SWITCHES - 2013

Strategies for Wide Bandgap, Inexpensive Transistors for Controlling High-Efficiency Systems

Lowering the cost of wide band-gap devices to improve Energy Efficiency for electric motors

ENLITENED – 2016 foa

Energy-Efficient Light-Wave Integrated Technology Enabling Networks that Enhance Datacenters

Integrated photonic interconnects and switching networks to reduce data center demand for electricity

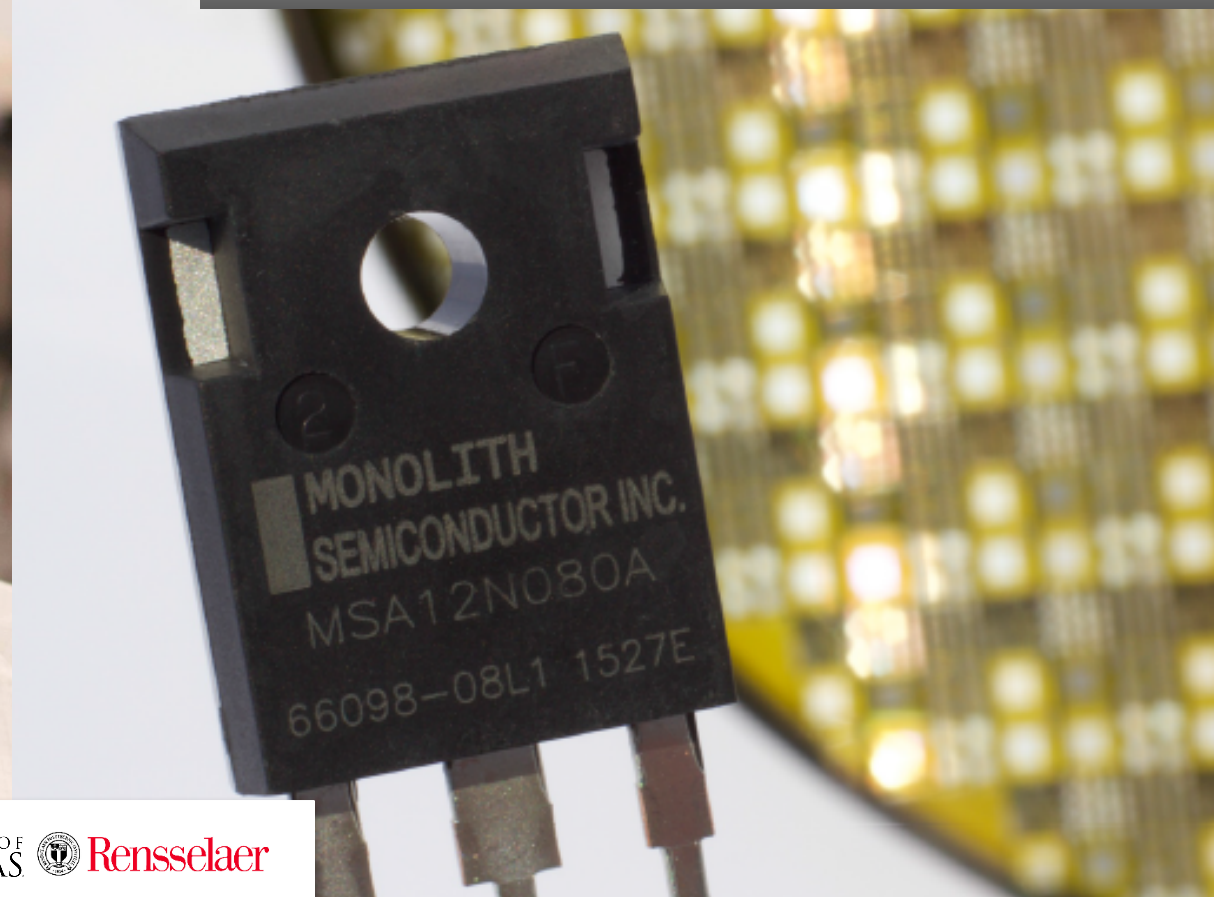
CIRCUITS – 2017 foa

Creating Innovative and Reliable Circuits using Inventive Topologies and Semiconductors

Novel circuit topologies, advanced control and drive electronics tailored to reduce power consumption across all sectors

MONOLITH

Economical SiC Device Fabrication



MONOLITH SEMICONDUCTOR INC.

United Technologies Research Center

UNIVERSITY OF ARKANSAS

Rensselaer

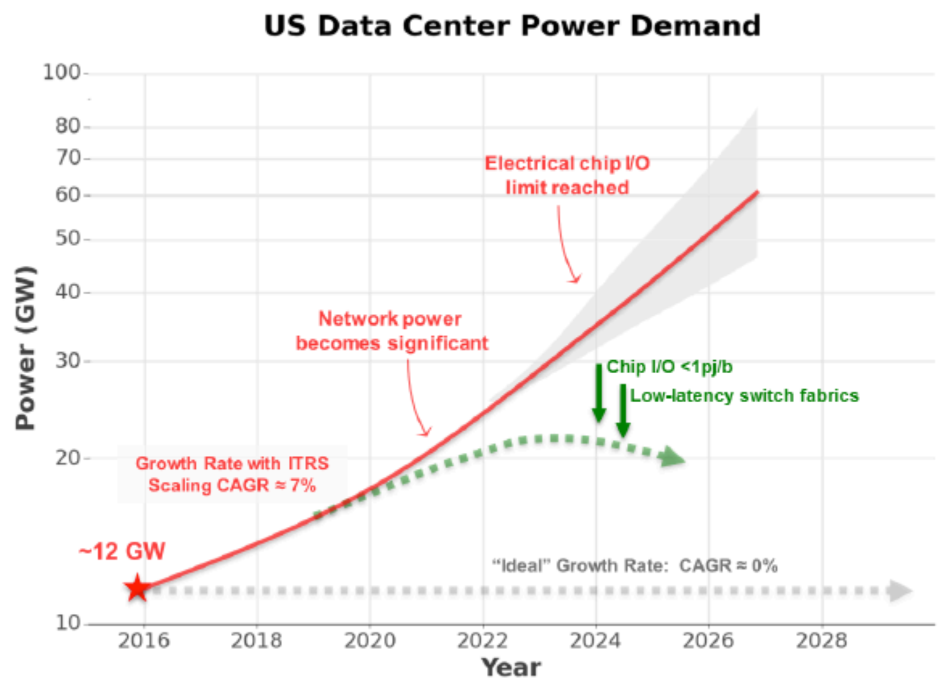
Impacts from Innovation require technical discipline

CIRCUITS

Technical Requirements

Category	Target
Power and Voltage	≥ 10 kW and ≥ 600V
Efficiency ($Q = P_{out}/P_{loss}$)	≥ 97.5% (Q ≥ 39) @ peak load ≥ 95% (Q ≥ 19) @ 5% peak load
Power Density	≥ 150 W/in^3 (≥ 9.15 kW/L)
Specific Power	≥ 5 kW/kg
Operation	168-hour continuous basic operation
Relative Cost	≤ 0.05 $/W

ENLITENED



2017 ARPA-E: **DE-FOA-0001727**

2016 ARPA-E: **DE-FOA-0001566**

The social compact for technical R&D

- Optimism: Investments in science and engineering R&D over the last ½ century have created opportunities for dramatically improved technical capabilities, including applications in incumbent markets such as Energy. Developing such advanced technologies is essential for US competitiveness.

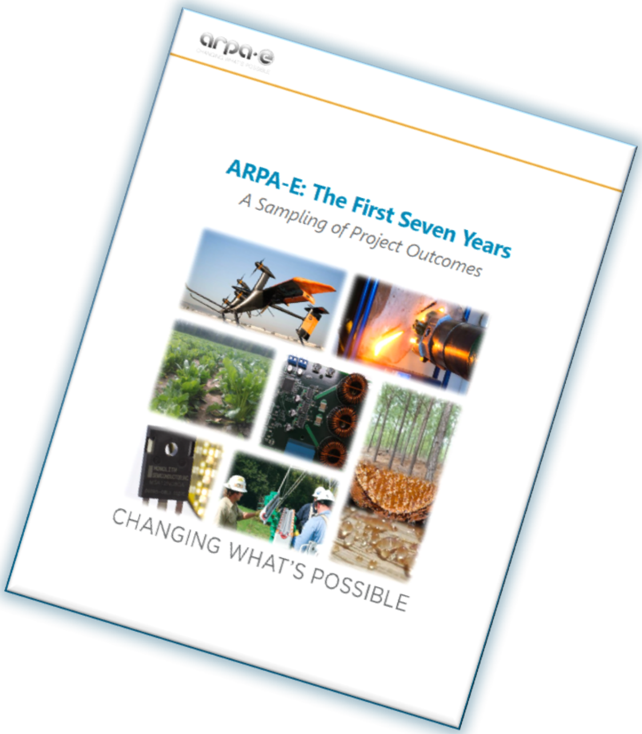
- Realism: The opportunities created by basic or curiosity driven research are too early stage and too high risk for commercial investment, but with focused development the best can be identified and prepared for commercial pathways.

- Engagement: We cannot afford to naïvely accept the tenet that basic science should be boxed off from follow-on activities, and that such follow-on activities are not appropriate for government support.

- The Future: How will we support the transitions of early-stage innovative technical ideas to readiness for commercial engagement?

Background slides

ARPA-E Impacts



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