Emerging Technologies: HVAC, WH and Appliance
BTO Peer Review 2016

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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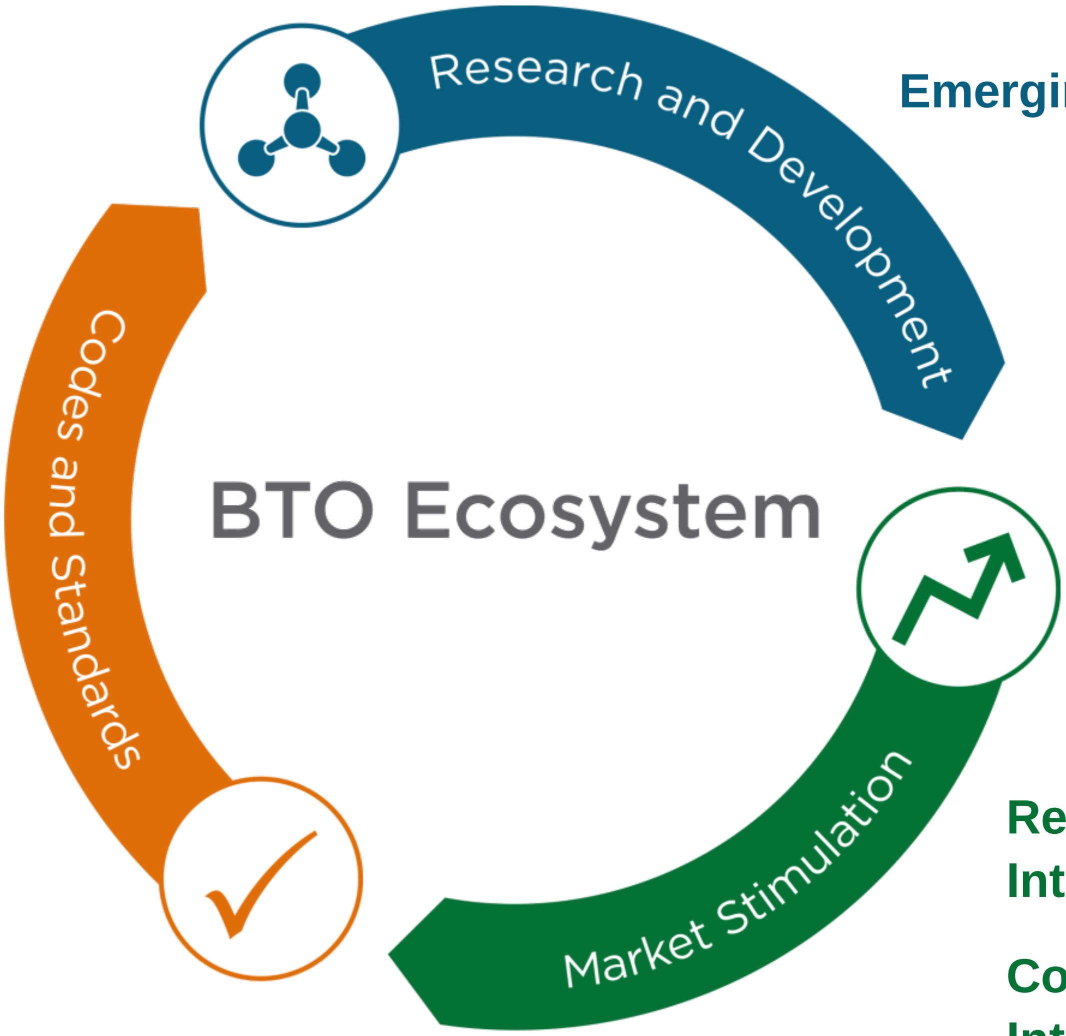
Building Technologies Office (BTO) Ecosystem

Codes and Standards

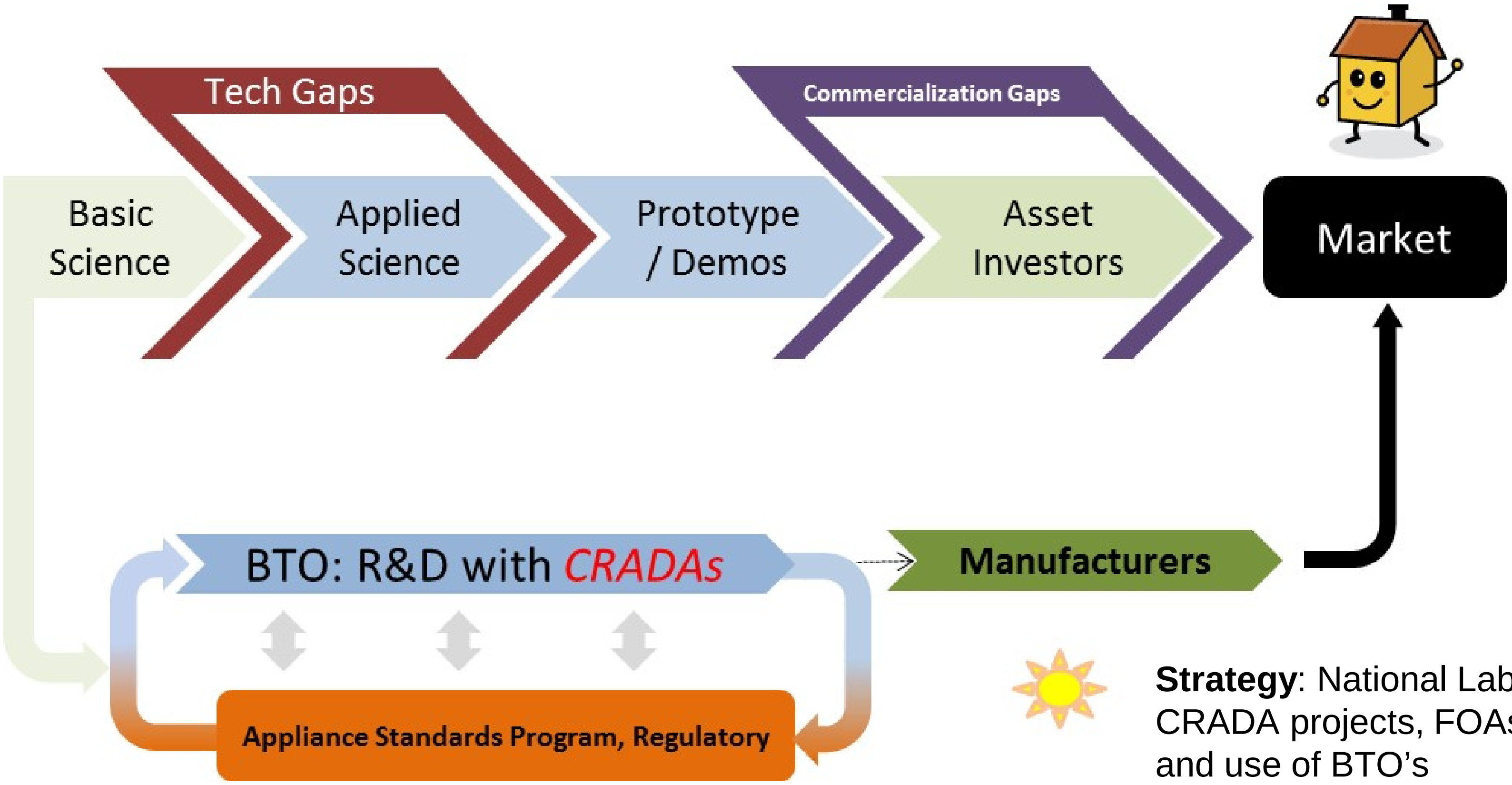


Emerging Technologies

Residential Buildings Integration

Commercial Buildings Integration

HVAC, Water Heating and Appliance R&D



CRADA : Collaborative Research and Development Agreement

Strategy: National Labs CRADA projects, FOAs and use of BTO's deployment teams with research homes

More than just discrete one-off projects but a continuum from low TRL engineering efforts into a "market-ready" product

Introduction

Program Goals:

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 30% by 2020 and cutting a building's use by 45% by 2030, relative to 2010 high-efficiency technologies.

HVAC/WH/Appliances goals require by 2020 that the potential energy use intensity (EUI) for:

- HVAC would be 60% lower
- WH would be 25% lower
- Appliances would be 15% lower
- All relative to 2010 energy-efficient baseline

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

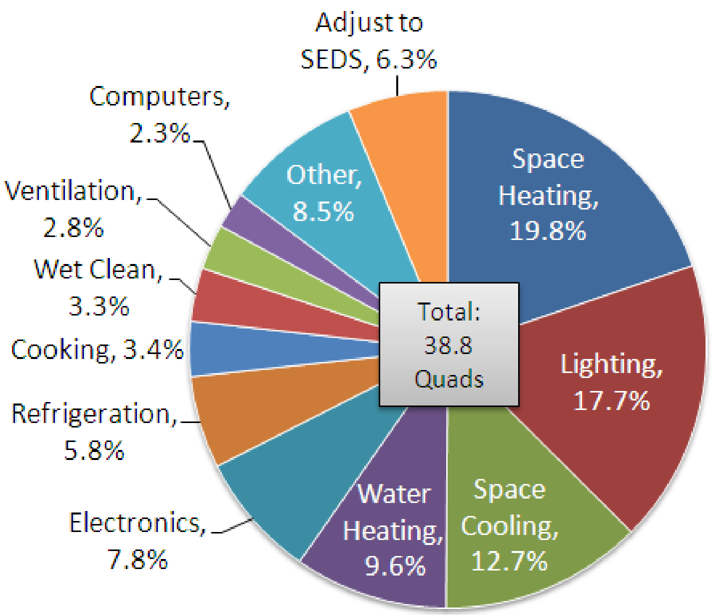
1) Accelerate the development of **near term** technologies that have the potential to save significant amount of energy (including cost reduction activities, bending the cost curve)
2) Accelerate the development of the **next generation** of technologies that have the potential of "leapfrogging" existing 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.

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*

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HVAC: Innovative and Economically Viable Solutions, *Efficiency first*

Regional Solutions

- *Low Ambient Heat Pump Research*
  - Where natural gas is unavailable or want to displace oil heat
  - Unlike standard heat pumps, can maintain capacity and efficiency (COP) at low ambient temperatures
- *Regional Solutions (Hot, Humid and Mixed)*
  - Air conditioning (AC) is more than just cooling air
  - Significant savings, on the order of 50-90%, are possible for technologies optimized for specific climates and applications
  - Large portion of the current building stock is located in hot and humid environments, which have the potential to create large latent (humidity) loads within buildings

Integrated Heat Pump (IHP) research, energy saving potentials approaching 50% when HVAC and water heating is coupled

Non-vapor compression research, no refrigerants (saving energy while reducing environment burdens)

- Potential of “leapfrogging” existing HVAC technologies by pursuing entirely new approaches
- Examples: Ab/Ad-sorption Heat Pumps, Electrocaloric, Electro Chemical Compression (ECC) technology, Magnetocaloric, Membranes, Thermoelastic, Thermoelectric, etc

Crosscutting technologies

- Heat exchanger research
- Compressor research
- Refrigerant research (Low-GWP solutions)
- Motors
- Materials Joining Technologies

Heat Pump Technologies: Regional Solutions (Cold Climates)

Cold Climate Heat Pump Technology

- Where natural gas is unavailable or want to displace oil heat
- Improving the performance of natural gas systems
- Unlike standard heat pumps, can maintain capacity and efficiency (COP) at low ambient temperatures
- Setting the standard for cold climate performance
- Targets for both electrical and natural gas systems

Current and Past BTO Activities

- IEA Annex 41, Cold Climate Heat Pumps
- Development of a High Performance Cold Climate Heat Pump (Purdue University)
- Supercharger for Heat Pumps in Cold Climates (Mechanical Solutions, Inc.)
- Cold Climate Heat Pump (CRADA Project at ORNL)
- High Performance Commercial Cold Climate Heat Pump (CCCHP) , (United Technologies Research Center)
- Residential Cold Climate Heat Pump (Unico)
- Natural Refrigerant High Performance Heat Pump for Commercial Applications, (S-RAM Dynamics)
- Natural Gas Air Conditioner and Heat Pump, (ThermoLift, Inc., Vuilleumier cycle)
- Low-Cost Gas Heat Pump For Building Space Heating, (Stone Mountain Technologies, Inc.)

DOE Cold Climate Heat Pump R&D Performance Targets (Electricity, Residential)

Ambient Temperature (°F)	COP	Maximum Capacity Decrease from Nominal (%)
47	4	0
17	3.5	10
-13	3	25

DOE Cold Climate Heat Pump R&D Performance Targets (Natural Gas, Residential)*

Ambient Temperature (°F)	COP	Maximum Capacity Decrease from Nominal (%)
47	1.3	0
17	1.15	20
-13	1.0	50

DOE Cold Climate Heat Pump R&D Performance Targets (Electricity, Commercial)

Ambient Temperature (°F)	COP	Maximum Capacity Decrease from Nominal (%)
47	4	0
17	3	10
-13	2.5	25

**COP based on higher heating value of natural gas*

Heat Pump Technologies: Regional Solutions (Hot, Humid and Mixed)

Separate Sensible and Latent Cooling AC Systems

- Target markets: Large portion of the current building stock is located in hot and humid environments, which have the potential to create large latent loads within buildings
- HVAC was the largest energy end use for U.S. residential and commercial buildings, consuming approximately 37.3% (or ~15.05 Quads) of the total energy used in buildings.
- Significant savings, on the order of 50-90%, are possible for technologies optimized for specific climates and applications (DOE's QTR)
- Air conditioning (AC) is more than just cooling air
- Total cooling load, composed of both the sensible load (temperature) and the latent load (humidity)
- Conventional air conditioning (AC) systems have limited control of sensible cooling and latent cooling capacities

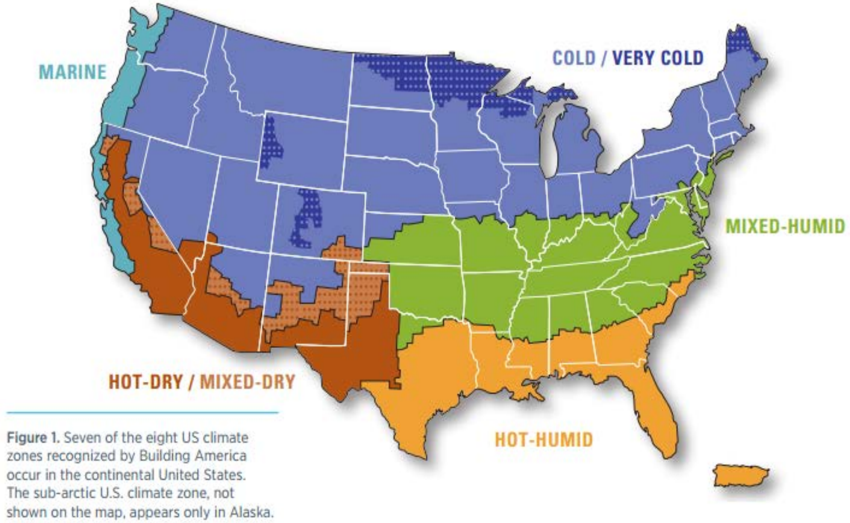

Figure 1. Seven of the eight US climate zones recognized by Building America occur in the continental United States. The sub-arctic U.S. climate zone, not shown on the map, appears only in Alaska.

Image Source: "High Performance Home Technologies – Guide to Determining Climate Regions by County." PNNL and ORNL. August 2010.

Climate Zone	Percentage of Homes with AC (2009), by Climate Zone
Very Cold / Cold	34%
Mixed-Humid	**31%**
Mixed-Dry / Hot-Dry	12%
Hot-Humid	**17%**
Marine	6%

Source: 2009 Residential Energy Consumption Survey (RECS), U.S. Energy Information Administration, Table HC7.6

Program: Core + FOAs

CORE

AOP: Critical to the program

2008-Present

FOA

Advanced Energy Efficient Building Technologies, DE-FOA-0000115 (June 29, 2009)

2009

- Research Focus: HVAC, Water Heating and Appliances: Cold Climate, Low-GWP, Refrigerant, Non-vapor compression, and Clothes Dryers

FOA

Energy Savings through Improved Mechanical Systems and Building Envelope Technologies, DE-FOA-0000621 (March 7, 2012)

2012

- High performance air source cold climate heat pumps
- Alternative space-heating systems
- Next generation heat exchangers for electric vapor-compression heat pumps and air conditioners

Program: Core + FOAs

FOA

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.

FOA

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

Program: Core + FOAs

FOA

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

FOA

2015

Building Energy Efficiency Frontiers and Innovation Technologies (BENEFIT)-2016, DE-FOA-0001383 (Dec 15, 2015)

- Innovation: HVAC&R Materials Joining Technologies

FOA

2016

Advanced Low-GWP HVAC&R Research Effort

- Major effort is planned in FY17 to pursue low-GWP HVAC&R systems, including short/mid-term projects (HFC alternatives, advanced vapor compression systems) and long-term projects (non-vapor-compression systems).
- An RFI will be released in the spring of 2016, based on information gathered through two workshops: *http://energy.gov/eere/buildings/articles/doe-and-stakeholders-consider-best-approach-major-hvacr-research-effort*

Tuesday, April 5, 2016

- ORNL - High Performance Refrigerator Using Novel Rotating Heat Exchanger
- SNL - RVCC Technology: A Pathway to Ultra-Efficient Air Conditioning..
- GE Global Research - Energy-Efficient Clothes Dryer
- ORNL - Novel Energy-Efficient Ventless Thermoelectric Clothes
- ORNL - Novel Ultra-Low Energy Consumption Ultrasonic Clothes Dryer
- Univ of FL - A Combined Water Heater, Dehumidifier and Cooler
- QM Power - Higher Efficiency HVAC Motors
- UTRC - Advanced Vapor Compression
- Mechanical Solutions - Advanced Vapor Compression
- UTRC - Non-Vapor Compression
- ORNL - Non-Vapor Compression
- Dais Analytic - Non-Vapor Compression

Wednesday, April 6, 2016

- Maryland Energy and Sensor Technologies - Non-Vapor Compression
- Xergy - WH SBIR Project
- Xergy - Non-Vapor Compression
- ORNL - High Performance Cold-Climate Multi-Stage Heat Pump
- ORNL - CO2 HPWH Development
- ORNL - Commercial Gas Absorption HPWH
- ORNL - High Efficiency Low Emission Refrigeration
- ORNL - Magnetocaloric Refrigerator
- University of Maryland - Miniaturized Air to Refrigerant Heat Exchangers
- Sheetak - Heat Pump Water Heater Using Solid-State Energy (TEs)
- S-RAM - Natural Refrigerant High-Performance Heat Pump
- Thermolift - The Natural Gas Heat Pump and Air Conditioner

Thursday, April 7, 2016

- Stone Mountain Technologies - Low-Cost Gas Heat Pump For Building
- UTRC - High Performance Commercial Cold Climate Heat Pump (CCCHP)
- Architectural Applications - Building Integrated Heat and Moisture
- Clean Energy Manufacturing Analysis Center (CEMAC) - HVAC

Thank You and Contact Info…

The HVAC/Water Heating/Appliance subprogram develops cost effective, energy efficient technologies with national labs and industry partners. Technical analysis has shown that heat pumps have the technical potential to save up to 50% of the energy used by conventional HVAC technologies in residential buildings. Our focus is on the introduction of new heat pumping technologies, heat exchanger technologies, and advanced appliances, e.g., refrigerator and clothes dryers. Heat exchangers are used not only in air conditioning, heating, water heating and refrigeration but also in nearly every application that generates waste heat, a major crosscutting research opportunity. We are also pursuing non-vapor compression technologies, which have the potential to replace or be integrated with conventional vapor compression technologies, can provide 50% reductions in energy consumption, and have extremely low-global warming potential.

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

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