Better Buildings
U.S. DEPARTMENT OF ENERGY

Better Buildings Summit Space Conditioning:

Next Generation HVAC and the Advanced RTU Campaign lead to Incredible Savings

Michael Deru
NREL

Washington, DC
May 8, 1:30-3:00

Agenda

- Introductions
- BTO’s HVAC, WH and Appliance R&D – Antonio Buoza, DOE
- Advanced RTU Campaign
  - Review recent progress and recognize achievements
  - RTU savings from advanced planning – Scott Williams, Target
  - Open discussion of challenges and solutions
- Wrap up

Meeting Goals

- Learn about DOE HVAC R&D efforts
- Advanced RTU Campaign overview and progress
- Learn about savings from a whole-building approach to RTU replacements
- Identify potential projects for 2015

BTO's HVAC, WH and Appliance R&D

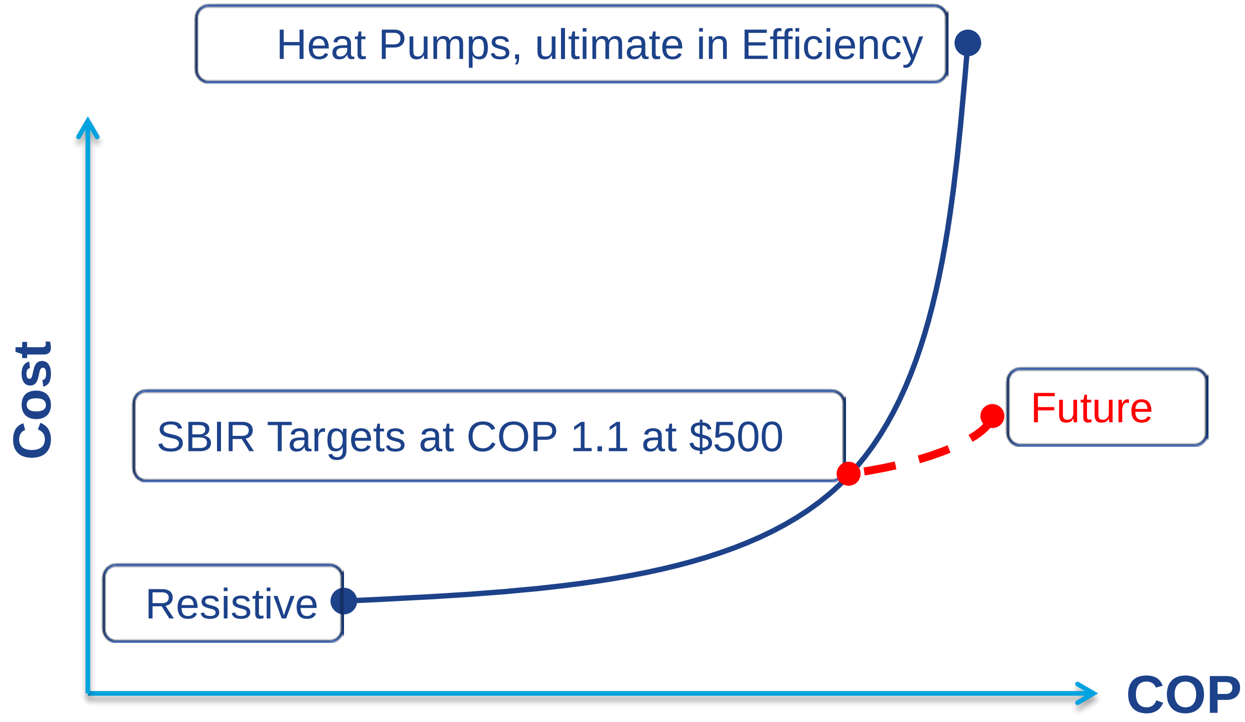
Antonio M. Bouza

U.S. DEPARTMENT OF ENERGY

Program Goals:

- *Support BTO's goals to achieve 50 percent building energy savings*
  - By 2020, develop technologies enabling 20 percent energy savings in HVAC; 30 percent energy savings in water heating, and 10 percent energy savings in appliances
  - By 2030, develop technologies enabling 40 percent energy savings in HVAC; 60 percent energy savings in water heating, and 20 percent energy savings in appliances
- Maintain the competitiveness of American industry

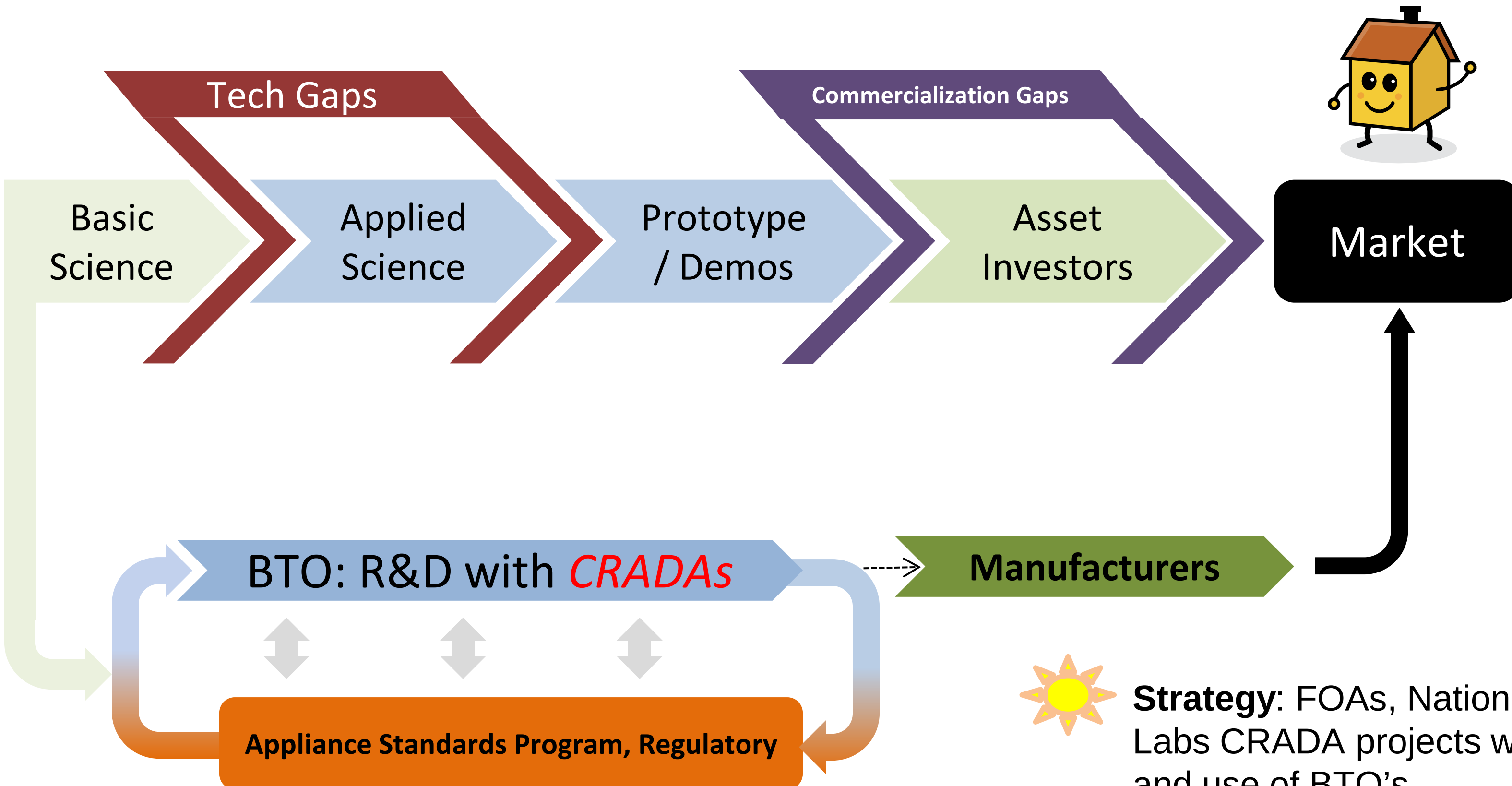
Water Heating *example*: Two prong approach



Two-pronged approach:

- Accelerate the development of ***near term technologies*** that have the potential to save significant amount of energy (which may include cost reduction activities)
- Accelerate the development of the ***next generation of technologies*** that have the potential of “leapfrogging” existing technologies by pursuing entirely new approaches that offer better performance, with reduced environment burdens.

HVAC, Water Heating and Appliance R&D



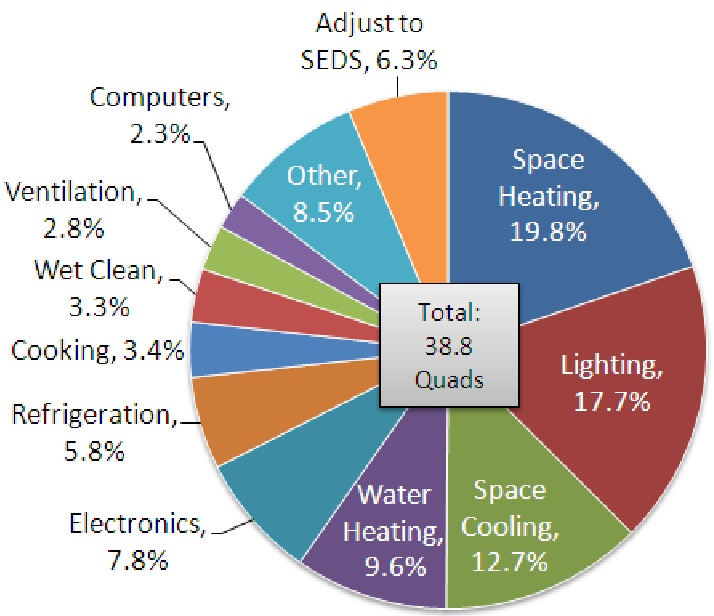
Strategy: FOAs, National Labs CRADA projects with and use of BTO's integration teams with research homes

CRADA : Collaborative Research and Development Agreement

The challenge…

- In addition to pursuing individual end-uses solutions integrated solution are also pursued
- In which energy cascading (using the waste heat from one process as the source of energy for another) is utilized
- Optimizing energy use in a building, a global optimum point instead of just a local minimum (single end-use)
- Board approach also includes pursing crosscutting technologies that enable better HVAC, water heating and appliances
- A fast way to develop new technologies and get them into the market is through CRADAs and FOAs (with manufactures as team members)
- Program seeks to build upon its past and speed the market availability and acceptance of new technologies
- Not working in vacuum, most equipment is covered by appliance standards

Buildings Primary Energy Consumption



Integrated Heat Pump (IHP) Technologies, a huge opportunity

Integrated Approach

- Energy cascading is the process of using the waste (or residual) heat from one process as the energy source for another
- Concept is to merge several end-use together, generate a new solution, coupling things together
- Good example exists today from BTO's integrated heat pump work where the waste heat from the AC is used to heat water for free with energy saving potentials approaching 50%
- HVAC Integrated Heat Pump (IHP) Technologies:
  - Air Source (AS)-IHP (2-speed), ***40% to 45%*** energy savings vs. min efficiency equipment suite
  - AS-IHP (variable speed), ***45% to 55%*** energy savings vs. min efficiency equipment suite
  - Multifunction Natural Gas-driven HP (10 to 17.5 kW), 70% peak demand savings; 40% source energy savings vs. minimum efficiency electric heat pump, with power generation
  - Thermolift, one year effort to demonstrate Vuilleumier heat pump (VHP) technology
  - Developing Standard Method of Test (MOT) for IHP, working with ASHRAE/AHRI

Today's IHP technology from BTO…
more products in the pipeline

ClimateMaster

- Multifunction Electric Heat Pumps, GS-IHP
- Space conditioning, water heating, dehumidification, and ventilation
- Trilogy 40 Q-Mode™ could save about 60% of annual energy use and cost for space conditioning and water heating in residential applications
- 30% more efficient than any other available ground-source heat pump
- Broke the 40 EER Barrier in the USA
- Award Winning

Regional Solutions (Cold Climates)

Cold Climate Heat Pump Technology

- Target markets: Cold climate regions
  - Where natural gas is unavailable or want to displace oil heat
  - Improving the performance of natural gas systems
- Unlike standard heat pumps, can maintain capacity and efficiency (COP) at low ambient temperatures
- Technology includes multi-stage compressors, non-HFC refrigerants (e.g. CO_2) and absorption systems.
- If electricity generated from low carbon sources, can reduce carbon emissions from gas heating

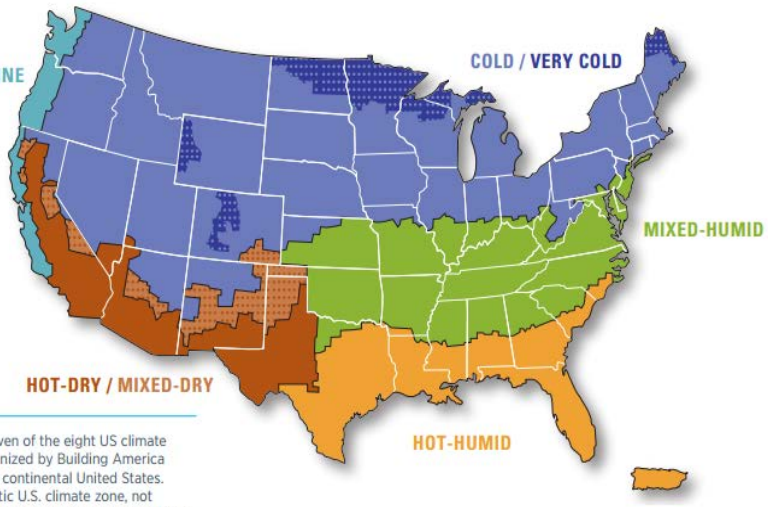


Figure 1. Seven of the eight US climate zones recognized by Building America occur in the continental United States. The sub-arctic U.S. climate zone, not shown on the map, appears only in Alaska.

Image Source: "High Performance Home Technologies – Guide to Determining Climate Regions by County." PNNL and ORNL. August 2010.

Regional Solutions (Cold Climates)

DOE's targets

- Setting the standard for cold climate performance
- Targets for both electrical and natural gas systems

Current BTO Activities

- IEA Annex 41, Cold Climate Heat Pumps
- Development of a High Performance Cold Climate Heat Pump (Purdue University)
- Supercharger for Heat Pumps in Cold Climates (Mechanical Solutions, Inc.)
- Cold Climate Heat Pump (CRADA Project at ORNL)
- High Performance Commercial Cold Climate Heat Pump (CCCHP) , (United Technologies Research Center)
- Residential Cold Climate Heat Pump with Variable Speed Boosted Compression, (Unico)
- Natural Refrigerant High Performance Heat Pump for Commercial Applications, (S-RAM Dynamics)
- Natural Gas Air Conditioner and Heat Pump, (ThermoLift, Inc., Vuilleumier cycle)
- Low-Cost Gas Heat Pump For Building Space Heating, (Stone Mountain Technologies, Inc.)

DOE Cold Climate Heat Pump R&D Performance Targets (Electricity)

Ambient Temperature (°F)	COP	Maximum Capacity Decrease from Nominal (%)
47	4	0
17	3.5	10
-13	3	25

DOE Cold Climate Heat Pump R&D Performance Targets (Natural Gas)*

Ambient Temperature (°F)	COP	Maximum Capacity Decrease from Nominal (%)
47	1.3	0
17	1.15	20
-13	1.0	50

COP based on higher heating value of natural gas

Regional Solutions (Hot, Humid and Mixed)

Separate Sensible and Latent Cooling AC Systems

- Target markets: Large portion of the current building stock is located in hot and humid environments, which have the potential to create large latent loads within buildings
- HVAC was the largest energy end use for U.S. residential and commercial buildings, consuming approximately 37.3% (or ~15.05 Quads) of the total energy used in buildings.
- Significant savings, on the order of 50-90%, are possible for technologies optimized for specific climates and applications (DOE's QTR)
- Air conditioning (AC) is more than just cooling air
- Total cooling load, composed of both the sensible load (temperature) and the latent load (humidity)
- Conventional air conditioning (AC) systems have limited control of sensible cooling and latent cooling capacities

Current BTO Activities

- DOE workshop, Spring 2013
- Next Steps being worked on… FOA Topic?

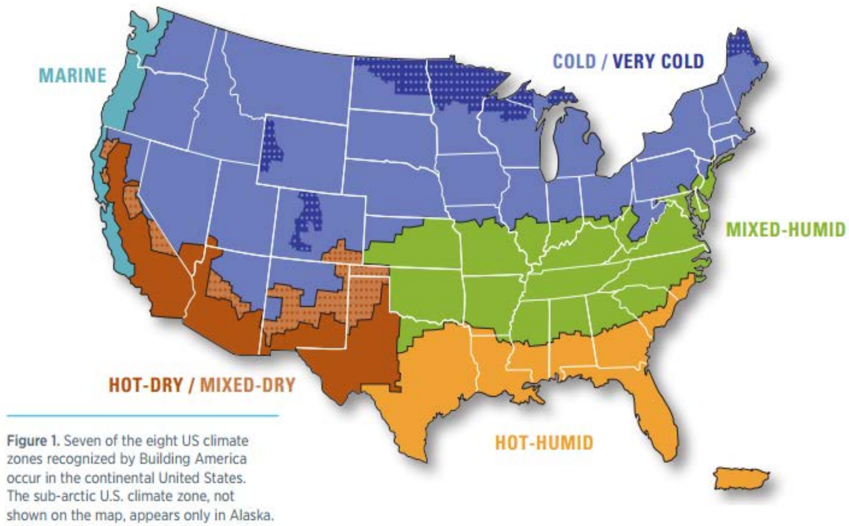


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Image Source: "High Performance Home Technologies – Guide to Determining Climate Regions by County." PNNL and ORNL. August 2010.

Climate Zone	Percentage of Homes with AC (2009), by Climate Zone
Very Cold / Cold	34%
Mixed-Humid	**31%**
Mixed-Dry / Hot-Dry	12%
Hot-Humid	**17%**
Marine	6%

Source: 2009 Residential Energy Consumption Survey (RECS), U.S. Energy Information Administration, Table HC7.6

Heat Pump Technologies, still a huge opportunity for *Water Heating*

Heat Pump Water Heaters

- Electric Heat Pump Water Heater (HPWH) with low-GWP option (**CO_2**), 15% energy savings compared to Energy Star HPWH and better performance in colder climates
- Absorption (ABS) HPWH, 45% energy savings compared to Energy Star Natural Gas Storage WH
- Next generation of water heating solutions
  - Address the high first cost issue
  - Sheetak (Thermoelectric, **TE**) and Xergy (Electrochemical compressor technology, **EC**), SBIR projects are planting the seeds of change towards a non-vapor compression future
  - Modular designs for greater flexibility

Today's technology from BTO

HVAC, WH & Appliance: Non-vapor-compression technologies

What comes after vapor compression technology?

- Absorption Heat Pump, Adsorption Heat Pump, Bernoulli Heat Pump, Brayton Heat Pump, Critical-Flow Refrigeration Cycle, Duplex-Stirling Cycle, Ejector Heat Pump, Electrocaloric, Electro Chemical Compression (ECC) technology, Evaporative Cooling, Evaporative Liquid Desiccant A/C, Magnetocaloric, Membrane Heat Pump, Pulse-Tube Refrigeration, Standalone Liquid Desiccant A/C, Standalone Solid Desiccant A/C, Thermoacoustic, Thermoelastic, Thermoelectric, Thermotunneling, Vuilleumier Heat Pump and Vortex-Tube Cooling

Desirable characteristics:

- Good LCCP (Life Cycle Climate Performance), continuous response to part-load conditions, integrated thermal storage, minimal/zero water consumption, cost effective, reduced size/weight and readily available materials

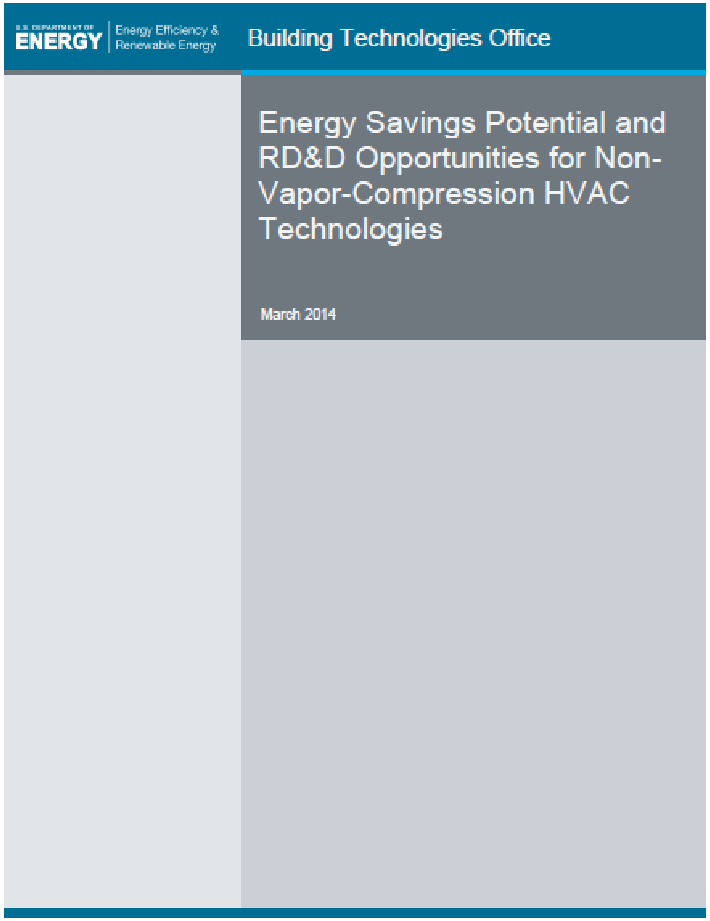
Moving towards non-vapor-compression air conditioning technologies

- Potential of “leapfrogging” existing HVAC technologies by pursuing entirely new approaches that offer better performance with reduced environment burden
- Use water heating as a starting point towards future AC technologies
  - Non-vapor compression water heating solutions, are near term viable solutions… while going beyond resistive heating
  - Xergy and Sheetak SBIR projects are planting the seeds of change towards a non-vapor compression future

Report: Non-vapor-compression technology

While vapor-compression technologies have served heating, ventilation, and air-conditioning (HVAC) needs very effectively, and have been the dominant HVAC technology for close to 100 years, the conventional refrigerants used in vapor-compression equipment contribute to global climate change when released to the atmosphere.

- Identifies alternatives to vapor-compression technology in residential and commercial HVAC applications
- Characterizes these technologies based on their technical energy savings potential, development status, non-energy benefits, and other factors affecting end-user acceptance and their ability to compete with conventional vapor-compression systems
- Makes specific research, development, and deployment (RD&D) recommendations to support further development of these technologies, should DOE choose to support non-vapor-compression technology further.


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

Building Technologies Office

Energy Savings Potential and RD&D Opportunities for Non-Vapor-Compression HVAC Technologies

March 2014

http://energy.gov/eere/buildings/downloads/non-vapor-compression-hvac-technologies-report

Advanced RTU Campaign

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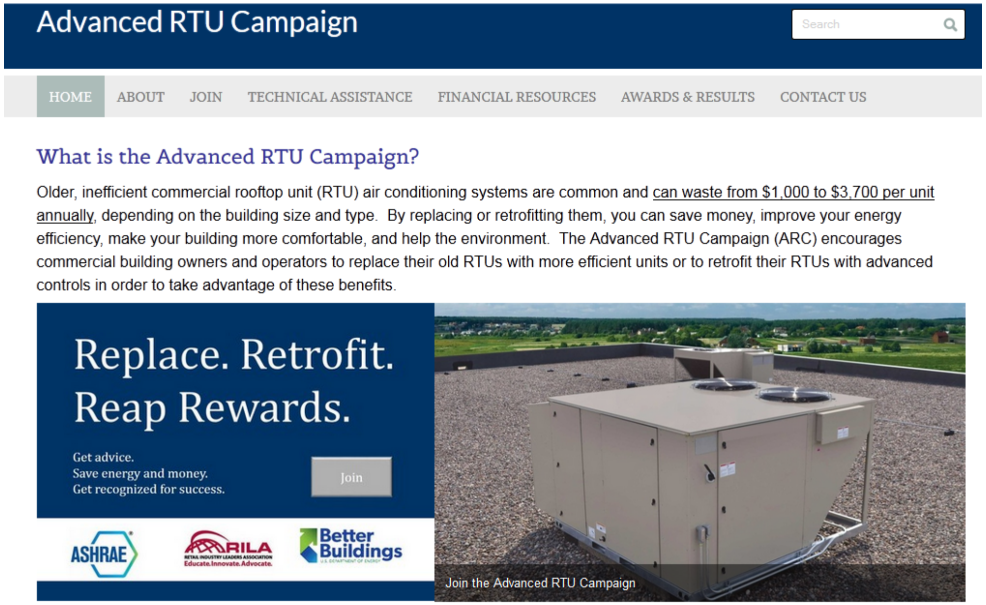
Advanced RTU Campaign

- Launched May 30, 2013
- Runs through 2015
- Promotion of high-efficiency RTU solutions
  - High-efficiency replacements and new installations – CEE Tier 2 and above
  - Advanced control retrofits
  - Quality Installation and Quality Maintenance
- Organizing Partners →



ASHRAE

RILA RETAIL INDUSTRY LEADERS ASSOCIATION Educate. Innovate. Advocate.

Better Buildings U.S. DEPARTMENT OF ENERGY

Supporting Partners (83)

Utility or Efficiency Organization

- 360 Energy Group, LLC
- Burlington Electric Department
- Columbia Water & Light
- Commercial Building Consortium
- DNV GL
- Efficiency Vermont
- Energy Center of Wisconsin
- Fort Campbell DPW Utilities
- HVACRedu.net
- New Buildings Institute
- Nicor Gas
- NYSERDA
- RealWinWin, Inc.
- Red Rocks Community College
- Rocky Mountain Education Center
- SPEER
- SWEEP

Trade or Industry Organization

- BOMA International
- HARDI
- International Ground Source Heat Pump Assoc.
- NAIOP
- PRSM

RTU Supplier

- cfm Distributors, Inc.
- Coburn Supply
- Temperature Equipment Corp.

Manufacturer

- Allied Commercial
- BELIMO Americas
- Carrier
- Daikin McQuay
- Emerson
- Enerfit
- Ingersoll Rand (Trane)
- Integrated Comfort Inc.
- Lennox
- Mitsubishi Electric Cooling & Heating
- NexRev
- Transformative Wave Technologies

Consultant/Contractor/Service Provider

- 4Sight Energy Solutions
- Advantek Consulting Engineering, Inc.
- Air Comfort Corporation
- Aire Rite Air Conditioning and Refrigeration
- All State Air Control Sales And Service Inc.
- Anura Systems Inc
- Arbogast Energy Auditing
- Automated Decision
- Bay Air Systems Inc.
- Benchmark Group
- Better Efficiency Solutions & Technologies (BEST)
- Buffalo Energy, Inc
- Capital Engineering
- Capitol Engineering Company
- ClimaCheck
- Comfort Systems USA - VA, NC, SC
- Comprehensive Energy Serivices

Consultant/Contractor/Service Provider

- Cooper Oates Air Conditioning
- Crosby-Brownie
- Design-Aire Engineering, Inc.
- Ecova
- EMCOR Facility Services
- Emerging Energy Solutions
- Fusion Systems Engineering
- Greenspeed Energy Solutions
- GridNavigator
- Grunau Company
- Hauser Mechanical
- Horizon Energy Services
- Incenergy
- JashGroup
- John Chardoul, P.E. Consulting
- M&E Engineers
- MacDonald-Miller Facility Solutions
- Magran
- Mechanical Design Studio Inc.
- Murphy & Miller, Inc.
- Rise Engineering
- SEDESCO
- Solution Dynamics
- Southland Industries
- The Wasmer Company
- Total Performance Diagnostics
- Van Boerum & Frank Associates, Inc.
- Vital Engineering Corporation
- W.L. Gary Company Inc
- WorkingBuildings of North Carolina PLLC

Participating Partners (27)

Adidas
Belk, Inc.
Cadmus
City of Greensboro
City Of St Cloud Florida
Drury Southwest Inc.
Empire Screen Printing
Johnstone Supply
JT Katrakis & Associates
Kallen & Lemelson Engineers
L-3 Communications - CS West
Macy's, Inc.
NASA
National Grid
Newhall Property Partnership
PetSmart
REI
Riverdale Country School
Taitem Engineering
Target
The Campus At Marlborough- Hines Global REIT
West Holt Medical Services
Westmoreland County Community College
Whole Foods

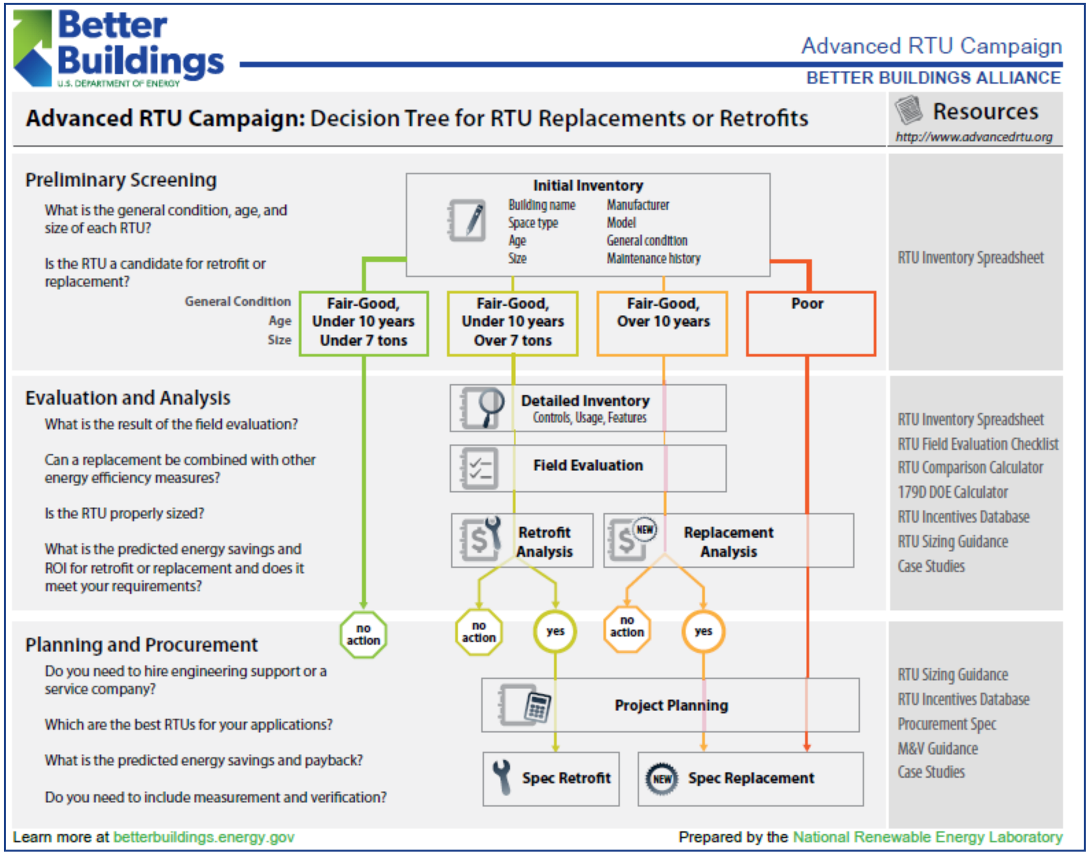
Advanced RTU Campaign Impacts

- Webinars – 12, over 1,100 participants
- In the News – 25 articles by third parties
  - "Facility managers who have already done low-hanging-fruit lighting upgrades know the RTU is the largest target." Greentech Media, Dec 13, 2013.
- Installations and energy saved

Year	High-Efficiency RTU Installations	RTU Retrofits	Estimated Annual Savings (kWh)
2013	7,080	6,279	137,310,863
2014 commitments	7,096	7,000	144,059,982

Advanced RTU Campaign Resources

- Website
- RTU evaluation resources
- Calculators
- Specifications
- Case studies



RTU Evaluation Process

Gather Information

- ❑ **Initial RTU Inventory:** RTU Inventory Spreadsheet
- ❑ **Preliminary Screening:** Bin RTUs for retrofit, replacement, or no action
- ❑ **Detailed Inventory:** RTU Inventory Spreadsheet
- ❑ **Visual-Based Field Evaluation:** RTU Field Evaluation Checklist

Analyze

- ❑ **Analysis:** make the business case and prioritize actions. RTU Incentives Database, RTU Comparison Calculator, 179D DOE Calculator, RTU Sizing Guidance, and ARC Case Studies

Plan

- ❑ **Project Planning:** See the list of ARC Supporting Partners

Take Action

- ❑ **Procurement:** Procurement Specifications for guidance
- ❑ **Measurement and Verification (M&V):** Use the M&V Guidance

RTU Inventory Spreadsheet

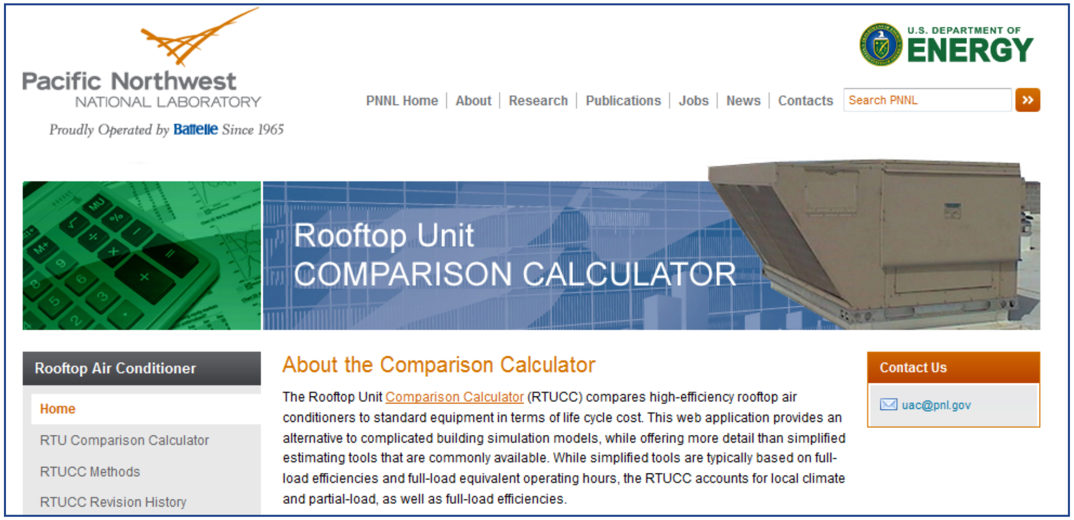
- Starting point – modify to fit your needs
- Combines
  - Preliminary Screening
  - Detailed Inventory
  - Field Evaluation results

Advanced RTU Campaign
Prepared by the National Renewable Energy Laboratory

Rooftop Unit Inventory Spreadsheet
Version 2.0, 10/28/2013

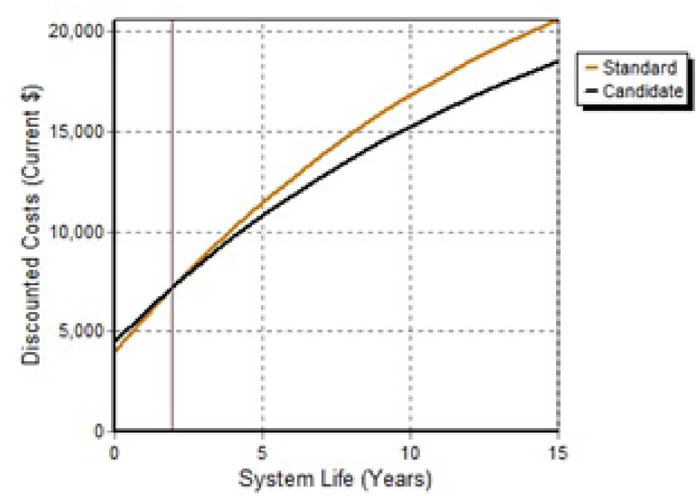
		RTU #1	RTU #2	RTU #3
Preliminary Screening	Building ID			
	Space type			
	Age or installation date			
	Cooling capacity (ton, Btu/h, W)			
	Manufacturer			
	Model number			
	Serial number			
	Original nominal efficiency (EER, SEER, IEER)			
	Maintenance history			
	Major repairs			
	General condition (good, fair, poor)			
	Initial Screening Recommendation			
Detailed Inventory	Area served (ft^2)			
	ft2/ton)			
	Operational hours			
	RTU control			
	Evaporator fan control			
	Evaporator fan size (hp)			
	Evaporator fan voltage and phases			
	Economizer control (none for no economizer)			
	Refrigerant type			
	Refrigerant quantity (lb, kg)			
	Heating type			
	Additional features (ERV, DCV, ...)			
Results from Field Evaluations	Condenser coil condition			
	Refrigerant piping condition			
	Cabinet condition			
	Evaporator coil condition			
	Burner section condition			
	Compressor condition			
	Air dampers condition (OA, economizer, and return air)			
	Fan motors condition			
	Recommendation			
	Priority			
	Notes			

Rooftop Unit Comparison Calculator



RESULTS

ALBANY, NY	Candidate	Standard	Savings
Annual Energy Consumption (kWhrs)	9,469	11,880	2,410
Annual Operating Cost ($)	1,536	1,826	289
15 Year Life Cycle Cost ($)	18,493	20,627	2,134
Annualized Cost ($)	2,030	2,265	234
Net Present Value ($)	2,134		
Payback (yrs)	1.9		
Rate of Return (%)	57.79		
Savings to Investment Ratio (SIR)	5.27		



- www.pnnl.gov/uac
- Simple to use and quick results

Whole Building Approach to RTUs

Scott Williams, Target
Group Manager of Mechanical Engineering

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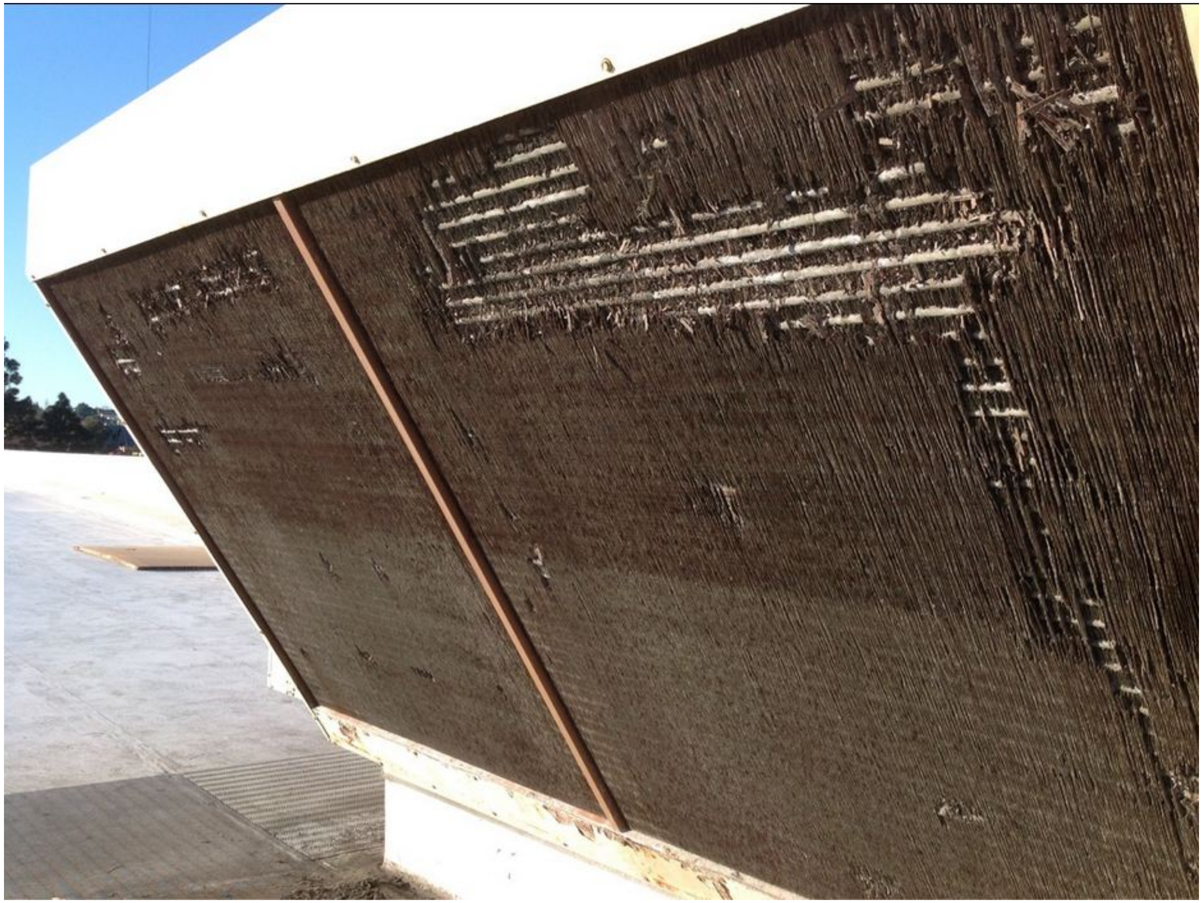
Target Experience – RTU Replacement

Scott D. Williams, PE - Target Engineering



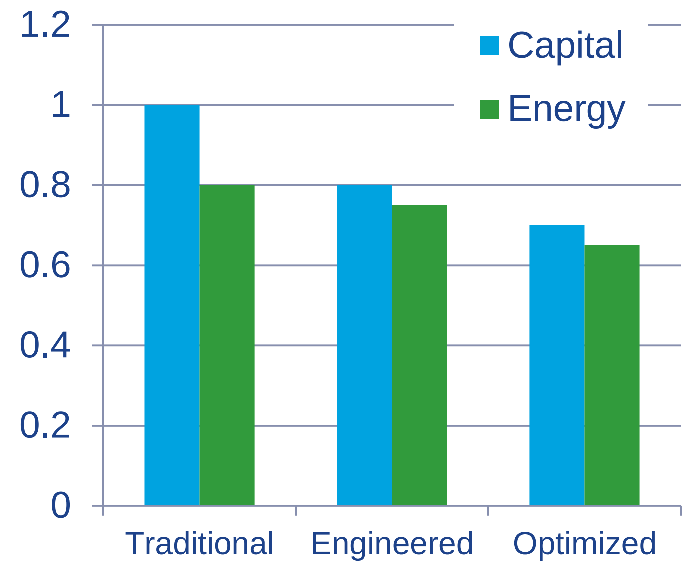
Target Experience – RTU Replacement

- Replacement candidates based on age, work order history, site survey. Typically 20 – 25 yr.
- Optimized re-engineered approach to RTU replacement can save 30% of capital cost versus one for one replacement and cut ongoing HVAC energy and operations cost by 40%.

- *It's much more than just buying high EER!*

Target Experience – RTU Replacement

- Traditional
  - One-for-one replacement with higher efficiency RTU
- Engineered
  - Estimate loads for existing building
  - Downsize RTUs save capital, improve performance
- Optimized Re-Engineered
  - Determine current building HVAC loads
  - Re-engineer HVAC system
    - Up-size, down-size, remove, re-balance,
    - Air flow effectiveness
    - Improve reliability, reduce O&M,



Target Experience – RTU Replacement

Example of Re-engineered Rightsizing:

- Existing 19 RTUs 297 Tons
- Replacement 15 RTUs 198 Tons
- At $1500 per ton, saves $150K capital

How?

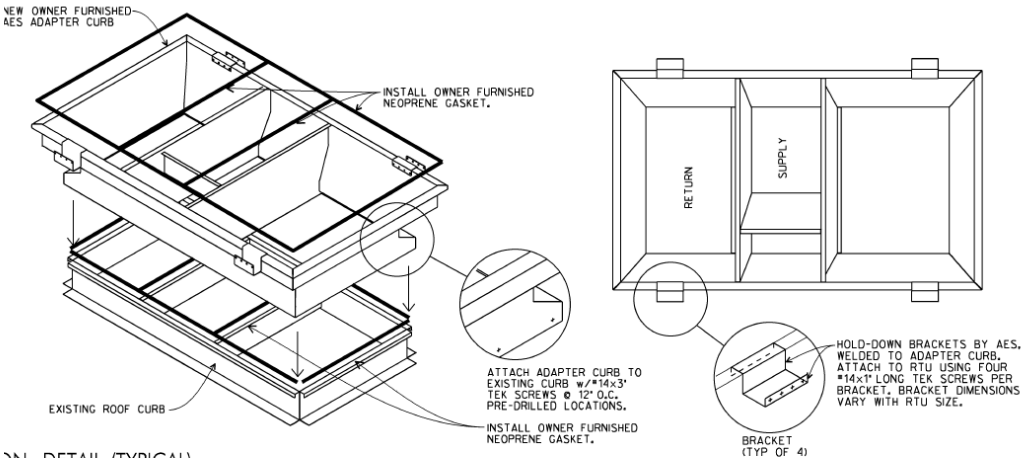
- Reduced lighting loads; better roof insulation; optimized ventilation; more accurate load calculations.

Other benefits:

- Provides ongoing energy and O&M reduction
- Better HVAC performance – reduced cycling of equipment

Target Experience – Other Benefits

- Airflow effectiveness to assure good IAQ and even temperature
- Sensors from removed RTUs control remaining RTUs
- Lower CFM/ton allows more tonnage on existing ductwork
- Complete test and balance of RTU.
- Control system rewire to improve reliably with fewer RTUs.
- Custom curb adapter to reduce friction loss
- Variable speed air supply with constant ventilation



Discussion

- Questions
- Comments

Wrap Up

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Discussion Questions

Backup slides

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Report: Radial Sandia Cooler

This market assessment and commercialization report characterizes and assesses the market potential of the rotating heat exchanger technology developed at Sandia National Laboratories (SNL), known as the Radial Sandia Cooler.

- Novel, motor-driven, rotating, finned heat exchanger technology
- Evaluated for the residential, commercial, industrial, and transportation markets
- Recommendations for commercialization

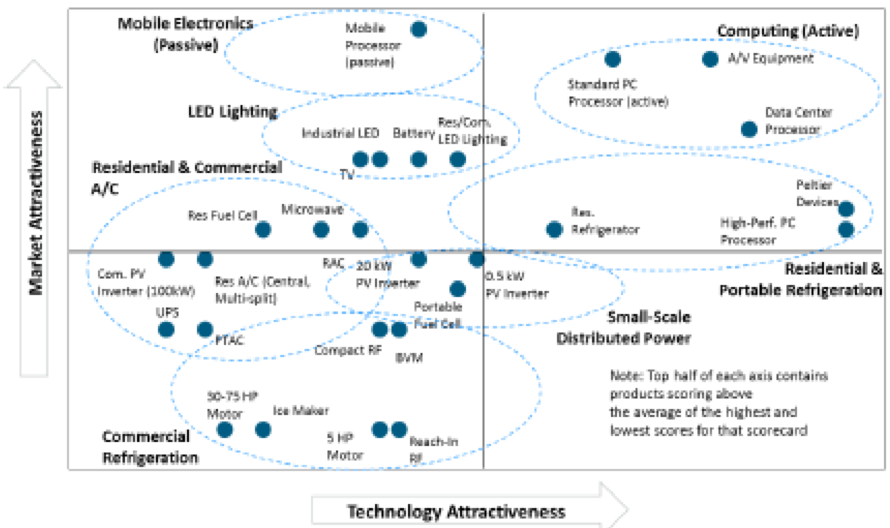

Figure 2-14. Scoring map, by product category

http://energy.gov/eere/buildings/downloads/radial-sandia-cooler-report

HVAC, WH and Appliance R&D

Current Projects:

HVAC

- 13 EER Window Air Conditioner (ORNL)
- Advanced Variable-Speed Air-Source IHP (ORNL)
- Cold Climate Heat Pump (ORNL)
- Develop Standard Method of Test (ORNL)
- IEA Collaboration (ORNL)
- Multi-Function Fuel-Fired Heat Pump (ORNL)
- Next Generation RTU (ORNL)
- Advanced Rotating Heat Exchangers (ORNL and SNL)
- High Performance Commercial Cold Climate Heat Pump (CCCHP), (UTRC, DE-FOA-0000621)
- Residential Cold Climate Heat Pump, (Unico, DE-FOA-0000621)
- Low-Cost Gas Heat Pump For Building Space Heating (Stone Mountain Technologies, DE-FOA-0000621)
- Natural Refrigerant High Performance Heat Pump for Commercial Applications (S-RAM Dynamics, DE-FOA-0000823)
- Rotating Heat Exchanger Technology for Residential HVAC (SNL, DE-FOA-0000823)
- Natural Gas Air Conditioner and Heat Pump (ThermoLift, DE-FOA-0000823)
- Thermodynamic Evaluation of Low-Global Warming Potential Refrigerants (NIST)

Water Heating

- Absorption HPWH (ORNL)
- CO2 HPWH (ORNL)
- Adsorption Heat Pump Water Heater (ORNL)

Appliances, and other

- Heat Pump Dryer (ORNL)
- High Efficiency Low Emission Refrigeration System (ORNL)
- Working Fluids Low GWP Refrigerants (ORNL)
- Advanced Compressor Technologies (ORNL)
- Magnetic Refrigeration (ORNL)
- Miniaturized Air to Refrigerant Heat Exchangers (UMD, DE-FOA-0000621)

HVAC, WH and Appliance R&D

Past Activities (ARRA):

HVAC	Water Heating	Working Fluids
• Development of a High Performance Cold Climate Heat Pump (*Purdue University and Emerson Climate Technologies*) • Development of a Non-CFC-based, Critical Flow, Non-Vapor Compression Cooling Cycle (*PAX Streamline, Inc. and Kansas State University*) • Improving Best Air Conditioner Efficiency by 20-30% through a High Efficiency Fan and Diffuser Stage Coupled with an Evaporative Condenser Pre-Cooler (*Florida Solar Energy Center*) • Advanced Magnetic Refrigerant Materials (*GE Global Research*) • Optimization of Regenerators for Active Magnetic Regenerative Refrigeration Systems (*University of Wisconsin Solar Energy Lab*) • An Innovative Reactor Technology to Improve Indoor Air Quality (*TIAX, LLC)*	• Development and Validation of a Gas-Fired Residential Heat Pump Water Heater (*Stone Mountain Technologies, Inc*.) • High Energy Efficiency R-744 Commercial Heat Pump Water Heaters (*Creative Thermal Solutions, Inc.)* • Water Heater ZigBee Open Standard Wireless Controller (*Emerson Electric Co*.)	• Energy Efficient Commercial Refrigeration with Carbon Dioxide Refrigerant and Novel Expanders (*TIAX, LLC*) • Low Global Warming Potential Very High Performance Air-Conditioning System (*United Technologies Research Center and University of Illinois-Urbana Champaign*) • Developing Next Generation Refrigeration Lubricants for Low Global Warming Potential/Low Ozone Depleting Refrigeration and Air Conditioning Systems *(Chemtura Corp.)* • Experimental and Numerical Investigation to Enhance the Performance of Building Heating and Cooling Systems Using Nanofluids *(University of Alaska Fairbanks)*