Multifamily Buildings: Real World Monitored Data on Hot Water Energy and Water Use

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Boston/Hartford/Providence/Baltimore

Founded in 1999, New Ecology, Inc. (NEI) is an innovative, mission-driven non-profit. We work closely with owners, developers, non-profits and governments to identify achievable strategies to make projects more sustainable and work to cost-effectively implement these strategies.

Learning Objectives

1. Understand the common gas-fired, central domestic hot water systems found in multifamily buildings
2. Understand the testing methodologies for determining existing DHW loads and usage patterns
3. Learn about domestic hot water usage, consumption profiles and system efficiencies
4. Understand data-based domestic hot water system design and sizing methodologies

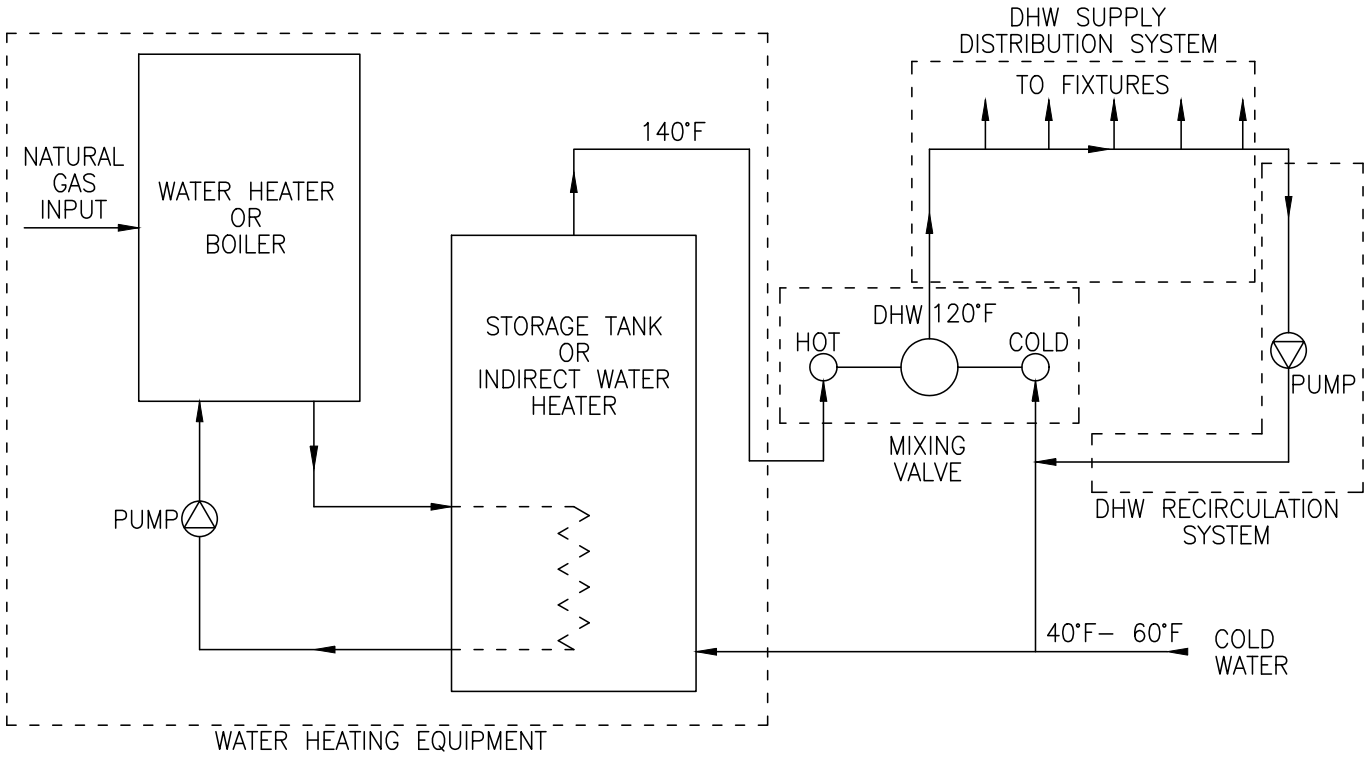
Learning Objective 1

Understand the common gas-fired, central domestic hot water systems found in multifamily buildings

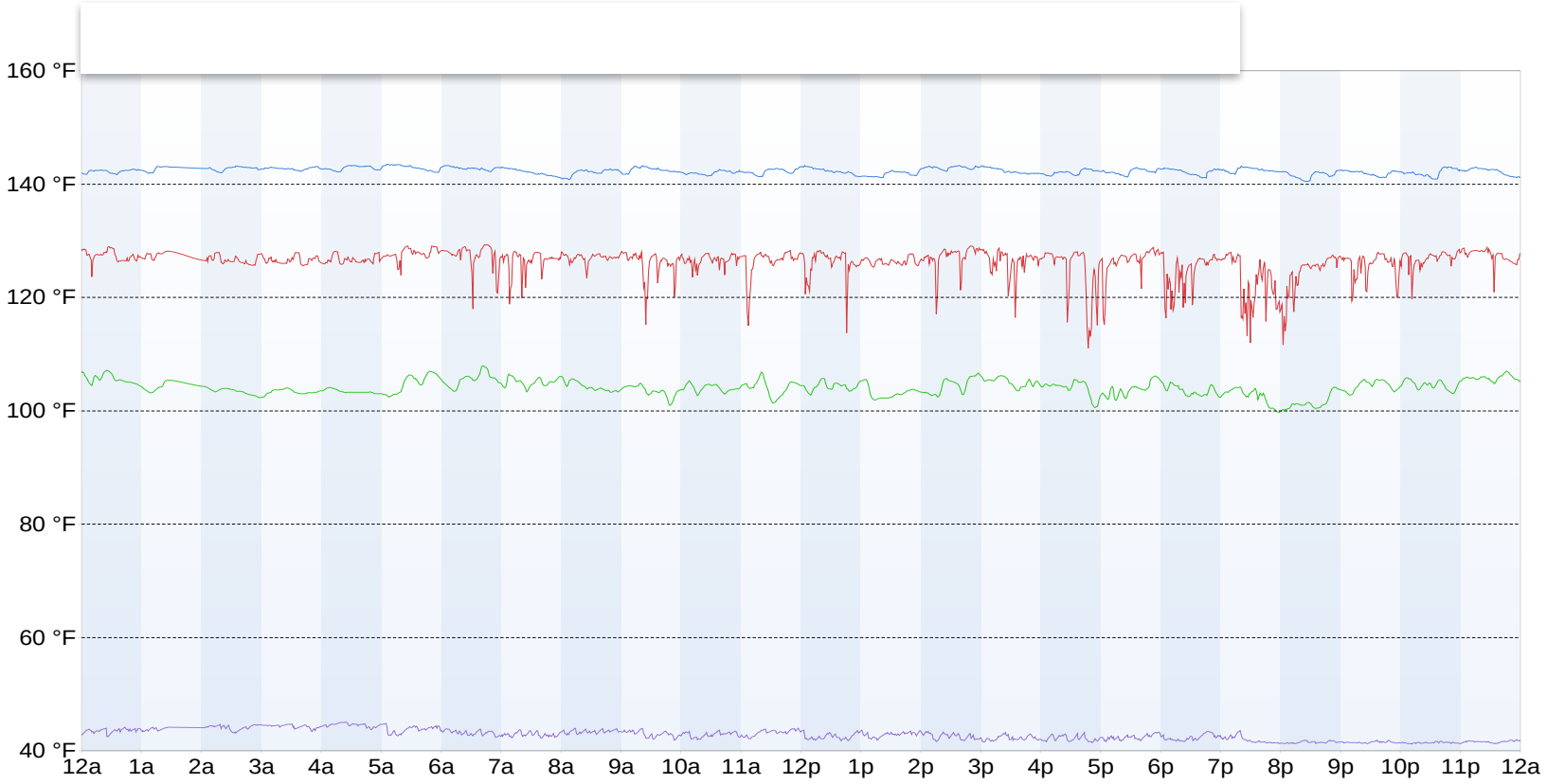
Common Multifamily Central DHW System Components

- Water Heating Equipment
- Mixing Valve- Maintains the supply water temperature delivered to building
- DHW Supply Distribution System – piping to distribute DHW from the mixing valve to the fixtures
- DHW Recirculation System – pumps and controls to circulate DHW throughout the building

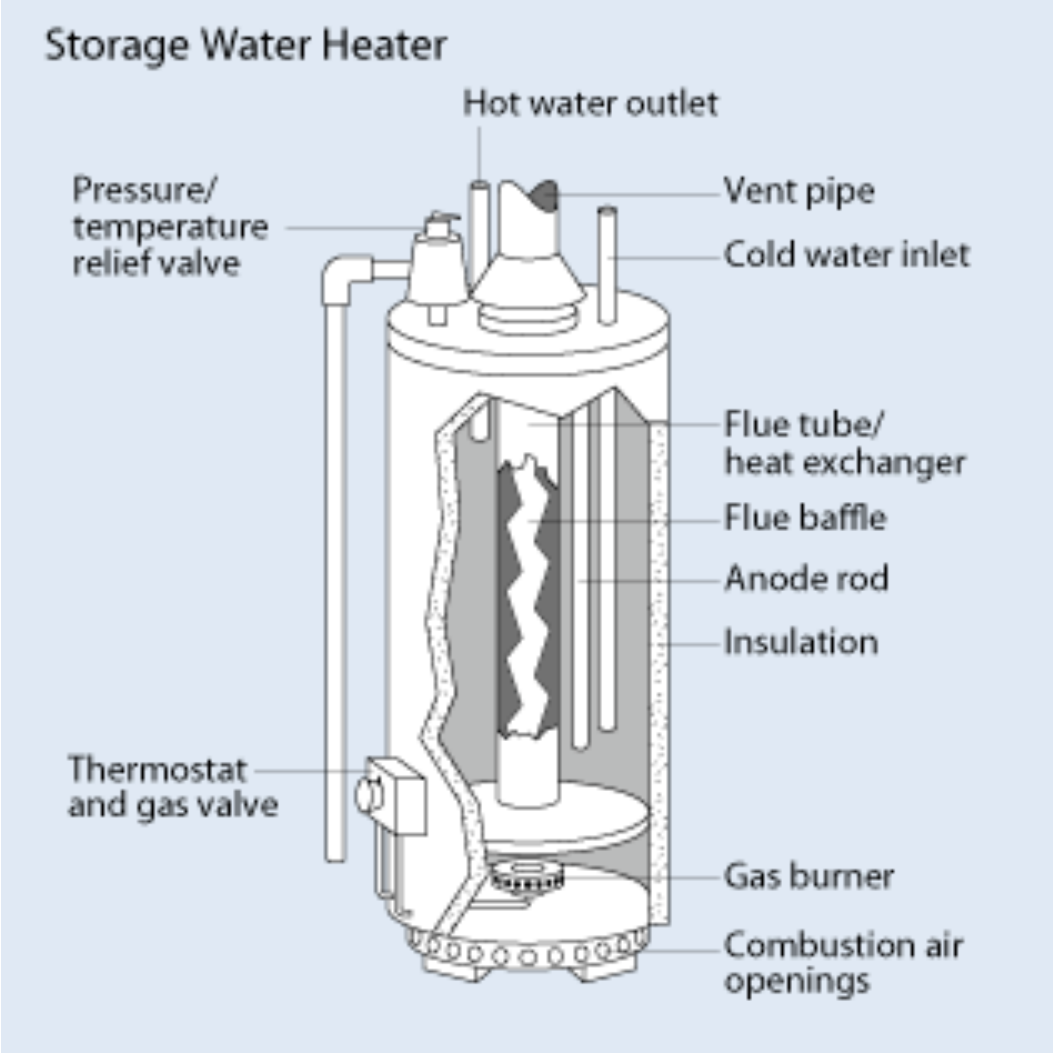
Representative Graphic of a Central DHW System



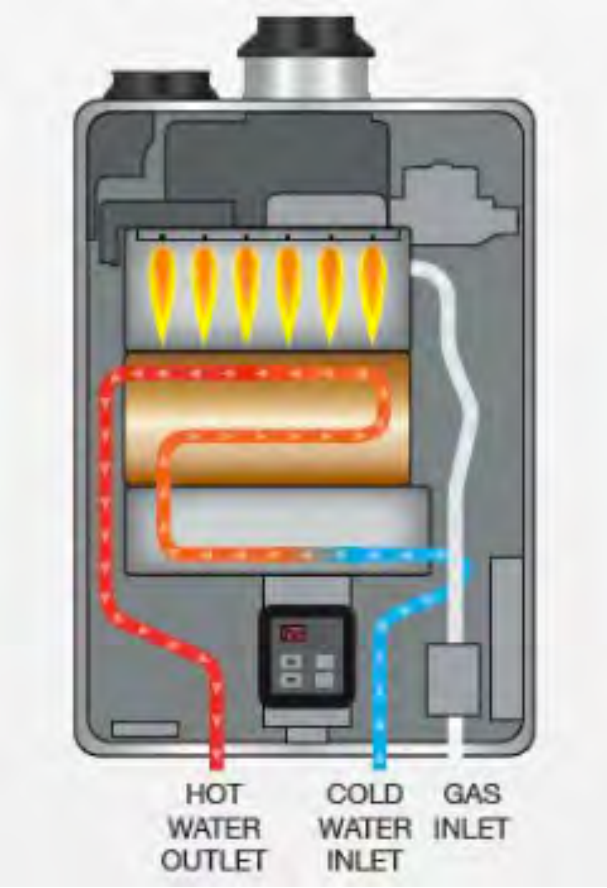
Central DHW System Temperatures Over One Day



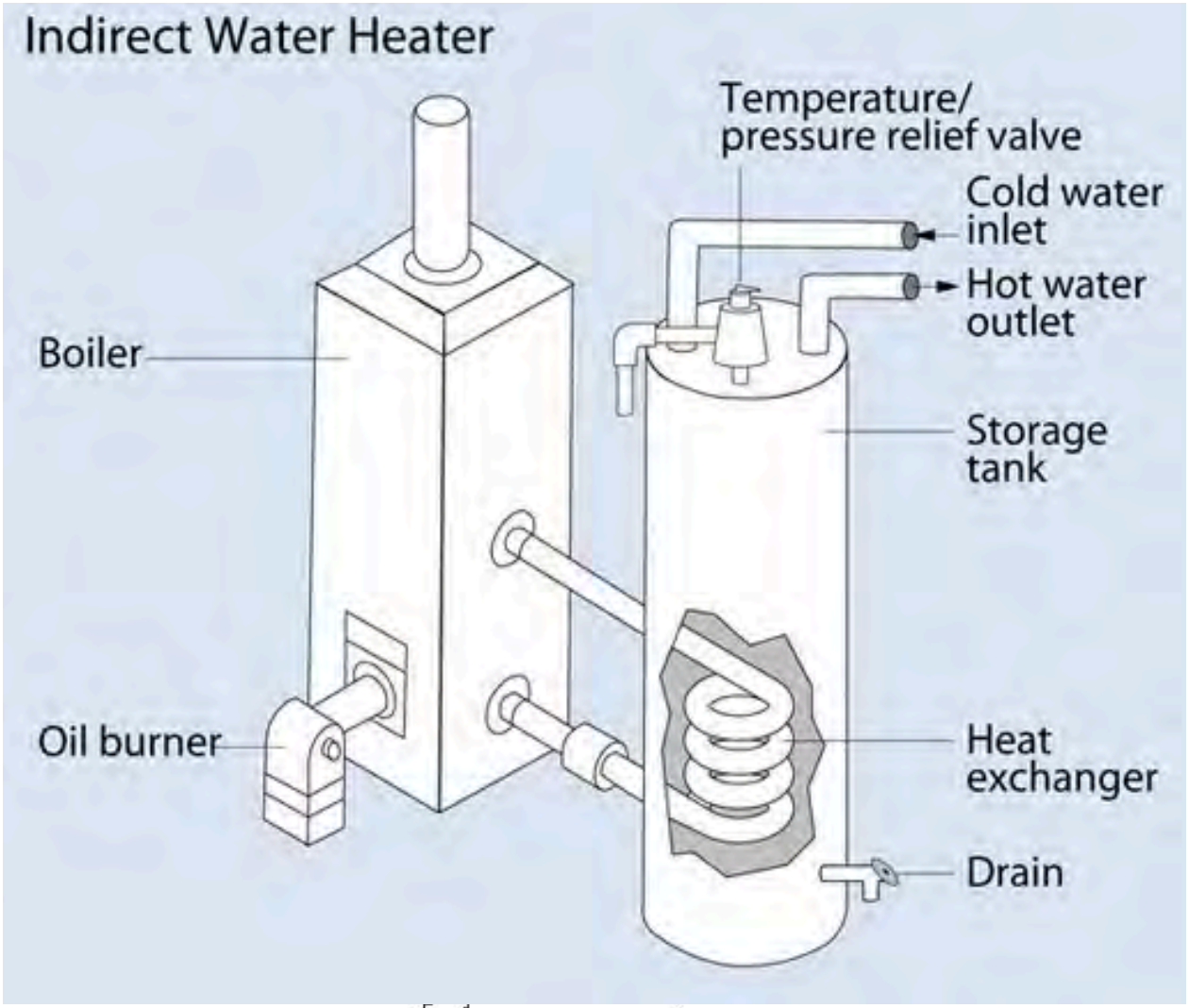
Gas-fired Storage Water Heater



Gas Instantaneous Water Heater (aka ”Tankless”)



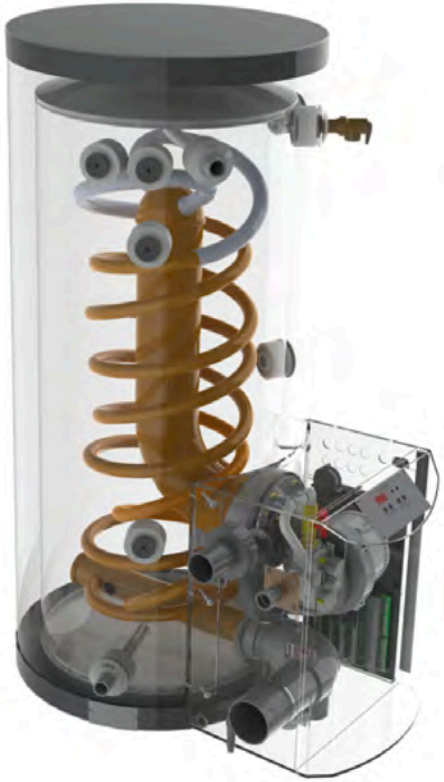
Indirect Water Heater



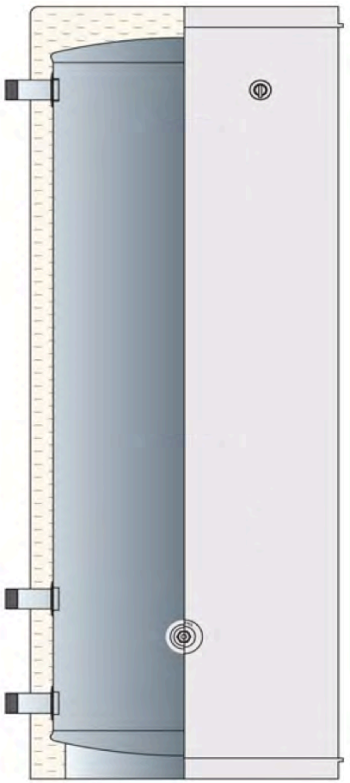
DHW Tank Types

Indirect-fired water heater

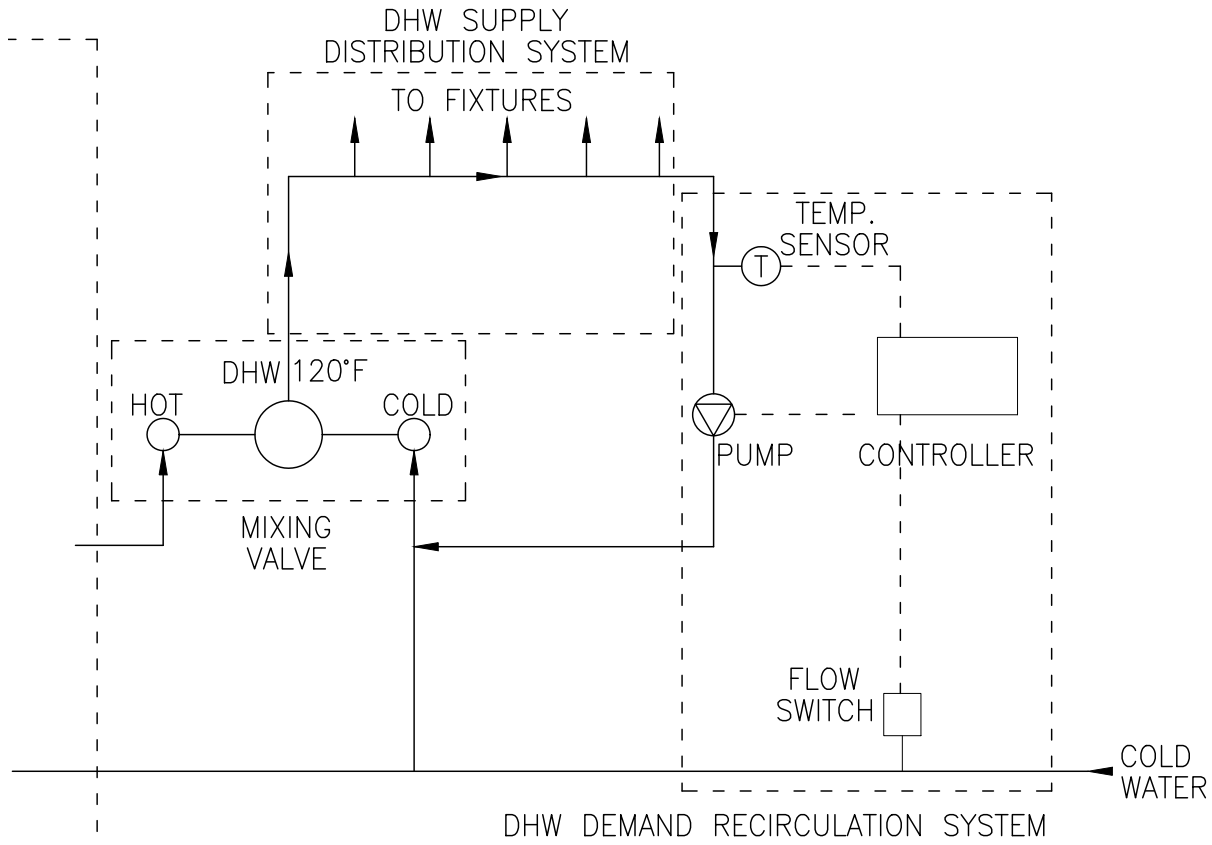
Direct-fired, storage water heater



DHW Storage Tank



DHW Demand Recirculation System



Learning Objective 2

Understand the testing methodologies for determining existing DHW loads and usage patterns

Experimental Instrumentation

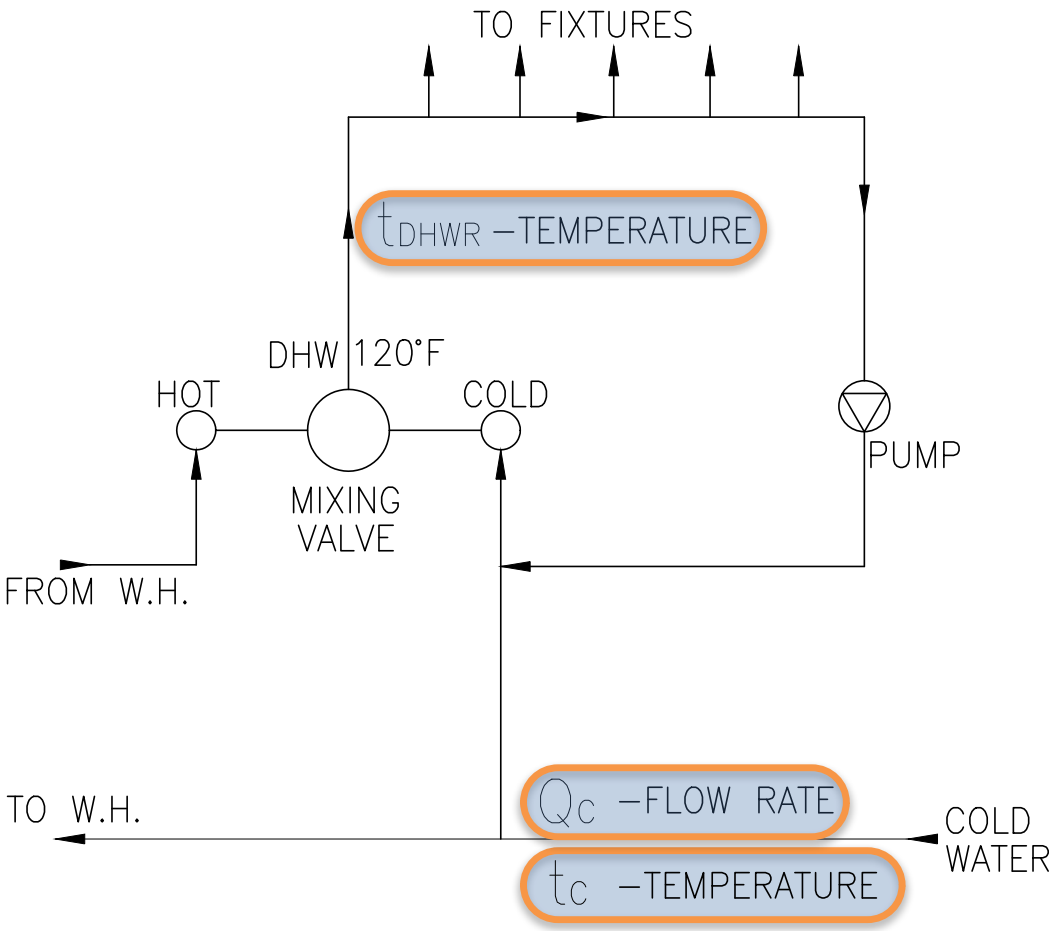
Ultrasonic Flow & Btu Meter

Fuji Electric Portaflow-C Kit

Data Logger & Controller

Schneider Electric - SmartStruxure Controllers

DHW System Schematic Showing Test Sensor Locations



Volumetric Data Points

- Ultrasonic Flow Meter – Velocity sampling rate of less than 1 second
- Utility Meter readings – natural gas and water meter readings at the start and end of testing

Data Accuracy & Error Checking

- Ultrasonic flow meter accuracy:
  - ±1 gpm for the range of flow rates encountered
- Temperature Sensor accuracy: ±1% temp reading
- Temperature sensor transient response
- Consumption below or above expected values
- Checking measured energy and water consumption against utility meters

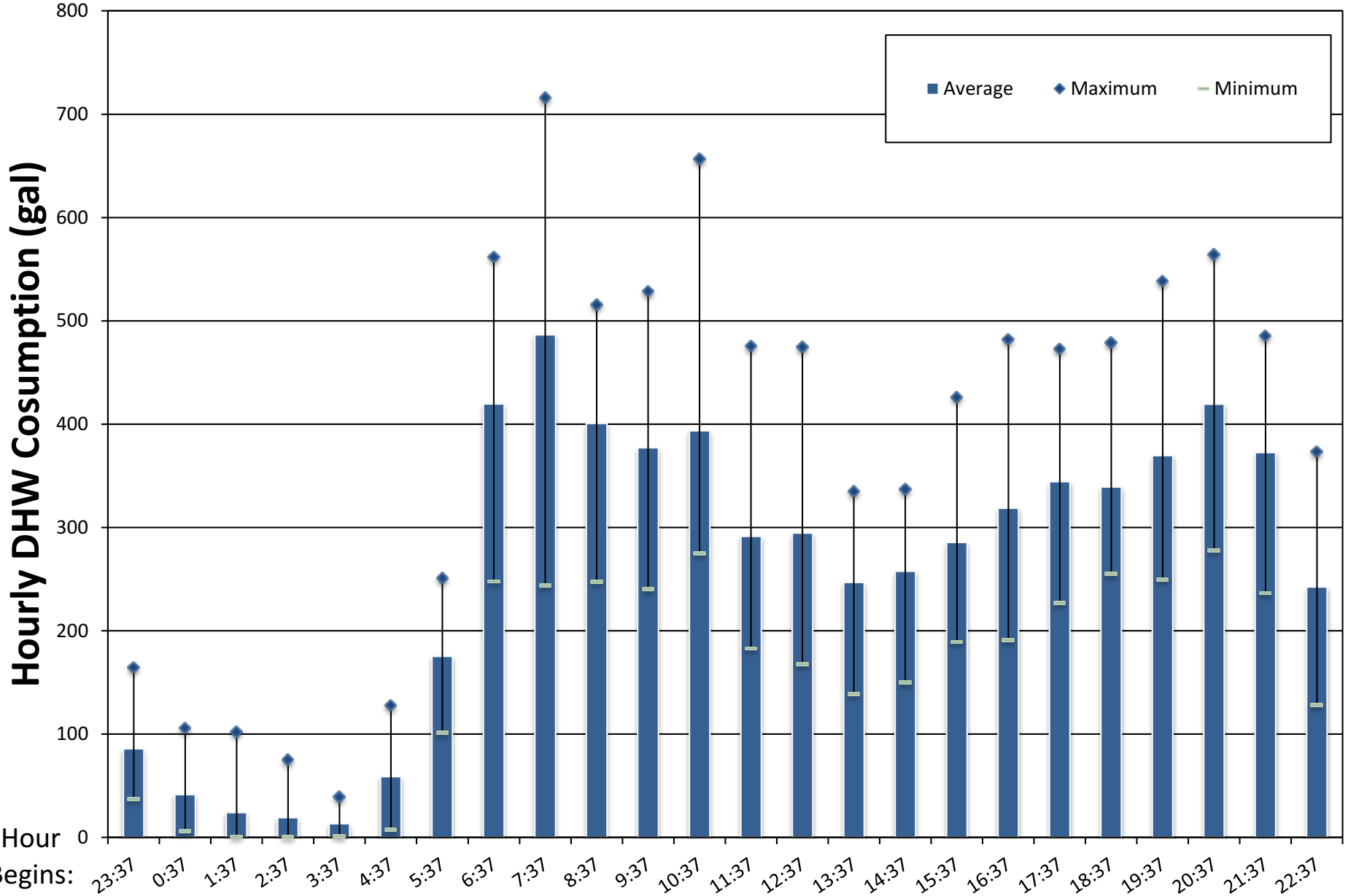
Learning Objective 3

Learn about domestic hot water usage, consumption profiles and system efficiencies

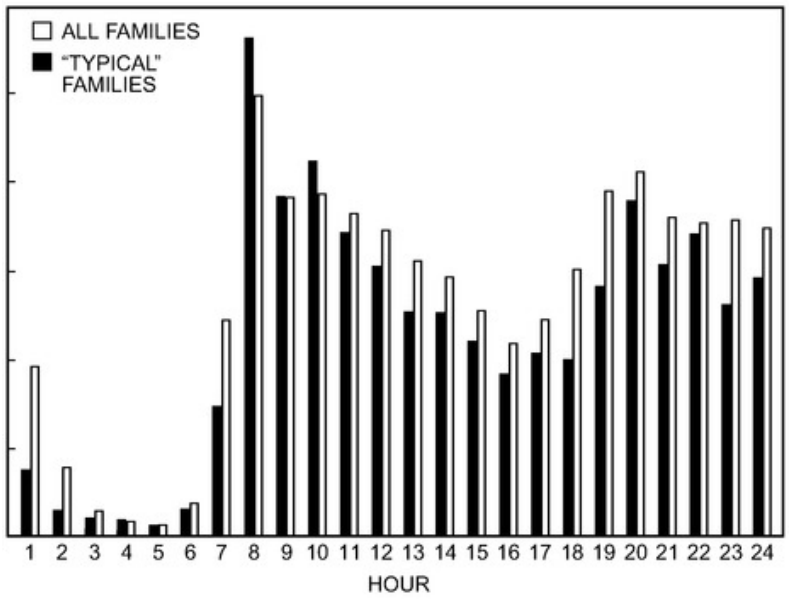
Building Example 1

- 188 units, 201 bedrooms, 17-stories
- Elderly population
- Central DHW System
  - Two 500,000 Btu/h gas instantaneous water heaters
  - Four 120-gallon storage tanks
  - Constant recirculation

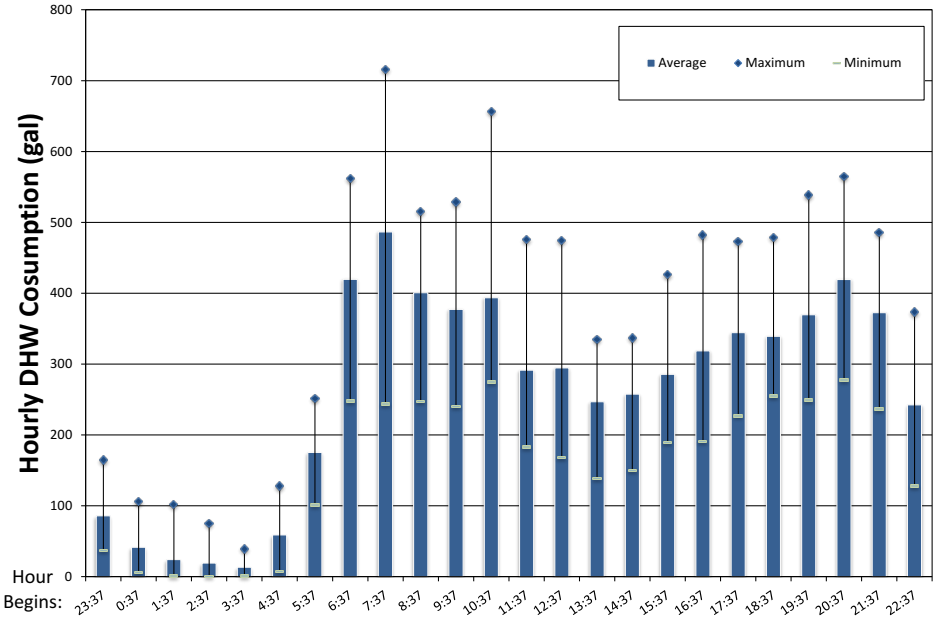
188-unit Bldg - Hourly DHW Consumption-
Based on Peak Hour July 2, 2014 at 11AM- August 5, 2014 at 9AM



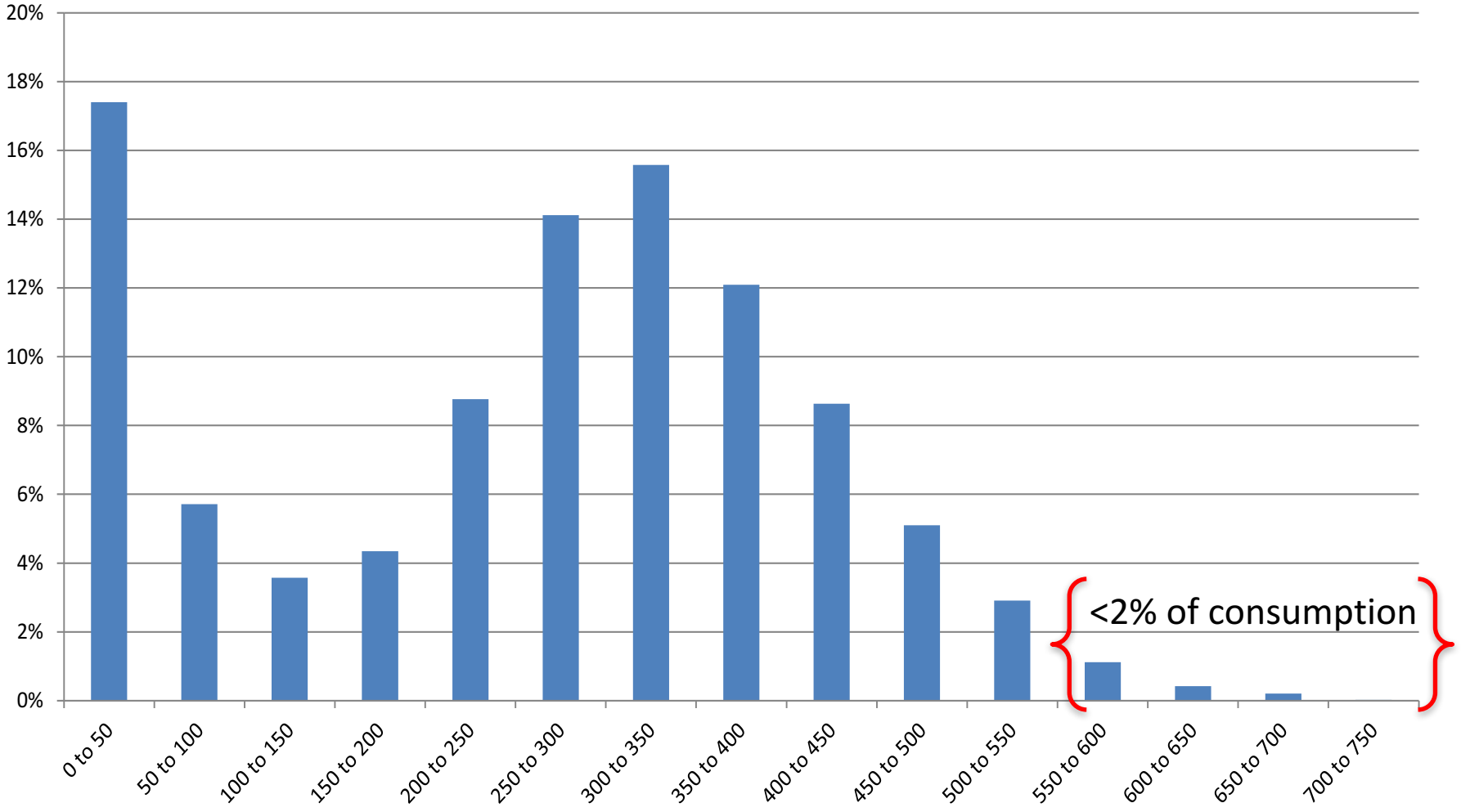
188-unit Bldg - Hot Water Consumption Profile Comparison to ASHRAE Multifamily Building Profile



Hourly DHW Consumption- Based on Peak Hour
July 2, 2014 at 11AM- August 5, 2014 at 9AM

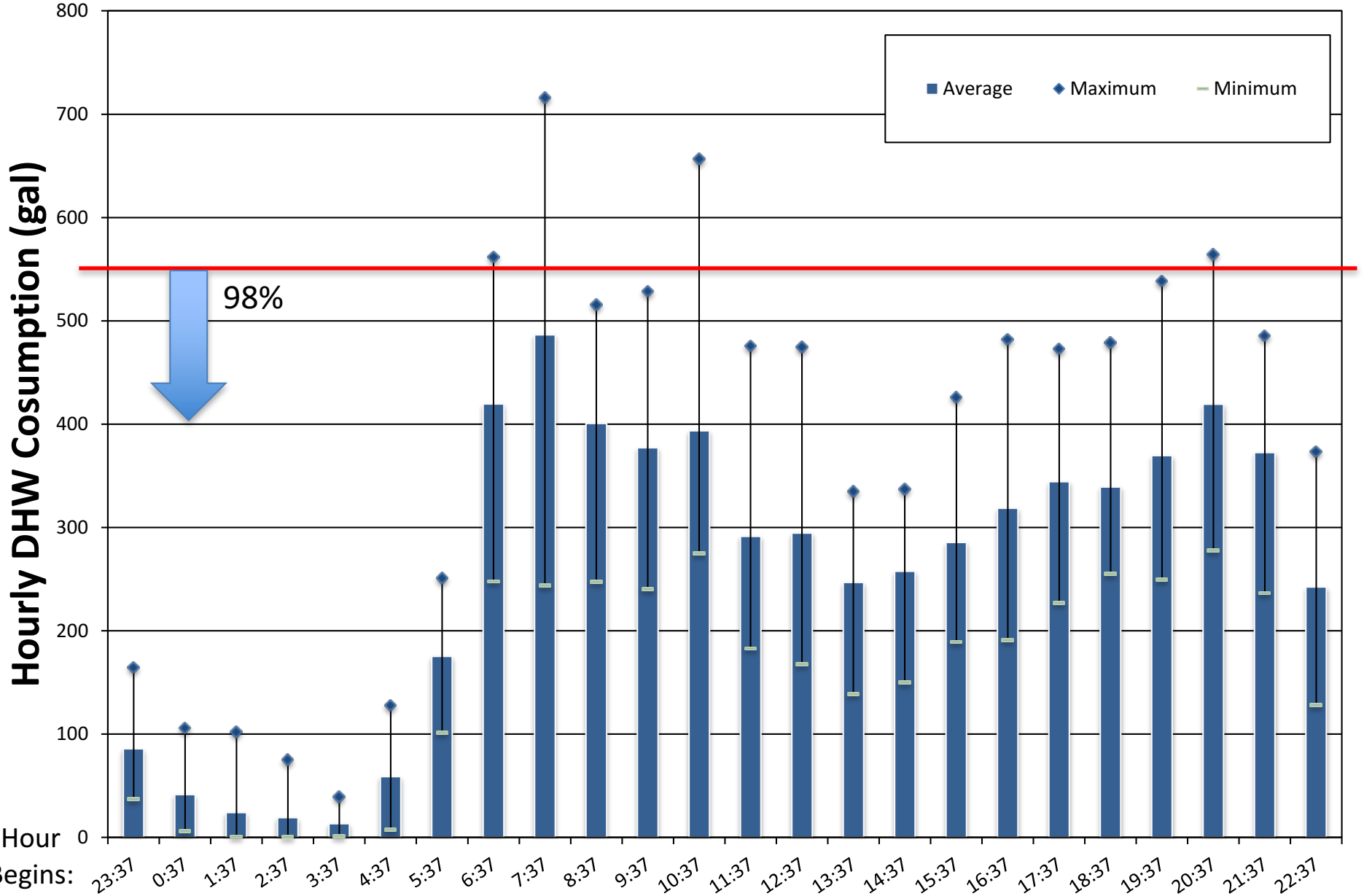


188-unit Bldg. - Histogram of Rolling DHW Consumption



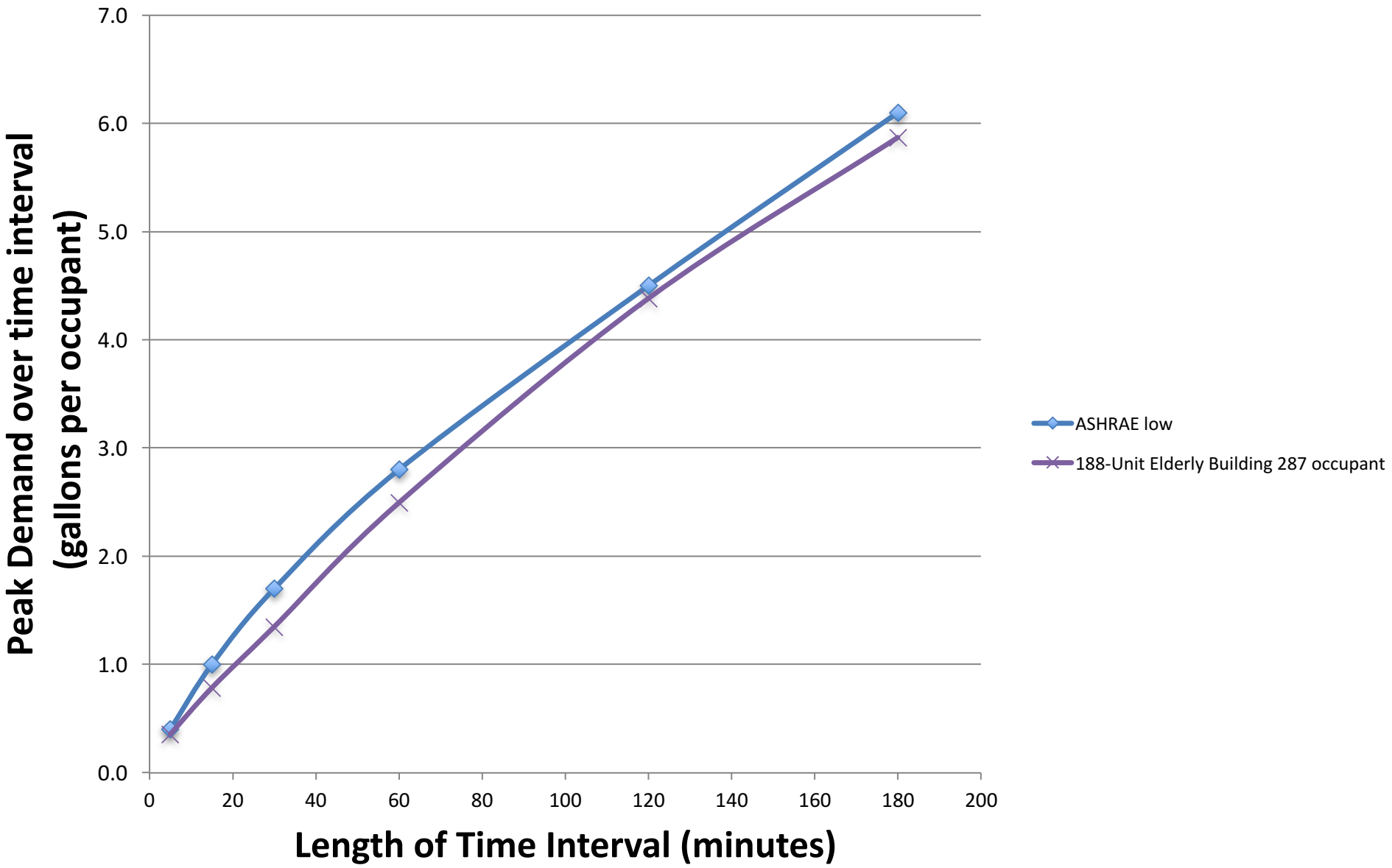
Gallons Consumed per Hour

188-unit Bldg - Hourly DHW Consumption-
Based on Peak Hour July 2, 2014 at 11AM- August 5, 2014 at 9AM



188-unit Bldg. - Peak DHW Consumption at Intervals

Time Interval (minutes)	Total Volume (gallons)	Average Flow Rate (gal/min)
5	102	20.4
10	225	15.0
30	387	12.9
60	716	11.9
120	1258	10.5
180	1685	9.4
1440	6882	4.8


Peak DHW Use at Intervals- Per Occupant
Peak Demand over time interval (gallons per occupant)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
20
40
60
80
100
120
140
160
180
200
Length of Time Interval (minutes)
ASHRAE low
188-Unit Elderly Building 287 occupant

188-unit Bldg. - Hot Water Consumption Data Summary

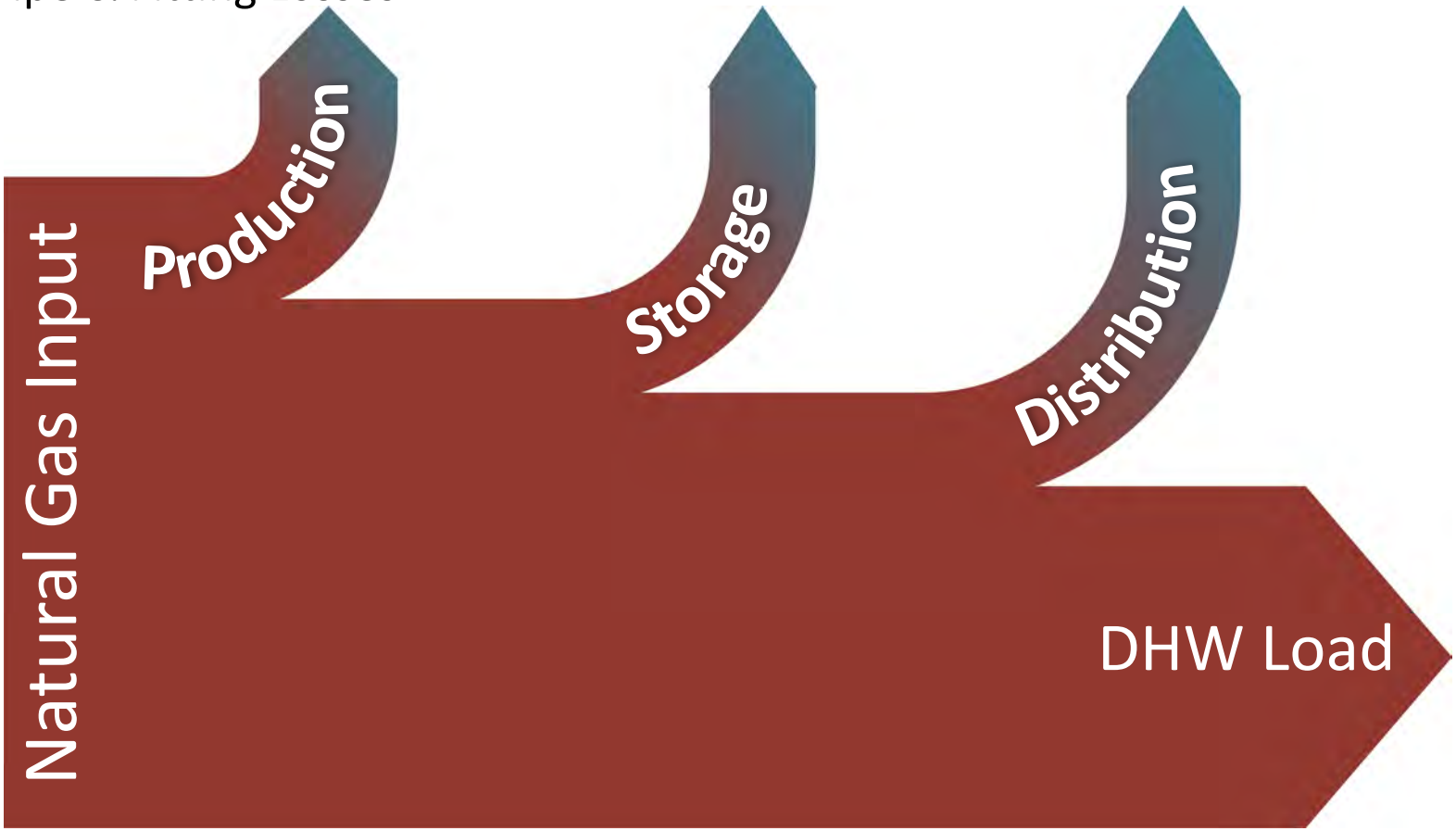
- Testing period: July 2, 2014 – August 5, 2014
- Maximum Peak Flow: 716 gal/h
- Minimum Flow: 0 gal/h
- Average Daily Consumption:
  - DHW: 6,260 gal (40% of total water)
  - Total Cold and Hot Water: 15,482 gal (Total from water meter)
- Normalized Flows
  - Per apartment: 32 gal/day
  - Per bedroom: 30 gal/day
  - Per occupant: 21 gal/day (based on HUD maximum occupancy)

Hot Water Energy Flow Diagram

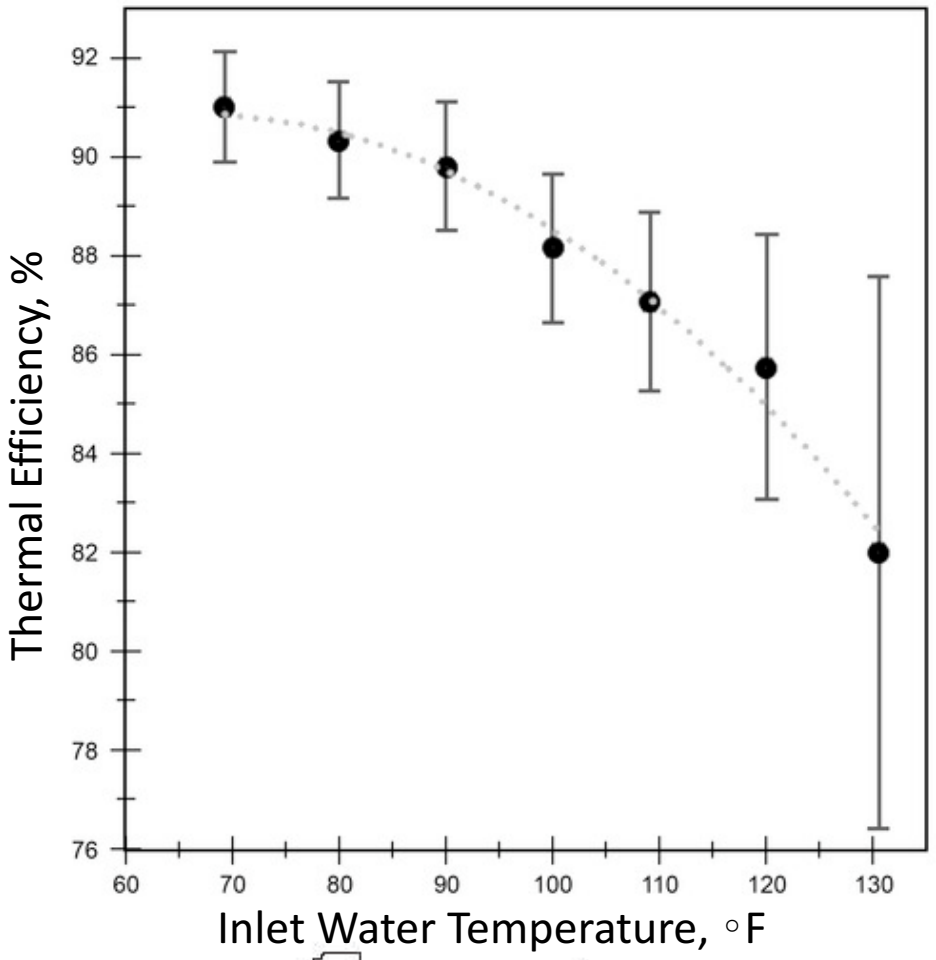
Production Losses
- Combustion Losses
- Jacket Losses
- Pipe & Fitting Losses

Storage Losses
- Jacket Losses

Distribution Losses
- Pipe & Fitting Losses
- Recirculation Losses

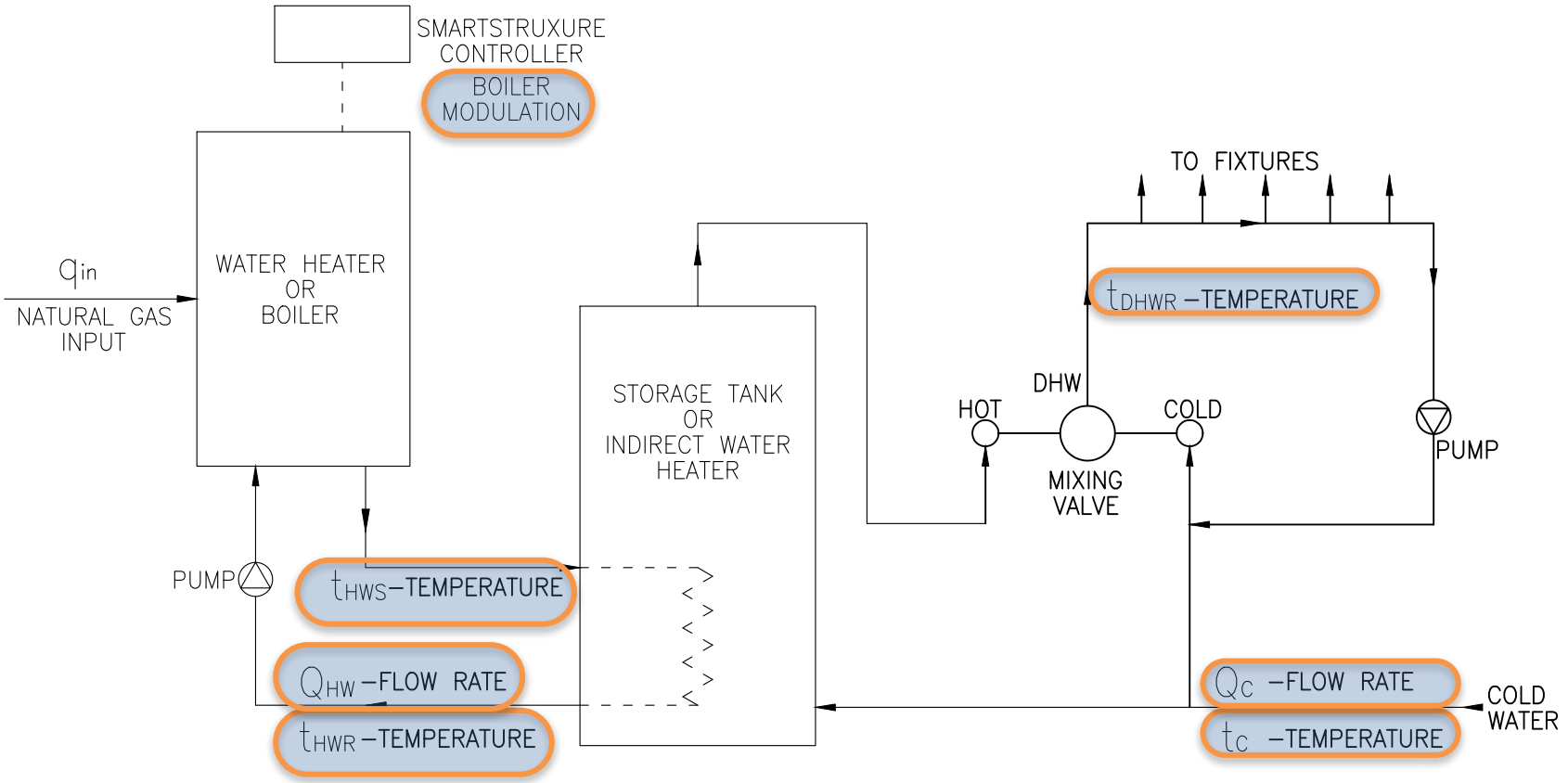


Effect of Inlet Water Temperature on Thermal Efficiency of Condensing Water Heater



From ASHRAE Handbook – HVAC Applications, Ch. 50

DHW System schematic showing location of test sensors



Data Points

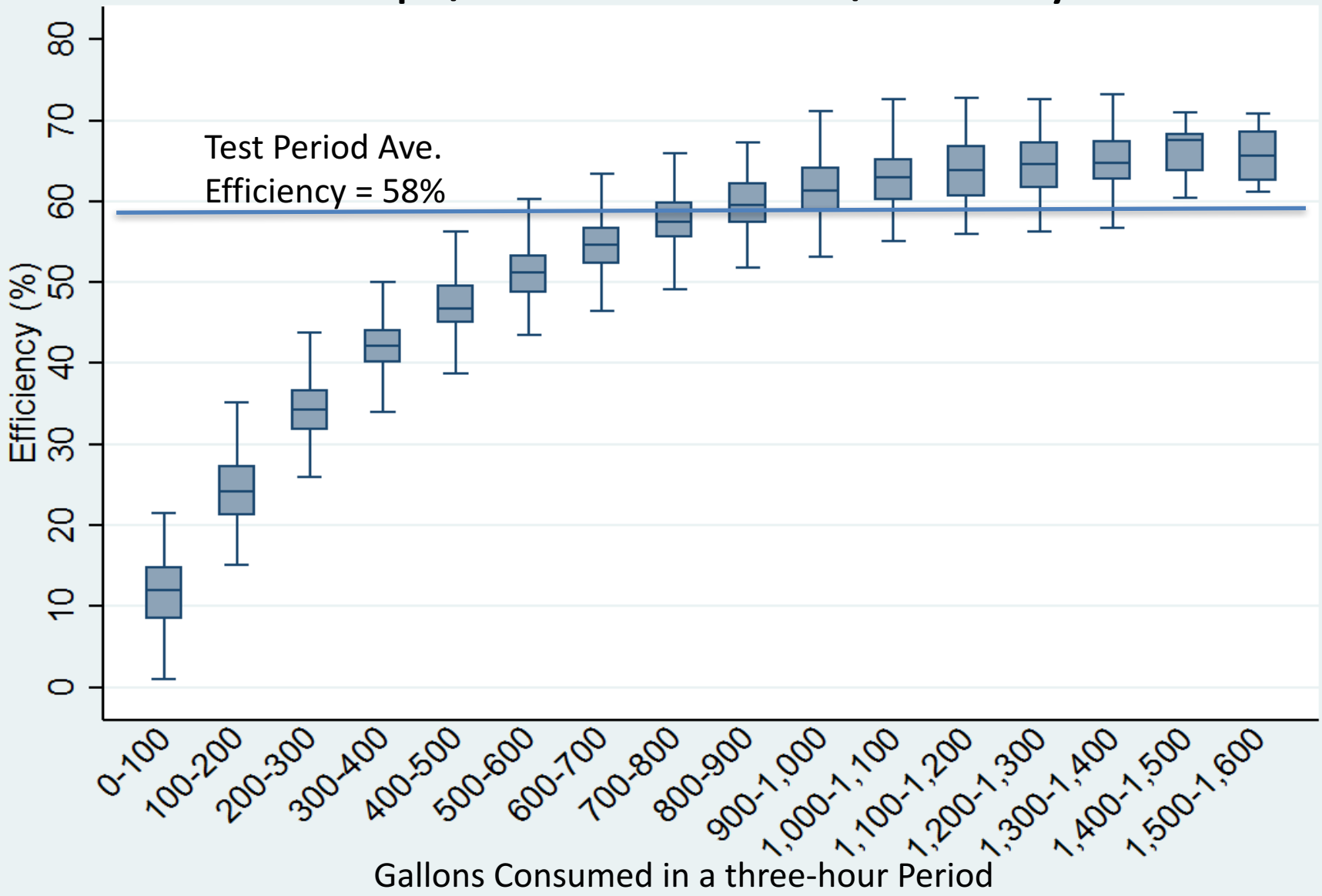
- Record water heater or boiler modulation as a 0 to 10 volt output every minute
- Utility Meter readings – natural gas and water

Total System Efficiency

Building Characteristics (Apts/bedroom/ population)	DHW System Description	Boiler or Water Heater Input (Btu/h)	Storage Volume (gal)	Measured System Efficiency
188/201/ Elderly	Water Heater, Storage Tanks and Constant Recirculation	2 x 500,000	480	58%
216/231/Elderly		2 x 500,000	480	65%
24/52/Families		1 x 286,000	120	40%

Total Efficiency = Energy consumed by tenants / Energy of Nat. Gas Used

Total System Efficiency at Different Loads
188 Apt/ 201 Bedroom/ Elderly



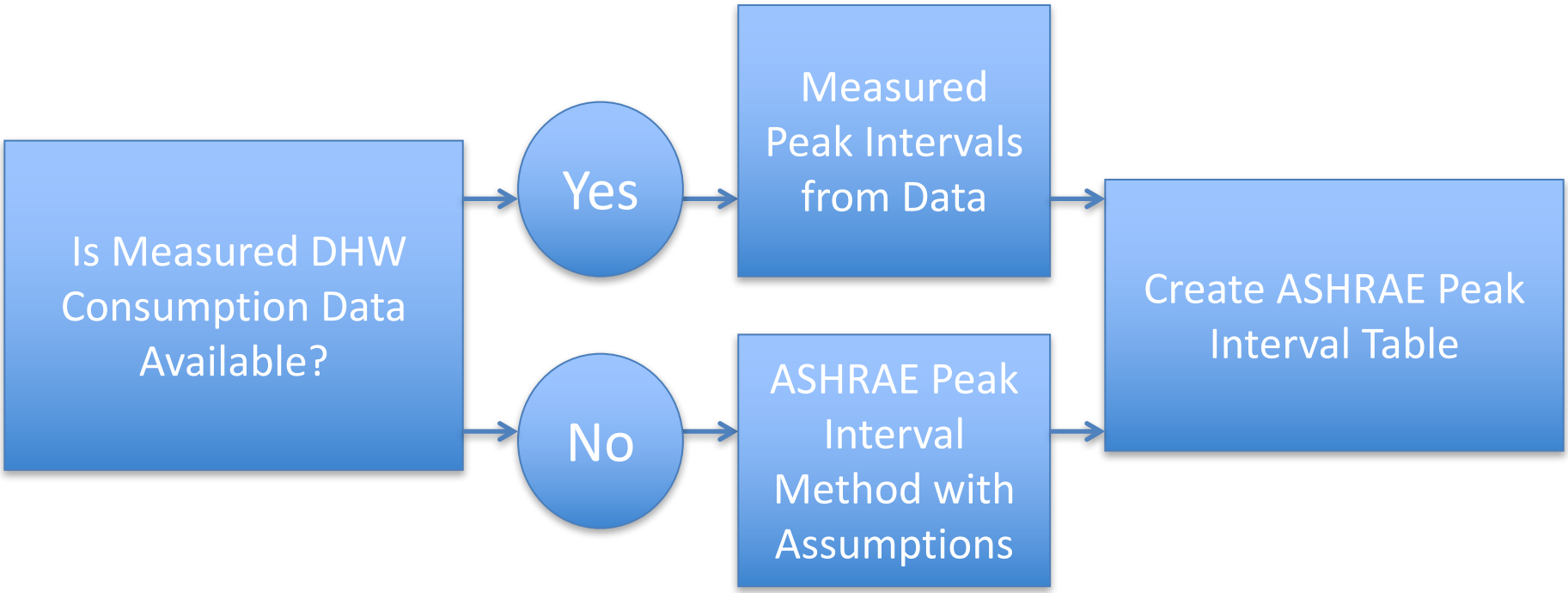
Learning Objective 4

Understand data-based domestic hot water system design and sizing methodologies

Design Guidelines of Central DHW Systems for Multifamily Buildings

- Reduce the heat loss
  - Keep water temperatures low to reduce pipe and equipment ambient losses
  - Minimize size and number of all components to reduce water volume and solid mass
  - Insulate everything
- Do not oversize equipment including water heaters, pipes and pumps
- Avoid short-cycling of water heater or boiler firing

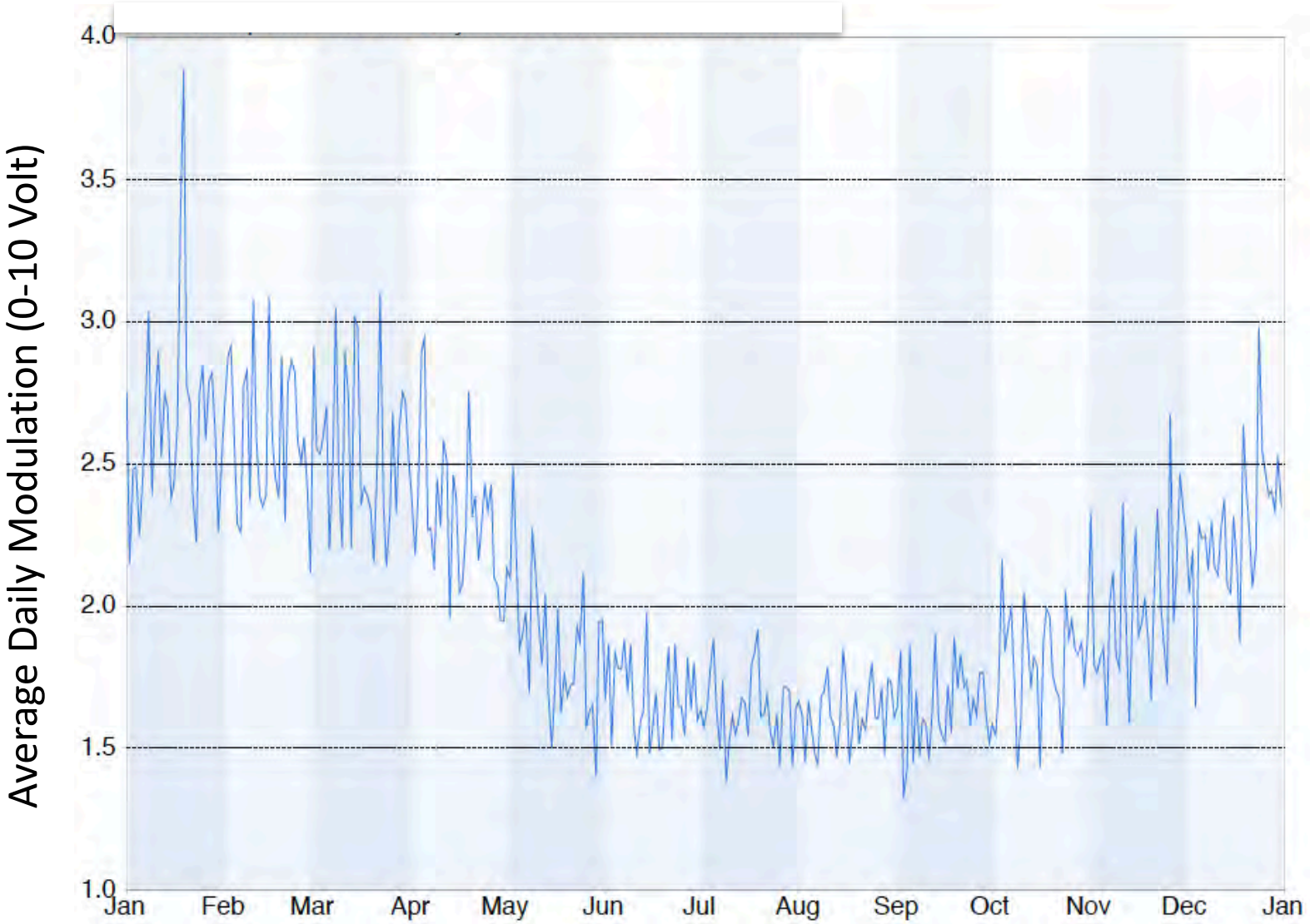
DHW Equipment Sizing Process

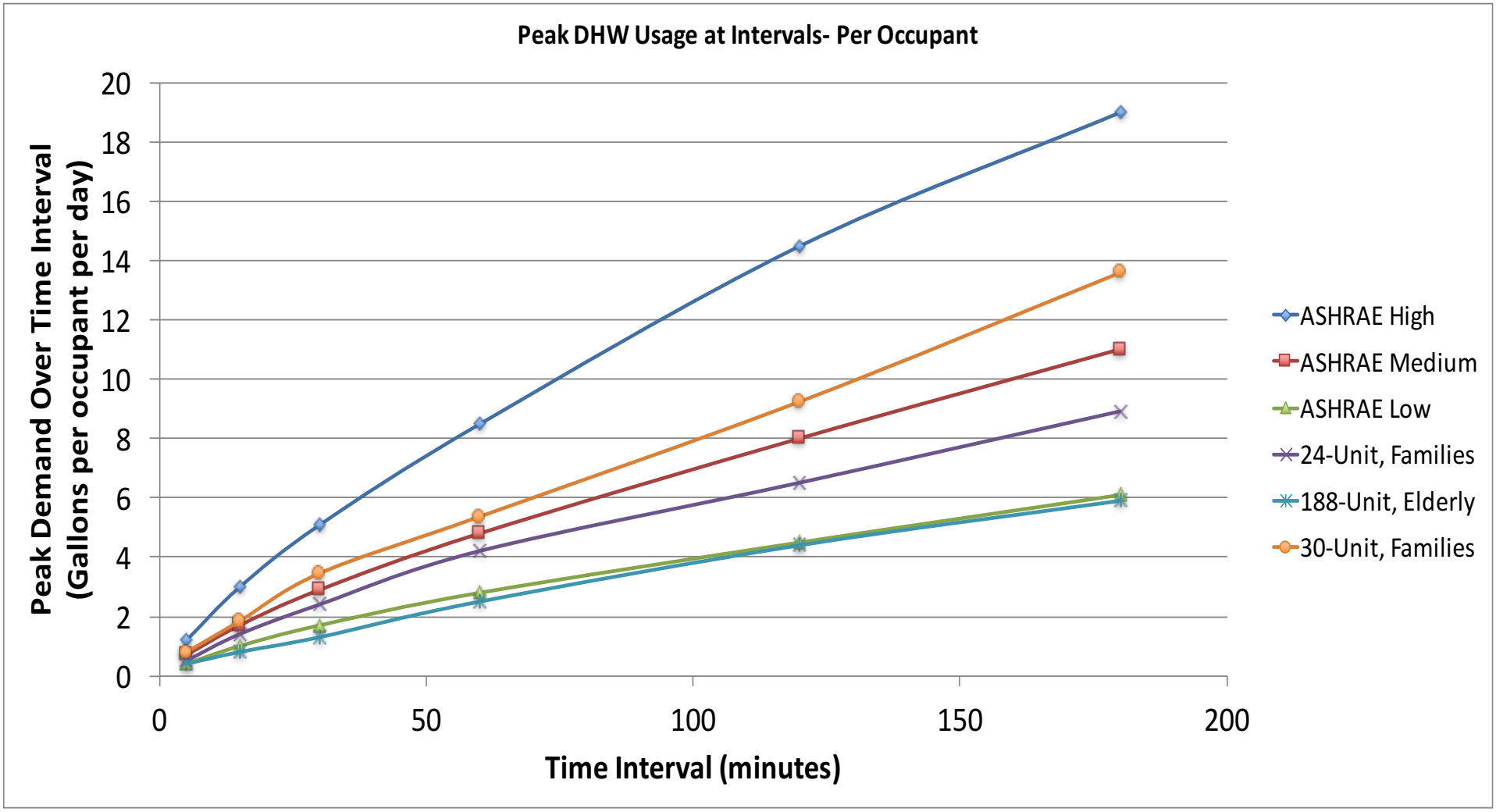


Step 1: DHW System Sizing – Establish Peak Interval Consumption

- Estimate Peak DHW Consumption
  - Measurement results
  - Use a factor of safety to account for limited test period
  - Use correction factor for seasonal cold water temperature variation
- ASHRAE sizing without measurement (new building or existing building without data)
  - Number of occupants
  - Occupant demographic
  - Estimate low, medium or high usage profile based on demographic

Average Daily Water Heater Modulation
24-Unit, Families




Peak DHW Usage at Intervals- Per Occupant
Peak Demand Over Time Interval (Gallons per occupant per day)
20
18
16
14
12
10
8
6
4
2
0
0
50
100
150
200
Time Interval (minutes)
ASHRAE High
ASHRAE Medium
ASHRAE Low
24-Unit, Families
188-Unit, Elderly
30-Unit, Families

Peak Interval Table

	188-Unit / 201 Bed / Elderly		24 Unit / 52 Bed / Families	
Interval Length	Measured Volume	ASHRAE Volume (Low Use)	Measured Volume	ASHRAE Volume (Medium Use)
5 minute	102	115	54	71
15 minute	225	287	138	173
30 minute	387	488	247	296
60 minute	716	804	431	490
120 minute	1,258	1,292	659	816
180 minute	1,685	1,751	911	1,122

Modified ASHRAE DHW System Sizing
188 Apt/ 201 Bedroom/ Elderly

Time Interval (minutes)	Total Measured Volume (gal)	Local Slope of Incremental (gal/min)	Ideal Heating Rate* (Btu/h)	Required Storage Volume (gal)
5	102	12.3	527,000	146
15	225	10.8	463,000	321
30	387	11.0	470,000	553
60	716	9.0	387,000	1,023
120	1,258	7.1	305,000	1,797
180	1,685	3.6	156,000	2,407

*Based on a 85° F temperature rise

Modified ASHRAE DHW System Sizing
24 Apt/ 52 Bedroom/ Families

Time Interval (minutes)	Total Measured Volume (gal)	Local Slope of Incremental (gal/min)	Ideal Heating Rate* (Btu/h)	Required Storage Volume (gal)
5	54	8.4	360,000	77
15	138	7.3	311,000	197
30	247	6.2	264,000	353
60	432	3.8	162,000	617
120	659	4.2		941
180	912			

*Based on a 85° F temperature rise

Design Step 1

- Create ASHRAE peak interval table
  - If possible, for existing buildings, measure DHW consumption for sizing calculation.
  - Run ASHRAE sizing calculations to determine combination of required heating rate and storage volume.

Design Step 2

- Determine balance of heating rate and storage volume based on the following considerations
  - A very small storage volume results in short firing times which is inefficient
  - Equipment cost
  - Available space for equipment
  - Adding DHW storage increases tank jacket losses
  - Equipment redundancy

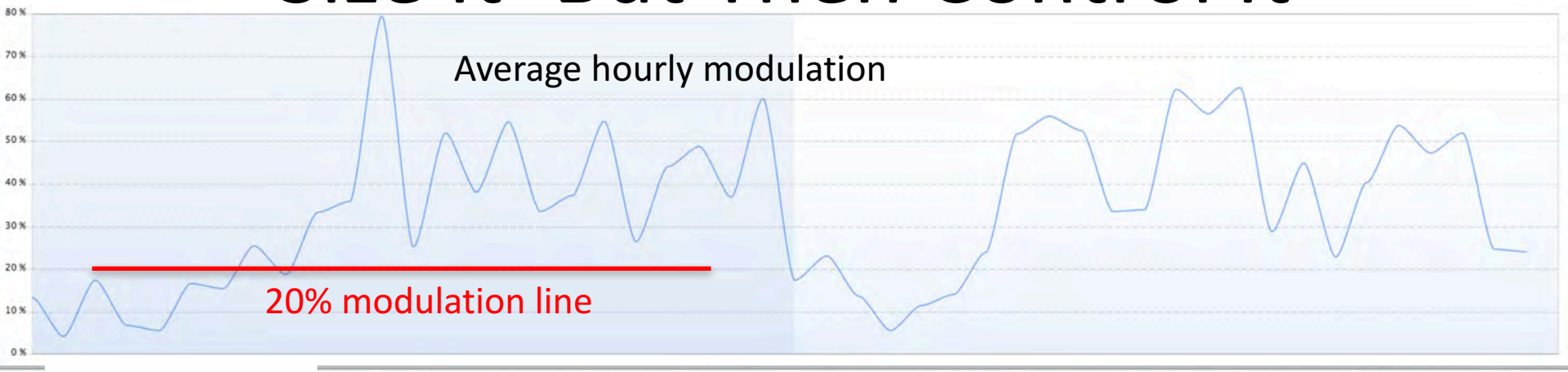
Design Step 3

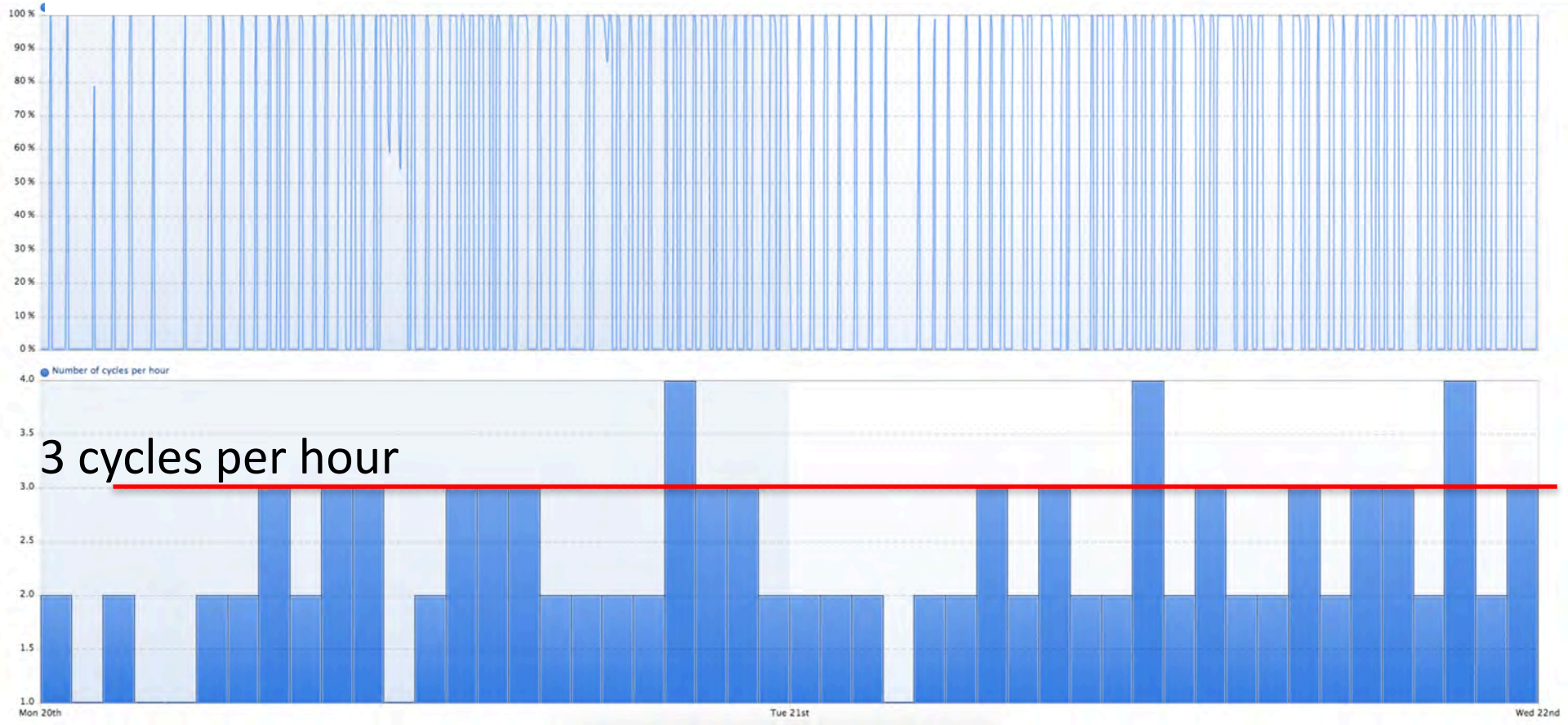
- Determine whether the DHW System will be standalone or combined with heating boilers based on the following considerations:
  - Advantages of separate heating and DHW systems
    - Simpler controls and settings
    - Potentially higher operating efficiency
  - Advantages of Combined heating and DHW systems (boilers with indirect water heaters)
    - Lower capital cost
    - Combustion heat exchanger may have longer life

Design Step 4

- Size other components
    - Distribution Piping – supply and recirculation
    - Mixing valve
    - Recirculation Pump
    - Demand Recirculation System
- Specify insulation of all components containing hot water

Size It- But Then Control It





Conclusions

- Use measured DHW consumption data for system sizing, if possible
- Size DHW system heating rate and storage using ASHRAE methodology
- Understand different DHW system types and efficiencies
  Direct-fired, condensing water heaters have the highest efficiency
- Appropriately-sized equipment results in higher efficiency

Additional Recommendations for Multifamily Buildings

- Commissioning & Optimization
- Consider redundant water heating capacity
- Fixtures - Low-flow faucet aerators and showerheads
- Low-flow Appliances - Energy Star labeled Clothes Washer and dishwasher

Future Work

- Addition of water meters on cold water makeup to DHW
- System efficiency optimization
- System efficiency of indirect DHW water heater and distribution system

Thanks to …

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  - Jessica Spanier & Yun Zhan, New Ecology, Inc.
- Special Equipment Support
  - Josh Sklarsky

Thank you!

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