DHW Measures and Concepts

Multi-Family Energy Measures Webinar Series

January 12, 2011
Public service program:

- Cash Incentives
- Energy Design Assistance
- Project Roundtable
- Educational Opportunities
- Program Coordination

Facilitate energy efficient design and construction in new multi-family housing through cash incentives and design assistance.
Eligible Customers

Multi-family buildings in PG&E service territory:

- 3 or more attached units
- New construction
- Exceed 2008 Title 24 Standards by at least 15%
- Submit complete application package prior to construction start
- Complete construction and verification by December 31, 2015

* Please contact HMG if you are unsure of the eligibility of your project.
Participant provides HMG with:
- Completed application
- Title 24 documentation
- Architectural plan-set (+MEP)
- Service territory verification
- W9 Form

HMG conducts a plan review to verify energy measures, estimated savings, % better than Title 24

Project enrolled, receives ‘Letter of Enrollment’

Third party HERS verification conducted during construction to ensure energy measures installed*

HMG verifies any changes to project since enrollment and ensures as-built still exceeds Title 24 by at least 15%

Project completed and incentives paid

*Note: the program verification protocols are in addition to any HERS measures on your Title 24
Incentive Information

Developer Incentives:
- $100 per unit plus incremental incentives based on energy savings
- HERS verification incentive: $60 per unit (max of $12,000 per project)

Energy Consultant Incentives:
- $50 per unit (max of $10,000 per project)
Domestic Hot Water
Domestic Hot Water
Domestic Hot Water
Domestic Hot Water

Water Heating Energy Use

- 15% of Electricity
- 25% of Natural Gas
- The most variable of energy use
  - Water heater capacity
  - Climate
  - Work schedule
  - Age
DHW Overview

Domestic Hot Water Systems consist of:
- Heat source
- Heat exchanger
- Piping system
- Plumbing fixtures
DHW Equipment Type

- Small storage water heaters
  - Gas or electric
- Large storage water heaters
  - Gas or electric
- Instantaneous water heaters
  - Gas or electric

Source: ArchiExpo, DailyGreen, Housing and Building Dept. New Zealand
DHW Equipment Type

- Boilers
- Indirect water heaters
DHW Equipment Type

Condensing Boilers

- Captures latent heat from moisture in the flue
- Condensing water heater technologies have thermal efficiencies of 0.90 – 0.96
- Conventional boiler thermal efficiencies 0.80 to 0.85
DHW Equipment Type

- Heat pump water heaters

Source: geappliances.com
Water Heating Efficiency

There are several types:

- **Energy Factor**
  - Overall efficiency = amount of hot water produced per unit of fuel consumed

- **Recovery efficiency**
  - How efficiently heat from fuel source is transferred

- **Standby losses**
  - Percent of heat loss per hour from stored water

- **Cycling losses**
  - Heat loss from the water as it circulates

- **Thermal efficiency**
  - Percent of heat from combustion transferred
Hot Water Distribution

- Reduces Hot Water Heating Costs by 25% to 50%
- Boiler or Commercial Water Heater
- Storage Tank
- Spring Loaded Check Valve
- Cold Water Feed from Utility
- Bypass Flow Sensor
- Shut-off Valve
- Methund® D'MAND® Pump
- Remote temperature sensor
DHW Mandatory Measures

- Equipment Certification
- Equipment Efficiency
- Pipe Insulation and Insulation Protection
- Storage Tank Insulation
- Recirculation Loops Serving Multiple Dwelling Units
Certification and Efficiency

- Small water heater efficiency is regulated by federal requirements and is summarized in Table 5-2

<table>
<thead>
<tr>
<th>Type</th>
<th>Size</th>
<th>Energy Factor (EF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Storage</td>
<td>≤ 75,000 Btu/hr</td>
<td>0.67-(0.0019*V)</td>
</tr>
<tr>
<td>Gas Instantaneous</td>
<td>≤ 200,000 Btu/hr</td>
<td>0.62-(0.0019*V)</td>
</tr>
<tr>
<td>Oil Storage</td>
<td>≤ 105,000 Btu/hr</td>
<td>0.59-(0.0019*V)</td>
</tr>
<tr>
<td>Oil Instantaneous</td>
<td>≤ 210,000 Btu/hr</td>
<td>0.59-(0.0019*V)</td>
</tr>
<tr>
<td>Electric Storage (exc. Table top)</td>
<td>≤ 12KW</td>
<td>0.97-(0.00132*V)</td>
</tr>
<tr>
<td>Electric Table Top</td>
<td>≤ 12KW</td>
<td>0.93-(0.00132*V)</td>
</tr>
<tr>
<td>Electric Instantaneous (exc. table top)</td>
<td>≤ 12KW</td>
<td>0.93-(0.00132*V)</td>
</tr>
<tr>
<td>Heat pump Water Heater</td>
<td>≤ 24 Amps</td>
<td>0.97-(0.00132*V)</td>
</tr>
</tbody>
</table>

*Note: V refers to tank volume (gallons). Effective Date January 20, 2004*
Certification and Efficiency

- California Appliance Efficiency Regulations
  - Large water heaters
  - Boilers

### Table F-3
Standards for Large Water Heaters

<table>
<thead>
<tr>
<th>Appliance</th>
<th>Input to Volume Ratio</th>
<th>Size (Volume)</th>
<th>Minimum Thermal Efficiency (%)</th>
<th>Maximum Standby Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas storage water heaters</td>
<td>&lt; 4,000 Btu/hr/gal</td>
<td>any</td>
<td>80</td>
<td>Q/800 + 110(Vr)1/2 Btu/hr</td>
</tr>
<tr>
<td>Gas instantaneous water heaters</td>
<td>≥ 4,000 Btu/hr/gal</td>
<td>&lt; 10 gal</td>
<td>80</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥ 10 gal</td>
<td>80</td>
<td>Q/800 + 110(Vr)1/2 Btu/hr</td>
</tr>
<tr>
<td>Gas hot water supply boilers</td>
<td>≥ 4,000 Btu/hr/gal</td>
<td>&lt; 10 gal</td>
<td>80</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥ 10 gal</td>
<td>80</td>
<td>Q/800 + 110(Vr)1/2 Btu/hr</td>
</tr>
<tr>
<td>Oil storage water heaters</td>
<td>&lt; 4,000 Btu/hr/gal</td>
<td>any</td>
<td>78</td>
<td>Q/800 + 110(Vr)1/2 Btu/hr</td>
</tr>
</tbody>
</table>
Mandatory Pipe Insulation

- **Non-recirculating systems**
  - Hot and cold water pipes for a length of five feet

- **Recirculating Systems**
  - All hot water pipes must be insulated

- **Indirect domestic hot water system**
  - From the heating source to the storage tank.
Mandatory Pipe Insulation

- R-4 is typical requirement *(standards table 150-B)*
  - 1.0” thick insulation on pipes < 2.0” diameter
  - 1.5” thick insulation on pipes > or = 2.0” diameter

- If pipes are outdoors, pipe insulation must be suitable for outdoor use. E.g. shielded from solar radiation
Mandatory Pipe Insulation

- Some exemptions:
  - Piping penetrating framing
  - Piping in exterior walls when using QII
  - Piping in attics continuously buried by insulation
  - Other piping
    - Gas
    - Condensate
    - Waste
    - Roof drains
Storage Tank Insulation

- R-12 blanket required for small water heaters with energy factor (0.58)

- Not required:
  - Energy factor is better than 0.58
  - More than 75,000 btuh input rating

Source: www.greatergoods.com
Storage Tank Insulation

- Indirect systems using storage tanks
  - External R-12
  - Internal R-16
Multi-family Recirculation Loops

- **Air release valves**
  - Minimizes pump damage due to cavitation of pump

- **Backflow prevention in recirculation loop**
  - Backflow:
    - hot water flowing up cold water lines or
    - where cold water flows up hot water lines.

- **Pump isolation valves**
  - Enables repair of pumps

- **Connection of cold water supply**
  - Need check valve between water heater and 1st tee off cold water supply
Solar Thermal Systems

- Credit in Title 24 for water heating
- Most coastal projects at > 25% above code threshold are using solar hot water (2005)
- Alternative to high-efficiency boilers
- Complimentary to central systems
- Title 24 consultant inputs the Solar Savings Fraction and solar water heating designer sizes the actual system

www.solarshop.com
Thank you!

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Central DHW Systems in Multifamily Buildings

Matthew Haro
Heschong Mahone Group
January 12, 2011
Outline

● Central DHW System Energy Flow
● Water Heaters and Boilers
● Distribution Network
● Equipment Sizing
● Why go Solar
PIER MF DHW Research

Study Overview

- Field study and analysis provided in-depth understanding of distribution system heat loss mechanisms
  - Field DHW system monitoring at 30+ MF buildings
  - Detailed DHW performance evaluation of 9 MF buildings
    - HW & CW flows, temperatures, and pressures; gas flows
    - System controls study and cool down tests
    - System heat balance and energy flow analysis
- A spreadsheet based model was developed and validated with field measurement data
DHW Heat Loss Mechanisms

- Water Heater or Boiler Losses
  - Combustion Efficiency
  - Standby Losses
- Recirculation Loop Losses
  - Hot Water Draw Flow Losses
  - Recirculation Flow Losses
- Branch Losses
PIER MF DWH Research

System Energy Flow

Central DHW Systems in Multifamily Buildings
Field study included investigation of recirculation loop design/installation practices, which were used to support performance analysis and modeling.
Water Heaters and Boilers:

Loss Mechanisms

- **Combustion Efficiency**
  - Natural Draft limit is 78%
  - Condensing units achieve 90+%  
- **Standby Losses**
  - Flue Losses (Natural Convection)
  - Storage Tank Surfaces
  - Standing Pilot Light
  - Fittings

Central DHW Systems in Multifamily Buildings

1/12/2011
Water Heaters and Boilers:

**Efficiency Options**

- Increased Tank Insulation
- Electronic Ignition
- Flue Dampers
- Forced or Induced Draft
- Modulating Burner
- Condensing
DHW Recirculation Loop Losses

**Hot Water Draw Flow**

- Reduced demand saves energy
  - Low flow rate fixtures and appliances
  - Conservation – Shorter showers, etc.
- Hot water draw profile varies
  - Weekday vs. Weekend
  - Occupant demographics
  - Controls
- Reduce hot water supply temperature
DHW Recirculation Loop Losses

Recirculation Flow Losses

- **Purpose of recirculation flow**
  - Transportation
  - Temperature control

- **Potential for savings: Turn pump off**
  - Saves energy
  - Turn off pump during no or low demand
  - Turn on only when hot water is needed
DHW Distribution Network

- Heat Transfer: \( Q = UA\Delta T \)
- Pipe Location
- Pipe Length
- Pipe Sizing
- Use long radius bends
- Use multiple recirculation loops
Central DHW Systems in Multifamily Buildings

PIER MF DWH Research

System Energy Flow

Water Heater Losses

Recirculation Loop Losses

Branch Losses*

Distribution Losses

End-Use Energy

Include pipe inside and outside of dwelling units
Equipment Sizing

- Water Heater or Boiler Sizing
- Pump Sizing
Why Go Solar

- Reduced gas usage
- High utilization potential
  - Sustained hot water demand
  - Offset recirculation loop losses
- Low cost for new construction
Summary of Savings Tips

- Adequately insulate hot water pipe
- Reduce pipe volume
- Reduce pipe temperature
  - Reduce hot water supply temperature
  - Use Controls
- Route pipe through conditioned space
- Do not oversize equipment
Multifamily Central DHW Temperature Modulation Control Study Results

Multifamily Webinar
January 12, 2011

Nehemiah Stone
Outline

• Background on CDHW Systems
• Background on Study
• Energy Impact Results
• Other Important Findings
Typical Configuration

Primary Loop

Secondary Loop
<table>
<thead>
<tr>
<th>#</th>
<th>Strategy</th>
<th>Description</th>
<th>What is Controlled?</th>
<th>Continuous Monitoring?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Demand Control</td>
<td>One sensor monitors flow (demand) and another sensor monitors water temperature near the last apartment. If temp in supply line is high enough when demand occurs, pumps stays off. If temp is too low, pump comes on until temp near last apartment rises $X$ degrees, then shuts off.</td>
<td>Pump on/off</td>
<td>possible, but not seen</td>
</tr>
<tr>
<td>2</td>
<td>Temperature Modulation Control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Set Schedule</td>
<td>Pumps stays on 24/7. Hot water supply temp is kicked up or down to ensure water is just hot enough to meet the varying demand. Schedule is set after 2-4 weeks of usage data is collected. Schedule is modified by contractor if changes in occupancy or use warrant it.</td>
<td>Hotwater supply temp.</td>
<td>yes, remote</td>
</tr>
<tr>
<td>4</td>
<td>Learned Schedule</td>
<td>Pumps stay on 24/7. Hot water supply temp is kicked up or down to ensure water is just hot enough to meet the varying demand. Schedule is set automatically by controller based on previous ~ two weeks of temperature data (as a surrogate for water use demand data).</td>
<td>Hotwater supply temp.</td>
<td>no</td>
</tr>
<tr>
<td>5</td>
<td>Constant Return Temperature</td>
<td>Pumps stay on 24/7. Hot water supply temp is dynamically adjusted by controllers to maintain 103°F return temperature 24/7.</td>
<td>Hotwater supply temp.</td>
<td>Local, with alarms</td>
</tr>
</tbody>
</table>
Typical Details

• Average Usage:
  – 208 therms/apt (100-515 range)
  – 9200 therms/pump (3900-18,900 range)

• 236 gal storage (100-400 range)

• 44 Apts. per loop (20-200 range)

• Median vintage = 1940 (1910-2000 range)

• 29,000 sq.ft. (9700 to 55,000 range)
• In CA, there are 4.2 Million MF households, About ½ in Sempra’s territory
• The 4.2M pay about $.7 Billion per year for DHW energy
• In much of Sempra’s area, energy/household for DHW is greater than energy for heating and cooling combined.
Perspective

• In California, MF gas use for DHW is four to ten times as high as for heating
• Clothes dryers in existing MF are generally beyond the reach of EE programs (fuel switching)
• Stoves and ovens have no efficiency standards
• Net result
  – When targeting MF property gas savings, water heating is the primary target.
Study Background

• For PY2004/05 participants installing controls on central domestic hot water (CDHW) systems, billing analysis:
  – Indicated savings of about 1/8 of what was expected by program managers
  – Suffered from incomplete and some unverifiable data
  – Prompted Sempra to commission a new study
Studied Sites

• 50 Multifamily Energy Efficiency Rebate Program participants
• 139 Central DHW systems
• Without previously existing controls
Eliminated

- Sites with one gas meter for whole campus
- Sites with CDHW on same meter as heating
- Sites with unverifiable other end uses
- *NOT* sites with other known minor end uses with relatively consistent usage patterns (e.g., barbecues, spa, laundry)
Study Summary

- Controls incentivized in statewide MF Energy Efficiency Rebate (MFEER)

<table>
<thead>
<tr>
<th>Vintage</th>
<th>Expected Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre 1970</td>
<td>45 therms/pump</td>
</tr>
<tr>
<td>Post 1970</td>
<td>34 therms/pump</td>
</tr>
</tbody>
</table>

- Measured savings averaged 14, 12, and ¼ therms/yr-apt across three control manufacturers (avg. 25% realization rate)
# Savings by Manufacturer

<table>
<thead>
<tr>
<th>Controls Manufacturer</th>
<th>therms</th>
<th>Realization Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturer A</td>
<td>14</td>
<td>35.4%</td>
</tr>
<tr>
<td>Manufacturer B</td>
<td>12</td>
<td>30.4%</td>
</tr>
<tr>
<td>Manufacturer C</td>
<td>0.25</td>
<td>0.6%</td>
</tr>
</tbody>
</table>
Savings Relates to Installers

• Many installations resulted in negative savings!
• Negative savings correlated well to installers
Savings from Installations

Ex Post Savings Total (therms)

No. Apt Units
Other Important Findings

• <5% had maintenance contracts for the boiler systems
• Site personnel made ~95% of repairs and adjustments w/o adequate knowledge
• When all you have is a thermostat, everything is temperature problem
Top Five Problems Found

1. Un-insulated system piping (80% of the systems inspected)
2. Calcium carbonate build-up in tank type heaters (Roughly 2/3rds of the tanks inspected have never been drained/flushed)
3. Dirty burner tips (Aprox 50% were not maintained)
Top Five Issues

4. Roughly 30% of the systems inspected had soot accumulation on the heat exchanger, and approximately 15% of heat exchangers had signs of flame roll out conditions

5. Boiler controllers and tank stats on approximately 15% of the systems inspected were out of calibration
More Findings

– Close to 10% of site personnel stated they have *known* system faults

– Approximately 50% changed the set point prior to control installation in response to tenant complaints

– Roughly 10% had tenant complaints before *and* after control installation

– Approximately 80% of the site personnel did not know who to call regarding the controls
More Findings

• Broken refractory in fire box: Aprox 10% needed brick/equipment replacement

• 20% of systems inspected had low hot water return temperatures in the primary loop causing condensate deposition on heat exchanger
Controls Installers

• When asked how installer determined appropriate set point with the control, almost all said they left it as it was

• When asked much later, how they dealt with set points above 128° or higher, they all said they set it down to 128°
For Adults…

For Children, it is MUCH faster!

Hot water causes third degree burns...

in 1 second at 156°
in 2 seconds at 149°
in 5 seconds at 140°
in 15 seconds at 133°
Summary

• Controls don’t work in a vacuum
• Stuff goes wrong and it needs to be fixed or expected savings won’t occur
• Monitoring performance may save as much, or more energy than the controls themselves
• Train installers and site personnel
Questions?

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