Compact DHW Distribution in Single Family New Construction Homes

2016 ACEEE Hot Water Forum

Farhad Farahmand (TRC)

Gary Klein (Gary Klein and Associates)

Marc Hoeschele and **Peter Grant** (Davis Energy Group)

Yanda Zhang (ZYD Energy)

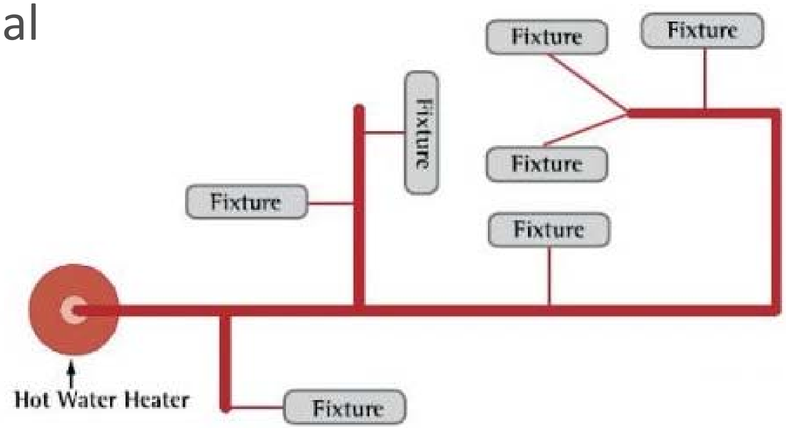
February 22nd, 2016

Overview

- Background
  - Scope and goals
  - Status quo and California's Title 24
- Methodology and Findings
  - Performance analysis
  - Workshops and interviews
- Next steps
  - Preliminary measure selections
  - Lab and field demonstrations

Scope for Compact Distribution Design

- Inform programs, design guidelines, and code (Title 24)
  - Designs to reduce water, energy, and time wasted
  - Improve end-user satisfaction
  - Consider cost effectiveness
- Hot water distribution (e.g. pipe diameter, fixture locations)
  - Related elements are considered (e.g., water heater type, insulation)
- New construction, single family residential
  - Not multifamily or nonresidential
- Our role
  - Performance analysis
  - Engagement
  - Measure development
  - Demonstration

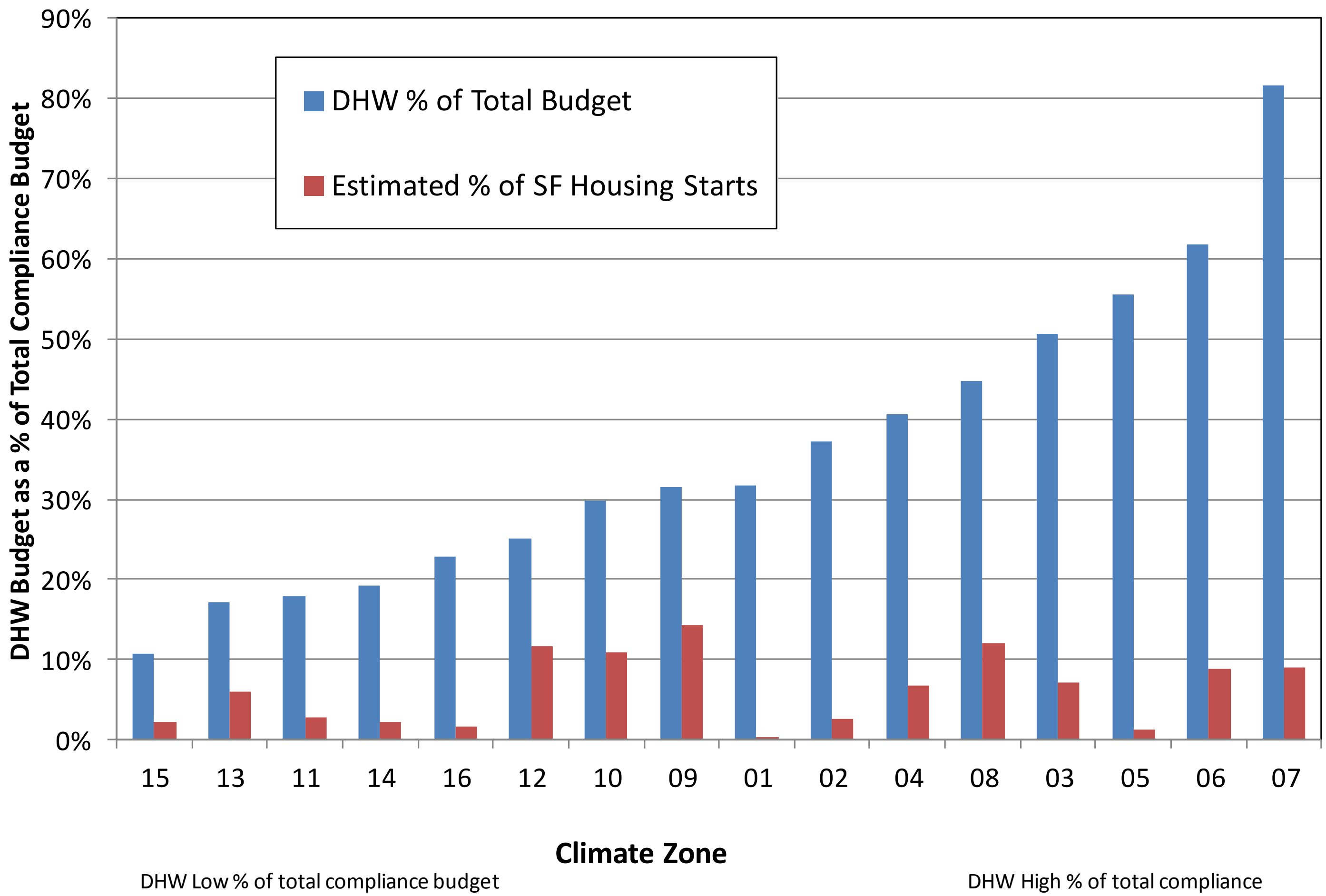


Source: https://buildingsfieldtest.nrel.gov/hot_water_distribution

Literature Review

- Current Practices
  - PEX piping
  - Trunk and branch
  - Water heater located in garage
  - Direct paths often avoided (DEG, 2012)
- Research
  - **Water Usage:** 17 gpd-person of hot water, though there is significant variation (Lutz, 2011) (Henderson, 2015)
  - **Water Waste:**
    - 1.8 gal of warmup waste per shower (1.1 gal is behavioral).
    - 9-25% of water is wasted (Sherman, 2014) (Henderson, 2015)
  - **Circulation Systems:** Pumps save 5-20% of hot water, and increase gas usage by 1-30% (Henderson, 2015) (Nones, 2015) (Hoeschele, 2014)
    - Based on limited field studies and detailed modeling

A Big Part of Title 24's Standard Budget



Title 24 Compact DHW Req's

- Prescriptive requirements - 150.1(c)8A
  - Path A: tankless
  - Path B: Storage water heaters
    - Floor Area Served is defined per water heater
    - HERS field verified piping length

Floor Area Served (ft2)	Maximum Measured Water Heater To Use Point Distance (ft)
< 1000	28'
1001 – 1600	43'
1601 – 2200	53'
2201 – 2800	62'
>2800	68'

- Performance paths
  - Credits and penalties for alternate distribution methods

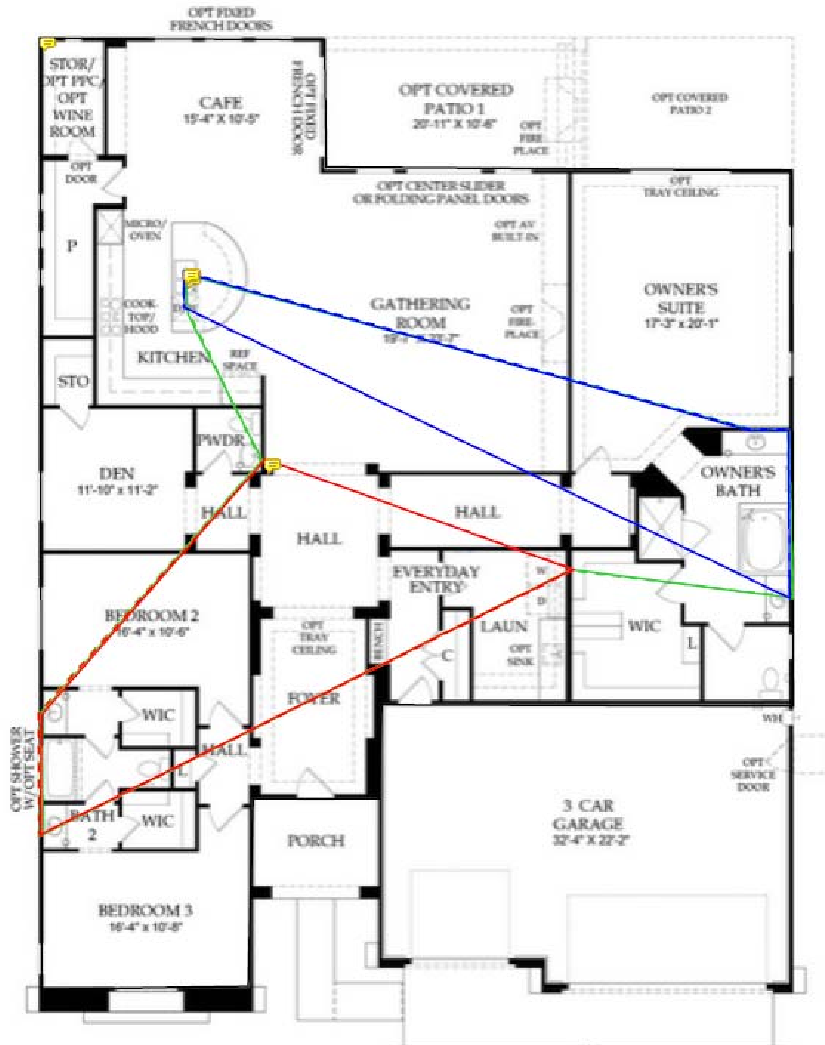
Methodology and Findings

Characterizing Fixtures with Polygons

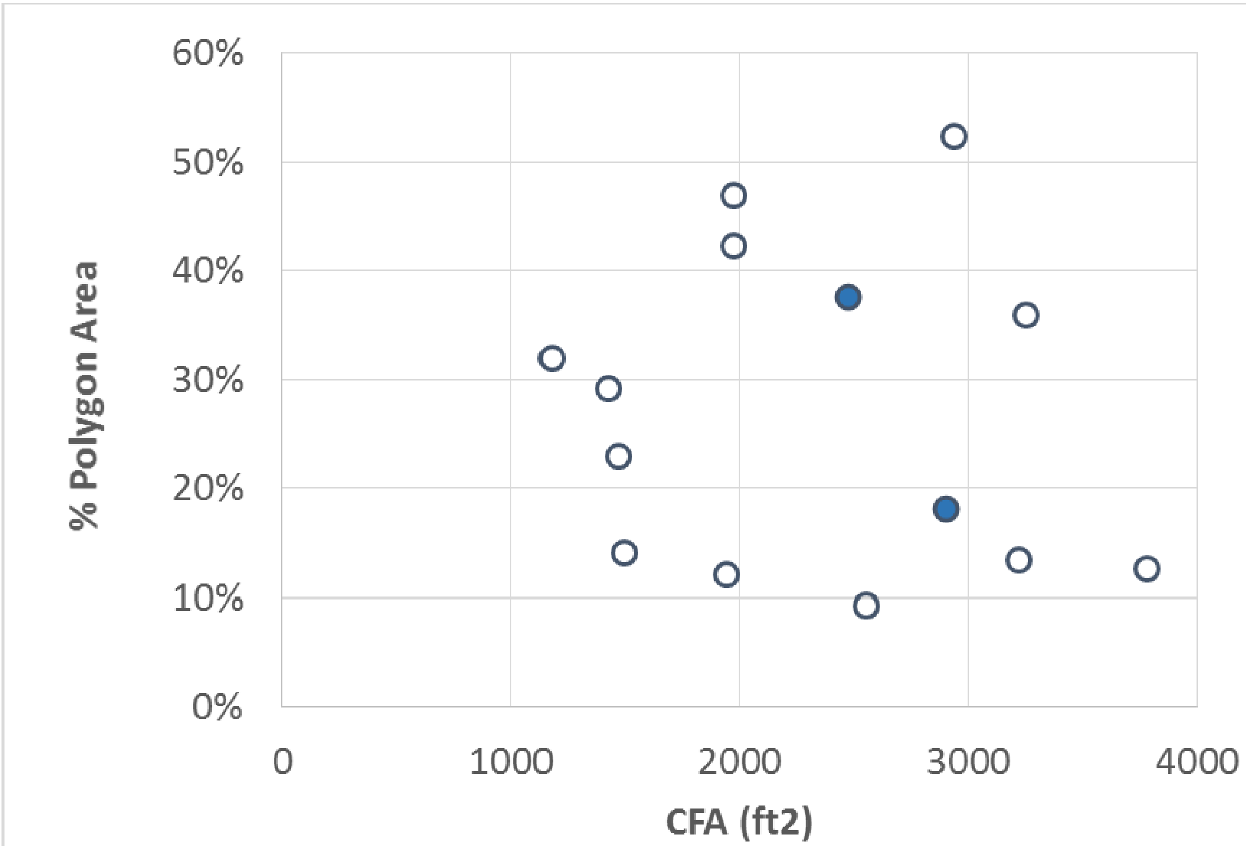
(Polygon Area) / (Conditioned Floor Area)

= Polygon %

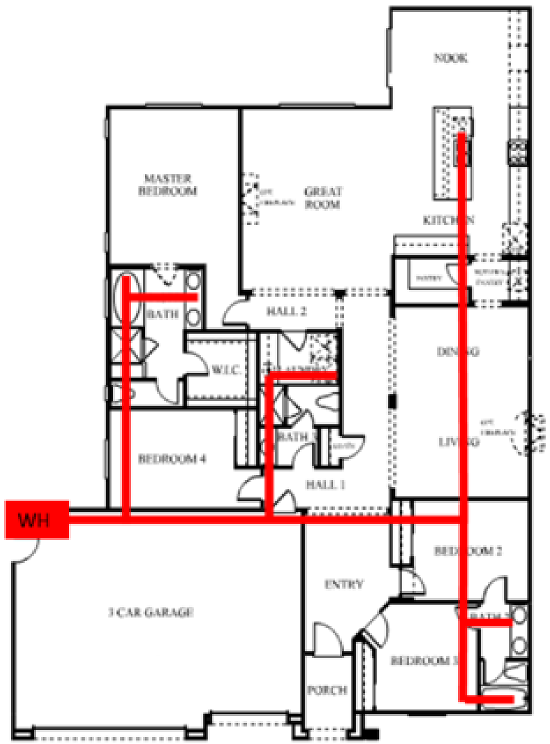
→ 1,170 / 3,253 = **36%**



Architectural Compactness Variation

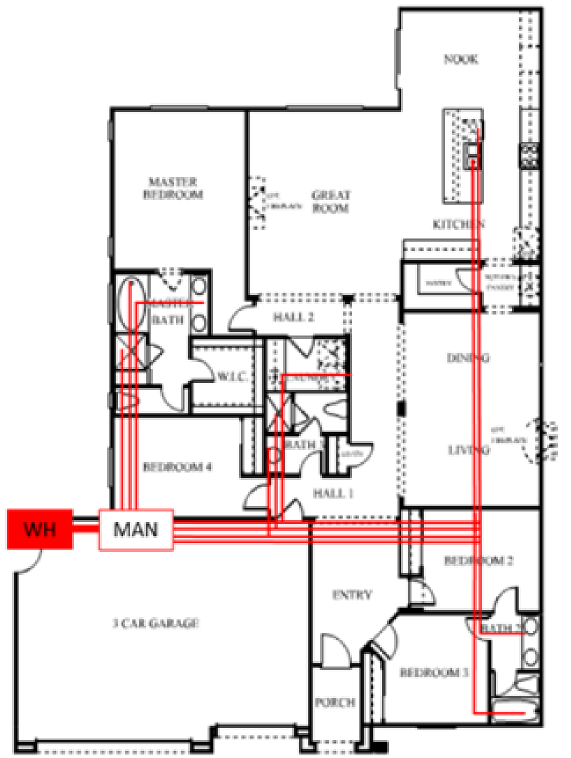


Varying Designs for Volume Estimates



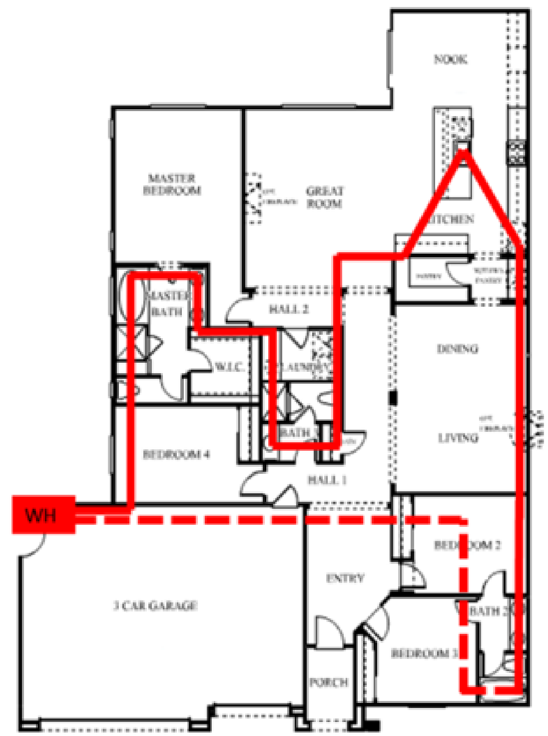
Trunk and branch

4 zones



Home run

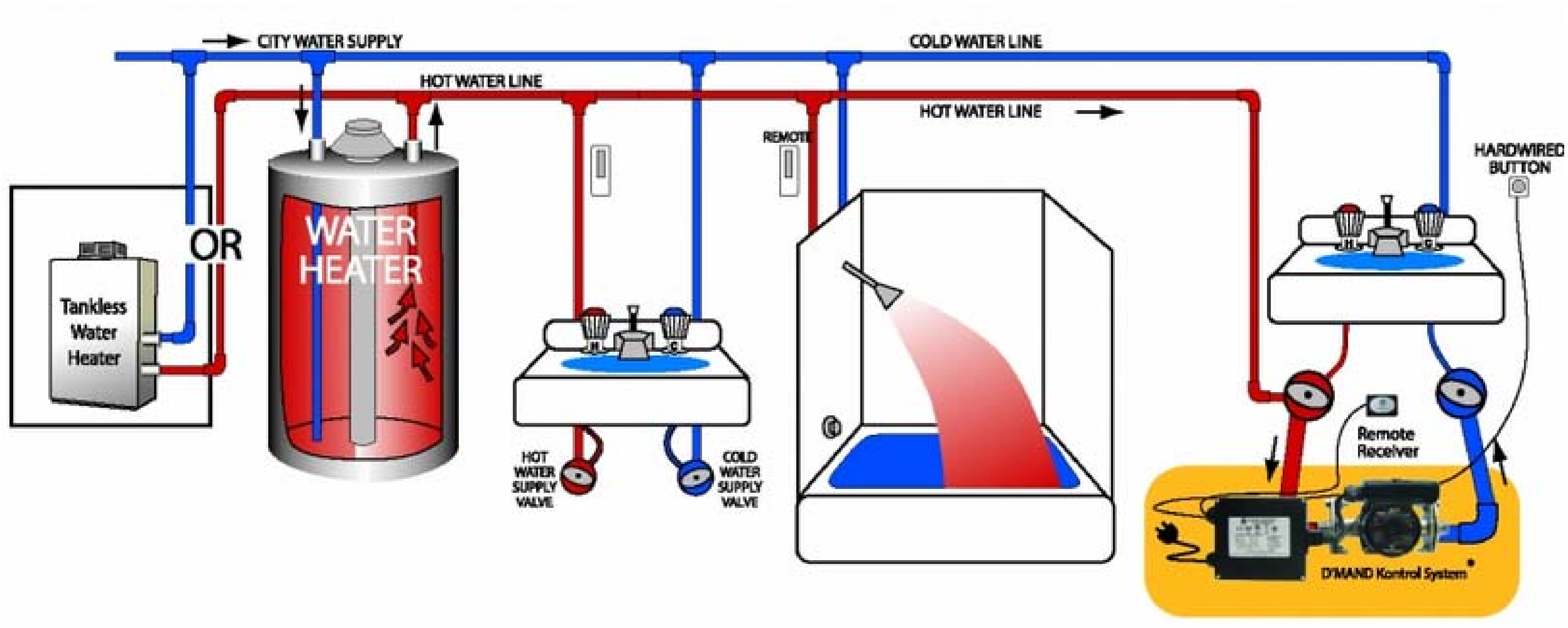
10 zones



Circulation

1 zone

Not Yet Analyzed, but Promising



Source: http://www.gothotwater.com/

Varied WH Location and Distribution

- Used standard draw schedules/events

1-Story Floorplan	2-Story Floorplan
Base case, T&B, WH in garage	Base case, T&B, WH in garage
T&B, WH central in garage	-
T&B, WH central in attic	-
T&B, WH in pantry	T&B, WH in pantry
-	T&B, 2x WH
HR, WH in pantry	HR, WH in pantry
HR, WH central in attic	-
Circulation	Circulation
-	Circulation, 2 zones

WH = Water Heater, T&B = Trunk and Branch, HR = Home Run

Condensed Results

Description	Wasted Gallons/Day	% of Base Case	Avg Wait Time (s)	% of Base Case
Base case, T&B, WH in garage	4.9	100%	38	100%
T&B, WH ext wall of pantry	3.7	75%	25	67%
HR, WH ext wall of pantry	3.0	62%	15	39%
Circulation	0.6	12%	4	9%

- Moving WH centrally saves water and time
- Home run system seems to improve performance over T&B
- Circulation saves the most water and time
- Investigating implications for energy waste

How Long Should We Wait?

Volume in the Pipe (ounces)	Minimum Time-to-Tap (seconds) at Selected Flow Rates					
	0.25 gpm	0.5 gpm	1 gpm	1.5 gpm	2 gpm	2.5 gpm
2	4	1.9	0.9	0.6	0.5	0.4
4	8	4	1.9	1.3	0.9	0.8
8	15	8	4	2.5	1.9	1.5
16	30	15	8	5	4	3
24	45	23	11	8	6	5
32	60	30	15	10	8	6
64	120	60	30	20	15	12
128	240	120	60	40	30	24

ASPE Time-to-Tap Performance Criteria

(green)	Acceptable Performance	1 – 10 seconds
(orange)	Marginal Performance	11 – 30 seconds
(pink)	Unacceptable Performance	31+ seconds

Source: Domestic Water Heating Design Manual – 2nd Edition, ASPE, 2003, page 234

Workshop for Interim Feedback

- Attendees included builders, plumbing engineers, and policymakers
- 15 seconds time-to-tap may be marketable
- Barriers to relocating WH indoors (leaks, $$$)
- Considering fixture layout in floorplans is
  - Most economical
  - Least palatable
- Code should consider reducing minimum DHW pipe diameter req's
- Survey builders (next slide)

Builder Survey Feedback

- Interviewed 2 plumbers and 7 builders
- Builders commonly received wait time complaints
  - Longest wait times commonly exceed 60 seconds
  - Some pre-plumb homes to be compatible with circulation
- Demand circulation systems
  - Heavily penalized in Title 24
  - Passed up by homebuyers
- Builders prefer circulation loop to an under-sink system because of reduced wait time at all fixtures

Builder Survey Feedback (con't)

- Opposite results from workshop – most preferred:
  - Locating WH closer to use points
  - Designing homes more compactly
- Home run systems discontinued due to high costs, no perceived improvement in efficiency

	Base Cost	Incremental Costs for Compact Design Methods				
	T&B, WH in garage	Demand recirculation	Home run	WH location inside	Under-sink circulation	2 water heaters
No. of Data Points	5	6	2	4	4	2
Average	$3,840	$1,280	$250	$1,120	$860	$2,380

Next Steps

Researching Compact Measures

- Water savings are important, but:
  - Homebuyers value cost savings and time savings more
  - Title 24 values energy savings more
- Measures that save time, energy, and are likely cost effective
  1. Water heater close to hot water fixtures (attic or kitchen exterior walls)
  2. Optimized two-zone design (trunks)
  3. Under-sink circulation priming (under-sink pumping)
- Does not preclude other measures

Research Methods to Refine Measures

- Energy savings performance model
  - TRNSYS a black box
- Field demonstrations of measures
  - 6 installations, each with a conventional baseline
  - Measuring entrained volume and time-to-tap
- Lab Testing at the Applied Technology Services (ATS)
  - Attain data to validate energy savings model
  - Collect pressure drop vs. flow rate data
  - Demo measure savings

Thank You!

Farhad Farahmand ffarahmand@trcsolutions.com

Competing priorities

Perspective	Priority #1	Priority #2	Priority #3	Priority #4
Homeowner	Time savings and convenience	Reliability	Low incremental cost	Water savings
Builder	Minimize homeowner complaints	High value (T24 credits) compared to incremental cost	Reliability	
Plumber	Minimize homeowner complaints	Low installation cost, easy implementation		
Title 24	Energy savings	Water savings	Cost effectiveness	Reliability

Assessment of Compact Solutions

Solution	Time savings	Energy Savings	Cost	Reliability	Water Savings	Market-ability	Key Barriers
Central WH Location	Medium	High	Medium	Medium	Medium	Medium	Market acceptance
Central Fixtures	Low	Medium	Low	High; same as status quo	Medium	Low	Market acceptance
Multiple WHs	Medium	Medium; penalty with storage	High	Medium; more maintenance	Medium	High	Market acceptance
Circulation	High	Low	Medium	Medium	High	High	Costs, energy penalty
Home Run	Medium	Medium	Low	Medium	Medium	Medium	Costs