
# DOE's Building Technologies Office: Refrigerant R&D

*Regulations & Standards Session*

# #1 Introduction

## Program Goals for HVAC, Water Heating and Appliance R&D:

**Support BTO's goals to achieve 50 percent building energy savings**

- By 2020, develop technologies enabling 10 percent energy savings in HVAC; 20 percent energy savings in water heating, and 15 percent energy savings in appliances
- By 2030, develop technologies enabling 25 percent energy savings in HVAC; 35 percent energy savings in water heating, and 30 percent energy savings in appliances
- Maintain the competitiveness of American industry

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

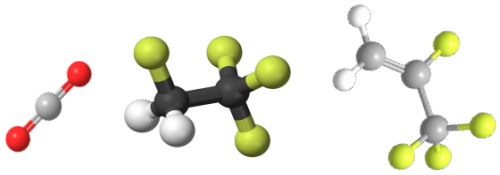
1) Accelerate the development of **near term** technologies that have the potential to save significant amount of energy (including cost reduction activities, bending the cost curve)
2) Accelerate the development of the **next generation** of technologies that have the potential of "leapfrogging" existing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

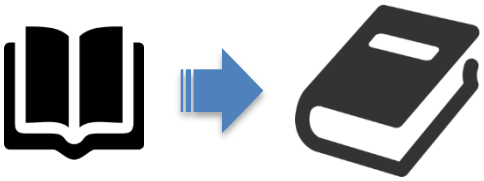
The goal is to develop technologies that save energy and reduce our environment burden while *introducing them in the simplest application first, highest probability of success*.

# #2 BTO's Search for New Refrigerants

*Fundamentals*

- A team of researchers from the National Institute of Standards and Technology (NIST) and the Catholic University of America were tasked by BTO to identify and evaluate potential low-GWP alternative refrigerants
- Recently received the International Journal of Refrigeration (IJR)'s Best Paper Award for 2013/2014, for their paper
- "A thermodynamic analysis of refrigerants: Possibilities and tradeoffs for low-GWP refrigerants."
- Authors: M.O. McLinden, A.F. Kazakov, J.S. Brown, P.A. Domanski
- Study 'closes the book' on refrigerants possibilities
- Award is evidence of BTO's leadership in funding world-class refrigerant research



NIST

# #3 ARRA Projects

*Natural Refrigerant R&D (past)*

- **Developing Next Generation Refrigeration Lubricants for Low Global Warming Potential / Low Ozone Depleting Refrigeration and Air Conditioning** (Chemtura Corporation): Create, characterize, and evaluate new synthetic ester lubricants for compressor refrigerants. These are needed with new CFC-free refrigerants like CO2 and hydrocarbons that can react with conventional lubricants.

- **Energy Efficient Commercial Refrigeration with Carbon Dioxide Refrigerant and Scroll Expanders** (TIAX): Demonstrate the performance of the TIAX CO2 scroll expander and scroll compressor for supermarket refrigeration applications and greenhouse gas reducing technology. A scroll expander/compressor uses a simple spiral-shaped design to continuously compress and expand working fluids and gases.

- **Natural Refrigerant Very-High Efficiency HVAC System** (UTRC): Design, develop and demonstrate a natural refrigerants based very high efficiency residential AC system that provides: a 30% reduction in annual energy consumption. Propane and CO2 were used as the working fluids.

# #4 ARRA Projects

*Natural Refrigerant R&D (past)*

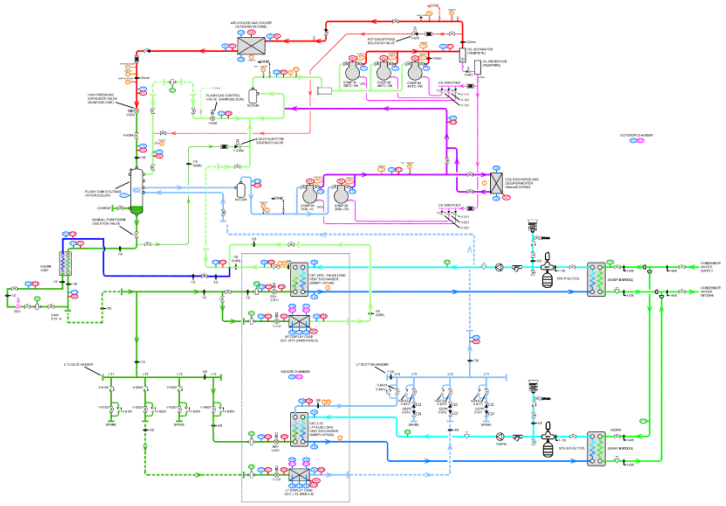
- **Development and Validation of a Gas-Fired Residential Heat Pump Water Heater** (Stone Mountain Technologies, Inc.): Develop gas-fired residential absorption heat pump water heater (ammonia) . Primary fuel efficiency 2.4 times higher than conventional gas storage water heaters, and 2.1 times higher than electric heat pump water heaters. Have approximate 3 kW (10,000 Btu/hr) heating capacity.
- **High Energy Efficiency R744 Commercial Heat Pump Water Heaters** (Creative Thermal Solutions): Develop a high efficiency R-744 (carbon dioxide) heat pump water heater with cooling capability for air-conditioning and refrigeration. The unit will be targeted for commercial use where some cooling load is typically needed year-round. Improved efficiency through two-phase ejectors, and high efficiency interior permanent magnet motors.
- **Development of a Water Based, Critical Flow, Non-vapor Compression Cooling Cycle** (Kansas State University): Develop and demonstrate water-based, non-vapor compression cooling system which uses a multi-phase, supersonic/hypersonic nozzle. The use of pressurized water as the refrigerant lowers cost and provides significant environmental benefits.

# #5 Current Projects

*Natural Refrigerant R&D*

## HillPhoenix: Transcritical CO2 Supermarket Refrigeration System (Advansor System)

- Research supported by BTO, Oak Ridge National Laboratory's (ORNL's) cooperative research and development agreement (CRADA) with **HillPhoenix**
- Low GWP refrigerant (CO2), with 25 percent lower energy consumption than existing systems, and 78% lower GHG emissions
- Traditional supermarket refrigeration systems found in most grocery stores across the country are vulnerable to issues which can cause significant refrigerant leakage, emitting environmentally harmful greenhouse gases at an average rate of about 25% of their total normal operating charge per year (EPA, 2012).
- ORNL (CRADA with Hillphoenix
- Low-emission, high-efficiency commercial refrigeration system suitable for use in current U.S. supermarkets
- Hillphoenix's Second Nature® "Advansor System" is the first to be UL listed in North America and already has 12 applications in the U.S.

Hillphoenix A DOVER COMPANY

OAK RIDGE National Laboratory

# #6 Current Projects

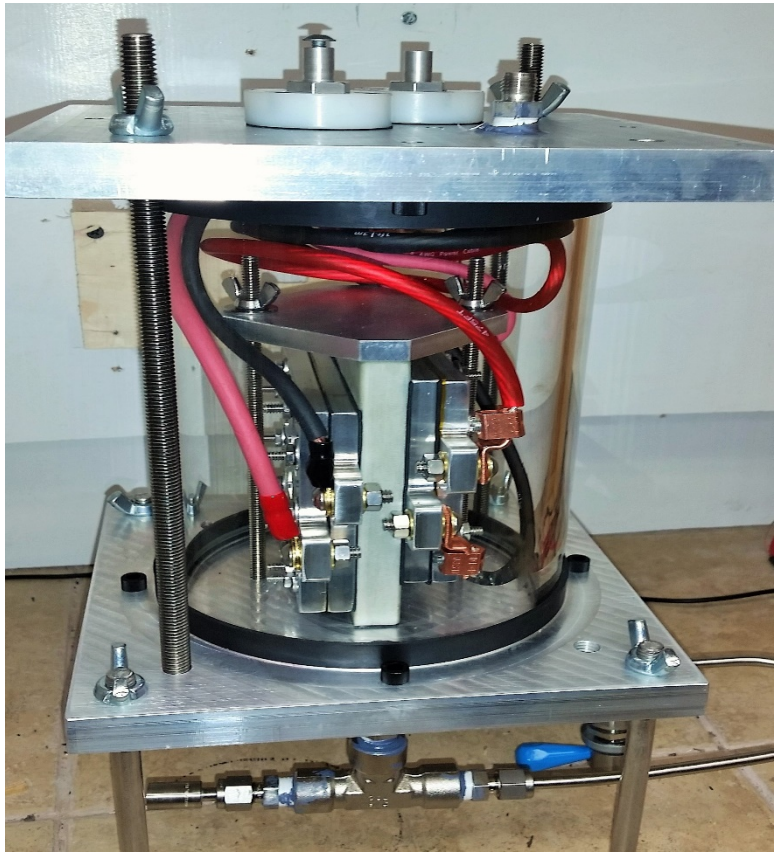
*Natural Refrigerant R&D*

XERGY

GE Appliances

## XERGY: Advanced Hybrid Water-Heater Using Electrochemical Compression (ECC)

- Develop a heat pump water heater utilizing electrochemical compression technology
- Electrochemical compression (ECC) is a transformative solid state technology that allows for the use of water as the refrigerant in a vapor compression cycle.
- Electro-Chemical Compression (ECC) uses an external voltage to **pump a water refrigerant**, carried by protons, across a solid polymer electrolyte membrane
- ECC of water requires low pressure operation (~2 kPa to 26 kPa) which is impractical using traditional compressors
- Multiple **small cells are combined** to create units with the required pumping capability and efficiency
- If project targets are met, payback period will be less than 2 years



# #7 Current Projects

*Natural Refrigerant R&D*

## Stone Mountain Technologies, Inc.: Low-Cost Gas Heat Pump for Building Space Heating

- Develop and demonstrate a gas-fired absorption heat pump, with heating COP's greater than 1.0 at low ambient. Design simplicity and volume manufacturing requirements emphasized from conception. Achieving a projected 2-5 year economic payback to drive market penetration is a higher priority than ultra-high efficiency.
- Optimized Simple Single-Effect Cycle That Predicts Target Performance (ammonia).
- Low-Cost Solution Pump Successfully Scaled Up Factor of 10.
- Alpha Packaged Prototype Fabricated & Lab Tested
- Preliminary manufacturing cost estimate within target range.

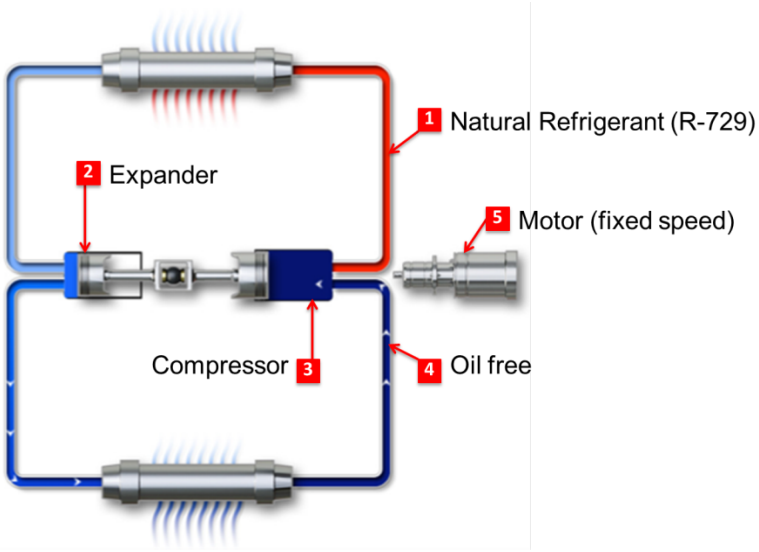

| DOE Cold Climate Heat Pump R&D Performance Targets (Natural Gas, Residential)* | | |
|---|---|---|
| Ambient Temperature (°F) | COP | Maximum Capacity Decrease from Nominal (%) |
| 47 | 1.3 | 0 |
| 17 | 1.15 | 20 |
| -13 | 1.0 | 50 |

# #8 Current Projects

*Natural Refrigerant R&D*

## S-Ram: Natural Refrigerant High Performance Heat Pump for Commercial Applications

- Project aims to develop a regenerative air source heat pump for commercial and industrial heating, ventilation, and air conditioning (HVAC) applications
- Using air as the working fluid, the heat pump eliminates all use of hydrofluorocarbon (HFC) refrigerant—a major greenhouse gas.
- Heat pump will operate over a temperature range of -40°F to 210°F, enabling excellent performance in both cold climates and industrial applications.
- The initial units will have a 20-ton cooling capacity and a 240,000 British thermal units (BTU)/hour heating capacity—a 50% improvement over existing state-of-the-art technology.



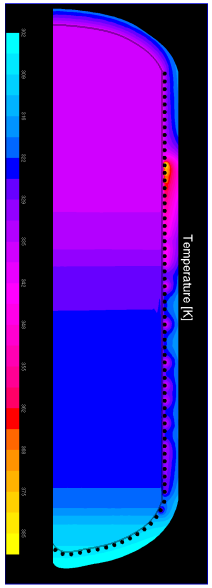

| DOE Cold Climate Heat Pump R&D Performance Targets (Electricity, Commercial) | | |
|---|---|---|
| **Ambient Temperature (°F)** | **COP** | **Maximum Capacity Decrease from Nominal (%)** |
| **47** | **4** | **0** |
| **17** | **3** | **10** |
| **-13** | **2.5** | **25** |

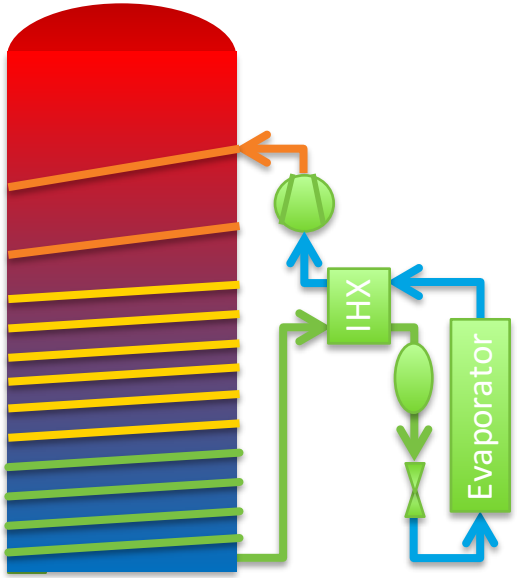
# #9 Current Projects

*Natural Refrigerant R&D*

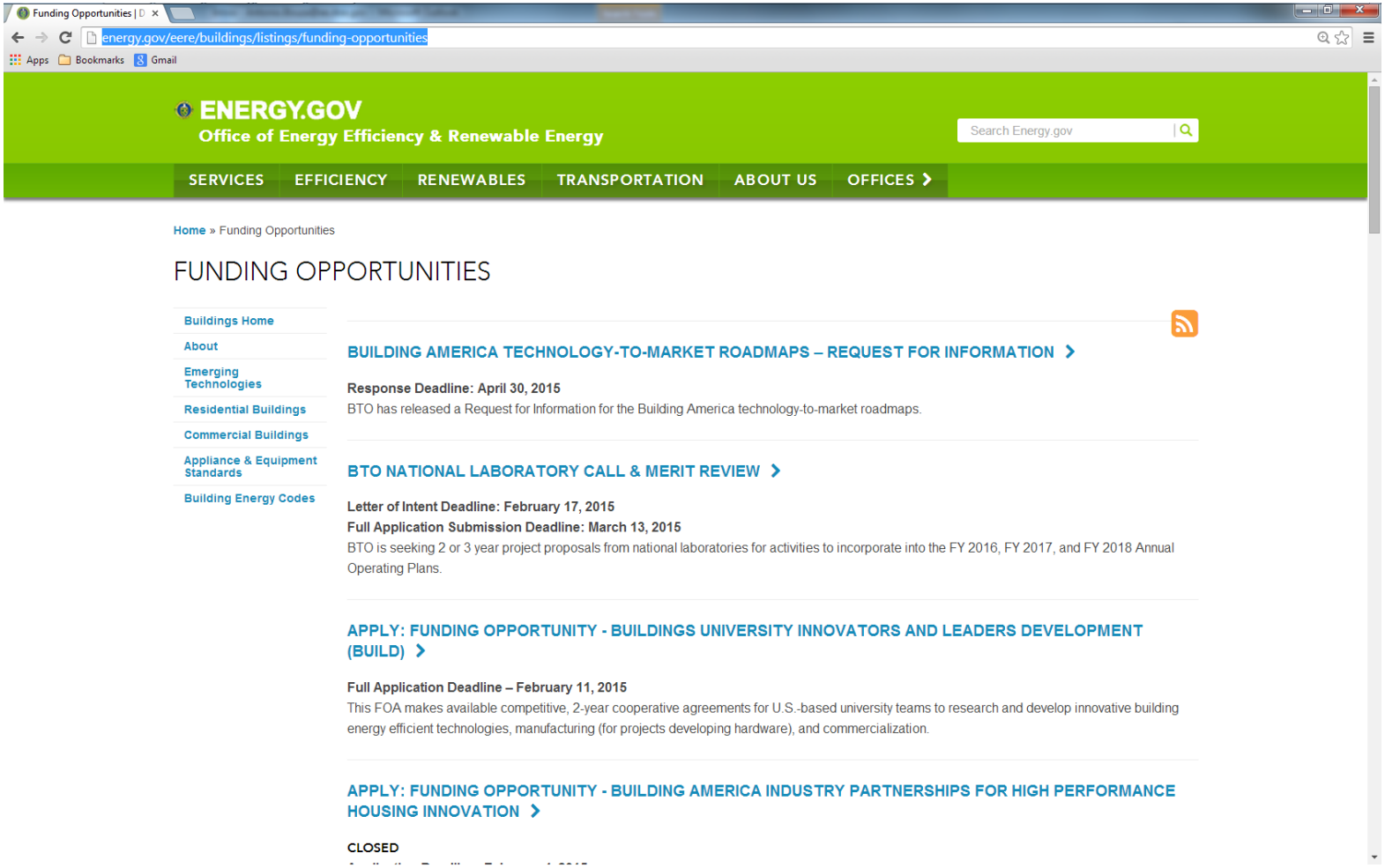
## ORNL: CO2 Heat Pump Water Heater

- Project is developing a carbon dioxide (CO2) heat pump water heater (HPWH) that meets ENERGY STAR® standards for HPWHs
- Project team will demonstrate the performance and energy savings of field ready CO2 HPWH prototypes in ORNL research houses and perform Gate 6 evaluation (passage from engineering development to product demonstration).
- Project team will perform a design optimization of wrap-around gas cooler design to improve system reliability and reduce cost
- With full deployment, ORNL estimates that cost-effective CO2 HPWHs could reduce energy use by 0.8 quads a year
- Unlike currently available electric heat pump water heaters, a CO2-based system would have minimal GWP.



# #10 BTO's Funding Opportunities




*http://energy.gov/eere/buildings/listings/funding-opportunities*

# ATMOsphere AMERICA business case natural refrigerants

25 & 26 June - Atlanta, Georgia

**Antonio M. Bouza**
Technology Manager | General Engineer
U.S. Department of Energy l Building Technologies Office
antonio.bouza@ee.doe.gov

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