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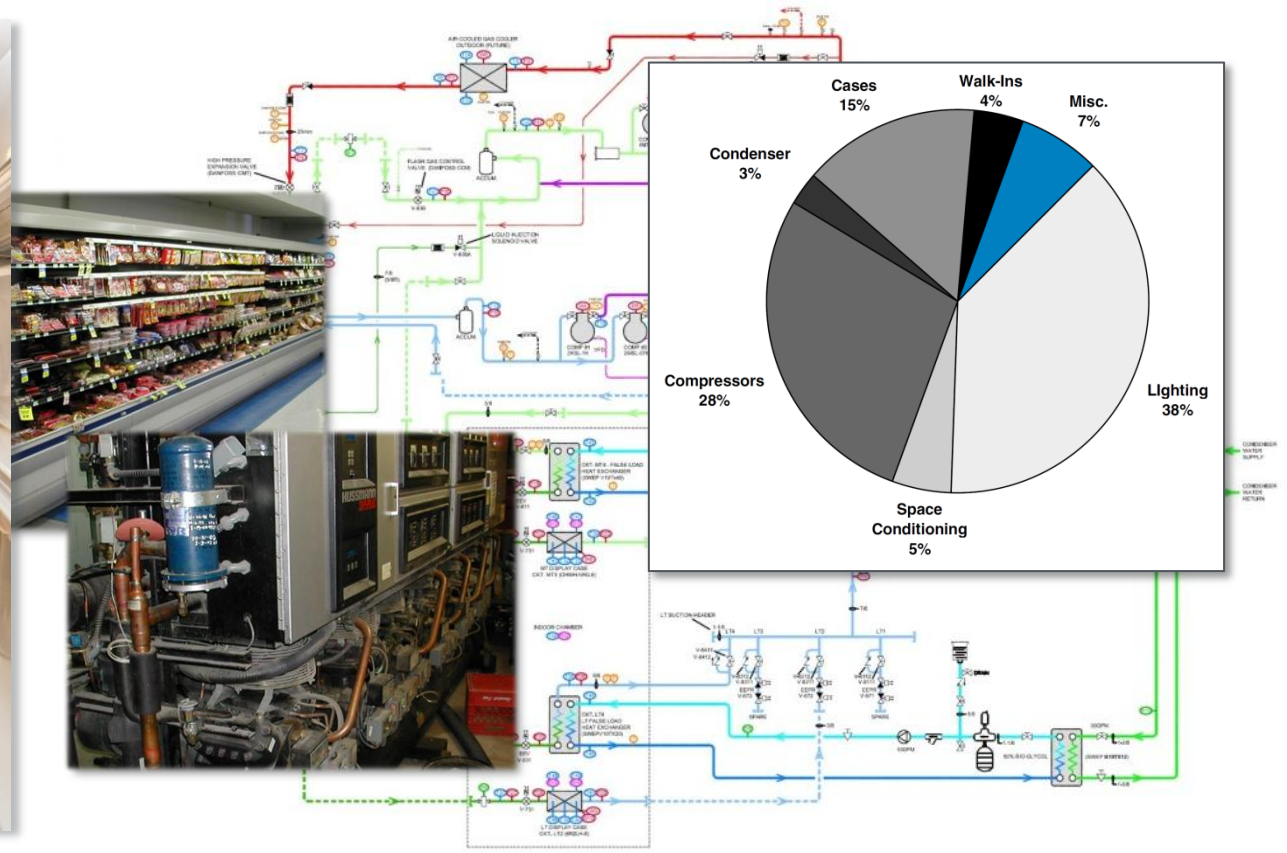


# Working Fluids Low GWP Refrigerants - CRADA

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# Purpose & Objectives



## Problem Statement:

- High GWP refrigerants increase $CO_2$ equivalent emissions for HVAC&R equipment
- Low GWP alternatives may increase energy consumption, introduce safety risks, require significant modifications to equipment, and have higher costs

## Impact of Project:

- Primary market segment is the residential and commercial HVAC&R industry
- Provide the HVAC&R industry with validated and standardized LCCP modeling tools
  - Enable the optimal design of HVAC&R equipment with lower life cycle greenhouse gas emissions
- Provide information for optimal selection of refrigerant replacements for HVAC&R systems

# Purpose & Objectives



## Project Focus:

- Reduce energy and carbon emissions used in HVAC&R equipment by 50% compared to today's best common practice
- Alternative refrigerants with low global warming potential (GWP) are needed to achieve these goals
- Provide guidance to the HVAC&R community on selecting alternative, energy-efficient, low GWP refrigerants
- Enable U.S. manufacturers to position themselves as world leaders in the next generation of alternative refrigerant technologies
  - Job creation and growth

# Approach



- Develop alternative low GWP refrigerants in cooperation with Honeywell and DuPont
- Develop Life Cycle Climate Performance (LCCP) tool
  - Assess environmental impacts of alternative refrigerants
    - Direct emissions:  refrigerant leaks
    - Indirect emissions:  energy consumption
  - Identify candidate alternative refrigerants for experimental study
- Characterize performance of candidate alternative refrigerants in HVAC&R equipment
  - Compressor calorimeter evaluations
  - Supermarket refrigeration system
  - Suggest appropriate lower GWP alternatives for HVAC and commercial refrigeration applications

# Approach continued



- Supports AHRI Low-GWP Alternative Refrigerants Evaluation Program (AREP)
  - Industry-wide cooperative research program
  - Performance evaluation of low-GWP refrigerant candidates
    - 38 refrigerant candidates supplied by 6 refrigerant suppliers
  - 21 entities conducting performance evaluations of refrigerants
    - Equipment manufacturers, universities, national laboratories
    - Compressor calorimeter tests, system drop-in tests, soft-optimized system tests
  - Evaluation results to be released to the public

# Approach

## Key Issues:

- Large quantity of high GWP refrigerants currently in use in existing HVAC&R equipment
- History
  - Montreal Protocol: Transformation of refrigerant industry
    - Chlorofluorocarbons (CFC)
      - » Production ceased in 1996 (developed countries)
    - Hydrocholorofluorocarbons (HCFC)
      - » Reduce use by 75% by 1 Jan 2010 (developed countries)
      - » 100% reduction by 2030
  - Kyoto Protocol
      - » Hydrofluorocarbons (HFC) (Zero ODP, High GWP)
      - » GWP levels are under debate (European push for low)

# Approach

## Key Issues (continued):

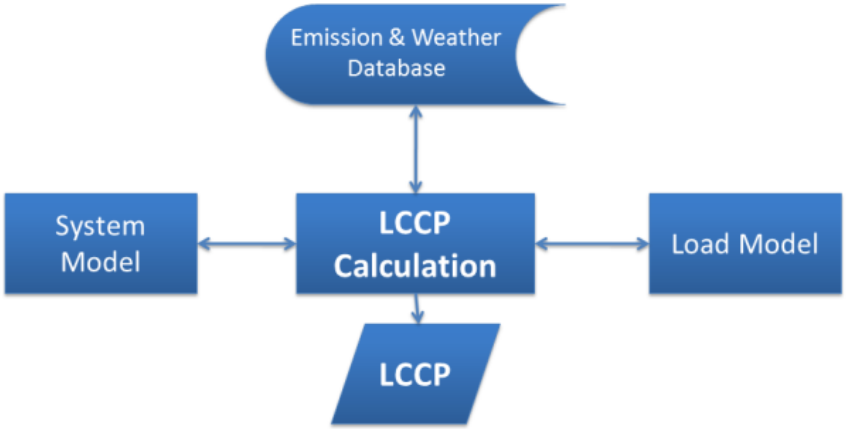
- Identify low GWP refrigerant replacements which are drop-in replacements:
  - Minimal equipment modification, high efficiency, low cost
- Optimize HVAC&R equipment for low GWP refrigerants if no suitable drop-in replacements are found

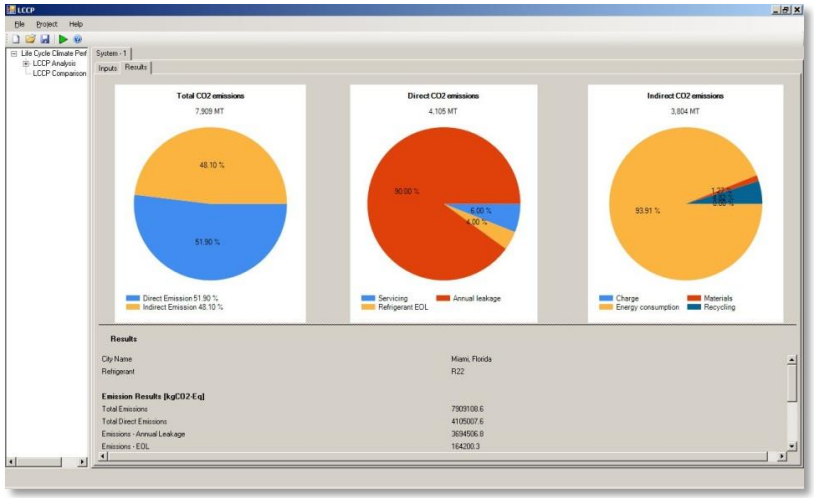
## Distinctive Characteristics:

- Develop an open-source LCCP design tool with industry input (AHRI)
  - Anticipated to be the internationally recognized “go-to” tool to assess environmental impacts of HVAC&R equipment
- Determine low GWP refrigerant performance:
  - Supermarket refrigeration system, under controlled lab conditions
  - Compressor calorimeter evaluations
  - HVAC, HPWH, and refrigerators

## Accomplishments:

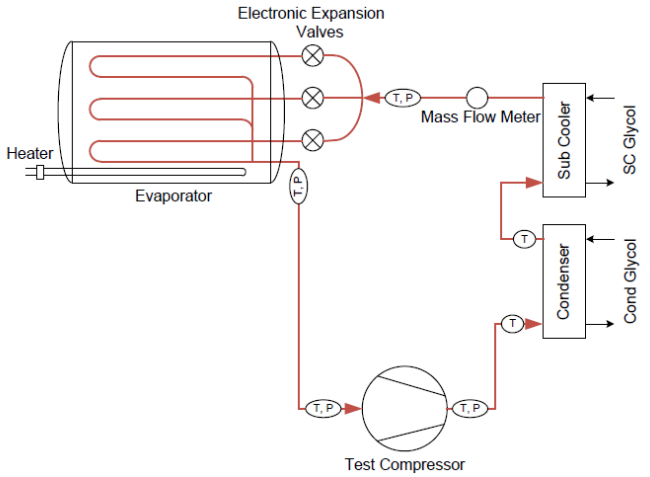
- Developed an Open Source LCCP Tool
  - Calculates $CO_2$ equivalent emissions of refrigeration systems
  - Web-based and desktop versions available at http://lccp.umd.edu/
  - Tool interfaces with third-party system modeling tools, load models and emissions and weather databases
  - Currently models medium-temperature, low-temperature and combined medium- and low-temperature refrigeration systems
  - Future version to model air-source heat pumps, chillers and secondary loop refrigeration systems



## Accomplishments:

- Compressor calorimeter evaluation of R-410A alternatives
  - Three low GWP alternatives
    - R-32, DR-5, L-41A
  - Scroll compressor
    - Air-conditioning and heat pump applications
  - Performance of alternatives are comparable to R-410A
- Supermarket refrigeration system installed
  - Compressor rack and condenser
  - Display cases
  - Fully instrumented




## Progress on Goals:

- Open source LCCP tool developed
  - International interest:
    - Demonstration of tool through webinars
    - Peer review of tool at national and international forums
      - » IIR Working Group on LCCP
      - » ASHRAE MTG on Low GWP Refrigerants
      - » Significant feedback regarding LCCP modeling methodology and $CO_2$ emissions factors
- Compressor calorimeter evaluation of R-404A alternatives in-progress (ARM-31a, D2Y-65, L-40)
- HPWH and Refrigerator tests with 1234yf
- Evaluation of alternative refrigerants in supermarket refrigeration system in-progress (R-404A, R-407F, R-1234yf blends)

# Project Plan & Schedule

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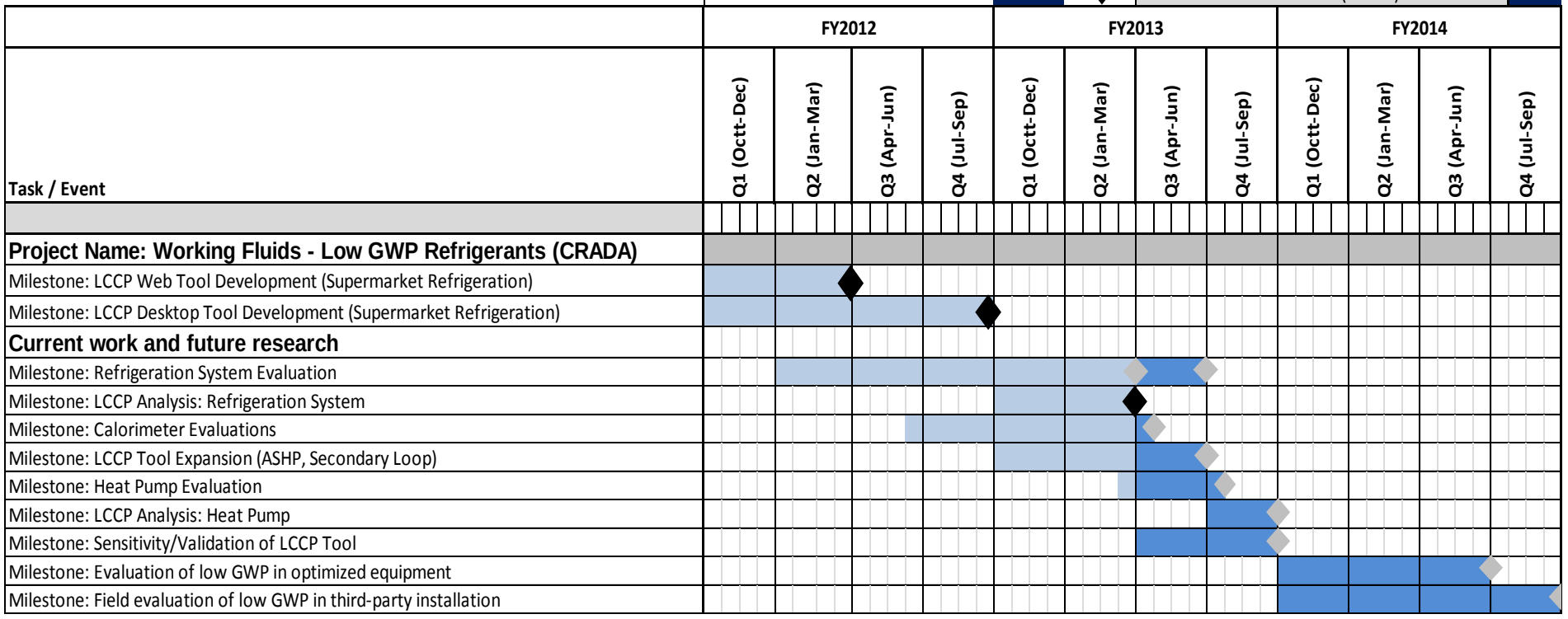
Original initiation date: September 1, 2011
Planned completion date: September 30, 2014

Refrigeration system evaluation delayed due to failure of false load heat exchanger

| Summary | |
|---|---|
| WBS Number or Agreement Number | |
| Project Number 18810 | |
| Agreement Number 6800 | |

| Legend |
|---|
| Work completed |
| Active Task |
| Milestones & Deliverables (Original Plan) |
| Milestones & Deliverables (Actual) |



# Project Budget



Project Budget: Total - $4100k (DOE)

Partner (Honeywell and DuPont) Budget - $4000k

Variances: None

Cost to Date: $3800k

Additional Funding: FY14 - $1000k

| Budget History | | | | | |
|---|---|---|---|---|---|
| FY2011 | | FY2012 | | FY2013 | |
| DOE | Cost-share | DOE | Cost-share | DOE | Cost-share |
| $2000k | $1400k | $1700k | $1200k | $400k | $1400k |

# Project Integration, Collaboration & Market Impact



## Partners, Subcontractors, and Collaborators:

- ORNL
  - Expertise in HVAC&R equipment performance evaluation and modeling
- Honeywell
  - Supplier of alternative lower GWP refrigerants
  - Expertise in refrigeration equipment selection, operation and modeling
- DuPont
  - Supplier of alternative lower GWP refrigerants
  - Expertise in refrigeration equipment selection, operation and modeling
- University of Maryland
  - LCCP Design Tool development
  - Expertise in modeling thermal systems

# Project Integration, Collaboration & Market Impact



## Technology Transfer, Deployment, Market Impact:

- Web-based LCCP tool has received over 450 unique hits since public release (March 2012)
  - User feedback has resulted in continuous improvement of the tool
- Several publications and a webinar publicizing the LCCP tool have generated international interest
- Results from calorimeter evaluations and supermarket refrigeration system will be used to guide decisions on use of alternative lower GWP refrigerants
  - Provide information for future regulations limiting/banning use of high GWP HFC refrigerants

# Project Integration, Collaboration & Market Impact



PUBLICATIONS

- Abdelaziz et al. 2012. Development of Low Global Warming Potential Refrigerant Solutions for Commercial Refrigeration Systems using a Life Cycle Climate Performance Design Tool. 14th International Refrigeration and Air Conditioning Conference, 16-19 July 2012, Purdue University, West Lafayette, IN.
- Sharma et al. 2013. Evaluation of Alternative Refrigerant Performance in Air to Refrigerant HXs. 2013 Winter ASHRAE Meeting, 26-30 January 2012, Dallas, TX.
- 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, 2-4 April 2013, Paris.

WEBINAR

- Introduction to Life Cycle Climate Performance (LCCP) Design Tool. Webinar hosted by University of Maryland, 8 Feb 2013.

FORUMS

- International Institute of Refrigeration (IIR) Working Party on LCCP Evaluation
- American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Multi-Disciplinary Task Group (MTG) on Alternative Low GWP Refrigerants

IMPACT

- Publications/webinars and ORNL's participation in IIR and ASHRAE forums has generated international interest in LCCP and the evaluation of low GWP refrigerants

## Next Steps and Future Plans:

- Complete compressor calorimeter evaluations of R-404A alternatives (ARM-31a, D2Y-65, L-40)
- Evaluate energy efficiency of alternative refrigerants in supermarket refrigeration system:
  - Baseline refrigerant (R-404A)
  - Low GWP refrigerants (R-407F, R-1234yf blends)
- Assess environmental impacts of alternative refrigerants using LCCP tool
- Provide recommendations to the HVAC&R community for selecting alternative low GWP refrigerants
- Additional efforts: Field evaluations of energy and LCCP performance of alternative low GWP refrigerants in HVAC&R equipment