

Building America Expert Meeting Report: Hydronic Heating in Multifamily Buildings

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The ARIES Collaborative

October 2011

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Definitions

EMS Energy Management System

TRV Thermostatic Radiator Valve

Executive Summary

The U.S. Department of Energy’s Building America program develops technologies with the goal of reducing energy use by 30% to 50% in residential buildings. Toward this goal, the program sponsors “Expert Meetings” focused on specific building technology topics. The meetings are intended to sharpen Building America research priorities, create a forum for sharing information among industry leaders and build partnerships with professionals and others that can help support the program’s research needs and objectives.

The topic of this expert meeting was cost-effective controls and distribution retrofit options for hot water and steam space heating systems in multifamily buildings¹ with the goals of reducing energy waste and improving occupant comfort.

The objectives of the meeting were to:

1. Share knowledge and experience on new and existing solutions: what works, what doesn’t and why, and what’s new.
2. Understand the market barriers to currently offered solutions: what disconnects exist in the market and what is needed to overcome or bridge these gaps.
3. Identify research needs.

Presentation topics included:

- Overview of the market need – extent of the problem; potential energy savings.
- State of the market/technology – examples of technologies available for retrofits.
- Market barriers – why haven’t the existing solutions gained more market share: cost, information, technology, motivation.
- Case studies – profiles of completed and planned retrofit projects.
- New solutions – new technologies and products on the horizon.

¹ The Building America program focuses on buildings three stories and under, however most technologies and case studies discussed at the meeting are applicable to both low and high rise multifamily buildings.

1 Meeting Overview

1.1 Title

Multifamily Hydronic and Steam Heating Controls and Distribution Retrofits

1.2 Research Question

The research question addressed by this expert meeting is: what are the best options for cost-effectively retrofitting hot water and steam space heating controls and distribution systems in existing low-rise, multifamily buildings to reduce energy waste and improve occupant comfort?

1.3 Justification of Need

There is a large stock of low-rise multifamily buildings in the Northeast and Midwest with space heating provided by hot water or steam. Typically, residents of these buildings do not pay for heat directly (e.g. heating-related energy use is not sub-metered). Losses from these systems are typically higher than would be expected for buildings with centralized heat provided by a boiler serving multiple units (e.g. a significant number of apartments are overheated much of the time). This is often evidenced by open windows on cold winter days. Controls and distribution are often faulty and can be more cost-effective than boiler replacements.

Upgrades in these buildings often consist of new higher performance boilers, yet costs remain high due to excessive space temperatures and/or inefficient thermal distribution. The major underlying problems are typically: 1) outmoded and inefficient boiler controls; and/or, 2) the inability to regulate the amount of heat provided at the point of use (e.g., by radiators).

Cost reductions and overall system efficiency can be achieved in several ways including: improving the boiler control strategy; intelligently (via homeowner operated and/or automated valves) controlling room temperature according to need (instead of opening a window); and/or, altering the distribution of heat within the building in ways that better reflect demand.

Existing technologies (e.g. thermostatically controlled radiator valves) have been offered as solutions to these problems, but have not been widely accepted by the retrofit market. New wireless technologies are becoming available to cost-effectively monitor indoor space temperatures, centralize and automate thermostat set points and dynamically adjust heat distribution patterns. But, these new technologies have seen limited application and lack credible and independent performance verification and optimization. However, the benefits of better control are potentially substantial. Depending on the condition of the existing building, savings on the order of 30% of the heating fuel use compared to the same building with standard outdoor reset controls have been observed.²

² The 30% savings figure is cited from an unpublished study of the same technology, retrofitting controls onto a steam heating system in a high-rise building in New York City as well as numerous manufacturer produced case studies. To our knowledge, there are no peer-reviewed published studies quantifying the benefit of indoor space temperature-based reset boiler control retrofits.

1.4 Relevance to Building America Goals

The meeting topic addresses an important retrofit strategy that can cost-effectively impact a large number of housing units in a short timeframe. Independent of other energy-saving strategies, hydronic heating controls can go a long way towards meeting the overall 30% and 50% Building America whole-home energy use reduction target. There is a large stock of housing that could benefit from better hydronic controls: mainly existing multifamily residential buildings with hydronic heating systems serving multiple units.³

Specific presentation topics included:

- Overview of the market need: extent of the problem; potential energy/carbon reductions.
- State of the market/technology; how practitioners are currently applying the technology; information lacking in the market.
- Case studies: profiles of completed and planned retrofit projects.
- Solutions offered by vendors.

1.5 Audience

The meeting brought together a group of experts with deep experience in multifamily building hydronic and steam heating systems, from both the engineering and management communities. Attendees included:

- Heating system engineers
- Manufacturers of heating system controls and products
- Building management
- Researchers studying the issue
- Representatives from utilities and other organizations with an interest and expertise in the topic

1.6 Location

The one-day meeting was held in New York City, where a critical mass of companies and building professionals working in the topic area are located. New York is also a large potential market for this retrofit measure.

New York City is also a logical location because of the NYC Greener, Greater Buildings Plan which requires energy audits, public disclosure of energy benchmarking results and eventually energy use reductions in buildings over 50,000 square feet, which includes many low-rise multifamily buildings, the majority of which are heated with hot water or steam. This law is

³ According to the 2005 American Housing Survey, there are about 3.2 million occupied hydronically heated low-rise housing units in the United S. Nearly 90% of these homes are in the Northeast or Midwest; with a large portion being rental units (40%), and occupied by the elderly (24%). Most hydronically heated homes are older, with only 1% being classified as New Construction (built within the past four years) in the 2005 AHS data. (U.S. Census Bureau, Current Housing Reports, Series H150/05, *American Housing Survey for the United States: 2005*, U.S. Government Printing Office, Washington, DC, 20401, Printed in 2006).

expected to spur activity in low-cost, high payback energy retrofit measures, such as improved heating controls.

1.7 Organizers

The meeting was organized by the ARIES Collaborative Building America research team led by The Levy Partnership, Inc. in partnership with The Building Performance Lab of the City University of New York Institute for Urban Systems and The Steven L. Newman Real Estate Institute of Baruch College.

2 Agenda

The meeting was held on July 13, 2011, from 10:00am–4:00pm at Baruch College of the City University of New York, located on 137 East 22nd Street, 2nd floor, New York, NY. The agenda follows.

Time	Topic	Speakers
10:00-10:15	Welcome and introductions	Emanuel Levy, The Levy Partnership (ARIES) Michael Bobker, CUNY Building Performance Lab
10:15-10:20	Goals of the meeting	Jordan Dentz, The Levy Partnership (ARIES)
10:20-11:30	Panel 1 – Distribution and Control	Thomas Butcher, Brookhaven National Laboratory Michael Bobker, Building Performance Lab, CUNY Sean Maxwell, Steven Winter Associates
11:30-1:00	Panel 2 – Behavior, Response and Programs	Tim Allen, Taitem Engineering Betsy Jenkins, Taitem Engineering Phil Madnick, Consolidated Edison Robert Venuti, Anchor Energy Group and Robert Germain, PE
1:00-1:45	Lunch provided	
1:45-3:00	Panel 3 – Web and Wireless Options	Vincent Clerico, HeatTimer Corp. Simon Soloff, Entech Boiler Controls David Ungar, US Energy Group
3:00-3:15	Break	
3:15-3:45	Overview of ARIES Hydronic Heating Research / Research needs	Hugh Henderson, CDH Energy (ARIES)
3:45	Concluding remarks	Jordan Dentz, The Levy Partnership (ARIES)

3 Attendees

Andrew Proulx	EnerSpective, Inc.
Asit Patel	ANP Energy Consulting Services Corp
Betsy Jenkins	Taitem Engineering
Bruce Kafenbaum	US Energy
Dan Holohan	Holohan Associates
David Davenport	Urban American
David Hepinstall	Association for Energy Affordability
David Podorson	The Levy Partnership (ARIES)
David Ungar	US Energy
Dennis Carapezza	H20 Degree
Emanuel Levy	The Levy Partnership (ARIES)
Hugh Henderson	CDH Energy (ARIES)
Jeffrey Clerico	Heat-Timer Corp.
John Winkler	National Renewable Energy Laboratory
Jordan Dentz,	The Levy Partnership (ARIES)
Louis (Louie) Gigante Jr.	Anchor Energy Group
Michael Bobker	Building Performance Lab, Baruch College
Nicole Reed	U.S. Department of Energy
Phil Madnick	Consolidated Edison
Robert (Bobby) Germain Jr.	PE
Robert Venuti	Anchor Energy Group
Sean Maxwell	Steven Winter Assoc.
Simon Soloff	Entech Boiler Controls
Sol Levy	Entech Boiler Controls
Steve Stone	DSM Engineering
Thelma Arceo	Community Environmental Center
Tim Allen	Taitem Engineering
Tom Butchee,	Brookhaven National Laboratory
Victor Zelmanovich	Intech 21
Vincent Clerico	Heat-Timer Corp.
William (Bill) Boss	Danfoss

4 Summary of Discussions

4.1 Panel 1 – Distribution and Control

4.1.1 *Energy Impacts of Advanced Hydronic Controls*

**Thomas Butcher, Deputy Chair – Sustainable Energy Technologies Department,
Brookhaven National Laboratory**

A wide variety of new, energy-saving control concepts for heating boilers are emerging on the market. This talk included an overview of how these controls can save energy and the practical magnitude of the potential of this new technology. Specific topics included steady state flue gas temperature and efficiency, average flue gas temperature in cyclic operation, cycling rates, energy losses between firing periods, and low load idle losses.

Key points included:

- Losses are impacted by:
 - Steady state flue gas losses
 - Off cycle loss during the heating season
 - Summer idle losses
- Control types include:
 - Outdoor reset: modulates the boiler temperature based on the outdoor temperature
 - Indoor reset: modulates the boiler temperature based on the indoor temperature
 - Cycle time control: modulates the boiler temperature based on predefined time cycles.
 - Purge control: extracts the heat from the boiler when it is put into the idle state and is either used constructively (e.g. for hot water), or is stored for use later.
 - The stack temperature in the boiler is essentially linearly dependant on the water temperature. Thus, lowering the water temperature lowers the stack temperature, which in turn lowers the flue gas losses and increases the combustion efficiency (e.g. reducing the water temperature from 200°F to 140°F (60°F) results in a stack temperature reduction from 370°F to 320°F (50°F), and an increase in combustion efficiency of 1.9%).
- In cyclic operation, the efficiency of the boiler drops the more the boiler is turned off. However, the rate of decrease in the boiler efficiency is much higher at higher water temperatures. Thus, lowering the water temperature will lower the cyclic losses.
- Lowering the idle losses can have a significant effect on energy savings (e.g. lowering the idle losses from 2% to 1% increases the overall efficiency by 7.6%, and lowering idle losses to 0.5% increases the overall efficiency by 11.8%).
- Idle losses are linearly dependent on the average boiler temperature (an increase boiler temperature increases the idle losses).

- Conclusions:
 - Hydronic boiler controls offer significant savings.
 - The primary source of savings is reduced off-cycle losses.
 - Many control options are on the market, and more are coming.

4.1.2 Steam Distribution Deficiencies and the Case for Hydronic Conversion

Michael Bobker, Director, The Building Performance Lab of the City University of New York Institute for Urban Systems

Mr. Bobker discussed the distribution deficiencies and difficulties that make it very challenging to obtain good distribution with steam systems. He provided an overview of findings from several studies of steam-to-hot-water conversions and discussed the connected theoretical and practical reasons why deep savings can occur.

Key points included:

- Ideally, old steam systems should be converted to hot water.
- Steam-to-steam boiler and control conversions typically underperform their expected savings (data from ASHRAE Journal, May 2010, shows three cases with an average projected savings of 11.3% and an average actual savings of 0.6%).
- Steam-to-water conversions typically exceed their expected savings (a data set of 15 cases in the Northeast showed an average projected savings of 36% and an average first-year actual savings of 38%).
- One pipe steam difficulties include:
 - Delivery temperature is not controllable, thus the system is dependent on cycling. Cycling leads to reduced comfort because, at best, the system is trying to predict the future heating demand and adjust to it, and at worst, it is reacting to over or under-heating, in which case comfort has already been affected.
 - Difficult to balance.
 - Thermostatic Radiator Valves (TRVs) are limited in effectiveness because they are dependent on cycling and because the seals are subject to early failure.
 - Most one pipe systems are old and are nearing the end of their life span.
- Benefits of hot water systems include:
 - Improved comfort, because it is not dependent on cycling.
 - Can use the system with new technologies such as condensing boilers, cogeneration systems, and solar thermal systems.

4.1.3 Fixing Steam Systems: Something Old, Something New

Sean Maxwell, Multifamily Energy Analyst, Steven Winter Associates

Multifamily steam systems operate under the same basic principles as all steam systems, but at larger scales, minor annoyances become major problems. Controls and distribution haven't made large advancements since the old-days, and we find that dramatic efficiency savings can be gained by applying tried-and-true concepts in a thorough and detailed manner. Mr. Maxwell reviewed some basics as well as recent advancements in steam control and distribution that makes refining the operation of these systems effective.

Key points included:

- The Deutsche Bank Americas Foundation & Living Cities Study was performed on 33 buildings; 15 “new” (post war) and 18 “old” (pre war).
 - The post-retrofit savings were substantial, but were greater for the “old” buildings.
 - The “old” buildings use only 20% more fuel than the “new” buildings.
- Case study: Jennings Hall
 - 9 stories, 150 units, originally pre-war building with a post-war addition.
 - Measures included:
 - Sealed combustion boilers (heating and DHW)
 - Building air sealing (heating)
 - Seal and balance ventilation (heating)
 - Window upgrade (heating)
 - Roof insulation upgrade (heating)
 - Low flow showerheads (DHW)
 - Clothes washer upgrade (DHW and common area electric)
 - Common area lighting upgrade (common area electric)
 - Apartment refrigerator upgrade (apartment electric)
 - Results were significant, especially for space heating energy usage.
- Basic one-pipe steam retrofits include:
 - Drying steam / eliminating water hammer: make sure the steam trap is functioning correctly.
 - Improving air venting.
 - Use of TRVs: they can be effective if used correctly.
 - Use of boiler controls.

- Effective retrofits for two-pipe steam systems include:
 - Use of inlet orifices: calibrated orifices used to reduce the steam pressure in the radiator, which also keep the system pressure higher.
 - Use of drop-in valve retrofits.
- Case Study: 77-unit Manhattan Coop:
 - Heating system recommendations: inlet orifices, TRVs, enhanced central controls.
 - Wireless space temperature sensors that use an averaging thermostat:
 - Abandons steam cycle concept.
 - Approaches operation of simpler systems.
 - Steam pressure reset control, adjusts header pressure according to outdoor temperature.

4.1.4 Discussion

Questions and comments:

- Is there clear evidence that converting a two-pipe steam system to hot water will result in energy savings?
 - The Minnesota Department of Energy did a series of conversions in the early 80's and found good savings with both one-pipe and two-pipe systems.
 - Still suffers from cyclical, on/off operation.
- Can hot water conversions be economical? Is that the key barrier?
 - Yes, that's the key barrier.
 - Details of the cost of piping retrofits are important to establish.
- Are there issues with asbestos or other health issues that might be holding that up?
 - Yes, it is a cost issue.
 - In the experience of one of the attendees, the risers in walls for such systems tend to be uninsulated.
- There exists a device to convert one-pipe steam radiators to hydronic systems. It contains two concentric pipes as an insert.
 - Must use new piping but can keep old radiators.
 - Unfortunately, the most expensive part of the retrofit, in terms of both labor and material, is the piping.
- For tall buildings, at the 8th to 10th floor, the static pressures become an issue for hot water systems
 - May need a new boiler because some boilers are only designed for up to 15 psi of pressure.

- An alternative is to use a heat exchanger.
- Another energy loss in steam systems is the loss of steam/water. Is this the same in both one and two-pipe systems?
 - One pipe losses of water/steam are from venting losses.
 - Two-pipe systems also suffer from venting losses but mostly from trap losses and spill.
 - Venting of flash steam is common, even with trap systems: is a source of leakage.
 - Traps are a large savings opportunity, but they tend to break often.
- Does anyone know what the offset of electrical energy for hydronic pumping is?
 - No one had an answer.
- In the opinion of Michael Bobker, the best steam systems can get the heat distribution balanced and running tip top with the windows closed, but the point is that the best steam system is required to do that, compared to an average hot water system.
- When buildings get up to about 15 units in size, the boiler requires a pre and post purge when it is cycled. How does that affect losses?
 - Short answer is: on the order of 3-4%, so it is significant.
 - Cycling rates can be phenomenal in commercial buildings.
- The key potential for retrofit savings is to prevent overheating and to get tenants to close their windows, and not to make improvements at the central plant.

4.2 Panel 2 – Behavior, Response and Programs

4.2.1 Setting Realistic Expectations for Temperature Reduction Measures

Tim Allen, Senior Energy Analyst, Taitem Engineering

This presentation demonstrated temperatures taken in overheated apartment buildings, as well as temperatures taken after installation of thermostatic radiator valves (TRVs), or range limiting TRVs. The purpose of the presentation was to explore realistic assumptions regarding existing temperatures in over-heated buildings, and realistic expectations regarding the impact of installing TRVs.

Key points included:

- Typical apartments with resident-controlled temperatures:
 - Use thermostats or TRVs
 - Have no programmable upper limits
 - Are not sub-metered
- Common savings assumptions of implementing resident-controlled temperatures are optimistic:
 - Commonly assume an average temperature reduction of 3-6°F.

- Evidence thus far shows an average temperature reduction of 0-3°F.
- In overheated buildings, with no apartment-level control:
 - Some apartments at 80-85°F
 - Building-wide averages at 74-76°F
- In buildings with unlimited resident temperature control (but not paid for by the resident):
 - Some apartments at 80-85°F
 - Building-wide averages at 73-75°F
- Overheating is typically in PART of the building, for PART of the winter.
- In conclusion:
 - There is not much difference between unrestricted apartment level control and no apartment level control, in terms of energy consumption.
 - Apartment level control seems to provide increased user comfort only due to psychological factors; there isn't much change in apartment temperatures.
 - Options include:
 - Range limiting TRVs and thermostats
 - Energy management systems
 - More rigorous research is needed.

4.2.2 Control Freaks – How to Save Energy and Increase Comfort Without Spending a Bundle

Betsy Jenkins, Senior Energy Engineer, Taitem Engineering

Heating system controls are often overlooked as a source of significant energy savings. Yet, control optimization can deliver better comfort and reduced energy consumption without the need for the replacement of boilers or other heating equipment.

Key points included:

- Temperature sensors were installed in all units that Taitem Engineering worked on, and thus they obtained a large sample set of actual apartment space temperatures. With this they found:
 - Considerable overheating
 - A wide range of temperatures.
- For every 1°F over 68°F of building-wide average temperature, an extra 3% of energy is consumed over the course of the heating season.
- Night setback has huge potential savings.
- An EMS might know that an apartment is over/under-heated, but it cannot send more or less heat to that unit.

- Education of the superintendants and building managers is key to getting boiler controls working correctly.

4.2.3 Consolidated Edison Incentives for Building Energy Management Systems

Phil Madnick, Assistant Program Manager, Consolidated Edison

Con Edison recently launched the Multifamily Energy Efficiency Program, which includes monetary incentives for mid-size multifamily buildings that install energy management systems (e.g. heating controlled in part by apartment temperature sensors), among other measures. Mr. Madnick described the rationale behind the program (a brief explanation of why they're offering the program); the performance standards for the EMS required by the program; the energy savings and incentive dollar calculation ascribed by the program; and a quick take on some preliminary savings results seen in the program.

Key points included:

- Con Edison will cover 70% of installed cost of an EMS, which drops the customer payback period from 5.4 to 1.6 years.
- Minimum system requirements:
 1. Must satisfy total resource cost calculation.
 2. Must possess remote access and monitoring capabilities via Web.
 3. Must install apartment sensors in 25% of units (no less than 5).
 4. Must have outdoor reset capability.
 5. Must use feedback sensors:
 - Stack temperature sensor
 - DHW temperature sensor
 - Outdoor temperature sensor
 - Supply or return water temperature sensor (for hot water systems)
 - Condensate return temperature sensor (for steam systems).
 6. Must perform boiler staging for multiple boiler systems.
- Market barriers:
 - Technophobia
 - Strict cost effectiveness standards.
- Behavioral impact of using EMS
 - Must educate the building manager.
 - Must commit to using the system and responding to alerts properly.
 - Must educate the super so he/she does not bypass the system.
 - A monitoring contract may be needed!

4.2.4 Sub-metering Steam Heating

Robert Venuti, President, Anchor Energy Group and Robert Germain, PE

Challenge: A large Manhattan co-op currently provides steam heat to tenants in multiple buildings. The co-op seeks to reduce its energy cost burden and improve resident comfort.

Solution: This presentation outlined one proposed solution designed to incorporate multiple forms of sub-metering and direct billing, including point-of-use, low-pressure steam sub-metering coupled with thermostatic climate control.

Key points include:

- Client situation:
 - 1,700 unit complex in the lower east side of Manhattan.
 - Master metered utilities (electricity, water/sewer, heating).
 - No apartment meters, no thermostats.
 - Residents control heat with windows.
 - Water leaks go undetected, resulting in enormous waste.
- Solution provides simple payback of 3.5 years, and appreciates the value of each unit by \$21,300.

4.2.5 Discussion

Questions and comments:

- Sub-metering is the best solution for reducing overheating.
- It is difficult to sub-meter steam but it can be done.
- Are there solutions to sub-meter one-pipe steam systems?
 - Yes, there are systems that can do that.
- One solution depends on installing wireless control valves at terminal points, but once you do that, the EMS only provides monitoring functionality, and the savings are really attributed to the thermostats. In contrast, an EMS system that modulates the boiler based on indoor temperatures really only works if the building is already balanced! Because it cannot lower the indoor temperature below the legal limit for even the coldest apartment. Thus, this perspective is that terminal control is the most effective.
- There is currently a \$115 rebate per TRV installed.

4.3 Panel 3 – Web and Wireless Options

4.3.1 Maximize Heating System Efficiency Through Increased System Monitoring Through the Internet

Vincent Clerico, Vice President Sales and Marketing, HeatTimer Corp.

Overcome the obstacle of getting accurate space temperature information from the tenants. Fine tune the weather-actuated Heat-Timer control logic by incorporating a wireless space sensor

network. Through the same Internet access, monitor other components of the system to improve safety, maximize efficiency and improve tenant comfort by being alerted to potential problems. Maintain multiple boiler “designed efficiency” by improving multiple boiler control logic. Different types of boilers should be controlled in various ways to maximize the efficiency of a particular type of boiler.

Key points included:

- Hot water resets control the system water temperature; they do not turn the pump on or off.
- Hot water systems can still be used with steam boilers if it is designed as an indirect system with a steam-to-water heat exchanger.
- Sequencing controls for multiple boilers:
 - Must be controlled as a team to maximize efficiency.
 - Must know what types of burners you have:
 - On/off
 - Low/high
 - 3/4 stage
 - Fully modulating
 - Typical control systems use parallel loading, putting equal loads on all the boilers. This is very inefficient, because the boilers are inefficient at low loads.
 - Other controls utilize sequential boiler controls. This increases the load on each boiler until it’s almost at capacity, and then initiates the next boiler.
- Use Internet communication options to save energy from both direct fuel usage and better equipment maintenance:
 - Web-based Applications:
 - No on-site server is required.
 - No local software is required on a personal computer.
 - Wireless Space Sensors allow control to *automatically* fine tune heating reset curve based on desired space temperature targets.
 - Alarm e-mail/text message capability can alert you when attention is required.
 - Can alarm on any monitoring point.
 - Reporting capability can be useful to see the performance of the system.
 - Additional sensor monitoring includes:
 - Boiler feed water
 - Boiler stack temperature
 - Sump pump failure

- Conductivity sensor
- Other controls

4.3.2 Energy Management Systems

Simon Soloff, President, Entech Boiler Controls

Mr. Soloff spoke on the following issues:

- Advantages of computerized temperature controls vs. mechanical controls.
- Hydronic vs. steam.
- Benefits of hydronic controls: moderate vs. full heat calls.
- Assessing the pros and cons of individual radiator controls; why didn't they pick up in the industry?

Key points included:

- Controlling by indoor temperature versus outdoor temperature can have great savings.
- Monitoring alone can be very beneficial; it can tell you what you *should* control.
- Most buildings are overheated.
- Most overheating can be mitigated with simple, building wide controls.
- Individual apartment controls:
 - Will only bring the temperature discrepancy between apartments down by one or two degrees. This will allow you to bring down the average building temperature by one or two degrees.
 - But, individual controls won't fix big problems.
 - Tenants react emotionally to individual controls; if they can't control them, they fear their heat is being taken away.
 - Individual controls are generally not worth the added expense and complications.
- Other factors effect comfort besides just the temperature:
 - On extra cold or windy days, tenants desire more heat.
 - The same indoor temperature can feel either too hot or cold suddenly, if the outdoor temperature changes suddenly.

4.3.3 Advances in Real-time Monitoring Technology for Heating System Controls

David Ungar, Chief Operating Officer, US Energy Group

This presentation focused on real-time monitoring and control technology via Web-based application services, and addressed alerting, reporting and benchmarking tools. It focused on how to use the tools to measure performance and compare against baseline years to demonstrate the effectiveness of system improvements in temperature control and preventative maintenance.

Key points included:

- Control/monitor building systems to optimize performance.
- Manage/analyze your entire portfolio from one place in just minutes.
- Run your systems at peak operating efficiency saving \$1000's per year.
- Get alerted to critical issues that impact efficiency and performance.
- Benchmark performance year over year to show real savings.

4.3.4 Discussion

Questions and comments:

- Has training for superintendents and building managers been successful? To what extent are they getting better?
 - Try to train supers before the heating season with seminars. It's also important to train the people to who install the equipment.
 - Include supers and building managers into the project management process to spend more time with them and build a relationship. This way, the information will stick better.
 - The Department of Energy is looking at building operator certification and a new project manager certification (at the building level).
 - BPI certification is a good start but it's not specific enough.
- Internet connectivity for small buildings can be expensive.
 - 3G/4G technology a possible solution; broadband is not required
- There are EMSs to gather data, and there are motorized control valves to control the heat, so how come there is no solution that meshes these technologies and makes a fully automated system?
 - There are some products available to do this.
 - The barrier is the cost, not the technology.
 - Costly to deliver and maintain.
 - Consider using wireless thermostats!

4.4 Overview of ARIES Hydronic Heating Research / Research needs

4.4.1 Overview of ARIES Hydronic Heating Research in Building America

Hugh Henderson, CDH Energy, member of ARIES Collaborative

The ARIES Building America team is studying the effects of control and distribution improvements to the hydronic heating system in a 42-unit Columbia housing development in Cambridge, MA. Researchers will attempt to optimize boiler controls using indoor temperatures and rigorously quantify the impact. A second phase will explore the feasibility and benefit of adding individual radiator zone control. The wireless communications network will enable the

central control strategy to operate the heating system efficiently by tailoring heat distribution based on space temperatures in individual zones.

Key points included:

- Research questions:
 - What is the impact of control strategies that use apartment temperatures for central boiler control on energy consumption and comfort?
 - How cost-effective is such a control retrofit?
 - How does energy performance and comfort compare to individual radiator valve controls in each apartment?
 - How cost-effective is centralized control of radiator valves?

- Technical approach:
 - **PHASE I:** Replace boiler controls with wireless system that supplies heat based on both apartment and outdoor temperatures. Rigorously quantify the effectiveness of this strategy.
 - **PHASE II (tentative):** Install radiator zone valves centrally controlled wireless using space temperature data.

- Test in various control modes:
 - Existing conditions (baseline outdoor reset).
 - Indoor temperature-based control (two different strategies).
 - Indoor temperature-based control with one-time manual balancing of system using riser valves (one building).
 - Spend several weeks in each mode.
 - Directly compare energy performance and comfort impacts after normalizing for weather.

- Analysis approach:
 - Daily load line analysis relating total boiler runtime to outdoor temperature for each day.
 - Compare resulting linear trends for different performance periods/control modes to discern impacts.
 - Multi-linear regression analysis with dummy variables to determine if the differences are statistically significant.
 - Related monthly runtimes to gas use to discern impact on fuel use.

4.4.2 Discussion

Questions and comments:

- Why are you limiting your research to low-rise buildings?
 - It is a Building America mandate.
- How are you planning to recover from night setbacks in a reasonable amount of time?
 - One solution is to check the outdoor temperature a couple hours before the temperature rise is needed and determine the time needed for recovery based on that.
- Hugh Henderson asked if a night setback is important for The ARIES Collaborative to implement?
 - Participants thought it was.
- Participants expressed that it would be beneficial to capture the pumping costs of the hydronic system.
- Participant asked if The ARIES Collaborative is going to capture the spread of apartment temperatures.
 - Yes, we will.
- To gather baseline data, we (ARIES) will mimic the existing controllers with the new ones.

5 Research Gaps and Barriers

Following are research gaps and barriers identified at the meeting:

- How can the remaining useful life of old steam heating systems (boilers and distribution) be determined so planned conversions to hydronic can be made at the appropriate time?
- What is the cost of converting small one-pipe steam heating systems to hydronic systems?
- What is the difference in performance between a well-balanced, tuned up steam system and a hydronic system serving a similar dwelling?
- Because hydronic systems achieve comfort levels much more easily than steam systems, what is the cost difference between tuning and upgrading a steam system with local controls versus converting to a simple hydronic system with building wide controls?
- What is the typical temperature distribution in multifamily buildings with various heating system types; e.g. how significant a problem is overheating and how does it vary by building type and heating system type and operation (specifically, whether residents have control of their space temperatures or not)? There were strong opinions on this subject, limited published data, but according to some of the energy management system companies at the meeting, much data exists in their systems and they are willing to share it with researchers.
- Night setback is a huge energy savings potential that is not being realized by many buildings, but the recovery time needs to be managed.

- Often building staff disable controls or put modulating boilers on manual. What motivates them to do this and how can it be prevented? Support and education for building staff is needed. A protocol for staff management of building energy management systems is also needed.
- How much heating energy can be saved in multifamily buildings by having the residents pay for their own heat? Sub-metering of electricity has been shown to reduce consumption by approximately 20%. Technologies are available to sub-meter hydronic heat; these need to be tested and demonstrated in various markets. Sub-metering steam heat is much more difficult, but not impossible.
- Energy management systems are cost effective for larger buildings. A version of an EMS for smaller buildings (less than 15 apartments) that is cost effective (first cost and operational cost) is needed.
- What is the difference in performance and cost between the following three scenarios?
 - Installing simple building-wide systems to lower the average heating season temperature (e.g. outdoor resets). An EMS in this case would monitor and control the system.
 - Installing individual controls to lower the temperature distribution gap. An EMS in this case would only provide monitoring.
 - Installing both building-wide controls and individual controls. This will allow you to lower the average heating season temperature another few degrees, because the temperature distribution gap has been narrowed.
- What are the electricity costs for pumping for various hydronic heating control strategies? And how does this affect the cost/benefit of converting a steam system to a hydronic system?

6 Next Steps

A number of the research questions identified at the meeting will be addressed by current and planned ARIES Building America research, including:

1. The project titled **Hydronic Heating Retrofits for Low-Rise Multifamily Buildings** will address the following:
 - Temperature distribution in three multifamily buildings with hot water distribution; analysis of overheating under various control schemes.
 - Effectiveness of night setback in a multifamily building heated with hot water.
 - Cost and benefit of hot water space heating control retrofits, including:
 - Outdoor reset with and without limited indoor temperature input
 - Indoor reset with and without zone control
2. The project titled **Innovative Solutions for Re-piping Heating Distribution in Small Residential Buildings** will address the following:

- The likely costs, life-cycle costs and benefits of converting small steam space heating systems to hot water distribution.
- The system options in terms of piping materials and configurations, valving options, radiation and other system components and their respective advantages and disadvantages.
- What barriers such as resident disruption and contractor reluctance inhibit conversions and what are effective ways to overcome these barriers?

The full list of research gaps and barriers discussed above will be submitted to the Building America Standing Technical Committee on Space Heating for review.

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