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ENERGY

DOE Building Technologies Office:
Advanced HVAC&R Research Effort

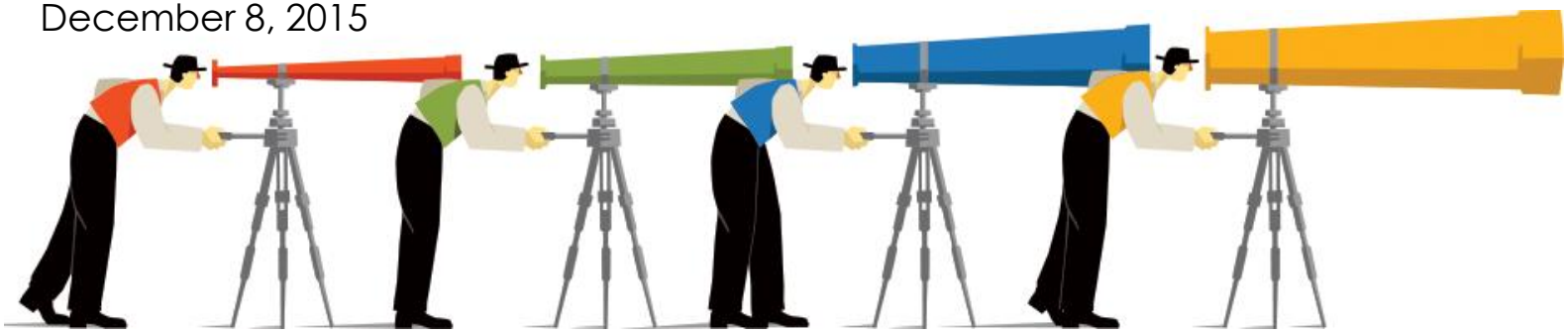
Workshop on Technical Focus and Structure

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

ASHRAE Headquarters, Atlanta, GA

10:00AM – 3:00PM

December 8, 2015



DISPUTES & INVESTIGATIONS • ECONOMICS • FINANCIAL ADVISORY • MANAGEMENT CONSULTING

Navigant,
on behalf of the **United States Department of Energy**,
welcomes you to this workshop on an
Advanced HVAC&R Research Effort

Introductions and Logistics

- Timing
- Restrooms
- Airport transportation

Breakout Discussion Groups

Group Braves

- Room 1-ABC

Group Falcons

- Room 2-AB

Group Hawks

- Room 3-A

Group Yellow Jackets

- Room 3-B

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30 mins Vision

90 mins Technical Focus

45 mins Lunch

90 mins Structure

30 mins Closing

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Who Supports Energy Efficiency R&D (Federal)?

Fundamental Research → **First Commercialization** → **Market Penetration**

Building Technologies Office

Emerging Technologies

- Commercial Buildings Integration
- Residential Buildings Integration
- Codes & Standards

http://energy.gov/eere/buildings/building-technologies-office

- ARPA-E
- NSF
- DOE Office of Science
- ONR
- FEMP
- ESTCP
- GSA Green Proving Grounds

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BTO Emerging Technologies Research Portfolio

Advanced windows

Advanced refrigerator technology

Building energy modeling

Low global warming potential (GWP) refrigeration

Heating, ventilating, air conditioning, water heating, and appliances

Solid state lighting

Sensors and controls

Advanced heat pump technology:

- **Air source heat pumps**
- **Integrated heat pumps**
- **Heat exchangers**

Building Envelope: Next generation insulation

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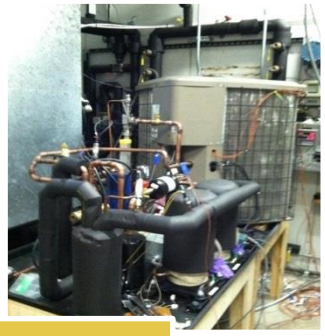
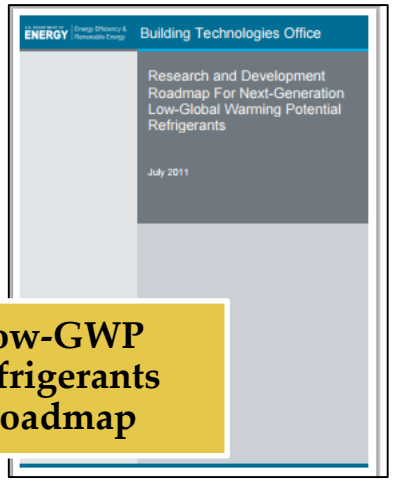
DOE Building Technologies Office (BTO) has supported innovation in HVAC&R through numerous R&D initiatives.



Residential Cold-Climate Heat Pump

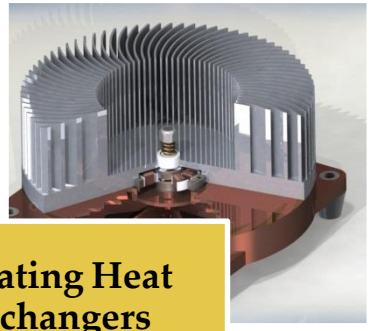
Supercharger for Heat Pumps in Cold Climates



Low-GWP Refrigerants Roadmap

New Low-GWP Supermarket Refrigerant

Multi-Function Gas-Fired Heat Pump



Rotating Heat Exchangers

See additional projects on BTO website: http://energy.gov/eere/buildings/hvac-water-heating-and-appliances

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Vision » Recent FOA awards

- **Low-GWP HVAC with ultra-small centrifugal compressor** – Mechanical Solutions, Inc. (MSI) (New Jersey) and Lennox Industries, Inc. (Lennox) (Texas). http://energy.gov/eere/buildings/downloads/low-global-warming-potential-hvac-system-ultra-small-centrifugal
- **High efficiency centrifugal compressor** - United Technologies Research Center (UTRC) (Connecticut) http://energy.gov/eere/buildings/downloads/high-efficiency-low-global-warming-potential-gwp-compressor
- **Advanced membrane HVAC** - Dais Analytic (Florida) http://energy.gov/eere/buildings/downloads/membrane-based-air-conditioning
- **Thermoelastic cooling system (TEC)** - Maryland Energy and Sensor Technologies, LLC (MEST) (Maryland) http://energy.gov/eere/buildings/downloads/compact-thermoelastic-cooling-system
- **Novel magnetocaloric A/C** – Oak Ridge National Laboratory (Tennessee). Vaccumschmelze GmbH & Co. KG., (Germany) is a key partner. http://energy.gov/eere/buildings/downloads/novel-solid-state-magnetocaloric-air-conditioner
- **Electrocaloric heat pump** - United Technologies Research Center (UTRC) (Connecticut) http://energy.gov/eere/buildings/downloads/high-efficiency-solid-state-heat-pump-module
- **Electrochemical compression (ECC) A/C** - Xergy, Inc. (Delaware) http://energy.gov/eere/buildings/downloads/low-cost-electrochemical-compressor-utilizing-green-refrigerants-hvac

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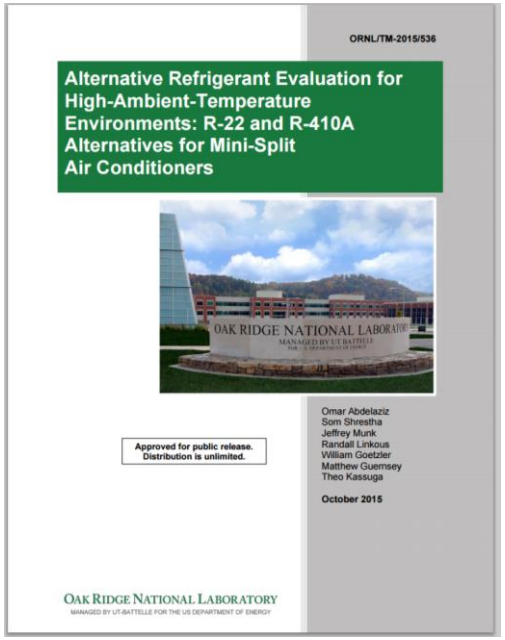
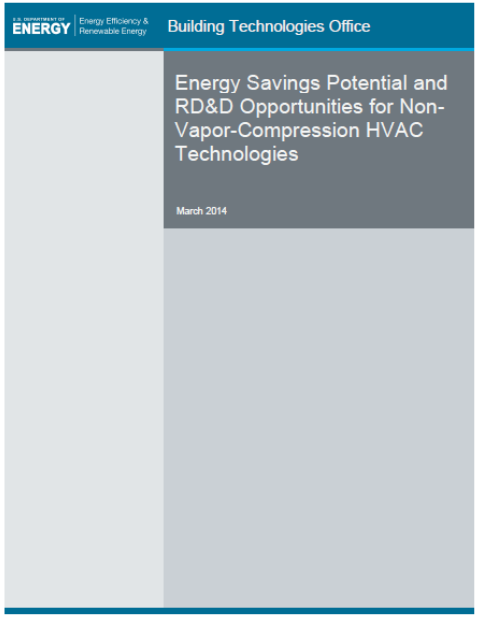
Report: Alternative Refrigerant Evaluation for High-Ambient-Temperature Environments

- Documents test results for both R-22 and R-410A alternatives in mini-split A/C
- Covers 10 alternative refrigerants

http://energy.gov/sites/prod/files/2015/10/f27/bto_pub59157_101515.pdf





Report: Non-Vapor-Compression HVAC Technologies Energy Savings Potential

- Identifies alternatives to vapor-compression technology in residential and commercial HVAC
- Characterizes each technology in detail, including RD&D opportunities

http://energy.gov/eere/buildings/downloads/non-vapor-compression-hvac-technologies-report

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Today, DOE BTO is exploring the launch of a major new research effort dedicated to advanced HVAC&R.

» Dedicated focus area(s)

» Centralized oversight

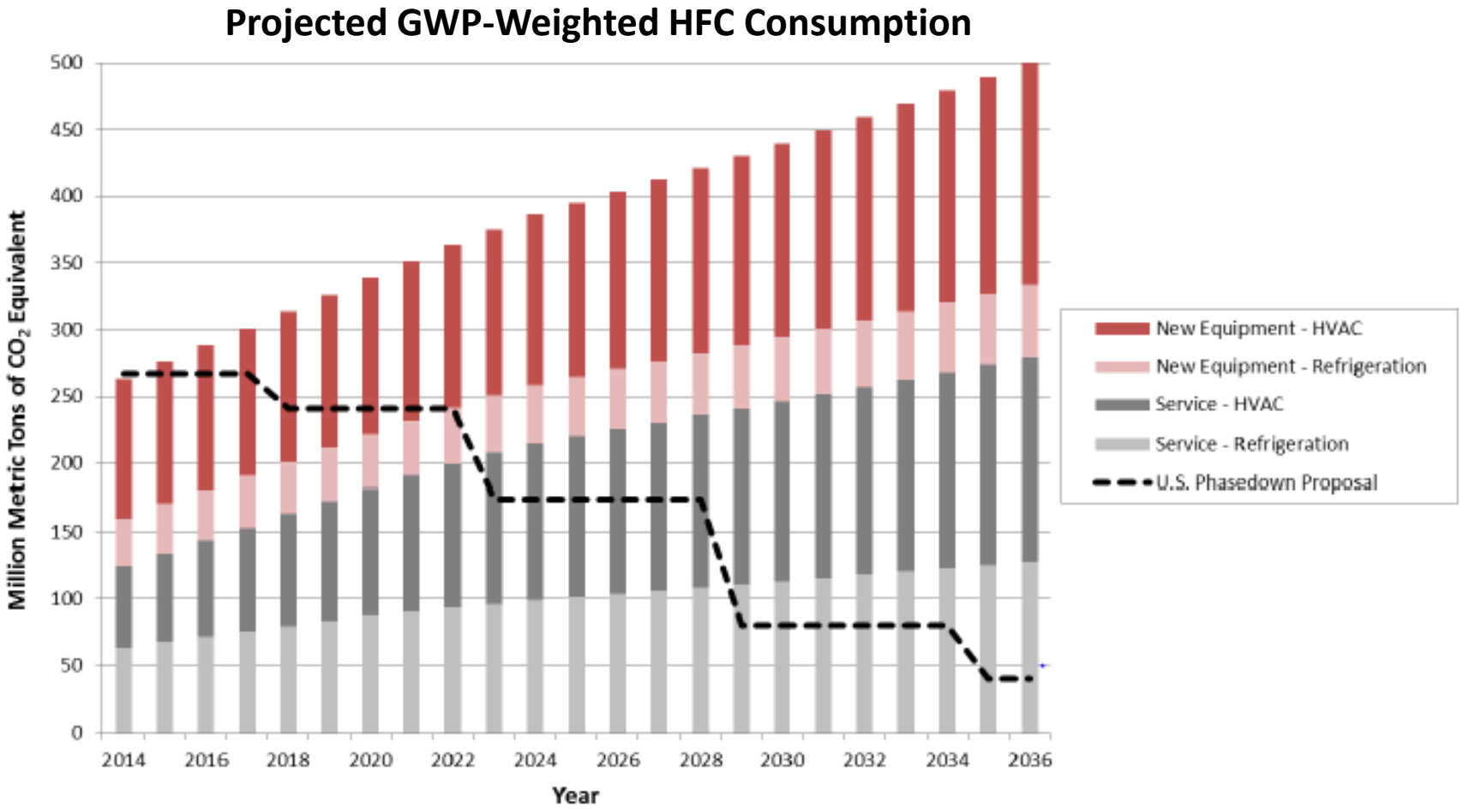
» Committed partners across industry, academia, research organizations

» Concentrated funding instead of independently funded projects

» Long-term mission oriented

» Open to new and innovative ideas and approaches

This effort supports the U.S. HFC phasedown proposal, which targets an 85% reduction by 2035.



Note: Baseline = 2014-16 average consumption

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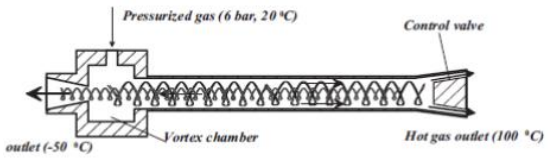
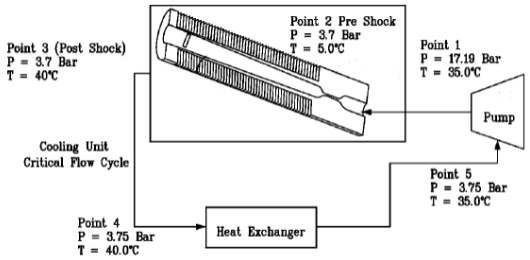
Key Driver: DOE's goal to develop next-generation technologies that 'leapfrog' existing technologies and result in dramatically improved efficiency with near-zero GWP cooling fluids.

Why this major research effort? Achieving DOE's goal will require a large, coordinated, and interdisciplinary approach in order to make transformative progress.

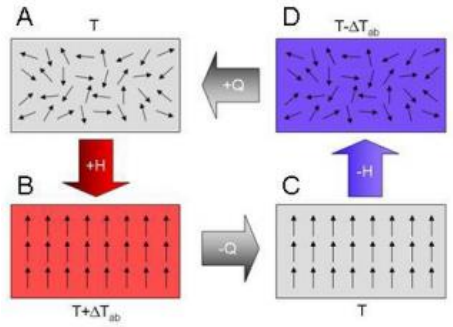
DOE envisions a future where low-GWP HVAC solutions are the new norm and non-vapor compression will be prevalent in several end uses.



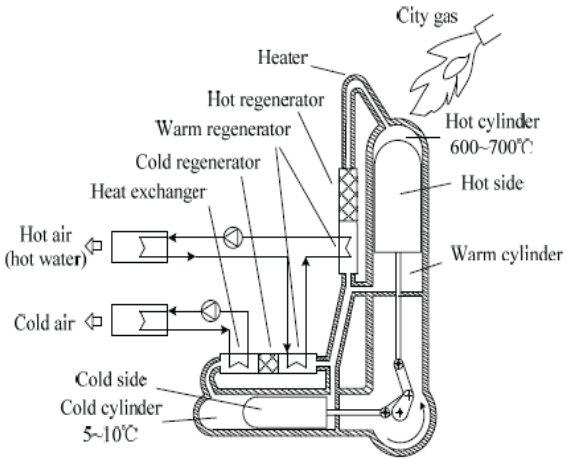
VORTEX TUBE CHILLER



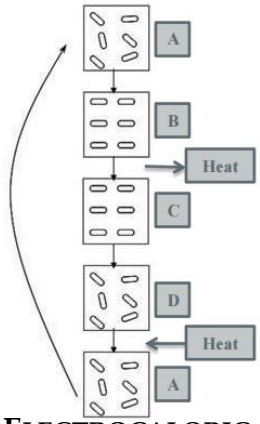
CRITICAL FLOW REFRIGERANT CYCLE



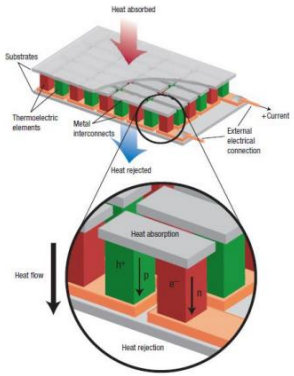
MAGNETOCALORIC COOLING



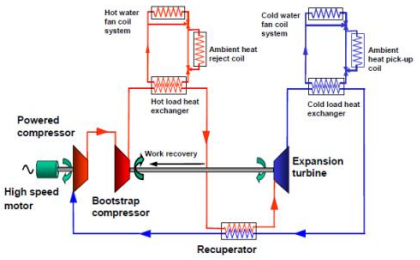
VUILLEUMIER HEAT PUMP



ELECTROCALORIC



THERMOELECTRIC



BRAYTON HEAT PUMP

Illustrative Examples

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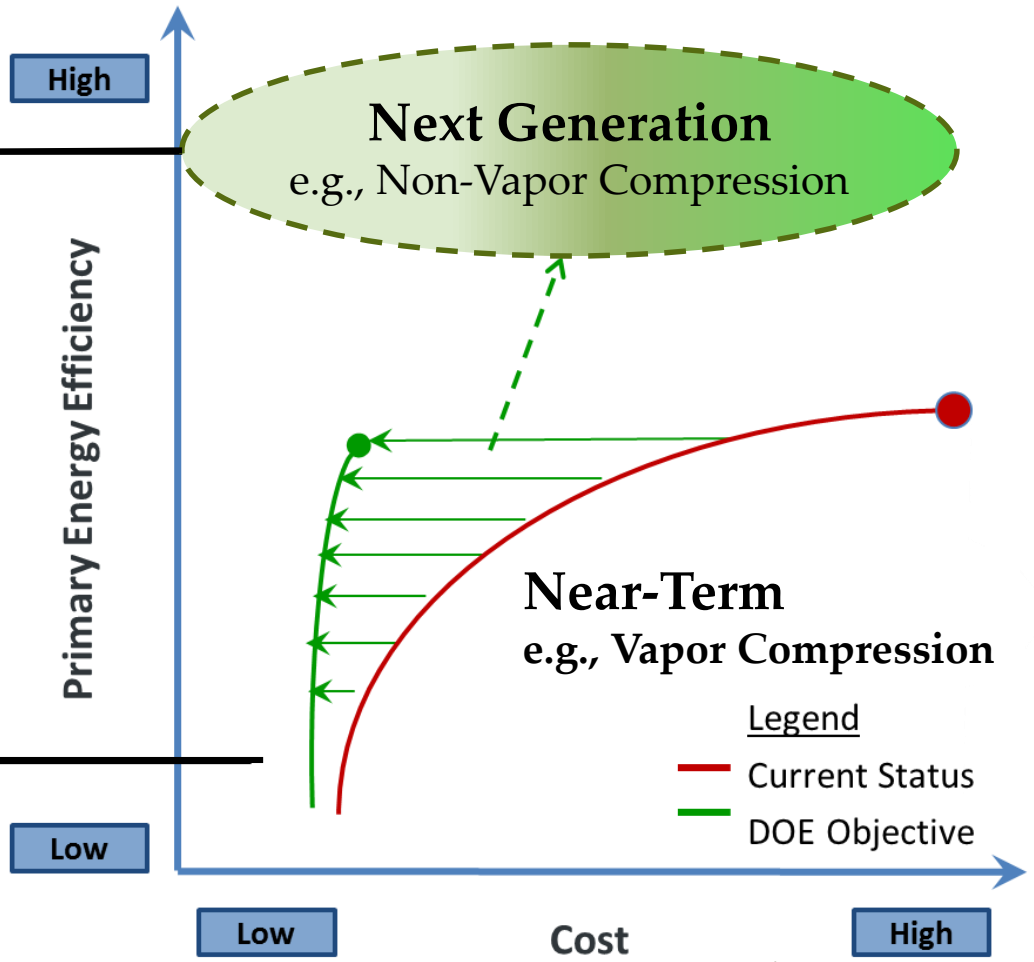
This effort will build on existing work on near term improvements and strive for transformational advances.

Next Generation

- Potential to "leapfrog" existing technologies
- Entirely new approaches

Near-Term

- Improve efficiency of current technologies
- May include cost reduction activities



Source: Refined from BTO Presentation: energy.gov/sites/prod/files/2014/05/f15/HVAC_Overview_Bouza_042314_and_042414.pdf

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Research goals will include successful demonstration of both vapor compression and non-vapor-compression technologies.

	Preliminary/conceptual goals
Near Term	Demonstrate emerging technology prototypes with **significantly lower lifecycle GWP and energy consumption** with **same high-volume cost**
Near Term	Demonstrate full-scale **non-vapor compression systems with higher efficiencies** than today's vapor compression systems
Long Term	Demonstrate full-scale **non-vapor compression** prototypes that reduce energy with **high-volume cost similar to today's state-of-the-art.**

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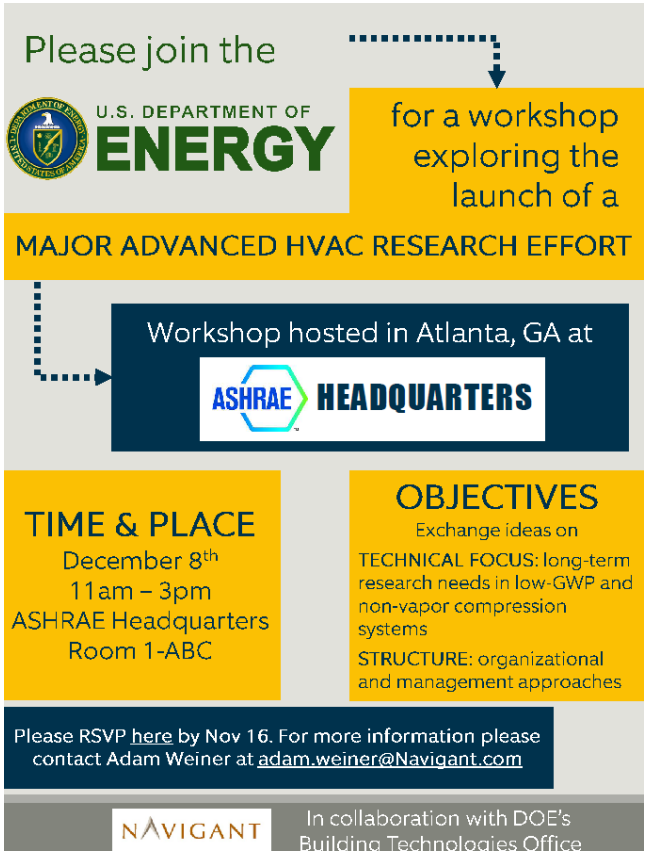
» BTO workshops:
  – ASME IMECE (Nov 17th)
  – ASHRAE HQ (today)

» Request for Information (RFI) – spring of 2016

» Intending to lead to a Funding Opportunity Announcement (FOA), pending availability of funds



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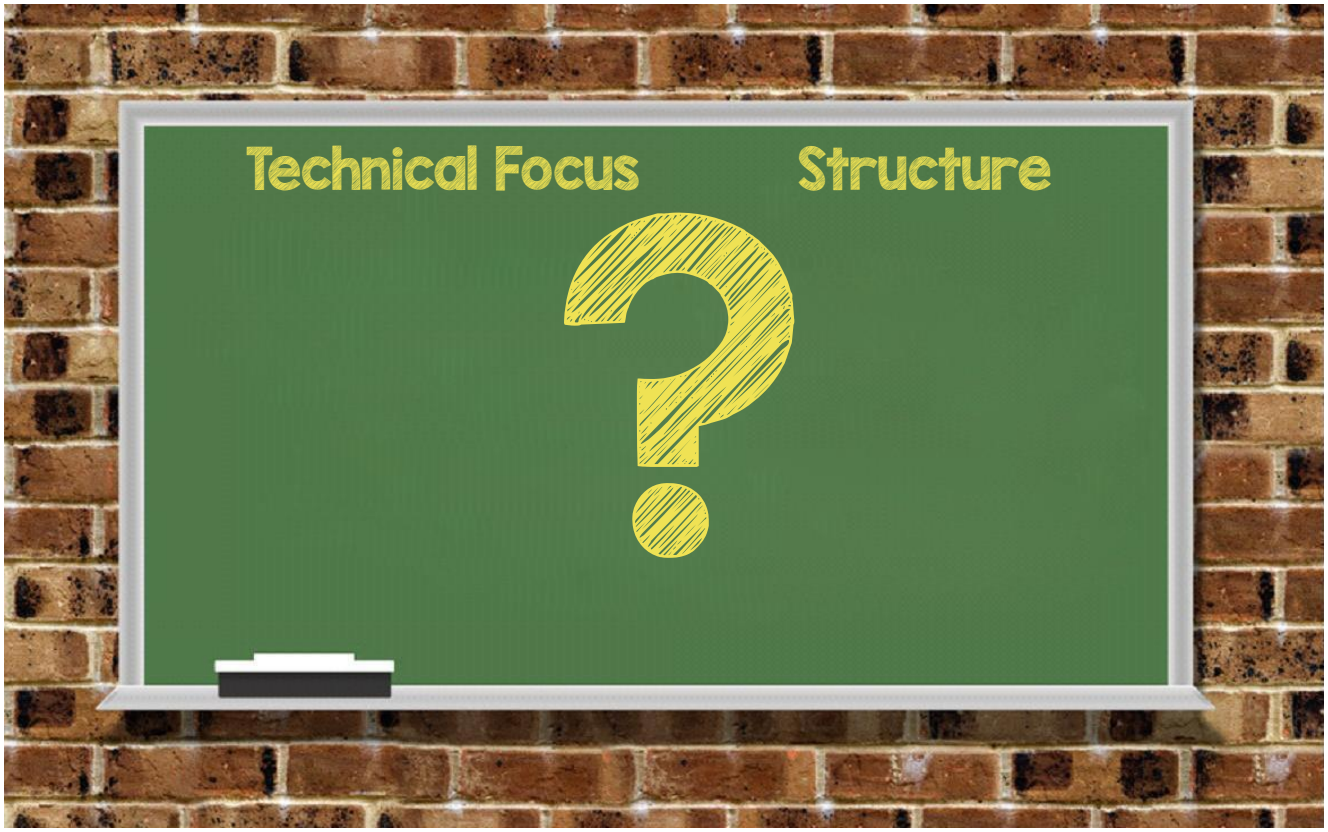
The objective of this workshop is to gather ideas on technical focus areas and best practices in structuring the research effort.



Today's discussion will focus solely on HVAC&R R&D.

Our discussion excludes:

» Policy issues

» Regulatory actions, such as efficiency standards

» Market transformation activities

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30 mins Closing

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DOE has identified broad research opportunities in advanced HVAC&R through past workshops.

Roadmap: Low-GWP Refrigerants

Roadmap: Emerging HVAC Technologies

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Technical Focus » HVAC Roadmap » Direct Impact Initiatives

Activity/Initiative	Topic
Direct-current (DC) HVAC to utilize solar PV w/o inverter losses and to facilitate microgrid integration	 Renewables & Storage
Separate sensible and latent control and quantify the energy savings	 AC/HP
Raise HP performance (all fuels) at low-ambient temperature	 AC/HP
Develop electrochemical compression systems	 AC/HP
Seasonal energy storage for residential and commercial	 Renewables & Storage

Activity/Initiative	Topic
Material advances to reduce the cost of small absorption systems	 AC/HP
Hybrid ventilation systems to combine mechanical & natural ventilation techniques (aka mixed-mode conditioning)	 Ventilation & Humidity
Ground-source heat pump (GHP) ground-loop cost and performance	 AC/HP
Alternative non-solid-state, non-thermally activated HPs with suitable efficiency, cost, and performance	 AC/HP
Solid-state cooling systems	 AC/HP

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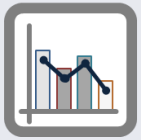
Technical Focus » HVAC Roadmap » Enabling Initiatives

Activity/Initiative	Topic
Analysis on energy impacts of incorrect commissioning, installation, operations, and maintenance	 Installation O&M
Open-source, open-architecture platform that enables smart grid connectivity for DR transactional communications	 FDD Controls
Low-cost sensor networks and control schemes	 FDD Controls
Standardized methods of data acquisition and data storage for equipment sizing at end of life	 Tools & Software
Renewable-integrated district heating, cooling, and power systems	 District Systems

Activity/Initiative	Topic
Open-source building automation system	 Tools & Software
Standardized building metric to incorporate energy, health, etc.	 Analysis, Education, Demonstration
New solutions for simultaneous heating and cooling in buildings	 Zoning Distribution
Energy analysis tools for homeowners to aid in purchasing new equipment	 Tools & Software
Compile lessons learned from NREL's high performance buildings database	 Tools & Software

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Technical Focus » Refrigerants Roadmap

Tier 1 Initiative/Activity		Category
Expand NIST modeling research to identify and explore theoretical properties of new low-GWP blends, particularly azeotropes.		Modeling and Evaluation Tools
Characterize the heat transfer and thermodynamic properties and efficiency performance of new refrigerants and blends.		New Refrigerant Development
Techniques for detecting and reducing refrigerant leakage in currently installed systems.		Equipment Development
System-level evaluations of newly identified fluids for specific applications.		Modeling and Evaluation Tools
Techniques for improving temperature control and operational efficiency of secondary loops in installed supermarket refrigeration systems.		Equipment Development
Improve LCCP models by conducting studies on average annual versus peak season performance in large systems.		Modeling and Evaluation Tools

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Technical Focus » Refrigerants Roadmap (cont.)

Tier 2 Initiative/Activity	Category	
Public repository for risk assessments, performance data, material compatibility data, and fire incidents for alternative refrigerants		Industry Collaboration
Prototype systems that demonstrate leak detection with high-reliability, inexpensive sensors		Equipment Development
Materials compatibility and stability of new refrigerants and blends		New Refrigerant Development
Additional A1 refrigerants or blends as drop-in options for servicing existing equipment		New Refrigerant Development

Tier 3 Initiative/Activity	Category	
Improve flammability test methods and prediction tools for blended compounds		Safety Risks
Flammability risk assessments on additional A2L, A3, and B2L fluids for a wider range of applications		Safety Risks
Investigate alternative system architectures that would inherently mitigate flammability risks with A2L and A3 fluids		Safety Risks

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BREAKOUT SESSION #1

--60 minutes of discussion--

Group Braves

Room 1-ABC

Group Falcons

Room 2-AB

Group Hawks

Room 3-A

Group Jackets

Room 3-B

Assign one person to report back to the larger group after the breakout; you will have 3 minutes each to share the major points.

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BREAKOUT SESSION #1

1. **Research decisions**
   How should the research agenda be determined?

2. **Topics and technologies**
   What research ***areas and/or specific technologies*** should be addressed?

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There is no single performer that can bring together all the necessary broad expertise and perspectives to succeed.

BTO anticipates that this effort will include:

» **Active** BTO project management

» Detailed annual **reporting** on progress, successes, challenges

» **Tangible** outcomes, i.e., actual hardware

» Strong **cooperation** from a broad array of contributors

» Comprehensive **evaluation** of effectiveness in reaching goals

» **Publicized** outcomes and lessons learned

BTO needs an interdisciplinary team, including resources in chemistry, materials science, electronics, and mechanics.

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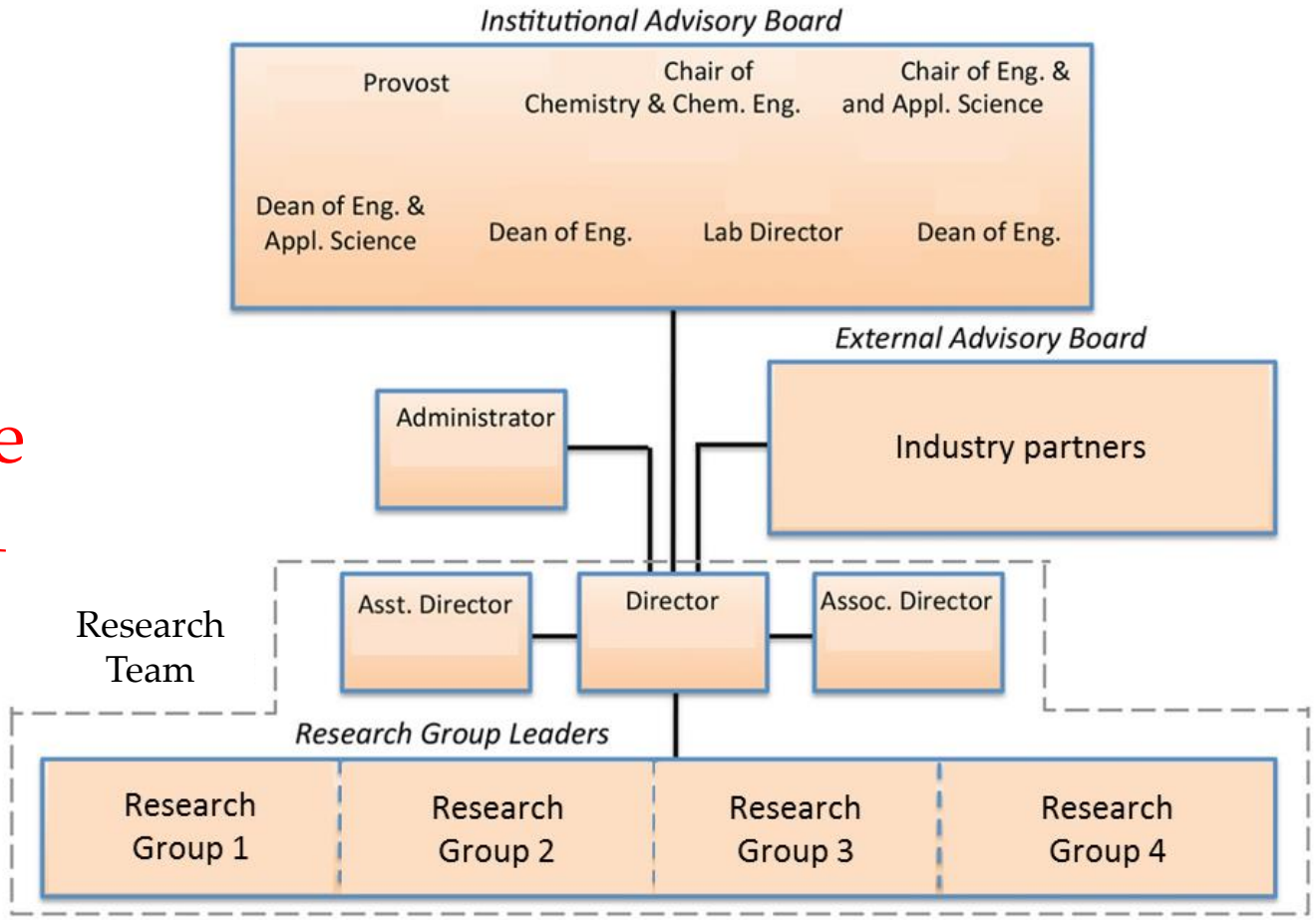
Various organizational structures have been used for similar research efforts.

Illustrative Example 1



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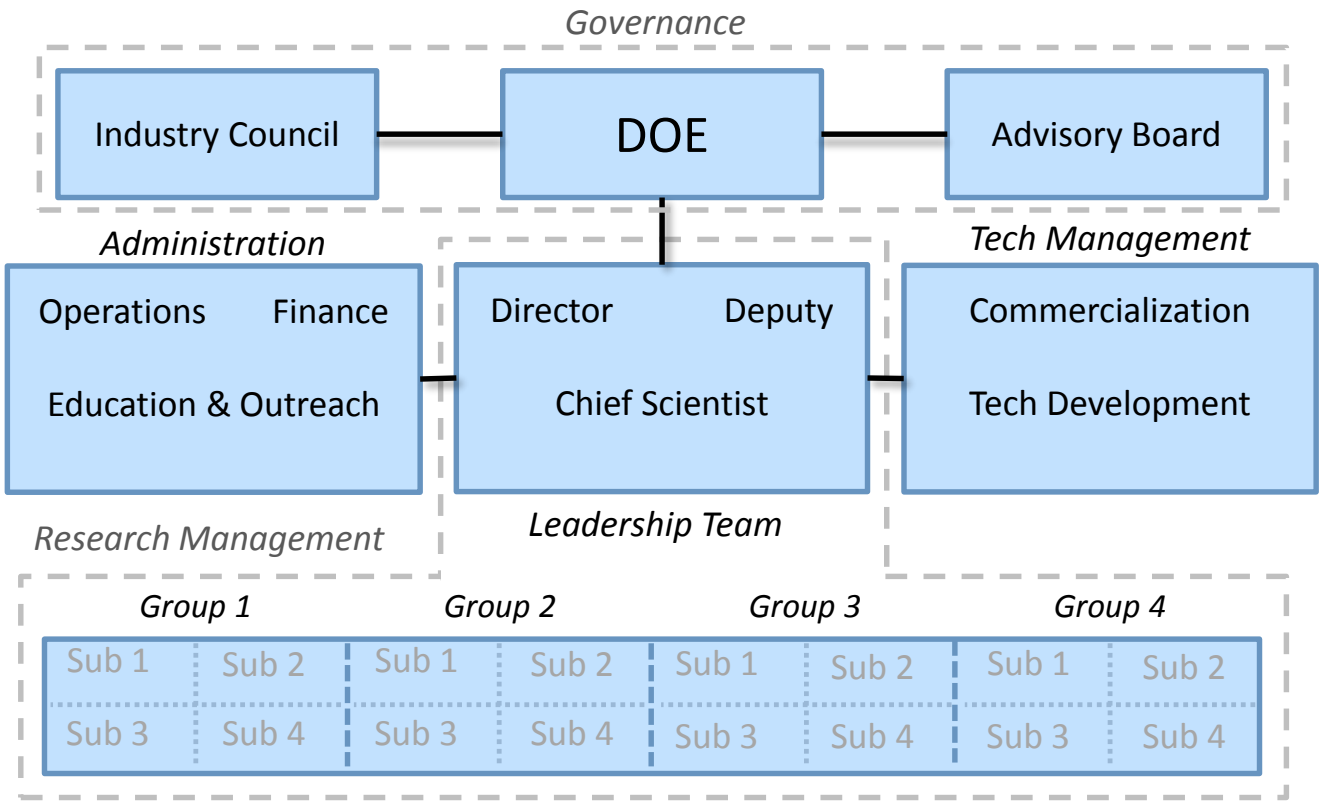
Each organizational structure provides different challenges and benefits in working towards their objectives.

Illustrative Example 2



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BREAKOUT SESSION #2

--60 minutes of discussion--

What works best to:

- Evaluate outcomes?
- Peer review?
- Build research partnerships?

Group Braves

Room 1-ABC

Group Falcons

Room 2-AB

Group Hawks

Room 3-A

Group Jackets

Room 3-B

Assign one person to report back to the larger group after the breakout; you will have 3 minutes each to share the major points.

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BREAKOUT SESSION #2

1. Players

Roles - Where should key players be involved? Leadership? R&D partners?
Advisors - Should research director report to advisors? Or only to DOE?
Structure - What should partnerships look like? with industry? others?

2. Evaluation

Characteristics - What form should evaluation take?
Independence - Are 3rd-party evaluators needed? Who could play this role?

3. Research approach

Team Quantity - How many parallel research teams? With how much interaction?
Topic Quantity - How many research areas and/or technologies for each team?

4. Other best practices

What other factors are important?
What else should DOE consider?

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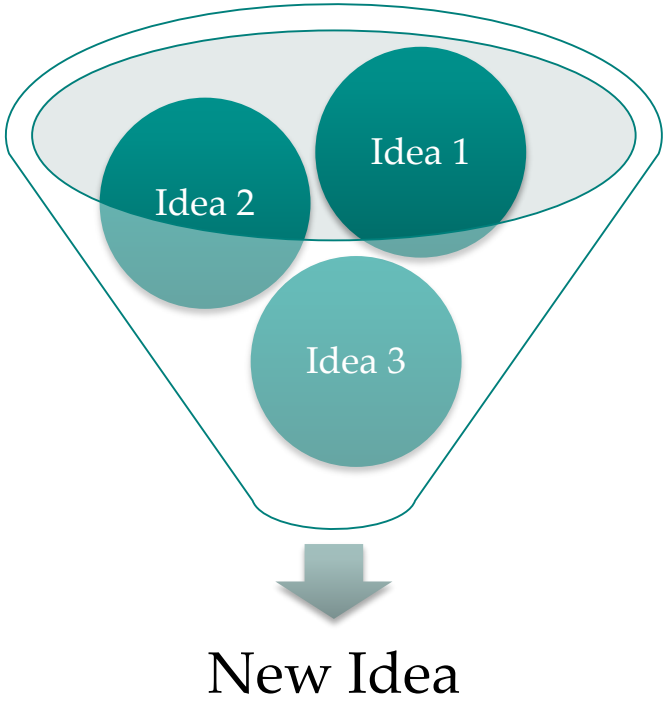
Additional Questions

Have the discussions today sparked any additional thoughts or ideas that we have not yet discussed?

- Combinations of existing ideas?
- New ideas?
- New twists?
- Important but missing details?
- New perspectives?



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Key CONTACTS

Thank you for your inputs

William Goetzler
Managing Director
Burlington, MA
781.270.8351
wgoetzler@navigant.com

Adam Weiner
Senior Consultant
Burlington, MA
781.270.8439
adam.weiner@navigant.com

Matt Guernsey
Associate Director
Burlington, MA
781.270.8358
matt.guernsey@navigant.com

Jim Young
Managing Consultant
Chicago, Il
312.583.3743
jim.young@navigant.com

DOE BTO Website for Emerging Technologies:
http://energy.gov/eere/buildings/emerging-technologies

Please make sure that your name, email, and organization are on the sign-in sheet!

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