Supermarkets Stakeholder Meeting #2

California Statewide Utility Codes and Standards Program

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- Summary of current code requirements
- Typical practice
- Summary of code change proposals
- Data/findings
- Specifics of code change proposals
- Remaining data collection and analysis
- Specific stakeholder requests

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Current Code Requirements

- **No existing Title 24 supermarket refrigeration requirements**
- Title 20 and Federal walk-in requirements
  - ECM motors
  - Insulation levels, strip curtains, lighting
  - Door heater wattage
- Display cases
  - 2012 Federal remote display case regulations expressed in daily energy use (kWh/day) with standardized reference compressor efficiency

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Current Code Requirements

- Refrigerated Warehouse 2008 Title 24 similarities and differences:
  - Floating head pressure to 70 F with variable speed fan and variable setpoint logic
    - Same as proposed for supermarkets
  - Evaporator fan variable speed
    - Proposed as a supermarket Reach code
  - Condenser sizing requirements
    - Supermarket analysis prioritized specific efficiency ahead of condenser sizing

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Typical Practice

- Typical new construction practice – observations from 2001-2010 Savings By Design IOU programs:
  - Floating head pressure to 70 F
  - Floating suction pressure control
  - Subcooling (at least on LT)
  - Variable speed condenser control (nearly 100% on evap condensers and ~50% on air-cooled)
  - History of condenser specific efficiencies

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Typical Practice

- Savings By Design reference base case
  - Fixed head pressure control at 80°F SCT
  - Condenser specific efficiency:
    - 53 BTUh/Watt for air-cooled condensers *
    - 140 BTUh/Watt for evap-cooled condensers *
  - Subcooling on LT systems using either MT system or economized compressors
  - Condenser design TD (approach)
    - Air-cooled: 10 F LT; 15 F MT
    - Evap-cooled: 20 F to 25 F depending on ambient

* Using reference conditions of 10°F TD for air-cooled and 70°F WBT/100°F SCT for evap-cooled

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Summary of Code Change Proposals

- Base measures:
  - Floating head pressure with variable speed
  - Condenser specific efficiency
  - Floating suction pressure
  - Mechanical subcooling
  - Liquid-suction heat exchangers
  - Display case lighting control
  - Prohibit open upright frozen food cases

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Summary of Code Change Proposals

- Reach measures:
  - Walk-in variable speed fan control
    - Changed from base code
  - Heat reclaim
    - (still potential base code measure – decide 12/13)
  - Secondary (indirect) cooling
    - Eliminate refrigerants from store area, using phase-change CO_2 or CO_2 and glycol.
    - Undetermined whether to require only CO_2 indirect on basis of better efficiency.

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Summary of Code Change Proposals

- Acceptance testing:
  - Acceptance testing cost to be added to base measure cost for control measures

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Analysis Methodology

- Energy analysis using DOE2.2R simulation
- Time dependent valuation (TDV)
  - 15 years life for all refrigeration measures
- B/C Ratio:
  - Total life-cycle TDV value / incremental cost plus discounted maintenance or replacement costs
  - BCR is primary determinant of cost effectiveness
- Simple payback shown for reference

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Analysis Methodology

Year	Base Case Carbon Forecast ($/ton)
2011	$ 13.98
2012	15.37
2013	16.89
2014	19.87
2015	22.85
2016	26.05
2017	29.26
2018	32.70
2019	36.14
2020	39.84
2021	43.67
2022	47.51
2023	51.62
2024	55.73
2025	60.13

- Economic value of carbon equivalent of direct HFC emissions:
  - Table values are 2013 Title 24 TDV factors, expressed in nominal dollars.
  - Used to evaluate value of direct refrigerant emissions along with energy cost reductions.

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Analysis Update

- Changes since last stakeholder meeting:
  - Added several missing line-ups and boxes which increased refrigeration load and base line energy usage in the reference large supermarket
  - Deleted measures:
    - Evaporator coil specific efficiency – too complex
    - Display case LED lights – Federal preemption
    - Display case night curtains – not cost-effective
    - Prohibit hot gas defrost – not cost effective *

      * Based on conservative leak rate assumptions; could change with better information on leakage impact.

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Direct Emissions Assumptions

- Condenser type impacts charge size; relative to systems with air-cooled condensers:
  - Evap-cooled condensers increase charge by 10%
  - Fluid-cooled condensers reduce charge by 60%
- Only 3 ECMs impact charge size & LR*
  - Floating head pressure
  - Refrigeration heat recovery
  - Secondary loop cooling

**Electric defrost in lieu of hot gas defrost was also assessed but was found to not be cost-effective, although it results in net GHG savings.*

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Direct Emissions Assumptions

System Configuration	Condenser Type	Refrigerant Type	Charge Size*	
			Centralized	Distributed
Small Supermarket (249,353 BTU/Hr)	Air	R-404A	725	360
	Evaporative	R-404A	800	400
	Fluid	R-404A	435	215
Large Supermarket (1,257,920 BTU/Hr)	Air	R-404A	3,655	1,830
	Evaporative	R-404A	4,020	2,015
	Fluid	R-404A	2,195	1,100
Big Box Food Store (1,517,440 BTU/Hr)	Air	R-507	4,410	2,205
	Evaporative	R-507	4,850	2,425
	Fluid	R-507	2,645	1,325

*Charge calculated for each refrigeration system type based on average pounds per BTU; estimated primarily based on available literature with consideration given to supermarket data, supermarket drawings, and manufacturer/user input.

*Recently revised due to updated base case store cooling capacities.

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Direct Emissions Assumptions

- Leak Rate (percent of charge per year)

System Configuration	Centralized	Distributed
Average	18%	15%
Range (of averages)	15% - 25%	10% - 15%

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Store and System Types for Analysis

Store and Refrigeration System Codes			
Small Supermarket 16,000 SF	Air-Cooled Condenser	Central	SAC
		Distributed	SAD
	Evap-Cooled Condenser	Central	SEC
	Fluid Cooler	Central	SFC
		Distributed	SFD
Large Supermarket 60,000 SF	Air-Cooled Condenser	Central	MAC
		Distributed	MAD
	Evap-Cooled Condenser	Central	MEC
	Fluid Cooler	Central	MFC
		Distributed	MFD
Big Box Food Store 160,000 SF	Air-Cooled Condenser	Central	LAC
		Distributed	LAD
	Evap-Cooled Condenser	Central	LEC
	Fluid Cooler	Central	LFC
		Distributed	LFD

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Floating Head Pressure

- Base case assumptions:
  - Fan cycling on air-cooled and two-speed on evap-cooled with fixed control setpoint of 80°F SCT; 90°F SCT for fluid cooler systems.
  - De-rate air-cooled condenser capacity by 15%; evap-cooled and fluid cooler capacity by 20%.
- Analysis assumptions:
  - Variable speed fan control with all fans controlled in unison.
  - Ambient-following (variable setpoint) strategy.
  - Low-limit setpoint of 70°F SCT.

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Floating Head Pressure

		Floating Head Pressure Results						
		Energy Savings (kWh)	Energy Savings/ SF (kWh)	TDV Cost Savings ($)	TDV Cost Savings /SF ($)	Measure Cost ($) *	Benefit/ Cost Ratio	Simple Payback (Years) *
CTZ 12 Sacramento	MXX Average	97,751	1.64	$ 163,147	$ 2.74	$ 35,251	4.63	3.01
CTZ 12 Sacramento	SXX Average	26,700	1.68	$ 44,967	$ 2.84	$ 13,923	3.23	4.35
CTZ 12 Sacramento	LXX Average	126,424	0.78	$ 211,759	$ 1.31	$ 39,436	5.37	2.60
CTZ 12 Sacramento	XAX Average	126,864	2.11	$ 209,313	$ 3.47	$ 33,055	6.33	2.17
CTZ 12 Sacramento	XEX Average	53,930	0.83	$ 105,289	$ 1.64	$ 27,191	3.87	4.20
CTZ 12 Sacramento	XFX Average	55,234	0.90	$ 87,936	$ 1.45	$ 27,191	3.23	4.10
CTZ 12 Sacramento	ALL Average	83,625	1.37	$ 139,958	$ 2.29	$ 29,537	4.74	2.94
CTZ 05 Santa Maria	ALL Average	84,431	1.38	$ 152,173	$ 2.50	$ 30,931	4.92	3.05
CTZ 10 Riverside	ALL Average	79,688	1.31	$ 131,868	$ 2.16	$ 30,931	4.26	3.23
	Maximum	195,975	2.83	$ 361,879	$ 5.25	$ 44,484	8.14	8.01
	Minimum	13,572	0.40	$ 21,991	$ 0.63	$ 13,040	1.69	1.89

* Cost includes present value of annual savings maintenance ($1,300 for large supermarket)

Store size: M = 60kSF large supermarket, S = 16kSF small market, L = 160kSF big box store

Condensing method: A = air-cooled, E = evap-cooled, F = fluid cooler

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Floating Head Pressure

- Direct emission assumptions
  - Increases leak rate by up to 5% for systems with air-cooled condensers in colder climates (based on industry input)
- Annual GHG impacts for supermarkets (Sacramento)[1]

System Type	Refrigerant Savings (pounds)	Refrigerant Savings ($MTCO_2eq.$)	Energy Savings ($MTCO_2eq.$)[2]	Net Savings ($MTCO_2eq.$)
SXX Average	(2) – (1)	(4) – (3)	11	**6 – 8**
MXX Average	(12) – (7)	(21) – (13)	40	**18 – 27**
LXX Average	(14) – (9)	(26) – (16)	49	**23 – 33**
XAX Average	(15) – (24)	(43) – (26)	51	**8 – 24**
XEX Average	0 – 0	0 – 0	18	**18**
XFX Average	0 – 0	0 – 0	23	**23**
XXC Average	(12) – (7)	(22) – (13)	30	**8 – 17**
XXD Average	(5) – (4)	(10) – (17)	38	**18 – 31**
ALL Average	**(10) – (6)**	**(17) – (11)**	**33**	**16 – 22**

[1] Although charge increase is only expected to occur in colder climates, energy savings for stores in the Sacramento climate zone were used to provide preliminary results.

[2] Based on annual electrical and natural gas consumption.

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Floating Head Pressure

- Lifetime Cost Savings (assuming a 15-year lifetime)

System Type	Measure Costs ($)	Refrigerant Savings ($)[1]	TVD Energy Savings ($)	TDV Carbon Savings ($)	Net Savings ($)[2]
SXX Average	$13,923	($311) – ($191)	$43,635	$3,298 – $4,125	**$32,698 - $33,646**
MXX Average	$35,251	($1,565) – ($963)	$161,759	$9,441 – $13,604	**$134,384 - $139,149**
LXX Average	$39,436	($1,845) – ($1,135)	$197,639	$11,683 – $16,780	**$168,041 - $173,848**
XAX Average	$33,055	($3,101) – ($1,908)	$205,204	$4,102 - $12,509	**$173,150 - $182,750**
XEX Average	$27,191	$0	$85,440	$9,434	**$67,683**
XXC Average	$29,146	($1,590) – ($954)	$123,263	$4,052 - $8,536	**$96,579 - $101,699**
XXD Average	$30,123	($716) – ($477)	$150,967	$14,273 - $15,954	**$134,401 - $136,321**
ALL Average	**$29,537**	**($1,240) – ($763)**	**$134,344**	**$14,273 - $15,954**	**$111,707 - $115,547**

[1] Assumes a constant lifetime cost of roughly $10/lb.

[2] Net Savings= Refrigerant Savings + TDV Energy Savings + TDV Carbon Savings – Measure Costs

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Floating Head Pressure

- Code recommendation:
  - Float head pressure to 70°F SCT, using variable speed fan control and variable setpoint logic.
- Open issues:
  - Confirm whether variable setpoint (wet-bulb following) is justified for evap-cooled vs. fixed setpoint (sensor accuracy).
  - Define how other control methods, which may be equal or better, would be allowed and approved.
  - Special topics for fluid coolers (e.g. water valves)
  - Add cost of acceptance testing.

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Condenser Specific Efficiency

- Base case assumptions:
  - Floating head pressure (previous measure).
  - Step-wise analysis to identify incremental cost/benefit, representing the typical design decision for a selection “at the margin”.
- Analysis assumptions:
  - Air-cooled: 65 BTUh/Watt minimum efficiency
  - Evap-cooled: 160 BTUh/Watt minimum efficiency

Using reference conditions of 10°F TD for air-cooled and 70°F WBT/100°F SCT for evap-cooled

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Condenser Specific Efficiency

- Background on supermarket condensers:
  - Air-cooled
    - All outdoors, essentially all direct-drive motors
    - Choice of standard and EC motors
    - Increasing use of micro-channel design
    - Fin spacing criteria on conventional models
  - Evaporative-cooled
    - Limitations on types available with multi-circuit.
    - Condenser located indoors requires ducting and additional fan static/power.

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Condenser Specific Efficiency

- Cost methodology:
  - Price lists do not correlate with specific efficiency; manufacturing cost is not exactly reflected in model-by-model sell price.
  - For cost vs. specific efficiency: Adjusted speed to achieve specific efficiency, then increased size to meet capacity.
- Condensers with EC motors:
  - Lower efficiency and more expensive.
    - Inherent variable speed offsets VFD in FHP measure
  - Max-speed of EC motor is “settable” = easily adjusted specific efficiency.

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Condenser Specific Efficiency

- Reference points:
  - Condenser published ratings do not reference a testing standard and are not certified ratings
  - Desire to avoid increasing condenser size and refrigerant charge unnecessarily
    - Variable speed in FHP measure does a good job of "prioritizing" better control over larger surface.
  - Air-cooled condensers used input power provided by mfgrs (OEM direct drive motors); evap condensers belt drive motor assumed fully loaded (conservative, often not fully loaded).

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Condenser Specific Efficiency

		Condenser Specific Efficiency Results (non EC motors)						
		Energy Savings (kWh)	Energy Savings/ SF (kWh)	TDV Cost Savings ($)	TDV Cost Savings /SF ($)	Measure Cost ($)	Benefit/ Cost Ratio	Simple Payback (Years)
CTZ 12 Sacramento	MXX Average	6,128	0.10	$ 18,353	$ 0.31	$ 2,537	7.23	3.45
CTZ 12 Sacramento	SXX Average	1,544	0.10	$ 4,875	$ 0.31	$ 767	6.35	4.14
CTZ 12 Sacramento	LXX Average	5,869	0.04	$ 20,980	$ 0.13	$ 3,860	5.44	5.48
CTZ 12 Sacramento	XAX Average	4,824	0.08	$ 18,238	$ 0.31	$ 3,020	6.04	5.22
CTZ 12 Sacramento	XEX Average	3,893	0.07	$ 7,731	$ 0.13	$ 1,124	6.88	2.41
CTZ 12 Sacramento	ALL Average	4,514	0.08	$ 14,736	$ 0.25	$ 2,388	6.17	4.41
CTZ 05 Santa Maria	ALL Average	2,811	0.05	$ 6,448	$ 0.11	$ 2,214	2.91	6.56
CTZ 10 Riverside	ALL Average	5,183	0.09	$ 15,970	$ 0.26	$ 2,388	6.69	3.84
Maximum		8,593	0.13	$ 31,174	$ 0.43	$ 5,054	8.30	15.86
Minimum		721	0.01	$ 1,334	$ 0.04	$ 375	1.42	1.89

- Savings for incremental difference:
  - 55 to 65 BTUh/Watt for air-cooled
  - 140 to 160 BTUh/Watt for evap-cooled
- Resolving inconsistent results in Santa Maria simulations

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Condenser Specific Efficiency

		Condenser Specific Efficiency Results (EC motors)						
		Energy Savings (kWh)	Energy Savings/ SF (kWh)	TDV Cost Savings ($)	TDV Cost Savings /SF ($)	Measure Cost ($)	Benefit/ Cost Ratio	Simple Payback (Years)
CTZ 12 Sacramento	MXX Average	6,128	0.10	$ 18,353	$ 0.31	$ 3,743	4.90	5.09
CTZ 12 Sacramento	SXX Average	1,544	0.10	$ 4,875	$ 0.31	$ 1,634	2.98	8.82
CTZ 12 Sacramento	LXX Average	5,869	0.04	$ 20,980	$ 0.13	$ 5,758	3.64	8.18
CTZ 12 Sacramento	XAX Average	4,824	0.08	$ 18,238	$ 0.31	$ 5,005	3.64	8.65
CTZ 12 Sacramento	XEX Average	3,893	0.07	$ 7,731	$ 0.13	$ 1,124	6.88	2.41
CTZ 12 Sacramento	ALL Average	4,514	0.08	$ 14,736	$ 0.25	$ 3,712	3.97	6.85
CTZ 05 Santa Maria	ALL Average	2,811	0.05	$ 6,448	$ 0.11	$ 3,273	1.97	9.70
CTZ 10 Riverside	ALL Average	5,183	0.09	$ 15,970	$ 0.26	$ 3,712	4.30	5.97
Maximum		8,593	0.13	$ 31,174	$ 0.43	$ 7,960	8.30	24.97
Minimum		721	0.01	$ 1,334	$ 0.04	$ 375	0.90	1.89

- Same except all air-cooled condensers are EC motor type
- Lower average BC ratio than non-EC condensers

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Condenser Specific Efficiency

- Code recommendations:
  - Require minimum specific efficiencies for remote condensers:
    - 65 BTUh/Watt for air-cooled condensers
    - 160 BTUh/Watt for evaporative cooled condensers
  - Rating basis:
    - Air-Cooled: 95°F Ambient and 105°F Condensing
    - Evap-Cooled: 70°F WBT and 100°F Condensing
    - Maximum 10 FPI fin spacing, not applicable to micro-channel
    - Zero (minimum) subcooling in condenser

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Condenser Specific Efficiency

- Open issues:
  - No requirements for evaporative or air-cooled fluid coolers due to complexities and design variables. Concern since these are often much less efficient, but are being used increasingly to reduce refrigerant charge.
  - No requirements for hybrid (air/evap) condensers, but air-cooled with add-on pre-cooler would still be covered. No rating basis; research needed.

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Floating Suction Pressure

- Base case assumptions:
  - Fixed setpoint control.
- Analysis assumptions:
  - Floating suction logic to adjust setpoint based on walk-in or case temperature requirements.
  - Allowed annual cost for ongoing service or setpoint verification.

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Floating Suction Pressure

		Floating Suction Pressure Results						
		Energy Savings (kWh)	Energy Savings/ SF (kWh)	TDV Cost Savings ($)	TDV Cost Savings /SF ($)	Measure Cost ($) *	Benefit/ Cost Ratio	Simple Payback (Years) *
CTZ 12 Sacramento	MXX Average	34,150	0.57	$ 67,751	$ 1.14	$ 10,149	6.68	2.48
CTZ 12 Sacramento	SXX Average	8,341	0.53	$ 16,495	$ 1.04	$ 5,075	3.25	5.07
CTZ 12 Sacramento	LXX Average	50,102	0.31	$ 100,130	$ 0.62	$ 10,149	9.87	1.69
CTZ 12 Sacramento	XAX Average	30,231	0.47	$ 62,563	$ 0.96	$ 8,458	7.40	2.33
CTZ 12 Sacramento	XEX Average	26,472	0.39	$ 51,063	$ 0.75	$ 8,458	6.04	2.66
CTZ 12 Sacramento	XFX Average	33,694	0.51	$ 65,552	$ 1.00	$ 8,458	7.75	2.09
CTZ 12 Sacramento	ALL Average	30,864	0.47	$ 61,459	$ 0.93	$ 8,458	7.27	2.28
CTZ 05 Santa Maria	ALL Average	29,299	0.45	$ 56,653	$ 0.87	$ 8,458	6.70	2.41
CTZ 10 Riverside	ALL Average	31,196	0.47	$ 61,242	$ 0.93	$ 8,458	7.24	2.26
	Maximum	62,400	0.69	$ 119,603	$ 1.33	$ 10,149	11.78	6.39
	Minimum	6,620	0.25	$ 12,620	$ 0.50	$ 5,075	2.49	1.36

* Cost includes present value of annual savings maintenance ($600 for large supermarket)

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Floating Suction Pressure

- Code recommendations:
  - Require floating suction pressure on systems with multiple compressors or single compressor with modulating capacity.
  - Exception for indirect (chiller) systems and systems above 30°F SST.
- Open issues:
  - Add cost of acceptance testing
  - ?

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Mechanical Subcooling

- Base case assumptions:
  - No mechanical subcooling.
- Analysis assumptions:
  - Subcooling on low temp systems using a medium temperature system or economized compressors.
  - Allowed for liquid line heat gain between system and loads.
  - No cost adjustment for smaller LT compressors
  - Assumed liquid lines already insulated (typical)

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Mechanical Subcooling

		Mechanical Subcooling Results						
		Energy Savings (kWh)	Energy Savings/ SF (kWh)	TDV Cost Savings ($)	TDV Cost Savings /SF ($)	Measure Cost ($) *	Benefit/ Cost Ratio	Simple Payback (Years) *
CTZ 12 Sacramento	MXX Average	25,369	0.43	$ 55,331	$ 0.93	$ 7,973	6.94	2.62
CTZ 12 Sacramento	SXX Average	8,857	0.56	$ 18,759	$ 1.18	$ 4,475	4.19	4.21
CTZ 12 Sacramento	LXX Average	65,179	0.40	$ 142,135	$ 0.88	$ 14,221	9.99	1.82
CTZ 12 Sacramento	XAX Average	26,541	0.36	$ 70,131	$ 0.94	$ 8,694	8.07	2.73
CTZ 12 Sacramento	XEX Average	26,473	0.36	$ 51,755	$ 0.71	$ 9,673	5.35	3.04
CTZ 12 Sacramento	XFX Average	43,061	0.61	$ 84,179	$ 1.19	$ 8,694	9.68	1.68
CTZ 12 Sacramento	ALL Average	33,135	0.46	$ 72,075	$ 1.00	$ 8,890	8.11	2.24
CTZ 05 Santa Maria	ALL Average	29,532	0.42	$ 57,312	$ 0.80	$ 8,890	6.45	2.51
CTZ 10 Riverside	ALL Average	34,136	0.48	$ 74,327	$ 1.03	$ 8,890	8.36	2.17
	Maximum	92,379	0.81	$ 181,153	$ 1.56	$ 15,793	12.39	8.38
	Minimum	4,198	0.14	$ 8,312	$ 0.28	$ 4,220	1.97	1.29

* Cost includes present value of annual savings maintenance ($400 for large supermarket)

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Mechanical Subcooling

- Code recommendation:
  - Require continuous mechanical subcooling to 50°F liquid temperature or lower on low temperature systems.
  - Exception for single compressor systems, cascade systems, and CO_2 DX systems.
- Open issues:
  - Discussion concerning ambient subcooling:
    - Prohibit due to propensity to increase charge and fan power, or define limitations to use properly.
  - Add cost of acceptance testing

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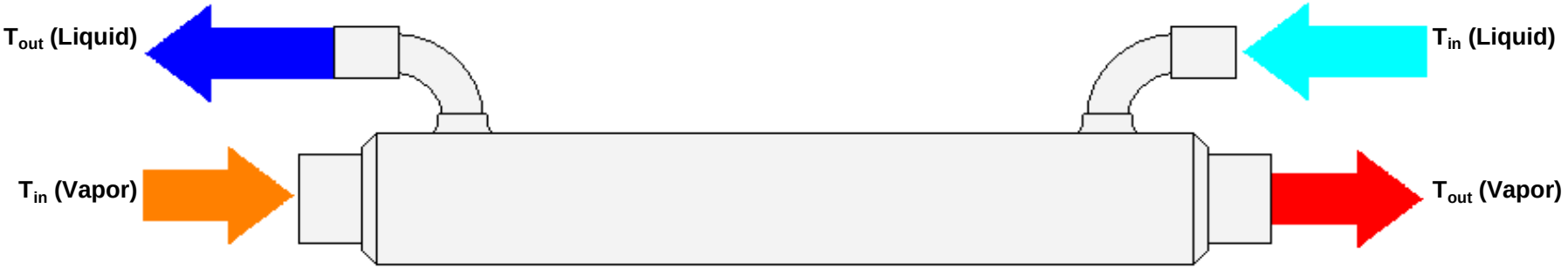
Liquid-Suction Heat Exchangers



- Increases system capacity by providing liquid subcooling.
- Maintains proper superheat at the compressor.
- Helps maintain stability with floating head pressure by subcooling to avoid flash gas at expansion valve.
- May become a no-cost option when impact on capacity if fully incorporated.

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Liquid-Suction Heat Exchangers

- Base case assumptions:
  - No heat exchangers; Leaving gas temperature with typical TXV superheat plus gains in fixture or box.
  - Floating head pressure measure and low temp mechanical subcooling measure.
- Analysis assumptions:
  - Low temp HX sized for 17°F subcooling.
  - Medium temp HX sized for 7°F subcooling.
  - LSHX applied to each walk-in or line-up circuit.

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Liquid-Suction Heat Exchangers

		All Liquid Suction Heat Exchanger Results						
		Energy Savings (kWh)	Energy Savings/ SF (kWh)	TDV Cost Savings ($)	TDV Cost Savings /SF ($)	Measure Cost ($)	Benefit/ Cost Ratio	Simple Payback (Years)
CTZ 12 Sacramento	LT WI Avg	17,148	0.13	$ 34,877	$ 0.27	$ 1,010	34.52	0.49
CTZ 12 Sacramento	LT Case Avg	13,482	0.30	$ 27,503	$ 0.61	$ 1,179	23.32	0.73
CTZ 12 Sacramento	MT WI Avg	3,996	0.04	$ 8,860	$ 0.09	$ 1,828	4.85	3.81
CTZ 12 Sacramento	MT Case Avg	7,022	0.16	$ 15,660	$ 0.36	$ 3,042	5.15	3.61
CTZ 12 Sacramento	ALL Average	41,293	0.63	$ 85,946	$ 1.32	$ 7,060	12.17	1.42
CTZ 05 Santa Maria	ALL Average	37,911	0.58	$ 74,980	$ 1.15	$ 7,060	10.62	1.55
CTZ 10 Riverside	ALL Average	43,332	0.66	$ 89,579	$ 1.38	$ 7,060	12.69	1.36

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Liquid-Suction Heat Exchangers

- Code recommendation:
  - Require liquid-suction heat exchangers installed on all DX circuits, for systems <= 25°F SST.
  - Sizing defined in degrees of subcooling at average operating conditions (i.e. entering liquid temperature of 55°F for LT and 75°F for MT).
- Open issues:
  - Address concern for problems caused by excessive subcooling; i.e. low load or low temp economizer producing colder (e.g. 30°F) liquid.

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Display Case Lighting Control

- Base case assumptions:
  - Applies only to non 24-hour stores.
  - Lights on continuously.
- Analysis assumptions:
  - Control fixture lights to turn off during non-sales hours.
  - Allow timed overrides for stocking.

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Display Case Lighting Control

		Display Case Lighting Control Results						
		Energy Savings (kWh)	Energy Savings/ SF (kWh)	TDV Cost Savings ($)	TDV Cost Savings /SF ($)	Measure Cost ($) *	Benefit/ Cost Ratio	Simple Payback (Years) *
CTZ 12 Sacramento	MXX Average	148,743	2.50	$ 218,384	$ 3.67	$ 11,321	19.29	0.63
CTZ 12 Sacramento	SXX Average	49,241	3.11	$ 68,570	$ 4.33	$ 5,588	12.27	0.95
CTZ 12 Sacramento	LXX Average	172,604	1.06	$ 265,315	$ 1.64	$ 12,659	20.96	0.61
CTZ 12 Sacramento	XAX Average	121,758	2.19	$ 181,371	$ 3.17	$ 9,856	18.40	0.67
CTZ 12 Sacramento	XEX Average	120,459	2.17	$ 179,094	$ 3.13	$ 9,856	18.17	0.68
CTZ 12 Sacramento	XFX Average	126,837	2.28	$ 189,307	$ 3.29	$ 9,856	19.21	0.65
CTZ 12 Sacramento	ALL Average	123,529	2.22	$ 184,090	$ 3.21	$ 9,856	18.68	0.66
CTZ 05 Santa Maria	ALL Average	122,016	2.20	$ 182,336	$ 3.18	$ 9,856	18.50	0.67
CTZ 10 Riverside	ALL Average	124,596	2.24	$ 182,220	$ 3.17	$ 9,856	18.49	0.66
	Maximum	179,916	3.21	$ 274,724	$ 4.43	$ 12,659	21.70	0.97
	Minimum	47,855	1.02	$ 66,454	$ 1.57	$ 5,588	11.89	0.59

* Cost includes present value of annual savings maintenance ($500 for large supermarket)

Supermarkets

Display Case Lighting Control

- Code recommendation:
  - Require automatic controls for display cases and point-of-sale box door lighting on non 24-hour stores.
  - Allow timed overrides for stocking; allow motion sensors in lieu of timed control.
- Open issues:
  - Add cost of acceptance testing

Supermarkets

No Open Upright Freezers

- Base case assumptions:
  - Reference baseline with open multi-deck frozen food line-up (i.e. 12’ frozen meat).
- Analysis assumptions:
  - Replace open cases with equal length of glass door cases.

Supermarkets

No Open Upright Freezers

- Results based on 12’ open upright freezer vs. 5 door reach-in freezer.

		Open Upright Frozen Food Cases						
		Energy Savings (kWh)	Energy Savings/ SF (kWh)	TDV Cost Savings ($)	TDV Cost Savings /SF ($)	Measure Cost ($)	Benefit/ Cost Ratio	Simple Payback (Years)
CTZ 12 Sacramento	MXX Average	9,919	0.17	$ 22,789	$ 0.38	$ -		

- No incremental cost (equal or lower total cost considering compressor size, etc.) – subject to input.

Supermarkets

No Open Upright Freezers

- Code recommendation:
  - Prohibit or limit use of open upright frozen food cases.
- Open issues:
  - Comments on why open upright frozen food cases might be necessary?

Supermarkets

Evaporator Fan Variable Speed

Reach Code Proposal

- Base case assumptions:
  - Continuous fixed speed control
- Measure assumptions:
  - Fan speed control as primary means of temperature control.
  - Minimum speed of 70%, with four hours per day forced to 90% regardless of load.

Supermarkets

Evaporator Fan Variable Speed

		Walkin Fans Variable Speed Results						
		Energy Savings (kWh)	Energy Savings/ SF (kWh)	TDV Cost Savings ($)	TDV Cost Savings /SF ($)	Measure Cost ($) *	Benefit/ Cost Ratio	Simple Payback (Years) *
CTZ 12 Sacramento	MXX Average	26,647	0.45	$ 50,652	$ 0.85	$ 17,868	2.83	5.59
CTZ 12 Sacramento	SXX Average	3,954	0.25	$ 7,595	$ 0.48	$ 6,546	1.16	13.80
CTZ 12 Sacramento	LXX Average	143,058	0.88	$ 276,056	$ 1.70	$ 27,321	10.10	1.59
CTZ 12 Sacramento	XAX Average	57,066	0.52	$ 110,602	$ 1.00	$ 17,245	6.41	2.52
CTZ 12 Sacramento	XEX Average	56,303	0.51	$ 107,849	$ 0.98	$ 17,245	6.25	2.55
CTZ 12 Sacramento	XFX Average	59,499	0.54	$ 114,058	$ 1.04	$ 17,245	6.61	2.42
CTZ 12 Sacramento	ALL Average	57,886	0.53	$ 111,434	$ 1.01	$ 17,245	6.46	2.48
CTZ 05 Santa Maria	ALL Average	57,072	0.52	$ 109,037	$ 0.99	$ 17,245	6.32	2.52
CTZ 10 Riverside	ALL Average	58,172	0.53	$ 110,980	$ 1.01	$ 17,245	6.44	2.47
	Maximum	148,165	0.91	$ 282,707	$ 1.74	$ 27,321	10.35	14.30
	Minimum	3,815	0.24	$ 7,271	$ 0.46	$ 6,546	1.11	1.54

Cost includes present value of annual measure maintenance ($800 for large supermarket)

Supermarkets

Evaporator Fan Variable Speed

Reach Code Proposal

- Code recommendation:
  - Require variable speed fan control on walk-in evaporators and secondary cooling coils, including automation to coordinate control with suction valves and floating suction.
- Open issues:
  - No field experience or testing; feasibility is an extension from larger RWH experience, which does include DX coils, albeit larger.
  - Reasonableness given Jan 1, 2014 start date?

Supermarkets

Refrigeration Heat Recovery

Reach Code Proposal

- Base case assumptions:
  - Floating head pressure (previous measure).
  - Space heating with natural gas.
- Analysis assumptions:
  - Heat recovery from refrigeration systems modeled using series configuration and holdback control to maintain condensing; allowing for indirect heat exchange loop.
  - Evaluated maximum savings available using recovery from all refrigeration systems.

Supermarkets

Refrigeration Heat Recovery

		Heat Reclaim Results								
		Energy Savings (kWh)	Energy Savings/ SF (kWh)	Natural Gas Savings (Therms)	Natural Gas Therms /SF	TDV Cost Savings ($)	TDV Cost Savings /SF ($)	Measure Cost ($) *	Benefit/ Cost Ratio	Simple Payback (Years) *
CTZ 12 Sacramento	MXX Average	-45,601	-0.77	19,052	0.45	$ 341,627	$ 5.74	$ 69,949	4.88	5.15
CTZ 12 Sacramento	SXX Average	-16,372	-1.03	7,547	0.48	$ 90,868	$ 5.73	$ 21,396	4.25	3.83
CTZ 12 Sacramento	LXX Average	-97,363	-0.60	36,655	0.23	$ 413,757	$ 2.55	$ 88,378	4.68	3.54
CTZ 12 Sacramento	XAX Average	-71,815	-1.12	23,665	0.38	$ 250,849	$ 4.15	$ 60,813	4.12	4.04
CTZ 12 Sacramento	XEX Average	-56,945	-0.85	23,715	0.39	$ 275,273	$ 4.59	$ 57,021	4.83	3.38
CTZ 12 Sacramento	XFX Average	-32,494	-0.45	23,871	0.39	$ 316,723	$ 5.24	$ 60,446	5.24	3.03
CTZ 12 Sacramento	ALL Average	-53,112	-0.80	23,757	0.39	$ 282,084	$ 4.67	$ 59,908	4.71	3.45
CTZ 05 Santa Maria	ALL Average	-54,060	-0.80	33,001	0.53	$ 397,876	$ 6.45	$ 60,054	6.63	2.26
CTZ 10 Riverside	ALL Average	-49,868	-0.75	16,704	0.28	$ 179,674	$ 3.08	$ 60,054	2.99	5.60
	Maximum	758	0.01	52,769	0.64	$ 671,321	$ 9.15	$ 95,545	8.19	9.09
	Minimum	-138,730	-1.71	5,342	0.15	$ 49,714	$ 1.28	$ 20,926	2.14	1.81

* Cost includes present value of annual savings maintenance ($2,000 annually for large supermarket, which accounts for additional refrigerant leakage replacement cost and labor to maintain proper settings and operation.)

* Simple payback based on $.12/kWh and $1.00/Therm.

Supermarkets

Refrigeration Heat Recovery

- Direct emission assumptions
  - Increases charge size by 20% or 0.05 lbs per 1,000 BTU/Hr of heating capacity (based on assumptions defined for ECM).
  - Increases leak rate by 5% (based on industry input)
- Annual GHG impacts for supermarkets (Sacramento)

System Type	Refrigerant Savings (pounds)	Refrigerant Savings ($MTCO_2eq.$)	Energy Savings ($MTCO_2eq.$)*	Net Savings ($MTCO_2eq.$)
SXX Average	(30) – (18)	(53) – (33)	35	(19) – 2
MXX Average	(151) – (92)	(269) – (164)	130	(139) – (34)
LXX Average	(182) – (111)	(329) – (201)	161	(168) – (40)
XAX Average	(124) – (76)	(222) – (137)	100	(122) – (36)
XEX Average	(209) – (126)	(376) – (225)	107	(269) – (119)
XFX Average	(74) – (46)	(133) – (82)	118	(16) – 36
XXC Average	(171) – (103)	(308) – (185)	109	(199) – (76)
XXD Average	(46) – (31)	(82) – (55)	108	26 – 53
ALL Average	**(121) – (74)**	**(217) – (133)**	**109**	**(109) – (24)**

*Based on annual electrical and natural gas consumption

Supermarkets

Refrigeration Heat Recovery

- Lifetime Costs (assuming a 15-year lifetime)

System Type	Measure Costs ($)	Refrigerant Savings ($)	TVD Energy Savings ($)	TDV Carbon Savings ($)	Net Savings ($)
SXX Average	$18,600	($3,956) – ($2,414)	$90,868	($9,611) – $1,058	$58,700 – $70,911
MXX Average	$55,200	($19,905) – ($12,144)	$341,627	($71,262) – ($17,578)	$195,260– $256,705
LXX Average	$77,200	($23,465) –($14,315)	$413,757	($86,064) – ($20,333)	$227,028 – $301,909
XAX Average	$51,500	($16,124) – ($9,922)	$250,849	($62,265) – ($18,548)	$120,961 – $170,879
XEX Average	$45,667	($27,262) – ($16,357)	$275,273	($137,538) – ($60,666)	$64,807 – $152,583
XFX Average	$51,500	($9,683) – ($5,959)	$316,723	($8,081) – $18,170	$247,459 – $277,435
XXC Average	$45,667	($22,319) – ($13,392)	$282,925	($101,621) – ($38,686)	$113,318 – $185,180
XXD Average	$57,333	($5,959) – ($3,973)	$280,822	$13,316 – $27,319	$230,846 – $246,835
ALL Average	**$50,333**	**($15,775) – ($9,624)**	**$282,084**	**($55,646) – ($12,284)**	**$160,329 – $209,842**

[1] Assumes a constant lifetime cost of roughly $10/lb.

[2] Net Savings= Refrigerant Savings + TDV Energy Savings + TDV Carbon Savings – Measure Costs

Supermarkets

Refrigeration Heat Recovery

Reach Code Proposal

- Code recommendation:
  - Require heat recovery from refrigeration to provide at least 25% of the design refrigeration heat of rejection for space heating, while increasing the refrigerant charge by no greater than 20% or 0.50 lbs per 1,000 BTU/Hr of heating capacity, whichever is less.
- Market support:
  - Substantial market support and application training needed to achieve maximum savings and penetration.

Supermarkets

Refrigeration Heat Recovery

- Open issues:
  - Feasibility of at least 25% heat recovery on various store types.
    - Simplest on stores with central station air handlers; AHUs most common on small and large supermarkets.
    - Big box stores always use packaged RTUs.
    - Design options with RTUs:
      - Water loop to multiple units.
      - Dedicated ventilation air preheating.
      - Specialized unit for refrigerated area.

Supermarkets

Secondary Loop Cooling – In Progress

Reach Code Proposal ?

- Possible code recommendation:
  - Prohibit direct cooling systems.
  - Require use of phase-change indirect (i.e. CO2) or limit pumping power to levels achievable with CO2 indirect.
- Open issues:
  - Discussion of cost impacts to customer, increased energy use with glycol (CO2 is near parity with direct refrigerant).
  - Quantify refrigerant leakage, energy and capital cost effectiveness, with refrigerant>CO2 valuation.

Supermarkets

Secondary Loop Cooling

- Charge Size and Leak Rate Assumptions
  - Average Leak Rate = 10%
  - Range of Averages = 5% – 15%

Base Case	Condenser Type	Charge Size (lbs)
Small Supermarket (249,353 BTU/Hr)	Air	200
	Evaporative	220
	Fluid	120
Large Supermarket (1,257,920 BTU/Hr)	Air	1,015
	Evaporative	1,115
	Fluid	610
Big Box Food Store (1,517,440 BTU/Hr)	Air	1,225
	Evaporative	1,350
	Fluid	735

Supermarkets

Secondary Loop Cooling

- Lifetime Costs (assuming a 15-year lifetime)

System Type	Measure Costs ($)	Refrigerant Savings ($)	TVD Energy Savings ($)	TDV Carbon Savings ($)	Net Savings ($)
SXX Average		$8,152 – $11,821			
MXX Average		$40,963 – $59,328			
LXX Average		$48,276 – $69,906			
XAX Average		$32,870 – $46,137			
XEX Average		$57,089 – $87,386			
XFX Average		$19,744 – $27,716			
XXC Average		$46,742 – $71,553			
XXD Average		$11,046 – $10,217			
ALL Average		**$32,464 – $47,018**			

[1] Assumes a constant lifetime cost of roughly $10/lb.

[2] Net Savings= Refrigerant Savings + TDV Energy Savings + TDV Carbon Savings – Measure Costs

Supermarkets

Secondary Loop Cooling

- Annual GHG impacts for supermarkets (Sacramento)

System Type	Refrigerant Savings (pounds)	Refrigerant Savings ($MTCO_2eq.$)	Energy Savings ($MTCO_2eq.$)*	Net Savings ($MTCO_2eq.$)
SXX Average	62 – 90	110 – 160		
MXX Average	311 – 451	554 – 802		
LXX Average	375 – 543	678 – 982		
XAX Average	253 – 354	453 – 636		
XEX Average	439 – 671	787 – 1204		
XFX Average	152 – 213	272 – 382		
XXC Average	359 – 550	644 – 986		
XXD Average	85 – 78	152 – 141		
ALL Average	**249 – 361**	**477 – 648**		

Supermarkets

Specifics of Code Change Proposal

- Applies to:
  - Retail food stores => 8,000 SF conditioned area
  - New construction
    - New building, expansion, gut-rehab
    - Remodel and retrofit in specific situations

Supermarkets

Specifics of Code Change Proposal

- Proposed Code Language:
  - To be completed; no existing code language.

Supermarkets

Remaining Data Collection and Analysis

- Decide on rating basis for condenser specific efficiency:
  - Air-Cooled TD possibly should be higher
  - Evap-Cooled TD probably should be lower
- Run analysis for additional climates.
- Resolve discrepancies in results from different climates.
- Compare results with existing facilities.
- Analyze secondary loop cooling systems (pending direction and valuation method for refrigerant losses).

Supermarkets

Specific Stakeholder Requests

- Additional information on axial evaporative condensers vs. application requirements (why limited to centrifugal fan condensers if located outdoors?) and actual application with external static (vs. “one size bigger” motor).
- Comments on ambient subcooling.

Supermarkets

QUESTIONS & COMMENTS

Supermarkets

Display Case Night Curtains (Deleted)

- Base case assumptions:
  - Applies only to non 24-hour stores.
  - No case curtains.
- Analysis assumptions:
  - Curtains to reduce infiltration on open upright medium temp display cases.
  - Reduction of 55% in air-exchange.

Deleted based on poor TDV economics, particularly when labor is considered, and questions concerning reliability of savings.

Supermarkets

Display Case Night Curtains (Deleted)

		Night Curtains on MT Open Cases Results						
		Energy Savings (kWh)	Energy Savings/ SF (kWh)	TDV Cost Savings ($)	TDV Cost Savings /SF ($)	Measure Cost ($)	Benefit/ Cost Ratio	Simple Payback (Years)
CTZ 12 Sacramento	MXX Average	34,122	0.57	$ 97,658	$ 1.64	$ 32,876	2.97	8.03
CTZ 12 Sacramento	SXX Average	8,555	0.54	$ 26,658	$ 1.68	$ 10,959	2.43	10.67
CTZ 12 Sacramento	LXX Average	4,977	0.03	$ 13,837	$ 0.09	$ 9,132	1.52	15.29
CTZ 12 Sacramento	XAX Average	15,101	0.37	$ 44,811	$ 1.12	$ 17,656	2.54	9.74
CTZ 12 Sacramento	XEX Average	14,313	0.34	$ 43,659	$ 1.08	$ 17,656	2.47	10.28
CTZ 12 Sacramento	XFX Average	17,455	0.41	$ 48,487	$ 1.18	$ 17,656	2.75	8.43
CTZ 12 Sacramento	ALL Average	15,885	0.38	$ 46,051	$ 1.14	$ 17,656	2.61	9.26
CTZ 05 Santa Maria	ALL Average	15,860	0.39	$ 47,503	$ 1.19	$ 17,656	2.69	9.28
CTZ 10 Riverside	ALL Average	16,448	0.39	$ 46,668	$ 1.12	$ 17,656	2.64	8.95
	Maximum	41,330	0.69	$ 109,404	$ 1.92	$ 32,876	3.33	21.56
	Minimum	3,530	0.02	$ 11,160	$ 0.07	$ 9,132	1.22	6.63

Includes cost to replace curtains at 7 years.

No cost allowed for system changes; inconsistent input on needs.

No allowance for night curtains not being used (manually operated)

Supermarkets

Display Case Night Curtains (Deleted)

- Code Recommendation:
  - Require case curtains on upright medium temperature cases including both low and high front cases (e.g. meat and produce) on non 24-hour stores.
- Open issues:
  - Define requirements for associated defrost and temperature controls modifications for proper operation.
  - Issues with system controls.

Supermarkets

No Hot Gas Defrost (Deleted)

Reach Code Proposal

- Base case assumptions:
  - Hot gas defrost on low temperature and certain medium temperature cases and boxes.
- Analysis assumptions:
  - Electric defrost in lieu of hot gas defrost.
  - Reduced compressor return gas temperature resulting from trunk piping.

Deleted based on negative total value, although this could change if leakage impact is actually higher.

Supermarkets

No Hot Gas Defrost (Deleted)

		Electric Defrost vs. Gas Defrost -- Electric Increase						
		Energy (Increase) (kWh)	Energy (Increase)/ SF (kWh)	TDV Cost (Increase) ($)	TDV Cost Increase /SF ($)	Measure Cost ($)	Benefit/ Cost Ratio	Simple Payback (Years)
CTZ 12 Sacramento	MXX Average	-36,111	-0.61	$ (102,124)	$ (1.71)			
CTZ 12 Sacramento	SXX Average	-6,493	-0.41	$ (18,138)	$ (1.14)			
CTZ 12 Sacramento	LXX Average	-41,689	-0.26	$ (116,046)	$ (0.72)			
CTZ 12 Sacramento	XAX Average	-28,017	-0.42	$ (78,747)	$ (1.19)			
CTZ 12 Sacramento	XEX Average	-28,232	-0.42	$ (78,979)	$ (1.19)			
CTZ 12 Sacramento	XFX Average	-28,111	-0.43	$ (78,687)	$ (1.20)			
CTZ 12 Sacramento	ALL Average	-28,097	-0.42	$ (78,769)	$ (1.19)			
CTZ 05 Santa Maria	ALL Average	-28,229	-0.43	$ (72,418)	$ (1.09)			
CTZ 10 Riverside	ALL Average	-28,072	-0.42	$ (71,412)	$ (1.08)			
	Maximum	-6,337	-0.25	$ (15,806)	$ (0.64)			
	Minimum	-42,336	-0.62	$ (117,057)	$ (1.72)			

- Comment on estimated owner savings due to lower leakage.

Supermarkets

No Hot Gas Defrost (Deleted)

- Direct emission assumptions
  - Reduces charge size by 10% (based on industry input)
  - Reduces leak rate by 5% (based on industry input)
- Annual GHG impacts for supermarkets (Sacramento)

System Type	Refrigerant Savings (pounds)	Refrigerant Savings ($MTCO_2eq.$)	Energy Savings ($MTCO_2eq.$)*	Net Savings ($MTCO_2eq.$)
SXX Average	10 – 17	18 – 30	(3)	16 – 27
MXX Average	51 – 84	92 – 150	(15)	77 – 136
LXX Average	62 – 102	112 – 184	(17)	95 – 167
XAX Average	43 – 69	76 – 124	(11)	65 – 113
XEX Average	70 – 117	126 – 209	(11)	114 – 198
XFX Average	26 – 41	46 – 74	(11)	34 – 63
XXC Average	57 – 96	103 – 172	(11)	92 – 160
XXD Average	17 – 26	31 – 46	(11)	19 – 35
ALL Average	**41 – 68**	**74 – 121**	**(11)**	**63 – 110**

*Based on annual electrical and natural gas consumption

Supermarkets

No Hot Gas Defrost (Deleted)

- Lifetime Costs (assuming a 15-year lifetime)

System Type	Measure Costs ($)	Refrigerant Savings ($)	TVD Energy Savings ($)	TDV Carbon Savings ($)	Net Savings ($)
SXX Average	$0	$1,346 - $2,206	($18,138)	$7,990 - $13,940	($8,801) - ($1,991)
MXX Average	$0	$6,772 - $11,101	($102,124)	$39,413 - $69,353	($55,938) – ($21,670)
LXX Average	$0	$7,983 - $13,086	($116,046)	$48,714 - $85,372	($59,349) - ($17,589)
XAX Average	$0	$5,534 - $8,992	($78,747)	$33,229 - $57,609	($39,985) - ($12,146)
XEX Average	$0	$9,122 - $15,204	($78,979)	$58,481 - $101,352	($11,376) – $37,576
XFX Average	$0	$3,323 - $5,400	(78,687)	$17,628 - $32,269	($57,735) - ($41,018)
XXC Average	$0	$7,468 - $12,447	(78,979)	$46,833 - $81,931	($24,678) - $15,399
XXD Average	$0	$2,216 - $3,323	(78,455)	$9,848 - $17,657	($66,391) - ($57,474)
ALL Average	**$0**	$5,367 - $8,798	**(78,769)**	$32,039 - $56,221	($41,363) - ($13,750)

[1] Assumes a constant lifetime cost of roughly $10/lb.

[2] Net Savings= Refrigerant Savings + TDV Energy Savings + TDV Carbon Savings – Measure Costs

Supermarkets

No Hot Gas Defrost (Deleted)

Reach Code Proposal

- Code recommendation:
  - Prohibit use of hot gas defrost.
  - Recommend (but not require?) use of trunk piping.
- Open issues:
  - Are there design configurations that would not allow a mandatory trunk piping?