U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

# BTO HVAC R&D


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25 YEARS OF ESTCP

SERDP • ESTCP SYMPOSIUM

2019 | Enhancing DoD's Mission Effectiveness

# HVAC, Water Heating and Appliance R&D

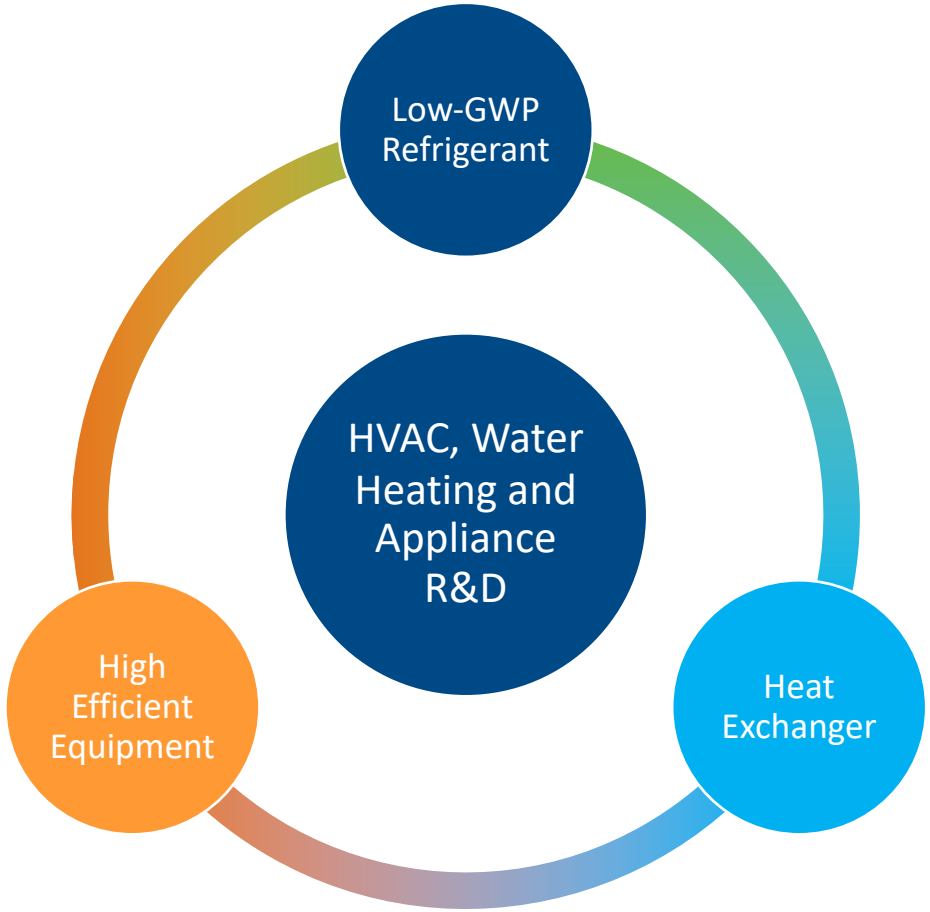
BTO's ultimate goal is to reduce the average energy use per square foot of all U.S. buildings by 50% from 2010 levels. Emerging Technologies Program's goal is to enable the development of cost-effective technologies capable of reducing a building's energy use per square foot by 45% by 2030, relative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

# HVAC, Water Heating and Appliance R&D



# 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**

*Advanced technologies*

*Tomorrow's technologies*

*Next generation technologies*

*4th Generation – "Global Warming"*

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

ODP ⇨ Zero

GWP ⇨ Low

# Future Packaged HVAC Systems

Will have:

- Low-GWP Refrigerants (A2, A2L, A3)
- New Compressor designs
- New Compact Heat Exchanger designs

# Refrigerant Changes Over Time

**The A/C industry is starting the transition to 4th generation refrigerants, which substantially reduce A/C greenhouse gas (GHG) emissions and help mitigate the environmental impact of increased A/C use.**

1830-1930

*1st Generation – "Whatever Worked"*
Hydrocarbons, $NH_3$, $CO_2$
ODP → Zero | GWP → Low

1931-1990

*2nd Generation – "Safety & Durability"*
CFC, HCFC (e.g., R-12, R-22)
ODP → Very High | GWP → Very High

1990-2010s

*3rd Generation – "Ozone Protection"*
HFC (e.g., R-410A, R-134a)
ODP → Zero | GWP → High

2010-future

*4th Generation – "Global Warming"*
Low-GWP HFCs (e.g., R-32), HFOs (e.g., R-1234yf), hydrocarbons, others
ODP → Zero | GWP → Low

- Montreal Protocol committed countries to phasing out 2nd generation refrigerants (some HCFCs still in use)
- Many countries use 3rd generation
- Interest in global warming mitigation is driving 4th generation deployment
- Includes revisiting some previously explored options, like $CO_2$ and hydrocarbons
- Risk assessments and mitigation measures have allowed use of some flammable refrigerants in certain applications



Calm, James. 2008. "The Next Generation of Refrigerants - Historical Review, Considerations, and Outlook." 1123–33.

# BTO Refrigerant Research is Comprehensive

- New compressor designs
- New refrigerants, thermodynamic properties (NIST, ORNL, etc)
- New blends, understanding glide (do not evaporate and condense at one constant temperature for a given pressure)
- New Heat Exchanger Designs
- New Lubricants for Low GWP refrigerants
- Reducing leaks, better joints
- Sensor development for leak detection
- Helping industry, domestic, and international organizations

# Search for R-410A replacement…

- R22 is a Hydrochlorofluorocarbon (HCFCs) refrigerant that was slightly better than R12, but was mandated for phase out in the U.S. in 2010 due to the Clean Air Act
- R22 is expected to be completely phased out by 2020

- R-410A was invented and patented by Allied Signal (now Honeywell) in 1991 as a replacement for R22
- R410A is a hydrofluorocarbon (HFCs) refrigerant
  - GWP (Global Warming Potential) of 2,090
  - ODP (Ozone Depletion Potential) of 0
- Near-azeotropic mixture of difluoromethane (CH2F2, called **R-32**) and pentafluoroethane (CHF2CF3, called **R-125**).
- R-410A was successfully commercialized in the air conditioning segment by a combined effort of Carrier Corporation, Emerson Climate Technologies, Inc., Copeland Scroll Compressors (a division of Emerson Electric Company), and Allied Signal

# BTO works with Industry

Many of the leading lower global warming potential (lower-GWP) alternatives to the current HFCs for air-conditioning and heat pump applications are flammable to some extent.

Working with industry in 2016, DOE announced a jointly-funded, $5.2 million partnership with the Air Conditioning, Heating, and Refrigeration Institute (AHRI), the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE), the Alliance for Responsible Atmospheric Policy, and other governments and international organizations to research how to safely use mildly flammable (A2L) and flammable (A3) as alternatives to hydrochlorofluorocarbons (HCFC) and HFCs refrigerants .

*DOE anticipates that their research will establish the knowledge base necessary to evaluate whether international codes could be modified to accept these low-GWP alternatives.*

AHRI
AIR-CONDITIONING, HEATING, & REFRIGERATION INSTITUTE

ASHRAE®

U.S. DEPARTMENT OF ENERGY

# AHRI Research BTO Award

Arlington, Va. — The Air-Conditioning, Heating, and Refrigeration Technology Institute (AHRTI), the research arm of the Air-Conditioning, Heating, and Refrigeration Institute (AHRI), has been selected by the U.S. Department of Energy for a $2.1 million funding award to conduct essential research on low global warming potential (GWP) refrigerants. AHRTI will lead a research program in collaboration with Oak Ridge National Laboratory (ORNL) and the National Institute of Standards and Technology (NIST).

*"This research will provide U.S. manufacturers with accurate refrigerant data to help them design, manufacture, and commercialize efficient and reliable HVACR products using more environmentally friendly refrigerants," said AHRI President & CEO Stephen Yurek, adding that, "the research also will help make U.S. manufacturers more competitive in the global market."*

Through this research program, AHRTI will be able to establish a database for the thermal and chemical stability of low-GWP refrigerants with lubricants and also their long-term compatibility with materials commonly used in air conditioning and refrigeration systems. Oak Ridge will develop heat transfer and pressure drop correlations for new refrigerants, which will be used for designing and optimizing heat exchangers. For it's part, NIST will measure property data of low-GWP refrigerant blends and incorporate them into the NIST database. This more accurate blend data will be used to improve confidence in the selection and optimization of blends for particular applications.

"The combined data from the three components of the program will help our industry overcome the hurdles of introducing new refrigerants and will build a foundation for our manufacturers to design and optimize more innovative, efficient products," said Yurek.

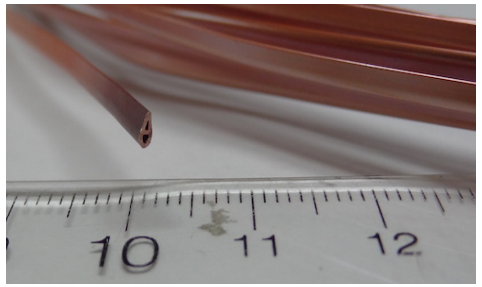
Source: http://www.ahrinet.org/News-Events/News-and-Shipping-Releases?A=1468

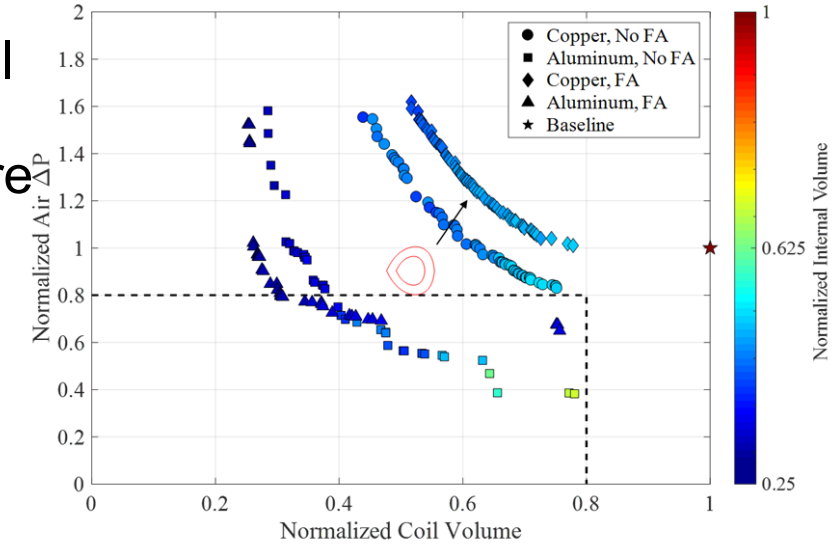
# Development of small centrifugal compressors suitable for Low-GWP refrigerants

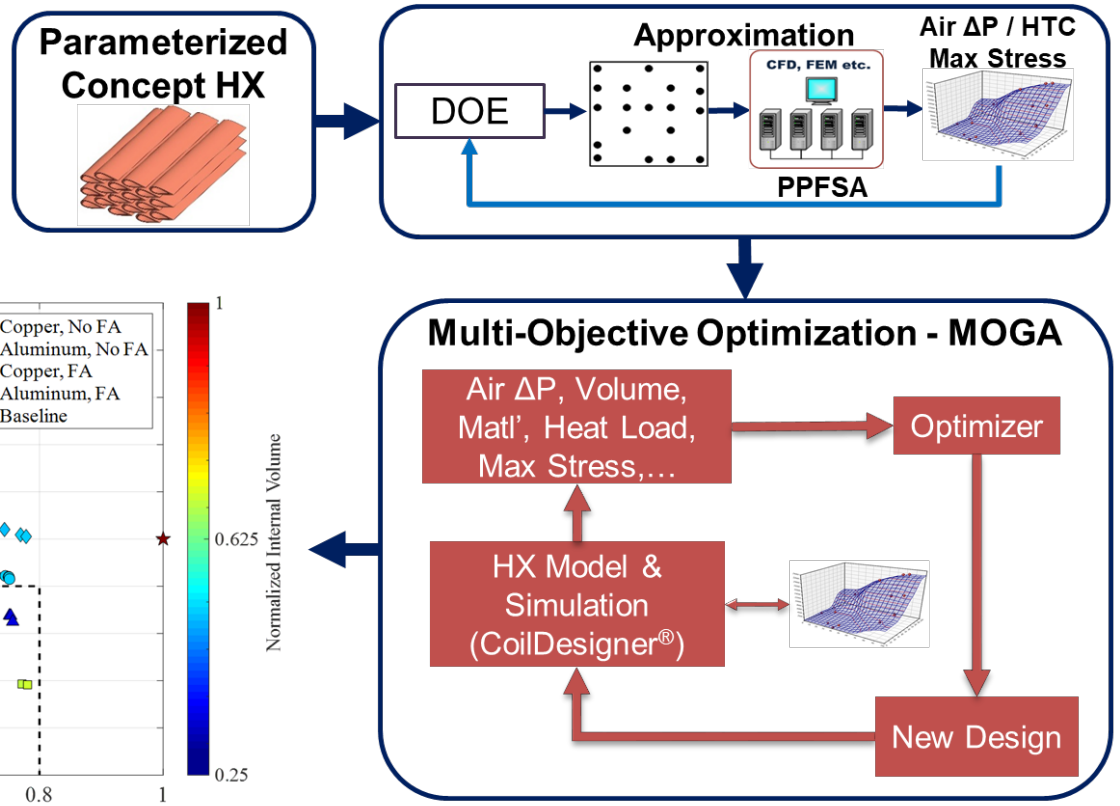
- Centrifugal compressors are commonly used in large chillers, but not in small HVAC systems, such compressors that will be able to handle low-GWP refrigerants
- Certain rotary compressor technologies in refrigeration and air-conditioning systems require oil to provide lubrication, cooling, and leak tightness between compression stages
- Managing the oil can be an issue and fouling in heat exchangers can lead to performance losses of 10-15% over time
- By moving to oil-less technologies, such as turbo-compressors
- Improvements would lead to approximately 0.2 Quads of savings in commercial refrigeration

# Design and Manufacturing of High-Performance, Reduced Charge Heat Exchangers

- Develop the next generation air-to-refrigerant heat exchangers using non-round tubes that are 25% smaller, 25% lighter and 30% reduced charge than state-of-the-art heat exchangers
- Reduced charge advantage will facilitate the use of alternative refrigerants (A2L, A3), which are some of the most efficient refrigerants available
- Make the systems 10% more efficient, saving 0.26 quads annually




MOGA = Multi-Objective Genetic Algorithm
PPFSA = Parallel Parameterized Fluid & Structural Analysis