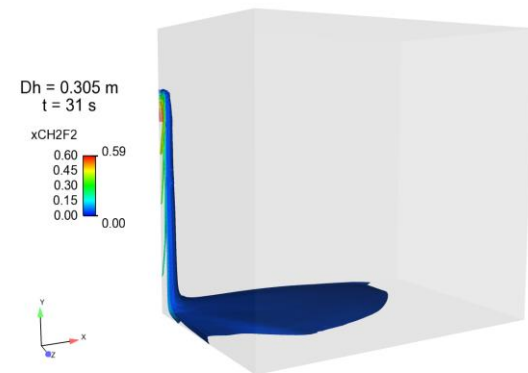
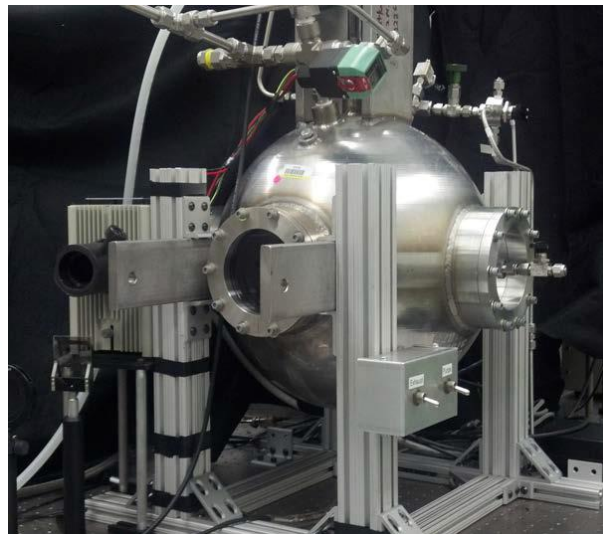
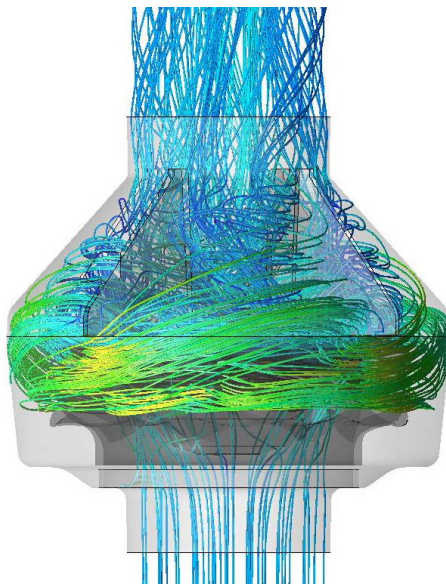


# Emerging Technologies: HVAC, WH and Appliance *BTO Peer Review 2019*



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# HVAC, Water Heating and Appliance R&D

BTO's ultimate goal is to reduce the average energy use per square foot of all U.S. buildings by 50% from 2010 levels. Emerging Technologies Program's goal is to enable the development of cost-effective technologies capable of reducing a building's energy use per square foot by 45% by 2030, relative to 2010 high-efficiency technologies.

Two-pronged approach to accelerate the development of new technologies:

- 1) Accelerate the development of near term technologies that have the potential to save significant amount of energy (including cost reduction activities, bending the cost curve)*
- 2) Accelerate the development of the next generation of technologies that have the potential of "leapfrogging" existing technologies by pursuing entirely new approaches (including crosscutting efforts)*

*The goal is to develop technologies that save energy and reduce our environment burden while introducing them in the simplest application first, highest probability of success.*

# Efficiency first, innovation with a purpose

DOE's ultimate goal is to develop the next-generation technologies that 'leapfrog' existing technologies and result in dramatically improved energy efficiency.

- **Short Term:** Develop and evaluate low-GWP alternative refrigerants, including flammability characterization and hot climate performance
- **Mid Term:** Develop HVAC&R systems that can handle low-GWP refrigerants
- **Long Term:** Develop non-vapor compression (NIK) systems that use zero-GWP refrigerants

Energy savings:

*Advanced technologies*

*Tomorrow's technologies*

*Next generation technologies*

*4<sup>th</sup> Generation – "Global Warming"*

Low-GWP HFCs (e.g., R-32), HFOs (e.g., R-1234yf), hydrocarbons, others

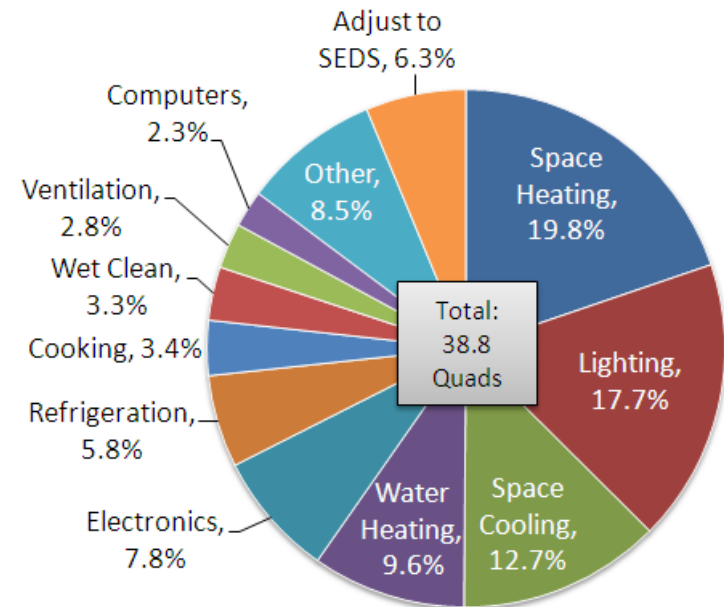
ODP → Zero

GWP → Low

# The challenge...

- In addition to individual end-use solutions, integrated solutions are also pursued
- Energy cascading (using the waste heat from one process as the source of energy for another) is utilized
- Optimizing energy use in a building, an optimum point instead of just a local minimum (single end-use)
- Broad approach includes pursuing crosscutting technologies that enable better HVAC, water heating and appliances
- A **fast way to develop new technologies** and get them into the market is through CRADAs and FOAs (with manufactures as primes or as team members)
- Program seeks to build upon its past results and speed market availability and acceptance of economically viable new technologies
- **Not working in a vacuum**, most equipment is covered by appliance standards
- Engage manufacturers and BTO deployment teams
- **Efficiency first**

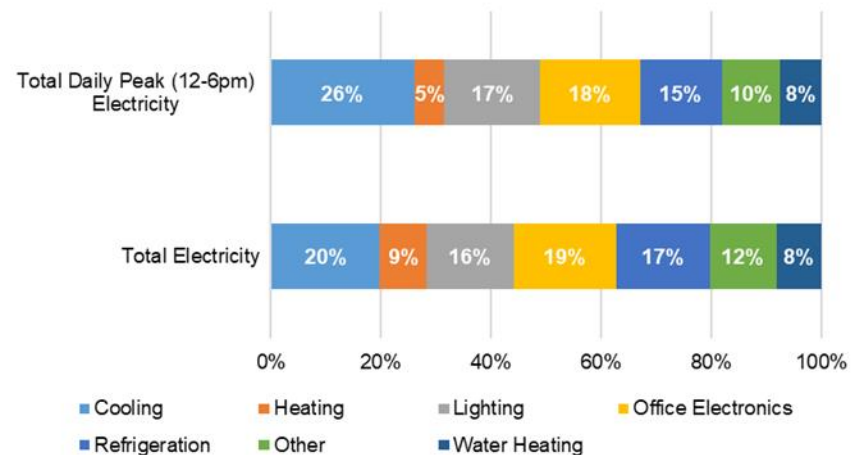
## Buildings Primary Energy Consumption



**CRADAs:** Collaborative Research and Development Agreements

# Grid-interactive efficient building (GEB) Report

- Grid-Interactive Efficient Buildings  
Technical Reports: Heating, Ventilation, Air Conditioning (HVAC), Water Heating, Appliances and Commercial Refrigeration
- **Tuesday, April 16, 2019 4-6 pm**
- Build on existing energy efficiency efforts and develop technical capabilities to optimize the flexibility between building loads and the electric grid
- Effort builds on energy efficiency R&D to also consider impacts of demand response, distributed energy resources, and energy storage to increase the flexibility of demand side management
- BTO is publishing a series of technical reports to explore the GEB-related potential of specific building technologies and capabilities to provide grid benefits



*Potential is significant in part because buildings are the primary users of electricity: 75% percent of all U.S. electricity is consumed within buildings and building energy use drives 80% of peak demand*

**Need Your Input/Feedback**

# BTO Strategy: Energy savings via Advanced technologies

Focus Areas	Outcomes
<p>Thermodynamic and HVAC system analysis of alternative low-GWP refrigerant replacements for R-410A, including toxicity, flammability, cycle COP, etc.</p>	<p>Through modeling, determined possible low-GWP refrigerant alternatives</p>
<p>Development of low-GWP alternative refrigerants</p>	<p>Commercialized a HFO replacement refrigerant for supermarket refrigeration</p>
<p>Development of a transcritical CO<sub>2</sub> supermarket refrigeration system</p>	<p>Commercialized a low-GWP, CO<sub>2</sub>-based supermarket refrigeration system</p>
<p>Experimental testing of low-GWP alternatives for R-22 and R-410A in mini-split air conditioners under high ambient temperature conditions</p>	<p>Proved low-GWP alternative refrigerants can perform well under extremely high ambient temperature conditions (up to 55°C)</p>
<p>Experimental testing of low-GWP alternatives for R-22 and R-410A in rooftop units (RTUs) under high ambient temperature conditions</p>	<p>Report Published</p>
<p>Evaluation of flammable refrigerants characterization and test methods (NIST), and charge limits (ORNL)</p>	<p>BTO Peer Review</p>

# BTO Strategy: Mid-Term, energy savings via tomorrow's technologies

Focus Areas	Description
<b>CO<sub>2</sub> heat pump water heaters</b>	<ul style="list-style-type: none"><li>• Replacing existing R-134a heat pump water heater with low-GWP CO<sub>2</sub> heat pump water heater</li></ul>
<b>Absorption and Adsorption heat pump water heaters</b>	<ul style="list-style-type: none"><li>• Use non-toxic working fluids with zero-GWP</li><li>• Significantly boost water heater efficiency by transferring heat to the water from fuel and ambient air</li></ul>
<b>Advanced compressors suitable for low-GWP refrigerants</b>	<ul style="list-style-type: none"><li>• Compressors that will be able to handle low-GWP refrigerants</li></ul>
<b>Low-GWP heat pumps using natural refrigerants</b>	<ul style="list-style-type: none"><li>• Developing air source heat pump for commercial applications—can operate in cold and hot climates</li></ul>

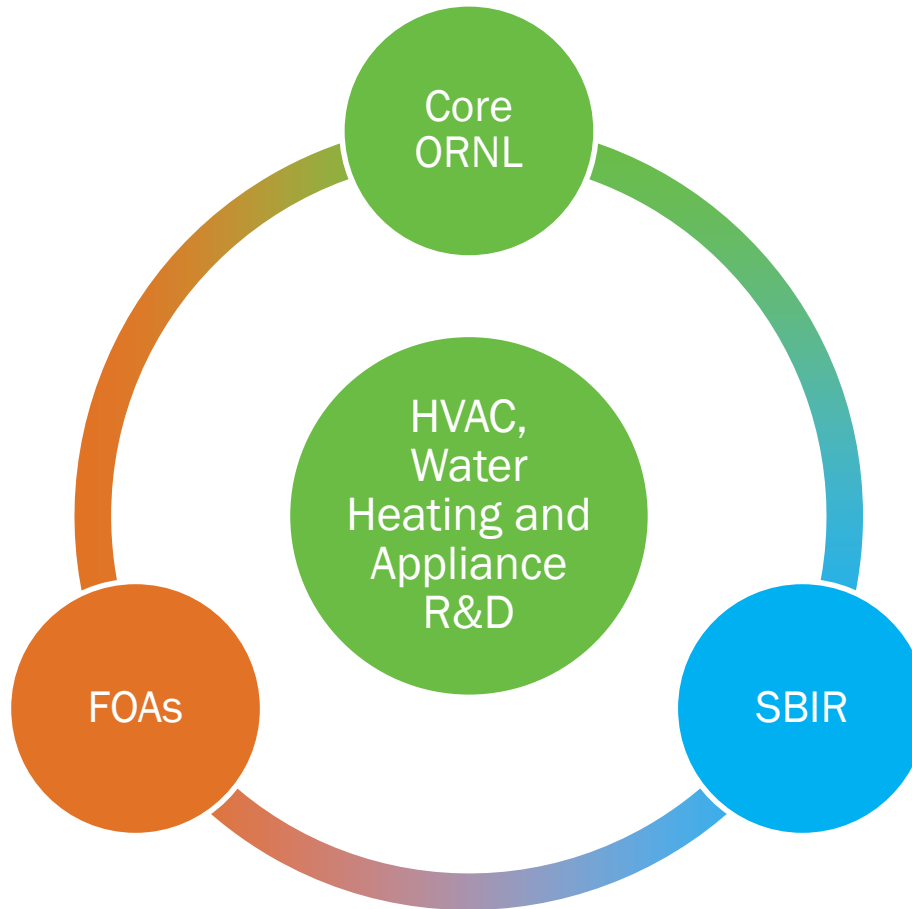
**BTO Strategy: Long-Term, energy savings via next generation technologies**

Develop non-vapor-compression solutions, including:

Focus Areas	Description
Magnetocaloric systems	<ul style="list-style-type: none"><li>• Developing a magnetocaloric refrigerator and air conditioner</li></ul>
Electrocaloric systems	<ul style="list-style-type: none"><li>• Electrocaloric systems require an electric field, rather than a magnetic field, to achieve cooling</li><li>• An electrocaloric air conditioner is being developed</li></ul>
Thermoelectric systems	<ul style="list-style-type: none"><li>• Developing heat pump water heaters and clothes dryers</li></ul>
Electrochemical compression	<ul style="list-style-type: none"><li>• Electrochemical compression is like an inverse fuel cell, in that compression requires no moving parts</li><li>• Developing a heat pump water heater and HVAC system</li></ul>
Thermoelastic cooling	<ul style="list-style-type: none"><li>• Air conditioner that works by stretching and compressing a material.</li></ul>
Membrane-based systems	<ul style="list-style-type: none"><li>• Can remove water vapor, and so is particularly good for high latent loads.</li></ul>



# HVAC, Water Heating and Appliance R&D



# Funding Resources HVAC, Water Heating and Appliance

- **2008-Present:** Core Funding at the National Labs
- **2009:** Advanced Energy Efficient Building Technologies, DE-FOA-0000115 (June 29, 2009): Research Focus: HVAC, Water Heating and Appliances: Cold Climate, **Low-GWP Refrigerant, Non-vapor compression**, and Clothes Dryers
- **2012:** Energy Savings through Improved Mechanical Systems and Building Envelope Technologies, DE-FOA-0000621 (March 7, 2012): High performance air source cold climate heat pumps: **Alternative space-heating systems**, and **Next generation heat exchangers** for electric vapor-compression heat pumps and air conditioners
- **2013:** Building Technologies Innovations Program, DE-FOA-0000823 (March 5, 2013): Open Topic: **Natural refrigerant air-sourced heat pump**, cold-climate applications, **heat exchangers** and natural gas heat pump and heat engine.
- **2014:** Building Energy Efficiency Frontiers & Incubators Technologies (BENEFIT) – 2014, DE-FOA-0001027 (Feb 4, 2014): Open Topic: Membrane-based absorption to cool and dehumidify (**WH, IHP and non-vapor compression**), **heat exchanger research**, and motors; Frontier Topic: Advanced energy efficient clothes dryers (electric and gas): innovative electrostatic precipitator, **thermoelectric heat pumping and ultrasonic technology**

# Funding Resources HVAC, Water Heating and Appliance

- **2014**: Building Energy Efficiency Frontiers and Innovation Technologies (BENEFIT)-2015, DE-FOA-0001166 (Oct 9, 2014); ***Innovation: Non-vapor compression HVAC technologies Frontiers: Advanced vapor compression HVAC technologies***
- **2016**: Building Energy Efficiency Frontiers and Innovation Technologies (BENEFIT)-2016, DE-FOA-0001383 (Dec 15, 2015): Innovation: ***HVAC&R Materials Joining Technologies***
- **2017**: Buildings Energy Efficiency Frontiers & Innovation Technologies (BENEFIT) – 2017, DE-FOA-0001632 (Nov 30, 2016) ***Topic 1: Open Topic for Energy Efficiency Solutions for Residential and Commercial Buildings – Early-stage (starting TRL 2-3); Topic 2: Advanced HVAC&R Research and Development, FRONTIERS section (starting TRL 4-5) and Topic 4: Open Topic for Energy Efficiency Solutions for Residential and Commercial Buildings – Pre-Commercial Stage, SCALE-UP section (starting TRL 6-7)***
- **2018**: Buildings Energy Efficiency Frontiers & Innovation Technologies (BENEFIT) – 2018, DE-FOA-0001825 (April 27, 2018): ***Topic 1: Advanced Separation Technologies for Building Energy Efficiency and Topic 6: Advancements in Natural Gas and Other Fuel-driven Equipment.***

# Monday, April 15th

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- ORNL - Low cost, high performance polymer composite heat exchangers
- ORNL - Integration of piezoelectric sensor-actuators into heat exchanger
- ORNL - Evaluation of Safe Refrigerant Charge Limits for Flammable Refrigerants
- ORNL - Mechanical Dehumidification Using High-Frequency Ultrasonic
- Mechanical Solutions - Development of an Innovative, High-efficiency Radon Fan
- ORNL - Oil-less Compressor/Rapid-cast, High-speed Centrifugal Compressor
- ORNL - Ultrasonic Clothes Dryer (CRADA – GE)
- ORNL - Max Tech Efficiency Electric HPWH with low-GWP Halogenated Refrigerant
- Trane - Improved Braze Joint Quality Through use of Enhanced Surface

# Tuesday, April 16th

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- ORNL - Novel Compact Flooded Evaporators for Commercial Refrigeration
- Arkema - Use of Cost-Effective Additives to Reduce Flammability in 2L Refrigerants
- Xergy - Hydrogen/Metal Hydride Based Heat Pump System for Large HVAC
- UTRC - High-efficiency Low Global-Warming Potential (GWP) Packaged Rooftop System
- *LBNL – Hybrid HVAC with Thermal Energy Storage Research and Demonstration*
- HVAC GEB Technical Report

- ORNL - Residential Gas-fired Cost-effective Triple-state Sorption Heat Pump
- ORNL - A Natural Gas-driven highly efficient thermo-vacuum clothes dryer
- ORNL - Advanced Adsorption technology for new high-efficiency
- ORNL - Cast Heat Exchanger Using the Novel Ce-Al Alloy
- ORNL - Drop-in, Retrofit Furnace with Maximum Efficiency – Self Powered System
- Stone Mountain - Pre-Commercial Scale-Up of a Gas-Fired Absorption Heat Pump
- ORNL - Real World Refrigerant Leak Assessments
- SNL - Fundamental heat transfer physics of rotating heat exchangers
- UMD College Park - Design and Manufacturing of High Performance Low Charge Heat Exchangers
- NIST - Modeling Tools for Flammability Ranking of Low-GWP Refrigerant
- ORNL- Non-Vapor Compression
- Optimized Thermal Systems - Advanced Serpentine Heat Exchangers to
- ORNL - Commercial Refrigeration Expansion Loss Reduction Technique

- ORNL - Peel & Stick Sensor for Refrigerant Leak Detection
- ORNL - Innovative, Low-Cost Ground Heat Exchanger (GHX) for Geothermal
- ORNL - Adhesive Bonding of Aluminum and Copper in HVAC&R Applications
  
- *New Projects*

# Thank You and Contact Info...



The HVAC/Water Heating/Appliance subprogram develops cost effective, energy efficient technologies.

<http://energy.gov/eere/buildings/hvac-water-heating-and-appliances>

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