UNIVERSITY OF TORONTO | Building Energy and Indoor Environment (BEIE) Lab

Characterization of space heating boiler operation in post-war MURBs

15th Canadian Conference on Building Science and Technology

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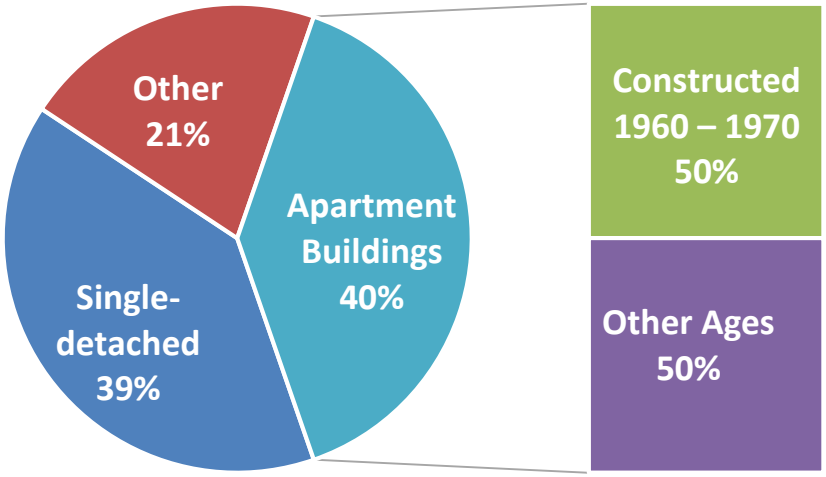
Overview

- MURBs, Energy and the Environment
- Heating System Operation and Design
- Case Study in Two MURBs
  - Building Profiles
  - Indirect Performance Assessment (Building 1)

MURBs, Energy and the Environment

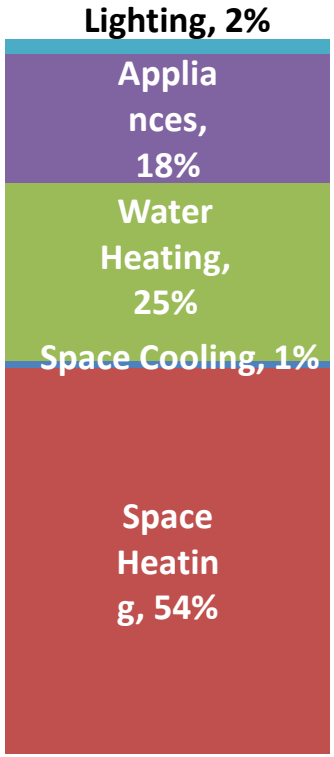
Building operation produce 24% of Ontario's GHG emissions

Existing Building Stock in the GTA



Data from: Statistics Canada, 2012 and Kesik and Saleff, 2009

Energy Use in Post-War MURBs



Data from: NRCan 2014 SHEU

Heating System Operation

In general, central heating system efficiency tends to decrease for low-load scenarios.

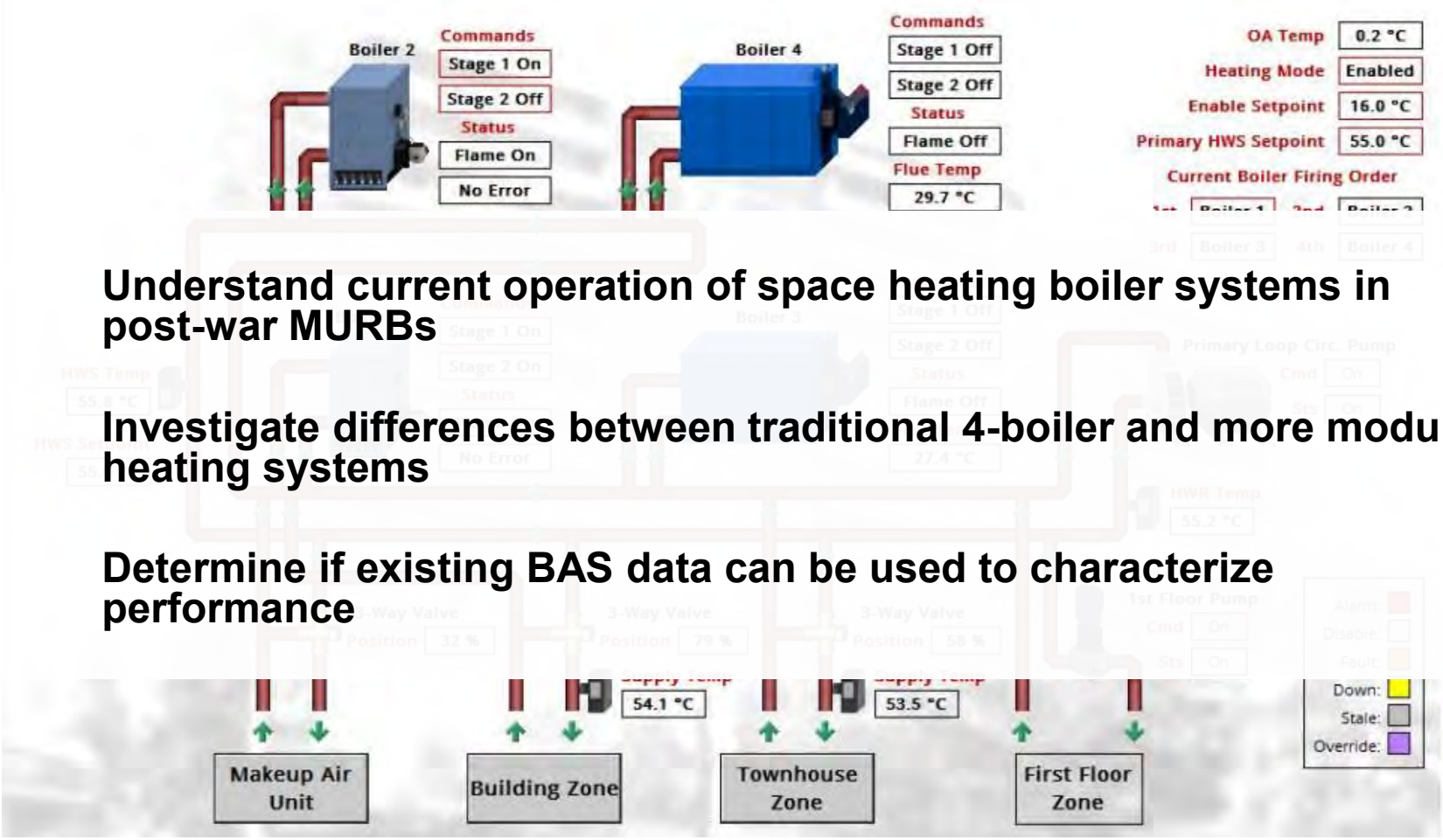
- **Studies in smaller MURBs**
  - 10 – 25% reduction in efficiency
- **Studies in institutional buildings**
- **No current inventory of system sizing or performance characterization in typical Ontario MURBs**

Heating System Design

MURB heating systems are designed for worst-case loading scenarios.

- **Ontario Building Code**
  - equipment efficiency only
- **Professional Liability**
  - for undersized equipment only
- **Division of cost between stakeholders**

Study Goals



1. **Understand current operation of space heating boiler systems in post-war MURBs**

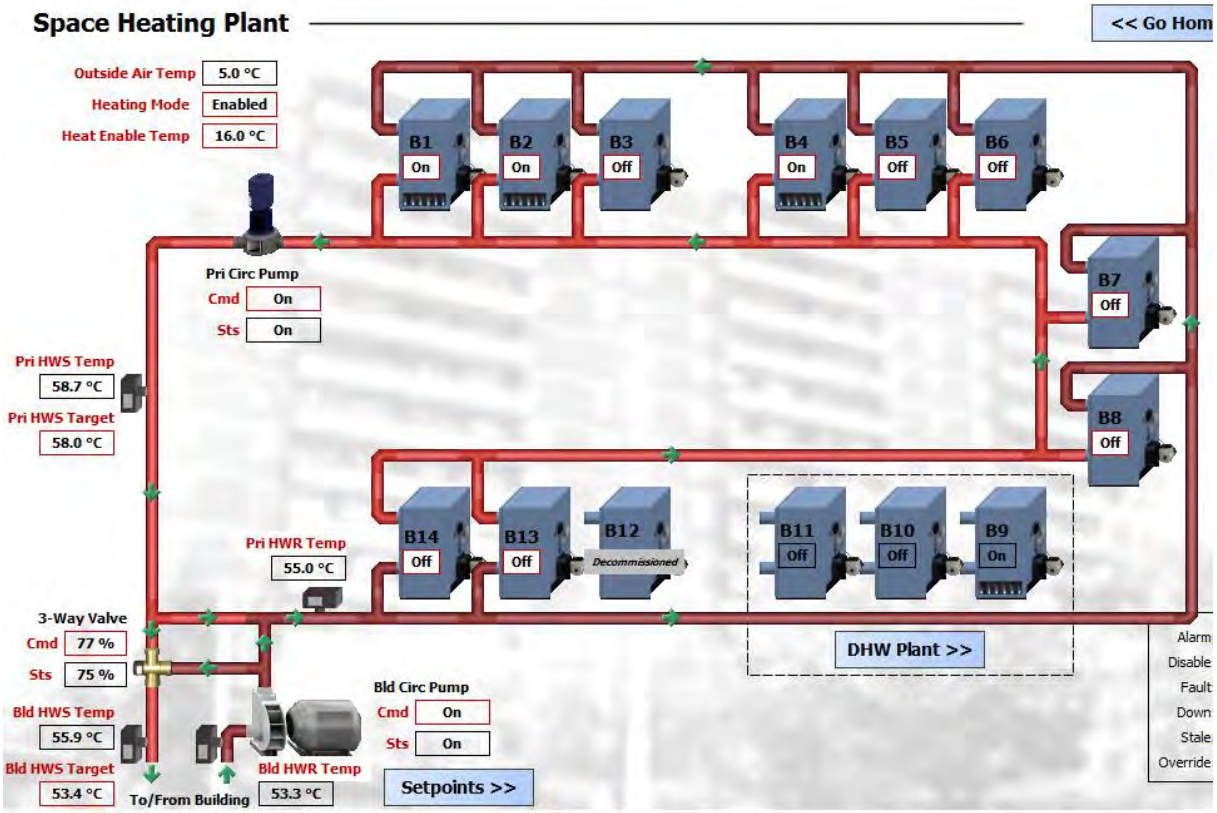
2. **Investigate differences between traditional 4-boiler and more modular heating systems**

3. **Determine if existing BAS data can be used to characterize performance**

Studied Buildings

Building 1: 1970s, 94 Suites on 7 Floors

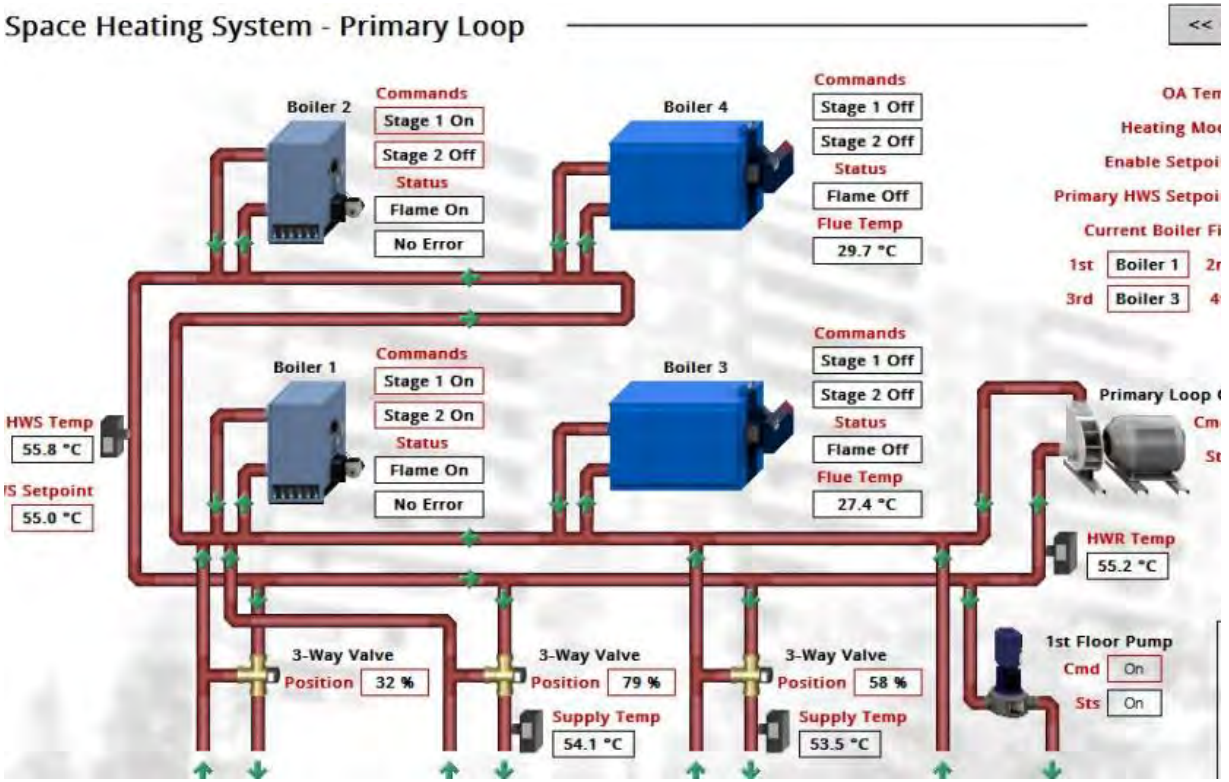
- Niagara Region
- 10 single-stage atmospheric
  - 300,000 BTU
  - 80% rated efficiency
- PID Controller (Primary Loop set-point)
  - Rotate through boilers



Studied Buildings

Building 2: 1966, 92 Suites on 7 Floors

- Greater Toronto Area
- Primary: 2 x two-stage atmospheric
  - 750,000 BTU
  - 85% rated efficiency
- Secondary: 2 x single-stage atmospheric
  - 2,000,000 BTU,
  - assumed 75% efficient
- PID Controller (Primary Loop set-point)
  - Primary boilers alternate as lead/lag based on totalized runtime weekly



Collected Data

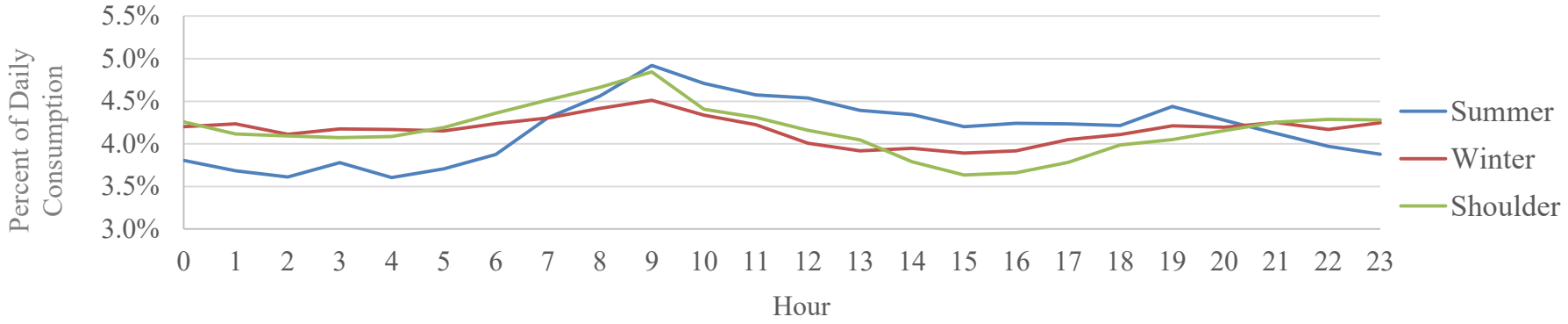
	Building 1	Building 2
Natural Gas	Hourly: June 2016 – March 2017	Hourly: May 2016 – May 2017
Equipment Monitoring	Boiler Status (On/Off): June 2016 – March 2017	Boiler Status (On/Off): December 2016 – April 2017 *missing data for one primary boiler Boiler Daily Total Runtime (s): December 2015 – May 2017
Building Hot Water Supply/Return	Temperature (0.1 ° C), 5-min interval: December 2016 – March 2017	Not Available

Natural Gas Consumption

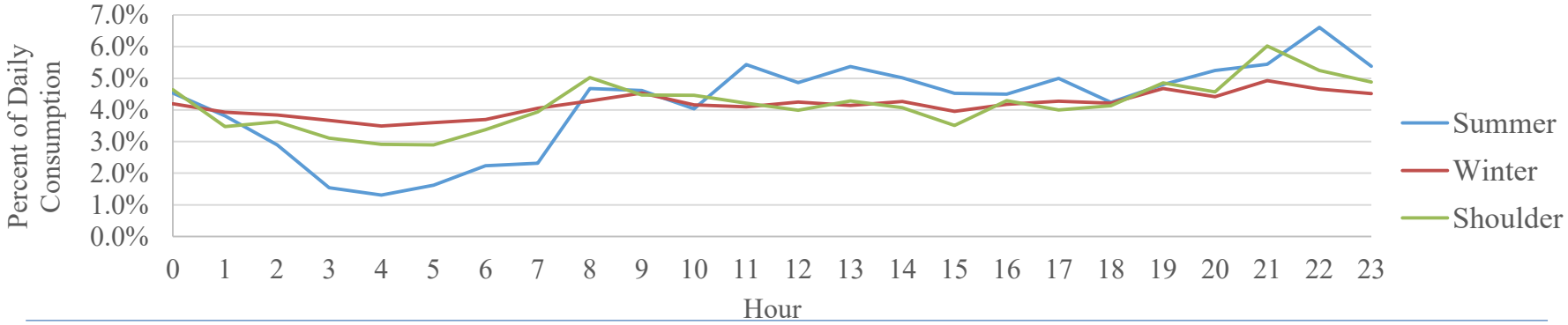
Differences in time distribution of NG consumption is likely due to occupants' DHW use.

Building 2's higher NG use may be due to occupant use, boiler η, or less modular config.

Building 1 - Daily 75 m³/day (Summer) to 824 m³/day (Winter)



Building 2 – Daily 151 m³/day (Summer) to 880 m³/day (Winter)



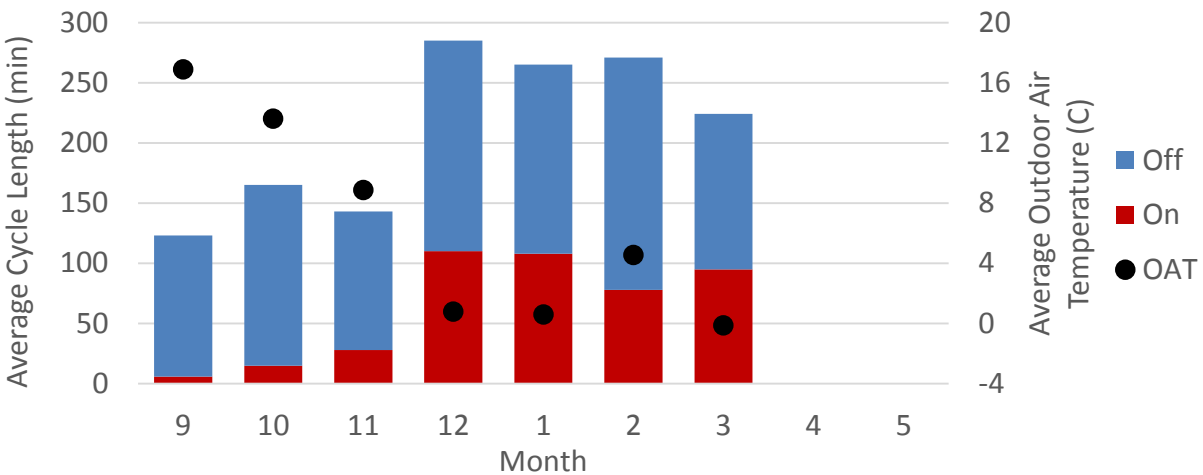
Boiler Cycle Lengths

Building 1's modular system had significantly longer cycle lengths.

Building 1:

Average cycle length:

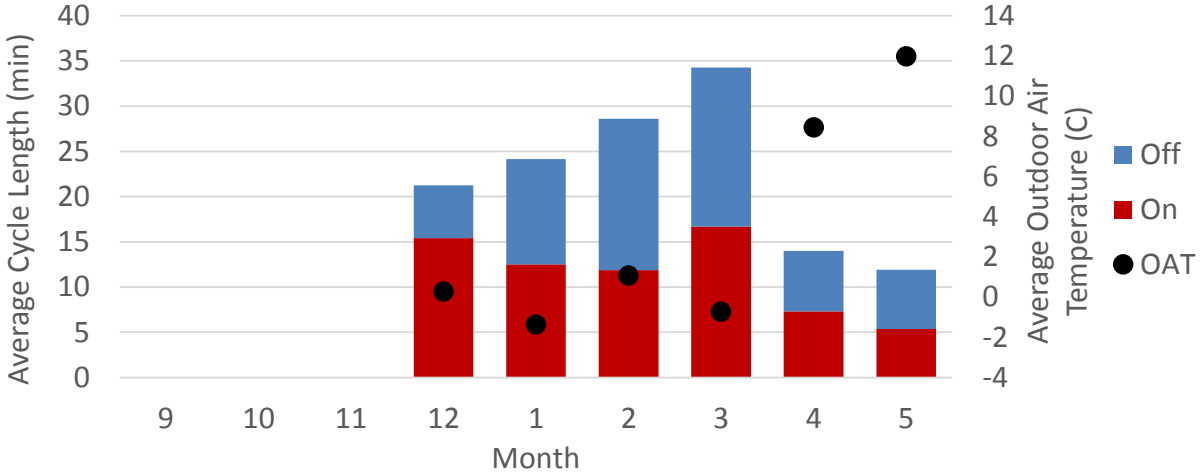
- **4 hours 45 min (Winter)**
- **2 hours 5 min (Shoulder)**



Building 2:

Average cycle length:

- **34 min (Winter)**
- **12 min (Shoulder)**

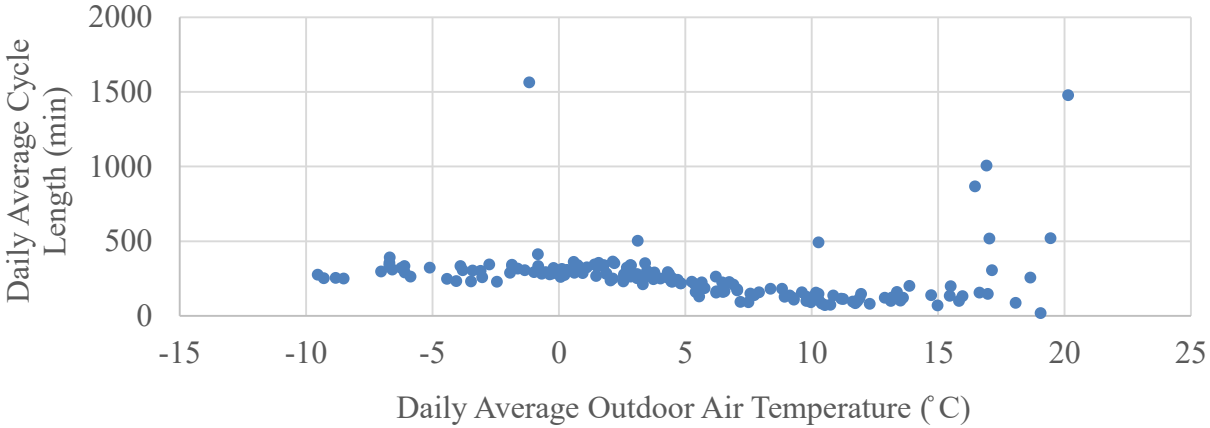


Boiler Cycle Lengths

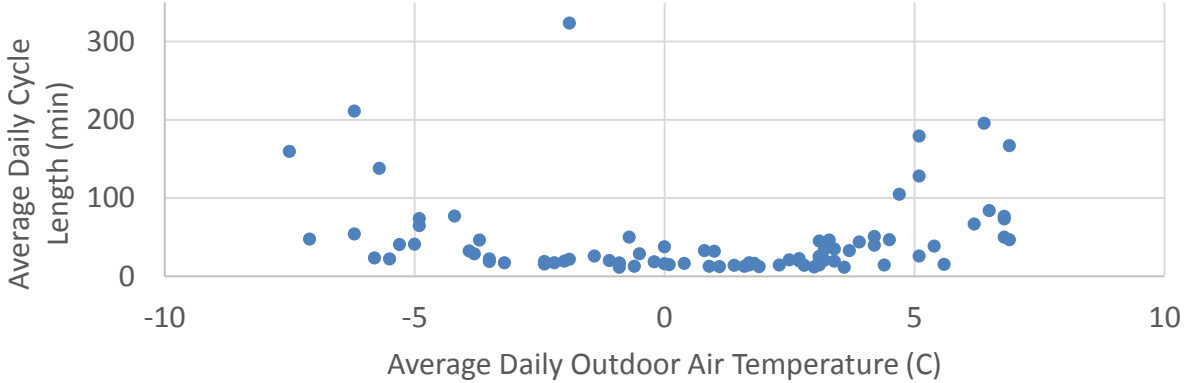
Boiler cycle lengths tended to increase for low OATs.

- Lower OATs typically mean higher space heating demand
- Cycle length increased for extremely high OATs due to long "Off" periods

Building 1:



Building 2:



Indirect Performance Assessment: Building 1

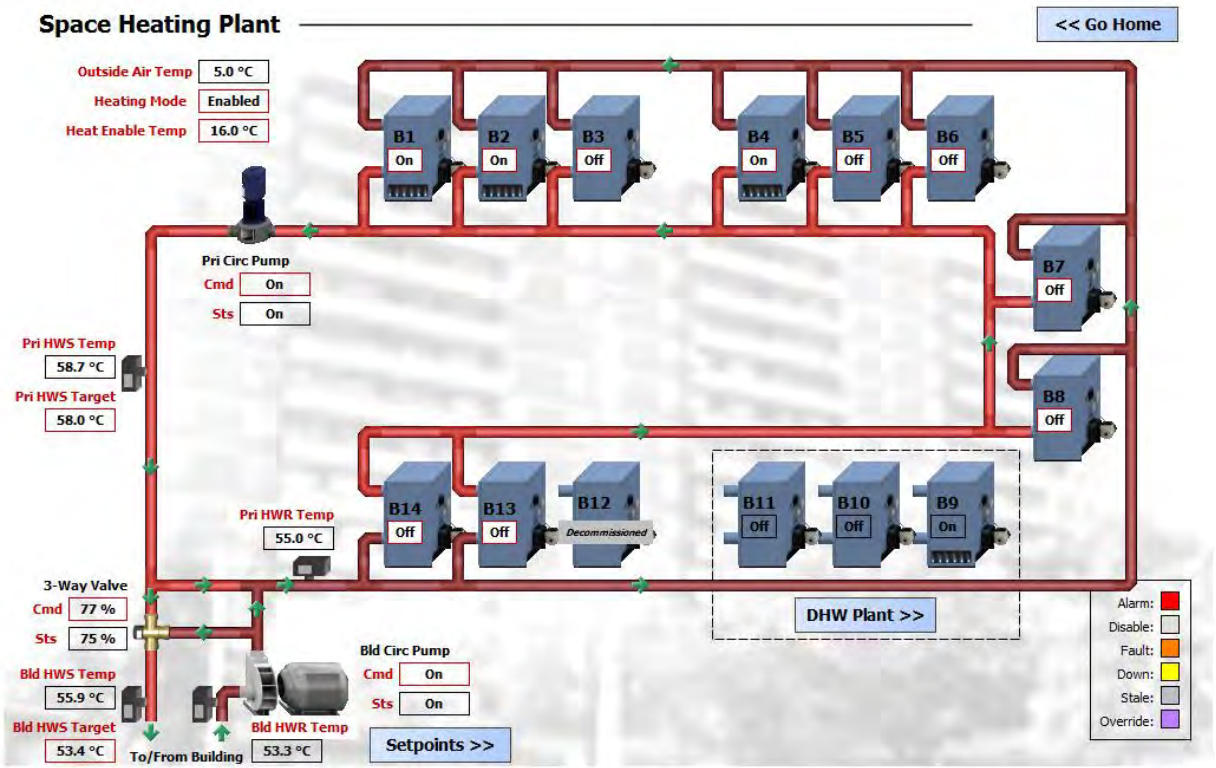
Relative Demand ≡ $T_{supply} - T_{return}$

Method

$$\textit{Space Heating Demand} = \dot{m}_{supply} c T_{supply} - \dot{m}_{return} c T_{return}$$

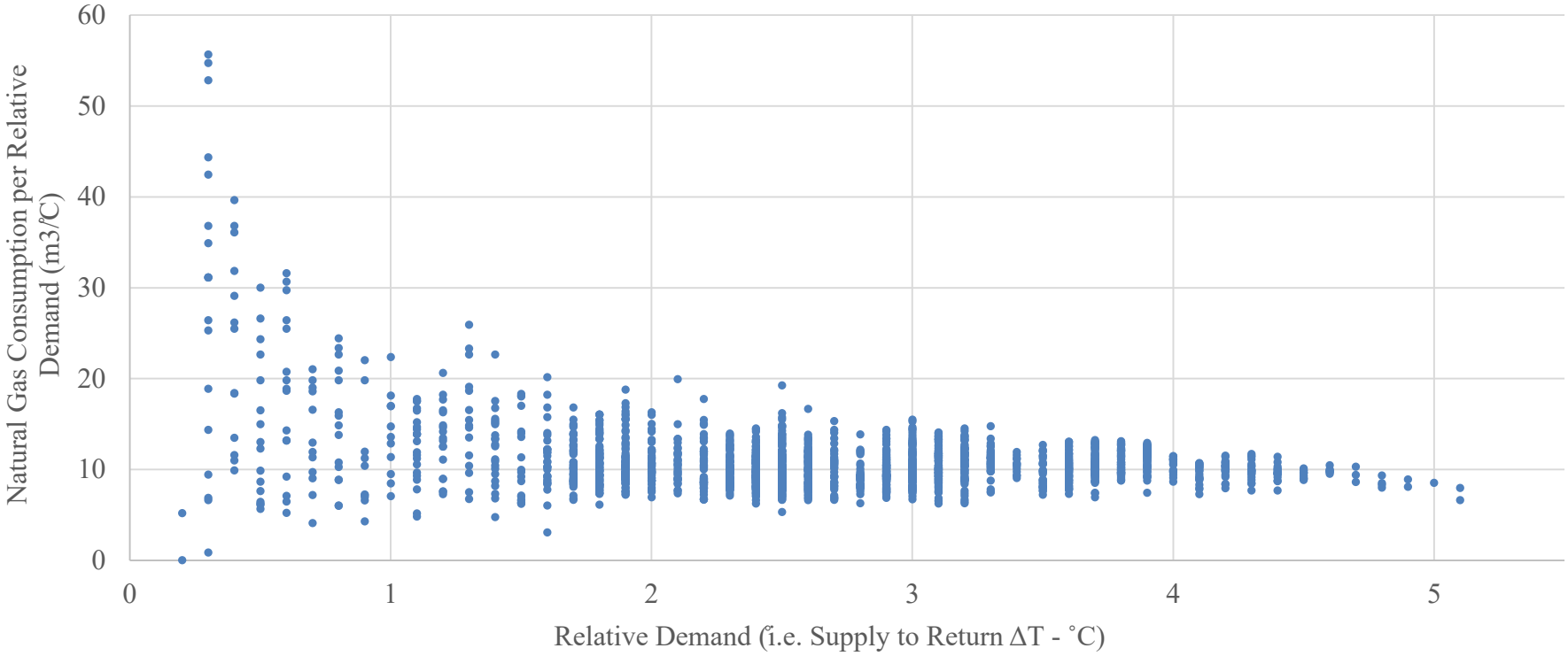
Building 1 has no variable pumping equipment

- Flow rate should be relatively constant
- Temperature can be used to determine a "Relative Demand"



Indirect Performance Assessment: Building 1

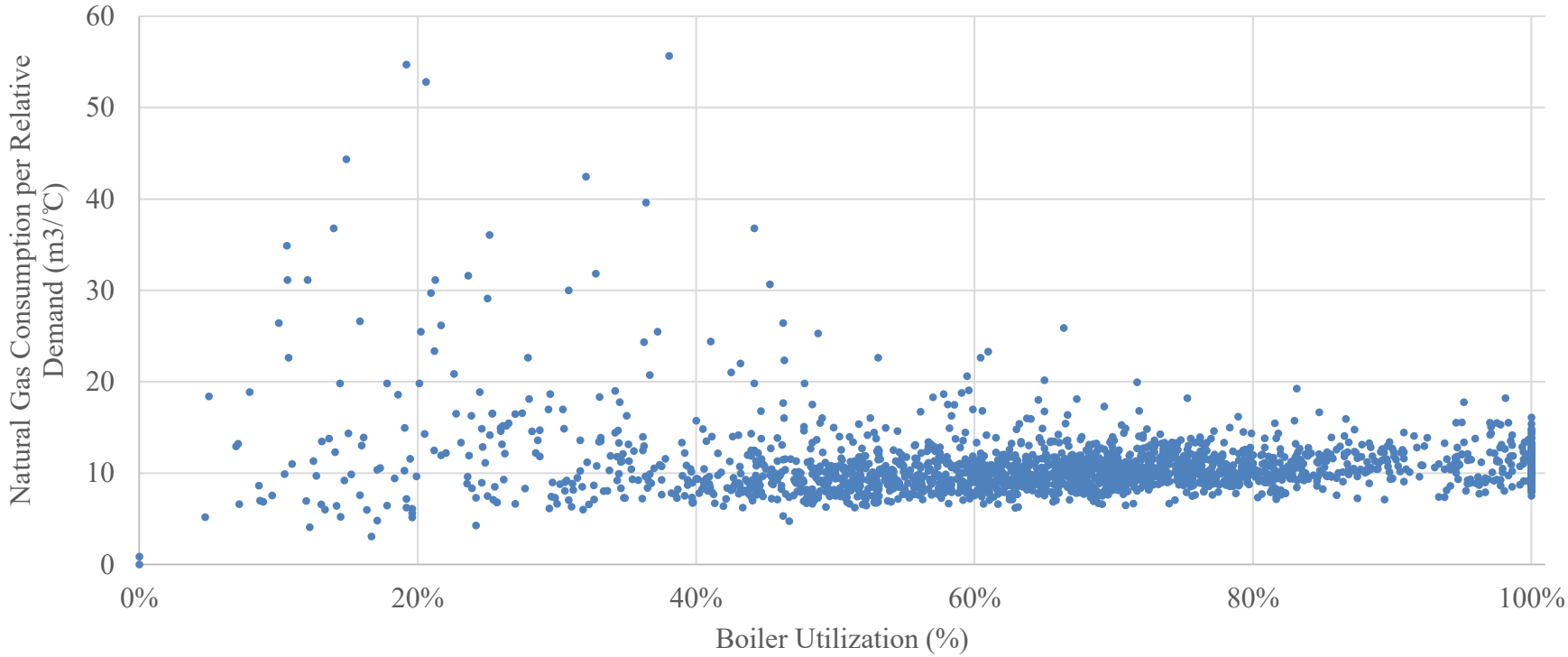
The natural gas consumed per degree Celsius of water temperature tended to increase at low Relative Demands.



Indirect Performance Assessment: Building 1

Hourly periods with low operating boiler utilizations exhibit a larger variation in natural gas demand per degree relative building demand.

NG/Relative Demand for utilizations < 40% did not appear to have any additional sensitivity to the outdoor air temperature or average time off per cycle.



Summary

Goal 1: Understand current operation of space heating boiler systems in post-war MURBs

- Lower space heating demand levels tended to decrease system performance
- Envelope retrofits or new systems that are oversized for building demand increase time spent in low loading scenario

Goal 2: Investigate differences between traditional 4-boiler and more modular heating systems

- The modular building system exhibited much longer cycle times
- Modular systems may provide long-term energy and cost savings through improving operational performance (through reduced cycling)

Goal 3: Determine if existing BAS data can be used to characterize performance

- Existing BAS systems can be used to perform a rudimentary assessment of heating plant performance in MURBs without variable speed pumps

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