REPI- 142-21

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SUMMARY

For REPI-142-21, utilizing the proposed language in REPI-91-21, the TRC team, representing BetterBuiltNW and the Northwest Energy Efficiency Alliance expanded the analysis and performed LCC savings and Simple Paybacks. The REPI-142-21 proposal was found to have net positive savings for all scenarios with the 16-ounce or 1 pint language as proposed.

This analysis by TRC/BetterBuiltNW was done to introduce a new potential energy efficiency measure for section R408 that aligns with savings already approved for the ERI path in the 2021 IECC-Residential Code.

This proposal recognizes that for this measure to be both effective and efficient, a useful hot water temperature of at least 105°F must be achieved in reasonable time at the tap. The analysis used savings estimates for this scenario.

CODE LANGUAGE PROPOSED:

408.2.6 (N1108.2.6) Compact Hot Water Distribution

For Compact Hot Water Distribution system credit, the volume shall store not more than 16 ounces of water in the piping between the hot water source and any hot water fixture when calculated using section R403.5.4 and R403.5.4.1.

To field or plan review verify that the system meets the prescribed limit, one of the following must be done:

1. At plan review
   a. Referencing ounces of water per foot of tube on plans as per Table R403.5.4.1
2. At rough in (plumbing)
   a. Referencing ounces of water per foot of tube installed as per Table R403.5.4.1
3. At final inspection
   a. In accordance with Department of Energy's Zero Energy Ready Home National Specification (Rev. 07 or higher) footnote on Hot water delivery systems.

REASON STATEMENT

This section is being re-submitted to better align with credit provided for compact hot water distribution outlined in section R405.4 and Table R405.4.2(1), building component “service water heating,” utilizing HWDS or the factor

for the compactness of the hot water distribution system. Inefficient hot water distribution systems have been recognized as a problem for many years as they result in energy and water waste, and result in long hot water delay times that are the cause of a considerable number of complaints by new home buyers. Recirculation systems are a solution to two of the three problems (water and wait time), but the thermal energy impact of different recirculation systemoptions has already been addressed in section **R403.5.1.1 Circulation system.**[1]

In all non-recirculation distribution options, water heater energy consumption and hot water waste are correlated. A decrease in water heater energy consumption follows a reduction in wasted water; therefore, improving insulation and reducing the piping length and/or pipe diameter have equal benefits for energy and water waste. In recirculation systems, water heater energy consumption and wasted hot water are independent, and often have an inverse effect (when recirculation is not demand based).[2]

This distribution system problem exists for a variety of factors including:

- An outdated pipe sizing methodology in the plumbing code that results in oversized hot water distribution systems since the assumed fixture flow rates are much higher than current requirements.
- Municipalities with design recommendations that force plumbers and designers to assume low supply water pressure, resulting in larger distribution piping, which waste more water and energy.
- Increasing efforts to conserve water has resulted in the realization of water savings due to improvements in showerhead and lavatory maximum flow rates; however, reduced flow rates often result in increased wait times if the hot water distribution system is not designed to accommodate lower flows.
- Increasing popularity of gas instantaneous water heaters, which offer improved operating efficiency, but can result in increased water waste when starting from a "cold start up" situation.
- Inefficient plumbing installations that are not focused on minimizing pipe length or pipe diameters.

The IECC has already addressed pipe insulation and Circulation systems in the 2021 IECC Residential provisions.

[1] *Residential Compact Domestic Hot Water Distribution Design:Balancing Energy Savings, Water Savings, and Architectural Flexibility* Farhad Farahmand, TRC Companies and Yanda Zhang, ZYD Energy

[2] *Evaluating Domestic Hot Water Distribution System Options With Validated Analysis Models* E. Weitzel and M. Hoeschele, Alliance forResidential Building Innovation

METHODOLOGY

REPI-142-21 was written to better align with the ERI, outlined in section R405.4 and Table R405.4.2(1) process for accounting for energy savings from compact hot water design, the methodology to address savings was taken threefold. First, savings calculated for the Codes and Standards Enhancement (CASE) Initiative, Compact Hot Water Distribution – Final Report, Measure Number: 2019-RES-DHW1-F were used as detailed analysis had already been completed and approved for Title 24 Code. Second, savings estimates were pulled from the California Energy Commission's Energy Research and Development Division Final Project Report: Code Changes and Implications of Residential Low-Flow Hot Water Fixtures, September 2021, CEC-500-2021-043. Finally, an average home 2,121 sq ft over two stories was modeled in REM/Rate v16.0.6 in 8 IECC climate zone locations, with Default, 1 quart, and 1 pint of water in the pipe savings.

Water savings are also estimated based on utilizing the first two approaches for analysis.

The savings below are averaged across approaches.

SAVINGS

This analysis focused on Therms and Water Savings as it is estimated that over 75% of Residential New Construction Water Heaters installed are gas tankless systems in California where many of the savings have already been accepted and analyzed. Nationally, ~68% of Residential New Construction Domestic Hot Water systems are gas fueled, according to the *Home*

Innovation Research Lab 's Annual Builder Practices Survey, 2021[4].

Climate Zone	Savings in Therms for 1 Pint	Savings in Therms for 1 Quart	Savings dollars 2021 EIA Nat Gas at 0.95 $/Therm Pint	Savings dollars 2021 EIA Nat Gas at 0.95 $/Therm Quart
2 and 3	13.33	8.77	12.66	8.33
4 and 5	18.65	10.97	17.74	10.42
6 and 7	20.5	11.8	19.48	11.09

These savings are rolled up from all three sources below and conservative values were taken whenever possible.

Average cost savings using a mixed, but not weighted combination of climate zone results were found to be as follows for calculated and calculated with conservation multiplier as such:

Savings in Therms for 1 Pint	Savings in Therms for 1 Quart	Savings dollars 2021 EIA Nat Gas at 0.95 $/Therms Pint	Savings dollars 2021 EIA Nat Gas at 0.95 $/Therms Quart
13.33	8.77	12.66	8.33
18.65	10.97	17.74	10.42
20.5	11.8	19.48	11.09
		$16.63 Average	$9.95 Average
		$13.37 w/ 0.8 conservative multiplier	$7.96 w/ 0.8 conservative multiplier

Energy Savings Compact Hot Water Distribution Design: **Title 24 CASE Report**

The following savings have been calculated for compact domestic hot water distribution only, as Drain Water Heat Recovery has already been included in the 2021 IECC. The California Energy Codes & Standards Case Report for *Compact Hot Water Distribution.* Measure Number: 2019-RES-DHW1-F, Residential Plumbing [3] performed savings analysis using 16 California climate zones. This analysis focused on Therm and Water Savings as it's estimated that over 75% of Residential New Construction Water Heaters installed are gas tankless systems. Nationally, ~68% of Residential New Construction Domestic Hot Water systems are gas fueled, according to the *Home Innovation Research Lab 's Annual Builder Practices Survey, 2021*[4]. California's climate zones correlate to IECC Climate Zones 2, 3b, 3c, 4c, 5b, and 6. Savings estimated should be conservative for climate zones 4c and higher as ground temperatures and therefore incoming water temperatures in California homes may be 1 to 3°F higher than in these cooler climates.

In climate zones 3b and lower, first year weighted average residential energy savings (translated from Therms/yr to Mmbtu/yr) are estimated to be per Single Family Home: Climate Zone Savings in Therms Savings in Mmbtu[2] are estimated to be per Single Family Home:

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Climate Zone	Savings in Therms (1 quart volume)	Savings dollars 2021 EIA Nat Gas of 0.95 $/Therm
2 and 3b	4.48	4.26
3c through 5	5.57	5.29
6 and 7 (extrapolated)	6.68	6.35

These estimates come from assumption of a 2,430 sq fthome with 3.5 bedrooms.

Energy Savings Compact Hot Water Distribution Design: CEC Code Changes and Implications of Residential Low-Flow Hot Water Fixture

The process used to assess cost-effectiveness was straightforward.

1. Determine a plan for the hot water, cold water, drain lines for fixtures and condensate, vent stacks for piping and gas, gas piping and electrical line for the baseline case hot water distribution system (provided in Chapter 5).

2. Calculate the material and labor costs for each part of the system.

- Materials are estimated primarily based on length, with an allowance for fittings.
- Labor is estimated based primarily on the hours to complete the installation.
- Material and labor costs are derived from the Plumbing Heating and Cooling Contractors (PHCC) cost estimator
- Only those parts of the system that changed were included in the analysis. For example, the vertical drops from the branches to the fixtures and appliances did not change so they were not included in the cost analysis.

3. Evaluate the cost differences for those strategies

Code Changes document

CZ/volume-based savings	1 pint savings in Therms/yr	1 quart savings in Therms/yr
CZ 3 through 5	19	11

Savings connected with maximum approach (1 pint in pipe + low-flow) and average approach (1.5 to 2 pint + federal minimum flow fixtures) and were analyzed in a 2,100 sq ft single story home and a 2,700 sq ft two-story home.

Energy Savings Compact Hot Water Distribution Design: REM/Rate analysis

The BetterBuiltNW team analyzed a 2,121 sq ft two-story home using RESNET/ANSI/IECC Standard 301 Default hot water system design (equivalent longest length of hot water pipe) against a 30% and 15% Compactness ratio factor and associated HWDS factor, based on the size if hot water footprint as calculated by ERI requirements 2021 IECC Table R405.4.2(1). To keep consistency with other analysis, the source of hot water was generated with a 0.95 EF Tankless Gas Water Heater.

Average utility rates of utility costs were based on 2021 EIA posted rates of:

- $0.13/kWh
- $0.95/Therms

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This home was modeled in 8 climate zones across the United States for comparative analysis.

Location	CZ	Default Costs	30%	15%	Avg	Max
Spokane, WA	5B	121	108	102	16	19
Fresno, CA	3B	85	76	72	11	13
Seattle, WA	4C	109	97	92	14	17
Atlanta, GA	3A	90	80	76	12	16
Missoula, MT	6B	126	112	106	17	20
Toledo, OH	5A	118	105	99	16	19
Minot, ND	7B	134	119	113	18	21
Austin, TX	2A	74	66	63	9.5	11
Average					14.19	17

Savings were then combined into buckets for warm, mixed, and cold climates.

CZ/volume	1 pint savings (Max)	1 quart savings (Avg)
2 and 3	(11+16+13)/3=13.3333	(11+12+9.5)/3=10.8333
4 and 5	(17+19+19)/3=18.3333	(16+17+16)/3=16.3333
6 and 7	(20+21)/2=20.5	(16+18)/2=17

Water Savings

Estimated impacts on water use are presented in the table below. Water use savings estimates are challenging given that hot water usage behaviors among individuals and households are highly variable and can depend strongly on the demographics of the household (Parker, D.; Fairey, P.; and Lutz, J.; 2015). In addition, the proposed compliance option approach ensures that compliant hot water distribution systems will be smaller than a conventional non-compact system but cannot precisely specify the design and configuration and hence the impacts on water waste. To provide a best approximation of water savings impacts, the Statewide CASE Team in California relied on detailed distribution simulation study completed under the U.S. Department of Energy's Building America program (Weitzel, E.; Hoeschele, M. 2014). In these estimates, it was assumed that all water savings occur indoors.

An average cost of $3/1000 gallons was used to estimate water savings.

Impacts on Water Use Table:

Analysis	1 pint	1 quart	$/gall
CEC report	1750		(1750/1000)*3=5.25
CASE		962	(962/1000)*3=2.89

Title 24 CASE Report	**On-Site Indoor Water Savings (gal/yr)**
Per Dwelling Unit Impacts (single family)	962
Per Dwelling Unit Impacts (multifamily)	321

CEC Code Implications Report	**On-Site Indoor Water Savings (gal/yr)**
Per Dwelling Unit Impacts (single family)	1,750

INCREMENTAL COST

Incremental cost findings from the California Energy Commission's Energy Research and Development Division Final Project Report: Code Changes and Implications of Residential Low-Flow Hot Water Fixtures, September 2021, CEC-500-2021-043 indicate that there may be up to $1,500 cost savings for designing and installing a system with less materials and with greater work efficiency due to reduced plumbing layout. The Codes and Standards Enhancement (CASE) Initiative, Compact Hot Water Distribution – Final Report, Measure Number: 2019-RES-DHW1-F reported that incremental cost is highly scenario dependent, but overall determined that there would be little to no cost increase.

For the purposes of this analysis, we assumed that while incremental costs are likely to be neither higher, nor lower than standard plumbing designs, a small incremental cost of $300 would cover the bases for an increased number of potential scenarios.

LCC

Life-cycle costs were calculated using the IECC-Residential LCC Calculator.

The most conservative estimated water savings were used for both 16 ounce and 32-ounce volume in pipe between fixture and hot water source was used for both LCC calculations.

Using energy savings for 16-ounce (1 pint) and water savings for 32-ounce scenarios, the LCC shows Simple Payback of 13.42 years for LCC with social cost of carbon (SCC) included. The LCC without SCC showed a Simple Payback of 16.07 years.

Measure Incremental LCC in both scenarios were found to be as follows:

16-ounce or 1-pint scenario:

Results					
	Discount Rate				
	3% nominal	3% real	7% real		
	DOE	OMB	OMB		
With SCC value					
Measure incremental LCC	$311.96	$232.33	$157.20		2020$ (+ for savings, - for increased cost)
Simple payback				13.42	Years
With SCC = $0					
Measure incremental LCC	$221.03	$141.40	$66.27		2020$ (+ for savings, - for increased cost)
Simple payback				16.07	Years

32-ounce or 1 quart scenario:

Results					
	Discount Rate				
	3% nominal	3% real	7% real		
	DOE	OMB	OMB		
With SCC value					
Measure incremental LCC	$94.03	$64.15	$37.69		2020$ (+ for savings, - for increased cost)
Simple payback				20.72	Years
With SCC = $0					
Measure incremental LCC	$39.90	$10.02	($16.45)		2020$ (+ for savings, - for increased cost)
Simple payback				24.42	Years

COST EFFECTIVENESS

As indicated in the LCC as seen above and using energy savings for 16-ounce (1 pint) and water savings for 32-ounce scenarios, the LCC shows Simple Payback of 13.42 years for LCC with social cost of carbon (SCC) included. The LCC without SCC showed a Simple Payback of 16.07 years.

When using the 32-ounce or 1 quart savings, the LCC shows Simple Payback of 20.72 years for LCC with social cost of carbon (SCC) included. The LCC without SCC showed a Simple Payback of 24.42 years.

REFERENCES

- *Residential Compact Domestic Hot Water Distribution Design: Balancing Energy Savings, Water Savings, and Architectural Flexibility* Farhad Farahmand, TRC Companies; Yanda Zhang, ZYD Energy
- *Evaluating Domestic Hot Water Distribution System Options With Validated Analysis Models* **E.** Weitzel and M. Hoeschele Alliance for Residential Building Innovation

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- California Energy Codes & Standards Case Report for *Compact Hot Water Distribution;* Measure Number: 2019-RES-DHW1-F, Residential Plumbing
- Home Innovation Research Labs Annual Builder Practices Survey, 2021
- Department of Energy Zero Energy Ready Home National Program Requirements (Rev. 07) [footnote 15)
- Efficient hot water distribution system - USBGC **LEED** BD+C: Homes *v4-* **LEED** *v4*
- Residential Hot Water Distribution Systems: Roundtable Session; JD Lutz, Lawrence Berkely National Laboratory; G Klein, California Energy Commission; D Springer, Davis Energy Group; BO Howard, Building Environmental Science & Technology
- Code Changes and Implications of Residential Low-Flow Hot Water Fixtures – CEC-500-2021-043. Gary Klein, Jim Lutz, Yanda Zhang, John Koeller.
- Time-to-Tap and Volume-until-Hot – Water, Energy, and Time Efficient Hot Water Systems. 2020 Educational Institute, March 2020, Gary Klein presentation.