



ASHRAE 2 – Chiller Efficiency Stakeholder Meeting 3

California Statewide Utility Codes and Standards Program

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ASHRAE 2 – Chiller Efficiency

Overview

- Chiller efficiency unchanged since 2001
- Chillers not federally pre-empted but T24 has always followed 90.1
- 90.1-2010 (2007 Addenda M, BL & BT)
 - Higher efficiencies and two paths for compliance (Path A & Path B)
 - Deleted category of air-cooled chiller without condenser
 - Consolidated positive displacement chillers (screw, scroll & reciprocating)
 - Extended range of non-standard “k” equation

ASHRAE 2 – Chiller Efficiency

Overview

- Proposal for Title 24 2013
 - Mandatory
 - Adopt 90.1 Chiller Efficiencies Paths A & B
 - Delete air-cooled without condenser
 - Consolidate positive displacement chillers (screw, scroll & reciprocating)
 - Adopt new non-standard “k” equation
 - Delete non-standard tables 112-H, I, J, K, L, M
 - Prescriptive Path
 - Require path B based on LCC
 - Provide exceptions as noted in following slides
 - Performance Path
 - Budget system to follow Prescriptive requirements

ASHRAE 2 – Chiller Efficiency

Definitions

ARI 550/590 is the Air-conditioning and Refrigeration Institute document entitled “Standard for Water Chilling Packages Using the Vapor Compression Cycle,” ~~1998~~2003 (ARI 550/590-~~98~~03).

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Proposed Code Change Mandatory

New Table 112D

Equipment Type	Size Category	Units	Before 1/1/2010		As of 1/1/2010 ^b				Test Procedure ^c
			Full Load	IPLV	Path A		Path B		
					Full Load	IPLV	Full Load	IPLV	
Air-cooled chillers	<150 tons	EER	≥9.562	≥10.416	≥9.562	≥12.500	NA ^d	NA ^d	ARI 550/590
	≥150 tons	EER	≥9.562	≥10.416	≥9.562	≥12.750	NA ^d	NA ^d	
Air-cooled without condenser, electrical operated	All capacities	EER	≥10.586	≥11.782	Air-cooled chillers without condensers must be rated with matching condensers and comply with the air-cooled chiller efficiency requirements.				
Water-cooled, electrically operated, reciprocating	All capacities	kW/ton	≤0.837	≤0.696	Reciprocating units must comply with water-cooled positive displacement efficiency requirements				
Water-cooled, electrically operated, positive displacement	<75 tons	kW/ton	≤0.790	≤0.676	≤0.780	≤0.630	≤0.800	≤0.600	
	≥75 tons and <150 tons	kW/ton	≤0.790	≤0.676	≤0.775	≤0.615	≤0.790	≤0.586	
	≥150 tons and <300 tons	kW/ton	≤0.717	≤0.627	≤0.680	≤0.580	≤0.718	≤0.540	
	≥300 tons	kW/ton	≤0.639	≤0.571	≤0.620	≤0.540	≤0.639	≤0.490	

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Proposed Code Change Mandatory

New Table 112D

Equipment Type	Size Category	Units	Before 1/1/2010		As of 1/1/2010^b				Test Procedure ^c
			Full Load	IPLV	Path A		Path B		
					Full Load	IPLV	Full Load	IPLV	
Water-cooled, electrically operated, centrifugal	<150 tons	kW/ton	≤0.703	≤0.669	≤0.634	≤0.596	≤0.639	≤0.450	
	≥150 tons and <300 tons	kW/ton	≤0.634	≤0.596	≤0.634	≤0.596	≤0.639	≤0.450	
	≥300 tons and <600 tons	kW/ton	≤0.576	≤0.549	≤0.576	≤0.549	≤0.600	≤0.400	
	≥600 tons	kW/ton	≤0.576	≤0.549	≤0.570	≤0.539	≤0.590	≤0.400	
Air-cooled absorption, single effect	All capacities	COP	≥0.600	NR ^e	≥0.600	NR ^e	NA ^d	NA ^d	ARI 560
Water-cooled absorption, single effect	All capacities	COP	≥0.700	NR ^e	≥0.700	NR ^e	NA ^d	NA ^d	
Absorption double-effect, indirect-fired	All capacities	COP	≥1.000	≥1.050	≥1.000	≥1.050	NA ^d	NA ^d	
Absorption double-effect, direct-fired	All capacities	COP	≥1.000	≥1.000	≥1.000	≥1.000	NA ^d	NA ^d	

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Proposed Code Change Mandatory New Table 112D Notes

- a. No requirements for:
 - Centrifugal chillers with Tchws_des<36F
 - Positive displacement chillers with Tchws_des<32F
 - Absorption chillers with Tchws_des<40F
- b. Must meet both COP and IPLV of either Path A or B
- c. See Section 101 Definitions
- d. NA means not applicable
- e. NR means no minimum requirement in this field

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Proposed Code Change Kadj Exception to 112(a) 1 of 3

EXCEPTION to Section 112(a): ~~Water-cooled centrifugal water-chilling packages that are not designed for~~

~~operation at ARI Standard 550 test conditions of 44°F leaving chilled water temperature and 85°F entering condenser water temperature shall have a minimum full load COP rating as shown in TABLE 112-H, TABLE 112-I, and TABLE 112-J, and a minimum NPLV rating as shown in TABLE 112-K, TABLE 112-L, and TABLE 112-M. The table values are only applicable over the following full load design ranges:~~

~~Leaving Chiller Water Temp. 40 to 48°F~~

~~Entering Condenser Water Temp. 75 to 85°F~~

~~Condensing Water Temp. Rise 5 to 15°F~~

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Proposed Code Change K_{adj} Exception to 112(a) 2 of 3

EXCEPTION to Section 112(a): Water-cooled centrifugal chillers not designed for operation at ARI Standard 550/590 test conditions of 44°F leaving chilled-water temperature and 85°F entering condenser water temperature with 3 gpm/ton condenser water flow shall have maximum full-load kW/ton and NPLV ratings adjusted using the following equation:

$$\text{Adjusted maximum full-load kW/ton rating} = \frac{\text{full-load kW/ton from Table 112D}}{K_{adj}}$$

$$\text{Adjusted maximum NPLV rating} = \frac{\text{IPLV from Table 112D}}{K_{adj}}$$

where

$$K_{adj} = A * B$$

$$A = \frac{0.00000014592 * (\text{LIFT})^4 - 0.0000346496 * (\text{LIFT})^3 + 0.00314196 * (\text{LIFT})^2 - 0.147199 * (\text{LIFT}) + 3.9302}{}$$

$$\text{LIFT} = \text{LvgCond} - \text{LvgEvap} \text{ (°F)}$$

$$\text{LvgCond} = \text{Full-load leaving condenser fluid temperature (°F)}$$

$$\text{LvgEvap} = \text{Full-load leaving evaporator fluid temperature (°F)}$$

$$B = 0.0015 * \text{LvgEvap} + 0.934$$

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Proposed Code Change Kadj Exception to 112(a) 3 of 3

EXCEPTION to Section 112(a):

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The adjusted full-load and NPLV values are only applicable for centrifugal chillers meeting all of the following full-load design ranges:

- Minimum Leaving Evaporator Fluid Temperature: 36°F
- Maximum Leaving Condenser Fluid Temperature: 115°F
- LIFT \geq 20°F and \leq 80°F

Centrifugal chillers designed to operate outside of these ranges are not covered by this standard.

EXCEPTION to Section 112(a): Positive displacement (air- and water-cooled) chillers with a leaving evaporator fluid temperature higher than 32°F, shall show compliance with Table 112D when tested or certified with water at standard rating conditions, per the referenced test procedure.

Proposed Code Change Prescriptive

- Lowest LCCA Either Path A or B (B likely)
- Exceptions for
 - Chillers with electrical service >600V
 - Chillers attached to a heat recovery system with a design heat recovery capacity of >40% of the design chiller cooling capacity
 - Chillers used to charge TES systems where the charging temperature is <40F
 - Chillers installed in plants with more than 3 chillers

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Industry Comments 1 of 2

ISSUE

- Misuse of IPLV in our analysis
- Failed to factor costs of VSDs
- Failed to factor electrical demand

RESPONSE

- We did not use IPLV, we used full DOE2 curves
- We used ARI's costs for this analysis
VSDs win most of our performance bids
- TDVs employed in analysis include electrical demand

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Industry Comments 2 of 2

ISSUES

- High voltage chiller costs for VSDs
- High Lift Operation
 - Heat recovery chillers
 - TES
- Large chiller plants

RESPONSE

- All of these are addressed in our proposal as exceptions

ASHRAE 2 – Chiller Efficiency

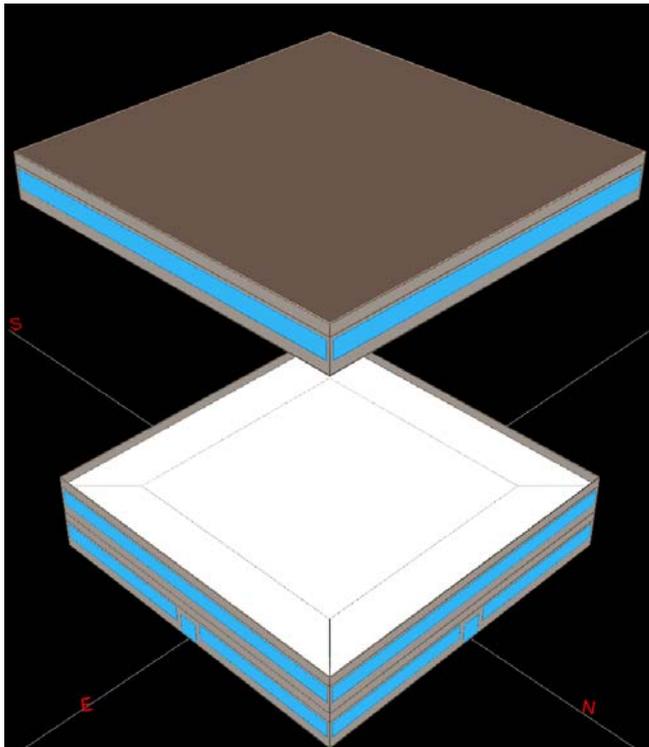
Estimated Energy Savings

- Energy savings estimated by energy model

- Large office building (10 floors, 100,000 sqft)
- 5 zones per floor
- Undiversified internal loads

	Lighting (W/sqft)	Equipment (W/sqft)	Occupancy (sqft/person)
1st floor perimeter zones	1.00	0.52	100
1st floor interior zone	0.76	0.34	215
2nd - 8th floor perimeter zones	1.31	1.48	85
2nd - 8th floor interior zones	1.05	0.98	80

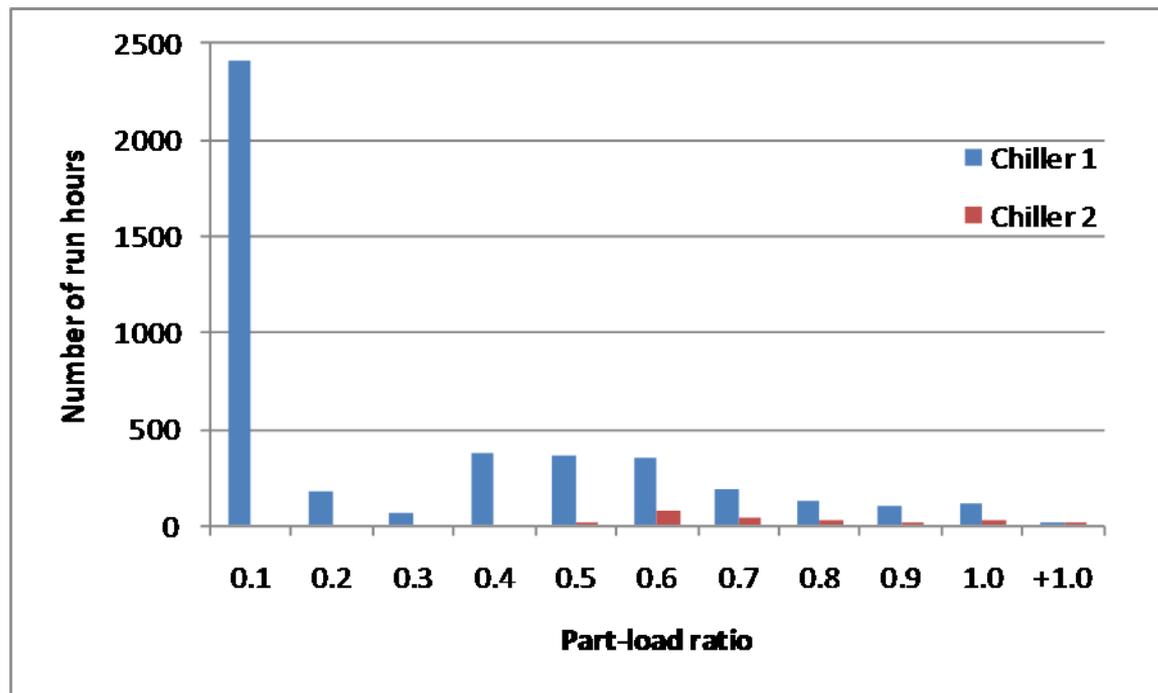
- System: large VAV AHU with CWH & HW coils, 55°F SAT
- Chiller plant
 - 2 equally-sized chillers
 - Chillers sized based on load
 - 1 2-cell cooling tower (water-cooled chillers)
 - CHW loop: 10°F delta T, CW loop: 18°F delta T
 - CHWST: 44°F with reset up to 47°F, CWST: fixed 65°F



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Estimated Energy Savings

- Chiller load profile, CZ 03: shows majority of hours are at low load condition.

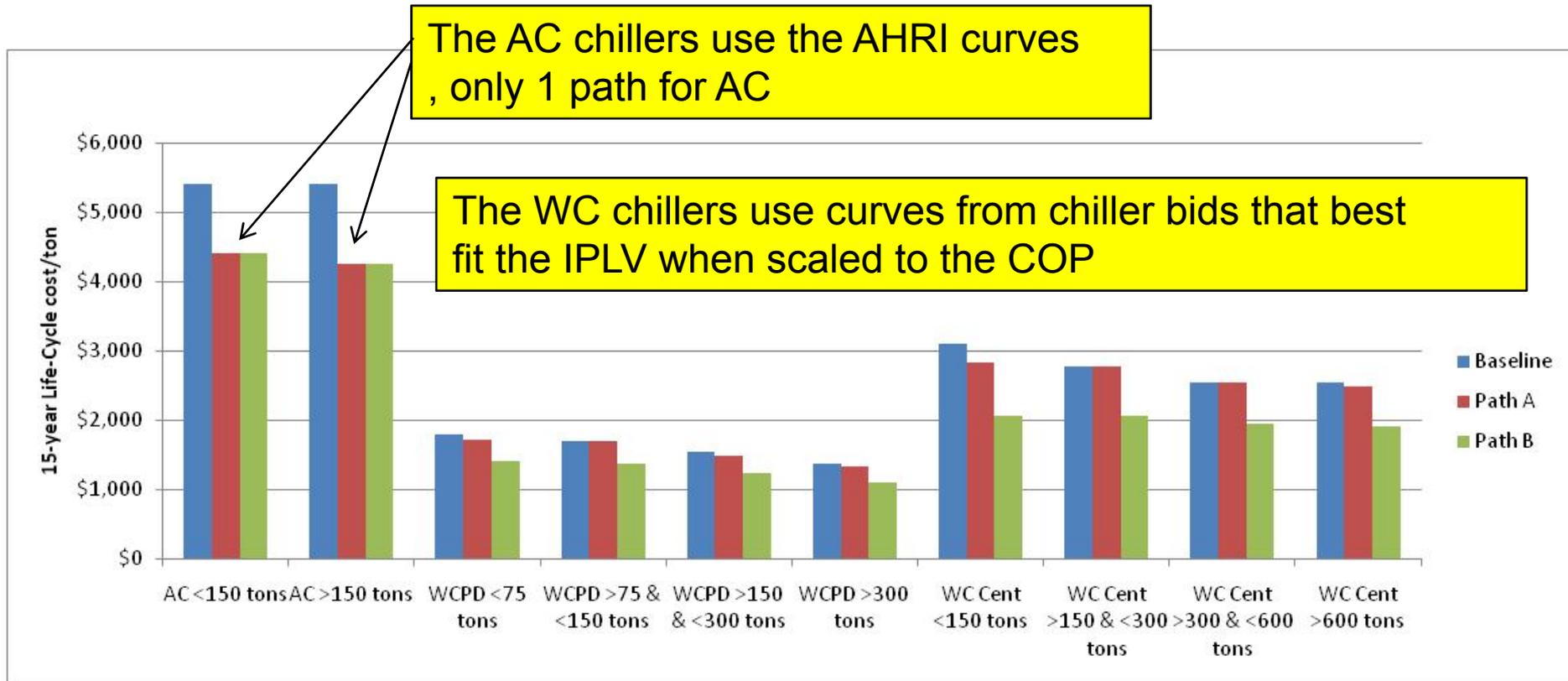


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LCC Results

CZ03

Lower is better (PV energy and cost)

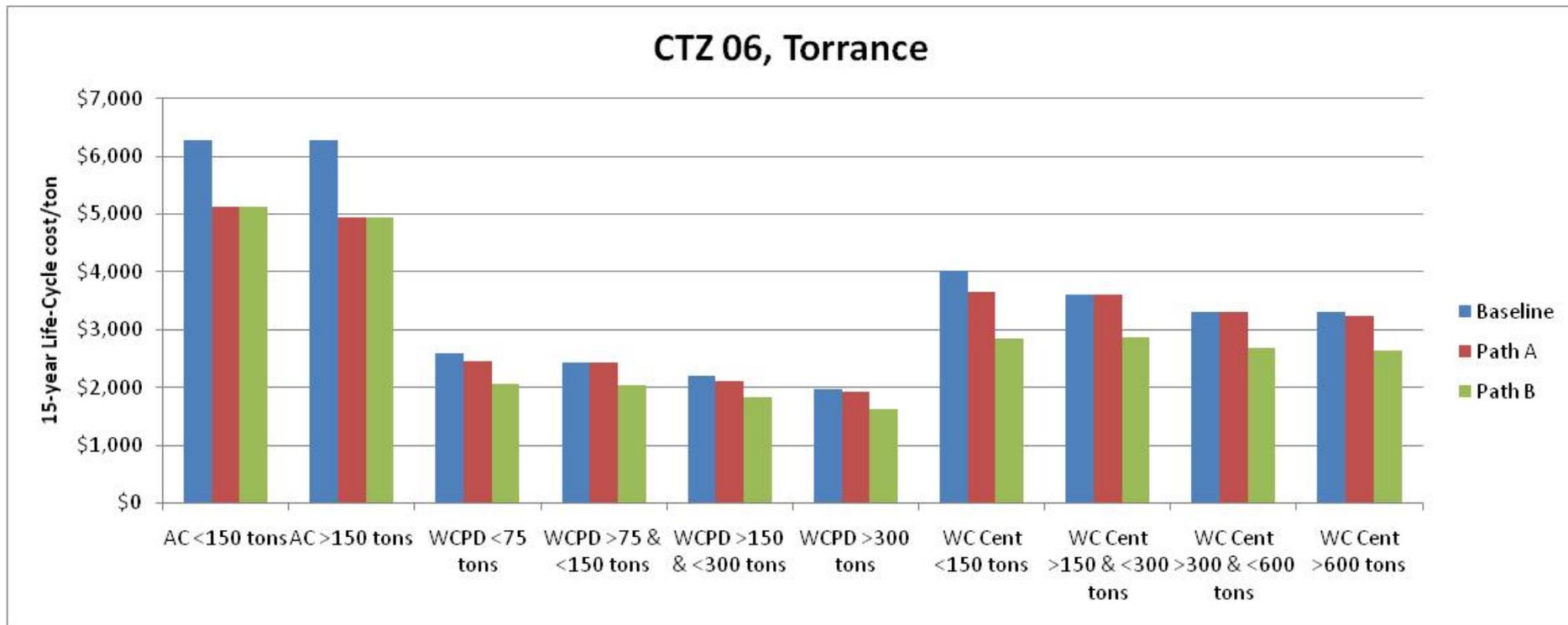


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LCC Results

CZ06

Lower is better (PV energy and cost)

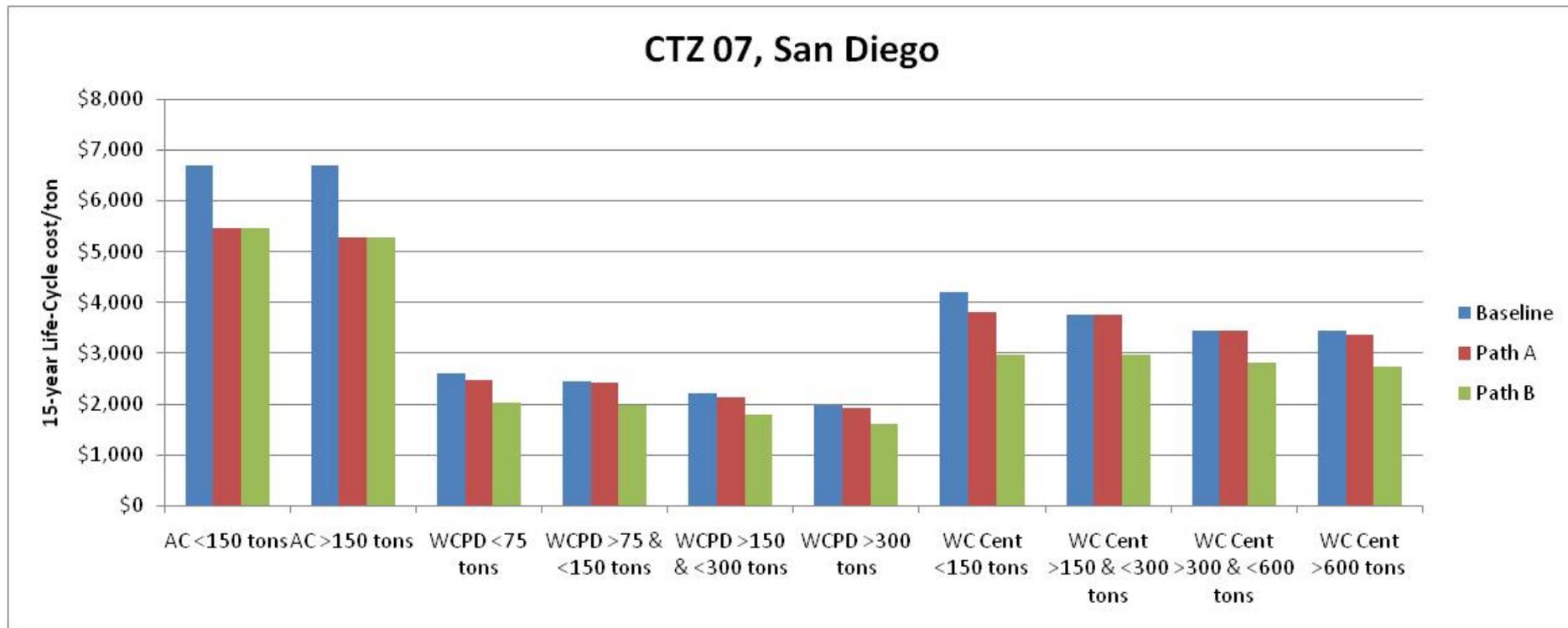


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LCC Results

CZ07

Lower is better (PV energy and cost)

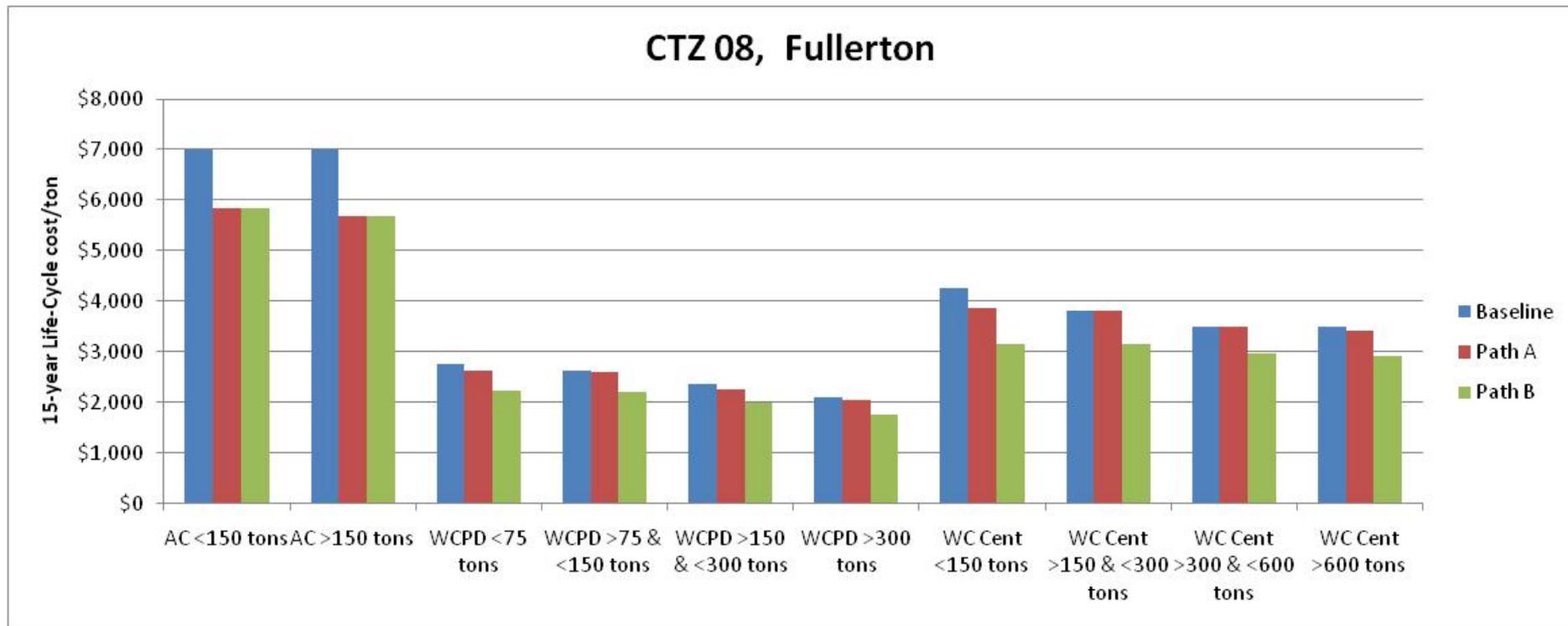


ASHRAE 2 – Chiller Efficiency

LCC Results

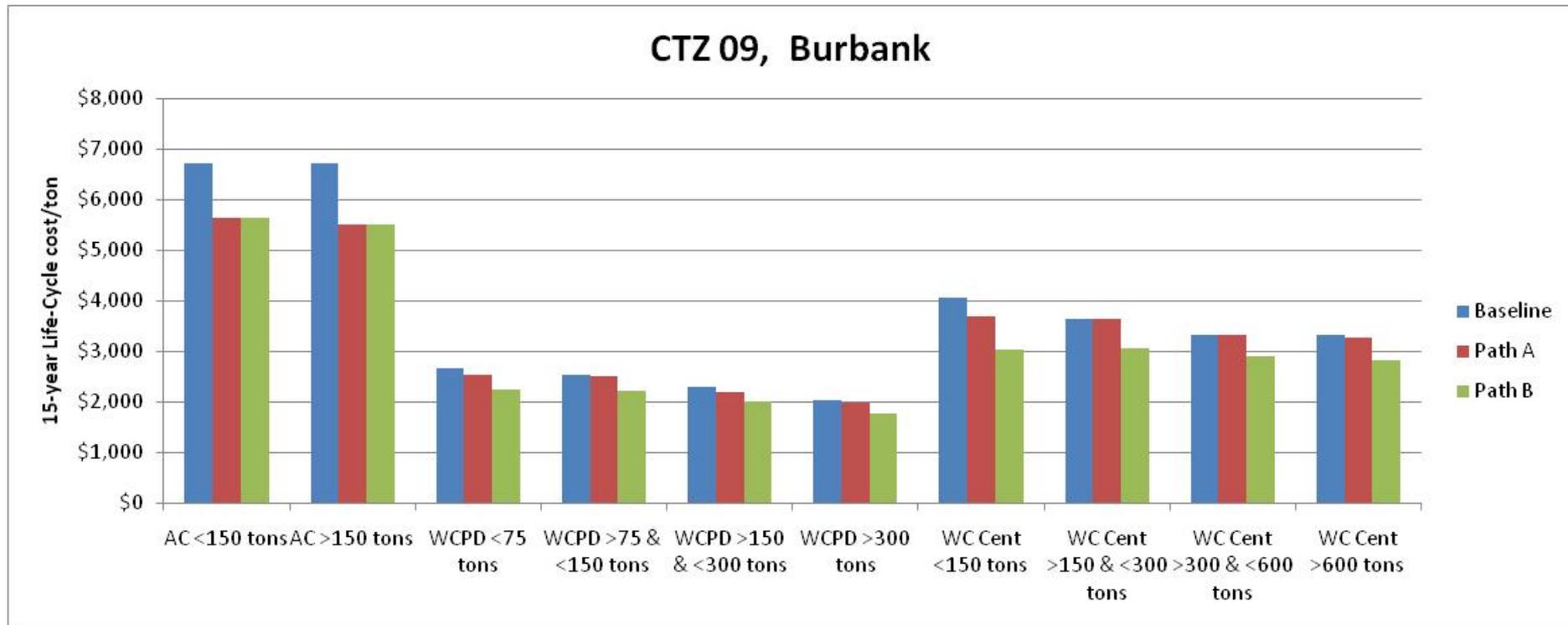
CZ08

Lower is better (PV energy and cost)



ASHRAE 2 – Chiller Efficiency LCC Results CZ09

Lower is better (PV energy and cost)

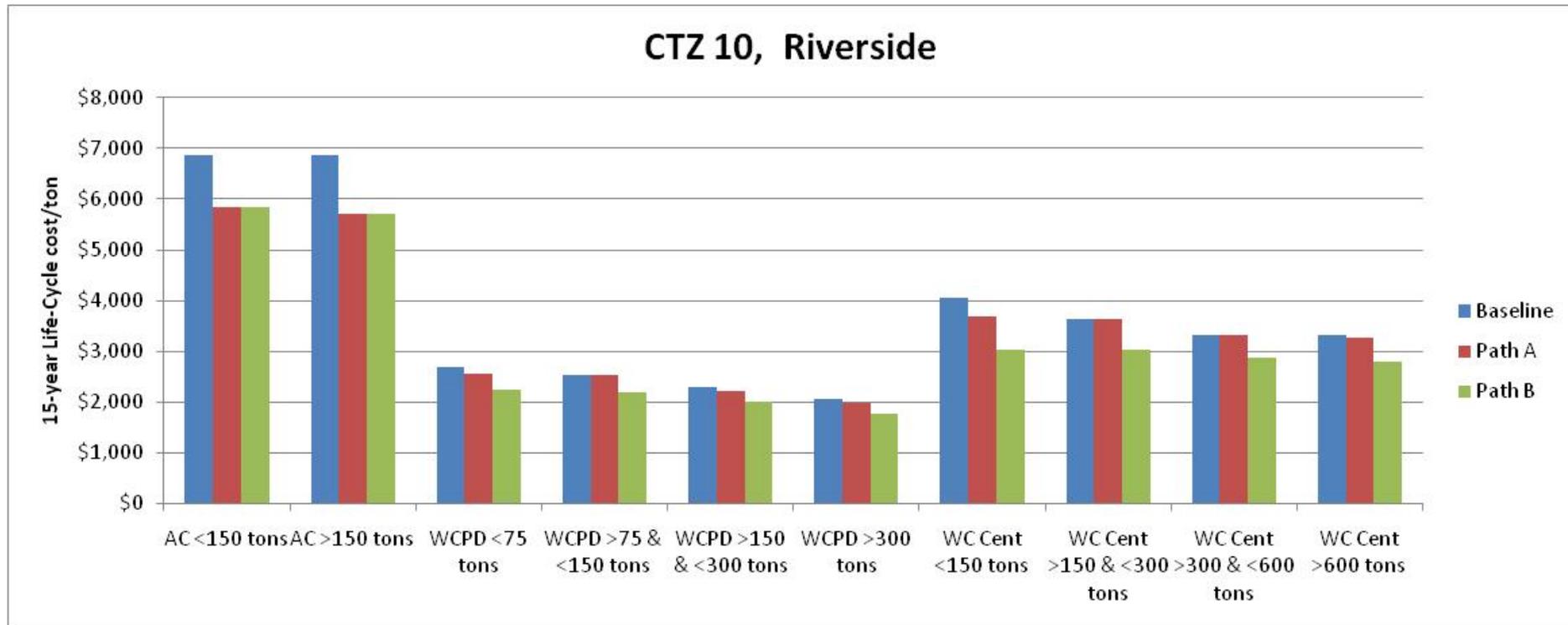


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LCC Results

CZ10

Lower is better (PV energy and cost)

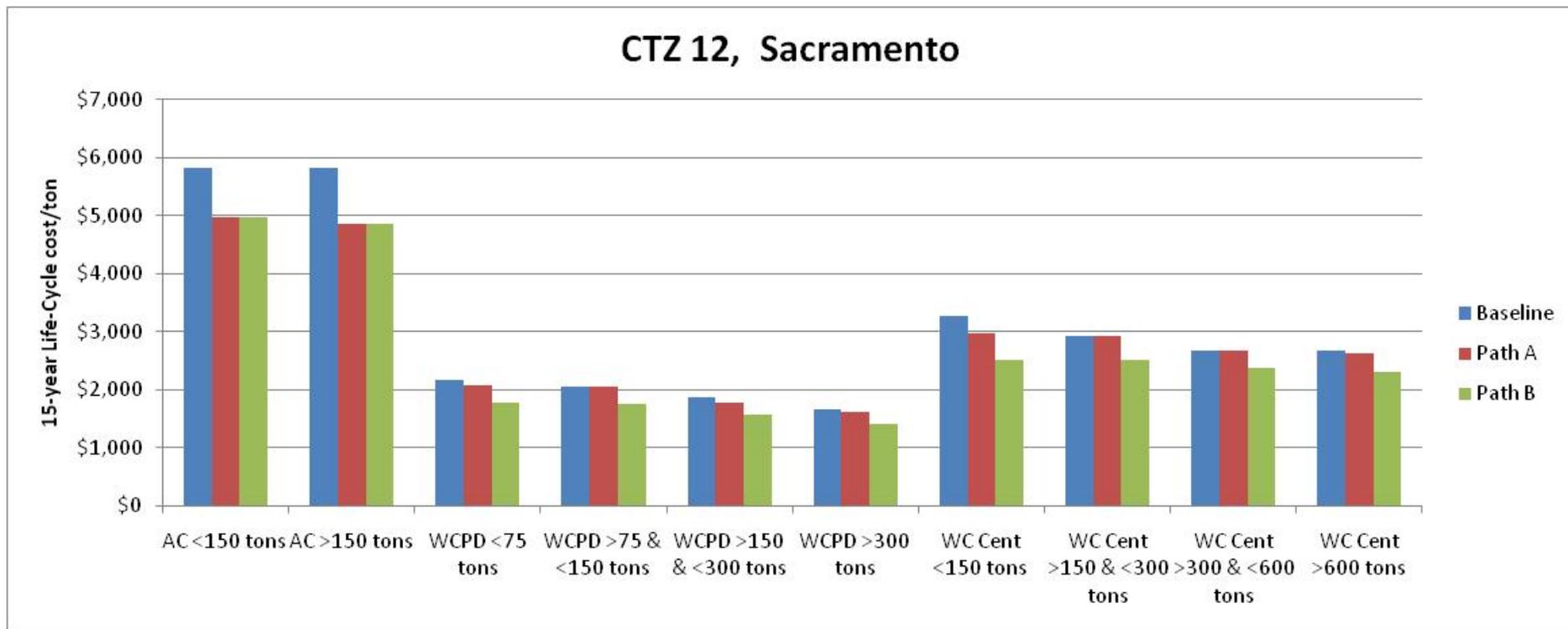


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LCC Results

CZ12

Lower is better (PV energy and cost)

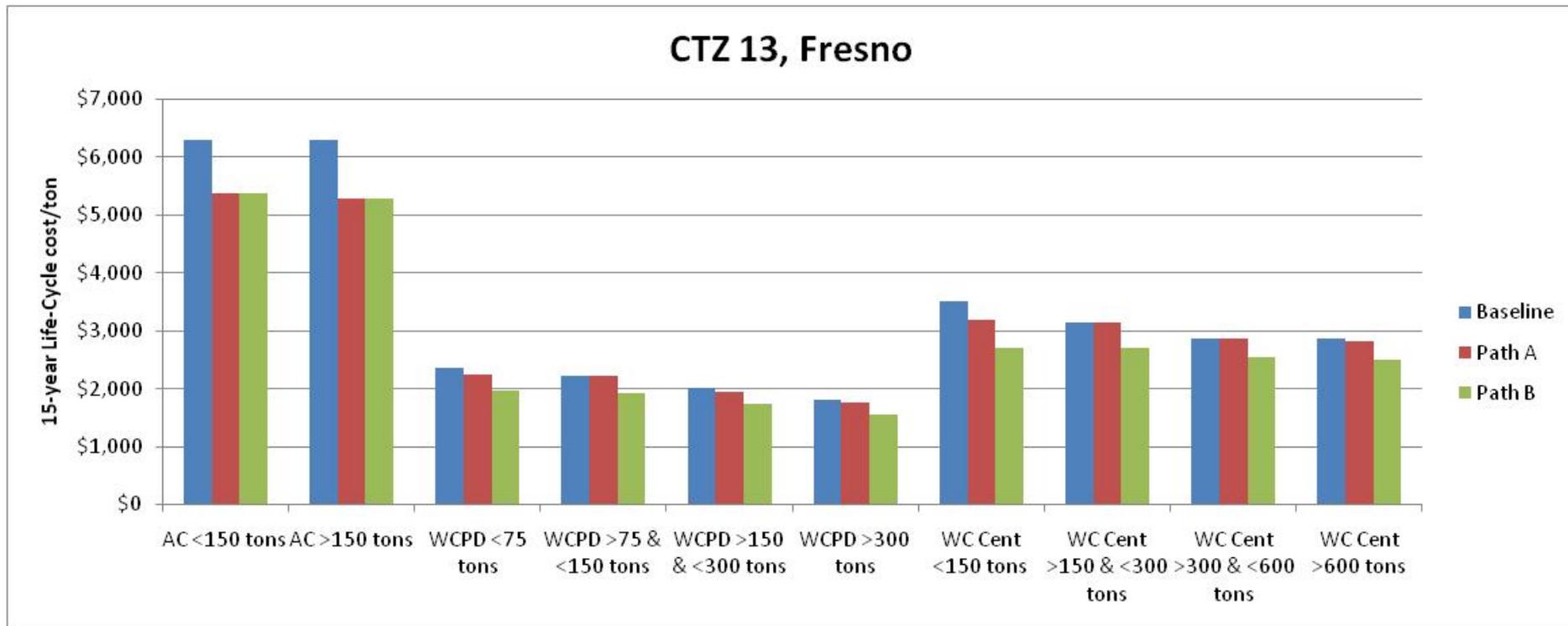


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LCC Results

CZ13

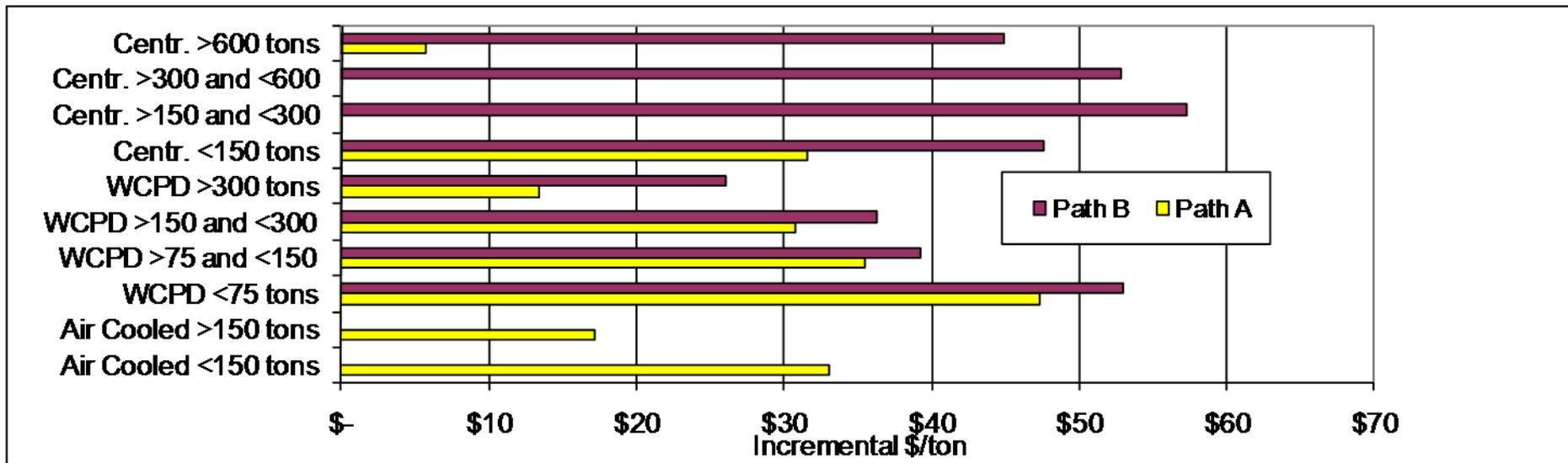
Lower is better (PV energy and cost)



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Incremental Costs From AHRI

- Incremental cost from chiller manufacturers
 - Cost source: AHRI working group from 90.1 analysis



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Next Steps

- Complete analysis for remaining climate zones
- Recalculate state-wide savings

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Air Cooled Chillers



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Rationale for Proposed Changes for Air-Cooled Chillers 144(i)

There is evidence that people are confused by and are gaming compliance with air-cooled chillers for example:

- If people put in a 299 ton chiller, it can all be air-cooled, but if they put in a 300 ton chiller, only a 100 ton can be air cooled, the rest must be water cooled. This is resulting in all sorts of gaming.
- People are putting in two-290 ton chillers (the plant capacity of 580 tons), but the chillers are interlocked so only one can operate at the same time. They can size the air-cooled condenser to accommodate both chillers and then later remove the interlock.
- People have put in <300 t air cooled chillers on a series of permits
- It is not clear how the requirements in 144(i) can be reconciled with the sizing requirements of 144(a).

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Proposed Changes for Air-Cooled Chillers 144(i) Base Requirement

- **144(i) Limitation of Air-Cooled Chillers**
- Chilled water plants ~~with more than 300 tons total capacity~~ shall not have more than 4300 tons provided by air-cooled chillers.
- **EXCEPTION 1 to Section 144(i):** Where the designer demonstrates that the water quality at the building site fails to meet manufacturer's specifications for the use of water-cooled equipment.
- **EXCEPTION 2 to Section 144(i):** ~~Plants that employ a cooling~~ Chillers that are used to charge thermal energy storage systems with a design charge temperature <40F.
- **EXCEPTION 3 to Section 144(i):** Air cooled chillers with minimum efficiencies approved by the Commission pursuant to Section 10-109(d).

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Proposed Changes for Air-Cooled Chillers 149(C) Additions and Alternations

- New space-conditioning systems or components other than new or replacement space conditioning ducts shall meet the requirements of Section 144 applicable to the systems or components being altered; and
- ~~EXCEPTION 1 to Section 149(b)1C: For expansions of existing chilled water plants, Section 144(i) applies only to expansions of more than 300 tons.~~
- EXCEPTION 21 to Section 149(b)1C: For replacements of equivalent or lower capacity electric resistance space heaters for high rise residential apartment units.
- EXCEPTION 32 to Section 149(b)1C: For replacement of electric reheat of equivalent or lower capacity electric resistance space heaters, when natural gas is not available.

Next Steps

- Present at workshops and get feedback

Questions



QUESTIONS & COMMENTS

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