13 EER Window Air Conditioner

2014 Building Technologies Office Peer Review

Broadway Apartment Building with WACs in NYC

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

Pradeep Bansal, bansalpk@ornl.gov
Oak Ridge National Laboratory

Project Summary

Timeline:

Start date: October 1, 2011

Planned end date: September 30, 2015

Key Milestones:

1. Complete preliminary simulations to predict design point performance; March 31, 2012
2. Testing of Lab Breadboard; September 30 2013
3. Design production ready unit; March 31 2014

Key Partners:

GE Appliances

Budget:

Total DOE $ to date: $1,365k

Total future DOE $: $100K

Target Market/Audience:

The primary market segment targeted by this project is the all residential and commercial applications where window air conditioners are utilized.

Project Goal:

This project aims to develop the next generation Window Air-Conditioner with energy efficiency ratio (EER) of 13 (or greater) that will result in 0.1 Quads per year technical potential of energy savings.

Purpose and Objectives

Problem Statement:

- **Develop a 13 EER window air conditioner (WAC)**
  1. EER is set between 9.7 and 9.8.
  2. Some older units have EER as low as 5!
  3. Variable speed compressors and advance controls won't show EER improvements (Indoor- 80°F, 51.5%RH, Outdoor- 95°F, 40.1% RH)
  4. A WAC typically costs between $99 - $599
  5. WAC is a less 'researched' topic in the literature
- **Thus improvements are limited to efficiency gains in the HXs, single speed compressor, and fan motors with minimal cost barrier!**

Target Market and Audience:

- Currently **57 million** WACs are used in the U.S.
  - Space **cooling and supplemental cooling** to improve comfort in older buildings that lack ducted central systems, and in cases where a central system upgrade is first -cost prohibitive
  - with annual energy consumption of about ~ **0.33 Quads**.

Purpose and Objectives

Impact of Project:

- **Impact:**
  - Technical potential of **0.1 Quads** per year of energy savings
  - Reduced greenhouse gas emissions
  - High EER (~13) WAC would raise the bar for future developments to build on
  - CRADA partner in position to launch high EER product in the market place

- **Impact Paths:**
  - **Near term:** Development and laboratory testing of
  - **Intermediate Term:** Publish research results at conferences
  - **Long term:** Market transformation from higher efficiency WACs

Approach

Approach:

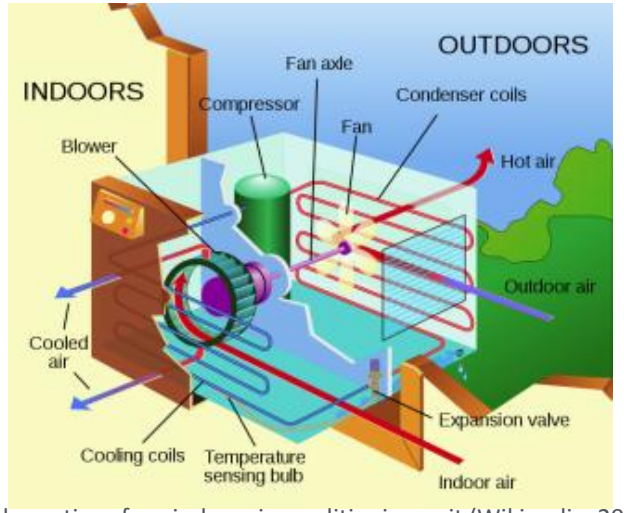
- **Characterize Baseline Unit Performance and Model development**
  - Characterize baseline WAC unit performance supplied by CRADA partner
  - Modify ORNL Heat Pump Design Model (HPDM) to include features specific to WAC such as “sling effect”; validate the model with baseline test data
  - Use modified ORNL HPDM to evaluate improvement strategies
  - Build successive WAC prototype(s) in consultation with CRADA partner for lab testing

- **Strategies for reduced energy consumption of WAC**
  - High efficiency compressor
  - High efficiency (ECM) fan motor
  - Advanced heat exchangers, including micro-channel HXs
  - Higher efficiency refrigerants
  - Reducing thermal bridging and internal air leakage

Approach

Approach:

- Produce a laboratory-scale prototype system to assess each advanced feature individually and then collectively
  - Test the prototype under standard DOE test conditions
- CRADA partner to arrange independent testing of prototype in a certified laboratory
- Make adjustments and test the final prototype
- Evaluate commercialization potential and conclude the project



Schematics of a window air conditioning unit (Wikipedia, 2013)

Approach

Key Issues/Features:

- Initial platform: 10,000 BTU/HR capacity and 10.8 EER
  - Highly compact & well engineered unit with excellent design features, such as:
    - 'slinger'
    - optimized heat exchangers
    - state-of-the-art R410A rotary compressor
    - minimal air leakage from the evaporator to the condenser side!

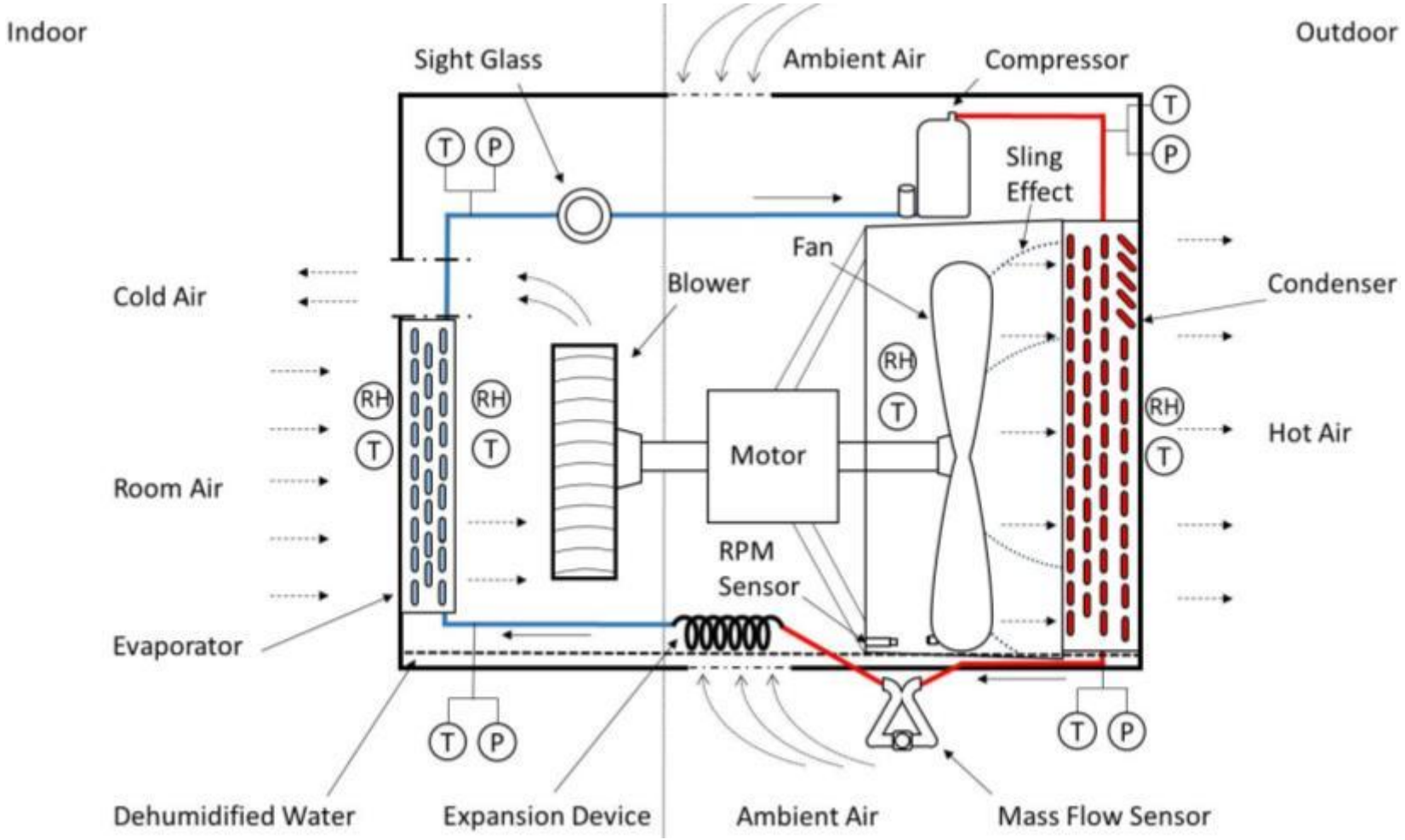
Approach

Distinctive Approach:

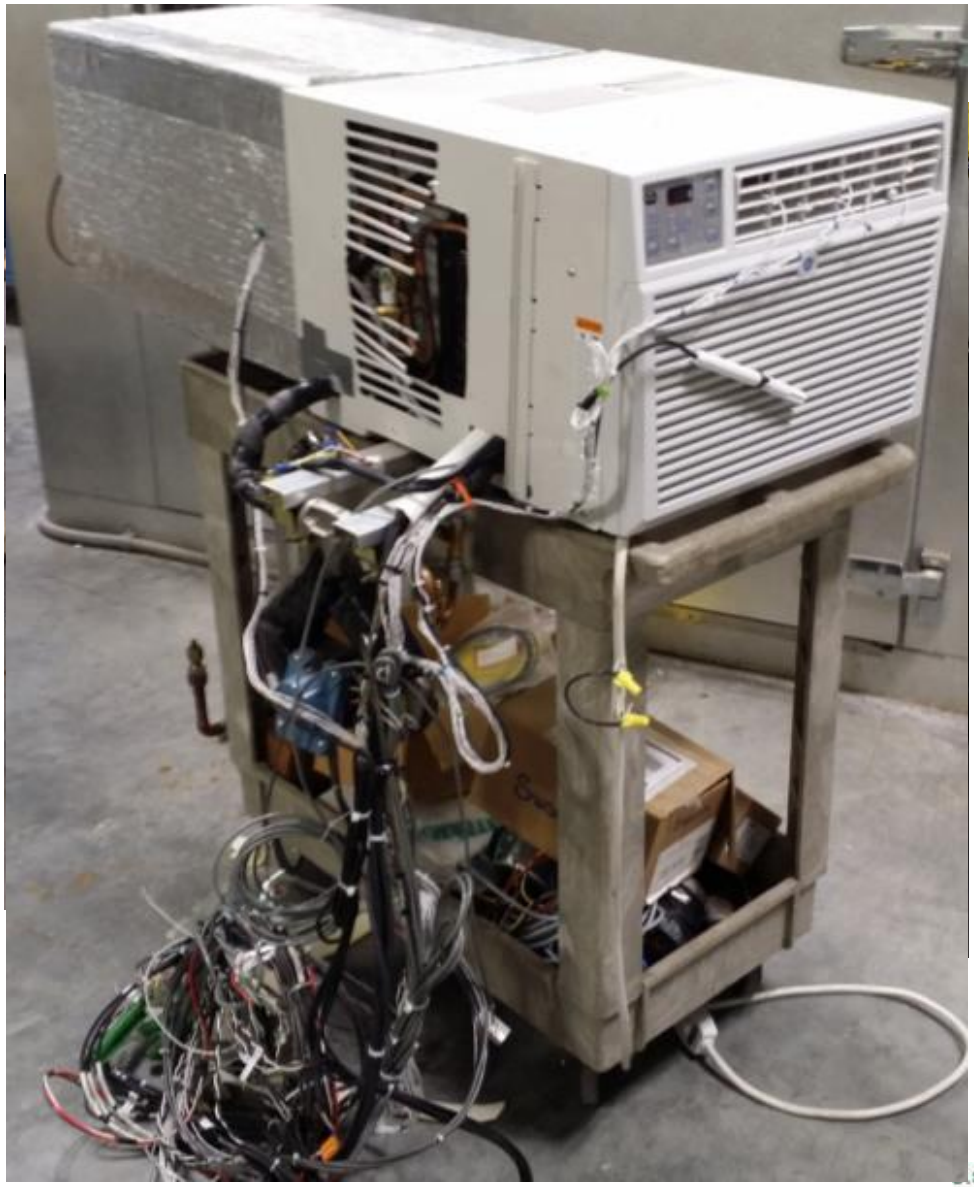
- Baseline testing of the Unit to achieve 10.8 EER
- Micro-channel HXs – unfortunately not suitable for WACs
- Replace the capillary tube with a needle valve for better control of refrigerant flow
- Replace AC fan motor with ECM DC fan motor
- Replace the original (10K) compressor with an 8K compressor, retain the original chaises, HXs (increase HX area for 8K) and AC fan motor.
- Experiment with 8K capacity and ECM fan motor
- Replace R410A [a mixture of R32 (70% by mole) and R125 (30% by mole)] with a low GWP mixture of R32 (85% by mole) and R125 (15%). R32 (100%) would be best but (i) its optimized compressor is currently not available for 115V, and (ii) a less flammable refrigerant mixture of R32/R125 was preferred by the CRADA partner for the domestic market.

Progress and Accomplishments

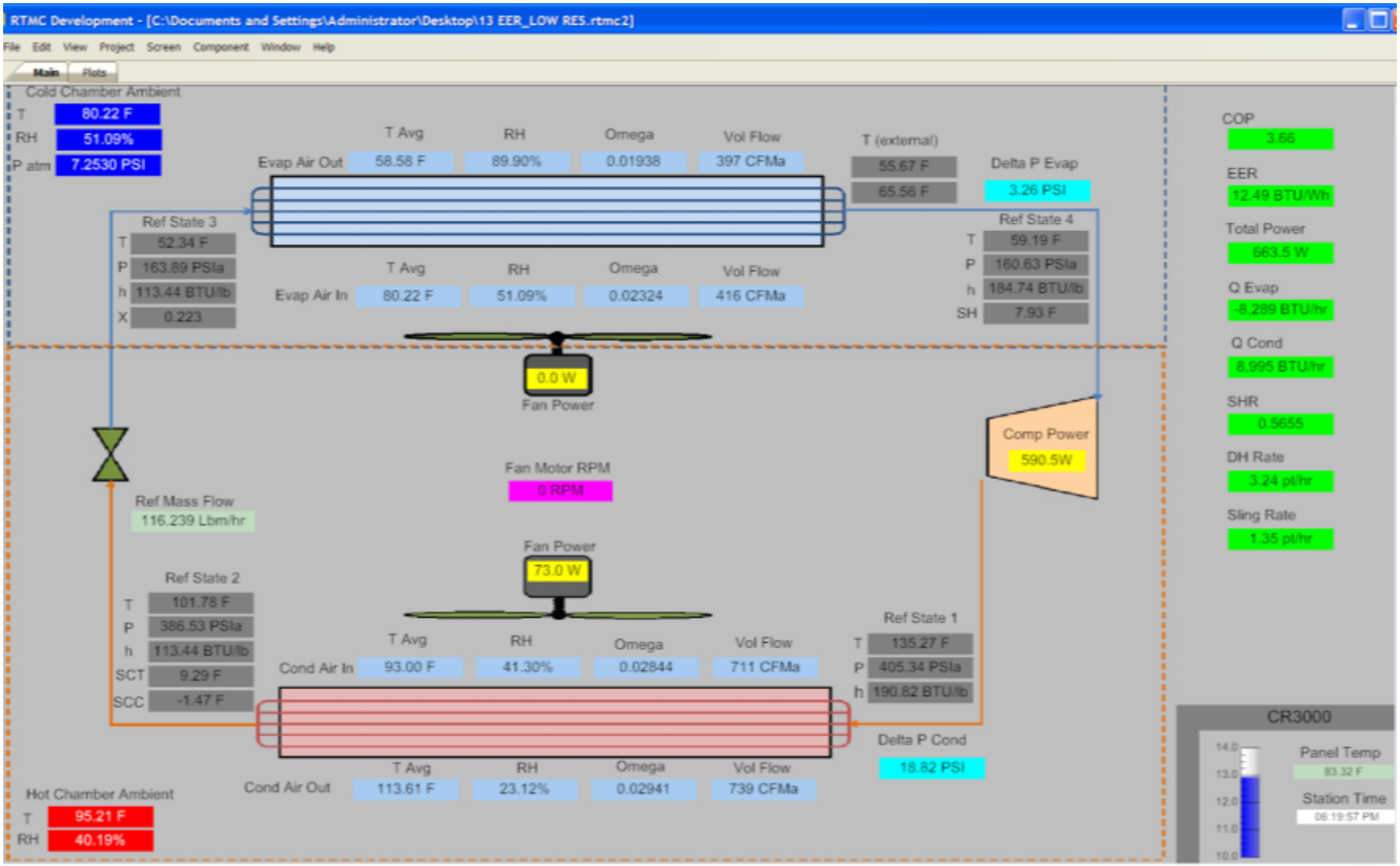
Schematics of Window Air Conditioner Prototype with Instrumentation



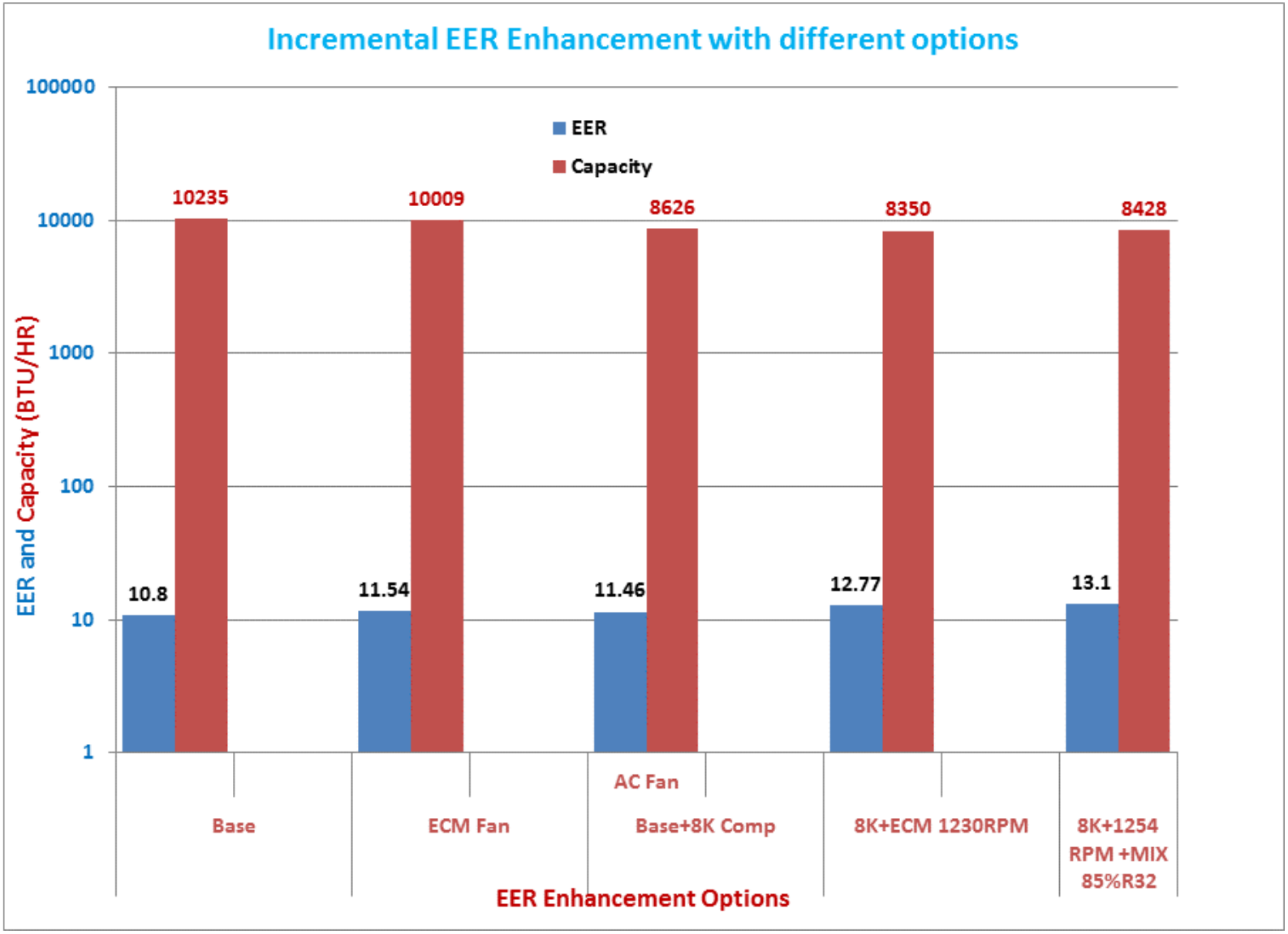
Progress and Accomplishments



Progress and Accomplishments



Progress and Accomplishments



Progress and Accomplishments

Lessons Learned:

- EER of 13.0 was achieved.
- The performance is quite sensitive to superheat
- Performance could be better if more efficient rotary compressors were available
- Emerging refrigerants that have low GWP may also assist in enhancing the EER further.

Project Integration and Collaboration

Partners, Subcontractors, and Collaborators:

- ORNL
  - Expertise in HVAC&R equipment performa evaluation and modeling
- GE Appliance – CRADA Partner
  - One of the major US appliance manufacturer
- Modine

Communications:

- PUBLICATIONS
  - Bo Shen and Pradeep Bansal, "Assessment of environmentally friendly refrigerants for window air conditioners," to be presented at 15th International Refrigeration and Air Conditioning Conference at Purdue, West Lafayette, IN, USA, July 14-17, 2014.

Next Steps and Future Plans

Next Steps and Future Plans:

- Evaluate performance of prototype refrigeration system in a certified independent laboratory
- Modify the unit with any adjustments and finalize the design
- Hopefully **BTO Standards program would raise the MEPS** to encourage CRADA partner to put a higher EER unit into production

Discuss future project activities and impacts. Describe tasks that could be added or expanded and impacts.

- Assess the performance advantage of the final prototype with-
  - Emerging low GWP refrigerants including R32 (100%) when their 115 V compressors are available
  - Test with other fan blade types

REFERENCE SLIDES

Project Budget

Project Budget: DOE total $1,465k FY12-15
Cost to Date: ~$1,268k through February 2014
Additional Funding: None expected.

Budget History					
FY2012 – FY2013 (past)		FY2014 (current)		FY2015 – FY2016 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$1,065k	*	$300k	*	$100k	*

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

Project Plan and Schedule