This project was supported in part by a grant from the Minnesota Department of Commerce, Division of Energy Resources through the Conservation Applied Research and Development (CARD) program.
Continuing Education

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 and Residential Contractors continuing education requirements.”

For additional continuing education approvals, please see your credit tracking card.
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 \(\sim 130^\circ\)

- **Radiator types**
  - Radiator types and size play a significant role in the \(\Delta T\) 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:
  – 2\textsuperscript{nd} 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

<table>
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<tr>
<th>Task</th>
<th>Task Name</th>
<th>Q1</th>
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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

- Gas use
- Flow
- Output
- Runtime
- Temp
- Temp
- Temp
- Temp
Daily Measured Performance

[Graph showing the relationship between Return Water Temperature [°F] and Outdoor Air Temperature [°F]. The graph includes data points for different conditions and labels for different data sets (d215_ex_02, d215_ex_03, d215_ex_05, d215_ex_06, d215_ex_07).]
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

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<tr>
<th>Capacity Estimates and Ratings (Btu/hr)</th>
<th>Min</th>
<th>Max</th>
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<td>99,000</td>
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<td>Emitters</td>
<td>at 140 Sup T</td>
<td>at 180 Sup T</td>
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<td>35,000</td>
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<td>Design Heating Load (Bill Analysis)</td>
<td>at -12 F OAT</td>
<td>38,500</td>
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</table>
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
At 0 °F the house needs ~25,000 Btu/hr
130°F will deliver the needed 25,000 Btu/hr at 0°F OAT.
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

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Site Example (Krogstad D215 ex 03)
Site Example (Krogstad D215 ex 03)
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.
Thank You!

Rebecca Olson
Residential Energy Program Director
Neighborhood Energy Connection
rebeccao@thenec.org
651-789-5705

Dave Bohac
Director of Research
Center for Energy and Environment
dbohac@mncee.org
612-802-1697

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