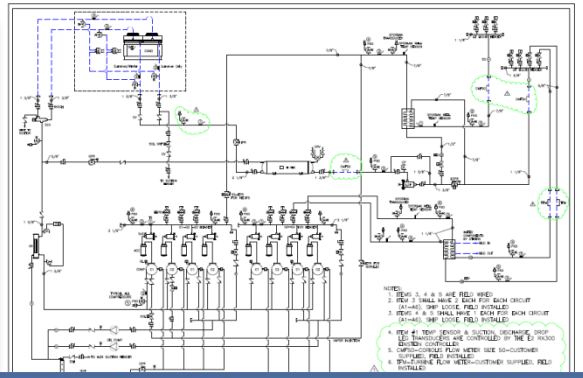
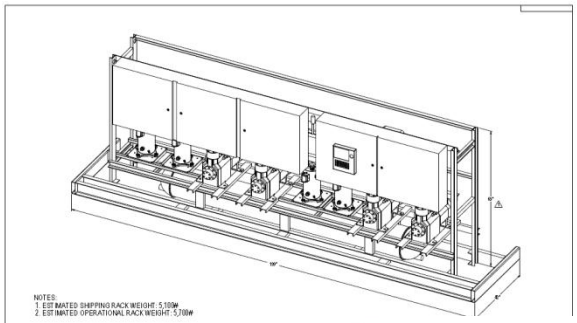
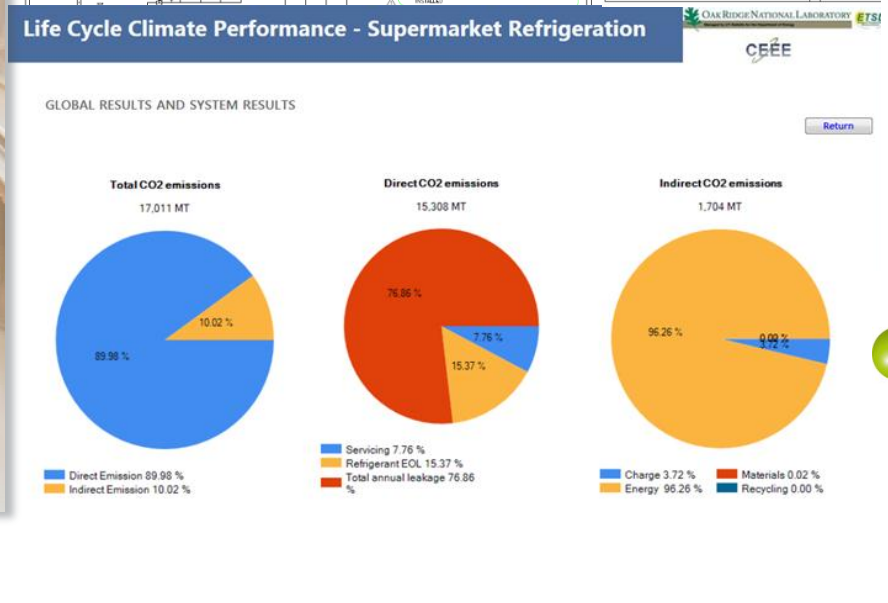
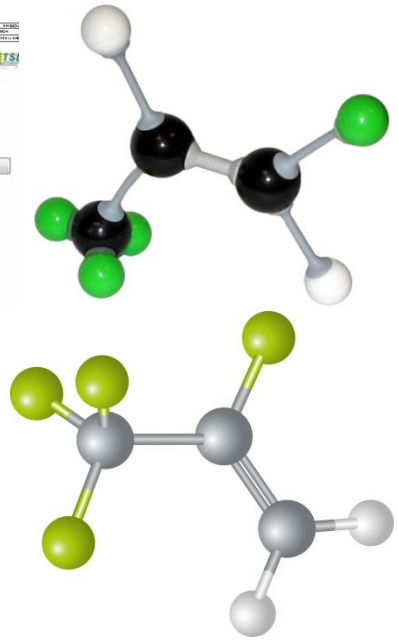
Working Fluids: Low Global Warming Potential Refrigerants

2014 Building Technologies Office Peer Review









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

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Project Summary

Timeline:

Start date: 01-Oct-2010

Planned end date: 30-Sep-2016

Key Milestones

1. Data analysis and reporting of supermarket system: baseline and alternative refrigerants; 12/31/2014
2. Perform initial field testing of alternative refrigerant in 3rd party installation; 9/30/2014
3. Deliver enhanced Life Cycle Climate Performance (LCCP) Design Tool; 9/30/2014

Budget:

Total DOE $ to date: $2,650K

Total future DOE $: $1,000K ($500K for FY15 and $500K for FY16)

Target Market/Audience:

Residential and Commercial Heating, Air Conditioning, and Refrigeration with a Primary focus on Commercial Refrigeration due to the large leak potential

Key Partners:

Honeywell	CRADA Partner and Key Contributor
University of Maryland 18 56	Subcontractor and LCCP Design Tool Developer

Project Goal:

To develop low Global Warming Potential (GWP) refrigerant solutions for the Heating, Air Conditioning and Refrigeration (HVAC&R) market through leadership in Life Cycle Climate Performance (LCCP) modeling, experimental evaluation, and field testing.

Purpose and Objectives

Problem Statement:

- HCFC phase out resulted in the use of high GWP HFC
- Newly developed low GWP refrigerants are blends that require more studies: flammability, glide, heat transfer, efficiency/GWP trade-off

Target Market and Audience:

- Residential and Commercial HVAC&R: emphasis supermarket refrigeration
- Using the BTO Market Definition; these sectors are responsible for ~ 11.4 Quads in 2030 (1.59 Quads for supermarket refrigeration)

Impact of Project:

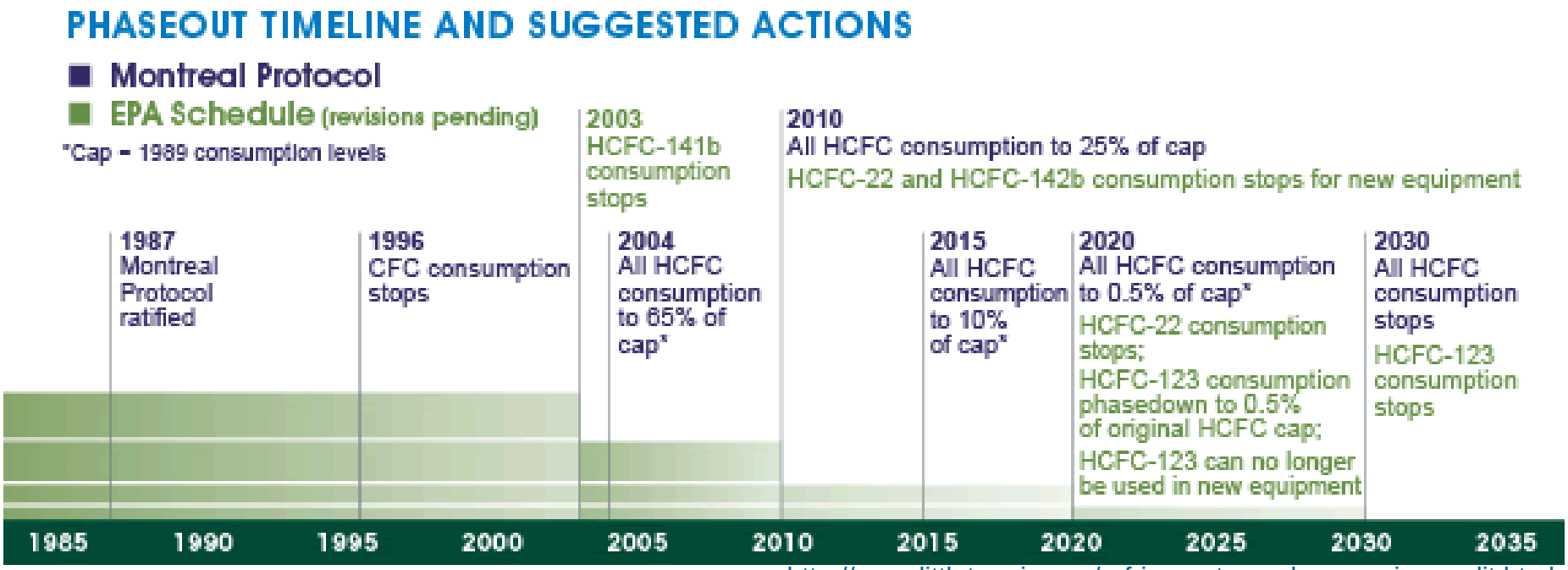
1. Development of a validated Open Source LCCP Design Tool
2. Development of best practices for low GWP refrigerant switch-over with a documented field study results
3. The project impact
   a. Number of software downloads and web-traffic, field test performance
   b. Successful pilot low GWP supermarket refrigeration installation
   c. Market share of low GWP supermarket refrigeration

Approach

- Characterize performance of alternative low GWP refrigerants developed by Honeywell, our CRADA partner in HVAC&R equipment
  - Heat exchangers testing
  - Compressor calorimeter testing
  - Supermarket refrigeration system

- Develop an Open Source Life Cycle Climate Performance (LCCP) **D**esign tool to allow the next generation of HVAC&R engineers to design equipment with life cycle emissions as an important decision factor

Approach: Key Issues



http://www.littletonair.com/refrigerants_and_your_air_condit.html

- Large quantity of high GWP refrigerants currently in use in existing HVAC&R equipment
  - R-404A has a GWP_{100} of 3700, typical Supermarket Refrigeration-Centralized DX charge is 3000 lbs
- Identify low GWP refrigerant replacements which are drop-in replacements

Approach: Distinctive Characteristics

- Develop an open-source LCCP Design tool
  - Anticipated to be the internationally recognized “go-to” tool to assess environmental impacts of HVAC&R equipment
  - Involve the industry: ASHRAE MTG.Low GWP, AHRI
  - Involve the international community: participation through IIR working party and IEA Heat Pump Center
- Determine low GWP refrigerant performance:
  - Supermarket refrigeration system, under controlled lab conditions using N-40 (GWP = 1273)
  - Compressor calorimeter evaluations
  - Heat exchanger evaluation

Progress and Accomplishments

Lessons Learned:

- Need for adequate moisture management
- Reduce number of quick coupling (leak potential)
- Need to proper size the expansion valves to achieve adequate superheat controls; especially with alternative refrigerants

Accomplishments:

- Developed an Open Source LCCP Design Tool (http://lccp.umd.edu/) with web-based interface for air source heat pumps and supermarket refrigeration (FY2013 Q4 Milestone)
- Tested baseline R-404A and alternative low GWP N-40 refrigerants in a supermarket refrigeration system under a controlled environment in an experimental test bed (FY2014 Q1 Milestone)
- Analyzed the LCCP of several supermarket refrigeration systems with various refrigerants
- Evaluated a heat exchanger with baseline and 2 alternative refrigerants (FY2014 Q2 Milestone)

Progress and Accomplishments

Home Page

lccp.umd.edu

DOE Links Most Visited Getting Started

Life Cycle Climate P

Life Cycle Climate Performance (LCCP) – C

ORNL LCCP Desktop Application Downloa

ORNL-LCCP Web Application

Life Cycle Climate Performan

LCCP Design Tool for Supermarket Refrigeration Systems

LCCP Evaluation Tool for Residential Heat Pump Systems

LCCP Design Tool for Residential Heat Pump Systems

Life Cycle Climate Performance - Supermarket Refrigeration

OAK RIDGE NATIONAL LABORATORY ETSD

CEEE

RUN

LCCP INPUT PARAMETERS

Select System Type: Combined MTLT DX Syste | Select Load Profile: Load Profile 1 | Select City: Chicago, Illinois [4]

Load-profile curve

SYSTEM INPUTS

Load sample values

Refrigerant [-]	R404A	Subcooling at Expansion Device [F]	50.4
System Charge [lb]	4409.25	Superheat at Evaporator Outlet [F]	65.0
Annual Leak Rate [%]	5	System Lifetime [yrs]	15
Refrigerant Loss-EOL [%]	15	Cut-off Temperature [F]	55.0
Service Leakage Rate [%]	0.05	Service Interval [year]	5

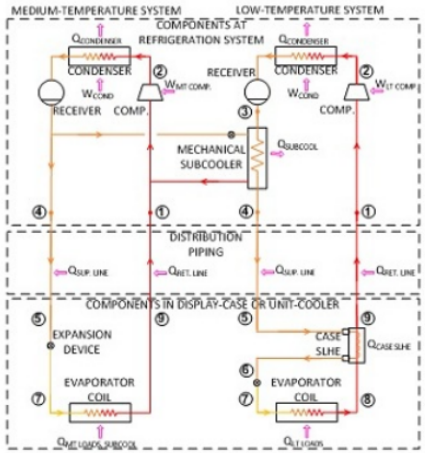
COMPONENT INPUTS [LT SYSTEM PARAMETERS]

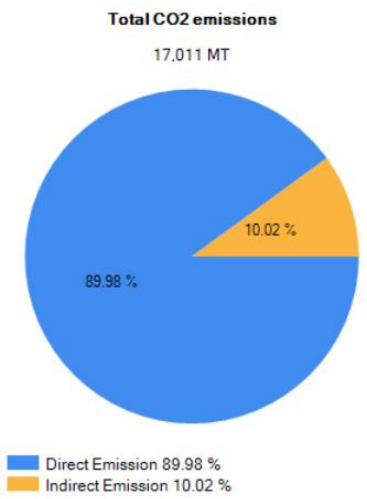
Load HTC values

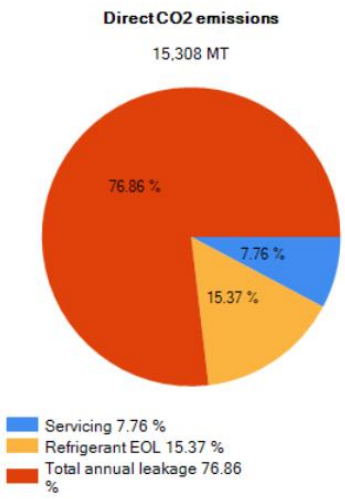
Suction Line HX Efficiency [%]	50.0	Suction Line Temperature Increase [F]	50.0
Nominal Load [Btu/hr]	300000.0	Liquid Line Temperature Decrease [F]	13.5

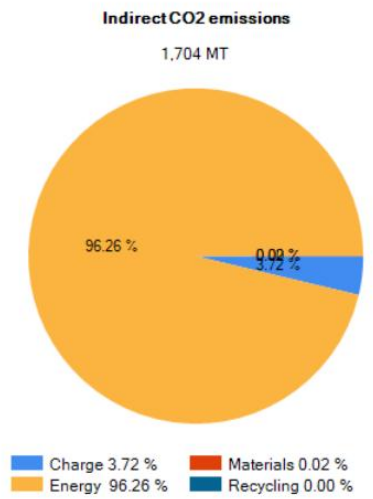
COMPRESSOR

Isentropic Efficiency [%]	65	RPM [-]	3600
Volumetric Efficiency [%]	80	Displacement [in³]	7.75
Number of compressors [-]	10		



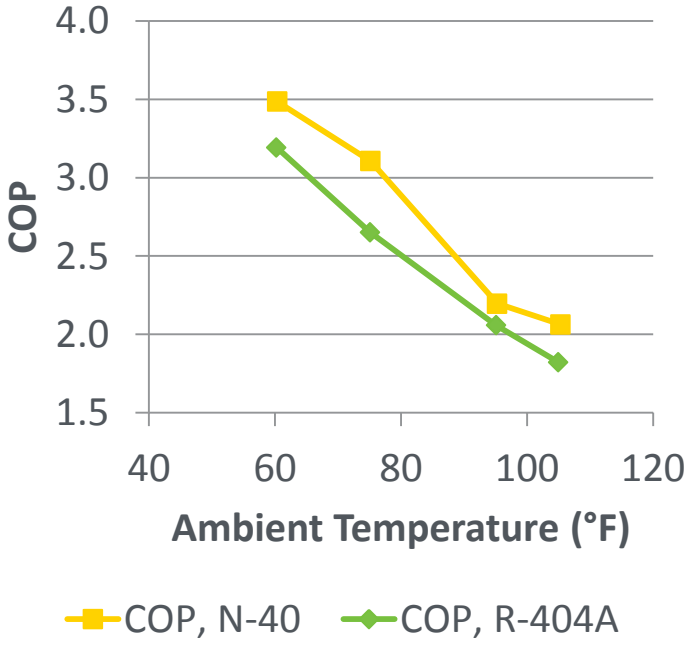


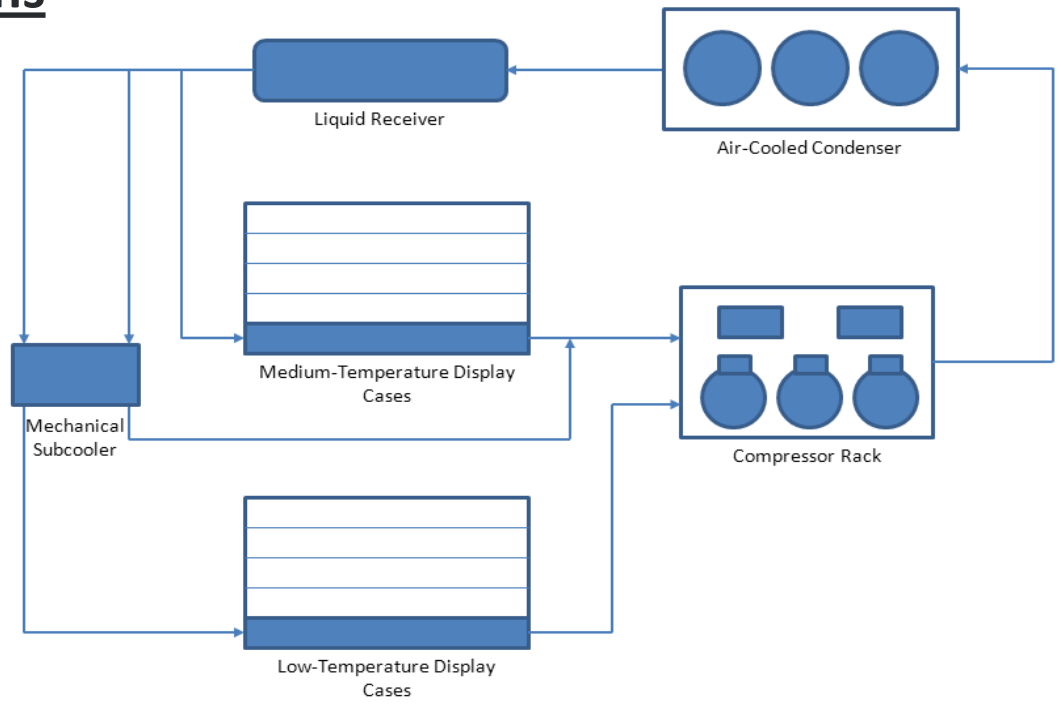




Progress and Accomplishments

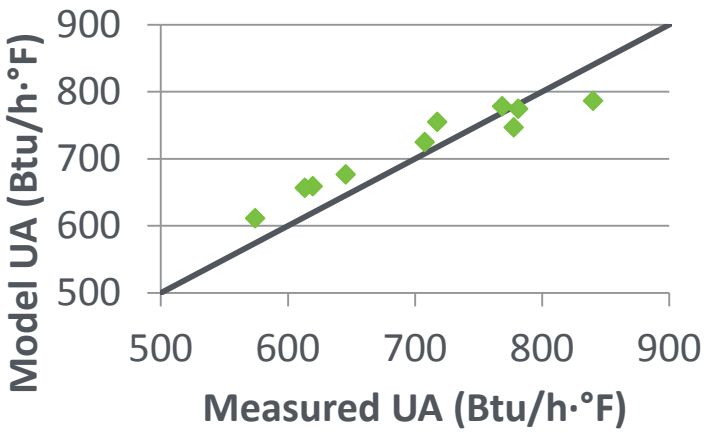
Full-Scale Supermarket Refrigeration Experimental Evaluation under Controlled Laboratory Conditions

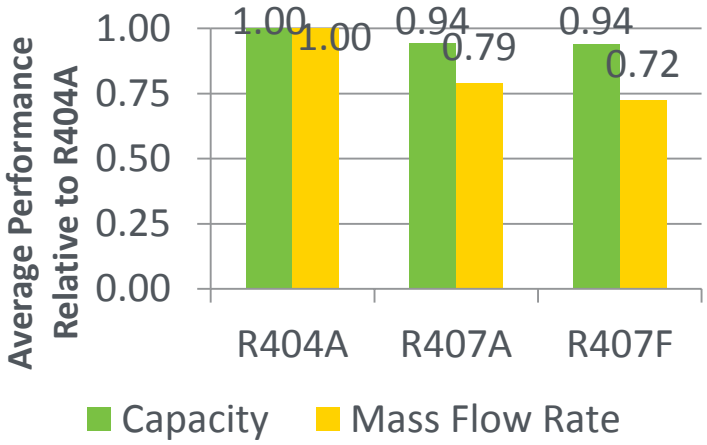




- N40 performance over R-404A over the ambient temperature range
  - Reduced compressor power by 3.7%
  - Increased refrigeration capacity by 7.5%
  - Increased system COP by 11.6%

Progress and Accomplishments





The actual superheat of 407A and 407F is usually higher than R404A. This results in matched capacities at lower refrigerant flow rates.

Progress and Accomplishments

Market Impact:

- Based on the favorable results of N-40 and its low GWP (1273); it is expected that it will become the optimal solution for supermarket refrigeration systems
  - The CRADA partner expects to launch it this year (pending some approvals)
  - "Relevant" end users have shown strong support for using N-40 already
- Web-based LCCP tool is highly used: 661 unique users to-date
- 2012 Purdue Conference Paper on LCCP of Commercial Refrigeration:
  - 167 downloads in the last year only
- ASHRAE MTG Alternative Global Warming Refrigerant
  - Growing membership
  - Expanding Program
- AHRI AREP
  - Successful participation in the program

Awards/Recognition:

None

Project Integration and Collaboration

Project Integration:

- ASHRAE MTG on low GWP refrigerant research
- AHRI AREP testing
- International Institute of Refrigeration (IIR) working party on LCCP
- Attending conferences (regional, national, and international)

Partners, Subcontractors, and Collaborators:

- Honeywell: CRADA Partner; low GWP refrigerant developer and global supplier
  - Mark Spatz: Director of Refrigerants Technology/Sponsor
  - Samuel Yana-Motta: Refrigerants R&D Leader/Project manager
  - Gustavo Pottker: Experimental Engineer/Scientist
  - Ankit Sethi: Modeling/Simulation Engineer/Scientist
  - Paul Sullivan: Application support
- University of Maryland: Subcontractor; development of Open Source LCCP **D**esign Tool
  - Reinhard Radermacher: Center Director
  - Vikrant Aute: Principal Investigator

Communications: Last 12 Months

SEMINAR PRESENTATIONS (1)

- Fricke et al. 2014. Air-to-Refrigerant Heat Exchangers. 2014 ASHRAE Winter Meeting.

CONFERENCE PAPERS (5)

- Fricke et al. 2013. Reducing the Carbon Footprint of Commercial Refrigeration Systems Using Life Cycle Climate Performance Analysis: From System Design to Refrigerant Options. 2nd IIR International Conference on Sustainability and the Cold Chain, Paris.
- Fricke et al. 2013. Energy Efficiency and Environmental Impact Analyses of Supermarket Refrigeration Systems. 2013 ASHRAE Summer Meeting.
- Abdelaziz et al. 2014. Development of Versatile Compressor Modeling using Approximation Techniques for Alternative Refrigerant Evaluation. 2014 ASHRAE Winter Meeting.
- Beshr et al. 2014. A Tool for Life Cycle Climate Performance (LCCP) Based Design of Residential Air Source Heat Pumps. 11th IEA Heat Pump Conference, Montréal.
- Beshr et al. 2014. An Evaluation of the Environmental Impact of Commercial Refrigeration Systems Using Low Global Warming Potential Refrigerants. 3rd IIR International Conference on Sustainability and the Cold Chain, London.

JOURNAL ARTICLES (1)

- Beshr et al. 2013. A Tool for Life Cycle Climate Performance (LCCP) Based Design of Residential Air Source Heat Pumps, *IEA Heat Pump Centre Newsletter*, Vol. 31, No. 3, 21-25.

WEBINARS (1)

- Aute et al. 2014. New Open Source Life Cycle Climate Performance (LCCP) Framework. University of Maryland College Park, April 18th, 2014.

Next Steps and Future Plans

Next Steps and Future Plans:

- Develop field test plan and identify field test site for evaluation of alternative refrigerant in 3rd party installation (6/30/2014)
- Perform initial field testing of alternative refrigerant in 3rd party installation (9/30/2014)
- Complete 3rd party field evaluation and report results (6/30/2015)
- Perform testing of low GWP refrigerants in equipment that has been modified or designed specifically for the alternative refrigerant (9/30/2015)

Planned and Submitted Publications:

- Beshr et al. 2014. 15th Int. Ref. & Air Cond. Conf., West Lafayette, IN.
  - ✓ An Evaluation of the Environmental Impact of Different Commercial Supermarket Refrigeration Systems Using Low Global Warming Potential Refrigerants.
  - ✓ Impact of Charge Degradation on the Life Cycle Climate Performance of a Residential Air- Conditioning System
  - ✓ An Evaluation of the Environmental Impact of Different Commercial Supermarket Refrigeration Systems Using Low Global Warming Potential Refrigerants
- Beshr et al. 2014. A Comparative Study on the Environmental Impact of CO2 Supermarket Refrigeration Systems. 11th IIR-Gustav Lorentzen Conf. on Nat. Ref., Hangzhou, China.
- Beshr et al. 2014. A Novel Modular Tool for Life Cycle Climate Performance (LCCP) Based Design of Vapor Compression Systems. *Env. Sci.& Tech.*

REFERENCE SLIDES

Project Budget

Project Budget: DOE Total $3,650K, FY11-16.
Variances: Budget cut by $850k due to program prioritization, timeline relaxed for 2 years to accommodate the budget cut.
Cost to Date: ~ $2,461K through February 2014
Additional Funding: None expected.

Budget History

FY2011 – FY2013 (past)		FY2014 (current)		FY2015 – FY2016 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$2,200K	*	$450K	*	$1,000K	*

* In-kind contribution from CRADA partner – matches or exceeds DOE funding level; exact total is confidential information

Project Plan and Schedule