Research Update:

Condensing Boiler Optimization

Duluth Energy Design Conference
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Minnesota Department of Commerce
Division of Energy Resources

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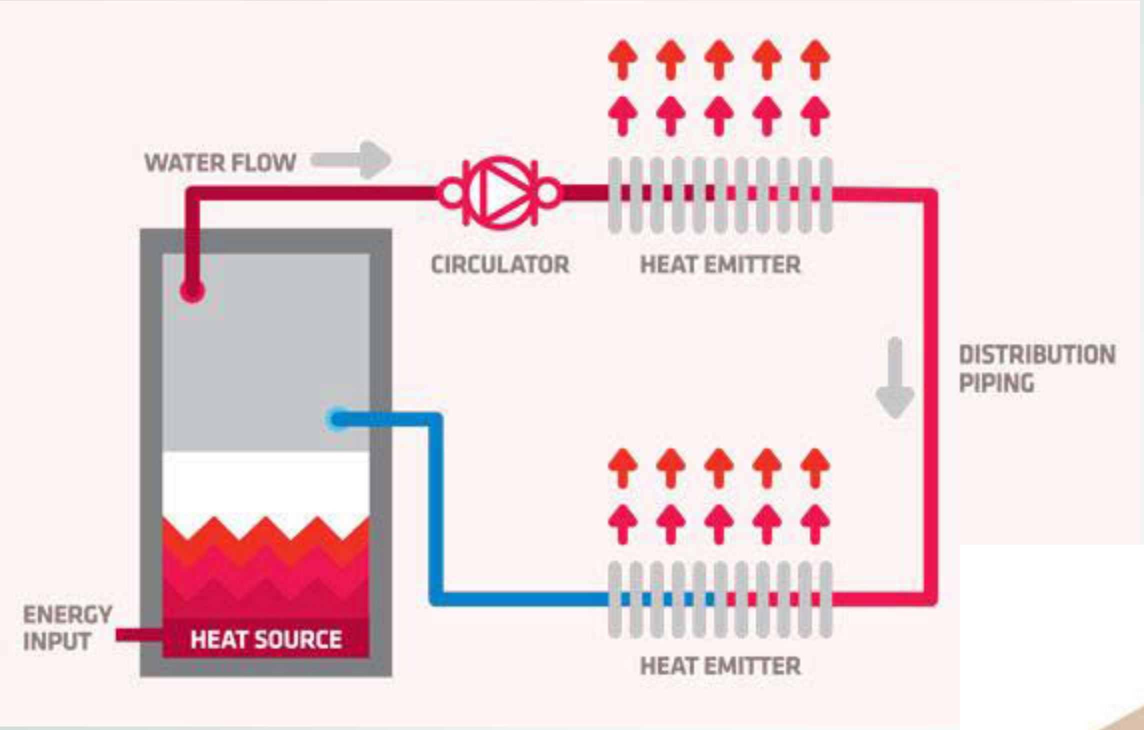
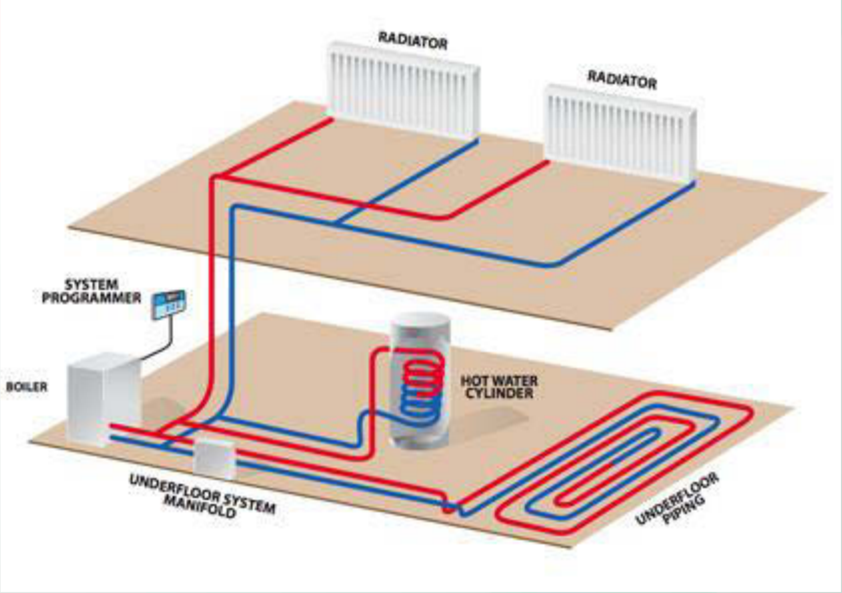
Introduction to Hydronic Heating



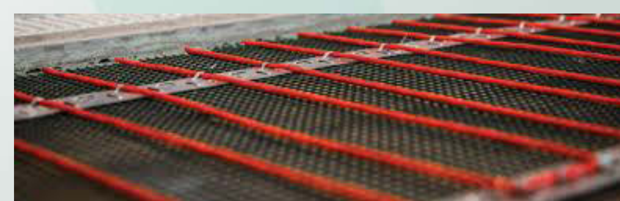


Introduction to Hydronic Heating

- Non-condensing vs. condensing
  - Conventional boiler: condensation of combustion gases can rust out heat exchanger
  - Condensing boiler: condensation of combustion gases is optimum for efficiency
- Difference in return temperature requirement
  - In order to get combustion gases to condense, the return water temperature needs to be below ~130°
- Radiator types
  - Radiator types and size play a significant role in the ΔT between supply and return temps.
- Issues with replacement from one to other
  - It's important to optimize efficiency when replacing a conventional boiler with a condensing boiler based on the above factors

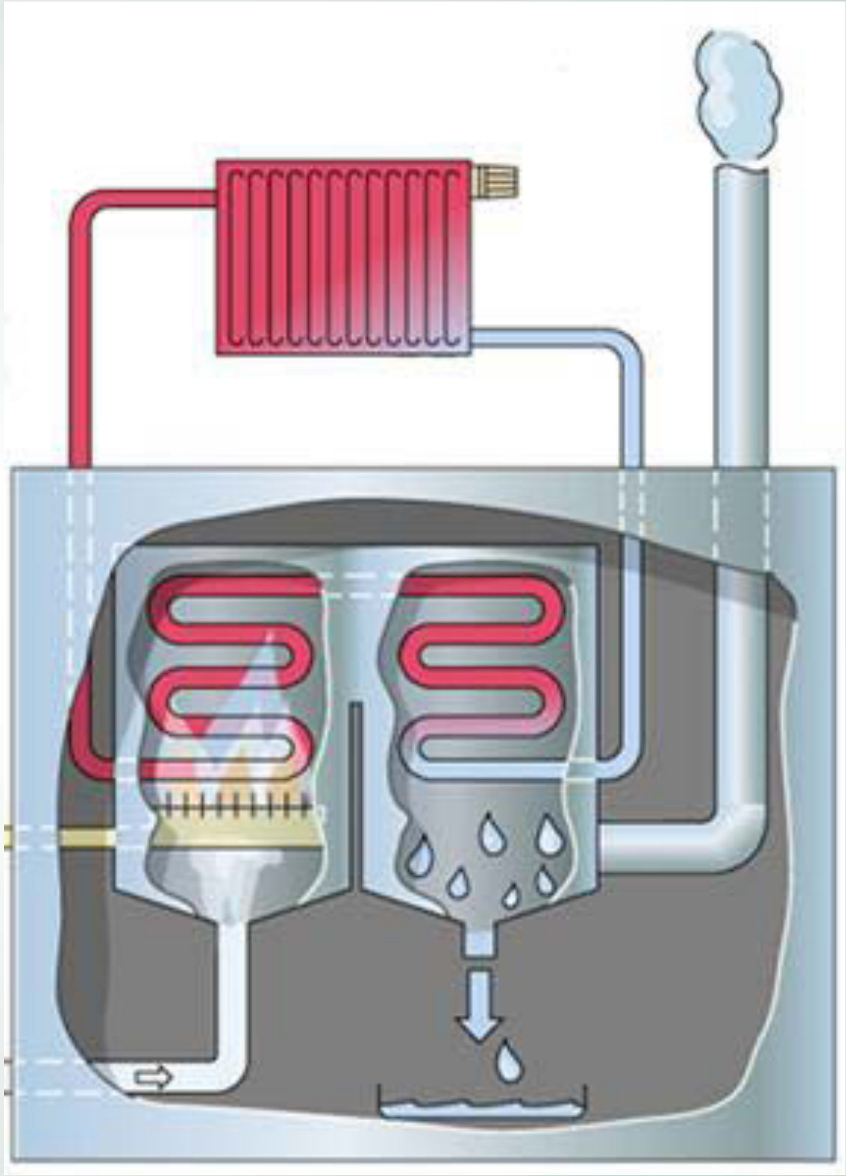
Hydronic Heating in MN

- Approximately 30% of MN homes are heated by a boiler
- Most of these are in older cities like St. Paul and Minneapolis
- Some in northern locations where central A/C is in less demand



Condensing Boilers

- How it works:
  - 2nd condensing heat exchanger
  - Less waste heat up the chimney
  - If return water temp is low, more heat is exchanged from the combustion gases to the boiler water: increasing efficiency
  - Supply temperature, flow rates and radiator type/size dictate return water temp.



Need for Condensing Boiler Research

- Lack of modulating condensing boilers in residential market
- Evidence that HVAC contractors and utilities have inconsistent confidence in products
- Prior research showing how important return temperature is on condensing boilers—commercial and hydronic air handler studies
- Need for quality installation protocol for utility savings and cost benefit confidence

Contractor Hesitance and Cost

- Cost of condensing units is generally high and variable
  - $6,500--$15,000 installation cost range
- Lack of confidence in operation at high efficiency
- Issues with early models and maintenance callbacks
- Confusion about supply set-temps and condensing rate optimization
- Not as many model options in this market as condensing forced air systems

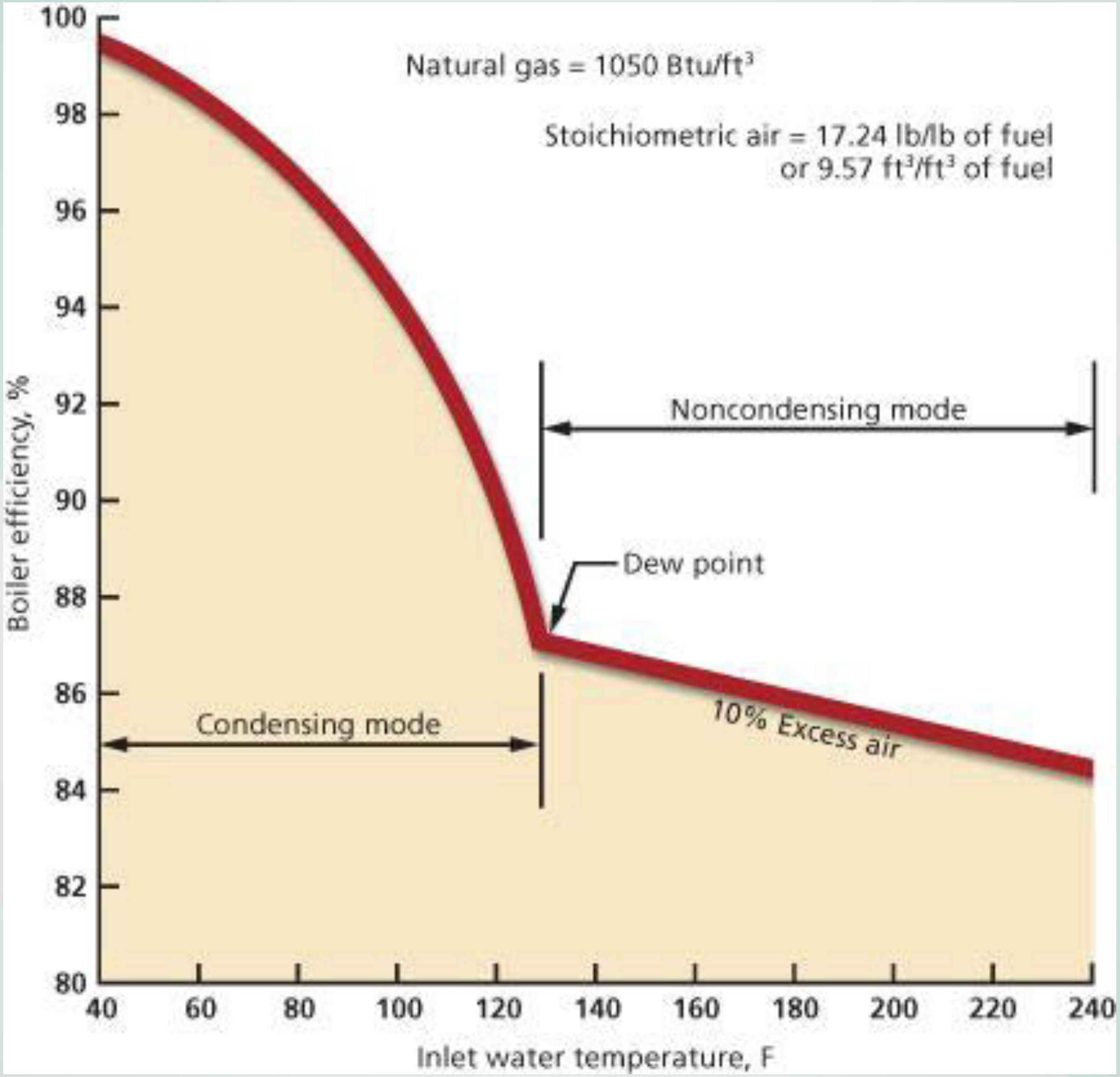
Condensing Boiler Rebates in MN

- Current rebates for condensing units are offered by:
  - Centerpoint Energy (91%+ AFUE=$500)
  - MN Energy Resources (90%+ AFUE=$200)
  - Great Plains Natural Gas (91%+ AFUE=$500)
  - Greater MN Gas (90%+ AFUE=$500)
  - Xcel: offers rebate at 84% or higher ($100), but doesn't have a separate tier for 90%+
- Xcel is considering adding a condensing tier, but needs more information about savings
- 2015/16 Federal tax credit: 95%+ AFUE=$150

Prior Research and Information

- Conclusions:
  - Return water temp is a primary factor
  - Flow rates can influence return water temperature
  - Outdoor reset needs to be installed and set-up properly
  - Needed more info pertaining to MN housing stock, radiator types, and climate as well as more field implementation guidelines
- Building America—Butcher/Arena
- Commercial Boiler study—CEE Russ Landry
- ASHRAE Handbook

Prior Research and Information



Research Project Structure

- Field and Market research
- Existing condensing boiler monitoring
- Draft retro-commissioning activities
- Monitor savings after retro-commissioning
- Development of Quality Installation Protocol for Utility rebates based on savings from retro-commissioning
- Work with contractors to install condensing boilers in homes using QI protocol
- Information dissemination through webinars, presentations and published reports

Research Project Timeline

Task	Name	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Assessment												
2	Existing boiler monitoring												
2.2	Exisiting monitoring												
2.3	recommissioning												
2.4	Post monitoring												
2.5	refinement of recommissioning checklist												
3	New boiler installation												
3.2	Installation												
3.3	Monitoring												
3.4	refinement of installation checklist												
4	Final report												

Market Research Structure

- Interview HVAC contractors about installation
  - Procedures
  - Pricing
  - Barriers
  - Incidence
- Interview homeowners about performance
  - Comfort
  - Maintenance
  - Issues
- Interview Utilities about rebate development and rationale

Early Market Research Results

- **Interview HVAC contractors about installation**
  - 2 companies interviewed so far
  - Low volume of boiler replacements and even lower volume of condensing
  - Some hesitation on cost vs. performance
  - Costs seem to be inconsistent with equipment and labor details
  - Plan to interview at least 5 more contractors
- **Interview homeowners about performance of existing condensing Boiler**
  - Comfort is very high in existing sites
  - Maintenance does not seem to be an issue with any of the sites
  - Most sites relied on contractor to choose model
  - All 6 residents said they would recommend condensing system to others
- **Interview Utilities about rebate development and rationale**
  - Preliminary discussion with Xcel indicates they are worried about cost effectiveness.
  - They may be getting high installation cost estimates, and not have a lot of confidence in the efficiency

Field Research Phase I

- Characterization of Typical MN households
  - Based on aggregate consumption data from existing programs
- Participant solicitation/selection
- 6 sites chosen with existing modulating condensing boilers installed within the last 5 years
- Sites have varied heating loads and construction characteristics
- All homes have cast iron radiators
  - Some have other convector types, (i.e. baseboard, in-floor, low mass)
- 3 sites have indirect water heaters
- Monitoring
  - Gas usage
  - Supply and return water temperature
  - Flow rates
  - Condensation rate

Field Research Phase I

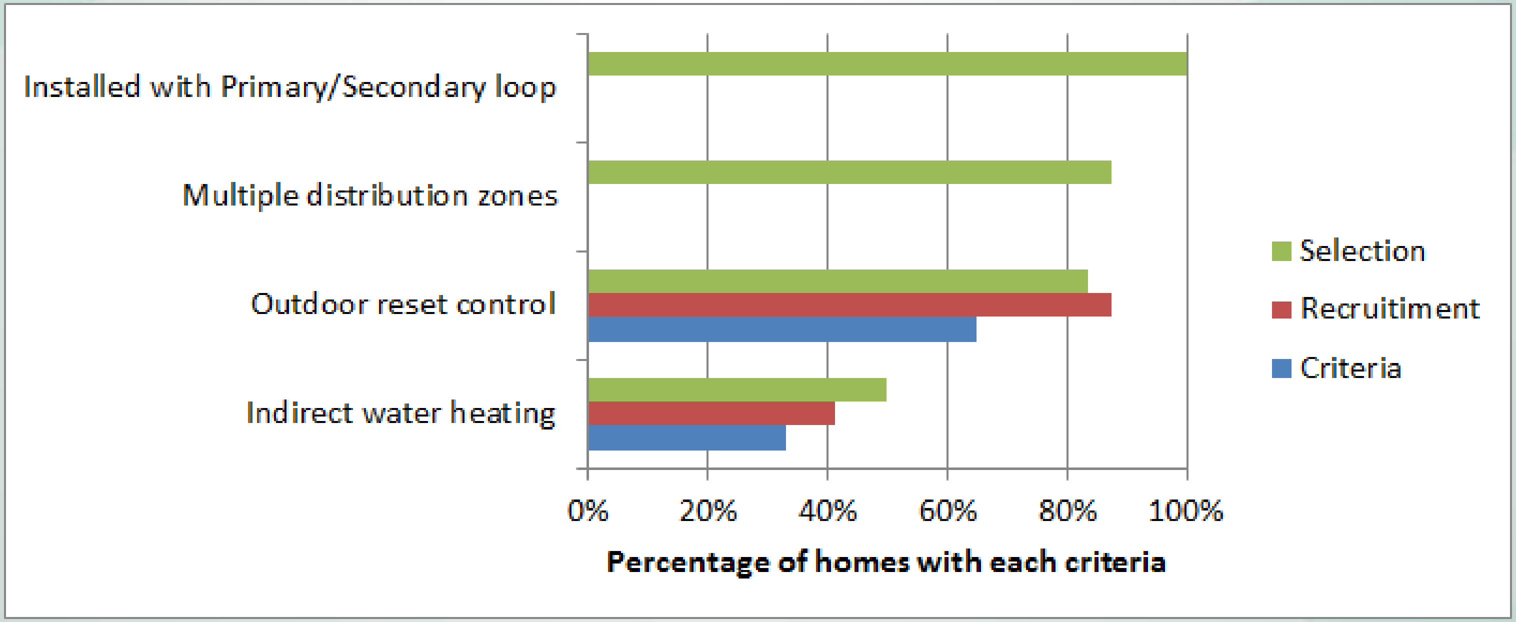
- 1st half of 2015/2016 heating season, monitor as installed
- Make minor changes to optimize efficiency
  - Adjust supply temp
  - Optimize turn-down ratio
  - Maybe adjust flow rates
- 2nd half of 2015/2016 heating season, monitor after adjustments
- Measure savings from 1st half to 2nd half
- Develop draft quality installation protocol

Site Selection Criteria

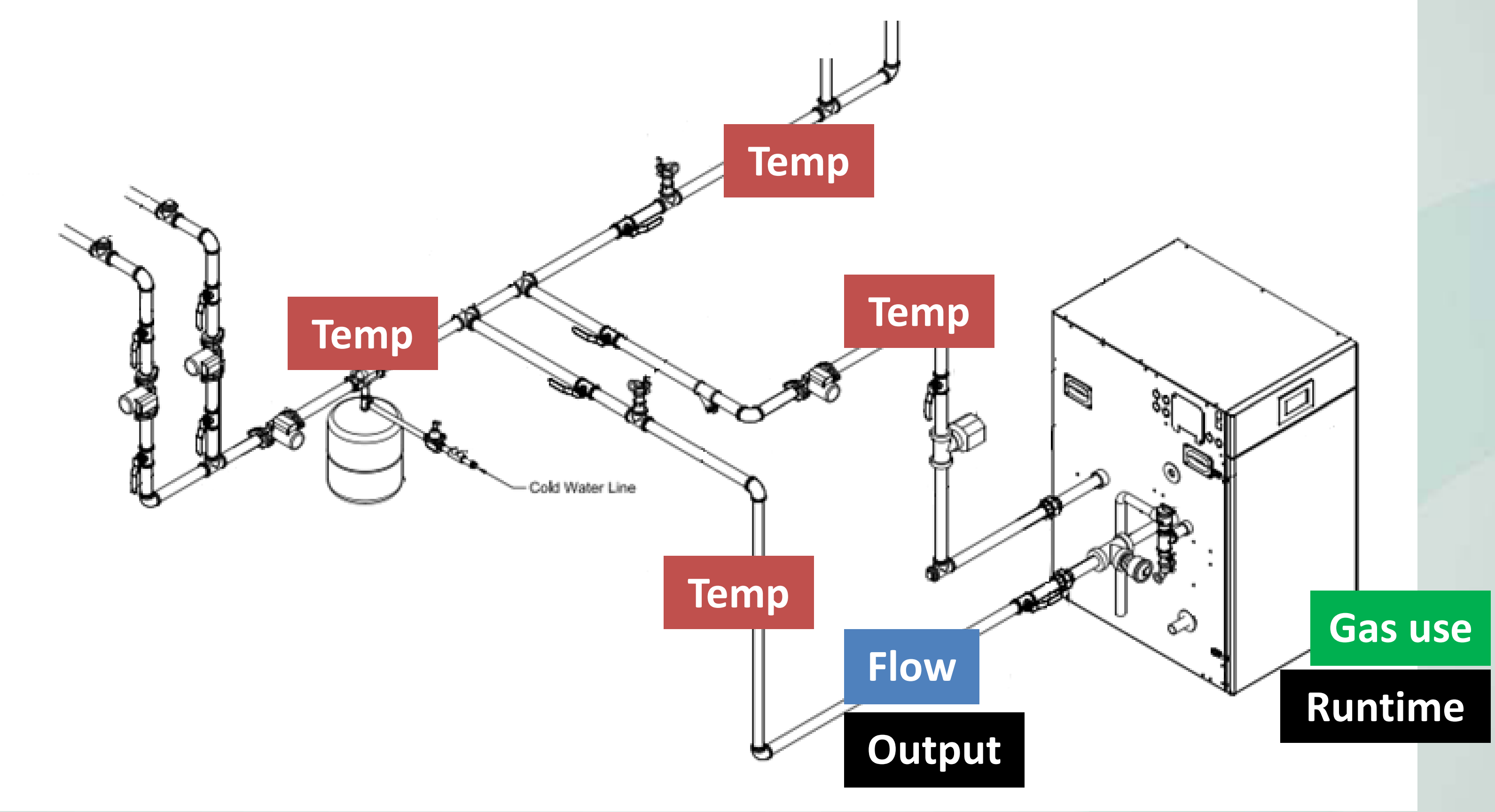
- At least 1 home per typical heating load quartile (420 to 700, 700 to 830, 830 to 1275, and >=1275 therms/yr)—based on MN aggregated residential utility program data
- At least 1 of each of the top 3 manufacturers—identified by utility rebate and local sales info
- A variety of installers
- MN program databases suggest between 30-36% of condensing boiler installs had indirect water heaters
- National Grid study found 30-40% of outdoor reset were not installed or installed poorly
- A variety of emitter types. Cast iron radiation, Low mass radiation, baseboards, and in-floor heating

Site Selection and Recruitment

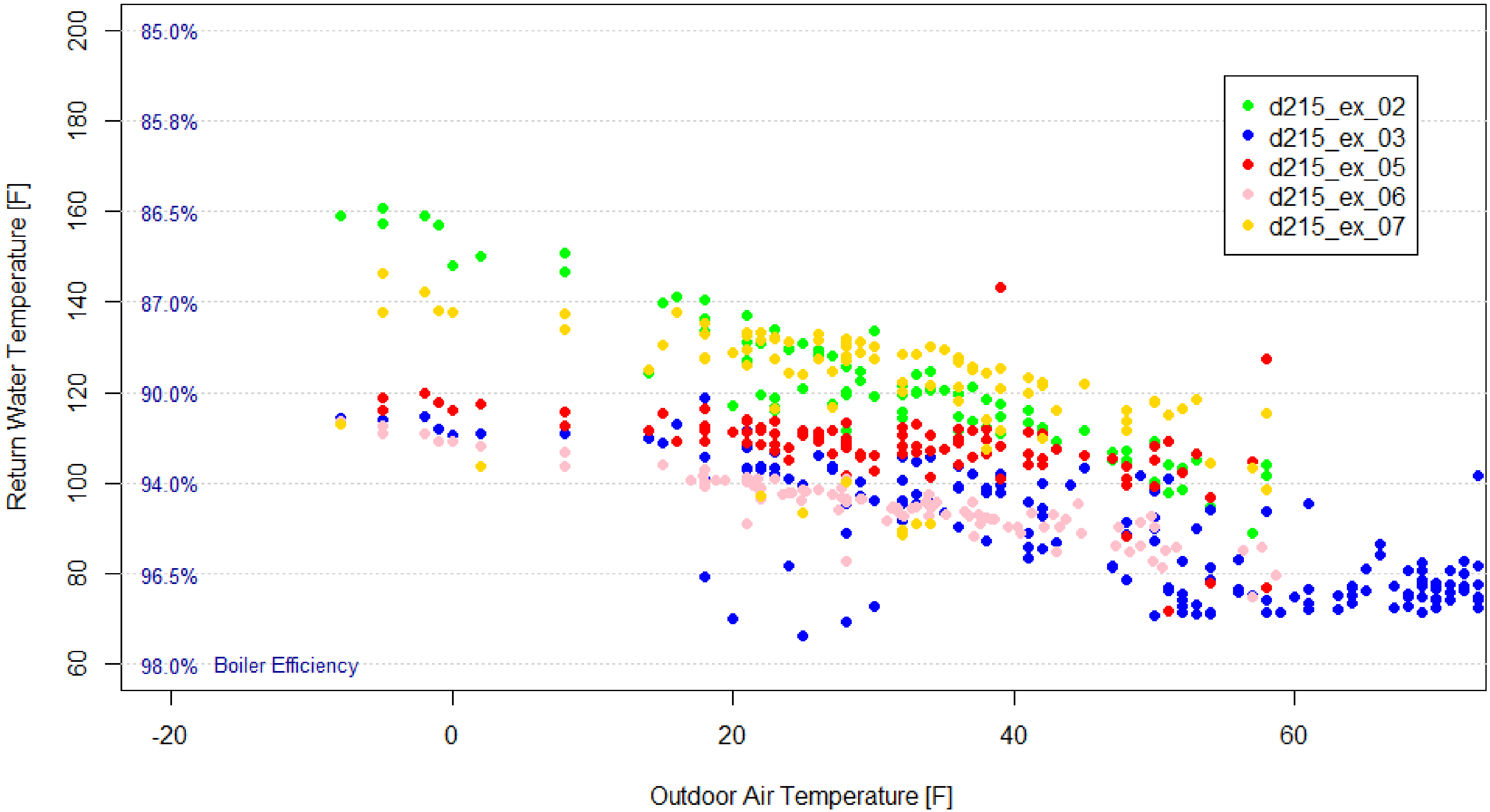
- **17 recruited homes had smaller loads than typical homes (Avg 720 therm/yr)**
  - In selected 6 sites, larger usage homes were slightly under represented
- **Identified 6 different manufacturers in recruitment.**
  - Top brands based on supplier and utility rebate data are represented in 6 selected sites
  - Triangle tube, Buderus, Bunham, Weil Mclain all included
- **11 different installers in recruited homes**
  - 5 different installers in selected sites



Monitoring Set-up



Daily Measured Performance



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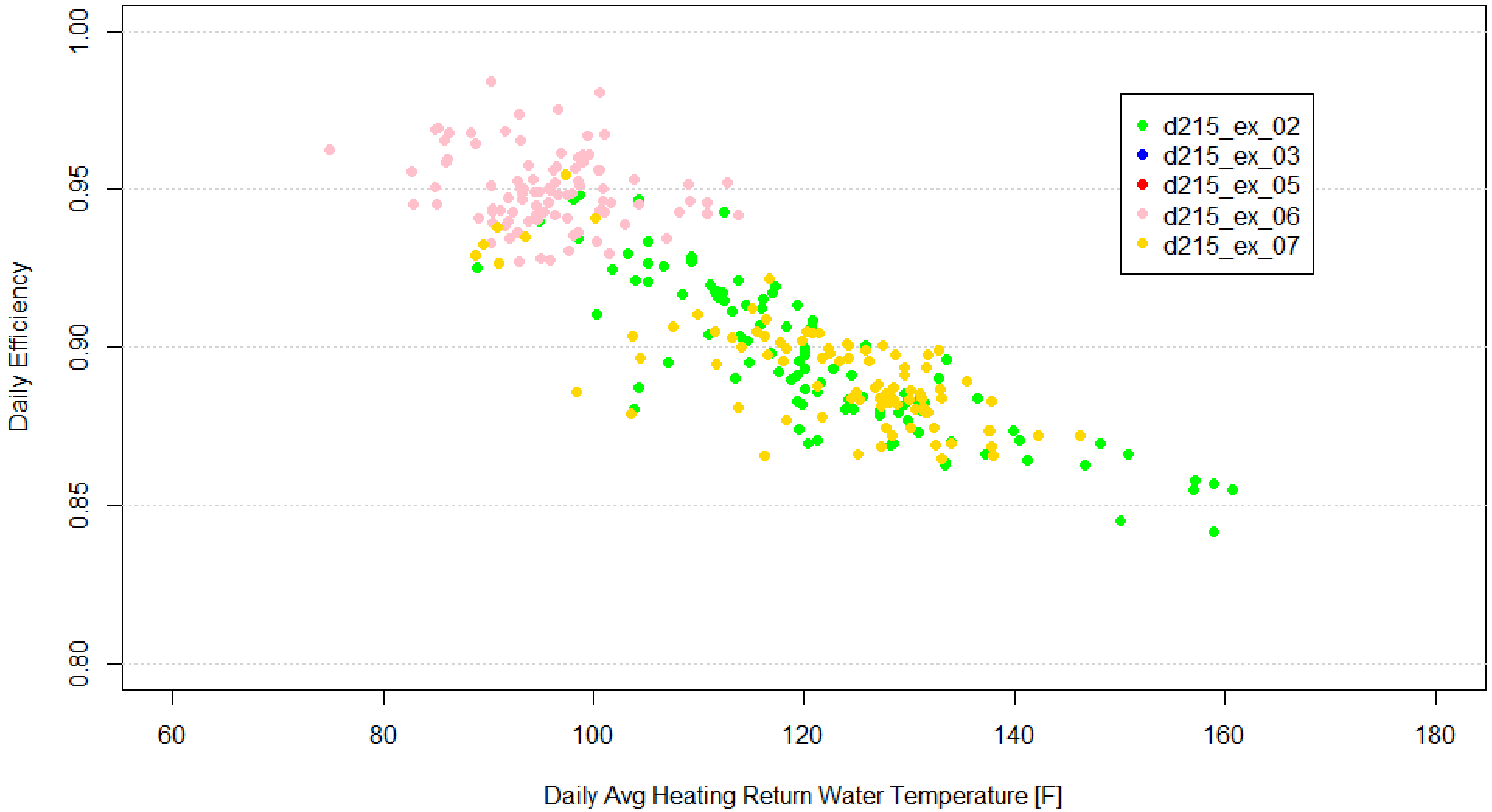
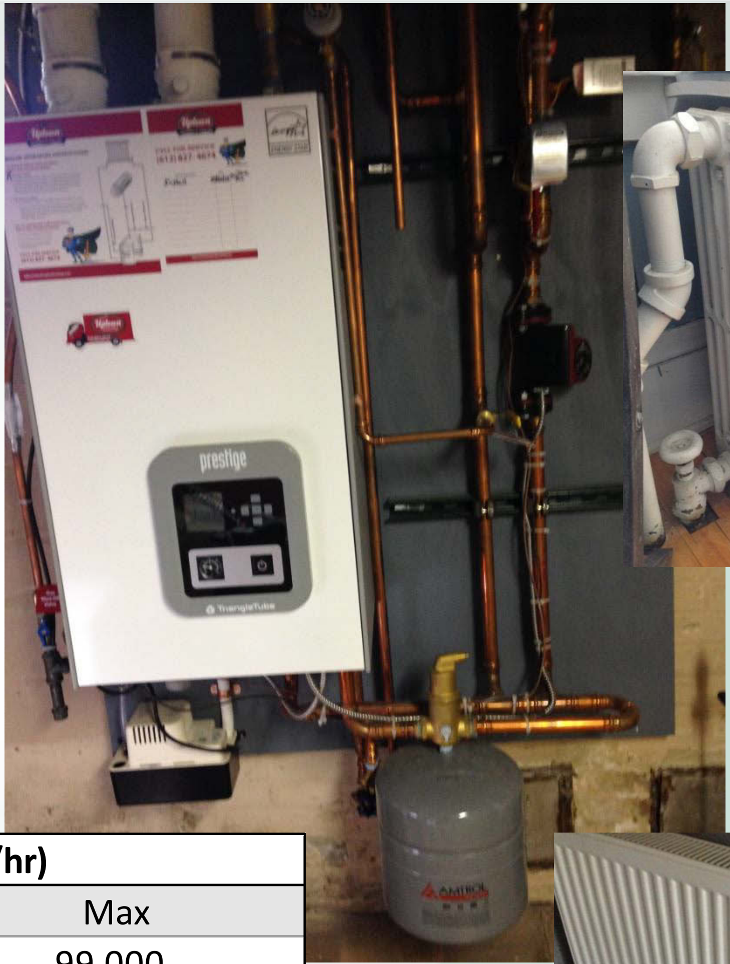


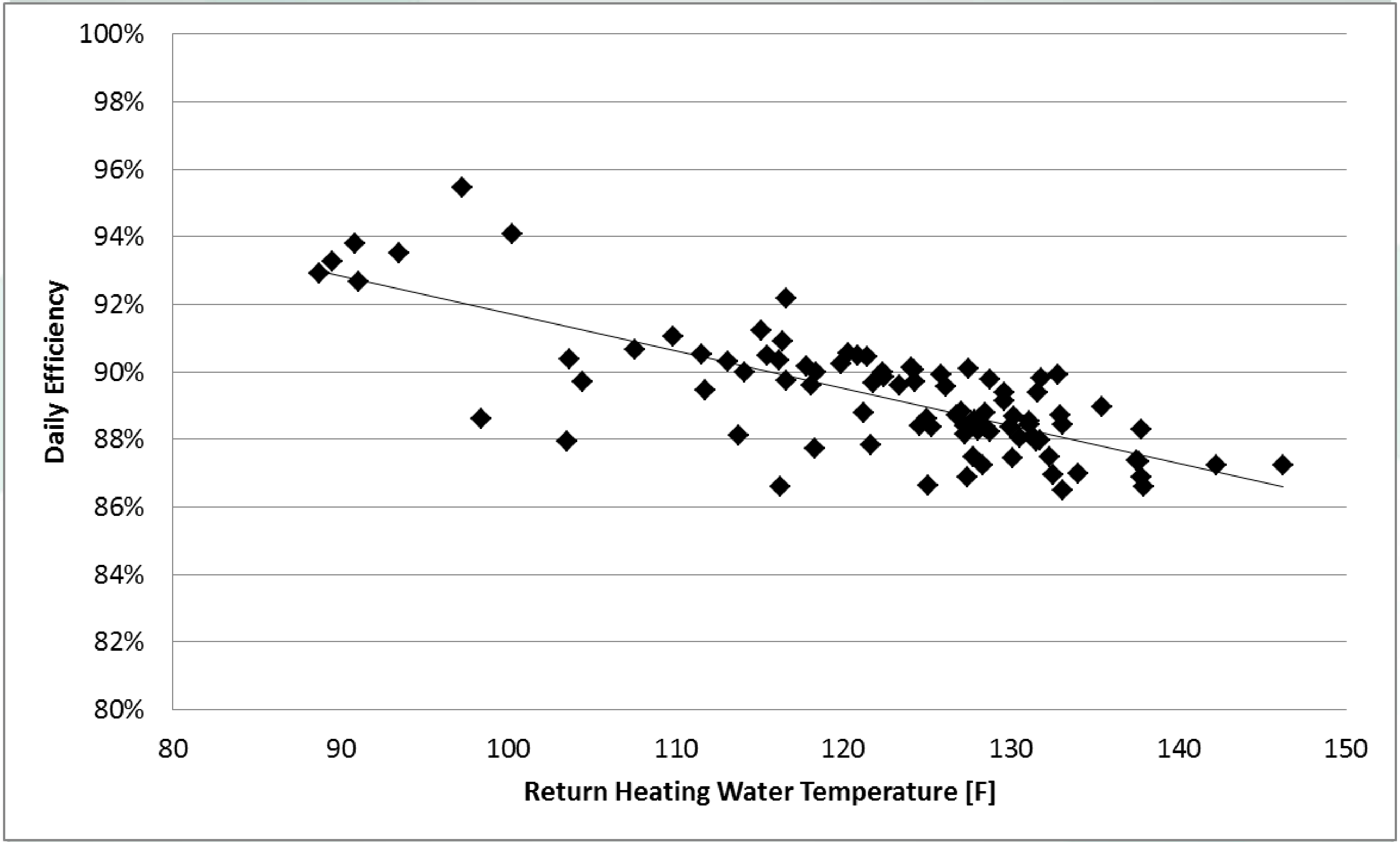
Site Example (Wiktor-D215 ex 07)

- Boiler for space heating only
- 6 Cast iron radiators
- 2 low mass radiators
- 3 zones w/ 3 t-stats



Capacity Estimates and Ratings (Btu/hr)		
Boiler Output	Min	Max
	28,500	99,000
Emmiters	at 140 Sup T	at 180 Sup T
	35,000	65,000
Design Heating Load (Bill Analysis)	at -12 F OAT	
	38,500	

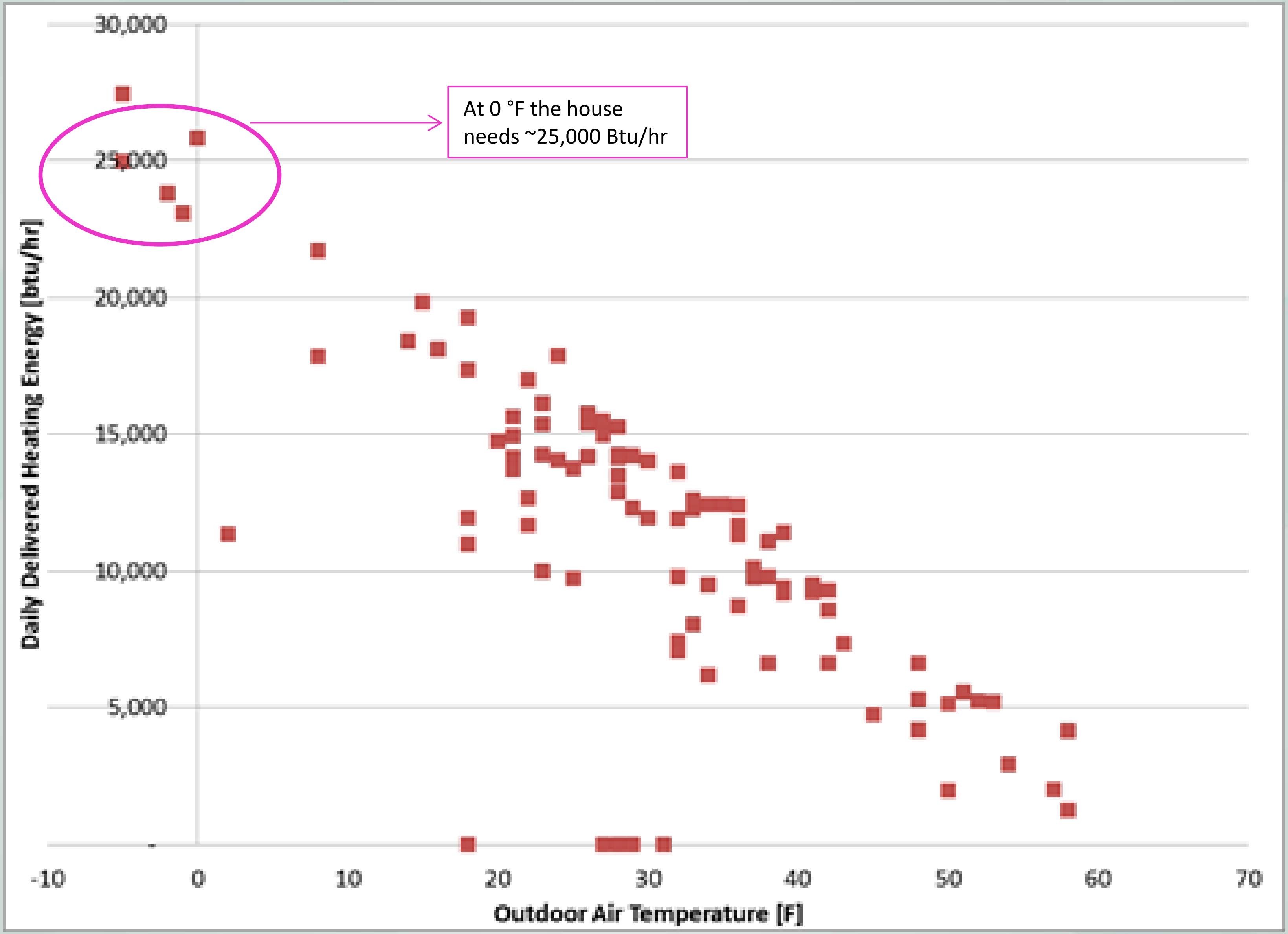
Site Example (Wiktor-D215 ex 07)



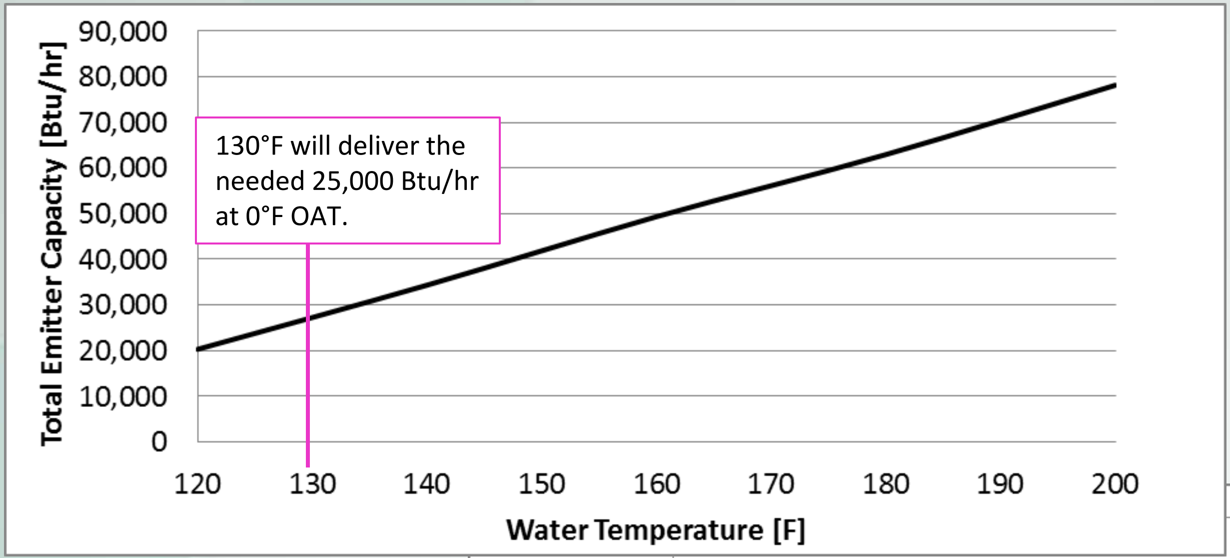
Supply Temperature Optimization

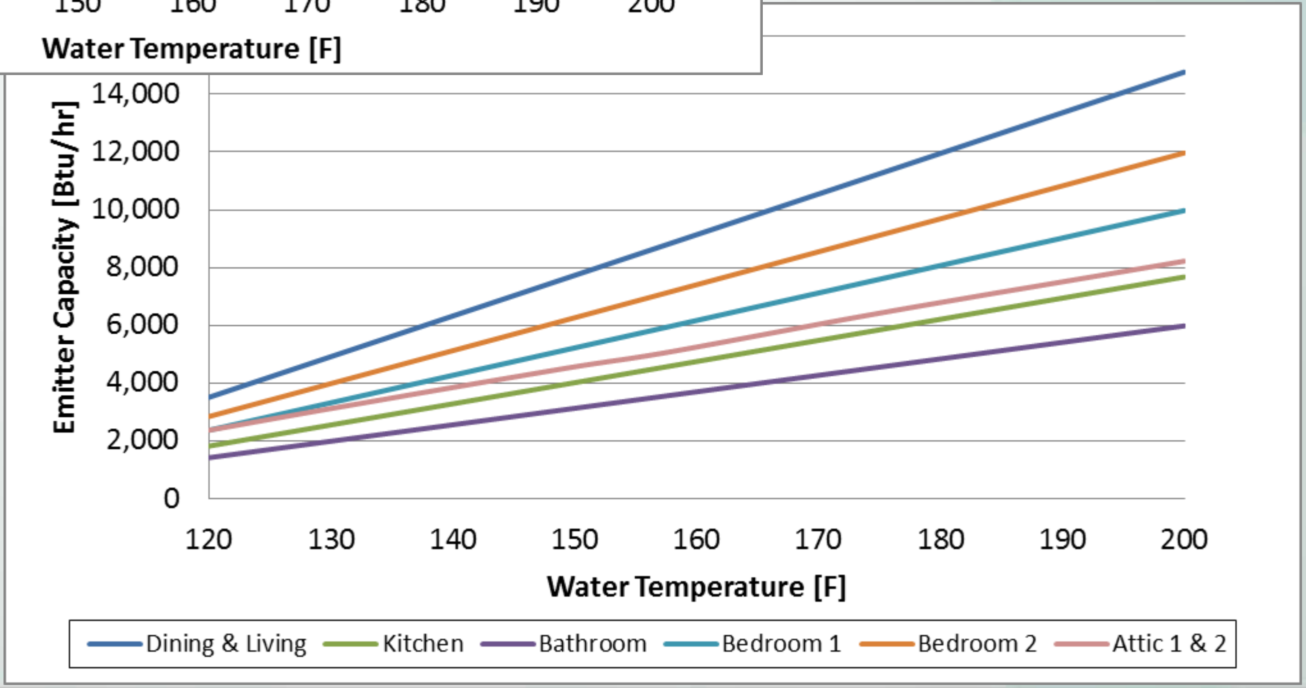
- Calculate or estimate the home heating load
- Calculate or estimate the emitter capacity
- Minimize the supply water temperature so that the house load can still be met

Site Example (Wiktor-D215 ex 07)

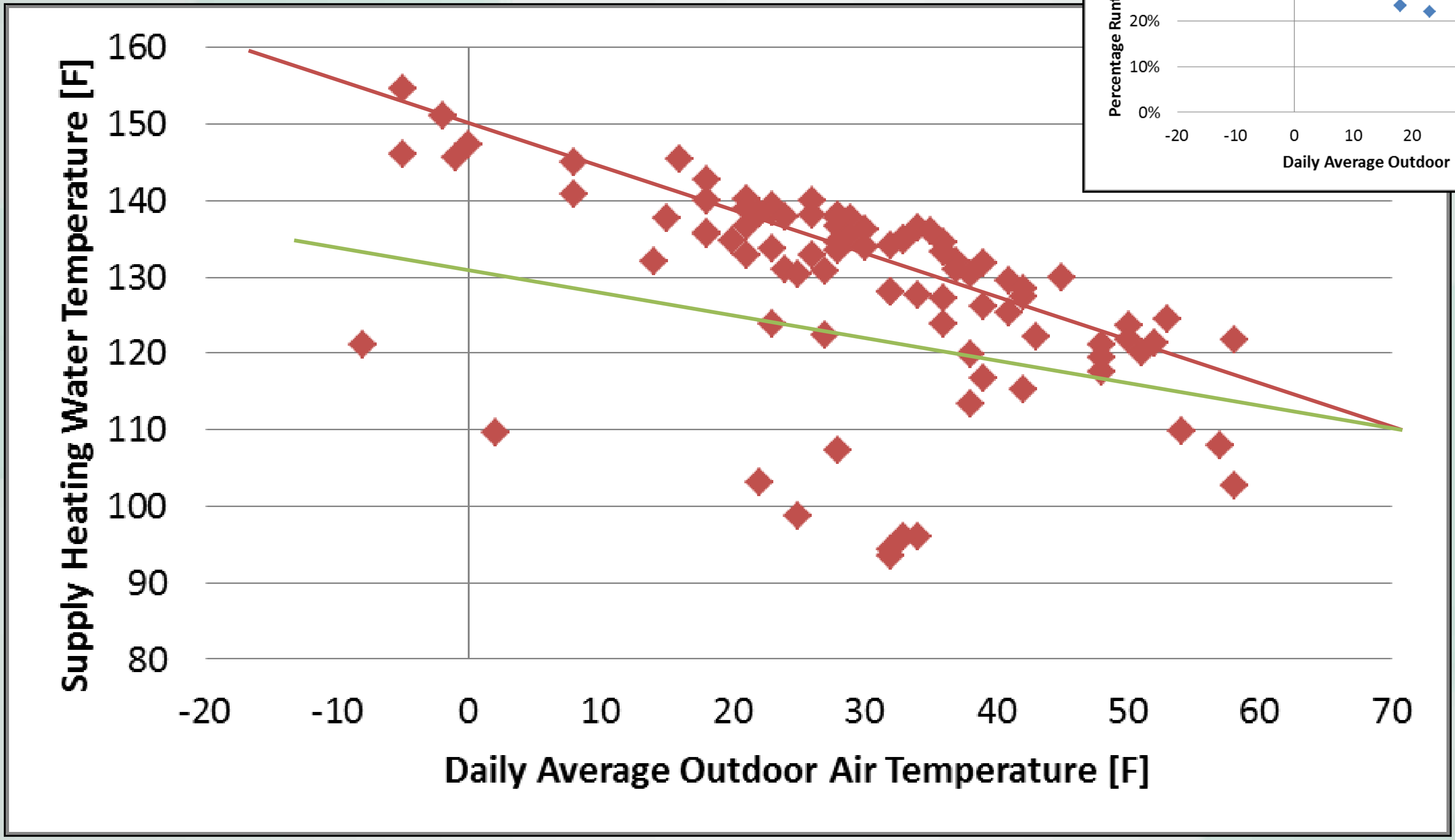


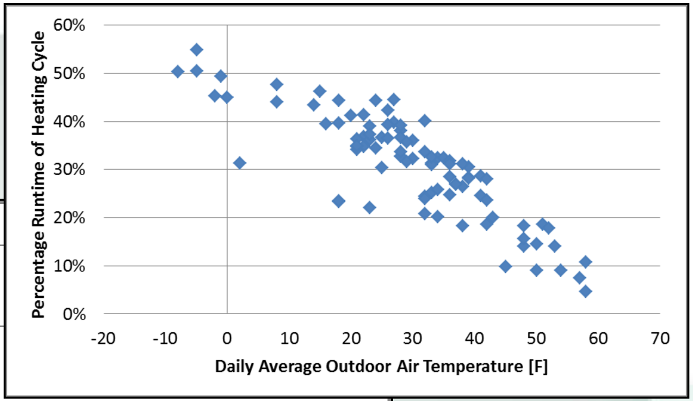
Site Example(Wiktor-D215ex07)Emitter Capacity





Site Example(Wiktor-D215ex07) Improvement

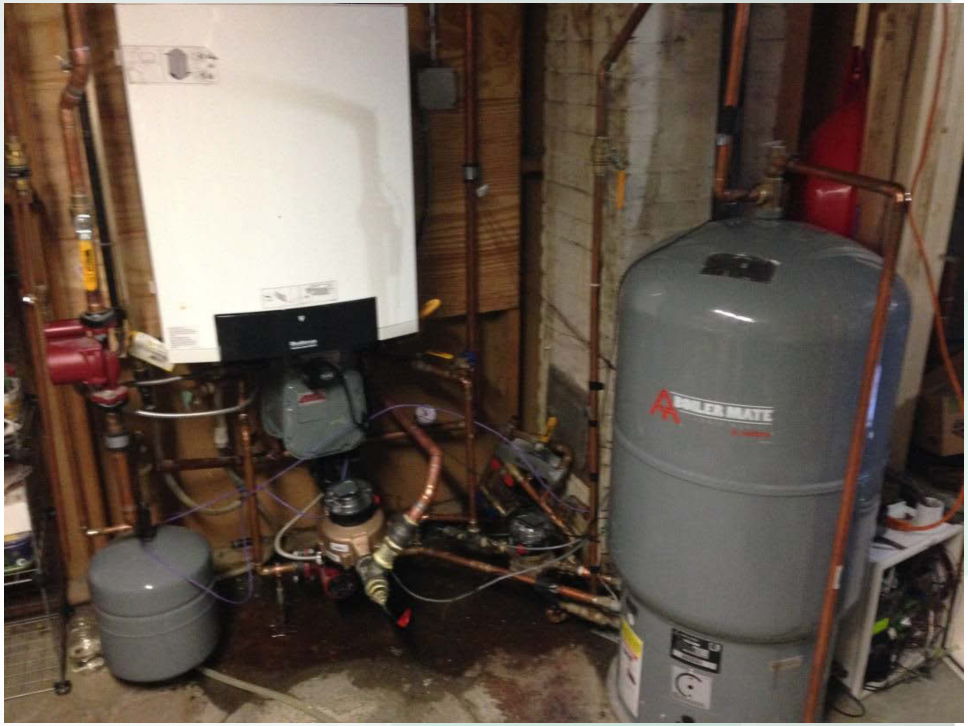


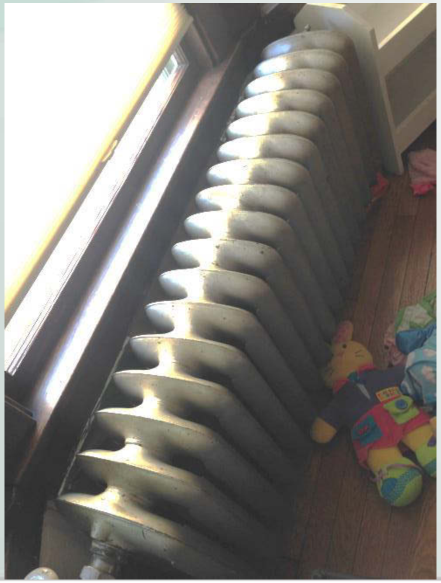


Current annual Efficiency ~87% Estimated Optimized Reset ~90%

Site Example (Krogstad D215 ex 03)

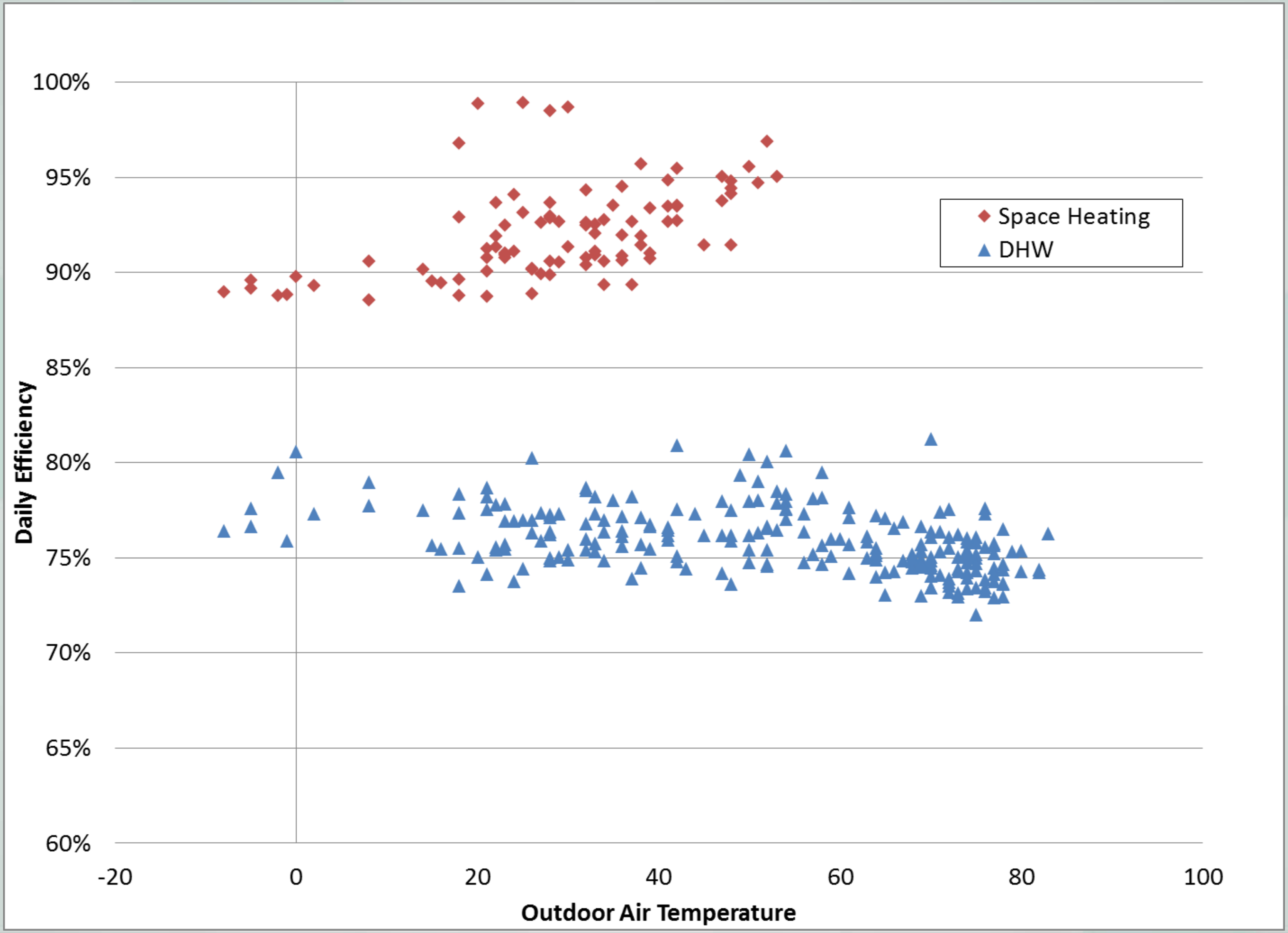
- Boiler and indirect water heater
- 6 Cast iron radiators
- 41 Gal WH set at 130°F





Capacity Estimates and Ratings (Btu/hr)		
Boiler Output	Min	Max
	22,745	75,200
Emmiters	at 140 Sup T	at 180 Sup T
	22,234	41,997
Design Heating Load (Bill Analysis)	at -12 F OAT	
	28,925	

Site Example (Krogstad D215 ex 03)



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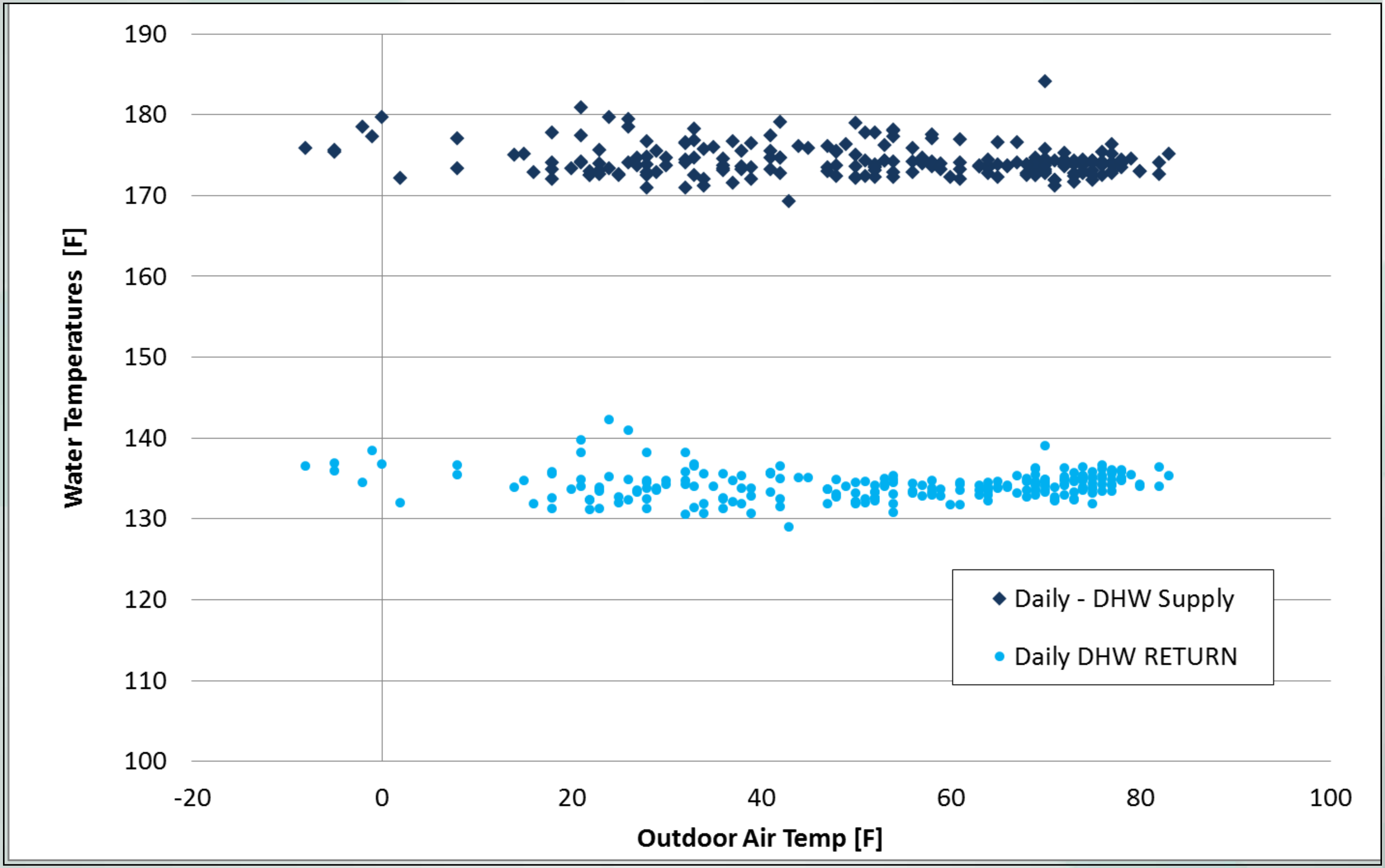

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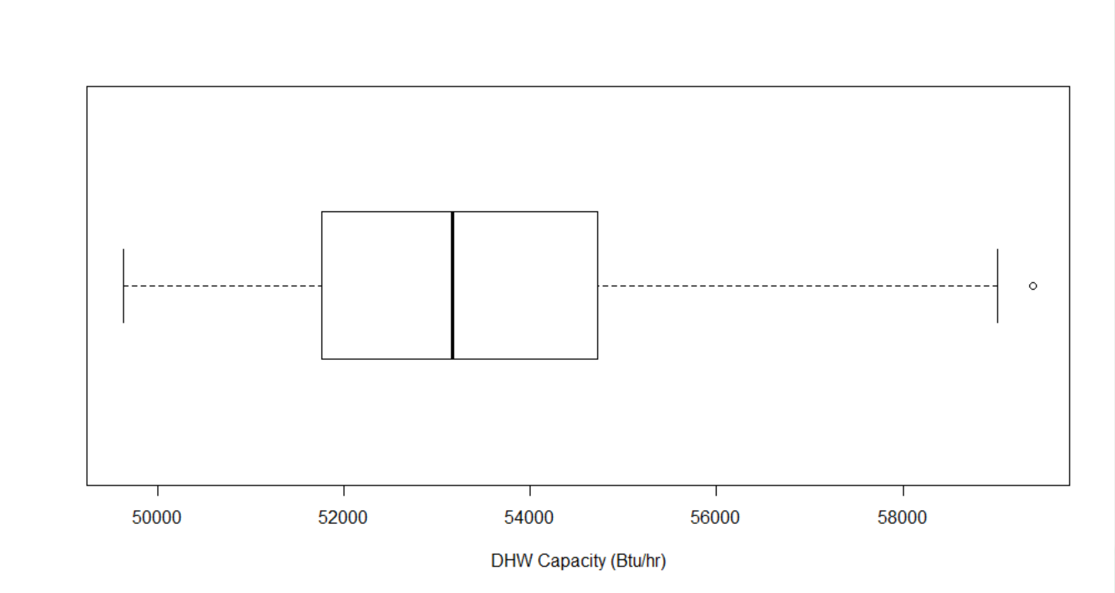

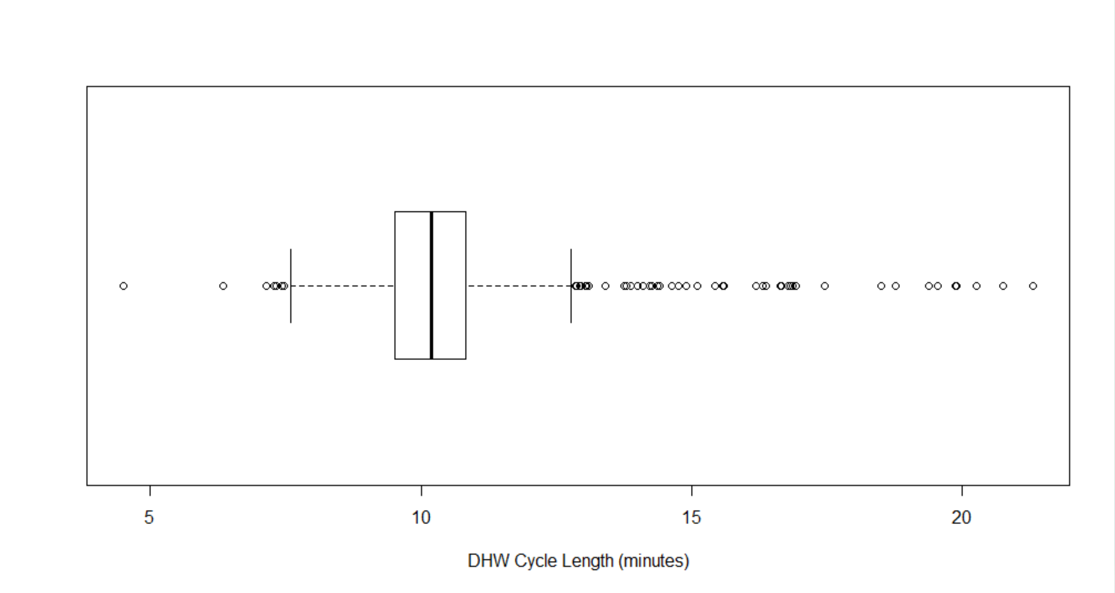

Retro-Commissioning Plan

- **Lower Supply Temperature**
  - Determine reasonable level to still meet load, but lower return temp. to optimize efficiency
- **Adjust overall Reset Curve**
  - Maximum supply temperature output at -12° vs. default of 0°
  - This will lower the slope of the curve making more points along the curve in the condensing mode
- **Potentially adjust DHW Supply**
  - Based on lower efficiencies of indirect tanks as well as indications of unused capacity
- **Potentially reduce pump speed**
  - Some sites have very high pump speeds that contribute to lower temp. drops between supply and return water

Field Research, Phase II

- Select 7-9 homes looking to replace non-condensing boiler with condensing boiler
- Use similar solicitation and selection criteria to Phase I
- Work with contractors to install new boiler in accordance with draft QI protocol in selected sites
- Monitoring
  - Gas usage
  - Supply and return water temperature
  - Flow rates
  - Condensation rate
- Measure efficiency and compare to Phase I to estimate potential savings associated with QI protocol

Dissemination Plan

- Hold several webinars and live presentations about project findings
- Work with contractors involved in interviews as well as installations to adopt QI protocol and hone in on pricing
- Work with WX agencies to determine assessment protocol for condensing boiler work scope
- Work with gas utilities not currently offering rebates for mod cons to implement rebate with QI protocol required
- Publish final research report and send out with DER newsletters etc.

THANKS

Thank You!

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