Saving Energy in Existing Multifamily Buildings

Duluth Energy Design Conference
February, 2015

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Center for Energy and Environment

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In accordance with the Department of Labor and Industry's statute 326.0981, Subd. 11,

"This educational offering is recognized by the Minnesota Department of Labor and Industry as satisfying **1.5 hours** of credit toward **Building Officials** continuing education requirements."

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Topics

- Who is CEE
- Perspective: Understanding the industry
- Energy use in multifamily buildings
- Retrofit highlights
  - Energy impact
  - Marketability
  - Ensuring success: I, O & M best practices

Who is CEE

The Center for Energy and Environment (CEE) is a nonprofit organization that promotes energy efficiency to strengthen the economy while improving the environment

- We conduct research and develop programs so that:
  - Businesses operate more efficiently and profitably;
  - Government agencies and nonprofits spend less on facilities and functions;
  - Utilities achieve their energy-efficiency goals at least-cost; and
  - Households save money and improve comfort.

What we do

- Energy Program Design and Delivery
- Engineering Services
- Innovation Exchange
  - Research
  - Education and Outreach
- Sound Insulation Program
- Public Policy
- Lending Center

CEE multifamily experience

- Facility assessments of over 2,000 buildings in Minnesota
- Completed over 20 research projects

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Current multifamily research projects

- Condensing boiler optimization
- Multifamily ventilation optimization
- Demand Controller recirculation loop controls
- Multifamily aerosol envelope air sealing
- Indoor pool optimization

All funded through the MN Department of Commerce's Conservation Applied Research and Development grant program.

The Conservation Applied Research and Development (CARD) grant program is funded by MN ratepayers, and administered by the Minnesota Department of Commerce, Division of Energy Resources

Current multifamily energy efficiency programs

- Energy Star multifamily 3rd party verifier
- One Stop Efficiency Shop lighting program with Xcel Energy
- Multifamily Energy Savings program with MN Energy Resources

UNDERSTANDING MULTIFAMILY BUILDINGS

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What we know about multifamily buildings

"Multifamily buildings are a tough energy efficiency nut to crack"

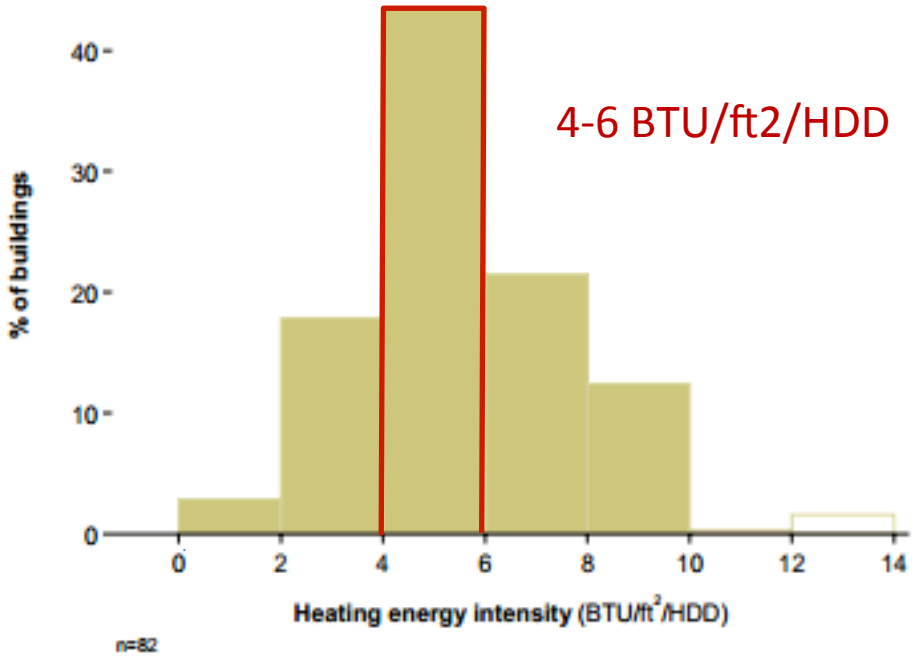
- **Why?**
  - "Split incentive" / diverging interests between resident and owner
  - "Lots of players in the orchestra"
  - Perception that technical challenges outweigh financial benefits

Market research on multifamily building owners and managers reveals perceptions of energy efficiency

- “Expensive”
- “Complex maintenance and upkeep”
- “Realized savings are questionable”
- “Improved comfort is a big benefit”
- “Has to be durable”
- “Trustworthy energy efficiency advice is needed”

MN multifamily buildings are Relatively "young and fit" buildings

- 78% "Post-War" and newer stock
- Natural gas = common heating fuel (~66%)
- Central hydronic = common heat system (83%)



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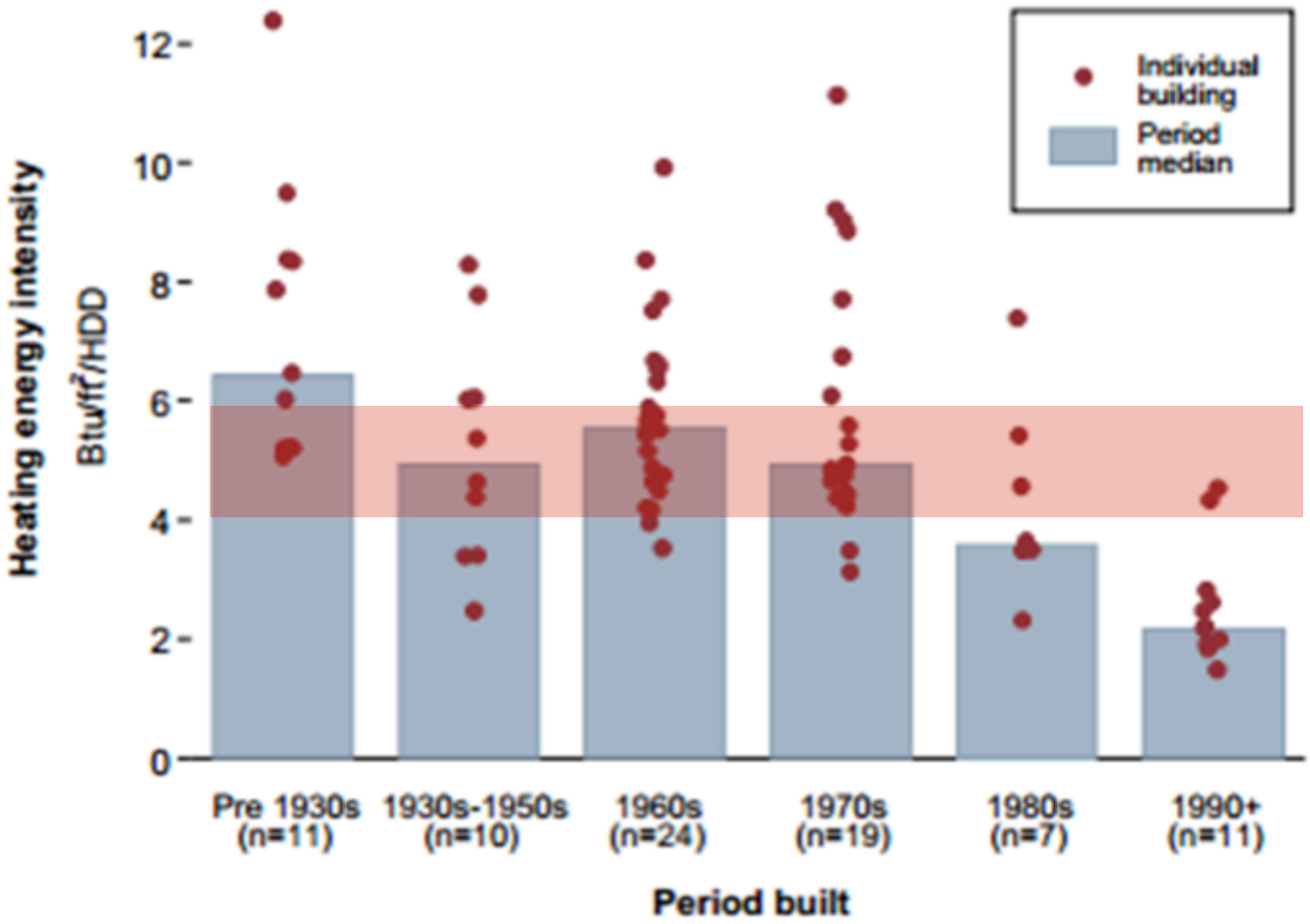
SOURCE: Minnesota Multifamily Rental Characterization Study, Energy Center of Wisconsin and Franklin Energy, 2013; sampled 120 bldgs in MN (78 in Twin Cities, 66 Greater MN)

…And yet outliers in (almost) every category



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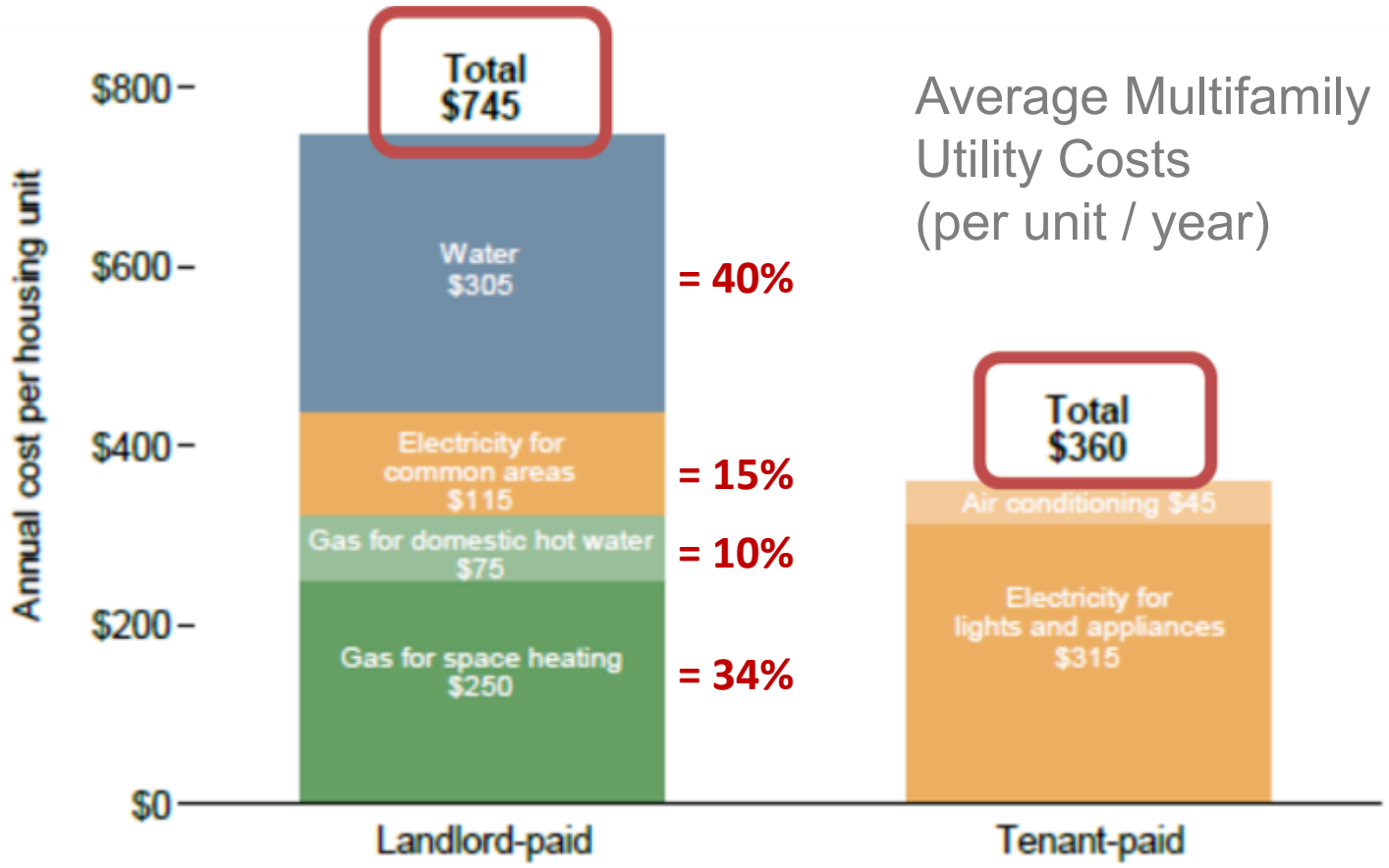
SOURCE: Minnesota Multifamily Rental Characterization Study, Energy Center of Wisconsin and Franklin Energy, 2013; sampled 120 bldgs in MN (78 in Twin Cities, 66 Greater MN)

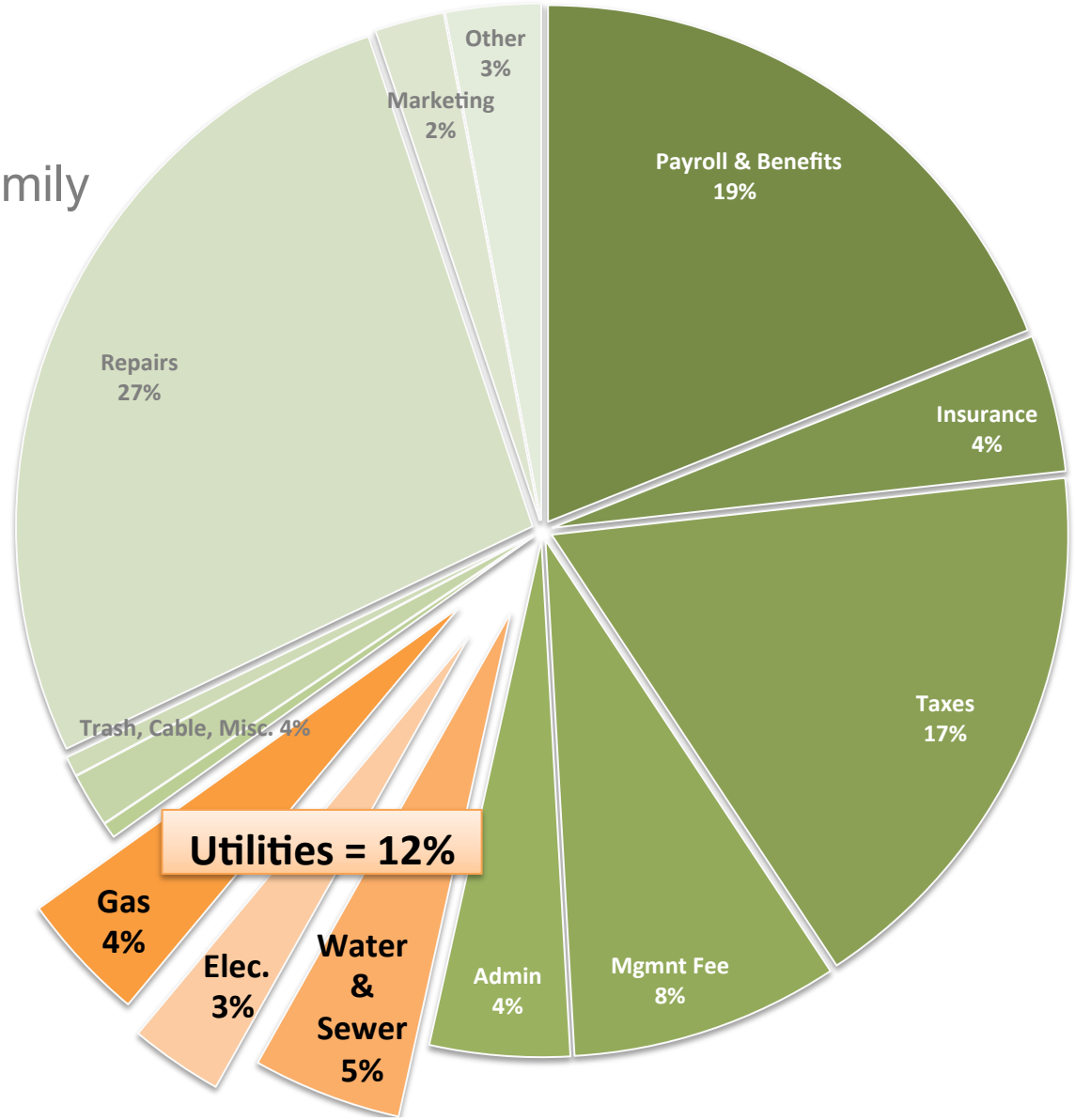
Water and space heating costs dominate



SOURCE: Minnesota Multifamily Rental Characterization Study, Energy Center of Wisconsin and Franklin Energy, 2013; sampled 120 bldgs in MN (78 in Twin Cities, 66 Greater MN)

…And yet they are a small piece of the expense pie

Average MN Multifamily operating expenses



Source: *2013 MN Multi Housing Association Expense survey.* 388 multifamily properties surveyed

i.e. Energy efficiency marketability goes well beyond payback

A good investment…

- ❑ Has aggressive energy paybacks
- ❑ Lowers O & M costs
- ❑ Improves building comfort
- ❑ Makes things easier for staff
- ❑ Is “tried and true”
- ❑ Is easy to implement
- ❑ Makes everyone look smart

MARKETABLE ENERGY EFFICIENCY STRATEGIES FOR MN MULTIFAMILY

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Good opportunities for energy savings – *beyond "the laundry list"*

- Optimizing existing condensing boilers
- Building ventilation modifications
- Demand-based hot water recirculation loop controls
- Aerosol envelope air sealing

Acknowledgements

- Projects discussed are supported in part by a grant from the Minnesota Department of Commerce, Division of Energy Resources through a Conservation Applied Research and Development (CARD) program

Optimizing condensing boilers

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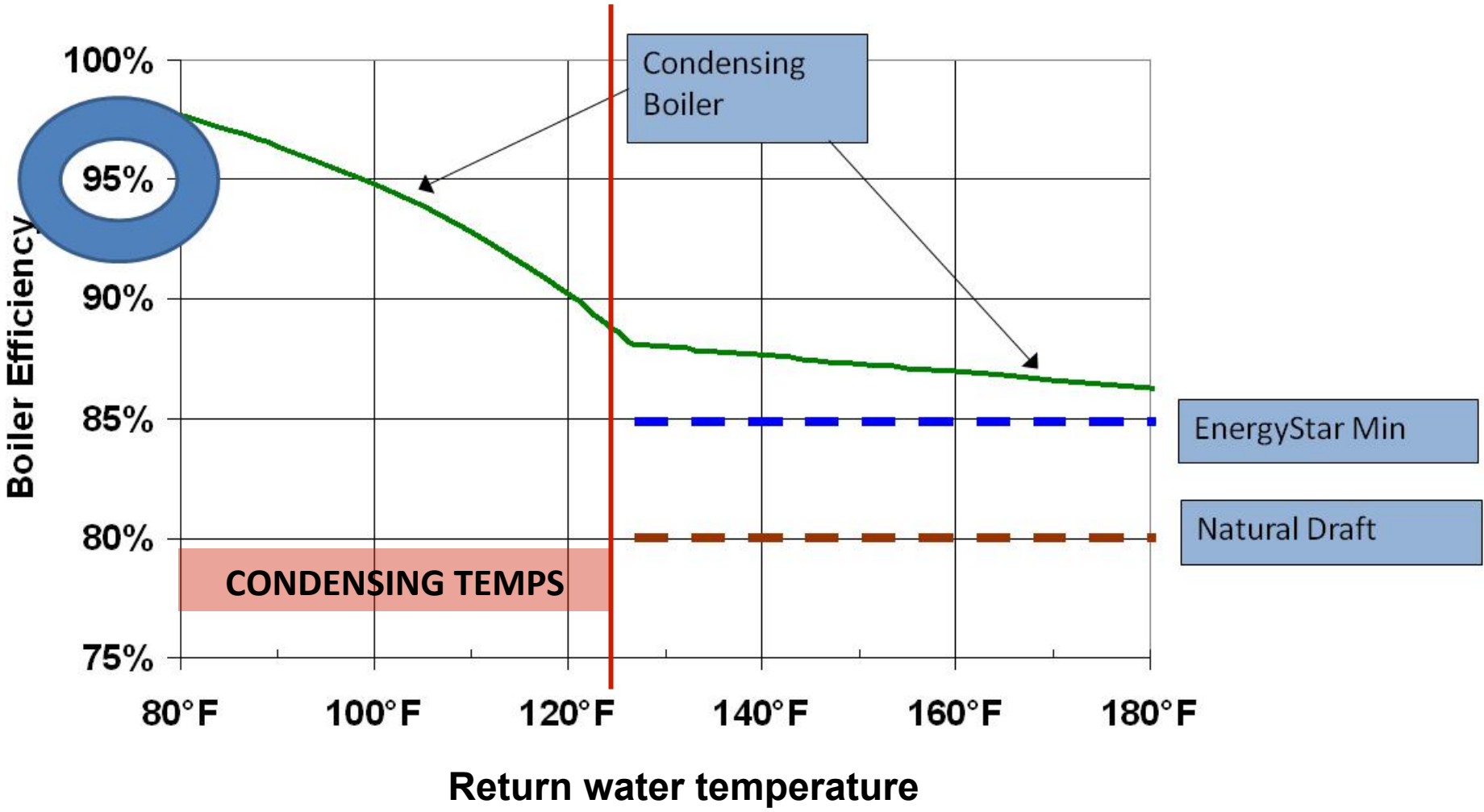
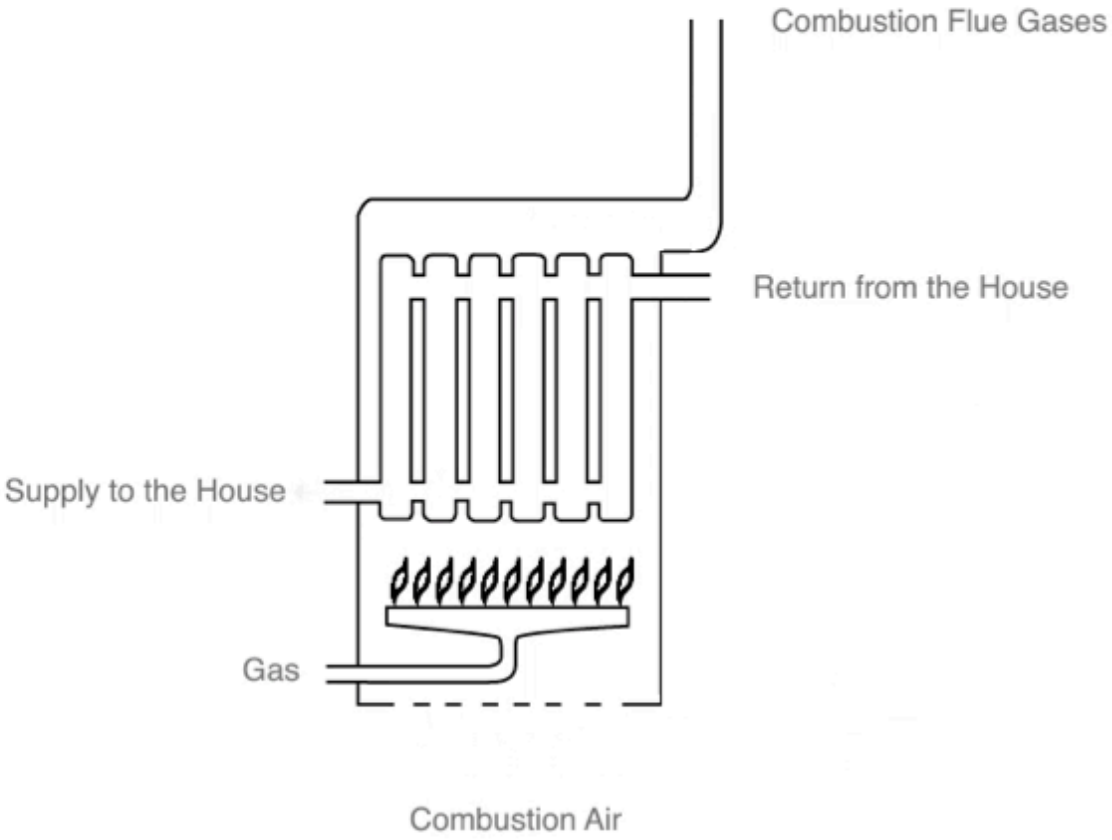
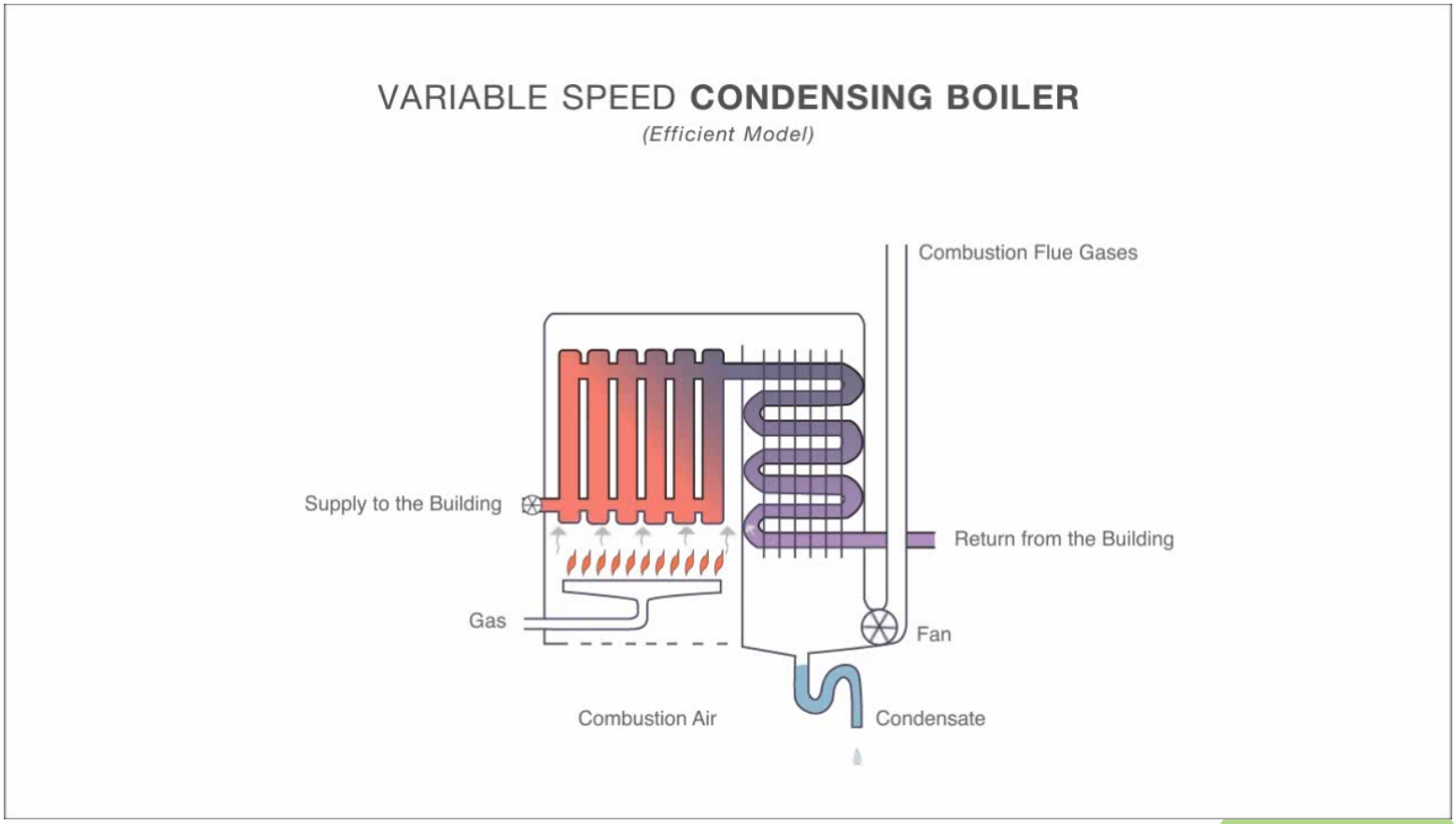
Achieving rated efficiency (>90% efficiency)



Conventional boiler



Condensing boiler



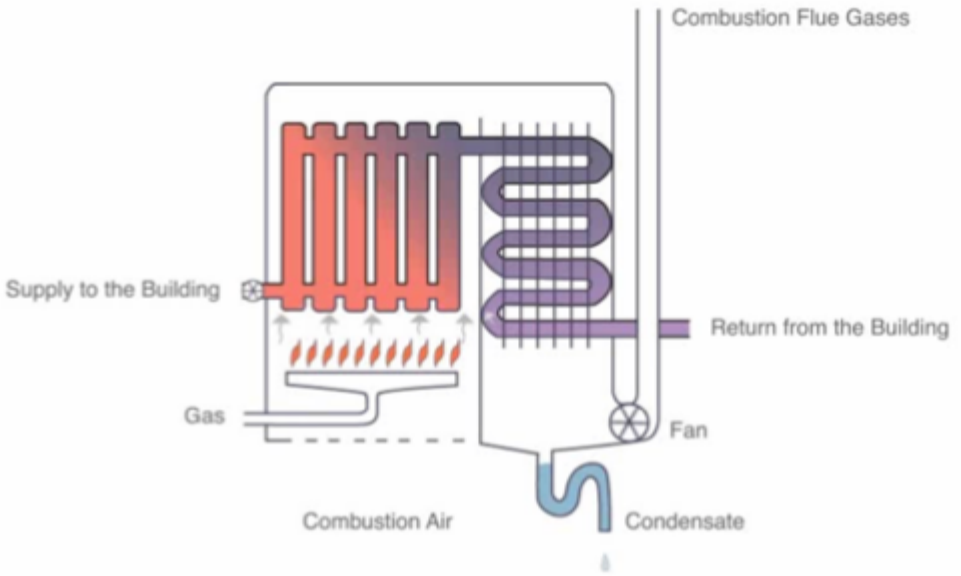
Condensing?

Benefits

- 4-10% of gained efficiency
- Eliminate short-cycling
- Getting what you paid “extra” for

The key: driving down return water temperature

- Maximize heat transfer at heating elements
- Send lower temp water out to the building
- Make sure boiler output matches demand
- Make sure your piping isn't dumping supply water into return
- Make sure domestic hot water is not integrated with space heating boiler



Excess air can dictate boiler efficiency

Measured as % Oxygen in flue gas

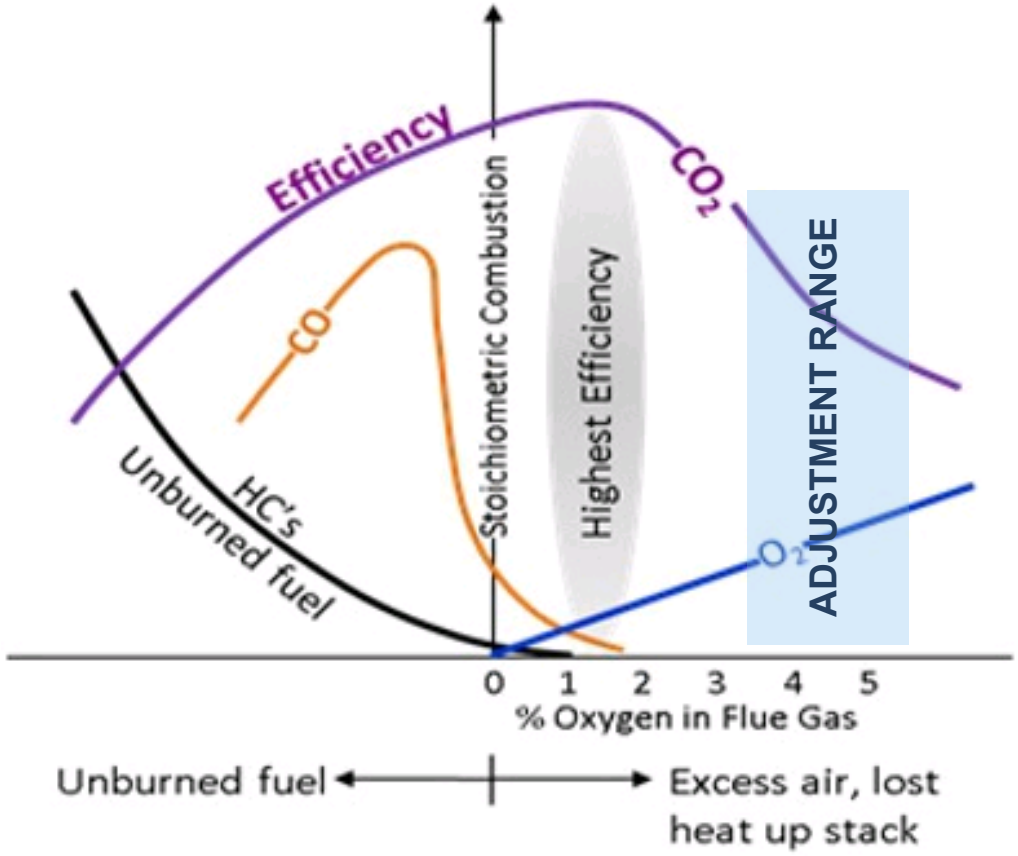
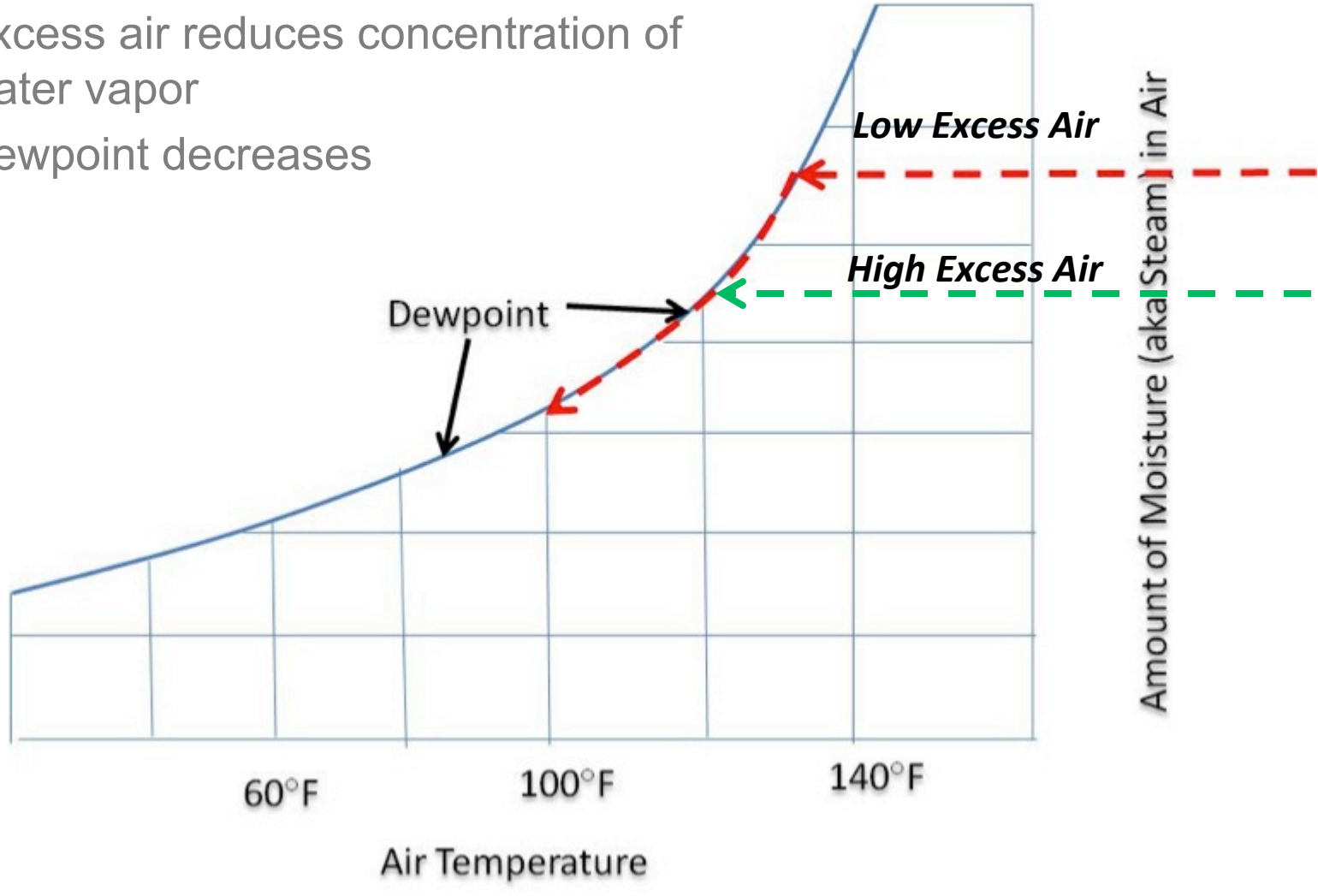


Image source: industrialheating.com

Condensing boiler sensitivity to excess air

- Controlling excess air very important
  - Excess air reduces concentration of water vapor
  - Dewpoint decreases



Oxygen levels in flue gas

Table 4: Recommended Combustion Levels

	Natural Gas All Models	Propane Solo 60/175/250	Propane Solo 399
O2 Min.	2.30%	2.70%	3.70%
O2 Max.	5.30%	4.70%	5.20%
CO2 Min.	8.80%	10.70%	10.00%
CO2 Max.	10.50%	12.00%	11.00%
CO Max.	100 ppm	100 ppm	100 ppm

Boiler 2

testo310
V5.2 42813307/1

Company_____
Address_____
Phone_____

11/20/2014 12:57:52 pm

Fuel Natural gas
CO2max 11.7%

4.3%	O2
99ppm	CO
155.8°F	Fluegas Temp
88.5%	Eff
Oppm	Ambient CO
65.1°F	Ambient Temp
--.-inH2O	Draft
23.6%	Excess air
--.-inH2O	Pressure
H- 9.24%	CO2 Low - 9.35
126ppm	Undiluted CO

Smoke no. - - -
Smoke no.Ø -
HCT ____°F
For questions call-_____

Boiler 1

testo310
V5.2 42813307/1

Company_____
Address_____
Phone_____

11/20/2014 12:28:07 pm

Fuel Natural gas
CO2max 11.7%

4.4%	O2
92ppm	CO
134.2°F	Fluegas Temp
89.0%	Eff
Oppm	Ambient CO
65.1°F	Ambient Temp
--.-inH2O	Draft
23.6%	Excess air
--.-inH2O	Pressure
H- 9.24%	CO2 Low 9.41
115ppm	Undiluted CO

Smoke no. - - -
Smoke no.Ø -
HCT ____°F
For questions call-_____

Heating elements: You're stuck with them

- It isn't cost effective to add more
- Dirty or blocked radiation affects heat transfer

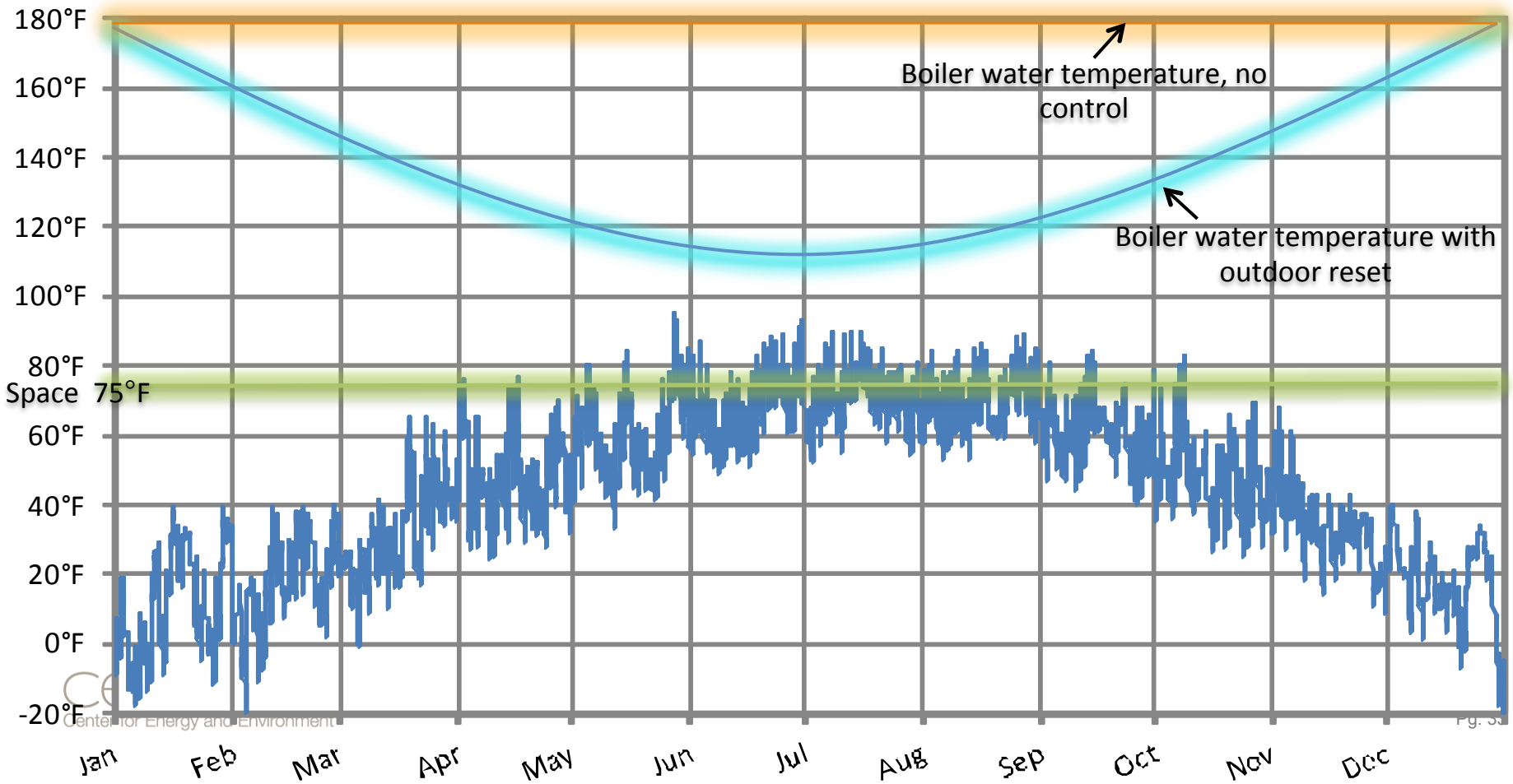
Control boilers for lowest possible output

- Optimized outdoor reset
- Finding the lowest max output temp for the building
- Sequencing and staging for optimal efficiency

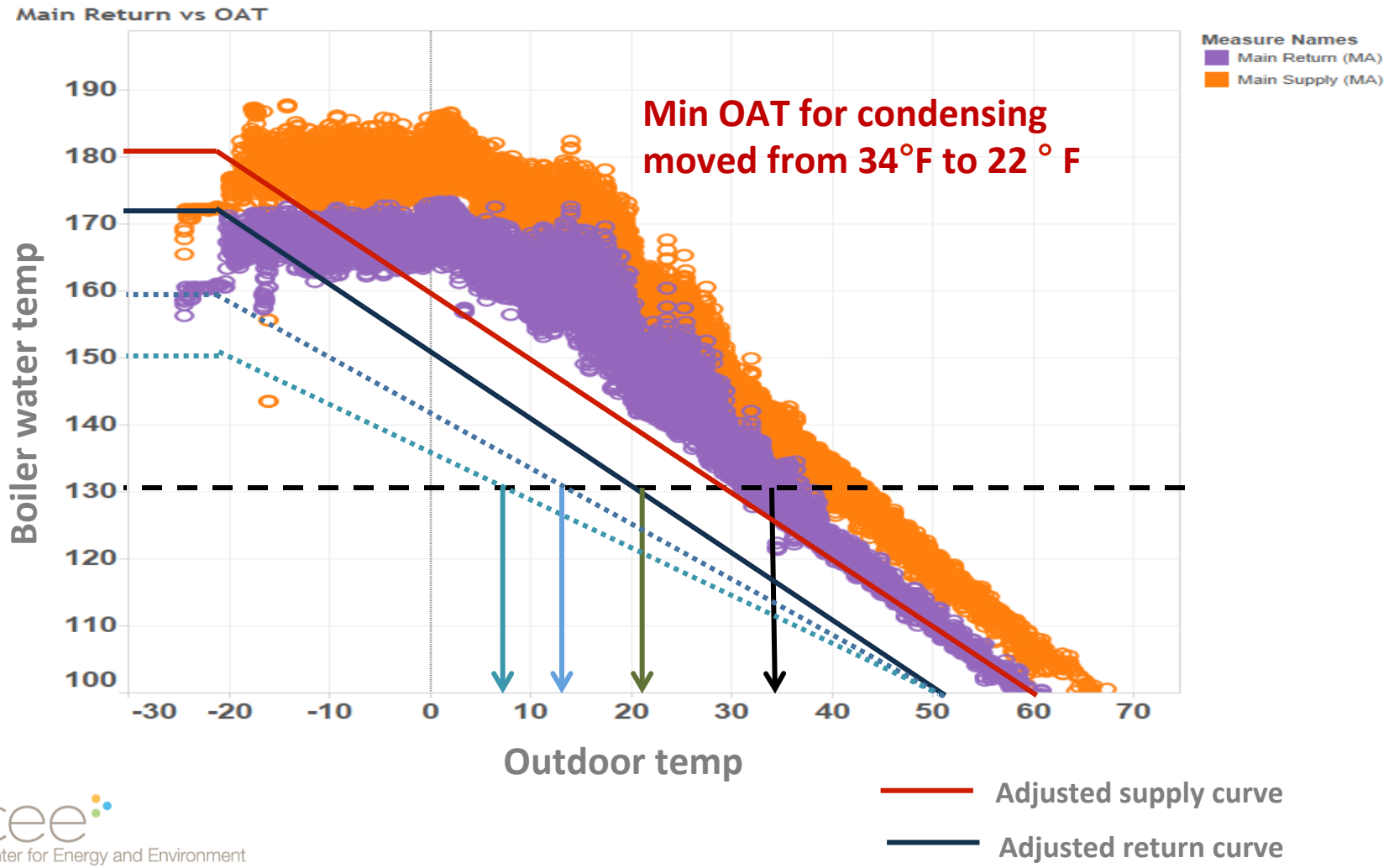
Control the boiler so it doesn't exceed demand

Outdoor reset lowers boiler water temperature

As outdoor temps get warmer, the building heating load gets smaller and the boiler water temperature can be lowered.



Optimizing outdoor reset

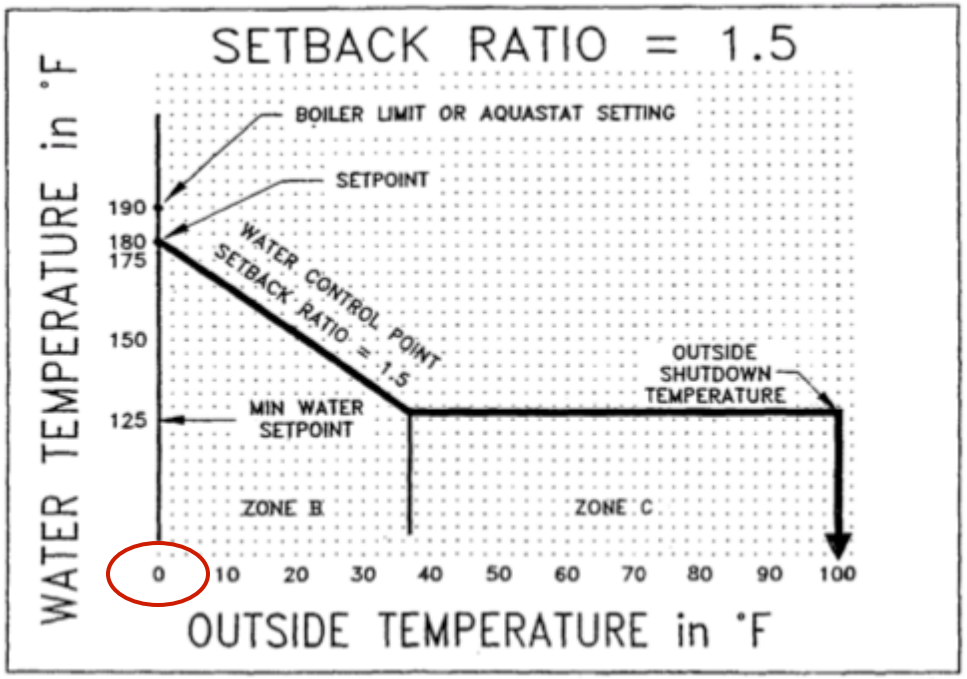


Outdoor reset adjustment

14 unit building:
9.5% space heating savings (no cost)
Reduced building over-heating

At replacement: Identify boiler control limitations

- This boiler control's non-adjustable minimum outside temp of 0°F is not ideal for MN



Boiler sequence and firing stage controls: matching output to load for best efficiency

Lower output firing stages have increased thermal efficiency

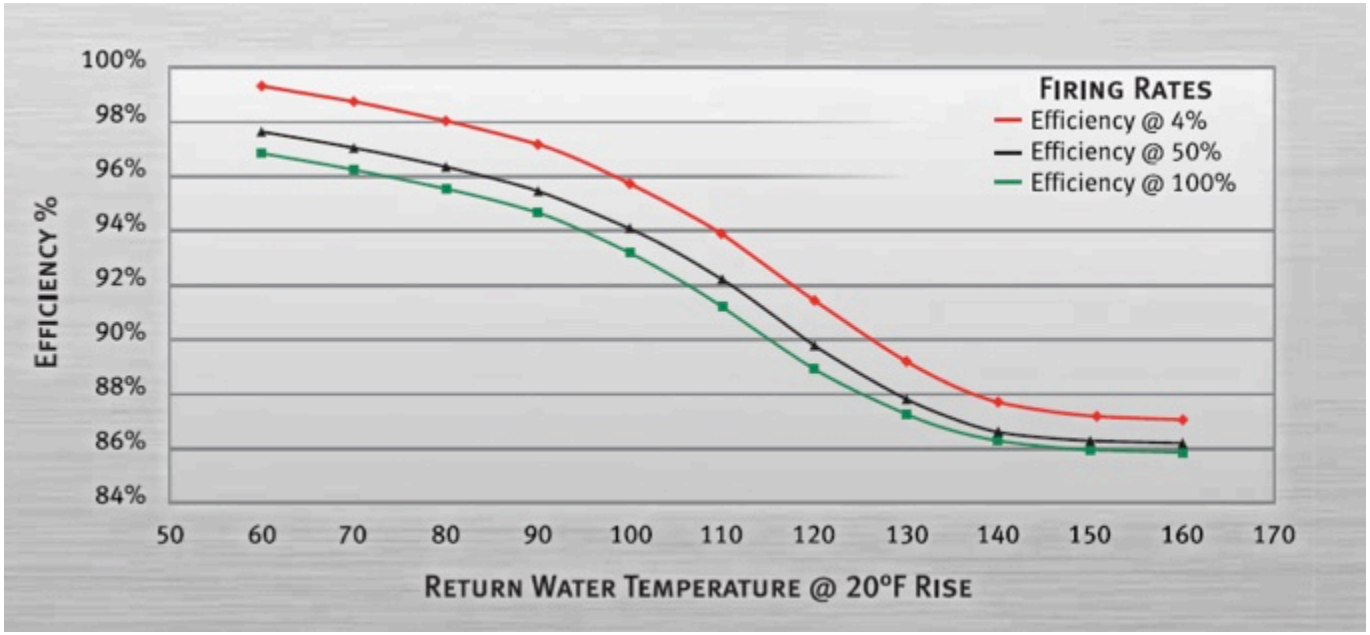


Image source: Lochinvar.com

Boiler cascade strategies

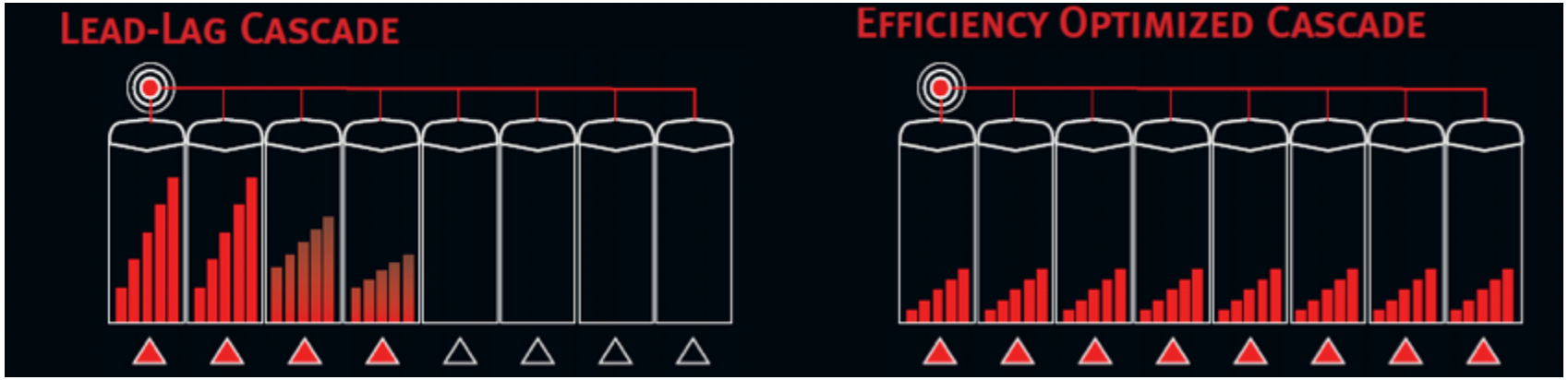


Image source: lochinvar.com

Sequencing boilers: mixed efficiency

41 unit building:
11% space heating savings
3 year payback
Reduced short-cycling

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Sequencing/staging: All firing on at once because they can't talk to each other

32 unit building:
6% space heating savings
5 year payback
Reduced short-cycling

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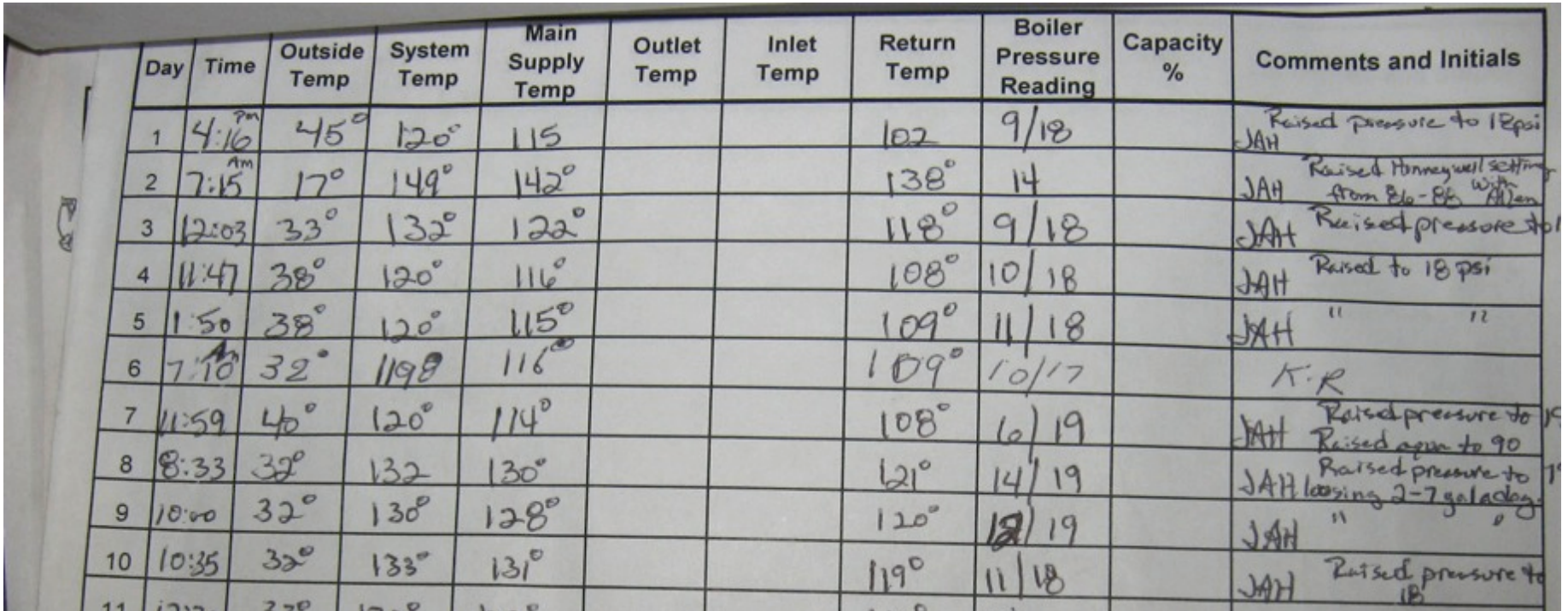
Little difference between boiler supply and return temperatures indicates potential for improvement

- Another testament to keeping a daily boiler log!

1- Adjust reset temps as low as possible

2- VFD pump control optimizes heat transfer as zones open and close

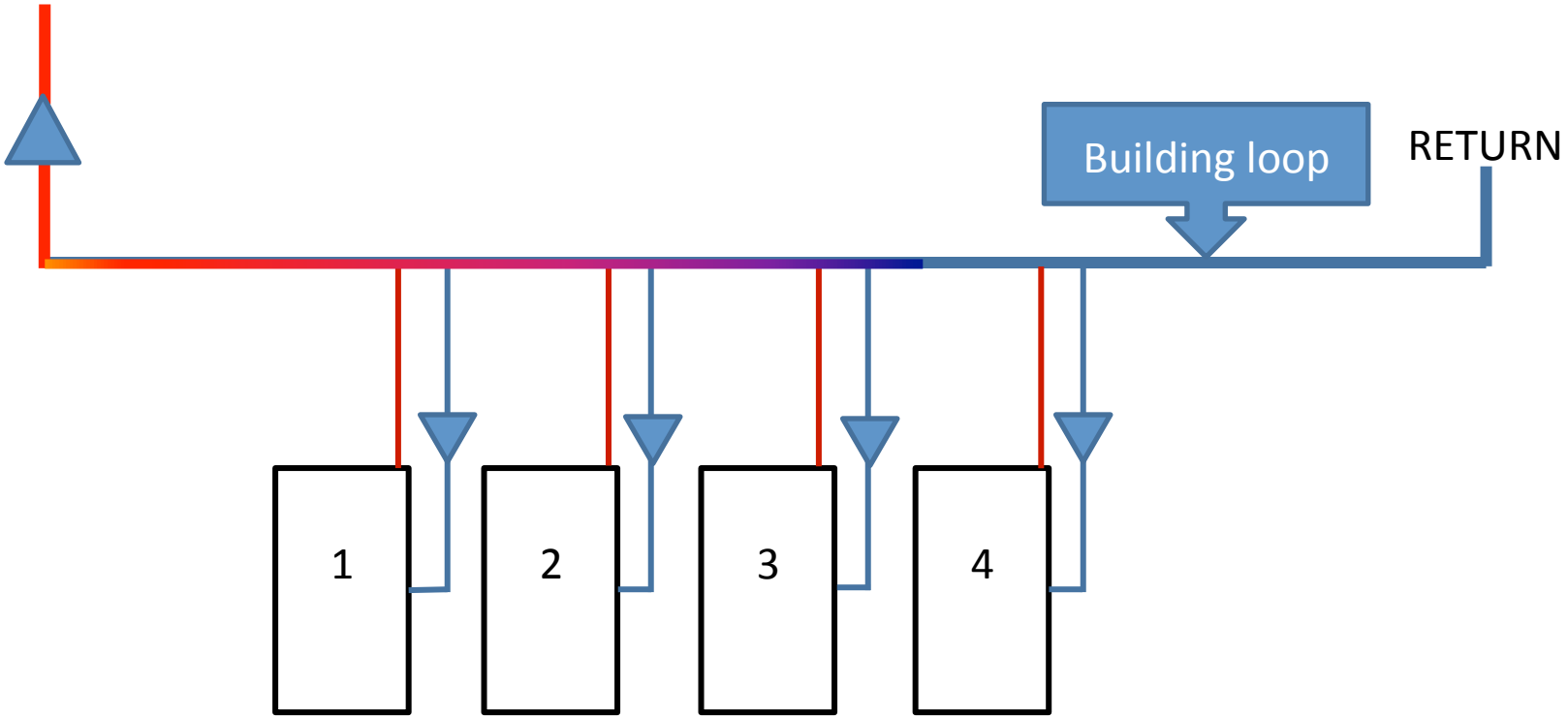


Day	Time	Outside Temp	System Temp	Main Supply Temp	Outlet Temp	Inlet Temp	Return Temp	Boiler Pressure Reading	Capacity %	Comments and Initials
1	4:16 Pm	45°	120°	115			102	9/18		Raised pressure to 18psi JAH
2	7:15 Am	17°	149°	142°			138°	14		JAH Raised Honeywell setting from 86-88 with Allen
3	12:03	33°	132°	122°			118°	9/18		JAH Raised pressure to
4	11:47	38°	120°	116°			108°	10/18		JAH Raised to 18 psi
5	1:50	38°	120°	115°			109°	11/18		JAH " "
6	7:10	32°	1198	116°			109°	10/17		K.R
7	11:59	40°	120°	114°			108°	6/19		JAH Raised pressure to
8	8:33	32°	132	130°			121°	14/19		Raised again to 90
9	10:00	32°	130°	128°			120°	12/19		JAH Raised pressure to loosing 2-7 go ladies
10	10:35	32°	133°	131°			119°	11/18		JAH " "
11										JAH Raised pressure to 18

Variable speed pumps (VFDs, VSDs)

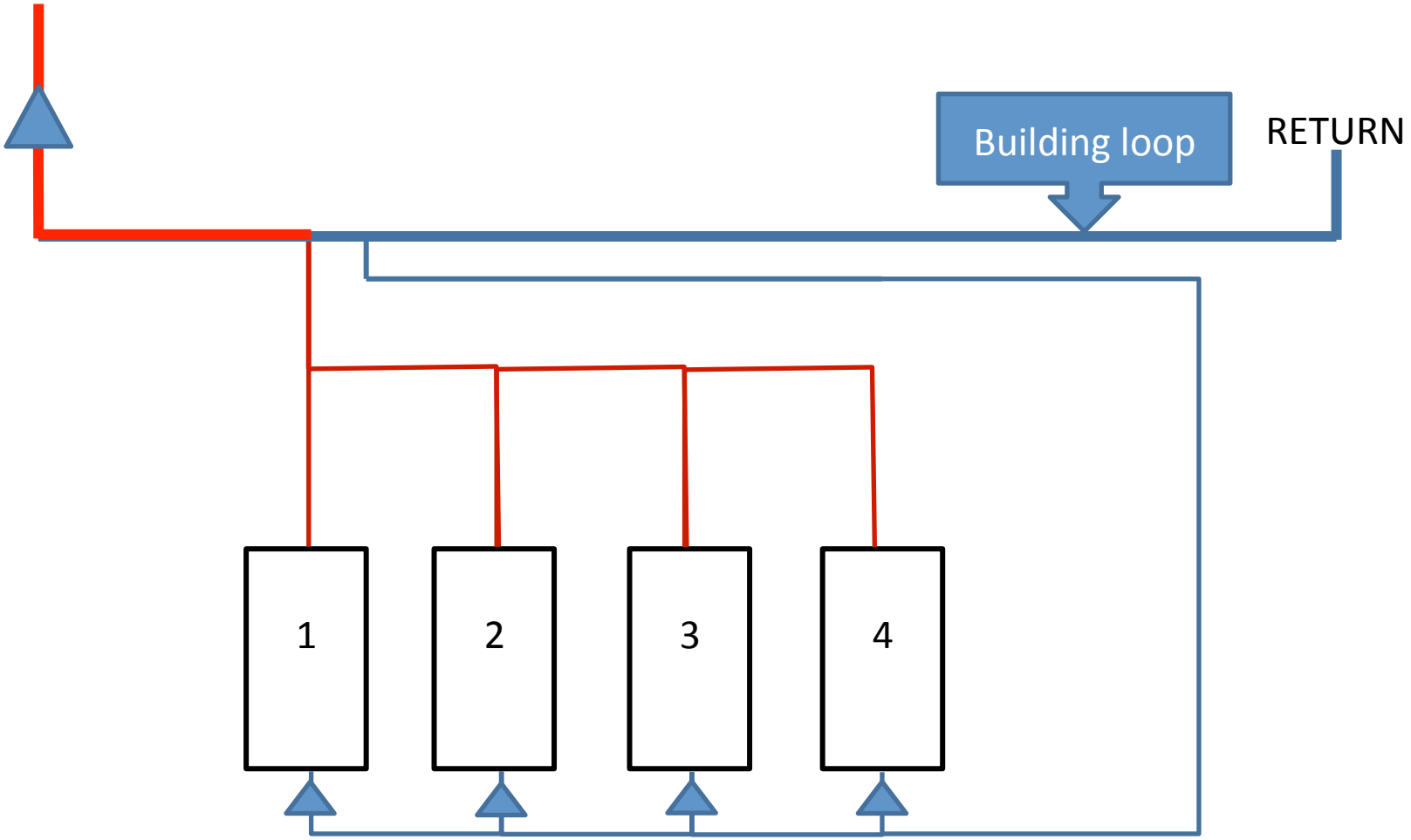
- Reduce the pump flow during part-load (when zones close)
  - Allows for lowered return water temperature—more potential boiler condensing conditions
  - Electricity savings

Boiler room piping: address at replacement



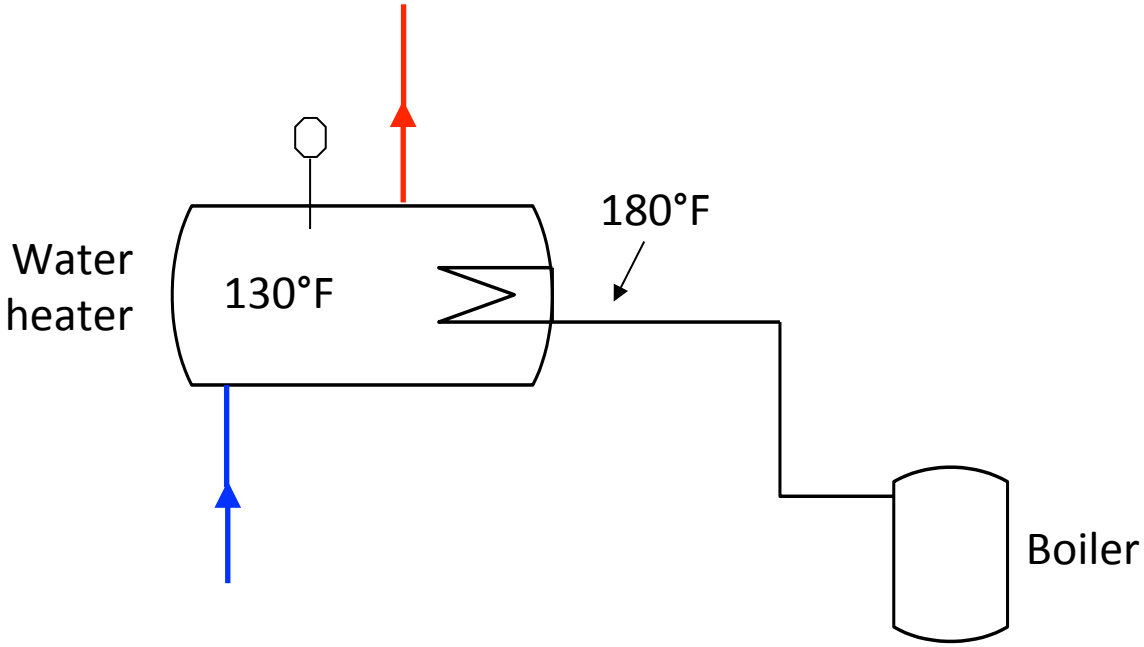
Not ideal: Adjacent boilers warm return water

Better piping



Domestic hot water can dictate return water temps

- Traditional coil-in tank requires high boiler temperatures, limiting boiler efficiency during DHW call



Summary: getting condensing boilers to condense!

- Proper oxygen levels in flue gas contribute to optimal condensing conditions
- Maintaining aggressive control settings prolongs condensing capabilities
- VFD pump controls reduce pump speeds at part loads to optimize heat transfer
- Boiler room piping can dictate return water temps
- Indirect (sidearm) water heaters will limit DHW efficiency

Optimizing ventilation systems

Optimizing ventilation systems

ISSUES

- **High fan power use**
- **Excessive ventilation airflow**
- Occupant complaints of drafts, odors
- Duct leakage
- Clogging and other flow balancing problems
- Difficult/costly to measure and quantify energy savings associated with retrofitting

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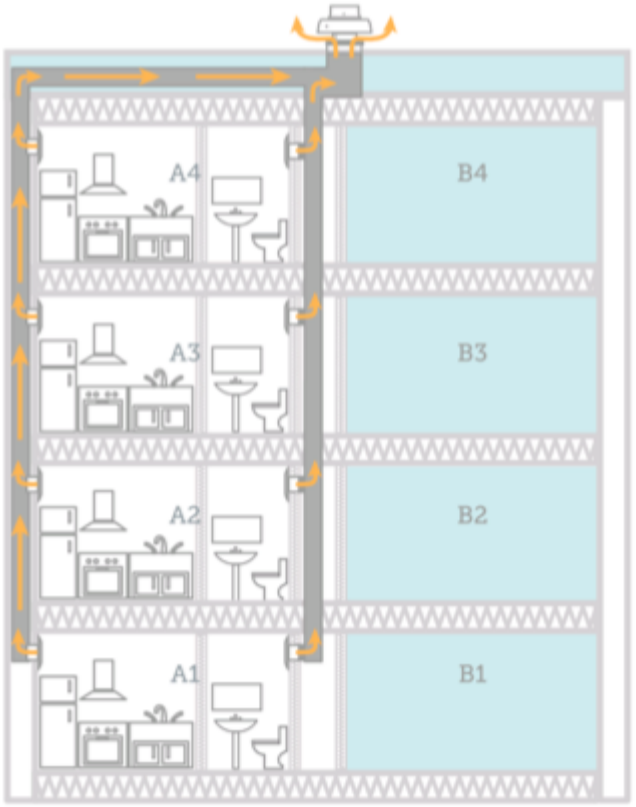
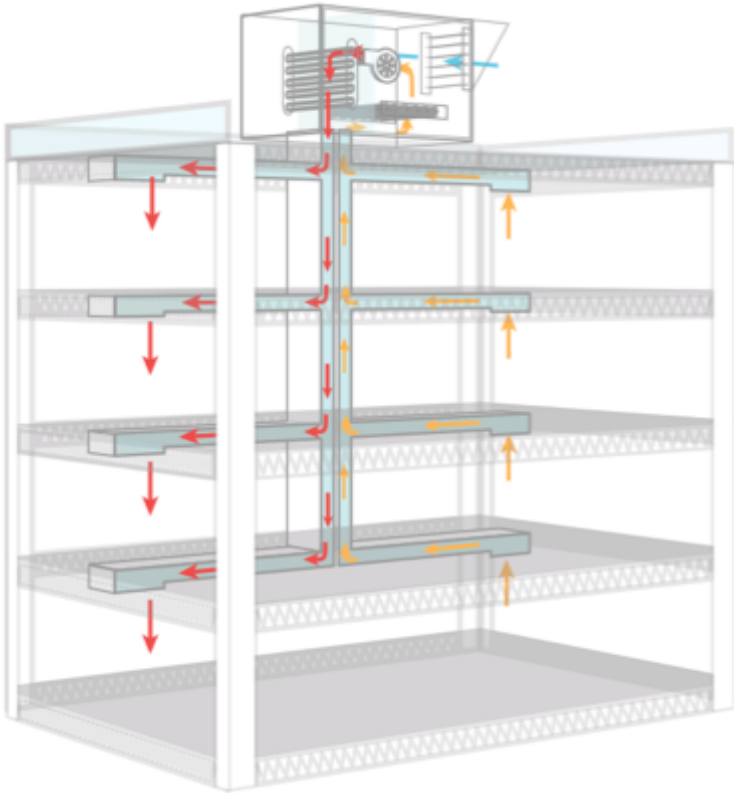
Central ventilation systems



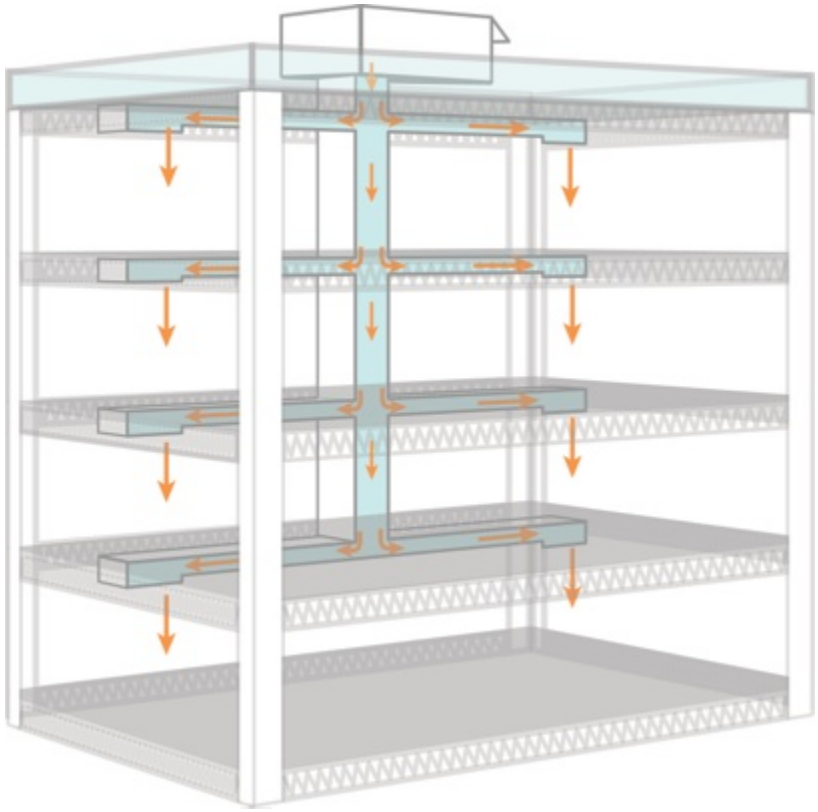
Central apartment exhaust



Central corridor/make up air systems

Corridor ventilation improvements

- Reduce fan speed to provide code required ventilation flow



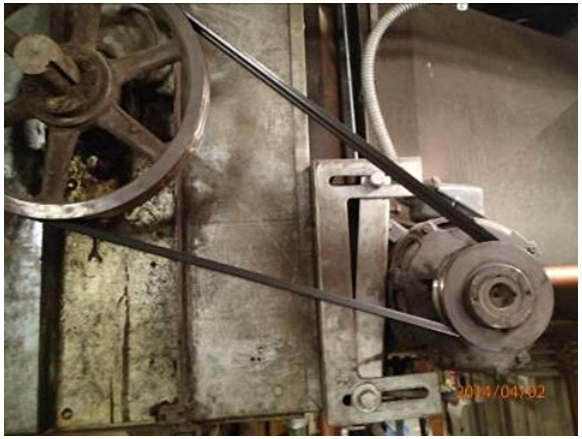
ISSUES

- Design flow rates were much higher than current required flow
- Faulty controls/sensors
- Flow rates not verified

Corridor ventilation retrofit in Minneapolis

Project: Re-sheave fan for lower flow

- 4,700cfm reduced
- 9,611 therms saved
- 7,244 kWh saved
- $6,899 annual savings
- <6 month payback



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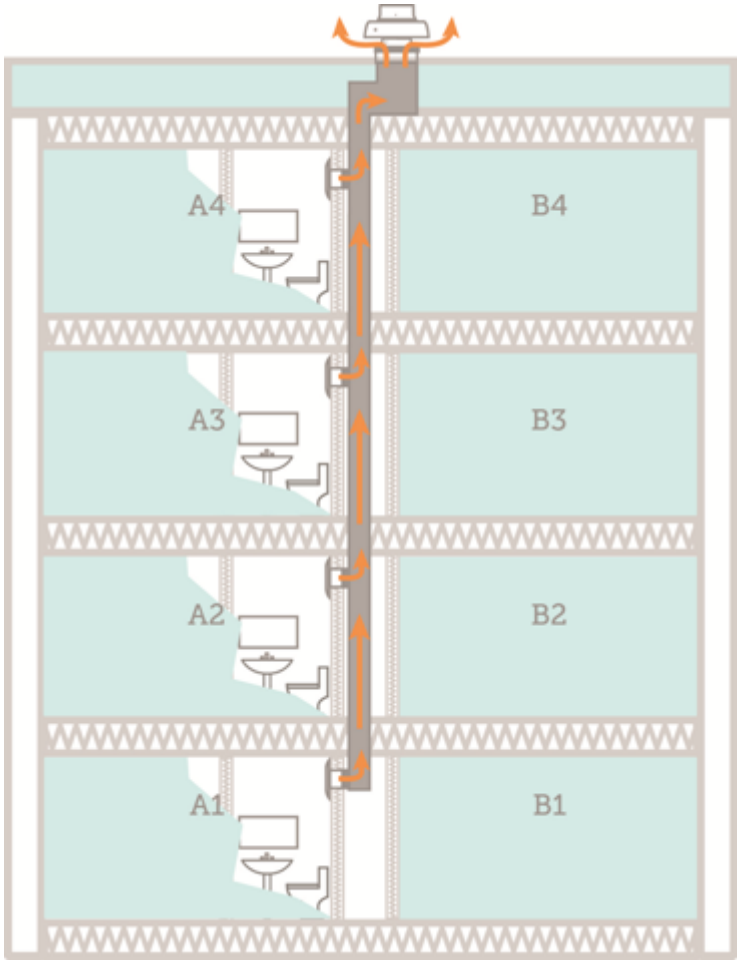
Central exhaust improvements

- Reduce & balance flow
- Seal inlets, curbs & ducts
- Install high efficiency fans

ISSUES

- Design flow rates were much higher than current required flow
- Unbalanced flow
- Flows difficult to verify and seldom measured



Central exhaust retrofit in Minneapolis

Project:

1- Replace operable balancing louvers with fixed orifices

2- Replace belt drive exhaust fans with high-efficiency type

- 2,299 cfm reduced
- 4,706 therms saved
- 21,979 kWh saved
- $5,037 annual savings
- 7 year payback
- Reduced odors and noise

Installing fixed balancing orifices

Replace balancing devices prone to clogging or tampering

Seal duct leakage at inlet

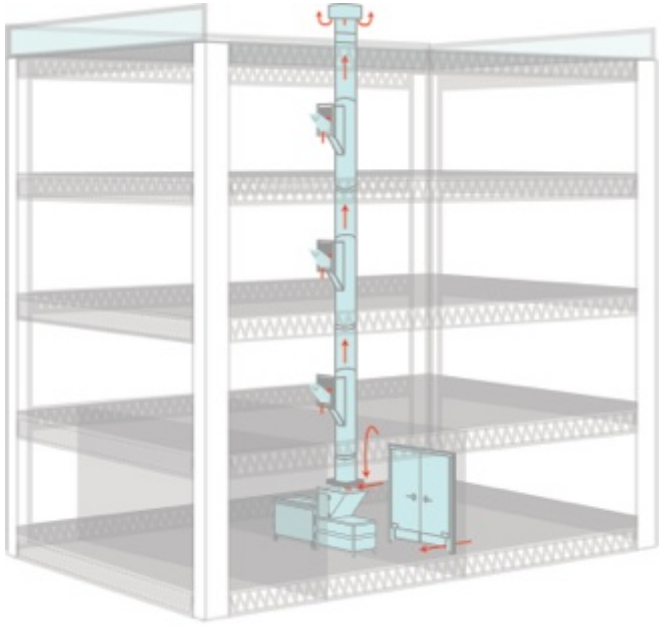
Install fixed orifice sized for correct flow, sealed to ceiling

Replacing exhaust fans

1. Seal leakage below fans at curb
2. Replace with EC fans with adjustable speed controls
3. Verify flow is correct

Trash chutes can affect ventilation performance

- Trash rooms may exhaust too much air
- Lack of air sealing can cause odor transfer
- Ventilation flow may be increased to compensate



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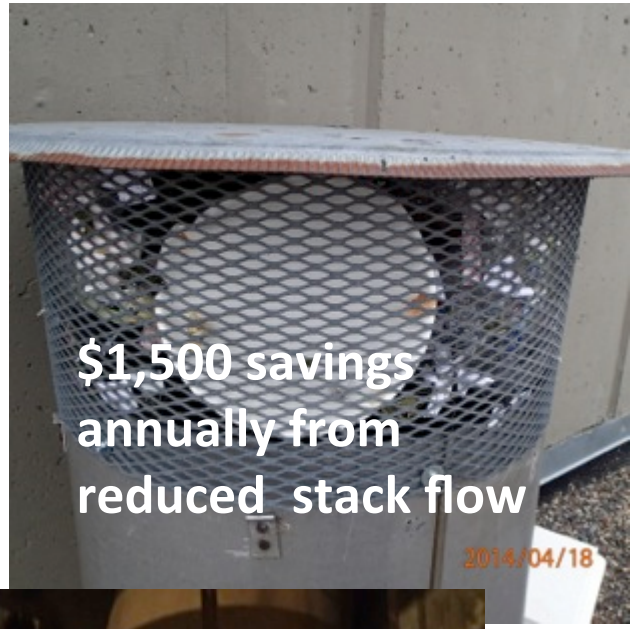
Addressing the trash chute

- Keep trash room doors closed
- Seal trash room off from rest of building
- If no door, seal chute to compactor/trash bin
- Reduce trash room exhaust fan flow rate
- Reduce chute cap opening



Stay tuned

- Ventilation assessment manual this spring
  - Guide for assessment and retrofitting central supply and exhaust systems (and trash chutes)
  - Audience: HVAC contractors and energy consultants
- Project report this summer
  - Energy savings opportunities found in 18 buildings
  - Retrofit outcomes on 6 buildings

Controlling hot water recirculation loops

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Hot water recirculation loops

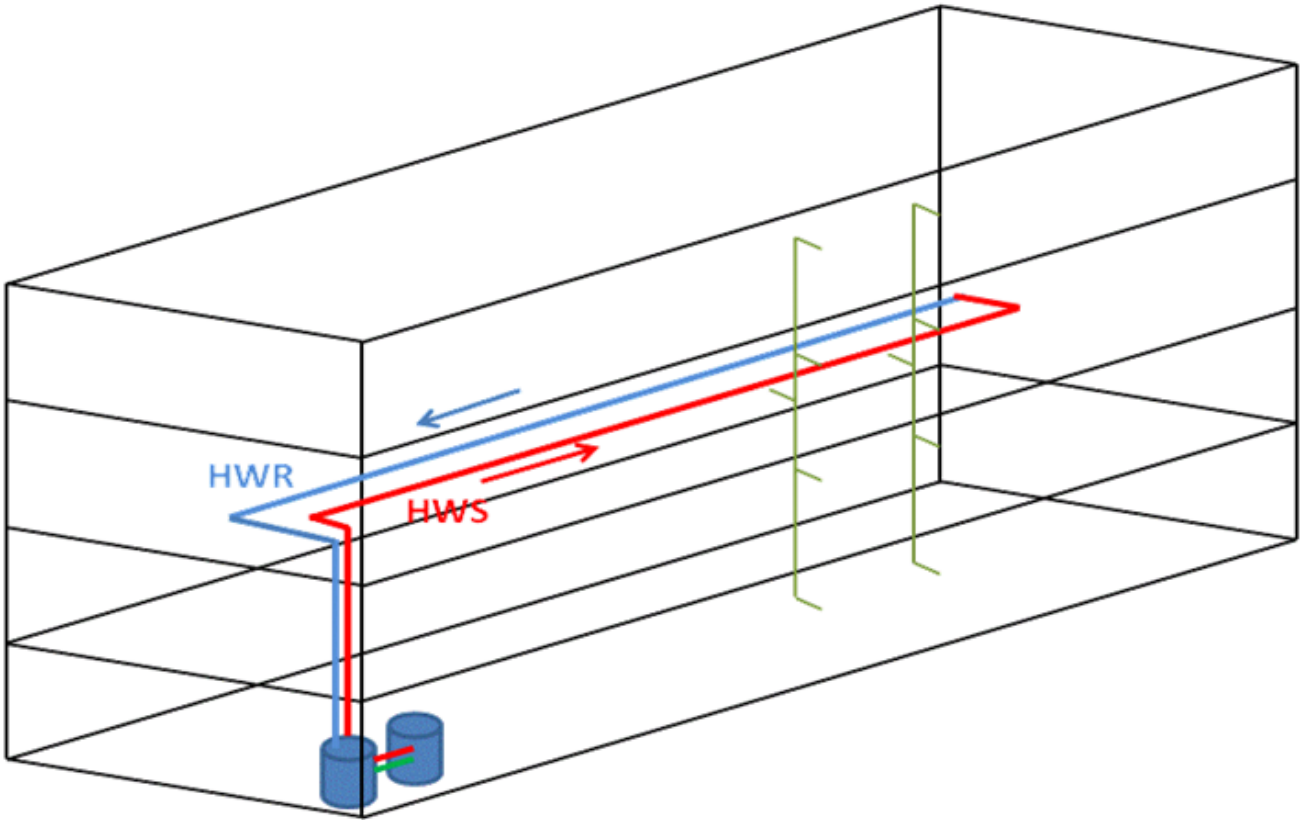

Image source: HMG, Inc

DHW energy losses

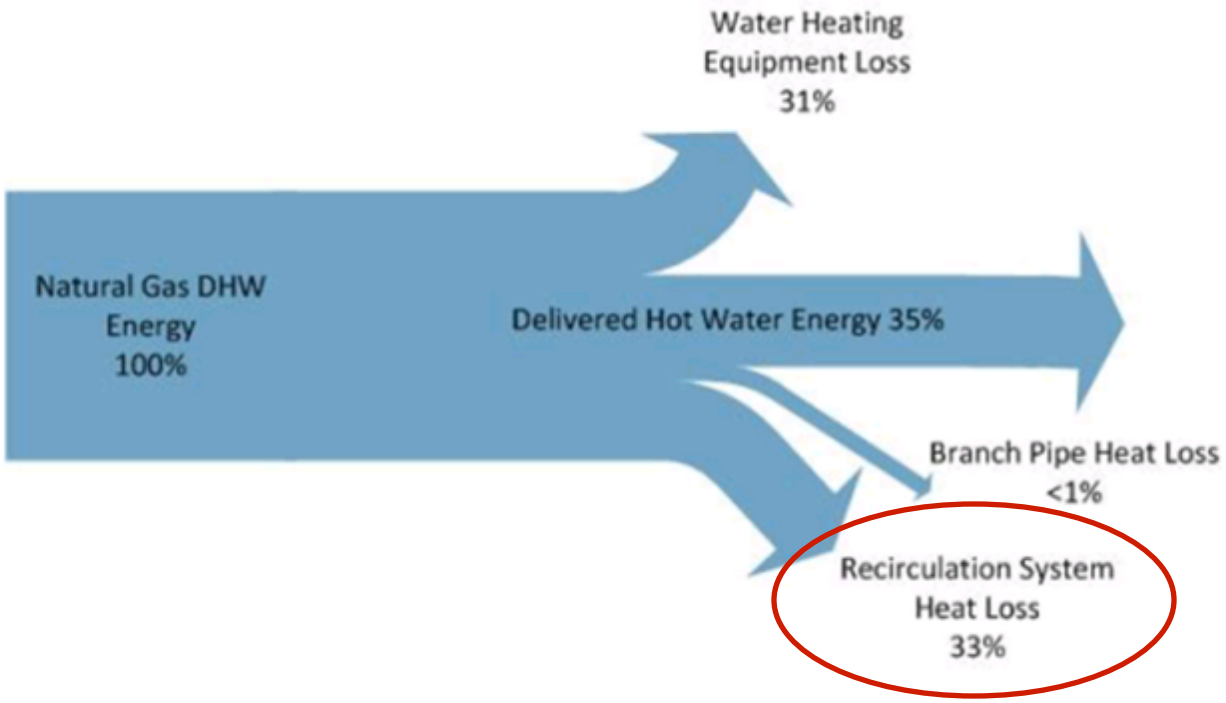

Image source: HMG, Inc. Multifamily Central Domestic Hot Water Distribution systems. 2013

Enovative's Demand Controller

- Control stops pump when there is no building demand *or* the recirculation loop temp is above 100F
- Pump run time reduced from 24/7 to average 14 mins/day

  (ARIES Collaborative/Building America study in 2014)

A good investment…

- ❑ Has aggressive energy paybacks
- ❑ Lowers O & M costs
- ❑ Improves building comfort
- ❑ Makes things easier for staff
- ❑ Is "tried and true"
- ❑ Is easy to implement
- ❑ Makes everyone look smart

Variables that affect predicted savings

- Tank efficiency
- Insulation on recirc loop pipes
- Seasonal consumption
- Incoming cold water temp
- Building consumption habits
- “Crossover”

DHW Savings
Range: 5-15%
Average: 9%

Rochester installation

- 3-story
- 39 unit building
- Built in 1955
- Failed water heaters
- Shower heads and faucet aerators installed along with building assessment

10% DHW savings from Demand Controller
Payback = 4 years
540 therms saved, 14 therms / unit

Aerosol envelope air sealing

Concept:

- Pressurize apartment unit
- Spray air sealing fog
- Sealant particles build up on gaps as they exit the envelope

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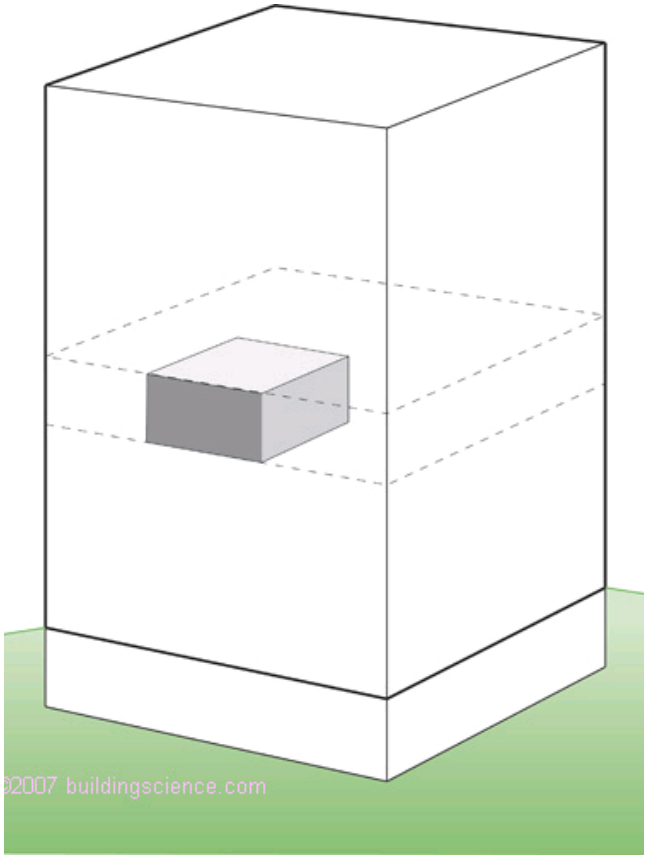
Multifamily compartmentalization

Creating an interior air barrier around each unit

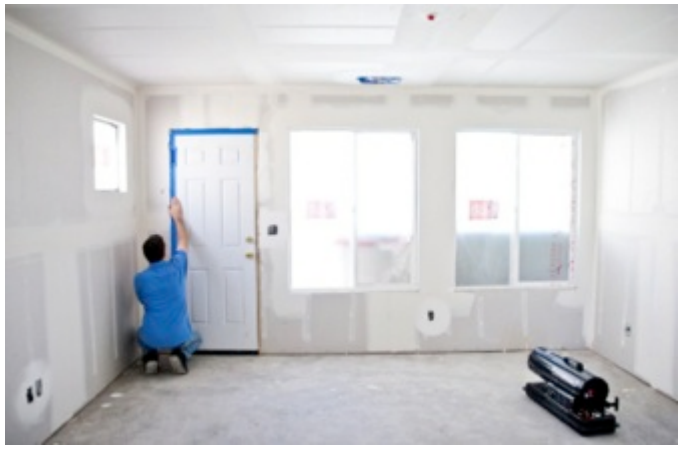
- Reduced stack effect
- Reduced noise transfer
- Reduced odor transfer/improved IAQ
- Increased comfort
- Increased energy efficiency



Nuts and bolts

PREP WORK

- Horizontal surfaces covered
- Windows, exterior doors covered
- Finished floor covered (ideal before flooring is installed)
- Door handles covered
- Plumbing fixtures covered
- Ceiling fans covered
- Radiators covered
- Sprinkler head openings covered
- Remove outlet/switch plates



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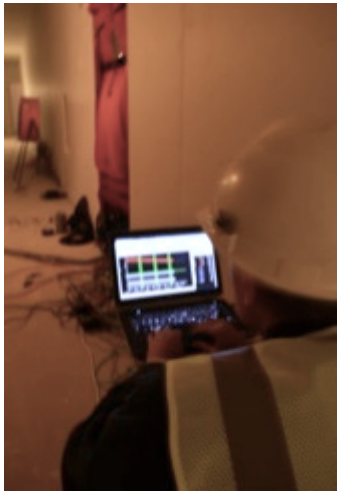
Nuts and bolts

SET UP/SEAL

- Blower door and nozzles
- 100Pa pressurization
- ~ 90% RH maintained

CLEAN UP

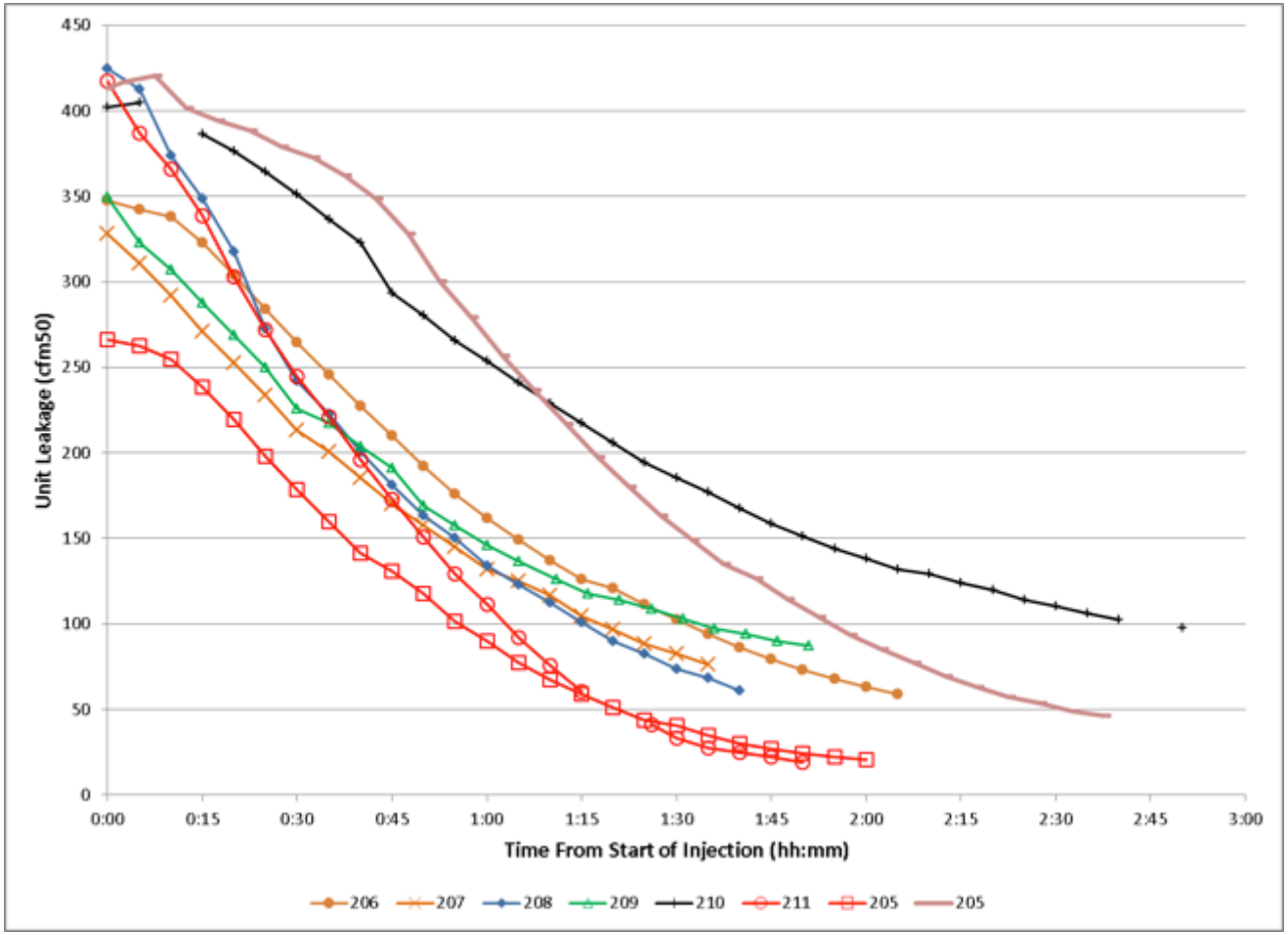
- Open windows, purge
- Remove masking



Preliminary results

- Air tightness result: 114 to 25 CFM50 total unit leakage (8 units sealed)
- Averaged 0.45 ACH50
- 78% to 95% tighter than the new code requirement of 3.0 ACH50
- 12-13 times tighter than Energy Star requirement for multifamily

Leakage reduced over injection period



Sealed penetrations

Sealed penetrations

Identifying the opportunity

IDEAL CANDIDATES

- Moderate rehabs “floors and cabinets”
- New construction

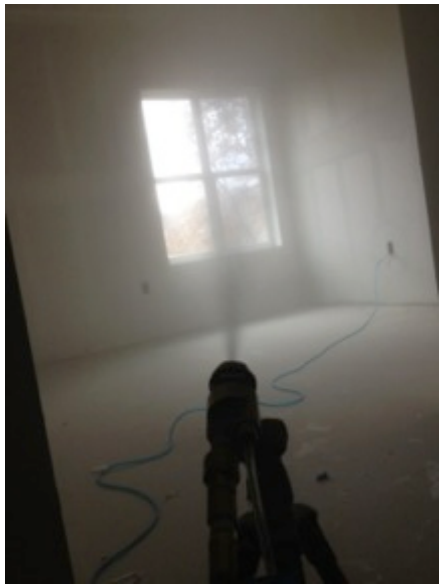
NOT IDEAL

- Where carpet is installed
- If occupied

Air sealing at lower cost?

Aerosol

- Prep
- Sealing process
- Simultaneous air leakage testing ensures results



Vs.

Manual air sealing

i.e. caulking/foaming

- Architectural specification
- Labor
- Air leakage test

=> Uncertain results

Marketable?

BENEFITS

- Reduced mid and high range noise transfer
- Reduced odor transfer
- Improved comfort
- Simultaneous air leakage testing ensures results
- Expedited process, labor savings potential

CONSIDERATONS

- Cost
- Not a solution for large air leak gaps
- Rehab or new construction only
- Balanced ventilation is crucial

A good investment…

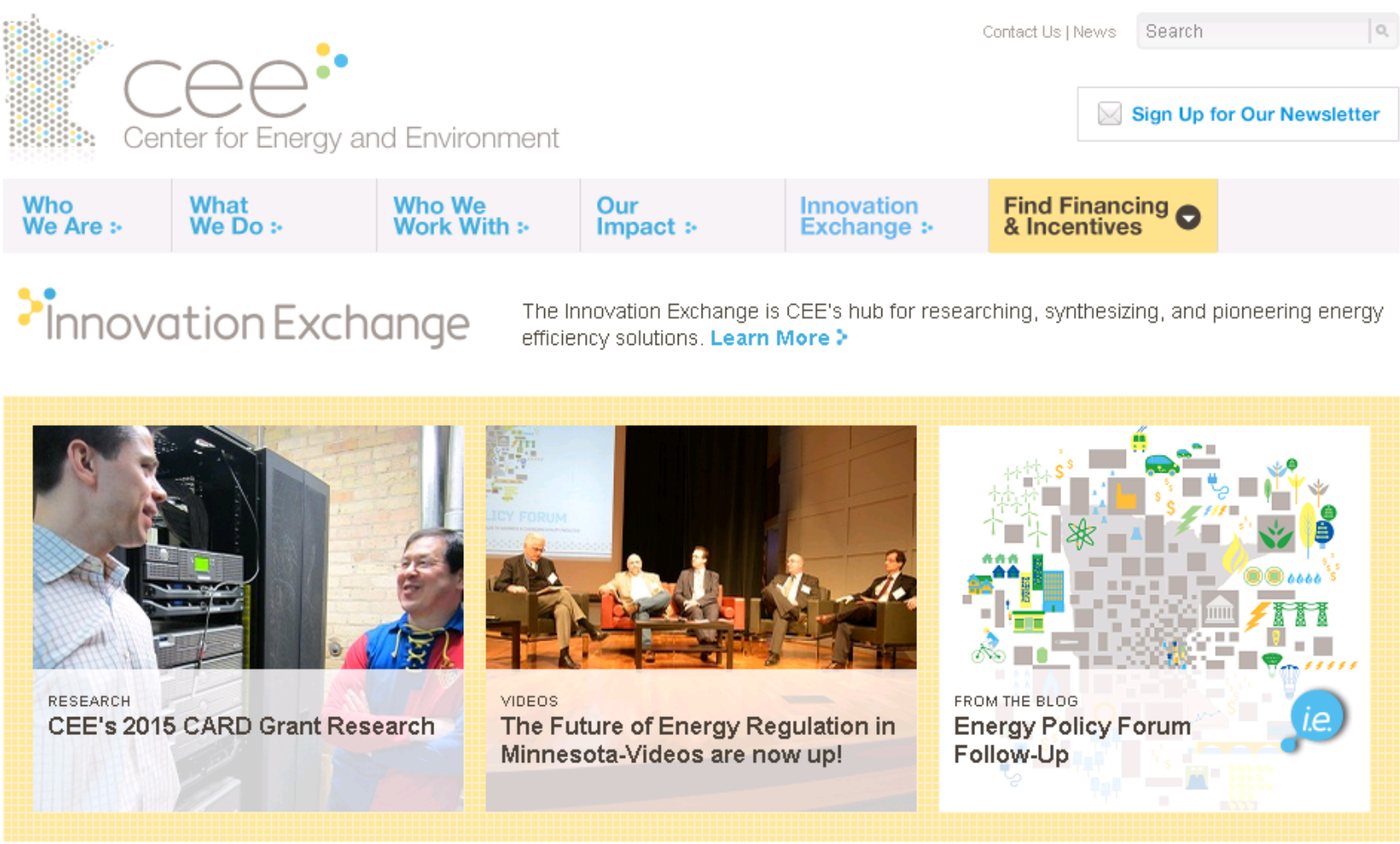
- ❑ Has aggressive energy paybacks
- ❑ Lowers O & M costs
- ❑ Improves building comfort
- ❑ Makes things easier for staff
- ❑ Is "tried and true"
- ❑ Is easy to implement
- ❑ Makes everyone look smart

Stay tuned for more info (Jan 2016)

Study will look at :

- 6 test sites; Rehabs and new construction in MN
- Enabling commercialization of process
- Air leakage reductions
- Sound attenuation
- ID leak site locations with fluorescent dye/black light photography
- Evaluation of time and materials required

More info CEE programs and research: mncee.org



THANK *you!*

Questions?

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