COMMERCE DEPARTMENT

Welcome

Conservation Applied Research & Development (CARD) Webinar

March 8, 2022

Racked Tankless Water Heaters: Savings and Efficiencies

Racked Tankless Water Heaters: Savings and Efficiencies



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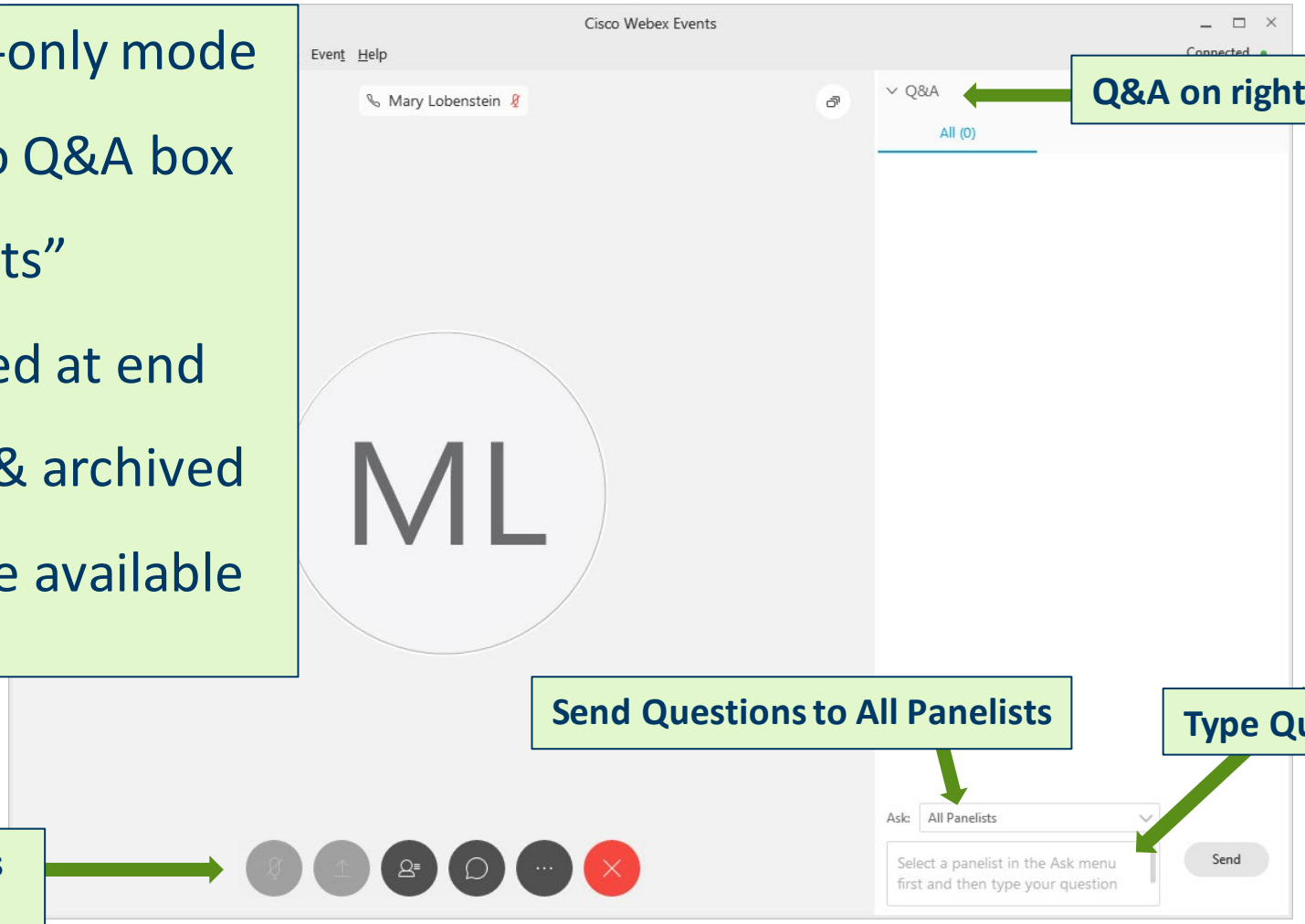
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Webinar Basics

- Attendees in listen-only mode
- Type questions into Q&A box
- Send to “All Panelists”
- Questions addressed at end
- Webinar recorded & archived
- Slide set will also be available



Q&A on right side of WebEx panel

Send Questions to All Panelists

Type Questions in Q&A box

Additional WebEx Controls at Bottom of Your Screen

Minnesota Applied Research & Development Fund

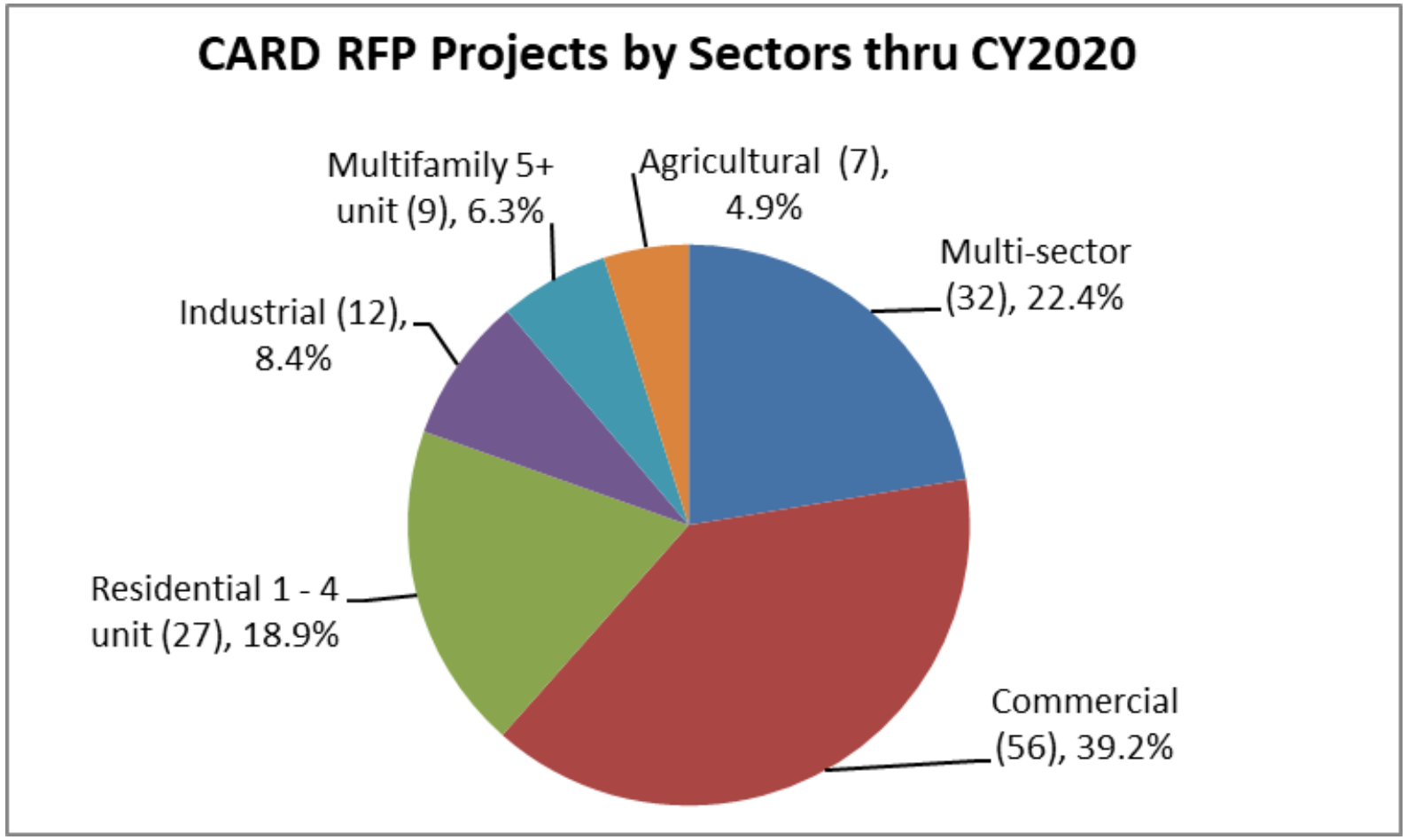
- **Purpose to help Minnesota utilities achieve 1.5% energy savings goal by:**
  - ***Identifying new technologies or strategies to maximize energy savings;***
  - ***Improving effectiveness of energy conservation programs;***
  - ***Documenting CO_2 reductions from energy conservation programs.***

- **Utility may reach its energy savings goal**
  - **Directly through its Conservation Improvement Program (CIP)**
  - **Indirectly through energy codes, appliance standards, behavior, and other market transformation programs**

Minnesota Statutes §216B.241, Subd. 1e

State Capitol Image: Courtesy Minnesota Department of Administration

CARD RFP Spending by Sector thru FY2020



RFP Summary

- 12 Funding Cycles
- 513 proposals
- 143 projects funded
- $31.2 million in research

COMMERCE DEPARTMENT
ENERGY RESOURCES

Demonstration of Packaged Central Condensing Tankless Water Heating Systems in Multifamily Buildings

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March 8, 2022

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Gas Technology Institute

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Center for Energy & Environment

gti cee

Acknowledgements

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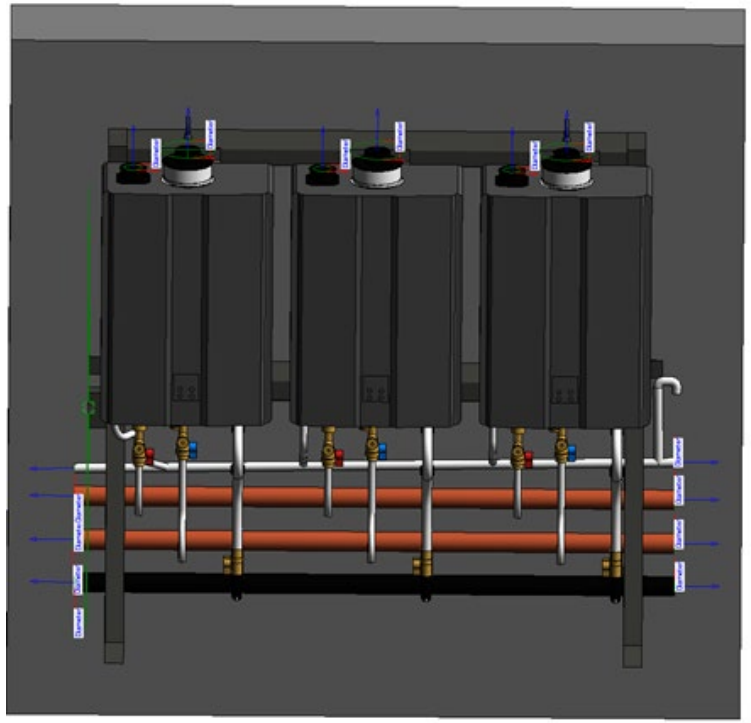
The authors would also like to acknowledge the following GTI members of Utilization Technology Development, NFP, for their financial support



Combined Condensing Tankless Water Heating (CCTWH) Technology







Overall Project - Summary

- **Demonstration**: Two CCTWH Systems installed at two multi-unit family buildings Twin Cities area
- **Analysis:** Develop CCTWH assessment tool and extrapolate to buildings based on occupancy, climate, etc.
- **Tech Transfer:** Measure assessment, model custom CIP measure





Site Summary

Site	Number of Units	Monitoring Period Start Date	Monitoring Period End Date	Days	Hot Water Use [Gallons Per Unit] per Day
1 – Baseline	23	5/9/19	3/15/20	311	27.9
2- Baseline	17	6/12/19	3/15/20	277	33.0
1-CCTWH	23	5/14/20	1/15/21	247	22.0
2-CCTWH	17	4/15/20	1/15/21	276	28.5

Image Source: CEE, Rinnai

Field Site 1





Name	Location	Building type	Number of Units	Building Built	Number of Bedrooms	Occupancy
Site 1	St Paul, MN	Apartment/rental	23	1968	1 & 2 bed	one unit unoccupied

Field Site 2





Name	Location	Building type	Number of Units	Building Built	Number of Bedrooms	Occupancy
Site 2	St Paul, MN	Apartment/rental	17	1970	1 & 2 bed	fully occupied

SWH - Baseline Configurations

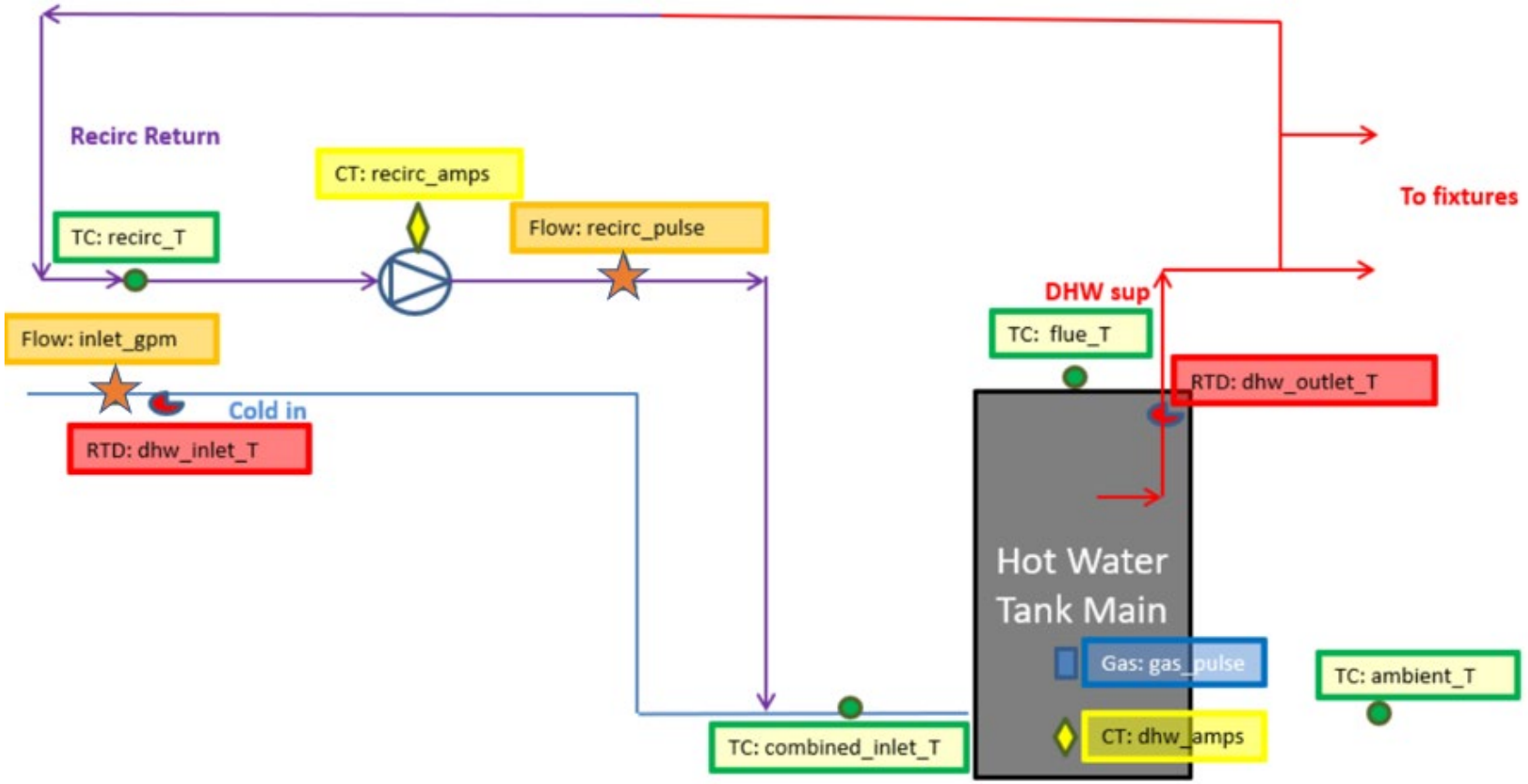
Site	Baseline SHW system	WH Make	WH Model	Input rate, Btu/hr	EF	Recirc Loop present	Recirc Operation	Storage Volume, gallons
1	Single tank type water heater	A.O Smith	BTR 197 108	199,000	0.80	yes	Uncontrolled, on 24/7	100
2	Single tank type water heater	Rheem	RFD250-86	250,000	0.80	yes	Uncontrolled, on 24/7	86

SWH - CCTWH Configuration

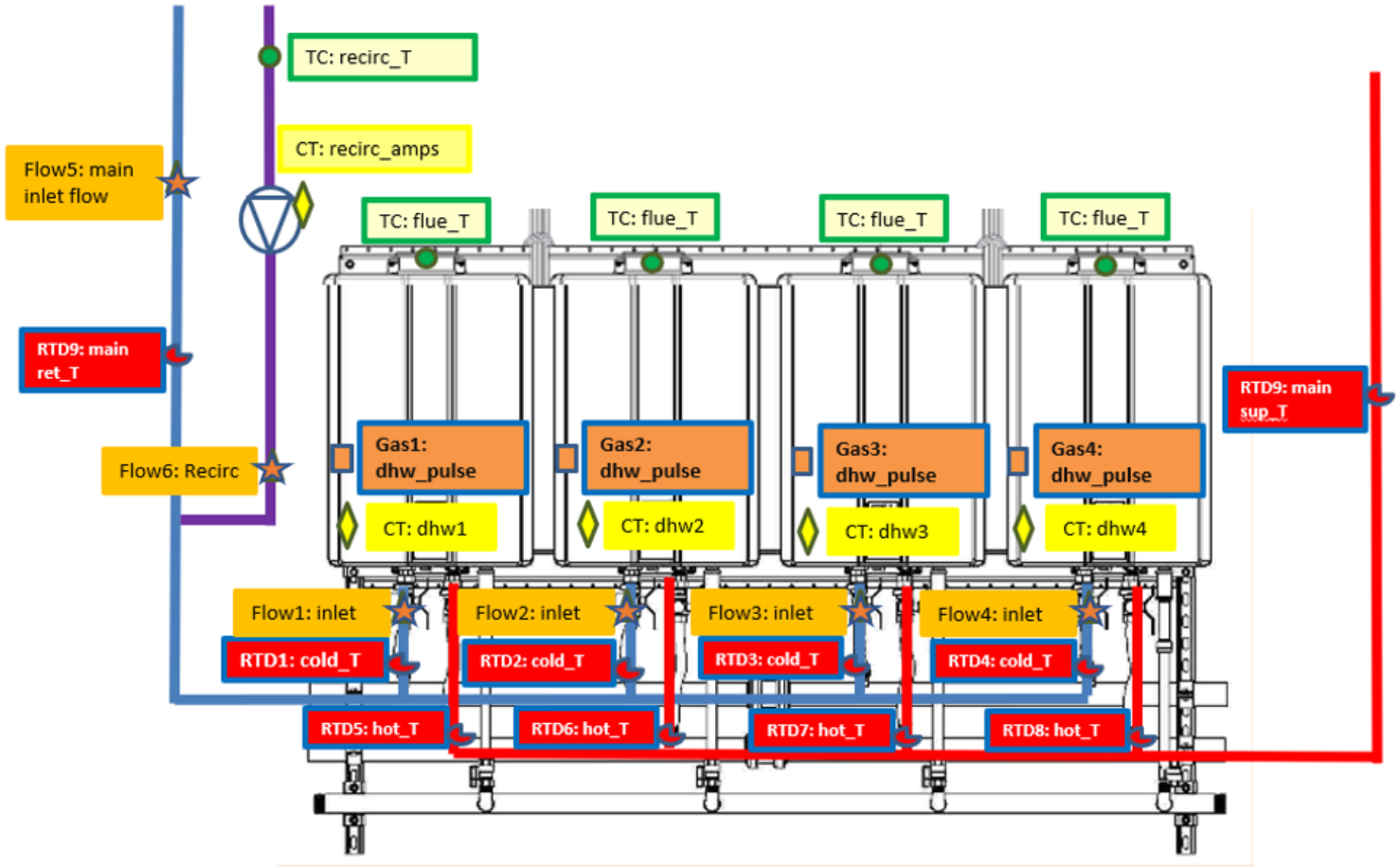
Site	CCTWH SHW system	TWH Make	TWH Model	Input rate range per unit, Btu/hr	EF
1	Racked Tankless — 4 units	Rinnai	Cu199i	15,200–199,000	0.96
2	Racked Tankless — 3 units	Rinnai	Cu199i	15,200–199,000	0.96

Data Analyses and Results

Baseline Monitoring



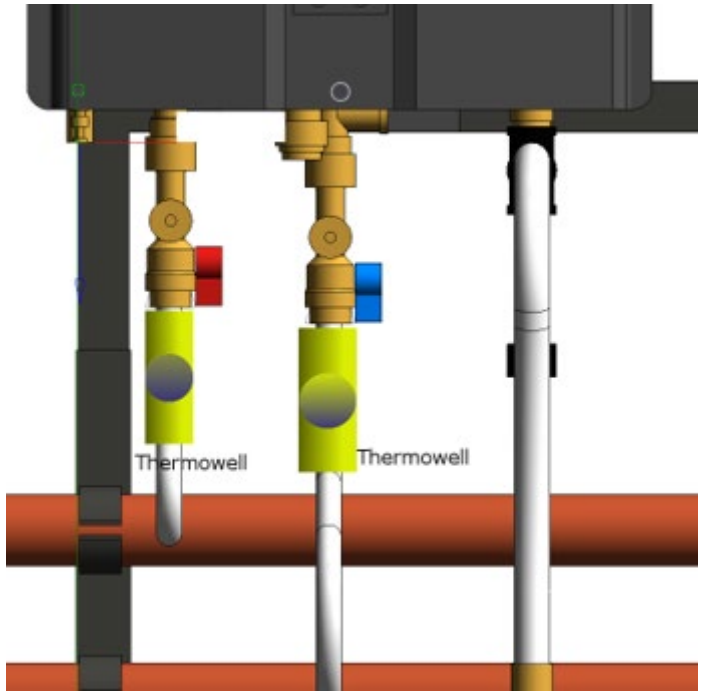
CCTWH Monitoring

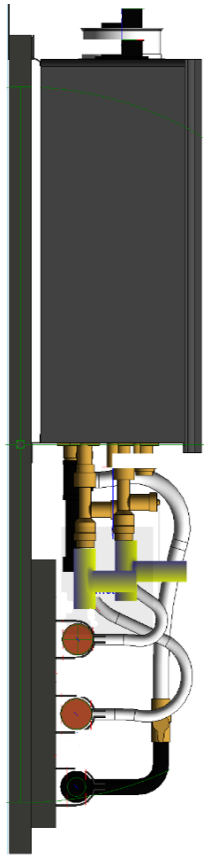


Racked Instrumentation

- RTD/TC for water
  - Each tankless inlet / outlet
  - Plumbed perpendicular Pete's plugs / thermowell, facing forward or out from rack
- TC for Flue Gas
  - ~6" from top of unit
  - ¼" NPT threaded port with 0.125" compression fitting.
- Gas Meter AC-250
  - Hard-piped, if necessary, in MN
- Water Meter Badger M25
  - Hot water capable >120°F
  - 10 ID upstream and 5 ID downstream straight pipe, facing forward or out from rack
  - Mounted horizontally

Racked System Instrumentation







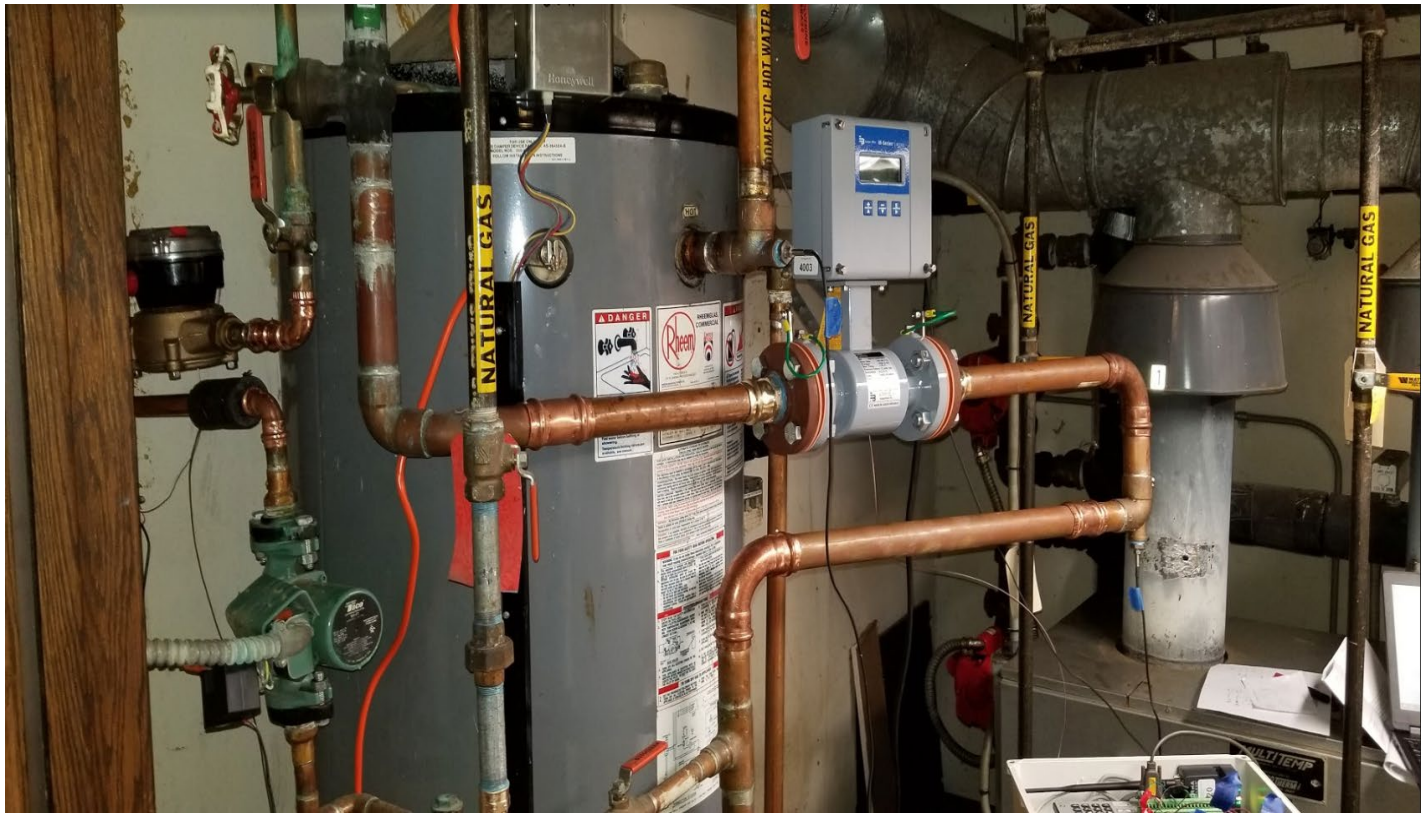
- Thermowells go here

Site 1





Site 2

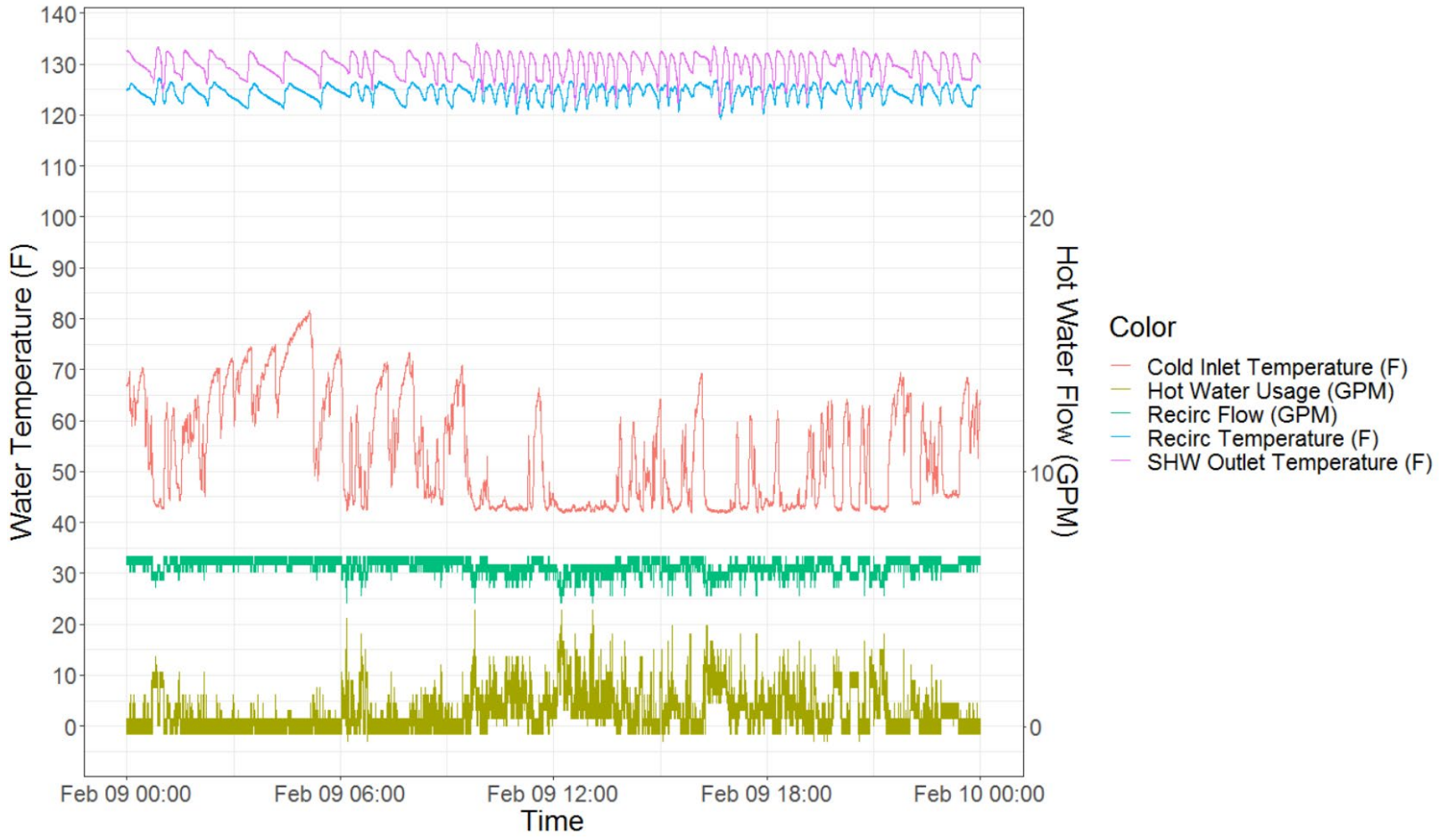

NATURAL GAS
DOMESTIC HOT WATER
NATURAL GAS
NATURAL GAS
DANGER
Rheem
Honeywell
MULTITEMP


NATURAL GAS

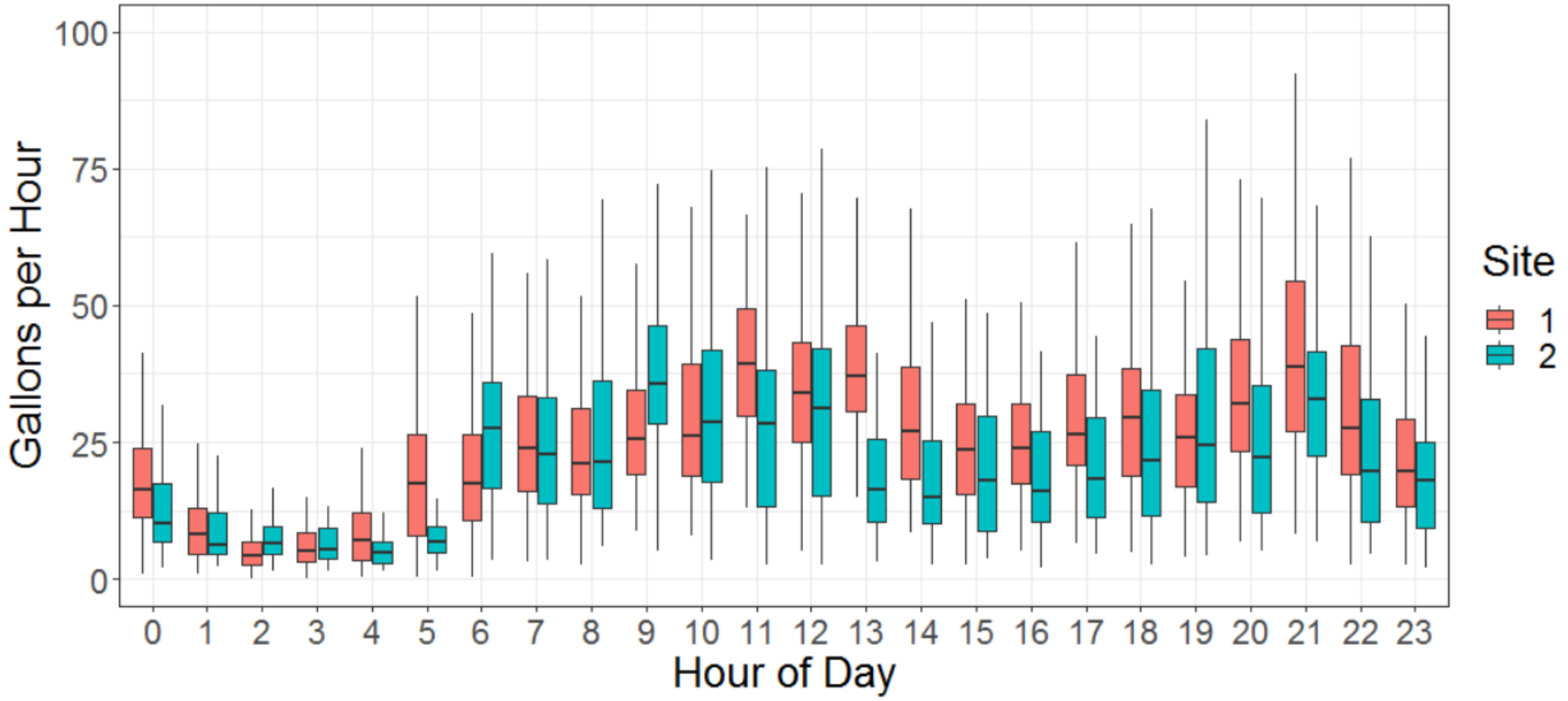
System Inlet Water Temperature Range



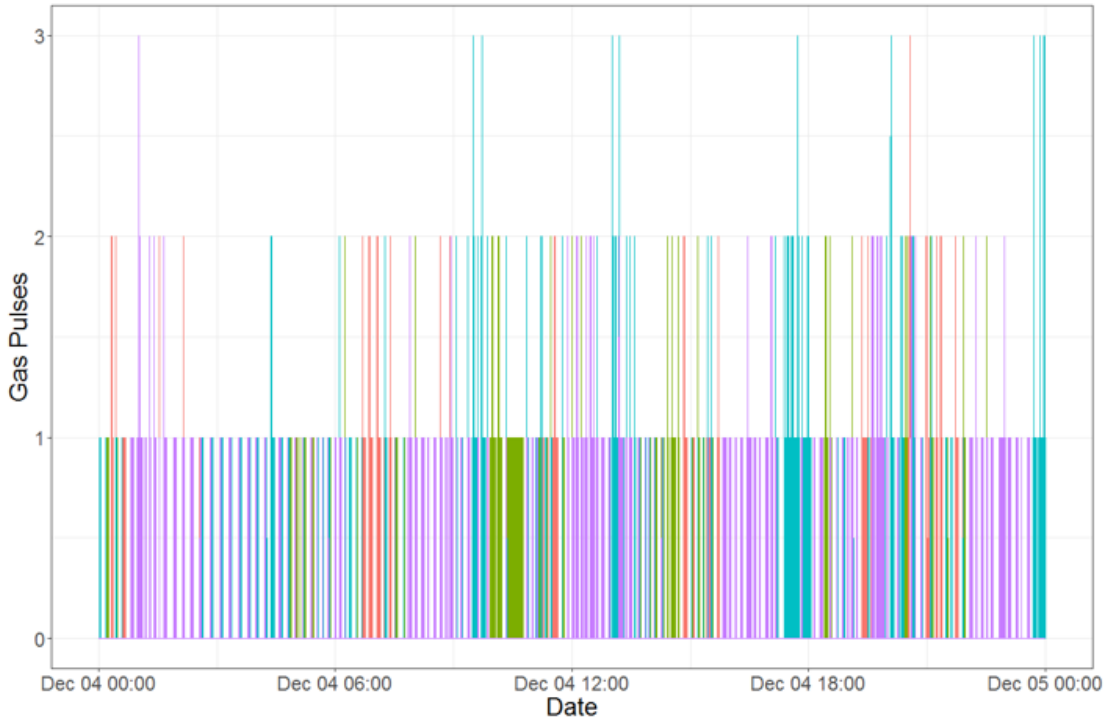
Typical Day of Operation

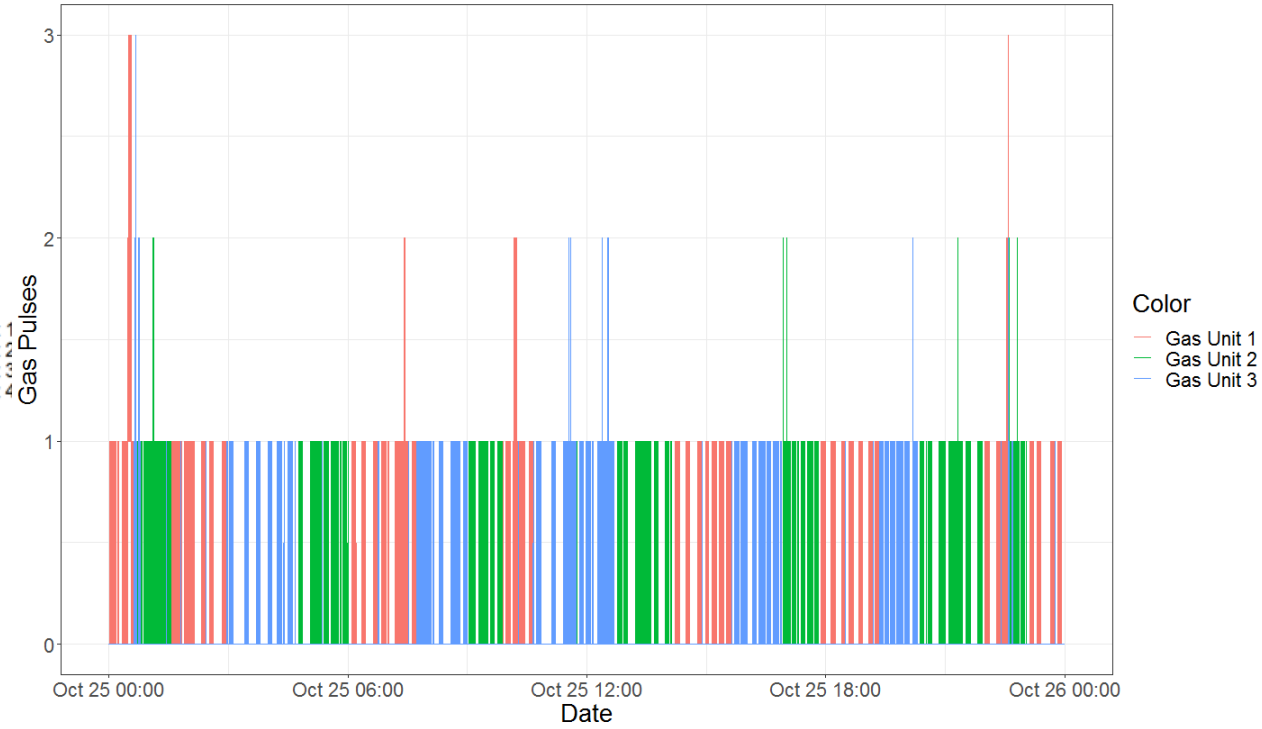


Hot Water Use

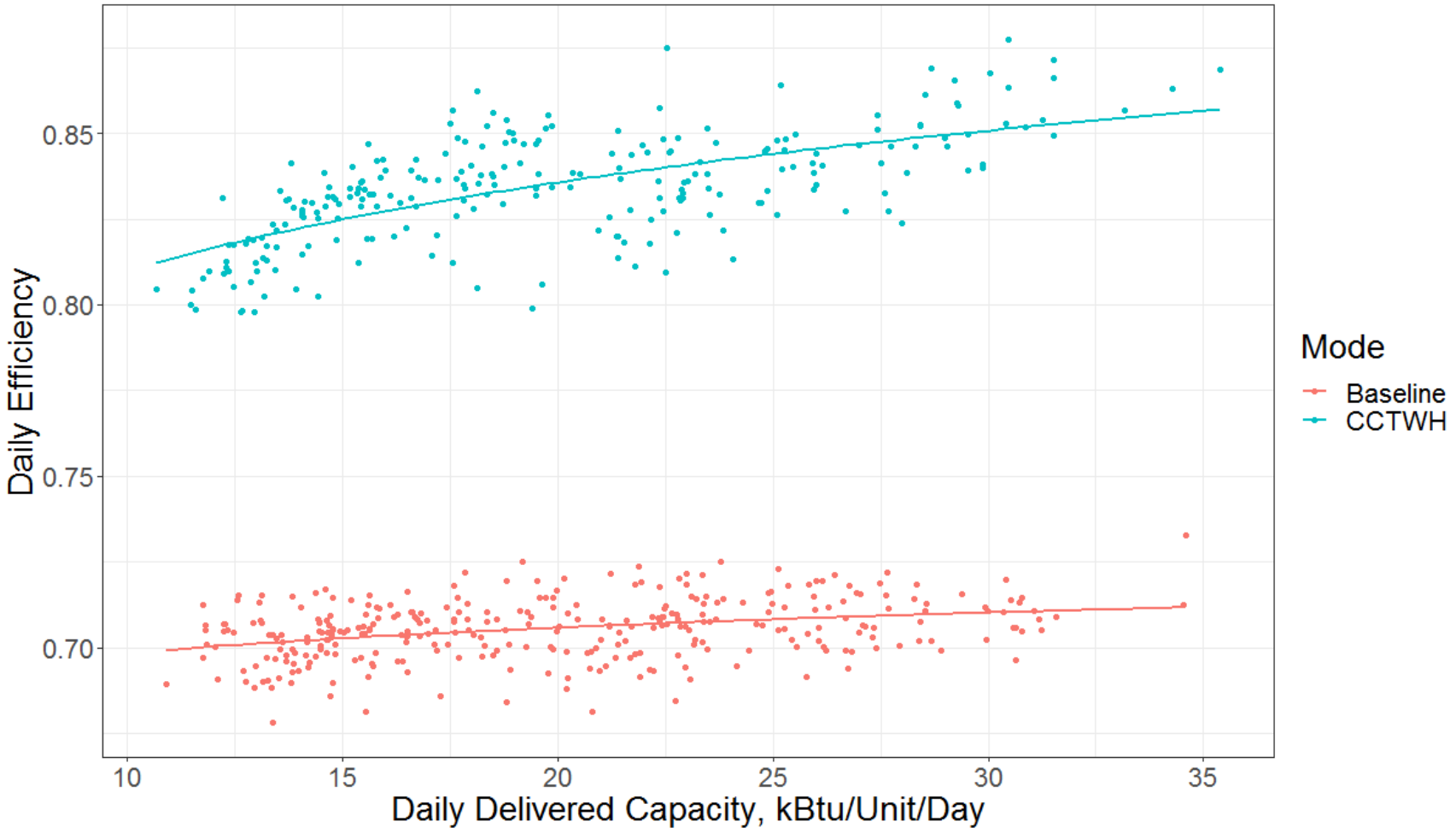


Operation

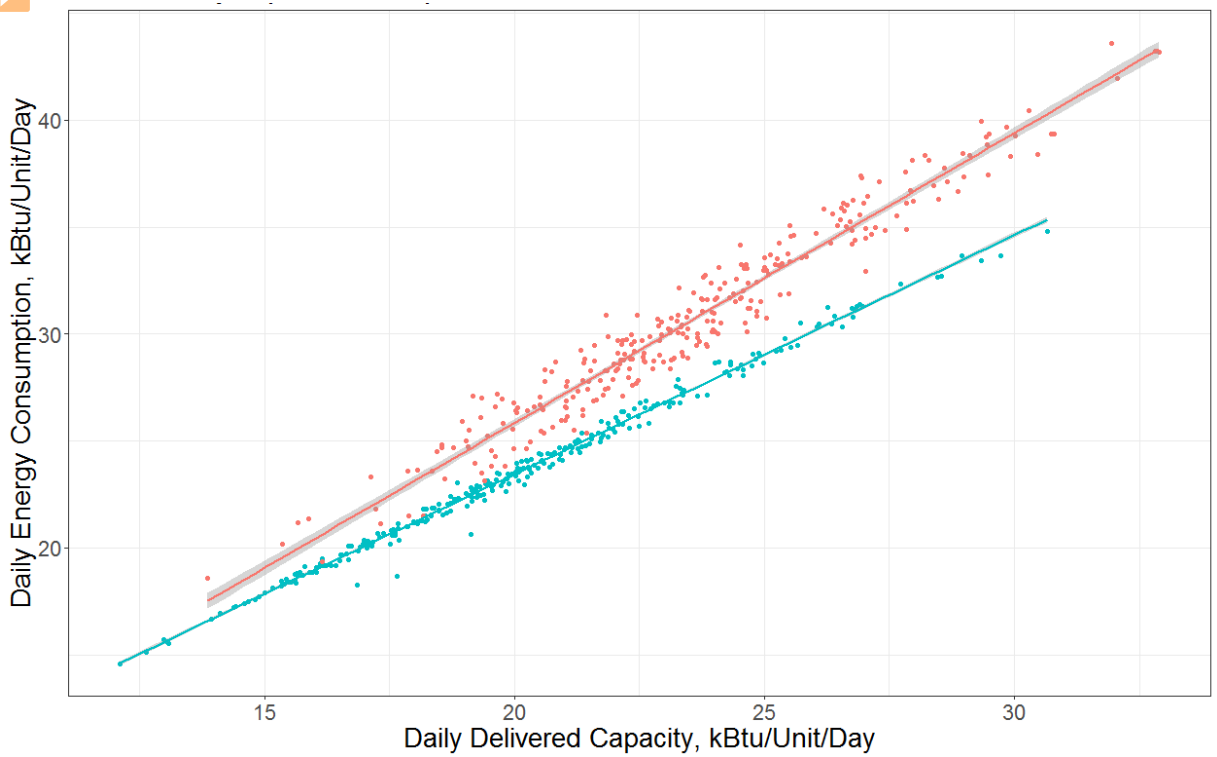

Gas Pulses
3
2
1
0
Dec 04 00:00
Dec 04 06:00
Dec 04 12:00
Dec 04 18:00
Dec 05 00:00
Date
Color
Gas Unit 1
Gas Unit 2
Gas Unit 3
Gas Unit 4

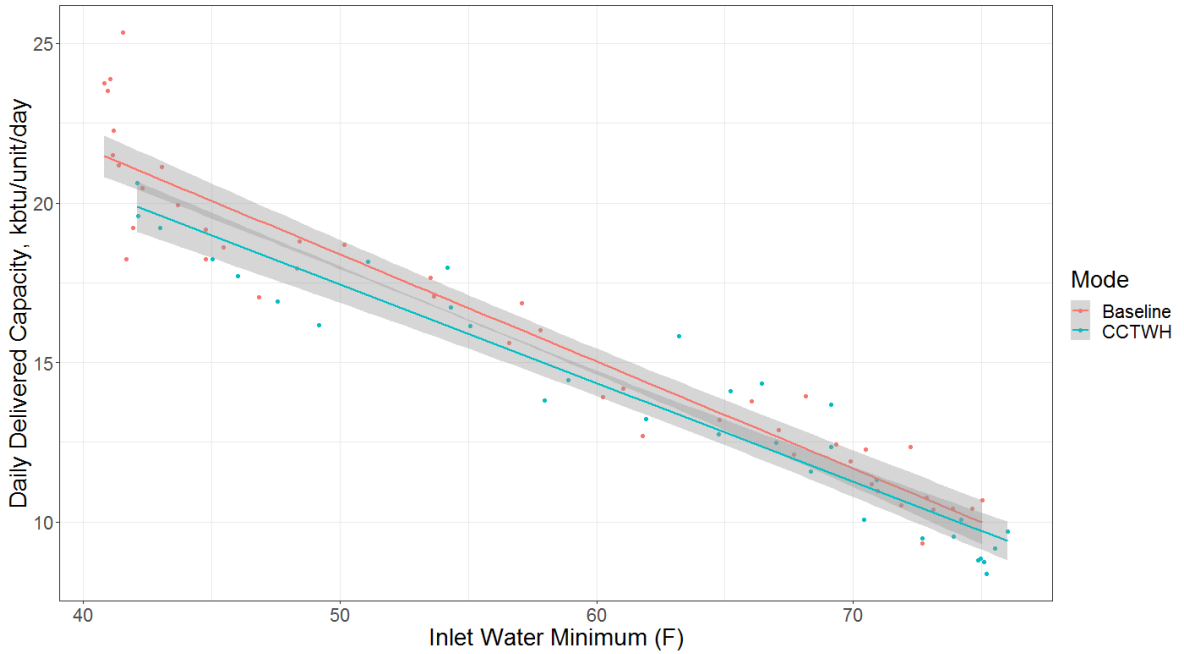

Gas Pulses
3
2
1
0
Oct 25 00:00
Oct 25 06:00
Oct 25 12:00
Oct 25 18:00
Oct 26 00:00
Date
Color
Gas Unit 1
Gas Unit 2
Gas Unit 3

Efficiency Comparison



Analysis Method





Baseline vs. CCTWH – System

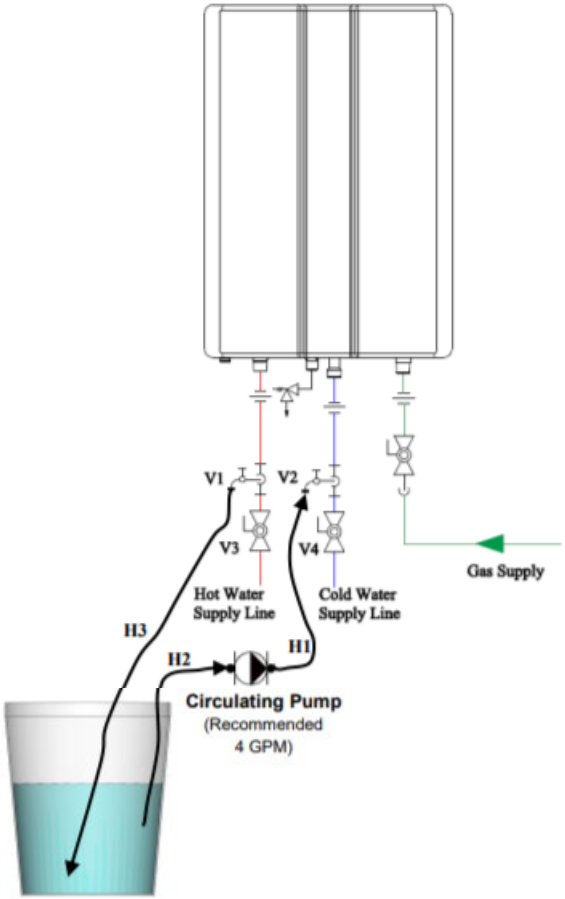
Testing period	Site	Q-out (kBtu/unit/day)	Q-in (kBtu/unit/day)	Efficiency	Annual Energy Use (Therms)	Energy Savings (Therms)	Percent Savings
Baseline	1	15.87	27.97	0.57	2348	—	—
	2	19.17	30.66	0.63	1903	—	—
CCTWH	1	15.14	25.82	0.59	2168	180	7.7%
	2	18.56	25.28	0.73	1569	334	18%

Baseline vs. CCTWH – Water Heater

Testing period	Site	Q-out (kBtu/unit/day)	Q-in (kBtu/unit/day)	Efficiency	Annual Energy Use (Therms)	Energy Savings (Therms)	Percent Savings
Baseline	1	19.71	28.02	0.70	2352	—	—
	2	23.58	30.69	0.77	1904	—	—
CCTWH	1	21.85	26.02	0.84	2184	168	7.2%
	2	21.52	25.14	0.86	1560	344	18.1%

CCTWH Maintenance

- Maintenance of each unit of the CCTWH is recommended for prolonged life of the system
  - Lime and Scale buildup – Recommendation is a flush of the heat exchanger annually
    - Will vary based on water hardness
  - Clean air and water filter



Surveys

- Conducted interviews with building owners, occupants, and the contractor before and after CCTWH installation.
- Interviewees were asked about the following.
  - Comfort complaints (lack of hot water with each system)
  - Maintenance schedules
  - Overall impressions of each system
  - Importance of the CCTWH's non-energy benefits
  - Challenges and complexities of each system

Survey Results

Building Owners

- Main concern before installation was occupant complaints regarding lack of hot water.
- Energy savings, space savings, and redundancy were big factors in their decision.
- Overall were satisfied with the CCTWH's installation and performance.

Building Occupants

- No complaints were observed for lack of hot water during test period.

Survey Results (Cont'd)

Contractors

- Had no experience with the CCTWH before the project.
- Potential issues were space constrictions and venting, both of which were easily addressed during the project.
- Came away with overall positive impressions of CCTWH.

CCTWH Assessment Tool

- Create a tool for use by a broad audience, including building owners, specifying engineers, contractors, and utilities to calculate costs and savings for multi-family units, hotels, schools, and universities.

Assessment Tool Inputs

- Equipment estimates were was based on local equipment prices, and labor costs to remove and install field test sites
- The recirculation/branch losses have a “Default” value of 34% of system input (per field test data), 44% for a “Poor” recirculation system and 24% for a “Good” circulation system.
- The Hot Water Usage tiers were based on Hunter Curves
- The entering cold water temperature used was for climate zone 6A-Rochester, MN.
- The utility costs were a 2018-2020 average from the EIA database
- The following examples use specifications for the building types (e.g., occupancy and number of units) are taken from US EERE - Prototype Building Models .

CCTWH Assessment Tool - Example

Building Description and Other Model Inputs

Building Type	Multifamily	*If "N/A" do not use*
# of dwelling units	80	*Number of Apartment or Hotel Units*
Avg bedrooms/dwelling unit	1	*Multifamily or Hospitality*
Estimated daily occupancy	200	*N/A*
Estimated Fixture Units	*240.0*	
OPTIONAL - Custom Fixture Units		link for resource, blank if unused
Hot Water Recirculation Efficiency	Default	
Recirculation Pump Size	0.33	hp
Apply Diversity Factor?	No	
Hot Water Characteristics		
Hot Water Usage Level	Default	
Thermostatic Temperature	140	F
Cold Water Mains Temperature	49.5	F ------>
Energy Prices		
	$ 0.67	per therm
	$ 0.10	per kWh

Typical Entering Cold Water Temperatures

	Min.	Avg.	Max.
7A - Int'l Falls, MN	34.7	43.9	53
6A - Rochester, MN	39.1	49.5	59.7
5A - Chicago, IL	44.7	54.1	63.5
4A - New York, NY	49.5	60.4	71.2
3A - Atlanta, GA	56.3	67.9	79.3
2A - Tampa, FL	68.7	85	77.3
1A - Miami, FL	80.3	82.9	85.4

Data from TMY3 - EnergyPlus

Outputs

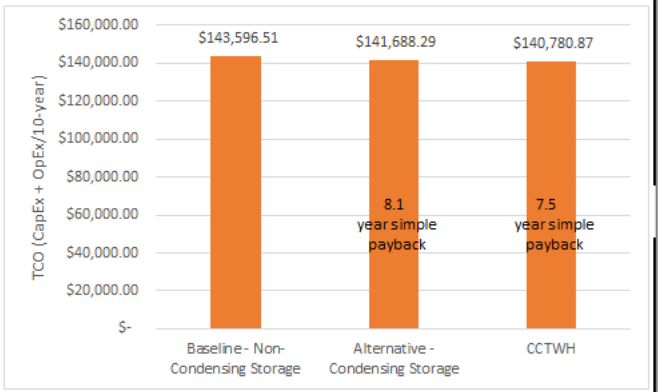
Hot Water Demand

Daily Draw	2268.3	Gal/day
Hot Water Energy Output	1.702	MMBtu/day
Design Output	1,738,201	Btu/hr

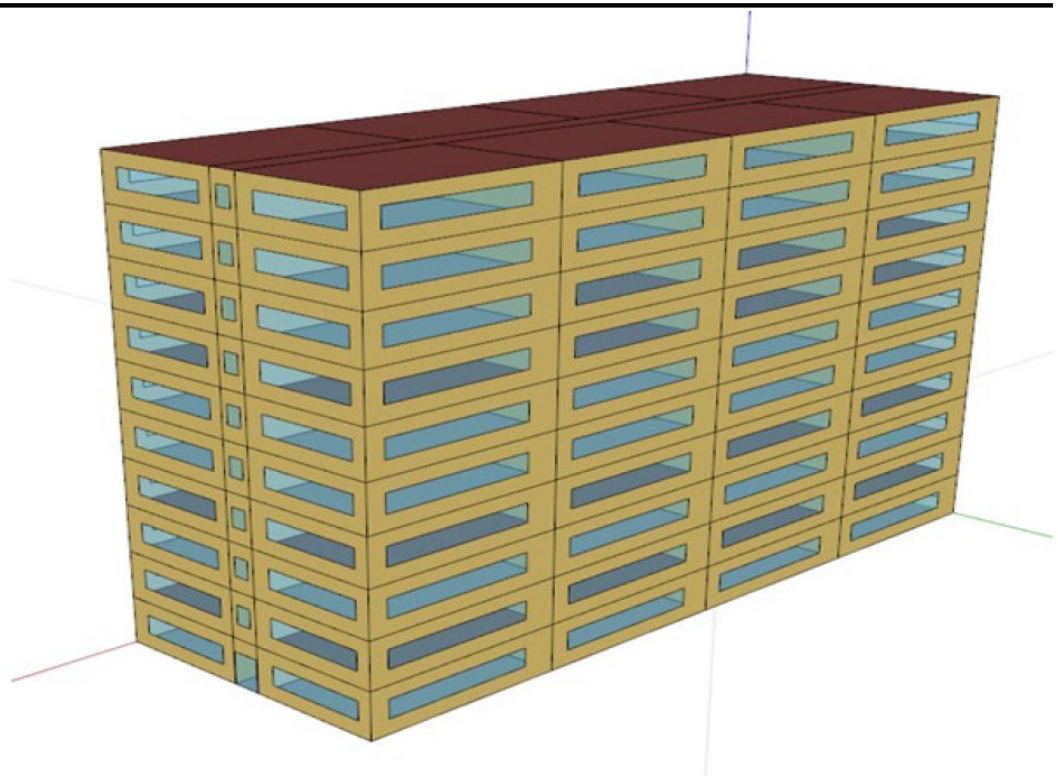
System Performance

			Annual Operating Costs
Baseline - Non-Condensing Storage	4.962	MMBtu gas/day	$ 12,349.34
Alternative - Condensing Storage	4.560	MMBtu gas/day	$ 11,366.61
CCTWH	4.492	MMBtu gas/day	$ 11,201.34
Recirculation Pump	5.91	kWh/day	

System Cost	Equipment Cost	10 year TCO (Equip + OpEx)	Simple Payback
Baseline - Non-Condensing Storage	$ 20,103.11	$ 143,596.51	
Alternative - Condensing Storage	$ 28,022.21	$ 141,688.29	8.1
CCTWH	$ 28,767.50	$ 140,780.87	7.5



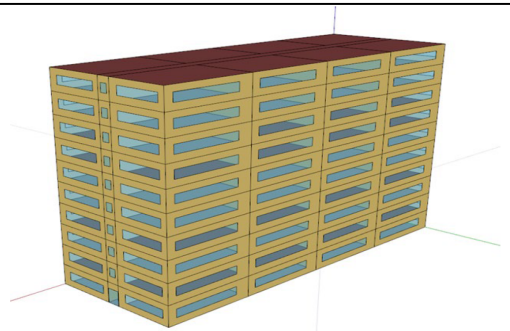
CCTWH Assessment Tool-Prototype Building Apartment Highrise



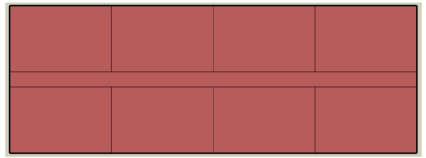
80 units-10 floors x 8 units per floor
950 sq ft per unit

Prototype Building Modeling Specifications

Pacific Northwest National Laboratory, updated on October 18, 2018

	Item	Descriptions			Data Source
Program					
	Vintage	NEW CONSTRUCTION			
	Location (Representing 8 Climate Zones)	Zone 1A: Honolulu, Hawaii (very hot, humid) Zone 1B: New Delhi, India (very hot, dry) Zone 2A: Tampa, Florida (hot, humid) Zone 2B: Tucson, Arizona (hot, dry) Zone 3A: Atlanta, Georgia (warm, humid) Zone 3B: El Paso, Texas (warm, dry) Zone 3C: San Diego, California (warm, marine)	Zone 4A: New York, New York (mixed, humid) Zone 4B: Albuquerque, New Mexico (mixed, dry) Zone 4C: Seattle, Washington (mixed, marine) Zone 5A: Buffalo, NY (cool, humid) Zone 5B: Denver, Colorado (cool, dry) Zone 5C: Port Angeles, Washington (cool, marine)	Zone 6A: Rochester, Minnesota (cold, humid) Zone 6B: Great Falls, Montana (cold, dry) Zone 7: International Falls, Minnesota (very cold) Zone 8: Fairbanks, Alaska (subarctic	Selection of representative climates based on ASHRAE Standard 169-2013
	Available fuel types	Gas, electricity			
	Building Type (Principal Building	**Multifamily**			
	Building Prototype	**High-Rise Apartment**			
Form					
	Total Floor Area (sq feet)	84,360 (152 ft x 55.5 ft)			*Reference: PNNL-16770: Analysis of Energy Saving Impacts of ASHRAE 90.1-2004 for the State of New York*
	Building shape				
	Aspect Ratio	2.75			
	Number of Floors	10			90.1 Envelope Subcommittee
	Window Fraction (Window-to-Wall Ratio)	South: 30%, east: 30%, north: 30%, west: 30% average total: 30%			Reference: Based on feedback from ASHRAE 90.1 SSPC established the Simulation Working Group
	Window Locations	See image			
	Shading Geometry	None			
	Azimuth	Non-directional			

CCTWH Assessment Tool-Prototype Building Apartment Highrise-Architecture

Thermal Zoning	Each floor has 8 apartments except ground floor (7 apartments and 1 office with equivalent apartment area) Total 8 apartments per floor with corridor in center. Zone depth is 25 ft for each apartment from side walls and each apt is 25' x 38' (950 ft²). 
Floor to floor height (ft)	10
Floor to ceiling height (ft)	10 (No drop-in ceiling plenum is modeled)
Glazing sill height (ft)	3 ft (4 ft high windows)

Architecture

Exterior walls	
Construction	Steel-frame walls (2X4 16 in o.c.) 0.4 in. stucco+5/8 in. gypsum board + wall Insulation+5/8 in. gypsum board
U-factor (Btu / h * ft^2 * °F) and/or R-value (h * ft^2 * °F / Btu)	Requirements in codes or standards
Dimensions	Based on floor area and aspect ratio
Tilts and orientations	Vertical
Roof	
Construction	Built-up roof: roof membrane+roof insulation+metal decking
U-factor (Btu / h * ft^2 * °F) and/or R-value (h * ft^2 * °F / Btu)	Requirements in codes or standards Residential; roofs, insulation entirely above deck
Dimensions	Based on floor area and aspect ratio
Tilts and orientations	Horizontal
Window	
Dimensions	Based on window fraction, location, glazing sill height, floor area and aspect ratio
Glass-Type and frame	Hypothetical window with a weighted U-factor and SHGC
U-factor (Btu / h * ft^2 * °F) SHGC (all)	Requirements in codes or standards Residential; vertical glazing
Visible transmittance	Same as above requirements
Operable area	100%

U-factor (Btu / h * ft^2 * °F) SHGC (all) Visible transmittance	NA
Foundation	
Foundation Type	Slab-on-grade floors (unheated)
Construction	8" concrete slab poured directly on to the earth
Slab on grade floor insulation Level	Requirements in codes or standards
Dimensions	Based on floor area and aspect ratio
Interior Partitions	
Construction	2 x 4 uninsulated stud wall
Dimensions	Based on floor plan and floor-to-floor height
Internal Mass	8 lbs/ft^2 of floor area
Air Barrier System	
Infiltration	Peak infiltration: 0.2016 cfm/sf of above grade exterior wall surface area, adjusted by wind Additional infiltration through building entrance

CCTWH Assessment Tool-Prototype Building Apartment Highrise-HVAC

HVAC		
	System Type	
	Heating type	Water source heat pumps
	Cooling type	
	Distribution and terminal units	Constant volume
	HVAC Sizing	
	Air Conditioning	Autosized to design day
	Heating	Autosized to design day
	HVAC Efficiency	
	Air Conditioning	Requirements in codes or standards
	Heating	Minimum equipment efficiency for electrically operated unitary and applied heat pumps
	HVAC Control	
	Thermostat Setpoint	75°F Cooling/70°F Heating
	Thermostat Setback	No setback for apartments
	Supply air temperature	
	Economizers	Requirements in codes or standards
	Ventilation	ASHRAE Standard 62.1 or International Mechanical Code See under **Outdoor Air**
	Demand Control Ventilation	Requirements in codes or standards
	Energy Recovery	Requirements in codes or standards
	Supply Fan	
	Fan schedules	See under **Schedules**
	Supply Fan Total Efficiency (%)	Depending on the fan motor size and requirements in codes or standards
	Supply Fan Pressure Drop	Depending on the fan supply air cfm
	Service Water Heating	
	SWH type	Central water heater with storage tank
	Fuel type	Natural gas
	Thermal efficiency (%)	Requirements in codes or standards
	Tank Volume (gal)	600 (central)
	Water temperature setpoint	140 F
	Water consumption	See under **Schedules**

CCTWH Assessment Tool-Prototype Building Apartment Highrise-Zone Summary

Zone Summary

Zone[1]	Area (ft²)	Conditioned (Y/N)	Volume (ft³)	Multipliers	Gross Wall Area (ft²)	Window Glass Area (ft²)	Lighting[4] (W/ft²)	People (ft²/person)	Number of People	Plug and Process (W/ft²)
G SW APARTMENT	950	Yes	9,499	1	630	189	1.34	380	2.5	0.62
G NW APARTMENT	950	Yes	9,499	1	630	189	1.34	380	2.5	0.62
OFFICE	950	Yes	9,499	1	630	189	1.10	950	1	0.62
G NE APARTMENT	950	Yes	9,499	1	630	189	1.34	380	2.5	0.62
G N1 APARTMENT	950	Yes	9,499	1	380	114	1.34	380	2.5	0.62
G N2 APARTMENT	950	Yes	9,499	1	380	114	1.34	380	2.5	0.62
G S1 APARTMENT	950	Yes	9,499	1	380	114	1.34	380	2.5	0.62
G S2 APARTMENT	950	Yes	9,499	1	380	114	1.34	380	2.5	0.62
M SW APARTMENT	950	Yes	9,499	8	630	189	1.34	380	2.5	0.62
M NW APARTMENT	950	Yes	9,499	8	630	189	1.34	380	2.5	0.62
M SE APARTMENT	950	Yes	9,499	8	630	189	1.34	380	2.5	0.62
M NE APARTMENT	950	Yes	9,499	8	630	189	1.34	380	2.5	0.62
M N1 APARTMENT	950	Yes	9,499	8	380	114	1.34	380	2.5	0.62
M N2 APARTMENT	950	Yes	9,499	8	380	114	1.34	380	2.5	0.62
M S1 APARTMENT	950	Yes	9,499	8	380	114	1.34	380	2.5	0.62
M S2 APARTMENT	950	Yes	9,499	8	380	114	1.34	380	2.5	0.62
T SW APARTMENT	950	Yes	9,499	1	630	189	1.34	380	2.5	0.62
T NW APARTMENT	950	Yes	9,499	1	630	189	1.34	380	2.5	0.62
T SE APARTMENT	950	Yes	9,499	1	630	189	1.34	380	2.5	0.62
T NE APARTMENT	950	Yes	9,499	1	630	189	1.34	380	2.5	0.62
T N1 APARTMENT	950	Yes	9,499	1	380	114	1.34	380	2.5	0.62
T N2 APARTMENT	950	Yes	9,499	1	380	114	1.34	380	2.5	0.62
T S1 APARTMENT	950	Yes	9,499	1	380	114	1.34	380	2.5	0.62
T S2 APARTMENT	950	Yes	9,499	1	380	114	1.34	380	2.5	0.62
T CORRIDOR[2]	836	No	8,359	1	110	24	0.55	0	0	24.56
G CORRIDOR	836	No	8,359	1	110	24	0.55	0	0	0
M CORRIDOR	836	No	8,359	8	110	24	0.55	0	0	0
TOTAL[3]	**84,360**		**843,481**		**41,495**	**12,360**			**199**	
AREA WEIGHTED AVERAGE							**1.26**	**348.73**		**0.80**

1. Each apartment zone contains one apartment with one bedroom, living room and bathroom.
2. Elevator load is added in the top floor corridor zone.
3. Only volume, and gross wall area include unconditioned space.
4. Listed lighting power density is based on applicable requirements in ASHRAE Standard 90.1-2004. The actual inputs for the models are based on appliable codes and standards

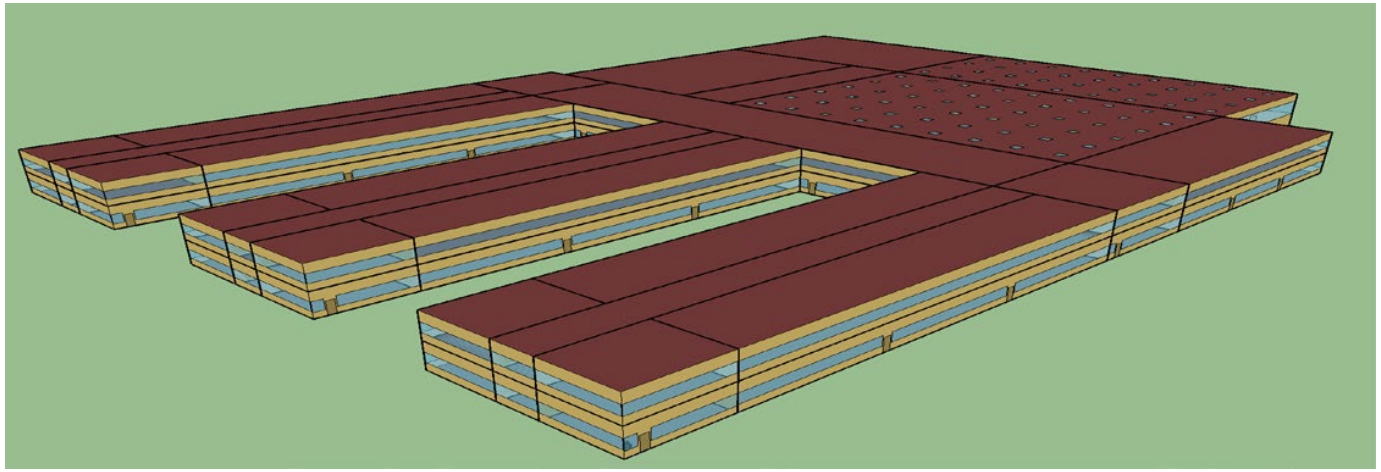
CCTWH Assessment Tool-Prototype Building Apartment Highrise-Minimum Outdoor Ventilation

Minimum Outdoor Ventilation Air Requirements

Zone	Area (ft^2)	Multipliers	Assumed Space Type	Total Occupants	Total OSA Ventilation (cfm/zone)			Total OSA Ventilation (cfm/ft2)		
				62.1-2004	90.1-2004 (62-1999)	90.1-2007 (62.1-2004)	90.1-2010 (62.1-2007)	90.1-2004 (62-1999)	90.1-2007 (62.1-2004)	90.1-2010 (62.1-2007)
G SW APARTMENT	950.0	1	Residential single bedroom apartment	2	55	55	55	0.06	0.06	0.06
G NW APARTMENT	950.0	1	Residential single bedroom apartment	2	55	55	55	0.06	0.06	0.06
OFFICE	950.0	1	Office space	5	95	81	81	0.10	0.09	0.09
G NE APARTMENT	950.0	1	Residential single bedroom apartment	2	55	55	55	0.06	0.06	0.06
G N1 APARTMENT	950.0	1	Residential single bedroom apartment	2	55	55	55	0.06	0.06	0.06
G N2 APARTMENT	950.0	1	Residential single bedroom apartment	2	55	55	55	0.06	0.06	0.06
G S1 APARTMENT	950.0	1	Residential single bedroom apartment	2	55	55	55	0.06	0.06	0.06
G S2 APARTMENT	950.0	1	Residential single bedroom apartment	2	55	55	55	0.06	0.06	0.06
M SW APARTMENT	950.0	8	Residential single bedroom apartment	2	55	55	55	0.06	0.06	0.06
M NW APARTMENT	950.0	8	Residential single bedroom apartment	2	55	55	55	0.06	0.06	0.06
M SE APARTMENT	950.0	8	Residential single bedroom apartment	2	55	55	55	0.06	0.06	0.06
M NE APARTMENT	950.0	8	Residential single bedroom apartment	2	55	55	55	0.06	0.06	0.06
M N1 APARTMENT	950.0	8	Residential single bedroom apartment	2	55	55	55	0.06	0.06	0.06
M N2 APARTMENT	950.0	8	Residential single bedroom apartment	2	55	55	55	0.06	0.06	0.06
M S1 APARTMENT	950.0	8	Residential single bedroom apartment	2	55	55	55	0.06	0.06	0.06
M S2 APARTMENT	950.0	8	Residential single bedroom apartment	2	55	55	55	0.06	0.06	0.06
T SW APARTMENT	950.0	1	Residential single bedroom apartment	2	55	55	55	0.06	0.06	0.06
T NW APARTMENT	950.0	1	Residential single bedroom apartment	2	55	55	55	0.06	0.06	0.06
T SE APARTMENT	950.0	1	Residential single bedroom apartment	2	55	55	55	0.06	0.06	0.06
T NE APARTMENT	950.0	1	Residential single bedroom apartment	2	55	55	55	0.06	0.06	0.06
T N1 APARTMENT	950.0	1	Residential single bedroom apartment	2	55	55	55	0.06	0.06	0.06
T N2 APARTMENT	950.0	1	Residential single bedroom apartment	2	55	55	55	0.06	0.06	0.06
T S1 APARTMENT	950.0	1	Residential single bedroom apartment	2	55	55	55	0.06	0.06	0.06
T S2 APARTMENT	950.0	1	Residential single bedroom apartment	2	55	55	55	0.06	0.06	0.06
T CORRIDOR	836.0	1	Corridors (public spaces)	0	42	50	50	0.05	0.06	0.06
G CORRIDOR	836.0	1	Corridors (public spaces)	0	42	50	50	0.05	0.06	0.06
M CORRIDOR	836.0	8	Corridors (public spaces)	0	42	50	50	0.05	0.06	0.06
TOTAL	**84,360**			**163**	**4,858**	**4,927**	**4,927**	**5.17**	**5.26**	**5.26**

1. Each apartment zone contains one apartment with one bedroom, living room and bathroom.
2. The ventilation requirements for other codes or standards are based on their reference ASHRAE Standard 62.1 or International Mechanical Code

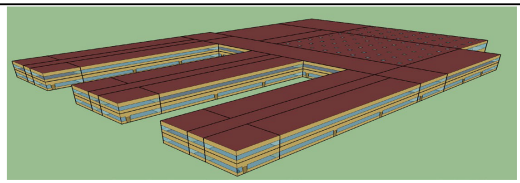
CCTWH Assessment Tool-Prototype Building School Secondary



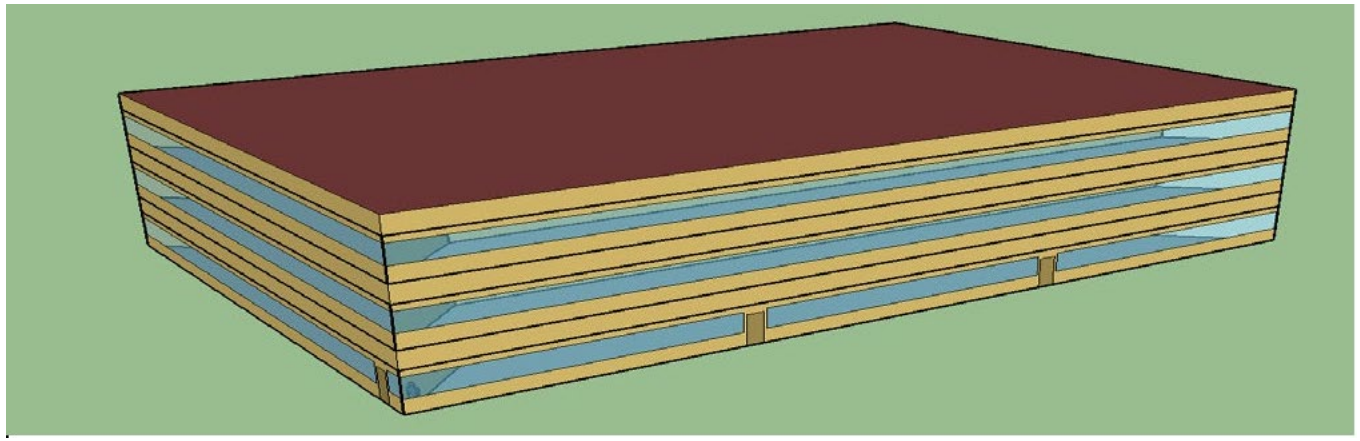
210,900 sqft – 2 floors
6,096 students

Prototype Building Modeling Specifications

Pacific Northwest National Laboratory, updated on October 18, 2018

	Item	Descriptions		
Program				
	Vintage	NEW CONSTRUCTION		
	Location (Representing 8 Climate Zones)	Zone 1A: Honolulu, Hawaii (very hot, humid) Zone 1B: New Delhi, India (very hot, dry) Zone 2A: Tampa, Florida (hot, humid) Zone 2B: Tucson, Arizona (hot, dry) Zone 3A: Atlanta, Georgia (warm, humid) Zone 3B: El Paso, Texas (warm, dry) Zone 3C: San Diego, California (warm, marine)	Zone 4A: New York, New York (mixed, humid) Zone 4B: Albuquerque, New Mexico (mixed, dry) Zone 4C: Seattle, Washington (mixed, marine) Zone 5A: Buffalo, NY (cool, humid) Zone 5B: Denver, Colorado (cool, dry) Zone 5C: Port Angeles, Washington (cool, marine)	Zone 6A: Rochester, Minnesota (cold, humid) Zone 6B: Great Falls, Montana (cold, dry) Zone 7: International Falls, Minnesota (very cold) Zone 8: Fairbanks, Alaska (subarctic
	Available fuel types	Gas, electricity		
	Building Type (Principal Building	**Education**		
	Building Prototype	**Secondary School**		
Form				
	Total Floor Area (sq feet)	210,900 (340 ft x 460 ft)		
	Building shape			
	Aspect Ratio	1.4		
	Number of Floors	2		
	Window Fraction (Window-to-Wall Ratio)	33% Ribbon window across all facades on both floors		
	Window Locations	Continuous Band		
	Shading Geometry	None		
	Azimuth	Non-directional		

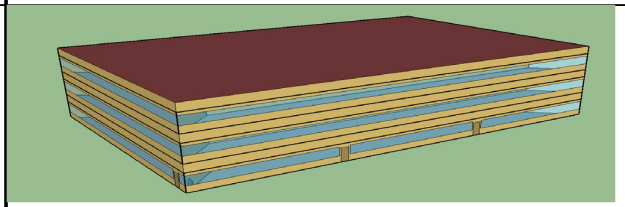
CCTWH Assessment Tool-Prototype Building Office Medium



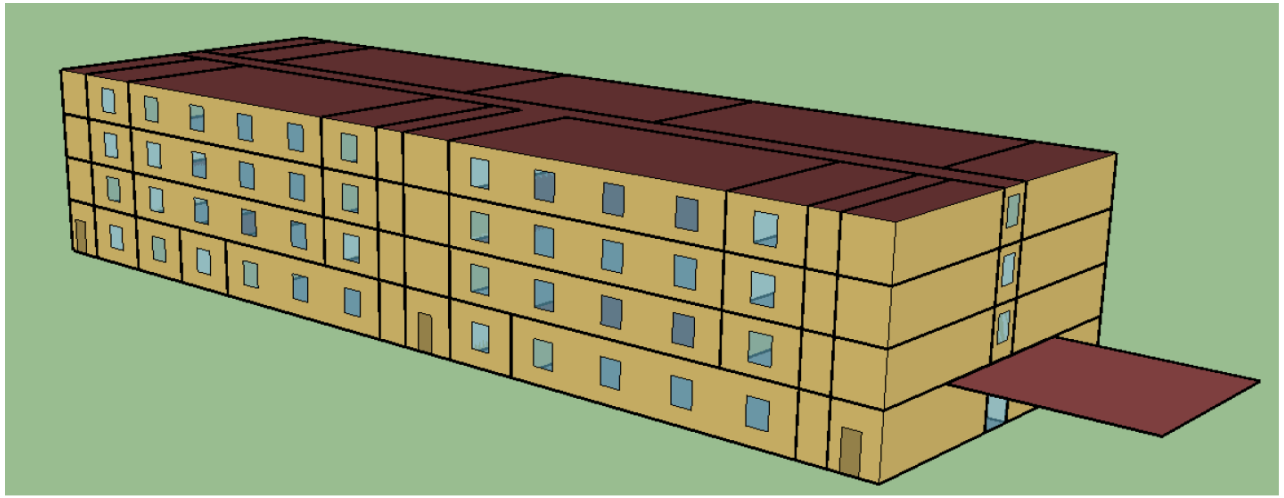
53,600 sqft – 3 floors
268 people

Prototype Building Modeling Specifications

Pacific Northwest National Laboratory, updated on October 18, 2018

	Item	Descriptions		
Program				
	Vintage	NEW CONSTRUCTION		
	Location (Representing 8 Climate Zones)	Zone 1A: Honolulu, Hawaii (very hot, humid) Zone 1B: New Delhi, India (very hot, dry) Zone 2A: Tampa, Florida (hot, humid) Zone 2B: Tucson, Arizona (hot, dry) Zone 3A: Atlanta, Georgia (warm, humid) Zone 3B: El Paso, Texas (warm, dry) Zone 3C: San Diego, California (warm, marine)	Zone 4A: New York, New York (mixed, humid) Zone 4B: Albuquerque, New Mexico (mixed, dry) Zone 4C: Seattle, Washington (mixed, marine) Zone 5A: Buffalo, NY (cool, humid) Zone 5B: Denver, Colorado (cool, dry) Zone 5C: Port Angeles, Washington (cool, marine)	Zone 6A: Rochester, Minnesota (cold, humid) Zone 6B: Great Falls, Montana (cold, dry) Zone 7: International Falls, Minnesota (very cold) Zone 8: Fairbanks, Alaska (subarctic
	Available fuel types	Gas, electricity		
	Building Type (Principal Building	**Office**		
	Building Prototype	**Medium Office**		
Form				
	Total Floor Area (sq feet)	53,600 (163.8 ft x 109.2 ft)		
	Building shape			
	Aspect Ratio	1.5		
	Number of Floors	3		

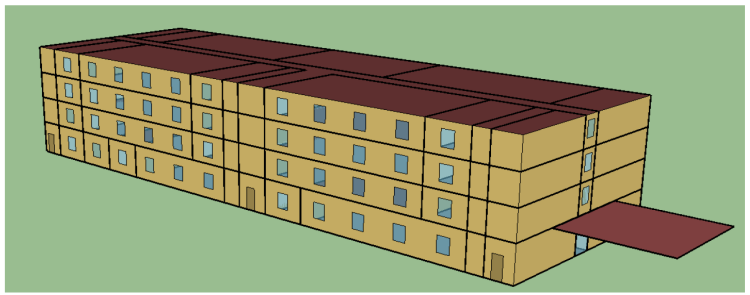
CCTWH Assessment Tool-Prototype Building Hotel Small



43,200 sqft – 4 floors

Prototype Building Modeling Specifications

Pacific Northwest National Laboratory, updated on October 18, 2018

Item	Descriptions		
Program			
Vintage	NEW CONSTRUCTION		
Location (Representing 8 Climate Zones)	Zone 1A: Honolulu, Hawaii (very hot, humid) Zone 1B: New Delhi, India (very hot, dry) Zone 2A: Tampa, Florida (hot, humid) Zone 2B: Tucson, Arizona (hot, dry) Zone 3A: Atlanta, Georgia (warm, humid) Zone 3B: El Paso, Texas (warm, dry) Zone 3C: San Diego, California (warm, marine)	Zone 4A: New York, New York (mixed, humid) Zone 4B: Albuquerque, New Mexico (mixed, dry) Zone 4C: Seattle, Washington (mixed, marine) Zone 5A: Buffalo, NY (cool, humid) Zone 5B: Denver, Colorado (cool, dry) Zone 5C: Port Angeles, Washington (cool, marine)	Zone 6A: Rochester, Minnesota (cold, humid) Zone 6B: Great Falls, Montana (cold, dry) Zone 7: International Falls, Minnesota (very cold) Zone 8: Fairbanks, Alaska (subarctic
Available fuel types	Gas, electricity		
Building Type (Principal Building	**Lodging**		
Building Prototype	**Small Hotel**		
Form			
Total Floor Area (sq feet)	43200 (180 ft x 60 ft)		
Building shape			
Aspect Ratio	3		
Number of Floors	4		

CCTWH Assessment Tool – Inputs & Outputs Apartment Highrise

Building Description and Other Model Inputs

Building Type	Multifamily	*If "N/A" do not use*
# of dwelling units	80	*Number of Apartment or Hotel Units*
Avg bedrooms/dwelling unit	1	*Multifamily or Hospitality*
Estimated daily occupancy	200	*N/A*
Estimated Fixture Units	*240.0*	
OPTIONAL - Custom Fixture Units		link for resource, blank if unused
Hot Water Recirculation Efficiency	Default	
Recirculation Pump Size	0.33	hp
Apply Diversity Factor?	No	
Hot Water Characteristics		
Hot Water Usage Level	Default	
Thermostatic Temperature	140	F
Cold Water Mains Temperature	49.5	F ------>
Energy Prices		
	$ 0.67	per therm
	$ 0.10	per kWh

Typical Entering Cold Water Temperatures

	Min.	Avg.	Max.
7A - Int'l Falls, MN	34.7	43.9	53
6A - Rochester, MN	39.1	49.5	59.7
5A - Chicago, IL	44.7	54.1	63.5
4A - New York, NY	49.5	60.4	71.2
3A - Atlanta, GA	56.3	67.9	79.3
2A - Tampa, FL	68.7	85	77.3
1A - Miami, FL	80.3	82.9	85.4

Data from TMY3 - EnergyPlus

Outputs

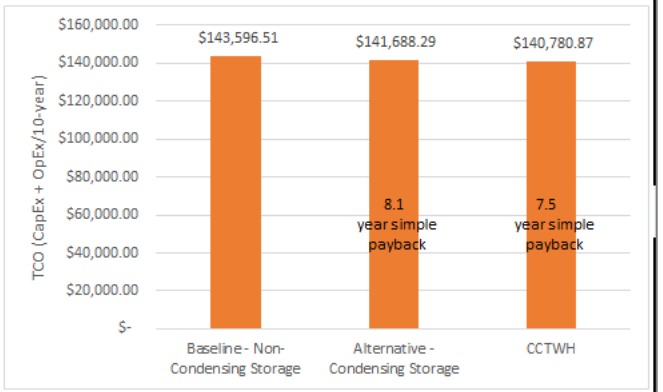
Hot Water Demand

Daily Draw	2268.3	Gal/day
Hot Water Energy Output	1.702	MMBtu/day
Design Output	1,738,201	Btu/hr

System Performance

			Annual Operating Costs
Baseline - Non-Condensing Storage	4.962	MMBtu gas/day	$ 12,349.34
Alternative - Condensing Storage	4.560	MMBtu gas/day	$ 11,366.61
CCTWH	4.492	MMBtu gas/day	$ 11,201.34
Recirculation Pump	5.91	kWh/day	

System Cost	Equipment Cost	10 year TCO (Equip + OpEx)	Simple Payback
Baseline - Non-Condensing Storage	$ 20,103.11	$ 143,596.51	
Alternative - Condensing Storage	$ 28,022.21	$ 141,688.29	8.1
CCTWH	$ 28,767.50	$ 140,780.87	7.5



CCTWH Assessment Tool-Outputs
School Secondary

Building Description and Other Model Inputs

Building Type	School	*If "N/A" do not use*
# of dwelling units	200	*N/A*
Avg bedrooms/dwelling unit	1	*N/A*
Estimated daily occupancy	6100	*Students or Office Workers*
Estimated Fixture Units	*2013.0*	
OPTIONAL - Custom Fixture Units		link for resource, blank if unused
Hot Water Recirculation Efficiency	Default	
Recirculation Pump Size	0.33	hp
Apply Diversity Factor?	No	
Hot Water Characteristics		
Hot Water Usage Level	Default	
Thermostatic Temperature	140	F
Cold Water Mains Temperature	49.5	F ----->
Energy Prices		
	$ 0.67	per therm
	$ 0.10	per kWh

Typical Entering Cold Water Temperatures

	Min.	Avg.	Max.
7A - Int'l Falls, MN	34.7	43.9	53
6A - Rochester, MN	39.1	49.5	59.7
5A - Chicago, IL	44.7	54.1	63.5
4A - New York, NY	49.5	60.4	71.2
3A - Atlanta, GA	56.3	67.9	79.3
2A - Tampa, FL	68.7	85	77.3
1A - Miami, FL	80.3	82.9	85.4

Data from TMY3 - EnergyPlus

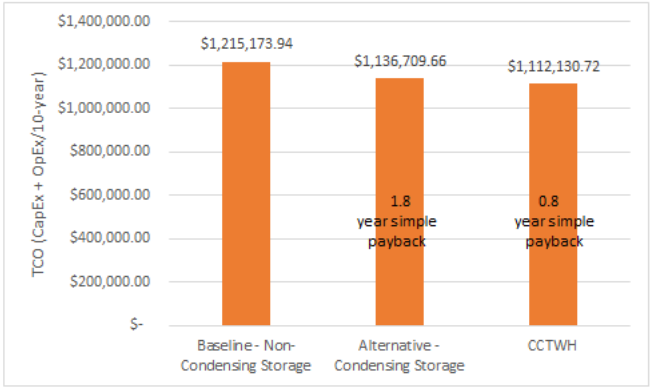
Outputs

Hot Water Demand

Daily Draw	21960.0	Gal/day
Hot Water Energy Output	16.475	MMBtu/day
Design Output	3,171,230	Btu/hr

System Performance			Annual Operating Costs
Baseline - Non-Condensing Storage	47.984	MMBtu gas/day	$ 117,560.94
Alternative - Condensing Storage	44.080	MMBtu gas/day	$ 108,012.44
CCTWH	43.389	MMBtu gas/day	$ 106,322.60
Recirculation Pump	5.91	kWh/day	

System Cost	Equipment Cost	10 year TCO (Equip + OpEx)	Simple Payback
Baseline - Non-Condensing Storage	$ 39,564.56	$ 1,215,173.94	
Alternative - Condensing Storage	$ 56,585.28	$ 1,136,709.66	1.8
CCTWH	$ 48,904.75	$ 1,112,130.72	0.8



CCTWH Assessment Tool-Outputs
Office Medium

Building Description and Other Model Inputs

Building Type	Offices	*If "N/A" do not use*
# of dwelling units	270	*N/A*
Avg bedrooms/dwelling unit	1	*N/A*
Estimated daily occupancy	270	*Students or Office Workers*
Estimated Fixture Units	*40.5*	
OPTIONAL - Custom Fixture Units		link for resource, blank if unused
Hot Water Recirculation Efficiency	Default	
Recirculation Pump Size	0.33	hp
Apply Diversity Factor?	No	
Hot Water Characteristics		
Hot Water Usage Level	Default	
Thermostatic Temperature	140	F
Cold Water Mains Temperature	49.5	F ------>
Energy Prices		
	$ 0.67	per therm
	$ 0.10	per kWh

Typical Entering Cold Water Temperatures

	Min.	Avg.	Max.
7A - Int'l Falls, MN	34.7	43.9	53
6A - Rochester, MN	39.1	49.5	59.7
5A - Chicago, IL	44.7	54.1	63.5
4A - New York, NY	49.5	60.4	71.2
3A - Atlanta, GA	56.3	67.9	79.3
2A - Tampa, FL	68.7	85	77.3
1A - Miami, FL	80.3	82.9	85.4

Data from TMY3 - EnergyPlus

Outputs

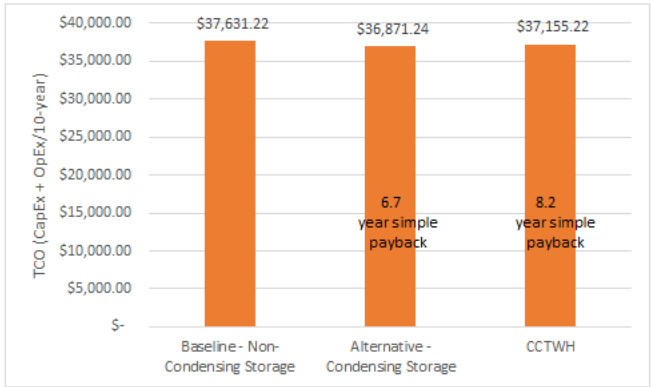
Hot Water Demand

Daily Draw	540.0	Gal/day
Hot Water Energy Output	0.405	MMBtu/day
Design Output	484,080	Btu/hr

System Performance

			Annual Operating Costs
Baseline - Non-Condensing Storage	1.186	MMBtu gas/day	$ 3,114.87
Alternative - Condensing Storage	1.091	MMBtu gas/day	$ 2,883.96
CCTWH	1.078	MMBtu gas/day	$ 2,852.50
Recirculation Pump	5.91	kWh/day	

System Cost	Equipment Cost	10 year TCO (Equip + OpEx)	Simple Payback
Baseline - Non-Condensing Storage	$ 6,482.55	$ 37,631.22	
Alternative - Condensing Storage	$ 8,031.68	$ 36,871.24	6.7
CCTWH	$ 8,630.25	$ 37,155.22	8.2



Comparison – Schools & Hotels

Building Type	School - secondary			Hotel - small		
	Baseline Non-Condensing Tank	Condensing Tank	CCTWH	Baseline Non-Condensing Tank	Condensing Tank	CCTWH
Occupancy or Dwelling Units	6100	6100	6100	40	40	40
Estimated Fixture Units	2013	2013	2013	100	100	100
Demand (gal/day)	21960	21960	21960	1000	1000	1000
Performance (Therms/day)	479.8	440.8	433.9	21.9	20.1	19.9
Annual Operating Costs ($)	117,561	108,012	106,323	5,573	5,142	5,075
Total Cost of Ownership-10 yr ($)	1,215,174	1,136,710	1,112,131	61,310	58,129	59,376
Payback - simple (yrs)		1.8	0.8		2.6	6.1

Comparison – Multi-Unit Family

Building Type	MUF-high rise		
	Baseline Non-Condensing Tank	Condensing Tank	CCTWH
Occupancy or Dwelling Units	80	80	80
Estimated Fixture Units	240	240	240
Demand (gal/day)	2268	2268	2268
Performance (Therms/day)	49.6	45.6	44.9
Annual Operating Costs ($)	12,349	11,367	11,201
Total Cost of Ownership-10 yr ($)	143,597	141,688	140,781
Payback - simple (yrs)		8.1	7.5

Comparison – Office Buildings

Building Type	Office -medium			Office - large		
	Baseline Non-Condensing Tank	Condensing Tank	CCTWH	Baseline Non-Condensing Tank	Condensing Tank	CCTWH
Occupancy or Dwelling Units	270	270	270	2400	2400	2400
Estimated Fixture Units	40.5	40.5	40.5	360	360	360
Demand (gal/day)	540	540	540	4800	4800	4800
Performance (Therms/day)	11.9	10.9	10.8	104.9	96.4	94.9
Annual Operating Costs ($)	3,115	2,884	2,852	25,876	23,792	23,431
Total Cost of Ownership-10 yr ($)	37,631	36,871	37,155	275,641	261,214	257,320
Payback - simple (yrs)		6.7	8.2		3.1	2.5

Comparison

Site	Testing period	Units	Annual Energy Field [Therms]	Annual Energy Assessment Tool [Therms]	Installed Cost	Marginal Cost	Annual Gas Savings [$]	Simple Payback Field [years]	Simple Payback Assessment Tool [years]
1	Baseline	23	2,348	2,798	$16,502	$2,735	177		15
2	Baseline	17	1,903	2,074	$12,398	$2,112	127		17
1	CCTWH	23	2,168	2,533	$19,237	$2,735	121	23	
2	CCTWH	17	1,569	1,883	$14,510	$2,112	224	9	

Conclusions

- The comparison of the systems at the two sites during the twenty-two-month field test period found that CCTWHs systems can be successfully installed and operated in multi-unit applications in Northern Midwest climates.
  - CCTWHs provided this energy savings with no significant change in hot water delivery.
- The CCTWH systems can save energy over tanked storage systems.
- The system efficiencies were calculated and included the recirculation loop.
- The measured water heaters efficiencies were calculated.
- The CCTWH results were compared to the existing baseline equipment and findings were extrapolated to other building types and loading patterns.

Recommendations

- Initial cost will be a significant hurdle for many properties. Rebates can help address this barrier, but further market transformation and increased contractor familiarity will be necessary to fully eliminate this barrier.
- In residential applications of instantaneous water heating systems, non-energy benefits helped grow the market.
  - Reduced footprint of a residential tankless system was a frequently cited reason for increased market share.
  - Smaller footprint would benefit both new construction and retrofit applications by fitting into mechanical spaces that are typically too small for tank systems.
  - Operation and maintenance, the control sequence that cycles through the racked units add life and reduce maintenance costs.

Questions?

Racked Tankless Water Heaters: Savings and Efficiencies



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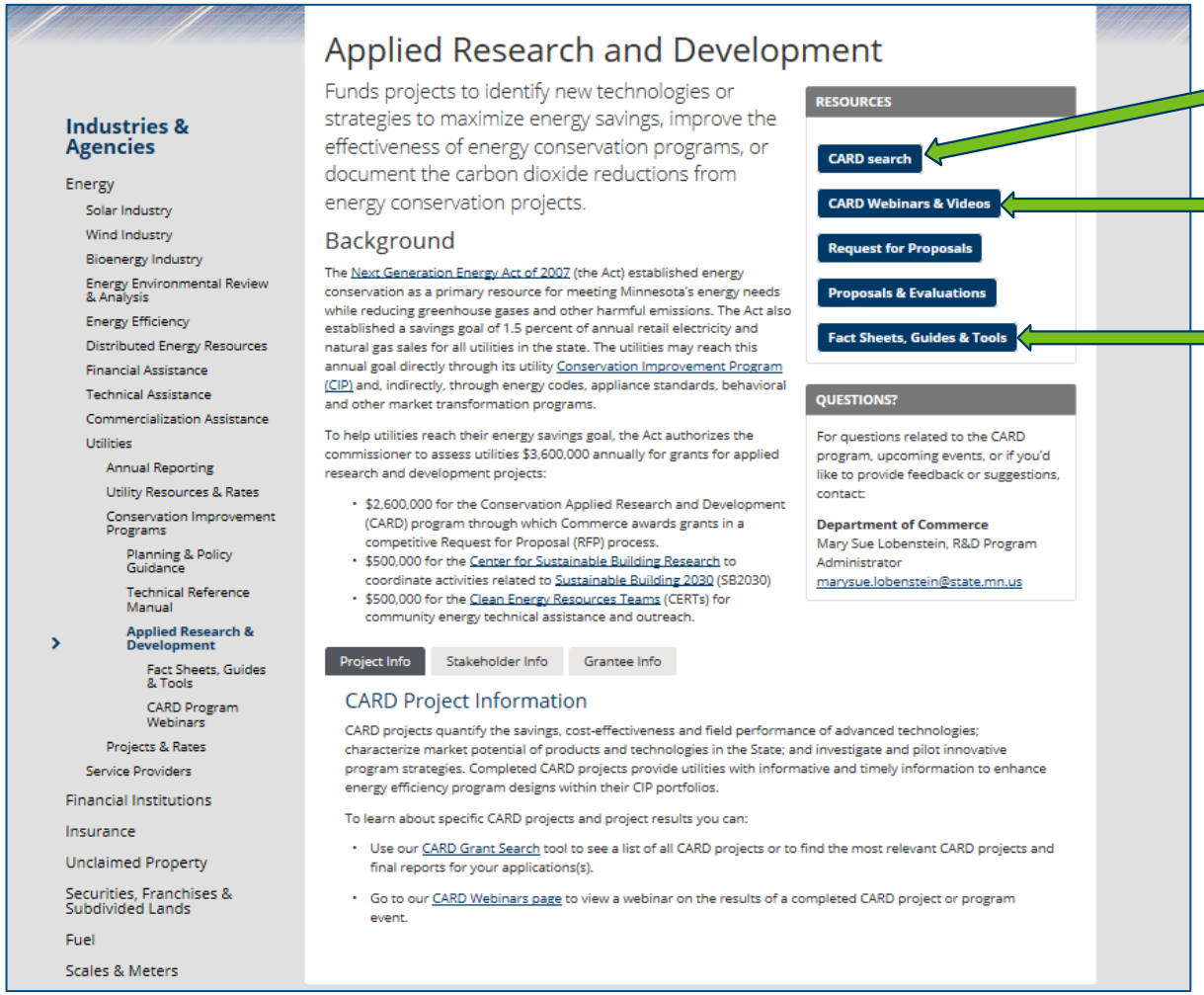
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Send us your questions using the Q&A panel

CARD Project Resources



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For **Other** research documents use **CARD Fact Sheets, Guidelines & Tools** Quick Link

Webinar Recording & Final Report available in couple months

R&D Web Page (https://mn.gov/commerce/industries/energy/utilities/cip/applied-research-development/)

Thanks for Participating!

Upcoming CARD Webinars:

- **March 22, 2022:** Center for Energy and Environment – Residential Multizone Air Distribution – An Energy Savings Opportunity?
- **April 13, 2022**: Center for Energy and Environment – Power over Ethernet (PoE)– What are the Benefits?
- **April 28, 2022**: Franklin Energy - Energy Savings Potential of Networked Lighting Control Systems in Small Business

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