Emerging Technology Demonstration: Multifamily Central Domestic Hot Water System Controls

2017 MPP Partner Summit
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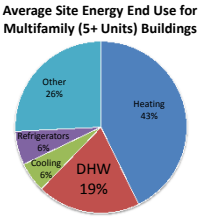
Water Heating
One of the Largest Residential Energy Uses

Water Heating is one of the largest multifamily energy users.



Source: U.S. Energy Information Administration, 2009 Residential Energy Consumption Survey

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Metropolitan NYC Multifamily Stock

- Population 19 million
- 1 in 16 US citizens
- 2.1 million occupied apts.
- 77% of multifamily buildings are 5 units or more
- Vast majority of buildings have CDHW

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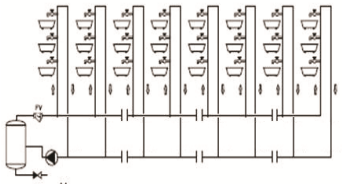
What is a CDHW System?

A Central Domestic Hot Water distribution system moves hot water from the heater to the fixtures.



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Why is a Recirculation Pump Required?

- A recirculation pump quickly distributes hot water throughout a building to reduce wait time for DHW
- Without a recirculation pump, the wait time would depend on how far one is from the heating plant

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CDHW Energy Performance Problems

- Old boilers
- High temp set points
- Un-insulated pipes
- Un-controlled recirculation pumps
- Cross-over problems
- Poor or inefficient plumbing design
- Unbalanced distribution
- Lack of PM regimen

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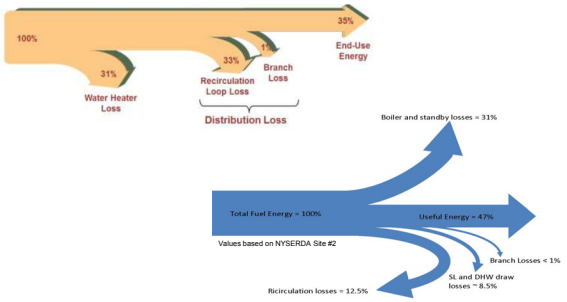
Typical CDHW Energy Waste with Continuous Pump Operation



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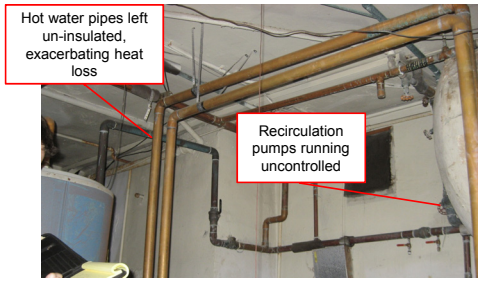
Distribution Losses



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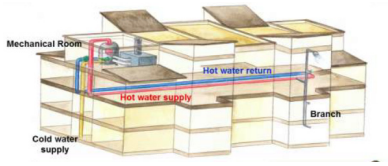
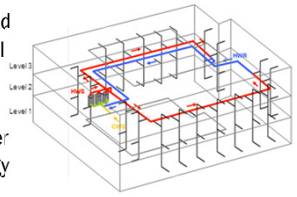
Hot Water Circulation Dilemma

- **Too little circulation**
  - Wastes Water
  - Frustrates tenants
- **Too much circulation**
  - Wastes energy
  - Deteriorates the system faster



Recirculation Loop Pump Controls

- Reduce thermal losses
- Reduce system wear and tear and increase useful life of mechanical equipment
- Maintain same hot water service using less energy



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Types of DHW Control

Timer Control

Temperature Control

Temperature Modulation

Demand Control

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Timer Control

- Turns pump on and off according to a schedule
- Off periods coincide with peak DHW usage
- When a user demands hot water during an "off" and no-demand period, water will be wasted as the temperature increases
- In larger buildings peak times are ill-defined or non-existent

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Temperature Control

- Controls pump based on temperature (usually 120˚F) via a sensor on the return line
- Reduces pump electricity, but maintains DHW loop temperature even without demand
- Often turned up past the supply temperature by building staff (effectively bypassing the control)

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Temperature Modulation Control

- Resets tank temp according to expected demand
- Lower demands require lower set point
- Reduces energy needed to keep tank hot when demand is low
- Does not control pump

Demand Control

- Controls pump based on demand and water temperature
- Measures demand via flow switch
- Measures return temperature
- The pump runs if there demand is detected AND return temperature is below ~105°F.

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Demand Control: Sensing Demand

- Flow sensor: senses real time demand and sends signal to control board to activate pump
- Detects flow rates of less than 0.2 gpm
- May be put on CW make up or HW supply pipe

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Temperature Sensor

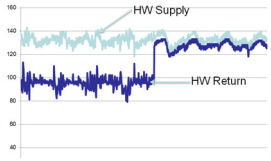
- Copper sensor indicates when the water in the pipes is not sufficiently hot (e.g., under 105°F)
- Resistance 10k, +/- 1%
- Sensors and pump communicate via a control box located on the pump

Benefits of Demand Controls

- Pump runs <1 hour per day
- Same level of hot water service
- Allows return pipe to cool during non-hot water usage
- Keeps high delta T from supply to return: very efficient

How Much Energy Can be Saved?

- Research demonstrates 10-30% reduction in total water heater fuel usage
- 90+% reduction in electricity used for pumping
- Cost payback 1/2 to 3 years



Previous Research

Study Source	Location	Building Characteristics	Control Type	Savings Compared to Continuous Pumping
CA Bldg. Engy. Eff. Standards	California	Low-rise, Two story, 44 units	Demand control	-
		Low-rise, four story, 88 units	Demand control	-
Benningfield Group	California	Total 35 sites (1540 units)	Demand control	1.78 MBtu/apt. to 9.57 MBtu/apt.
Enovative Kontrol Systems	California	Five story, 50 units	Demand control	30% gas, 78% pump
Enovative Kontrol Systems	California	30 units	Demand control	15% gas, 95% pump
Enovative Kontrol Systems	California	Two story, 8 units	Demand control	18% electricity for heater, 97% pump
Enovative Kontrol Systems	California	Five story, 189 units	Demand control	12% gas and 96% pump runtime
Enovative Kontrol Systems	California	Three story, 21 units	Demand control	16% gas, 98% pump
NYSERDA	New York	2 sites, less than 45 units	Timer control (night)	6%
		2 sites, less than 80 units 2 sites, more than 80 units	Timer control (morning and evening peak)	6%
		2 sites, less than 45 units	Temperature control	11%
HMG	California	Two story, 8 units	Temperature control	1%
			Temperature modulation	35%
			Demand control	44%
NYSERDA	New York	High Rise, 122 units	Demand control and Temp Modulation	8%
		Mid-rise, 54 units		12%
Building America/NYSERDA		Low-rise, 48 units		14%
		Low-rise, 54 units	Demand control	7%

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NYSERDA Research Buildings DHW Fuel Savings

Annual DHW Fuel…	A	B	C	D
Building characteristics	7 floors 66 br	15 floors 294 br	3 floors 81 br	3 floors 72 brs
Baseline Consumption (therms/br)	175	94	184	112
Reduction with Demand Control (therms/br)	12% (20.4)	9% (8.0)	6% (10.3)	7% (8.3)
Reduction with Temp. Modulation (therms/br)	2% (3.4)	8% (7.8)	-	2% (1.9)
Reduction with Demand Control & Temp. Modulation (therms/br)	15% (25.9)	12% (11.3)	-	15% (16.2)

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Research Buildings Simple Payback

Property	Building A	Building B	Building C	Building D
Annual DHW Cost (incl. pump electricity)	$15,900	$31,200	$16,400	$9,200
Installed Cost for Demand Control/Temp. Modulation	$3,000/ $2,000	$2,500/ $5,300	$3,000	$3,000/ $2,000
Demand Control Payback	2.1	1	3	3.7
Temp. Modulation Payback	11.2	3	-	18.5
Demand Control + Temp. Modulation Payback	3	2.5	-	4

Worst-case average payback:
- Demand control: <4 years
- Temp. modulation: 21 years

Average Annual $ Savings including interactive effects	
Demand Control	9%
Temp. Modulation	3%
Demand Control & Temp. Modulation	12%

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NYSERDA ETAC Project

- Install Demand Control Systems in 40 buildings
- Monitor the systems for 2-4 weeks
- Alternate demand control and continuous pumping weekly
- Estimate DHW energy use in each mode

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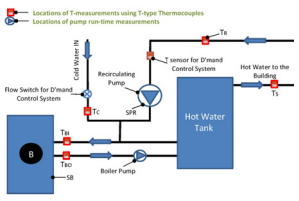
Measurements

- Temperatures:
  - Supply
  - Return
  - Make-up
  - Water to boiler
  - Water from boiler
- Run time
  - Boiler
  - Pump
- Calculations
  - Energy savings per day
- Document
  - Complaints
  - Implementation costs



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Demonstration Buildings Results

Site #	Floors	Apts.	% boiler run-time reduction	% pump run-time reduction
1	9	36	7.1%	25%
2	3	56	12.5%	33%
3	2	29	16.2%	99%
4	5	42	14.2%	98%
5	6	42	12.6%	93%
6	6	66	9.6%	91%
7	4	54	3.1%	81%
8	6	49	-1.5%	99%
9	4	32	13.2%	99%
10	6	66	-3.2%	100%
11	6	66	-1.1%	97%
12	6	44	16.1%	99%
13	5	74	5.2%	61%
14	4	8	17.7%	41%
15	6	41	18.9%	96%
16	6	60	13.5%	61%
17	6	38	11.7%	62%
18	6	17	0.3%	92%
19	6	11	13.6%	100%
20	6	19	10.5%	93%
21	6	18	7.6%	100%
Average for buildings with savings			**13%**	**79%**

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Demonstration Buildings Results

Site #	Installation costs ($)	Annual $ savings	Payback in years
1	975	3,281	0.3
2	2,074	1,365	1.5
3	2,074	916	2.3
4	2,074	1,777	1.2
5	2,074	1,198	1.7
6	2,074	949	2.2
7	6,206	273	22.7
8	2,074	n/a	n/a
9	2,074	555	3.7
10	2,074	n/a	n/a
11	2,074	n/a	n/a
12	2,074	1,209	1.7
13	2,074	216	9.6
14	1,350	2,704	0.5
15	1,150	6,306	0.2
16	2,340	4,206	0.6
17	2,340	4,000	0.6
18	1,750	85	20.5
19	1,750	1,376	1.3
20	1,750	2,174	0.8
21	1,750	2,161	0.8
Average for buildings with savings	**1,861**	**2,278**	**1.3**

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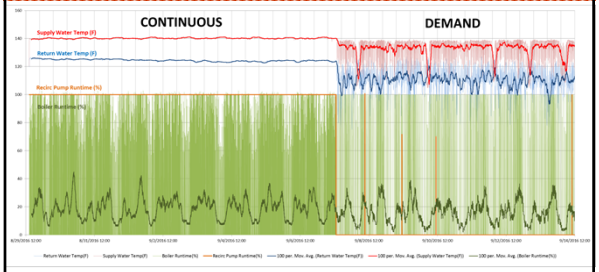
Site 12



Site #	Floors	Apts.	% boiler run-time reduction	% pump run-time reduction	Payback in years
12	6	44	16.1%	99%	1.7

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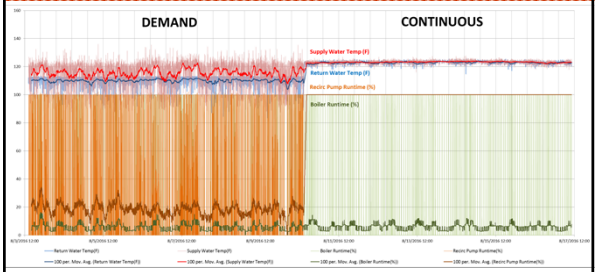
Site 7



Site #	Floors	Apts.	% boiler run-time reduction	% pump run-time reduction	Payback in years
7	4	54	3.1%	81%	22.7

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Issues

- **Balancing:** poorly balanced lines may limit savings potential
- **Crossover:** Can be exacerbated by discontinuous flow, requiring remediation
- **"Ghost" flow:** from gravity or driven by boiler pump must be halted
- **Old plumbing:** may increase installation cost

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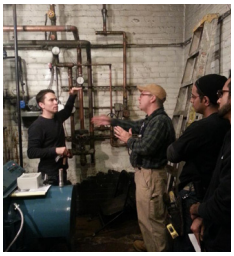
Issues

- **Tank stratification:** can be exacerbated by discontinuous flow, increasing supply temperature
- **Mixing valves:** many not rated for discontinuous flow, requiring replacement
- **Legionella:** conflicting regulatory guidance
- **Very large buildings:** may result in unacceptably long wait times during off peak



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