NAVIGANT

ENERGY

DOE Building Technologies Office:
Advanced HVAC&R Research Effort

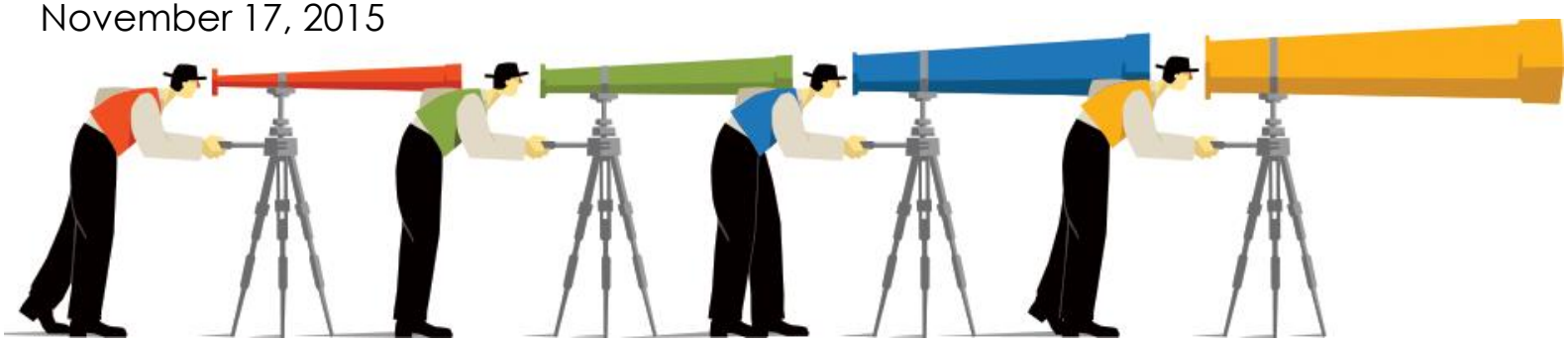
IMECE Workshop on Technical Focus and Structure

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

Room 339B, Hilton of the Americas, ASME IMECE 2015

9:00 am to noon

November 17, 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

Group Discussion

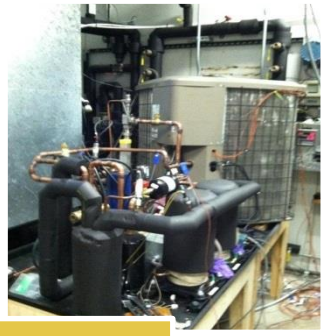
- ***Individual Insights***
- ***Shared perspectives***

NAVIGANT
ENERGY

Table of Contents

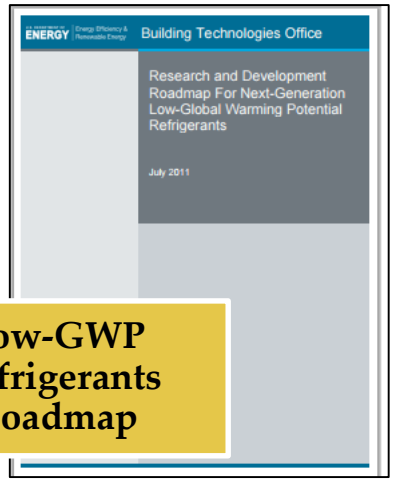
NAVIGANT
ENERGY

DOE BTO has supported the next generation of HVAC&R systems through numerous R&D initiatives.



Residential Cold-Climate Heat Pump

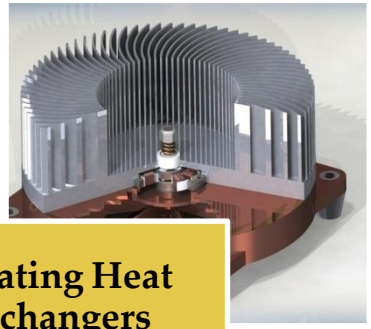
Supercharger for Heat Pumps in Cold Climates



Low-GWP Refrigerants Roadmap

New Low-GWP Supermarket Refrigerant

Multi-Function Gas-Fired Heat Pump



Rotating Heat Exchangers

NAVIGANT ENERGY

Vision » New FOA awards

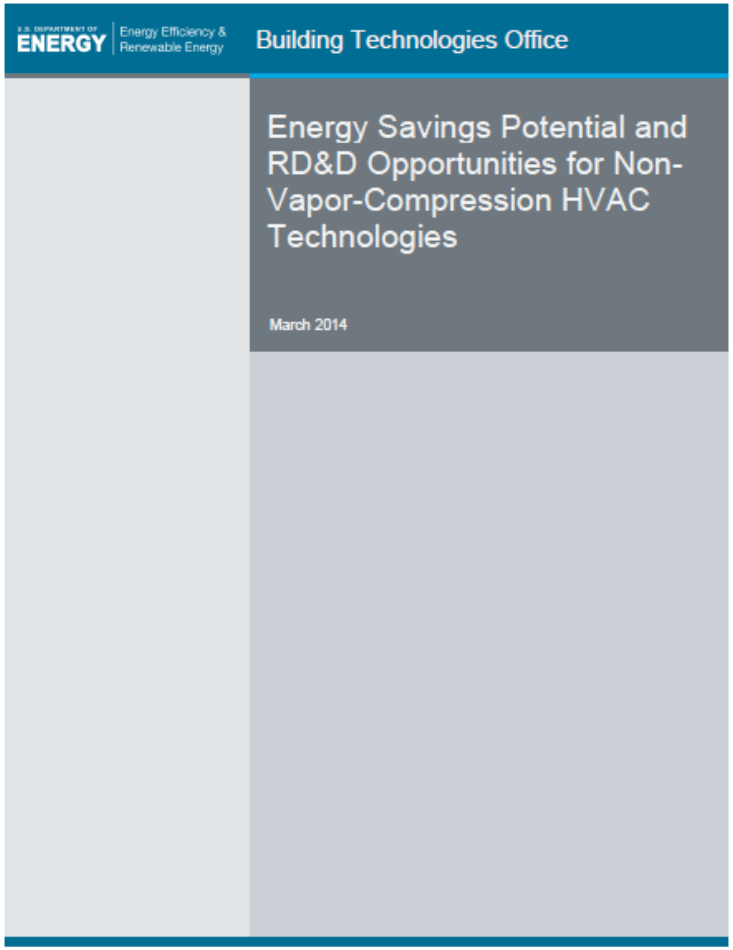
- **Low-GWP HVAC with ultra-small centrifugal compressor** – Mechanical Solutions, Inc. (MSI) (New Jersey) and Lennox Industries, Inc. (Lennox) (Texas). http://energy.gov/eere/buildings/downloads/low-global-warming-potential-hvac-system-ultra-small-centrifugal
- **High efficiency centrifugal compressor** - 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

NAVIGANT ENERGY

Vision » Non-Vapor Compression Technology Report

This Building Technologies Office report:

- Identifies alternatives to vapor-compression technology in residential and commercial HVAC applications
- Characterizes these technologies based on their technical energy savings potential, development status, non-energy benefits, and other factors affecting end-user acceptance and their ability to compete with conventional vapor-compression systems



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

NAVIGANT ENERGY

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

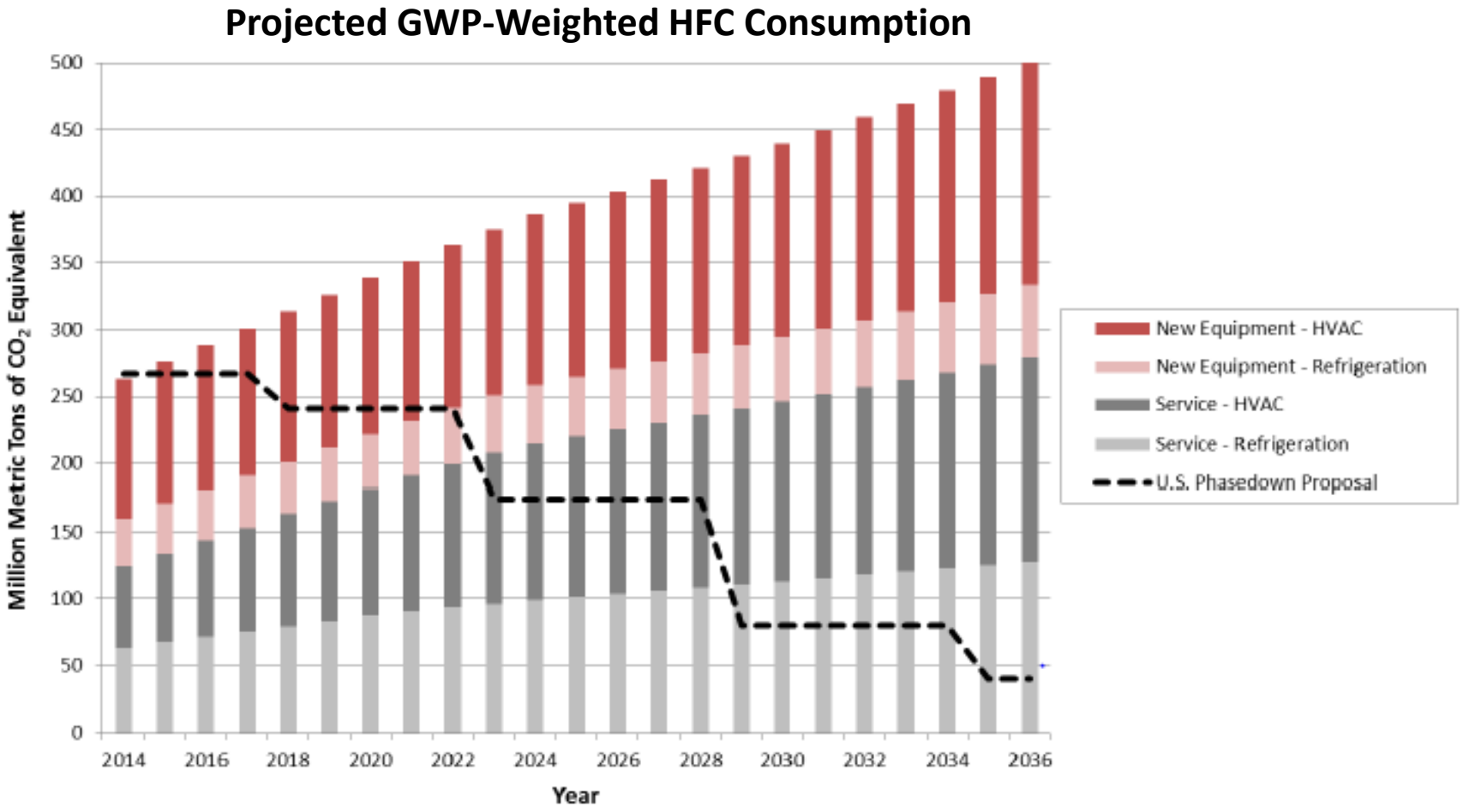
» Open to new and innovative ideas and approaches

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.

NAVIGANT
ENERGY

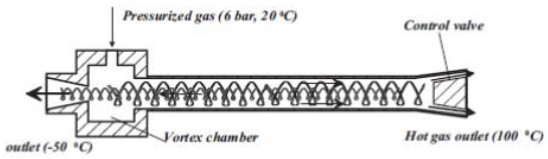
This effort supports the U.S. HFC phasedown proposal, which targets an 85% reduction by 2035.



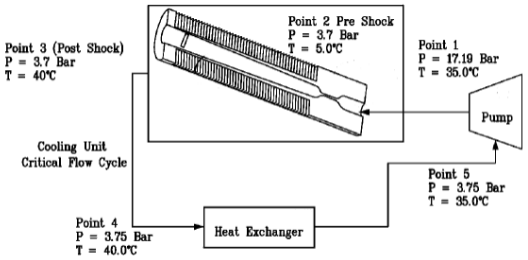
Note: Baseline = 2014-16 average consumption

NAVIGANT ENERGY

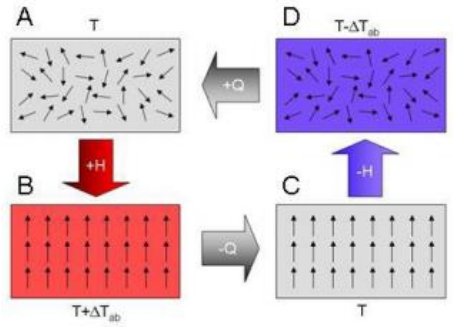
DOE envisions a future where low-GWP HVAC solutions are the new norm and non-vapor compression will be prevalent in several end uses



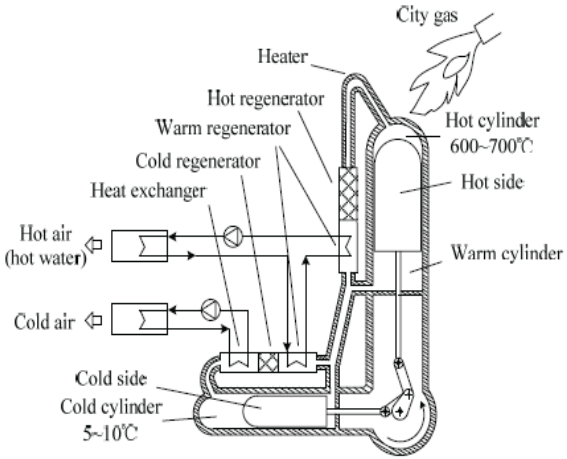
VORTEX TUBE CHILLER



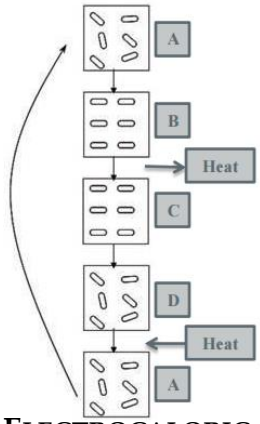
CRITICAL FLOW REFRIGERANT CYCLE



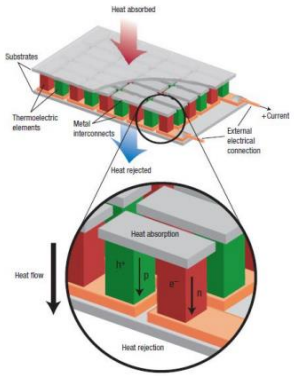
MAGNETOCALORIC COOLING



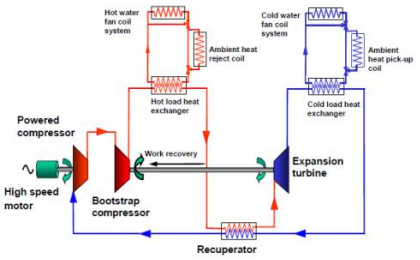
VUILLEUMIER HEAT PUMP



ELECTROCALORIC



THERMOELECTRIC



BRAYTON HEAT PUMP

Illustrative Examples

NAVIGANT ENERGY

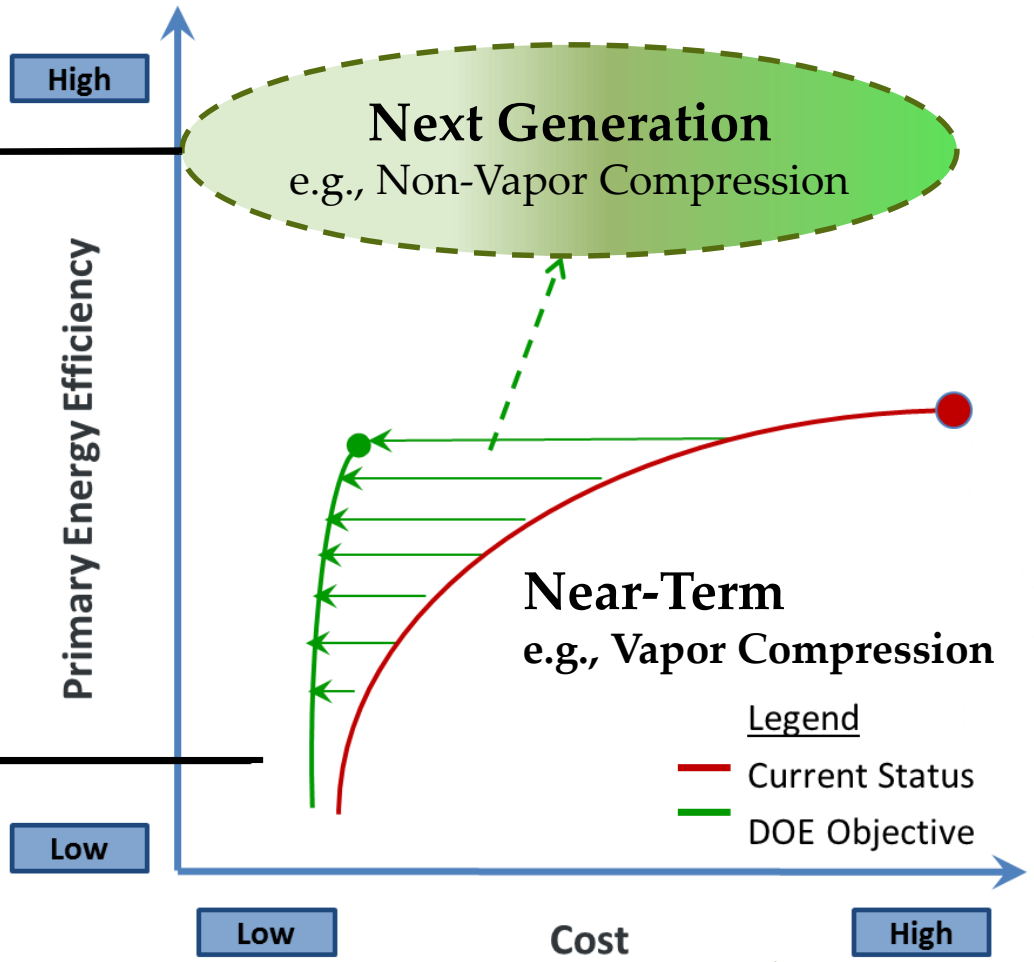
This effort will build on existing work on near term improvements and strive for transformational advances.

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

NAVIGANT ENERGY

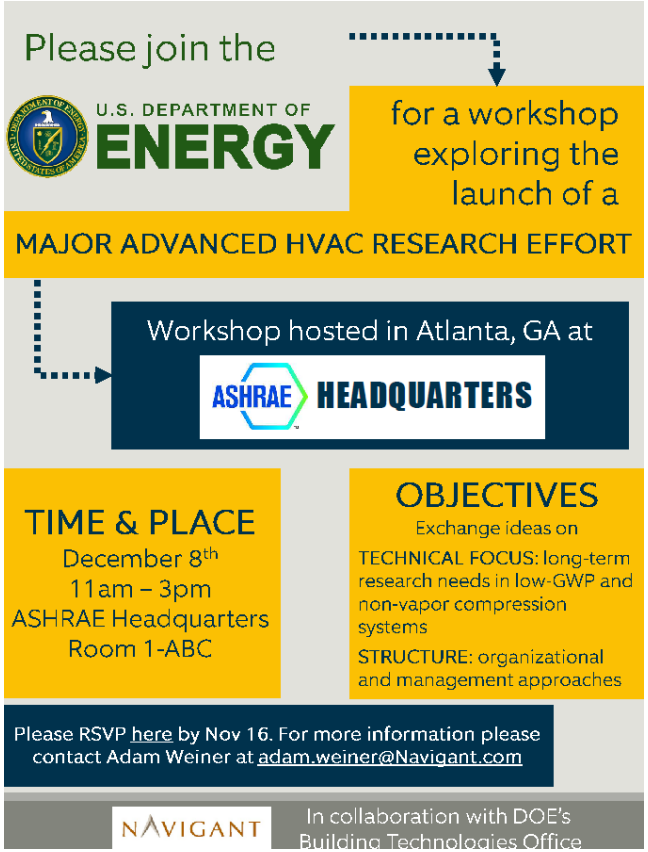
Research goals will include successful demonstration of both vapor compression and non-vapor-compression technologies.

	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.

NAVIGANT ENERGY

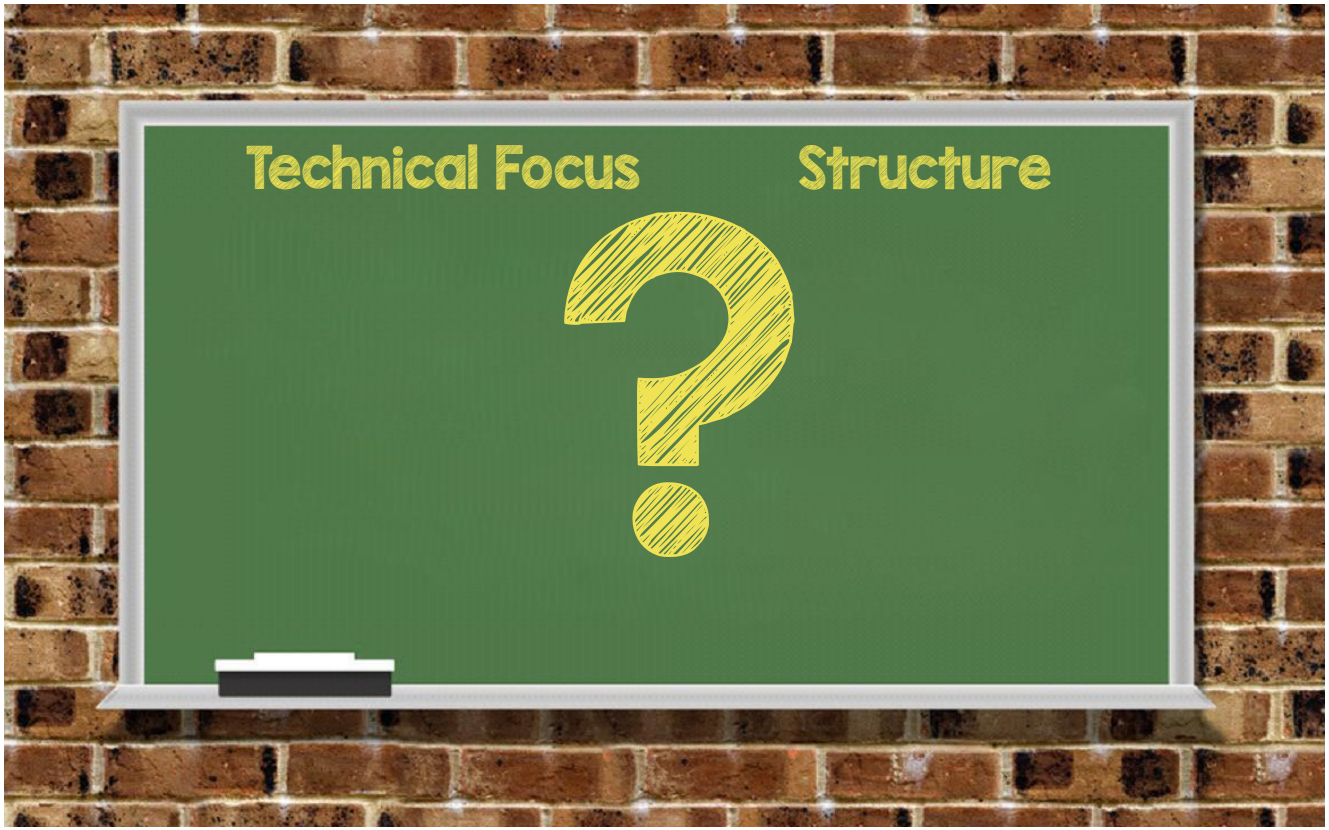
Vision » Research Effort Timeline

- BTO plans to have additional workshops, including at ASHRAE on December 8th
- Request for Information (RFI) – spring of 2016
- Will potentially lead to a Funding Opportunity Announcement (FOA), pending availability of funds



NAVIGANT
ENERGY

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.

While no less important, our discussion excludes:

- Policy issues
- Regulatory actions, such as efficiency standards
- Market transformation activities

Table of Contents

NAVIGANT ENERGY

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

Roadmap: Low-GWP Refrigerants

Roadmap: Emerging HVAC Technologies

NAVIGANT ENERGY

Technical Focus » HVAC Roadmap » Direct Impact Initiatives

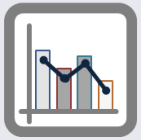
Activity/Initiative	Topic
Direct-current (DC) HVAC to utilize solar PV w/o inverter losses and to facilitate microgrid integration	 Renewables & Storage
Separate sensible and latent control and quantify the energy savings	 AC/HP
Raise HP performance (all fuels) at low-ambient temperature	 AC/HP
Develop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

NAVIGANT ENERGY

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

NAVIGANT
ENERGY

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

NAVIGANT
ENERGY

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

NAVIGANT
ENERGY

DISCUSSION

Guidance:

- » Think beyond your daily focus
- » Think about big picture
- » Build on others' ideas
- » Every idea has equal worth

NAVIGANT ENERGY

Table of Contents

NAVIGANT
ENERGY

Table of Contents

NAVIGANT ENERGY

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

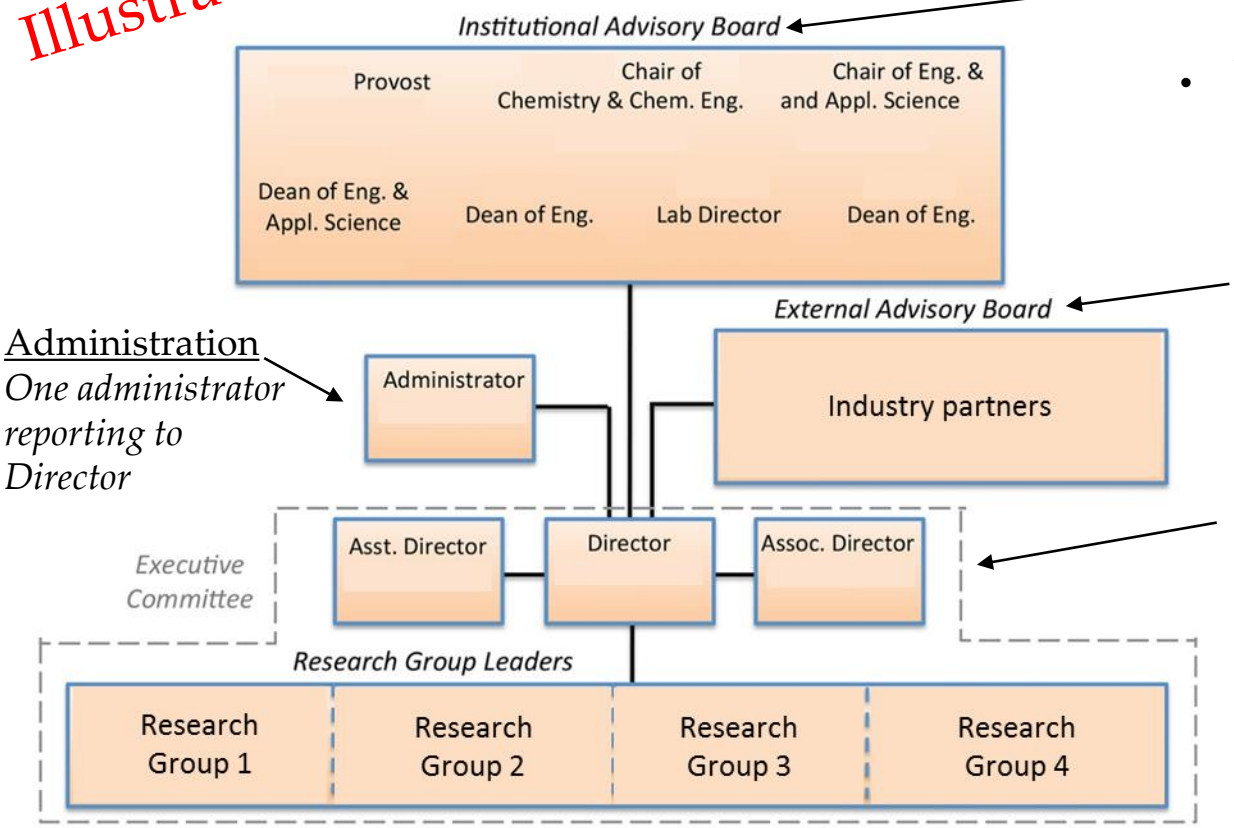
» **Publicized** outcomes and lessons learned

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

NAVIGANT ENERGY

To meet their goals, BTO wants to understand the organizational structure that delivers the needed resources.

Illustrative



Administration
One administrator reporting to Director

Institutional Advisory Board
- *Institutional partners distinct from industry partners*
- *Weekly meeting w/ Director*

External Advisory Board
- *Select industry partners on a separate board*

Executive Committee
- *1-3 Directors and multiple team leads (reporting to the Director)*

NAVIGANT ENERGY

DISCUSSION

What are the best (or worst?) practices in research management?

Guidance:

- Consider all of past experiences and those of others
- Build on others' insights
- Every insight has equal worth

What works best to:

- Manage and allocate resources?
- Select new research projects?
- Monitor & evaluate outcomes?
- Peer review?
- Publicize outcomes?
- Promote strong engagement from national labs, academia, and industry?

NAVIGANT
ENERGY

DISCUSSION

What makes a successful research partnership?

- What partners provide the best value for you? And for what roles?
- What is valuable about your research partnerships?
- What types of partners should DOE consider having involved?

Guidance:

- Consider all of past experiences and those of others
- Build on others' insights
- Every insight has equal worth

NAVIGANT
ENERGY

Table of Contents

Vision

Technical Focus

Coffee Break

Structure

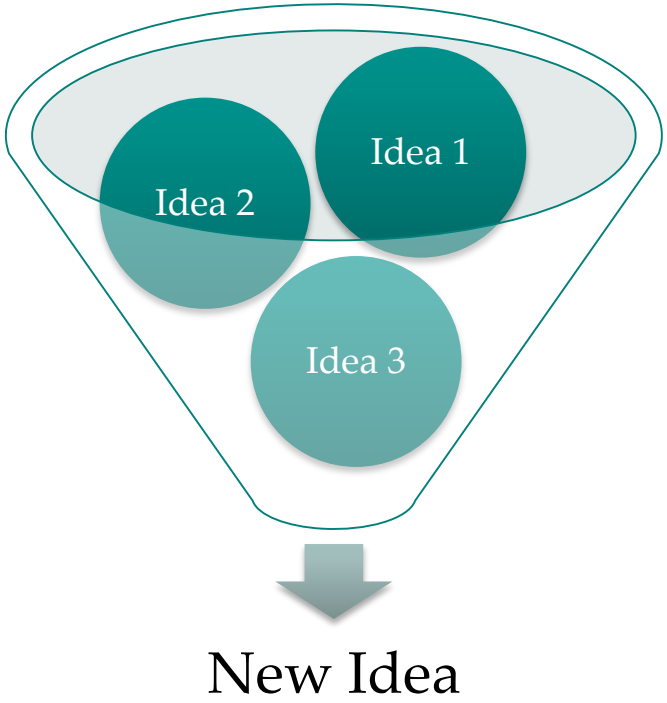
Review and Final Q&A

NAVIGANT
ENERGY

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?



NAVIGANT
ENERGY

Key CONTACTS

Thank you for your inputs

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

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

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

NAVIGANT
ENERGY