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

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Objectives

- Measure and analyze DHW load profiles and frequencies

- Determine total system efficiencies

- Determine best practices for design
  - System type
  - System size

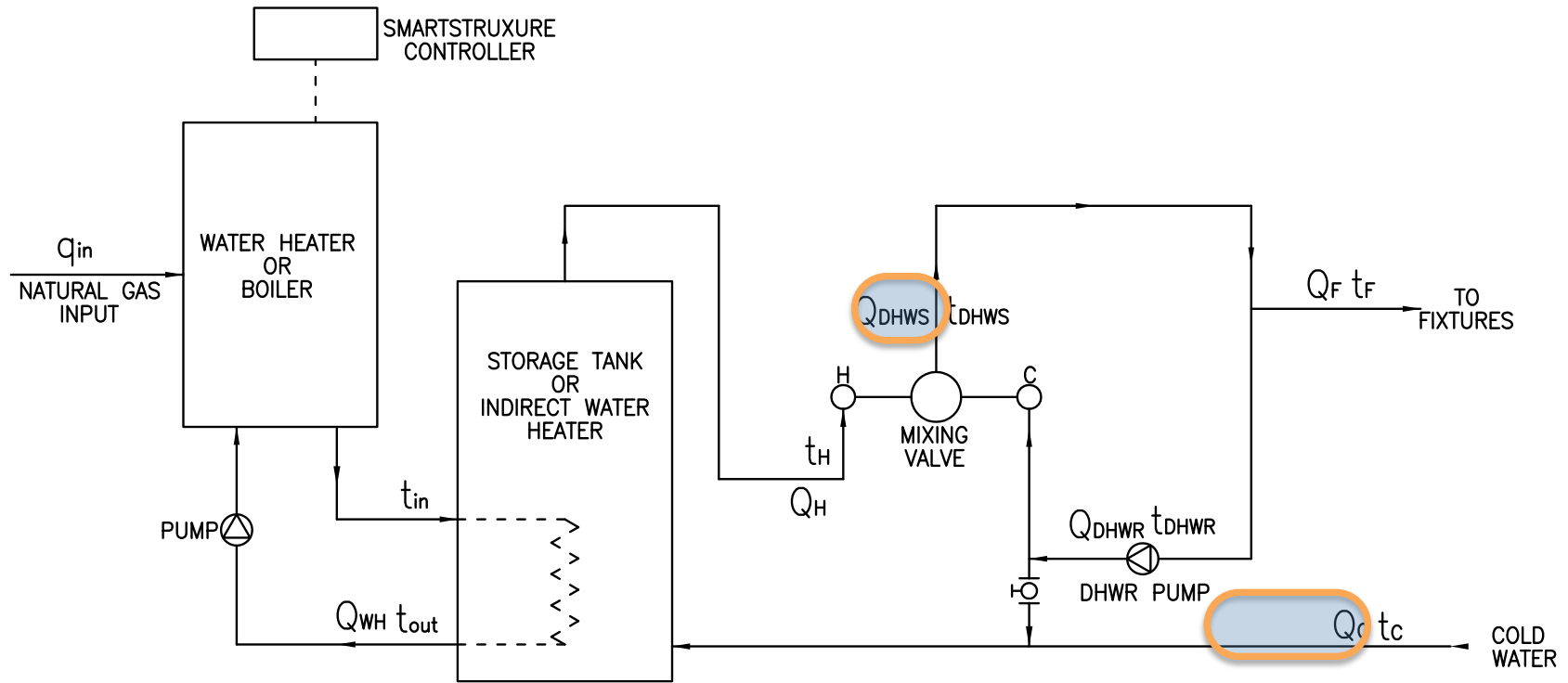# Experimental Instrumentation

Ultrasonic Flow & Btu Meter

Data Logger & Controller

Fuji Electric Portaflow-C Kit

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
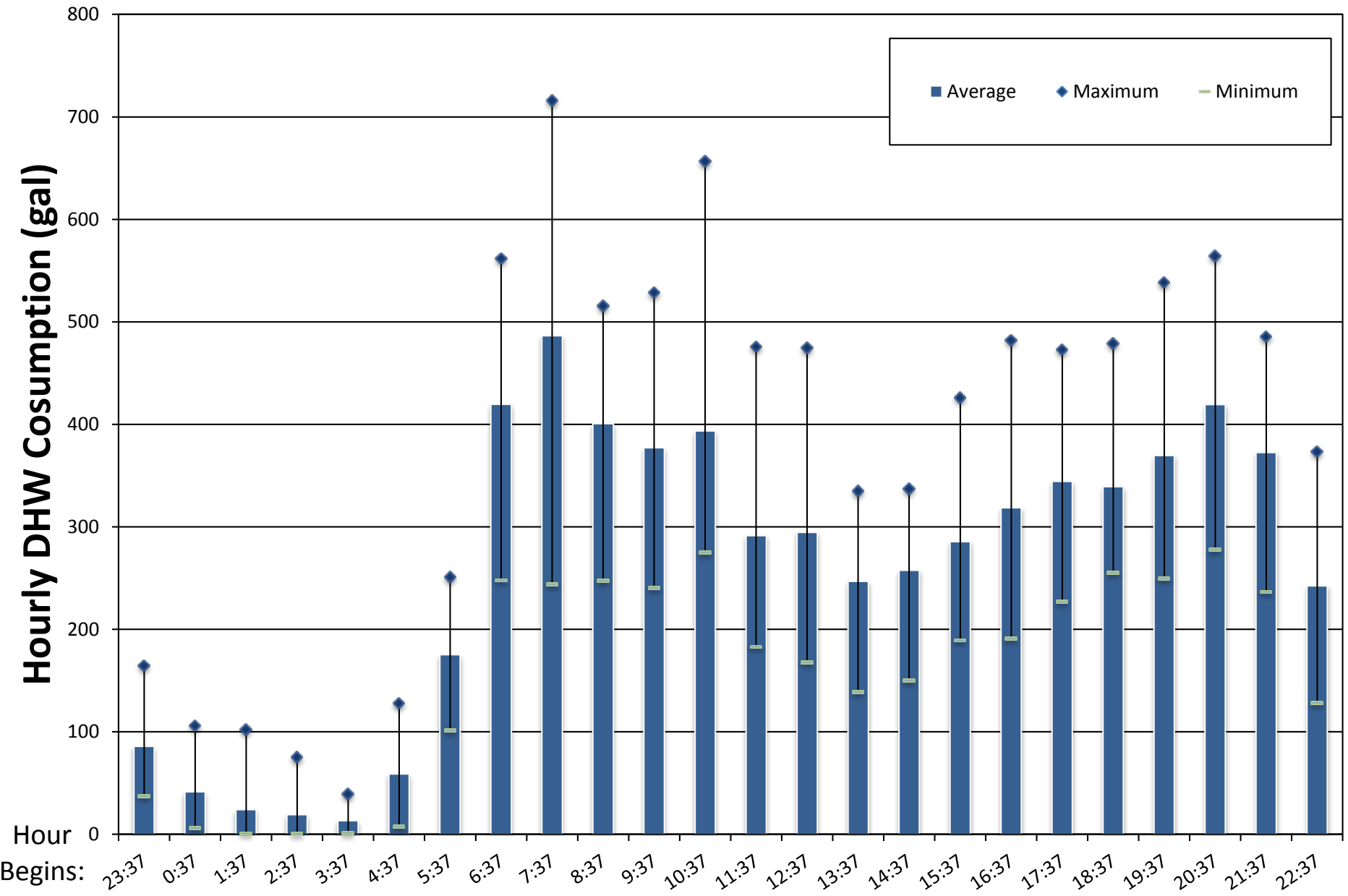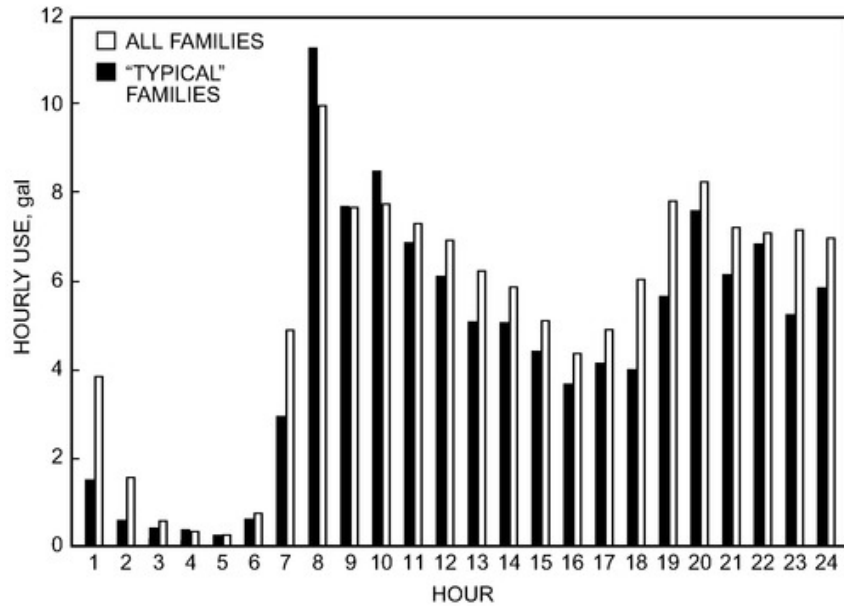
Building Characteristics

- 17-story, 188 units, 201 bedrooms
- Elderly population
- Two 500,000 Btu/h direct-fired water heaters
- Four 120-gallon storage tanks
- Constant recirculation

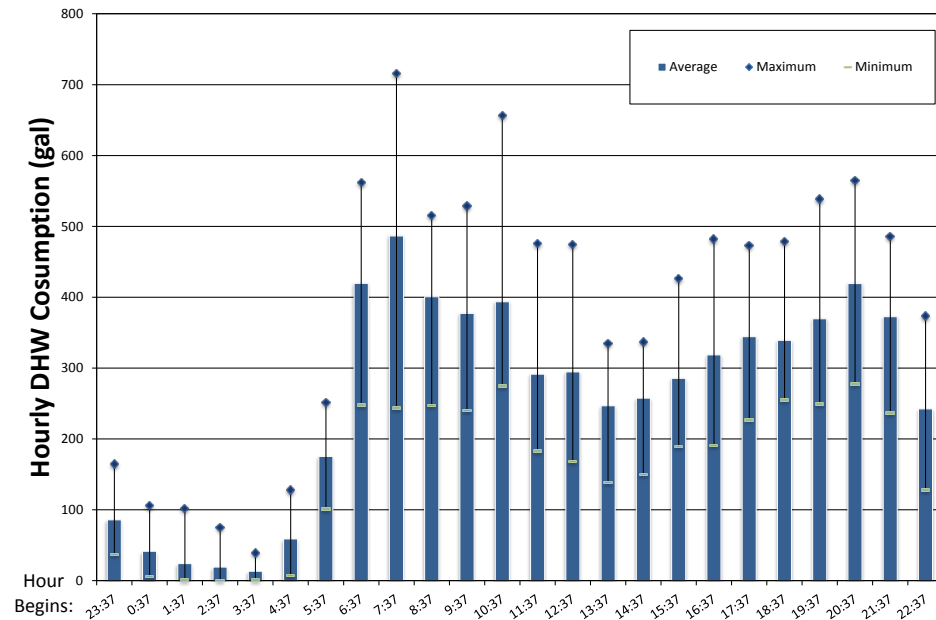17-Story, 188-unit Bldg - Hourly DHW Consumption-
Based on Peak Hour, July 2, 2014 11AM- August 5, 2014 9AM

17-Story, 188-unit Bldg – Hot Water Consumption Profile Comparison to ASHRAE
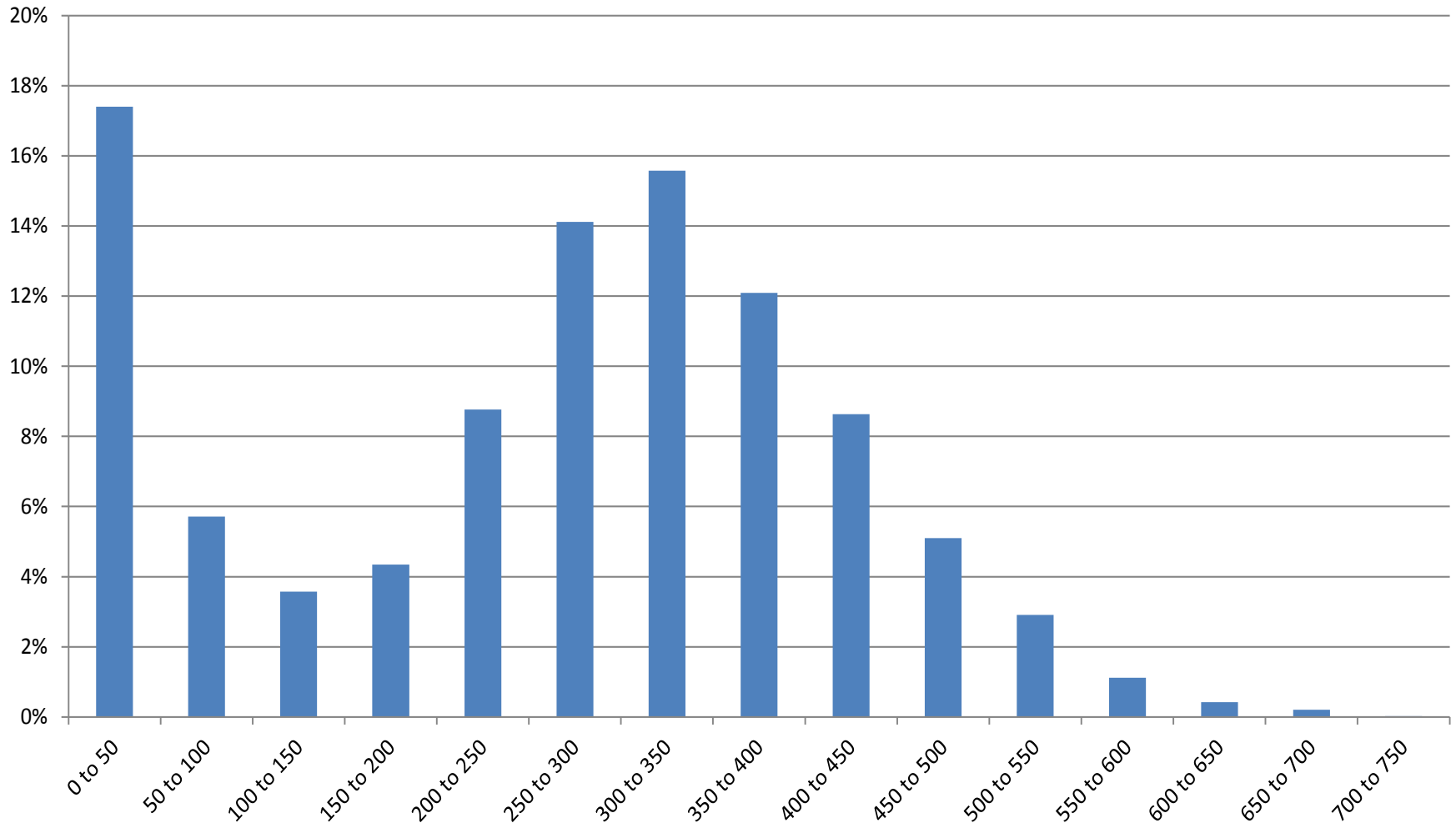

**Hourly DHW Consumption- Based on Peak Hour
July 2, 2014 at 11AM- August 5, 2014 at 9AM**

17-Story, 188-unit Bldg - Histogram of Rolling DHW Consumption

Gallons Consumed per Hour

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17-Story, 188-unit Bldg - Peak Flows at Time Intervals

Time Interval (minutes)	Total Volume (gal)	Average Flow Rate (gal/min)
5	102	20.4
15	225	15.0
30	387	12.9
60	716	11.9
120	1,258	10.5
180	1,685	9.4
1440	6,261	4.3

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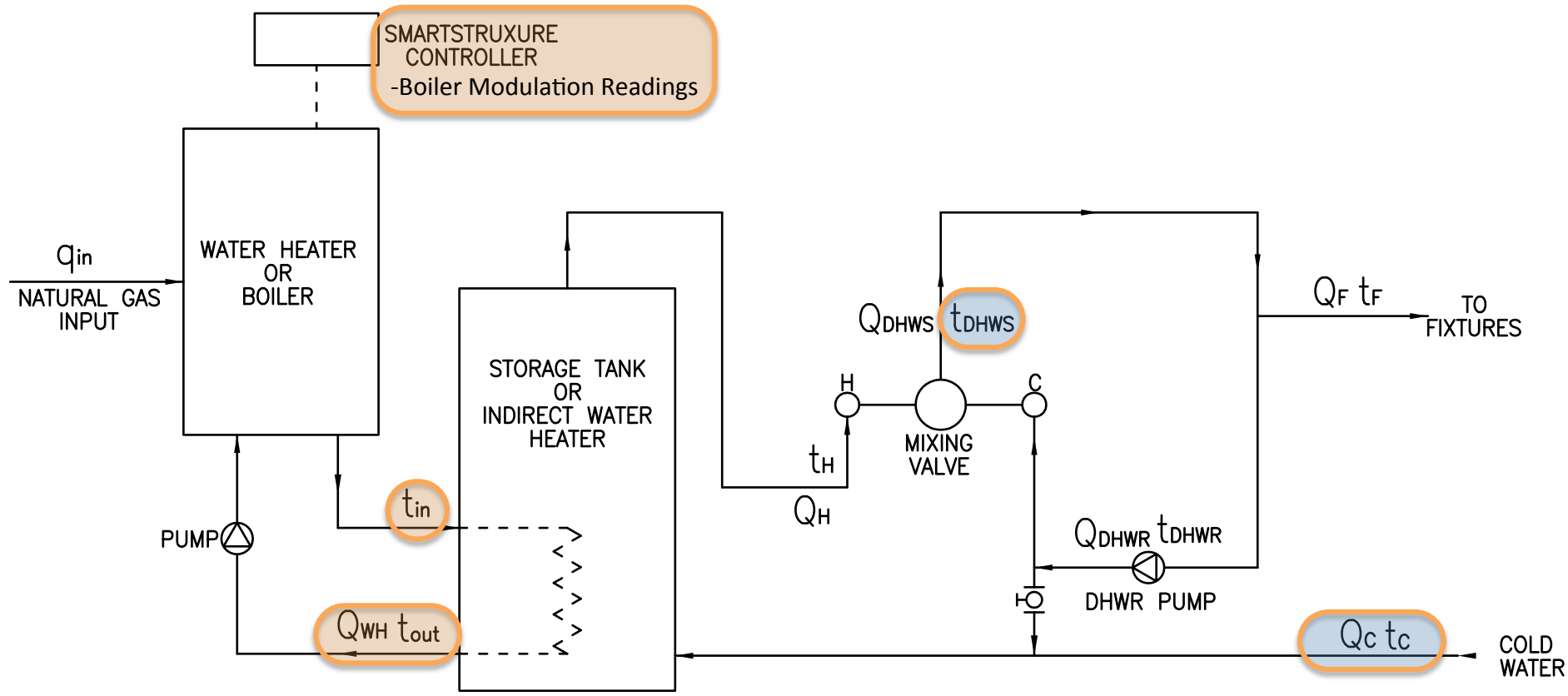
17-Story, 188-unit Bldg - Hot Water Loads Data Summary

- Average Daily Consumption: 6,260 gal
- Normalized Flows
  - Per apartment: 32 gal/day
  - Per bedroom: 30 gal/day
  - Per occupant: 21 gal/day (based on HUD maximum occupancy)
- Minimum Flow: 0 gal/h
- Maximum Peak Flow: 716 gal/h
- Testing period: July 2, 2014 – August 5, 2014

DHW System schematic showing location of test sensors

SMARTSTRUXURE CONTROLLER
-Boiler Modulation Readings

q_{in}

NATURAL GAS INPUT

WATER HEATER OR BOILER

PUMP

t_{in}

STORAGE TANK OR INDIRECT WATER HEATER

Q_{WH} t_{out}

t_H

Q_H

H

MIXING VALVE

C

Q_{DHWS} t_{DHWS}

Q_F t_F

TO FIXTURES

Q_{DHWR} t_{DHWR}

DHWR PUMP

Q_c t_c

COLD WATER

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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

Data Points

- Water heater or boiler modulation as a 0 to 10 volt output every minute

- Utility Meter readings – natural gas and water

Hot Water Energy Flow Diagram

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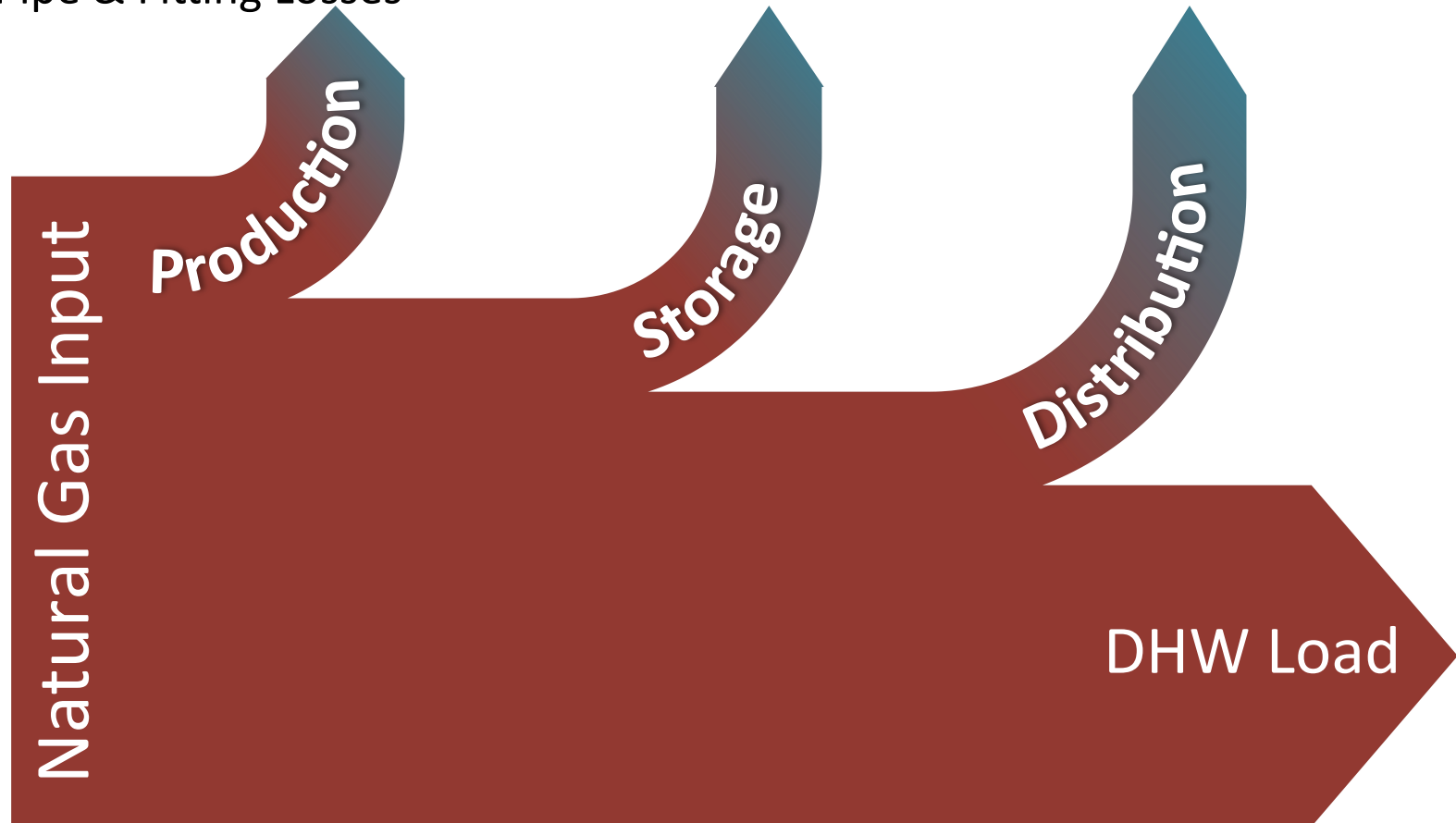- Combustion Losses
- Jacket Losses
- Pipe & Fitting Losses

Storage Losses
- Jacket Losses

Distribution Losses
- Pipe & Fitting Losses
- Recirculation Losses

Production

Storage

Distribution

Natural Gas Input

DHW Load

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	2x 500,000	480	58%
216/231/Elderly		2x 500,000	480	65%
24/52/Families		1x 286,000	120	40%

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

17-Story, 188-unit Bldg - Total System Efficiency at Different Loads

Efficiency (%)

Gallons Consumed in a 3-hour Period

★ excludes outside values
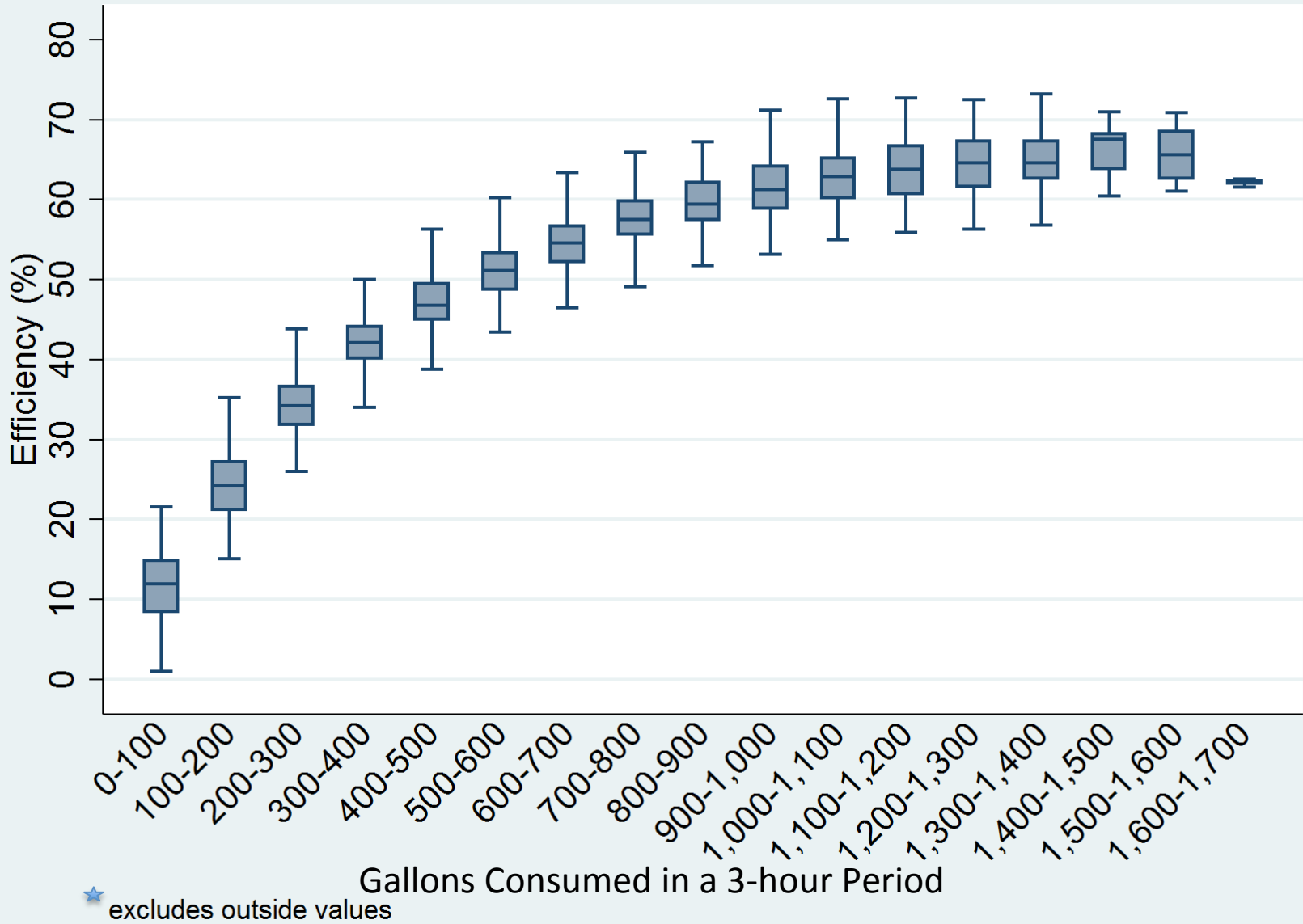
DHW Subsystem Energy Efficiency

Building Characteristics (Apts/bedroom/population)	System Type	Normalized DHW Consumption	Energy consumed/ Energy Input to tank
15/33/families	DHW Heater, Storage, constant recirc	19 gal/(bedr*day)	46%
26/37/families	Combined Heat & HW Boilers, Indirect WH, Demand Recirc.	35 gal/(bedr*day)	89%

Design 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

Recommended DHW Systems for Multifamily Buildings

- Large Buildings
  - Direct-fired, instantaneous water heaters with unfired storage tanks (240 – 600 gallons total) or
  - tankless water heaters with no storage
- Small Buildings
  - Hydronic boilers for space heating and indirect water heaters or
  - tankless water heaters with no storage
- All Buildings - Demand recirculation (but constrained by piping system in existing buildings)

Additional Recommendations for Multifamily Buildings

- Commissioning & Optimization
- Fixtures - Low-flow faucet aerators and showerheads
- Low-flow Appliances - Energy Star labeled Clothes Washer and dishwasher

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
1440	6,261	4.3	186,000	8,944

*Based on a 85°F temperature rise

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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Thank you!

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