Multi-family DHW and Solar Water Heating

CEC 2013 Title 24 Pre-rulemaking Workshop

California Statewide Utility Codes and Standards Program

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MF DHW System Improvement

- Central DHW System with Recirculation Loop
  - Multi-family buildings (low-rise & high-rise)
  - Hotel and motel buildings
- Technologies
  - Recirculation loop controls
  - Recirculation piping system designs
  - Solar water heating
- Holistic Approach
  - Integrated prescriptive package to cost-effectively maximize energy savings

Summary of Code Change Proposals

- Recirculation System Controls
  - Demand control / Temp modulation / continuous monitoring
- Recirculation System Designs
  - Standard design – reflect efficient design
  - Proposed design – establish a default design to enable compliance verification
- Solar Water Heating
  - Cost effectiveness – threshold solar fraction
  - Solar ready
    - Adequate roof area for collectors
    - Adequate space in boiler room for solar equipment
    - Specify future plumbing and conduit paths on building plans

LCC Analysis – Level 1 & 2

- Costs:
  - Demand control: $1000 equipment +$200 labor
    Useful life = 15 yrs
  - Plumbing cost reduction from optimization not included
- Energy Savings - 30 Year TDV
- Small variation among climate zones

	Building Proto-type	Measure Life (Years)	Additional Costs– Current Measure Costs (Relative to Basecase)	PV of Add'l Maintenance Costs (Savings)	PV of Energy Cost Savings	LCC Per Prototype Building
			($)	(PV$)	(PV$)	($)
Demand Control	Low-Rise	Res 30	$2,000	$0	$5,245	($26,562)
Demand Control + Optimal Design	Low-Rise	Res 30	($159)	$0	$37,707	($37,866)
Demand Control	High-Rise	NonRes 30	$2,000	$0	$3,871	($36,948)
Demand Control + Optimal Design	High-Rise	NonRes 30	($5,892)	$0	$57,487	($63,380)

Multi-family DHW and Solar Water Heating

LCC Analysis – Level 3 (CZ 10)

					BASE TDV		REACH TDV		
Collector Sizing	Bldg Proto-type	Mea-sure Life	Additional Costs– Current Measure Costs (Relative to Basecase)	PV of Additional Maintenance Costs (Savings) (Relative to Basecase)	PV of Energy Cost Savings – Per Proto Building	LCC Per Prototype Building	PV of Energy Cost Savings – Per Proto Building	LCC Per Prototype Building	Solar Savings Fraction
sf per gal/day		(yr)	($)	(PV$)	(PV$)	($)	(PV$)	($)	(%)
0.1	Low	30	$14,608	$5,213	$ 4,830	($29,674)	$ 15,790	($33,676)	10.74%
0.2	Low	30	$28,983	$7,999	$ 15,405	($28,424)	$ 37,059	($37,784)	24.43%
0.3	Low	30	$43,357	$10,786	$ 24,973	($25,090)	$ 55,550	($39,114)	36.36%
0.4	Low	30	$57,732	$13,572	$ 34,202	($21,150)	$ 73,231	($39,634)	47.76%
0.5	Low	30	$72,107	$16,359	$ 43,020	($15,718)	$ 88,898	($38,139)	57.52%
0.6	Low	30	$86,481	$19,145	$ 50,638	($7,351)	$ 100,633	($32,713)	64.58%
0.7	Low	30	$100,856	$21,932	$ 57,808	$2,484	$ 110,404	($25,324)	70.29%
0.8	Low	30	$115,231	$24,718	$ 63,958	$13,656	$ 118,398	($16,156)	74.98%
0.1	High	30	$20,534	$11,054	$ 3,618	($41,140)	$ 20,823	($46,722)	8.10%
0.2	High	30	$51,439	$17,045	$ 23,327	($33,578)	$ 60,732	($49,736)	22.27%
0.3	High	30	$82,345	$23,036	$ 40,466	($21,752)	$ 94,864	($46,971)	34.45%
0.4	High	30	$113,250	$29,027	$ 57,597	($9,273)	$ 128,102	($43,312)	46.25%
0.5	High	30	$144,155	$35,018	$ 73,614	$6,199	$ 157,231	($35,545)	56.32%
0.6	High	30	$175,061	$41,009	$ 88,223	$26,219	$ 180,146	($21,564)	63.91%
0.7	High	30	$205,966	$47,000	$ 100,977	$49,914	$ 198,067	($2,589)	69.73%
0.8	High	30	$236,872	$52,991	$ 111,907	$76,119	$ 212,594	$19,781	74.47%

LCC Analysis – Cost Effective Threshold

	BASE: Demand Control + Optimal design + Cost Effective Solar Fraction		**REACH**: Demand Control + Optimal design + Cost Effective Solar Fraction	
Climate Zone	Low-Rise	High-Rise	Low-Rise	High-Rise
1. Arcata	52%	33%	67%	45%
2. Santa Rosa	60%	44%	67%	60%
3. Oakland	65%	44%	75%	66%
4. San Jose Reid	63%	47%	70%	64%
5. Santa Maria	66%	53%	69%	67%
6. Torrance	69%	52%	74%	70%
7. San Diego	69%	51%	75%	71%
8. Fullerton	68%	51%	74%	69%
9. Burbank-Glendale	68%	51%	74%	69%
10. Riverside	69%	52%	75%	70%
11. Red Bluff	58%	42%	67%	59%
12. Sacramento	65%	46%	75%	65%
13. Fresno	54%	38%	65%	54%
14. Palmdale	75%	60%	78%	76%
15. Palm Springs	71%	51%	82%	72%
16. Blue Canyon	61%	48%	65%	62%

- Interpolating b/n collector sizing increment to obtain the cost effective solar fractions in each climate zone

Development of SF Requirements

- Cost-effective alternative compliance options exist to provide equivalent TDV energy savings

Climate Zone	HE Water Heater	HE Furnace	HE AC	TDV Energy Savings (kBtu/sqft)	TDV Energy Savings – (% of Water Heating Budget)	PV Energy Savings ($/sqft)	Additional Cost ($/ sqft)	LCC ($/ sqft)	Proposed Solar Fraction	TDV Energy Savings – Solar WH (kBtu/sqft)
1	Yes	Yes		7.5	23.8%	$1.29	$0.73	-$0.56	20%	6.3
2	Yes	Yes		8.3	27.1%	$1.43	$0.73	-$0.70	25%	7.6
3	Yes	Yes		6.5	21.3%	$1.13	$0.73	-$0.40	20%	6.1
4	Yes	Yes		7.1	23.5%	$1.23	$0.73	-$0.50	20%	6.0
5	Yes	Yes		6.7	22.0%	$1.16	$0.73	-$0.43	20%	6.1
6	Yes	Yes		5.4	18.4%	$0.94	$0.73	-$0.21	15%	4.4
7	Yes	Yes		5.3	17.99%	$0.92	$0.73	-$0.18	15%	4.4
8	Yes	Yes		5.5	18.8%	$0.96	$0.73	-$0.22	15%	4.4
9	Yes	Yes		5.5	18.7%	$0.95	$0.73	-$0.21	15%	4.4
10	Yes		Yes	9.7	33.1%	$1.67	$1.42	-$0.25	30%	8.7
11	Yes	Yes	Yes	13.8	46.3%	$2.39	$2.00	-$0.39	40%	13.4
12	Yes	Yes		7.6	25.1%	$1.31	$0.73	-$0.58	25%	7.5
13	Yes	Yes	Yes	13.7	47.2%	$2.38	$2.00	-$0.38	35%	13.1
14	Yes	Yes	Yes	14.6	49.1%	$2.53	$2.00	-$0.53	45%	13.4
15	Yes	Yes	Yes	18.0	66.9%	$3.12	$2.00	-$1.12	50%	13.5
16	Yes	Yes	Yes	13.9	43.2%	$2.41	$2.00	-$0.41	40%	12.9

LCC Analysis – Summary

- All three levels are cost effective
- Estimated roof area:
  - SF = 0.5 → ~ 0.40 sqft collector/g of hot water demand
  - Collector size: Low-rise: 540 sqft; high-rise: 1,160 sqft
  - General guideline
- Cost effective alternative compliance options exist

Number of Stories	% of building footprint
2	3%
3	4%
4	6%
5	7%
10	14%
20	28%

Proposed Prescriptive Requirements

- **Section 151(f) 8C**

C. For systems serving multiple dwelling units, a central water heating system that has gas or propane water heaters, boilers or other water heating equipment that meet the minimum efficiency requirements of Sections 111 and 113. ~~*and a water heating recirculation loop that meets the requirements of Section 113(c)2 and Section 113(c)5 shall be installed.*~~

Water heating recirculation loops meeting all of the following requirements shall be installed:

1. Meeting the requirements of Section 113(c)2 and Section 113(c)5 and be located at the center of the building on the first floor.
2. A solar water heating system with solar fraction specified in Table 151-C
3. A recirculation system equipped with demand control and a minimum of two recirculation loops each serving a portion of the building

Proposed Prescriptive Requirements

- **Table 151-C**

		Climate Zone															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
(requirements for other building components and systems – no change)																	
WATER-HEATING	General	System shall meet Section 151(f)8 or Section 151(b)1															
	Solar Savings Fraction for multifamily buildings	0.2	0.25	0.2	0.2	0.2	0.15	0.15	0.15	0.15	0.3	0.40	0.25	0.35	0.45	0.5	0.4

Proposed SWH Ready Code Language

- **Section 150(n)**

~~*(n) Water Heating Recirculation Loops Serving Multiple Dwelling Units. Water heating recirculation loops serving multiple dwelling units shall meet the requirements of Section 113(c)5.*~~

(n) Water Heating System Serving Multiple Dwelling Units.

1. Water heating recirculation loops serving multiple dwelling units shall meet the requirements of Section 113(c)5.
2. The following items shall be clearly shown and labeled on building plans/ drawings submitted for permitting purposes to facilitate potential future installation of solar water heating system:

Proposed SWH Ready Code Language

A. Marked area(s) of potential future solar collector on the roof or other available space (such as covered parking)

1. The area shall be at least 1.5 % times the number of stories times the total roof area or 30% of the total roof area and be oriented between 150˚ and 210˚.
2. The area shall be minimally shaded by vents, chimneys, architectural features, mechanical equipment or other obstructions that are on the roof or any other part of the building. Any vent, chimney, or other architectural feature shall be a minimum distance of twice the height from the reserved roof area(s).
   - Exception 1 to Section 150(n)2A2: Any vent, chimney, or other architectural feature to the north of the reserved roof area(s) shall be exempt from the minimum shading requirement.
   - Exception 2 to Section 150(n)2A2: Shading from trees, utility poles, other buildings, and other non-building sources are not included in the minimal shading requirement.
3. The area shall be sited in compliance with Section 2 of the California Department of Forestry and Fire Protection Office of the State Fire Marshal Solar Photovoltaic Installation Guideline, which provides for roof access and smoke ventilation

Proposed SWH Ready Code Language

B. Marked area inside or outside the boiler room where the water heating equipment reside, for potential solar water heating associated equipment. If the marked area is outside the boiler room, at least 2 ft space clearance shall be kept in all directions from the cold water inlet from potential future solar water heating related connections

C. Marked plumbing and conduit paths between the collector area on the roof and the boiler/water heaters in the boiler room

EXCEPTION to Section 150(n)2: buildings with a solar water heating system that meets Section 151(f) 8C ii.

QUESTIONS & COMMENTS

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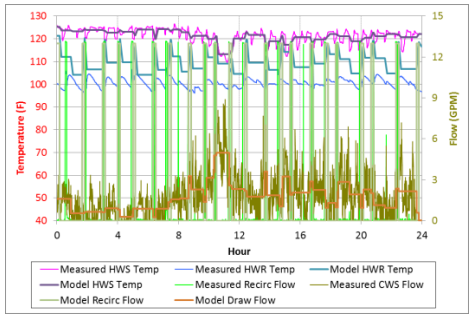
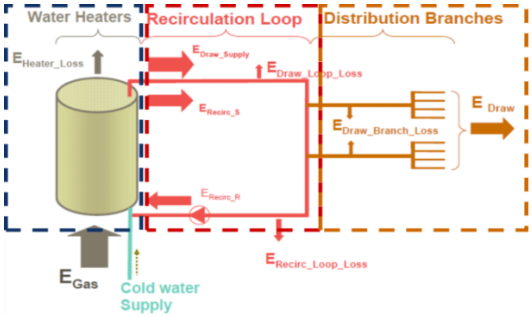
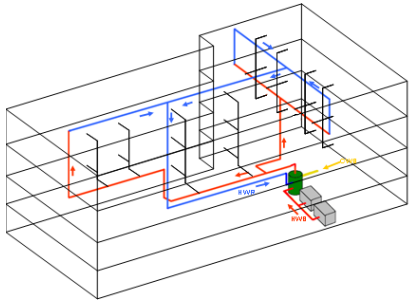
Methodology – PIER MF DHW Research

- Multi-year PIER Multi-family DHW System Research

Field performance study	Energy Flow Analysis	Recirculation Loop Modeling
Design practice survey > 50 buildings Performance Monitoring > 30 building	In-depth analysis of performance Overall η ~ 33% Recirc. loss ~ 34%	Stead-flow and cool-down Heat transfer Validated with measured control performance and piping designs





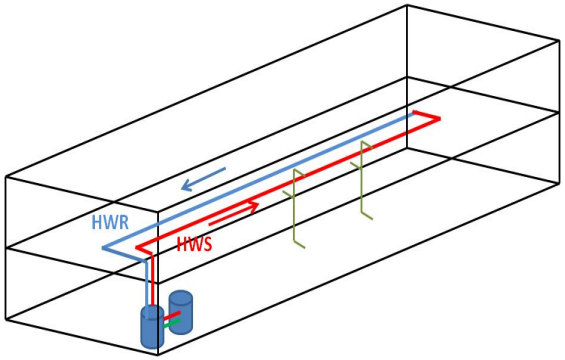


Methodology– CASE Efforts

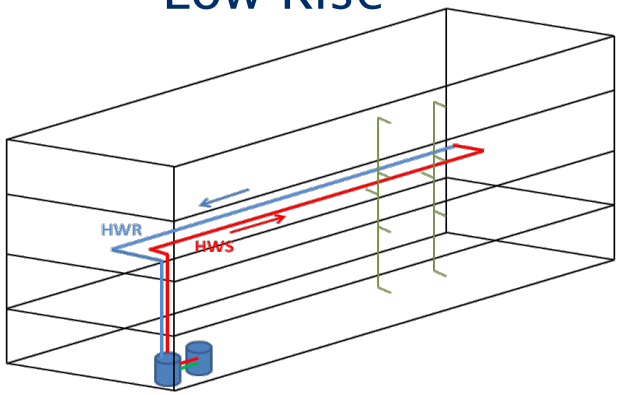
- Recirculation system ACM improvement
  - Water and Space Heating CASE study
  - Based on the detailed PIER recirculation model
  - Performance modeling of recirculation controls and piping designs – enable performance method
- Recirculation loop design
  - Investigation of different design options
  - Create standard and default designs
- Multi-family Solar Water Heating
  - Comprehensive investigation of MF solar water heating performance and costs

Data/Findings – Prototype Buildings

- For all energy savings and LCC analysis



Low Rise



High Rise

	Low Rise	High Rise
# of Floor	2	4
# of Unit	40	86
Unit Area (sqft)	870	870
Recirc. Loop Length (ft)	639	880
Recirc. Pump Power (hp)	0.25	0.5
Recirc. Flow Rate (GPM)	6	6
Recirc. Loop Vol. (Gal)	76	175

Data/Findings – Control Savings

- Use the PIER MF DHW Recirculation Model
- Control savings (continuous pumping as baseline)
  - Savings variations over 16 climate zones are very small

	Low Rise			High Rise		
Per Building	**kWh**	**kW**	**Therm**	**kWh**	**kW**	**Therm**
Temp Mod	0	0	405	0	0	535
Monitoring (-5˚F)	0	0	461	0	0	771
Temp Mod + Monitoring	0	0	785	0	0	1199
Demand Control	**128**	**0.14**	**1014**	**2035**	**0.23**	**1255**

Demand control has the highest savings

Data/Findings- Recirc. System Design

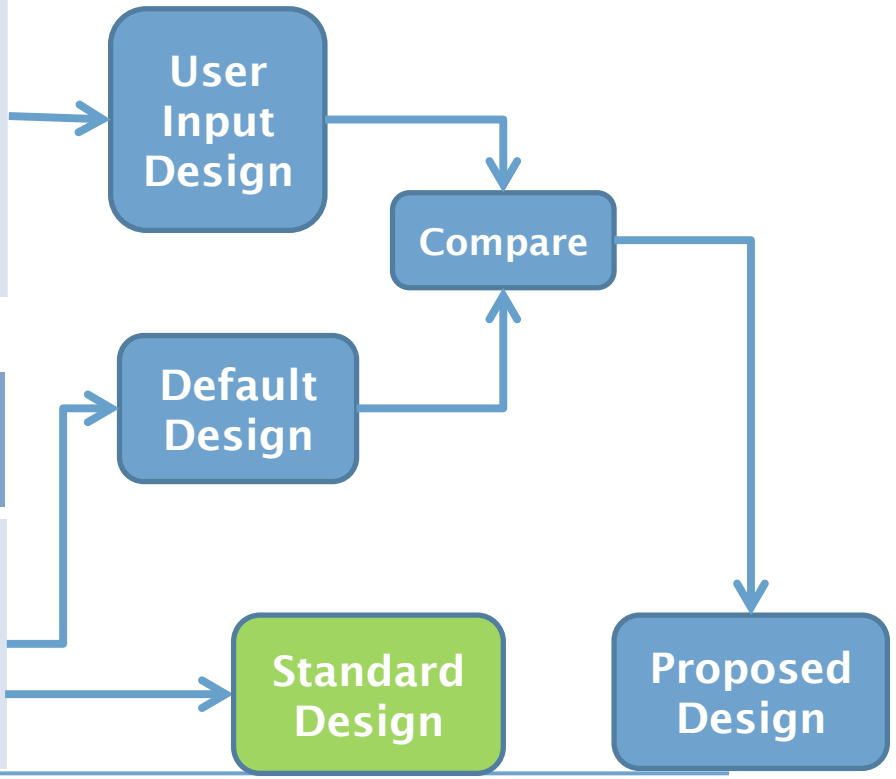
- Standard & Default Designs

USER INPUT

- Building Story, floor area
- Number of apartment/guest room
- Boiler room Location
- Number of Loops
- Supply and Return Loop section locations and length

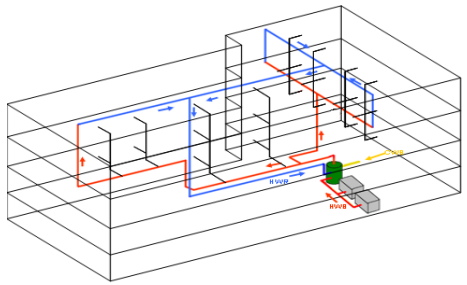
ACM Generate Standard & Default Loop Configuration

- Recirculation loop path
- Branch length and number
- Pipe diameters (Follow UPC)
- Pipe insulation thickness



Data/Findings – Default Design

User Inputs



4 stories / 2 loops

Supply Recirculation Pipe

Section #1	Section #2	Section #3
10	30	
Unconditioned Space 2”	Conditioned Space 2”	

Return Recirculation Pipe

Section #1	Section #2	Section #3
30	10	
Conditioned Space 1”	Unconditioned Space 3/4”	

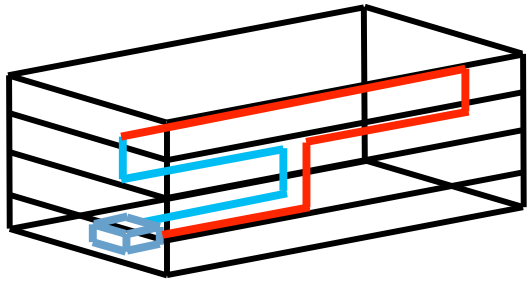
Generate ACM Default

Pipe surface area < Default?

No → **Keep user input**

Yes → **Pipe surface area adjustment factor**

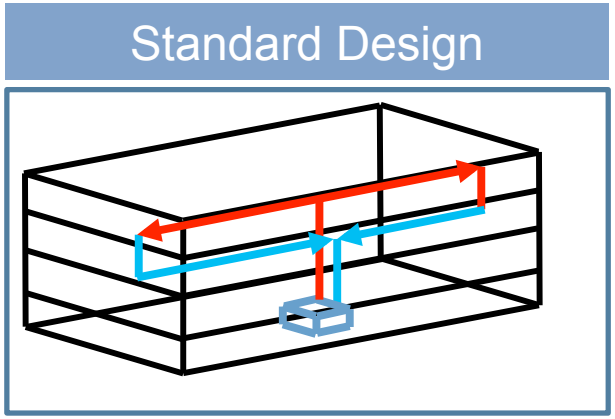
Default Design



	Supply	Return
Loop 1	80 ft	80 ft
Loop 2	80 ft	80 ft
Total	320 ft	

Data/Findings – Standard Design

- Dual loop design
  - Boiler room near the middle of the building
    - Any floor - 1st floor, garage, roof, middle floor
  - Smaller pipe diameters → less surface area
  - Smaller temp drop (not included in savings calc.)
- Verification
  - Res: HERS
  - NR: follow Appendix NA2
    - NR Field Verification & Diagnostic Test Procedures



Data/Findings – Annual Energy Savings

- Demand control as prescriptive requirement

Per Building	Low-rise			High-rise		
	kWh	kW	Therm	kWh	kW	Therm
Demand Control	1,228	0.139	1,083	2,035	0.232	1,359
Demand Control + Plumbing Design	1,429	0.163	1,456	2,651	0.303	2,062

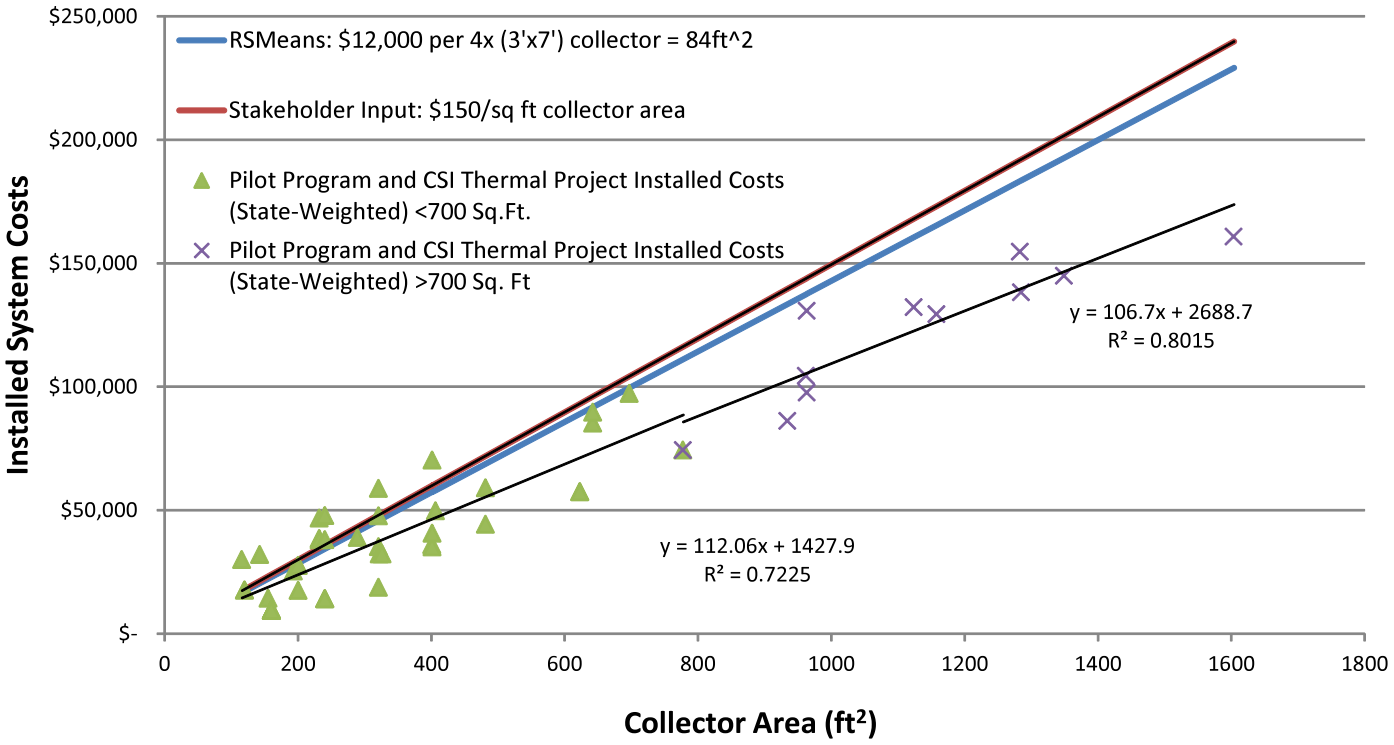
Data/Findings – SWH Energy Savings

- TRANSYS modeling: SWH used as a pre-heater
- Flat plate w/ active glycol (external HX); CZ 10 as an example

Building Prototype	Collector Sizing	Electricity Savings	Natural Gas Savings	TDV Electricity Savings	TDV Gas Savings	Base Code: PV of Energy Cost Savings	Reach Code: PV of Energy Cost Savings
	sf per gal/day	(kwh/yr)	(Therms/yr)	(TDV kBTU)	(TDV kBTU)	(PV$)	(PV$)
Low Rise	0.1	332	500	(8,041)	76,105	$11,788	$15,790
Low Rise	0.2	638	1,137	(15,303)	175,242	$27,699	$37,059
Low Rise	0.3	937	1,692	(22,314)	262,090	$41,526	$55,550
Low Rise	0.4	1,223	2,222	(29,077)	345,192	$54,747	$73,231
Low Rise	0.5	1,460	2,676	(33,437)	417,279	$66,477	$88,898
Low Rise	0.6	1,642	3,005	(35,936)	470,551	$75,270	$100,633
Low Rise	0.7	1,783	3,270	(37,602)	514,518	$82,596	$110,404
Low Rise	0.8	1,909	3,488	(39,312)	550,812	$88,586	$118,398
High Rise	0.1	596	754	(14,442)	113,413	$15,241	$20,823
High Rise	0.2	1,219	2,073	(29,233)	318,698	$44,575	$60,732
High Rise	0.3	1,828	3,206	(43,602)	495,875	$69,646	$94,864
High Rise	0.4	2,411	4,305	(57,327)	668,160	$94,062	$128,102
High Rise	0.5	2,901	5,242	(66,626)	816,588	$115,487	$157,231
High Rise	0.6	3,265	5,948	(71,605)	931,161	$132,363	$180,146
High Rise	0.7	3,564	6,490	(75,191)	1,020,478	$145,565	$198,067
High Rise	0.8	3,831	6,931	(79,079)	1,093,796	$156,256	$212,594

Data/Findings – SWH Installation Cost

- Depends on collector size and other design parameters
- Expected to decrease in future (not included in the CASE)



Data/Findings – Maintenance Costs

- Component Life Expectancy
- Maintenance Cost Table

Component	Life Expectancy (yr)	Implementations during Building Life
Collector	20	1.5
Solar Tank	15	2
Motor and Pump	10	3
Controller	20	1.5
Heat Transfer Fluid Check	1	20
Heat Transfer Fluid Check & Replacement	3	10

Building Prototype	Measure Life (Years)	Collector Sizing	PV of Add'l Maintenance Costs (Savings)
		sf per gal/day	(PV$)
Low-Rise	30 Res	0.1	$ 5,213
Low-Rise	30 Res	0.2	$ 7,999
Low-Rise	30 Res	0.3	$ 10,786
Low-Rise	30 Res	0.4	$ 13,572
Low-Rise	30 Res	0.5	$ 16,359
Low-Rise	30 Res	0.6	$ 19,145
Low-Rise	30 Res	0.7	$ 21,932
Low-Rise	30 Res	0.8	$ 24,718
High-Rise	30 NR	0.1	$ 11,054
High-Rise	30 NR	0.2	$ 17,045
High-Rise	30 NR	0.3	$ 23,036
High-Rise	30 NR	0.4	$ 29,027
High-Rise	30 NR	0.5	$ 35,018
High-Rise	30 NR	0.6	$ 41,009
High-Rise	30 NR	0.7	$ 47,000
High-Rise	30 NR	0.8	$ 52,991

LCC Analysis – Prescriptive Packages

- Prescriptive requirements to provide compliance flexibility
- Three levels of requirements with increased savings
  - Level 1: Demand Control only
  - Level 2: Demand Control + Optimal Recirc. Design
  - Level 3: Demand Control + Optimal Recirc. Design + Solar Water Heating