Advanced Building Energy Efficiency Research Activities at ORNL

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Climate Action 2016 forum

University of Maryland, College Park

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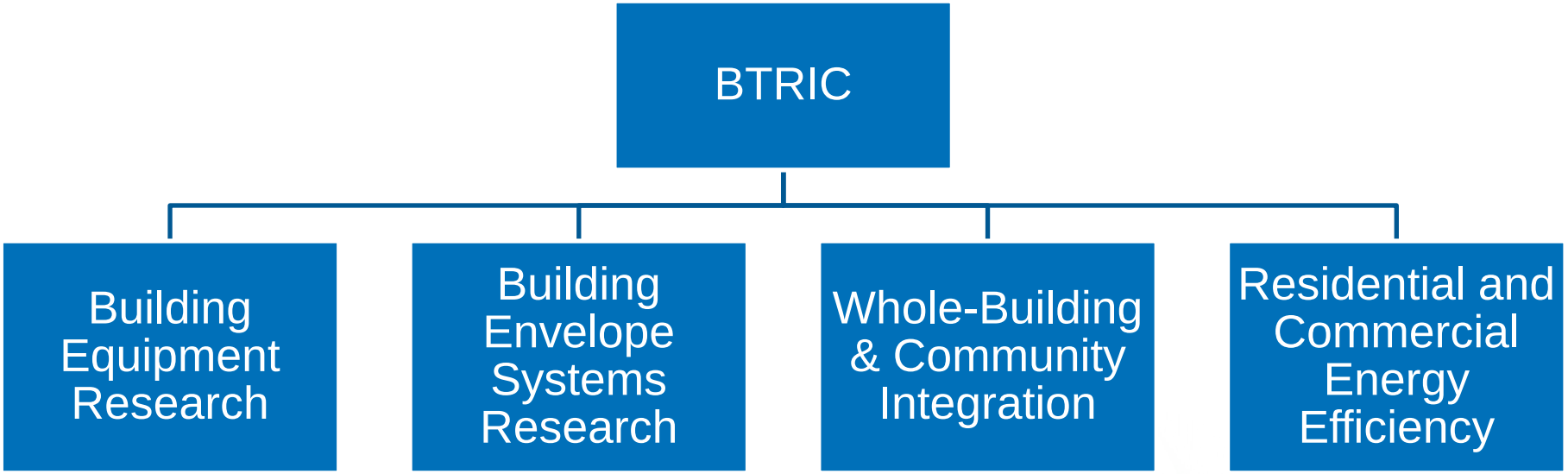
Building Technologies Research and Integration Center (BTRIC)



40+ years as BTO's (and predecessor's) lead lab for HVAC&R/Appliances
12 R&D 100 Awards
127 active industry partners
32 experimental apparatuses
19 active CRADAs

Leveraging Fundamental Science

- Pinpoint energy efficiency opportunities by accelerating searches for optimal materials, component designs, and manufacturing processes
  - Unique capabilities of the BTRIC
  - Sophisticated DOE National User Facilities at ORNL
- Success Stories:
  - Additive Manufactured Integrated Energy Systems (AMIE)
  - Neutron Flow Visualization
  - Ionic Liquids
  - Graphene Oxide Membranes
  - Additively Manufactured Components
  - Transparent Insulation
  - Commercialized Heat Pump Technology

AMIE: Integrated Energy Systems

- Advanced Manufacturing
  - Accelerated creation of the prototype vehicle and house demonstrates the program's function as an applied science tool to get energy efficiency products to market, faster
- Vehicle Technologies
  - Introduced onboard power generation and featured bidirectional wireless power transfer technology
- Building Technologies
  - Innovative single-room building module to demonstrate new manufacturing and building technology pathways
- Sustainable Electricity
  - Advanced building control and power management strategies integrate various energy systems while also leveraging the building as a virtual battery through demand-side load management.

From Concept to Reality in Less than 1 Year

- Leveraging ORNL leadership in key research areas

Lower Cost Sensors and Controls

- Wireless sensor target costs reduced to $1–$10 per node by leveraging advanced manufacturing techniques such as additive roll-to-roll manufacturing
  - Allows electronics components like circuits, sensors, antennae, photovoltaic cells and batteries to be printed on flexible plastic substrates (base materials).
  - The nodes can be installed without wires using a peel-and-stick adhesive backing.
- The ultra-low power smart sensors collect and send data to a receiver, which can capture data from many different peel-and-stick nodes and provide information to the energy-consuming system.

Enables

- Continuous commissioning,
- FDD, and
- Service organization notifications

Ensures optimal building system operations throughout their service life

Next Generation Insulation Materials

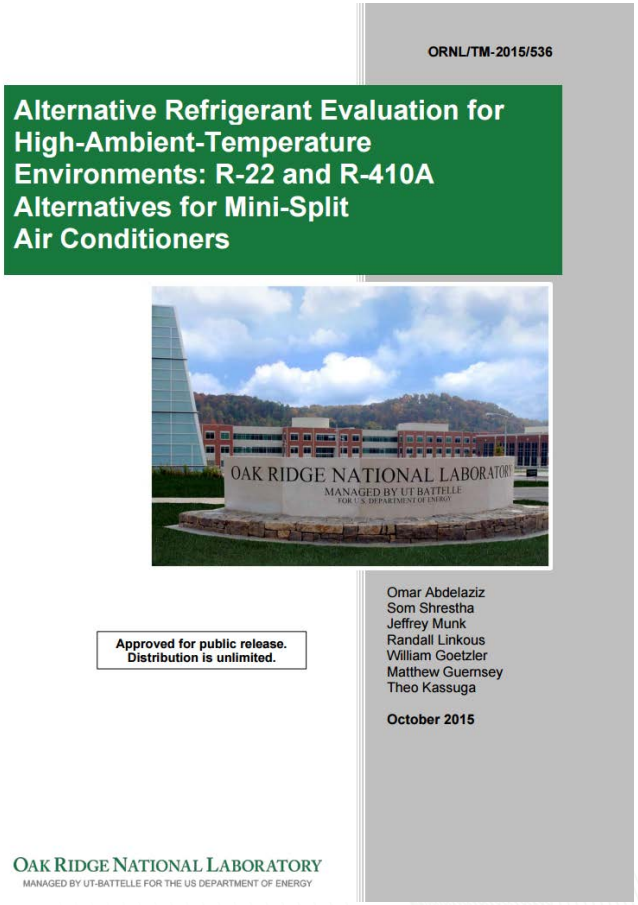
- Composite poly-iso foam board RUS=6 (RSI=1.06)) containing modified atmosphere insulation (MAI) cores developed to for target RUS=12 (RSI=2.11)
  - Double the effective insulation with existing wall systems
  - MAI technology is similar to vacuum insulation panels (VIPs) but NanoPore innovated the manufacturing process, and cut costs by half
- Firestone Building Products is developing a composite that uses poly-iso foam to encapsulate the MAI cores and protect against puncture of the barrier layers, it allows MAIs to be integrated into buildings without any special installation

ORNL's HVAC Activities

- Early R&D:
  - Magnetic AC (working with Vacuumschmelze)
  - Separate Sensible and Latent Cooling Technologies
    - Membrane AC (working with Dais Analytics)
    - Electrochemical Compressor and Ionic Liquids (Working with Xergy)
  - Residential Absorption Heat Pump
- Modeling & Laboratory research:
  - Commercial IHP with Thermal Storage
  - Residential Gas Engine IHP
  - Alternative Refrigerant Evaluation (AREP, HAT)
- Field Research:
  - Cold Climate Heat Pump
  - Residential IHP
  - High Efficiency RTU
  - Ground Source Heat Pump Data Mining
- International outreach: IEA and IIR

Alternative Refrigerant Evaluation for High Ambient Temperature (HAT) Environments

- Evaluated 6 alternatives to R-22
- Evaluated 5 alternatives to R-410A
- At 6 test conditions (up to 131°F/55°C ambient)
- ORNL/TM-2015/536
- http://info.ornl.gov/sites/publications/Files/Pub59157.pdf



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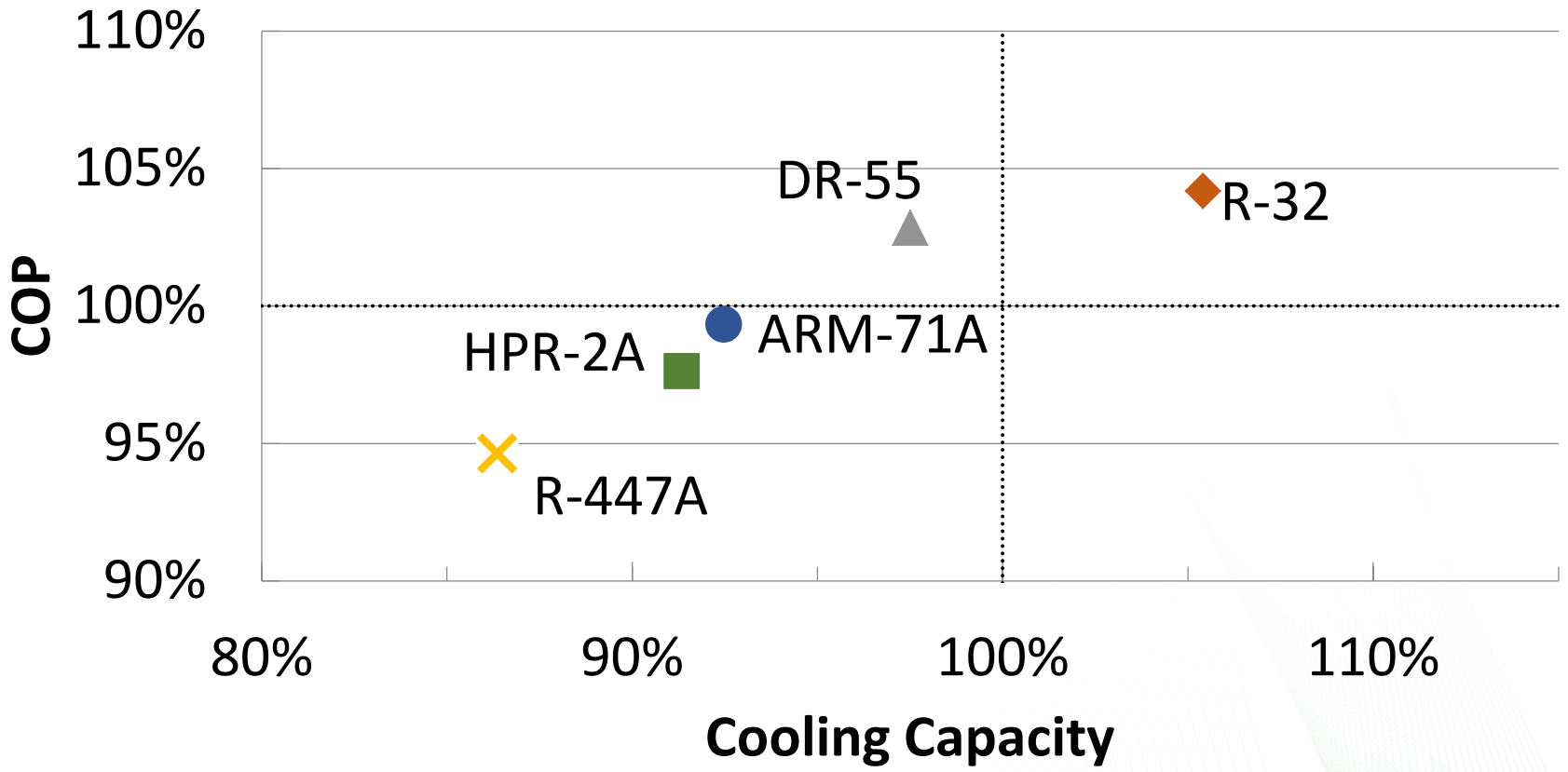
ORNL HAT Evaluation Campaign: Performance Relative to R-410A at 95°F Ambient Conditions



Cold Climate Heat Pump (CCHP)

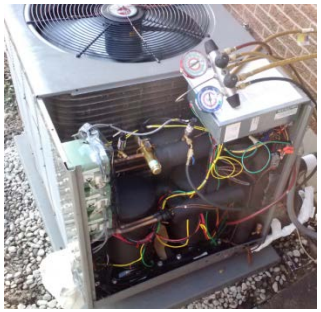
Project Goal:

Develop a 3-ton, high efficiency CCHP to eliminate strip heating

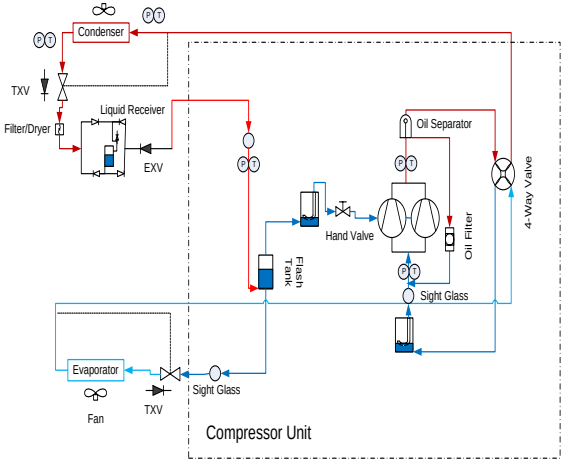
- Achieve COP@47°F > 4.0;
- Achieve capacity@-13°F > 75%, vs. rated capacity@47°F.

Target Market/Audience:

The principal target market is 14.4 M electric-heated dwellings using 0.16 quad/year for heating in cold regions.



Tandem, single-stage, field testing unit in Sidney, OH



Tandem, vapor-injection, lab prototype

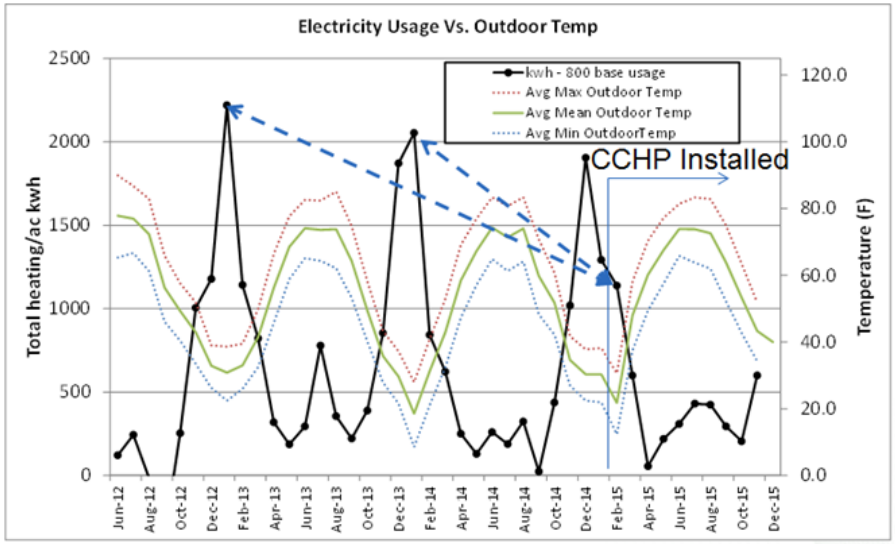
Key Partners:

EMERSON Climate Technologies

The Unico System — Small-Duct Central Heating & Air Conditioning

Recent Developments

- Complete 1-year field testing in Ohio



- **Achieved all project objectives**
- >40% heating energy reduction in the peak load month ($T_{ambient,avg}$ ~ 20°F).
- No resistance heat needed, down to -13°F outdoor temperature.

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ORNL's Water Heating Research

- Builds on
  - Signature expertise on the development of the Electric Heat Pump Water Heaters (HPWH) & IHPs
    - CRADA with GE successfully resulted in the development of GE Geospring
    - CRADA with ClimateMaster for development of Trilogy™ 40 Q-Mode Ground Source IHP
  - Signature expertise in sorption technologies
  - Strong industry support
- Focus on augmenting primary energy using ambient heat (heat pumping effect for gas and electric appliances)
- Focus on consumer needs (cost, efficiency, reliability)

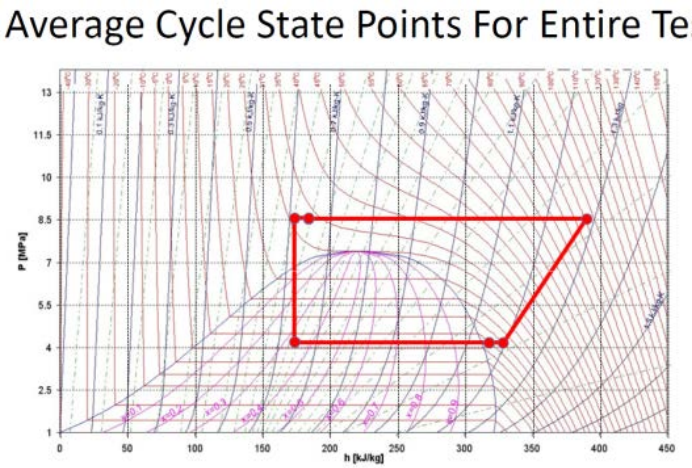
Commercial CO_2 HPWH & Max Technical Efficiency Electric HPWH with Low-GWP Halogenated Refrigerant

Project Goal:

Evaluate next generation high efficiency electric HPWHs for building applications, select best platform and develop system design with **primary energy factor of 0.81 or better at an installed cost premium of $11.94 / Gallon or lower**

Target Market/Audience:

Comm'l & Resid'l Electric Water Heaters



Timeline: (FY16–FY18)

Key Tasks/Milestones

1. FY16: techno-economic assessments of commercial CO_2 and Max. Tech. HPWHs underway
   1. Submit stage gate report supporting a go/no-go decision based on national potential energy savings, 8/31/16
2. FY17-18: Assuming "go" decision:
   1. Establish CRADA(s) for prototype dev/demo of comm'l CO_2 and/or max tech low-GWP HPWHs
   2. Demonstrate primary EF >0.8 in lab, 05/31/17
   3. Field demo final prototypes & draft CRADA reports; 9/30/18

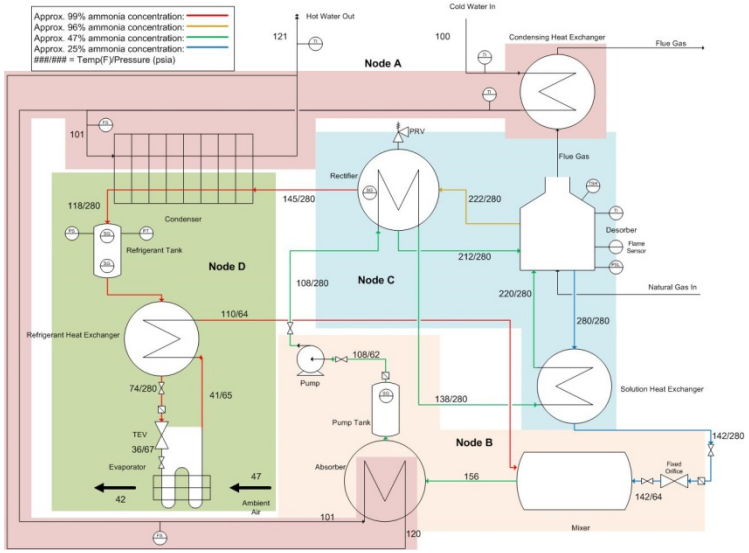
Commercial Absorption Heat Pump Water Heater: A.O. Smith CRADA

Project Objective

Develop high performance gas fired absorption heat pump water heaters

Target Market

Commercial gas WH: Capture 2-5% of the market to achieve 0.18 Quads of primary energy savings

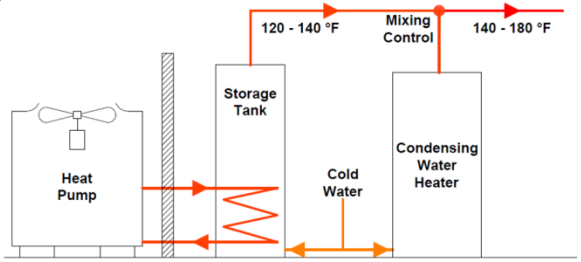


COPs greater than 1.6 are achievable

Key Partners

Recent Development

- Alpha prototype fabricated and delivered to ORNL



ORNL's Appliance Research

- Early R&D:
  - Magnetic refrigerator (Working with GE, CRADA)
  - Ultrasonic dryer (Working with GE)
  - High Performance Refrigerator using Novel Air Bearing HX (Working with SNL and UMD)
- Modeling and Laboratory Evaluation:
  - Thermo-electric Dryer (Working with Sheetak)
  - Heat Pump Dryer (Working with GE, CRADA)
- Field Evaluation:
  - Lower GWP Refrigerant (Working with Honeywell, CRADA)
  - High Performance Low Emission Refrigeration Systems (Working with Hill Phoenix, CRADA)
- Supporting Standards Program

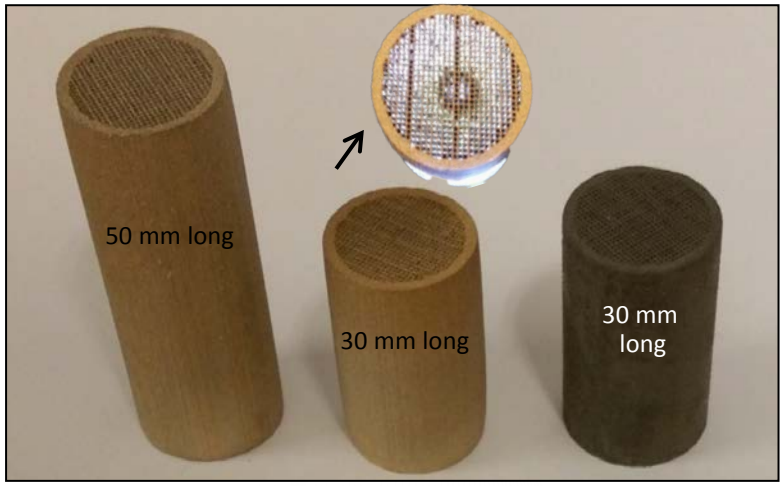
Magnetocaloric Refrigeration: GE CRADA

- The goal of this project is to develop a residential refrigerator with 25% lower energy consumption and reduced emissions using magnetocaloric refrigeration technology.

Highlights:

1. The 150 micron MCM microchannels have been successfully 3D printed.

2. MCM could be successfully sintered and the conditions at which the MCM can be sintered have been identified.



Evaluating quality of printing 200 µm microchannels

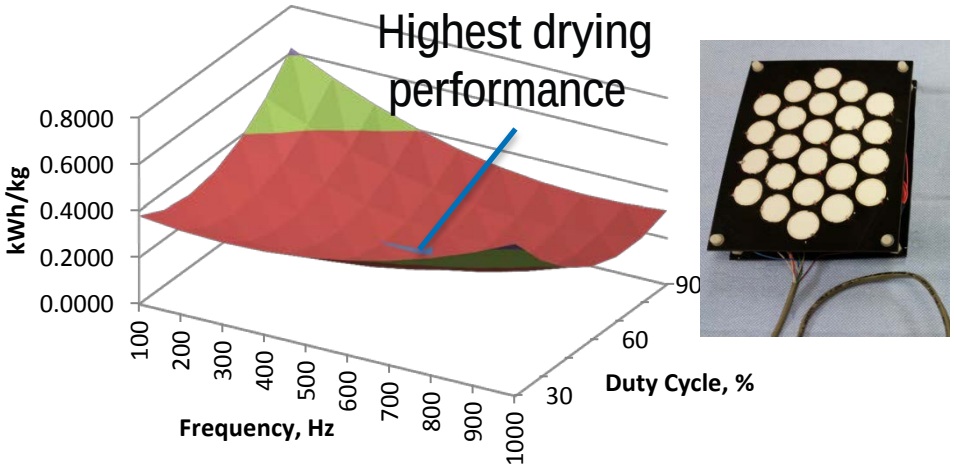
Ultrasonic Clothes Dryer

Project Objectives

Develop a high performance clothes dryer with EF>10 with drying time of less than 20 min using mechanical drying processes

Target Market

Residential and commercial clothes dryers (1% nation's energy consumption)



Curve fit on experimental data obtained with this custom amplifier

Key Partners

Timeline:

1. Develop and test a small-scale demo proof of the concept prototype and further validate the model –GO/NO GO(9/30/2015)
2. Design cold mist air carrier flow and mist passage (9/30/2016)
3. Develop the most appropriate full-scale ultrasonic dryer (9/30/2016)
4. Conduct comprehensive testing and refine/finalize the design of the full scale ultrasonic dryer (2/30/2016)

Goal	Drying time <20 min	Fabric size > 4 in^2
Achieved	~ 7.5 minutes	~14 in^2

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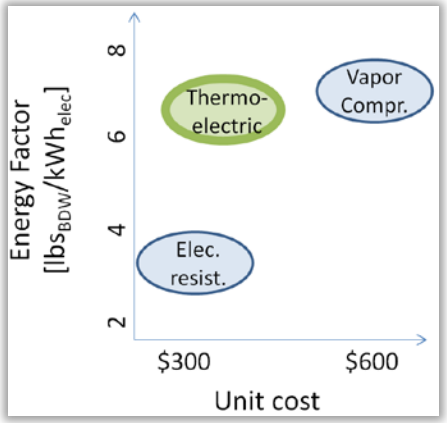
High Efficiency Heat Pump Clothes Dryer

Heat Pump Dryer: GE CRADA

- Achieving EF of 6.7 compared with 3.73 of baseline vented dryer : **80% more energy efficient.**

Thermo-electric Dryer: Sheetak

- TE can be less expensive than vapor compression
- Investigating drum-integrated and air-based approaches



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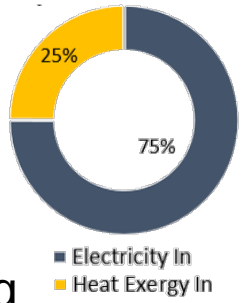
Cross Cutting Activities

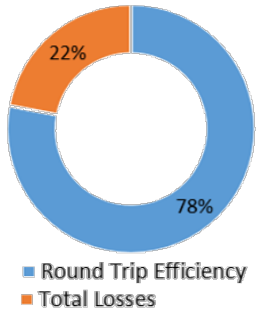
- Miniature Heat Exchangers (working with UMD)
- Modeling
  - HPDM
    - http://web.ornl.gov/~wlj/hpdm/MarkVI.shtml
    - Flexible: http://hpdmflex.ornl.gov/hpdm/wizard/welcome.php
  - SorpSim
  - CFD
  - LCCP (working with UMD)
- Energy Storage
  - Thermal
    - RoCo (working with UMD)
    - Electric Vehicle Heating (working with MAHLE)
  - Electric/Thermal (GLIDES)

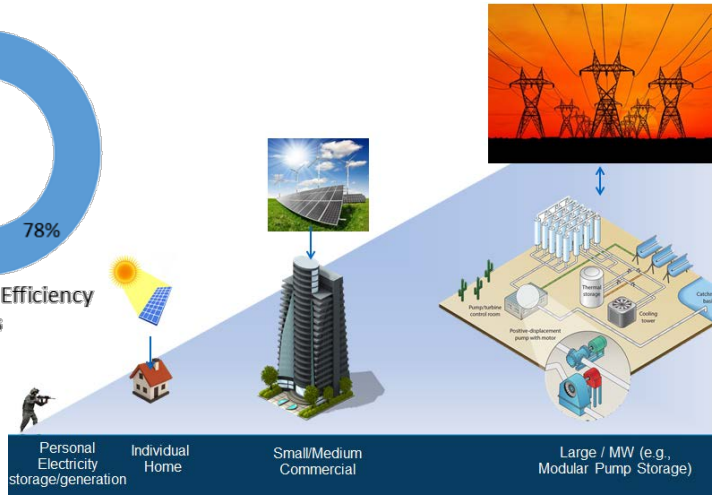
Ground Level Integrated Diverse Energy Storage (GLIDES), BEYOND BATTERIES

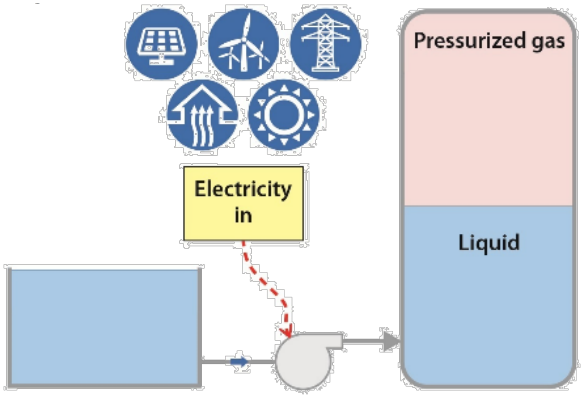
Project's Key Idea

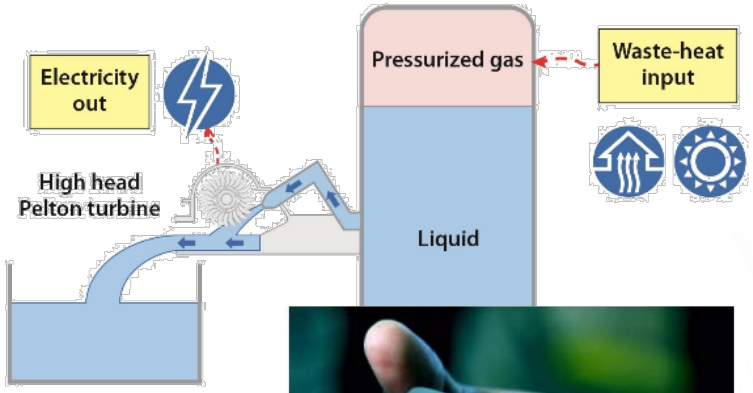
Approach isothermal compression using hydraulic machines and a hydraulic fluid as intermediary to compressing and expanding a gas











Additively Manufactured Pelton Buckets

GLIDES first- generation proof-of-concept 1.5-3 kW prototype

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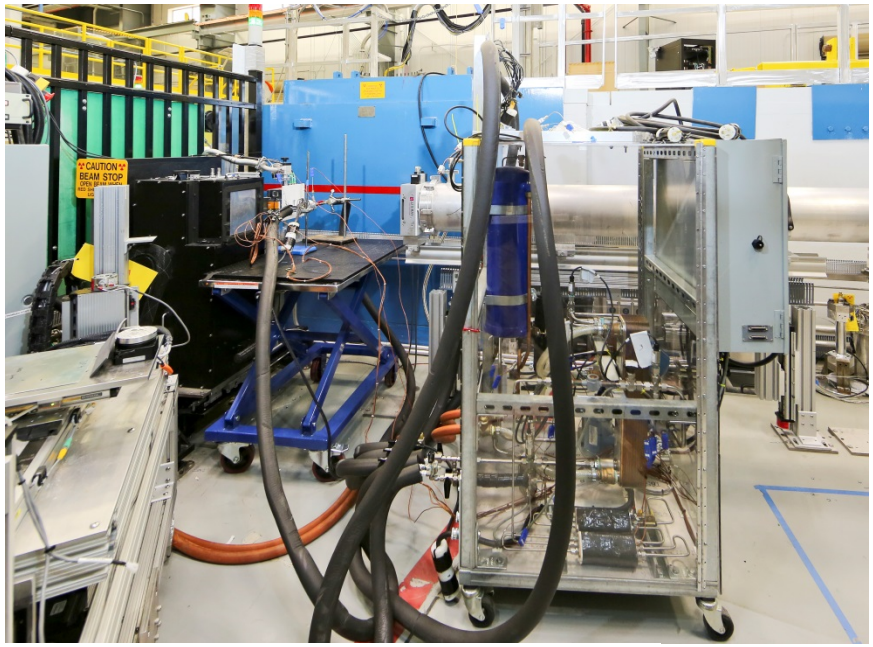
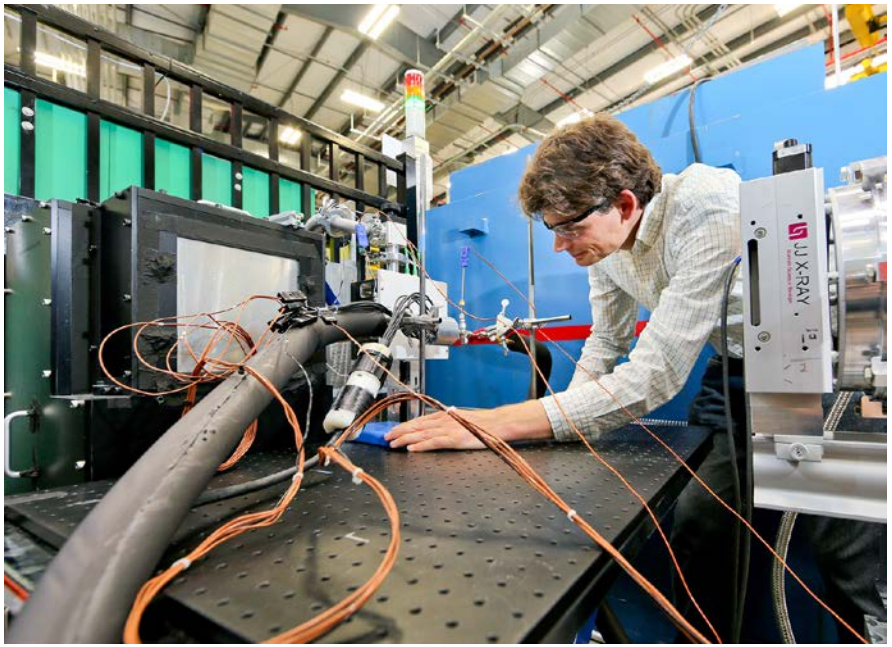
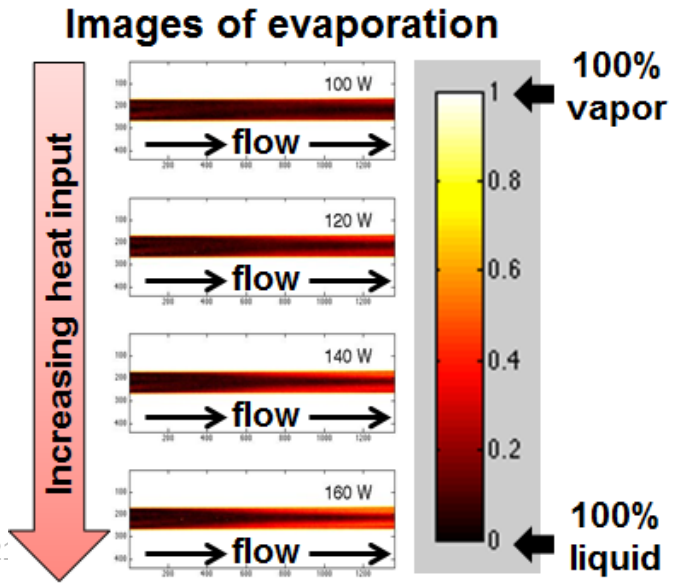
Visualization of flow inside heat exchangers







Neutron imaging to visualize evaporation, condensation, and 2-phase flow inside the heat exchangers of an operating vapor compression machine