APPENDIX B. ENGINEERING DATA

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APPENDIX B. ENGINEERING DATA

B.1 INTRODUCTION

This appendix presents baseline specifications and detailed cost-efficiency results for each of the fifteen commercial refrigeration equipment (CRE) equipment classes analyzed in the engineering analysis (Chapter 5).

B.2 BASELINE SPECIFICATIONS

Table B.2.1 shows baseline design options for each of the fifteen commercial refrigeration equipment classes analyzed in the engineering analysis. All changes to cost and efficiency are measured relative to this level in the engineering analysis. Refer to Chapter 5 of the TSD for details about each baseline technology.

Table B.2.2 shows baseline specifications (or case design specifications) for each of the CRE equipment classes analyzed in the engineering analysis. These specifications include dimensions, numbers of components, temperatures, nominal power ratings, and other case features that are necessary to calculate the energy consumption of each equipment class. In conjunction with baseline design option levels, the baseline specifications define the energy consumption and cost of the typical minimum technology equipment on the market.

Table B.2.1 Baseline Design Options

	VCT.RC.L	VOP.RC.M	SVO.RC.M	HZO.RC.L	HZO.RC.M	VCT.RC.M	VOP.RC.L	SOC.RC.M
Lighting for VOP, SVO, HZO and SOC	-	T8 Electronic	T8 Electronic	-	-	-	T8 Electronic	T8 Electronic
Lighting for VCT	T8 Electronic	-	-	-	-	T8 Electronic	-	-
Evaporator Coil Area	Standard Coil	Standard Coil	Standard Coil	Standard Coil	Standard Coil	Standard Coil	Standard Coil	Standard Coil
Evaporator Fan Motors	Shaded Pole Motor	Shaded Pole Motor	Shaded Pole Motor	Shaded Pole Motor	Shaded Pole Motor	Shaded Pole Motor	Shaded Pole Motor	Shaded Pole Motor
Doors for VCT.XX.L/I (30 x 67 in)	Standard Door	-	-	-	-	-	-	-
Doors for VCT.XX.M (30 x 67 in)	-	-	-	-	-	Standard Door	-	-
Doors for HCT.XX.L/I (18 x 20.5 in)	-	-	-	-	-	-	-	-
Doors for SOC.XX.M (20 x 24 in)	-	-	-	-	-	-	-	Standard Door
Condenser Coil Area (SC Only)	-	-	-	-	-	-	-	-
Condenser Fan Motors (SC only)	-	-	-	-	-	-	-	-
Compressor (SC only)	-	-	-	-	-	-	-	-

Table B.2.1 Baseline Design Options (Con't)

	VOP.SC.M	SVO.SC.M	HZO.SC.L	HZO.SC.M	HCT.SC.I	VCT.SC.I	VCS.SC.I
Lighting for VOP, SVO, HZO and SOC	T8 Electronic	T8 Electronic	-	-	-	T8 Electronic	-
Lighting for VCT	-	-	-	-	-	-	-
Evaporator Coil Area	Standard Coil	Standard Coil	Standard Coil	Standard Coil	-	Standard Coil	Standard Coil
Evaporator Fan Motors	Shaded Pole Motor	Shaded Pole Motor	Shaded Pole Motor	Shaded Pole Motor	-	Shaded Pole Motor	Shaded Pole Motor
Doors for VCT.XX.L/I (30 x 67 in)	-	-	-	-	-	Standard Door	-
Doors for VCT.XX.M (30 x 67 in)	-	-	-	-	-	-	-
Doors for HCT.XX.L/I (18 x 20.5 in)	-	-	-	-	Standard Door	-	-
Doors for SOC.XX.M (20 x 24 in)	-	-	-	-	-	-	-
Condenser Coil Area (SC Only)	Standard Coil	Standard Coil	Standard Coil	Standard Coil	Standard Coil	Standard Coil	Standard Coil
Condenser Fan Motors (SC only)	Shaded Pole Motor	Shaded Pole Motor	Shaded Pole Motor	Shaded Pole Motor	Shaded Pole Motor	Shaded Pole Motor	Shaded Pole Motor
Compressor (SC only)	Single Speed Hermetic	Single Speed Hermetic	Single Speed Hermetic	Single Speed Hermetic	Single Speed Hermetic	Single Speed Hermetic	Single Speed Hermetic

Table B.2.2 Baseline Specifications

	VCT.RC.L	VOP.RC.M	SVO.RC.M	HZO.RC.L	HZO.RC.M	VCT.RC.M	VOP.RC.L	SOC.RC.M
Case Length [ft]	12.7	12.0	12.0	12.0	12.0	12.7	12.0	12.0
Case Gross Refrigerated Volume [ft^3]	133.5	130.2	46.6	55.0	33.0	142.0	109.8	66.0
Case Total Display Area [ft^2]	65.0	53.3	40.0	46.0	33.0	65.0	44.7	51.0
Number of Bulbs in Conditioned Space [#]	6	12	9	0	0	6	0	15
Number of Bulbs NOT in Conditioned Space [#]	0	9	6	0	0	0	9	0
Number of Ballasts in Conditioned Space [#]	6	0	0	0	0	6	0	0
Number of Ballasts NOT in Conditioned Space [#]	0	7	5	0	0	0	3	5
Evaporator Fan Nominal Rated Wattage [W]	6	9	9	6	9	6	9	9
Number of Evaporator Fans per Case [#]	5	6	4	4	4	5	14	4
Condenser Fan Nominal Rated Wattage [W]	0	0	0	0	0	0	0	0
Number of Condenser Fans per Case [#]	0	0	0	0	0	0	0	0
Defrost Mechanism Type [OFF, ELE, MAN]	ELE	OFF	OFF	ELE	ELE	OFF	ELE	ELE
Defrost Time per Day [hrs]	1.0	4.5	3.0	1.0	1.0	1.0	2.0	1.2
Defrost+Drain Heater Power [W]	5000	0	0	3000	1000	0	8700	1600
Anti-Sweat Power Other Than Doors [W]	0	0	50	200	50	0	600	200
Condensate Pan Heater Power [W]	0	0	0	0	0	0	0	0
Discharge Air Temperature (DAT) [F]	-5	25	25	-10	25	32	-10	30
Saturated Evaporator Temperature (SET) Nominal [F]	-11	15	15	-20	15	27	-20	20
Saturated Condenser Temperature (SCT) Nominal [F]	0	0	0	0	0	0	0	0
Compressor Oversize Factor	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Insulation Thickness [in]	2.0	1.5	1.5	2.0	1.5	1.5	2.0	1.5
Wall Area [ft2]	200.0	175.9	113.4	140.0	93.3	204.0	214.0	84.6
Number of Doors [#]	5	0	0	0	0	5	0	6
Single Door Area [ft2]	13.0	0.0	0.0	0.0	0.0	13.0	0.0	3.5
Non-Door Glass Area [ft2]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0
Case Interior Surface Area [ft2]	145.0	130.2	72.5	82.0	48.4	146.5	118.5	61.6
Air Curtain Height [ft]								
Air Curtain Angle From Vertical [°]	-	8.5	47.0	90.0	82.0	-	7.3	-
Infiltrated Air Mass [lb/hr]	30	860	590	140	250	30	530	15

Table B.2.2 Baseline Specifications (Con't.)

Equipment Class	VOP.SC.M	SVO.SC.M	HZO.SC.L	HZO.SC.M	HCT.SC.I	VCT.SC.I	VCS.SC.I
Case Length [ft]	4.0	4.0	4.0	4.0	3.4	4.3	4.3
Case Gross Refrigerated Volume [ft3]	32.0	9.4	7.4	7.5	10.2	48.0	48.0
Case Total Display Area [ft2]	14.9	12.8	12.0	12.0	5.1	26.0	0.0
Number of Bulbs in Conditioned Space [#]	4	3	0	0	0	3	0
Number of Bulbs NOT in Conditioned Space [#]	3	2	0	0	0	0	0
Number of Ballasts in Conditioned Space [#]	0	0	0	0	0	3	0
Number of Ballasts NOT in Conditioned Space [#]	3	2	0	0	0	0	0
Evaporator Fan Nominal Rated Wattage [W]	6	6	6	6	0	9	9
Number of Evaporator Fans per Case [#]	2	1	1	1	0	2	2
Condenser Fan Nominal Rated Wattage [W]	9	9	6	6	9	6	6
Number of Condenser Fans per Case [#]	3	1	1	1	1	2	2
Defrost Mechanism Type [OFF, ELE, MAN]	OFF	OFF	ELE	ELE	MAN	ELE	ELE
Defrost Time per Day [hrs]	2.8	2.8	1.5	1.0	0.0	1.0	1.0
Defrost+Drain Heater Power [W]	0	0	900	400	0	2580	2580
Anti-Sweat Power Other Than Doors [W]	0	100	300	100	0	0	250
Condensate Pan Heater Power [W]	1500	1100	400	300	0	200	200
Discharge Air Temperature (DAT) [F]	25	25	-10	25	-20	-20	-20
Saturated Evaporator Temperature (SET) Nominal [F]	15	15	-20	15	-30	-30	-30
Saturated Condenser Temperature (SCT) Nominal [F]	95	95	95	95	95	95	95
Compressor Oversize Factor	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Insulation Thickness [in]	1.5	1.5	2.0	1.5	2.5	2.5	2.5
Wall Area [ft2]	61.0	40.2	52.0	54.0	36.8	77.0	77.0
Number of Doors [#]	0	0	0	0	2	2	2
Single Door Area [ft2]	0.0	0.0	0.0	0.0	2.6	13.0	13.0
Non-Door Glass Area [ft2]	0.0	0.0	4.0	4.0	0.0	0.0	0.0
Case Interior Surface Area [ft2]	47.5	21.3	19.5	19.8	26.1	64.0	64.0
Air Curtain Height [ft]							
Air Curtain Angle From Vertical [°]	6.1	57.0	85.0	85.0	-	-	-
Infiltrated Air Mass [lb/hr]	300	220	100	100	3	15	15

B.3 CHANGES TO LED LIGHTING ASSUMPTIONS

This section details changes to the LED lighting assumptions in the final rule engineering analysis relative to the Notice of Proposed Rulemaking (NOPR) by equipment class. Changes to the LED lighting assumptions for the 15 equipment classes analyzed in the NOPR are presented. If no mention is made of a particular value, that value remained unchanged from the NOPR.

B.3.1 LED Lighting Prices

For the NOPR, DOE could only identify LED luminaires on the market specifically for use in vertical refrigerated cases with transparent doors (i.e., the VCT equipment family). Since DOE could not identify LED luminaires specifically for use in open refrigerated cases (i.e., the VOP equipment family), DOE used the LED luminaires specifically for use in vertical refrigerated cases with transparent doors as the basis for the LED lighting for open refrigerated cases. When DOE re-examined the current state of LED lighting for the final rule, DOE was able to identify LED luminaires on the market specifically for use in open refrigerated cases. DOE updated the LED lighting prices for open refrigerated cases using these newly identified LED luminaires. DOE determined that the cost of a 4 foot, 15 Watt, 888 lumen output LED luminaire is $90.00.

For the final rule, DOE also updated the LED prices for lighting used in the VCT equipment family using the actual reduction in the lumen-based price of LED chips reported in DOE's Multi-Year Program Plan between 2007 and 2008. DOE's 2007 Multi-Year Program Plan reported that the latest available OEM device price for LED chips was $35/kilolumen.[1] DOE's 2008 Multi-Year Program Plan reported that the latest available OEM device price for LED chips was $25/kilolumen.[2] This equates to a 29 percent reduction in lumen-based LED chip costs from 2007 to 2008. For the final rule, DOE applied this 29 percent reduction in lumen-based LED chip costs to the LED lighting for the VCT equipment families, representing about a 9 percent reduction in LED system cost, assuming the costs of the power supply and LED fixtures did not change from the values used in the NOPR engineering analysis.

In the NOPR, because of the rapid development of LED technology, DOE conducted a sensitivity analysis to determine the economic impact of projected LED price reductions. As part of that sensitivity analysis, DOE broke down the cost of the LED system, by using the LED specifications in the NOPR engineering analysis and information obtained from LED lighting and integrated circuit manufacturers, to estimate the cost of the LED chips. For the final rule, DOE modified the cost breakdown from the NOPR (but maintained the total LED system cost) for the VCT equipment family. The 2007 total price of LED chips of the LED lighting system used in the VCT equipment family for the NOPR was $94.77. DOE applied the lumen-based price reductions reported in the DOE's Multi-Year Program Plan from 2007 to 2008 to the $94.77 from the NOPR to arrive at the 2008 value of $82.74. Maintaining the power supply and LED fixture cost from the modified NOPR, the LED system cost breakdown results in a total LED system cost of $114.99 for the final rule. The estimated cost breakdown used to calculate a total LED system cost for the VCT equipment family is shown in Table B.3.1.

Table B.3.1 VCT Equipment Family LED System Cost Breakdown

LED System Cost Component*	Cost Estimate (2008)
LED Chips	$82.74
Power Supply	$13.00
Balance of Fixture	$19.25
TOTAL	**$114.99**

* Accounts for mass-production volumes

B.3.2 LED Lighting Configurations

For the final rule, DOE was able to identify LED lighting specifically for use in both open refrigerated cases and refrigerated cases with transparent doors. Based on the new LED lighting identified for the final rule, DOE updated the case lighting configurations for each equipment class in the engineering analysis.

Lighting for use in cases with transparent doors function differently than lighting for use in cases without doors. Cases with transparent doors typically display boxed merchandise and only products on the front of the shelves are visible to the consumer. Therefore, the only portion of the display case that requires illumination is the area on the front surface of the case at the front of the shelves. Since this is only a limited area that requires lighting, LEDs offer an advantage over fluorescent lighting in vertical refrigerated cases with transparent doors because of the directional nature of LED lighting.

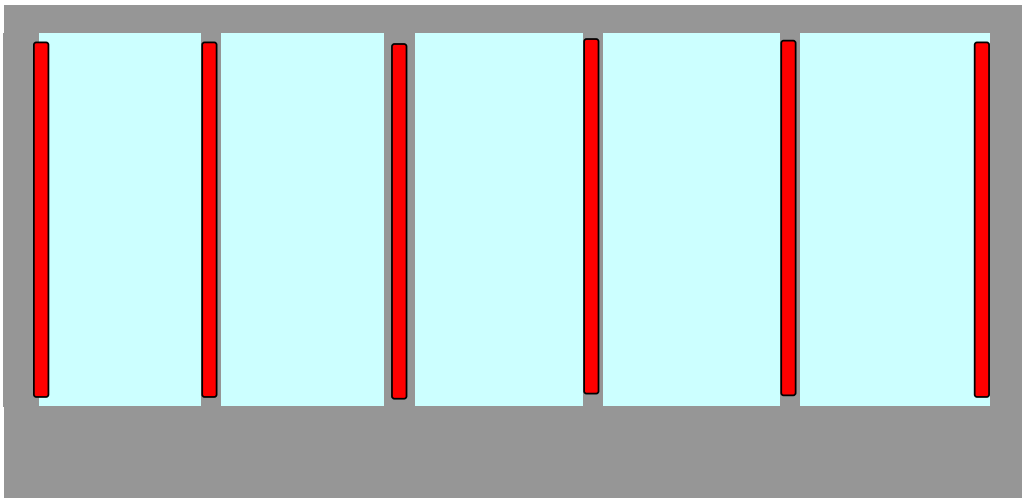
For the VCT equipment family, DOE assumed one fluorescent bulb on each mullion and a fluorescent bulb on each end of the case. There are two different types of LED lighting used in cases with transparent doors. A center mullion lighting fixture is used between doors and is designed to have half of the LED chips directed towards one door and half of the LED chips directed towards the other door. An end mullion lighting fixture has half the light output, cost, and power consumption of a center mullion lighting fixture. The LED chips in an end mullion lighting fixture are all directed towards the one door next to which they are located. Therefore, two end mullion lighting fixtures are the approximately equivalent to a single center mullion lighting fixture with regard to cost, light output, and power consumption. DOE modeled the LED lighting for the VCT equipment family using a center mullion lighting fixture and assumed one center mullion lighting fixture per door. Illustrative front views of the lighting configurations for both fluorescent and LED lighting for the VCT equipment family are shown in Figure B.3.1, Figure B.3.2, and Figure B.3.3. The red strips represent a fluorescent bulb inside the refrigerated volume, the blue strips represent an LED center mullion lighting fixture inside the refrigerated volume, and the green strips represent an LED end mullion lighting fixture inside the refrigerated volume.

Bulb In =
LED In =
1/2 LED In =

Center Mullion
End Mullion (one on either end of case resulting in the equivalent of a single center mullion)

VCT.RC.M

Lighting Type:	Fluorescent
Case Length [ft]:	12.7
Bulb Length [ft]:	5
Bulbs In:	6
Bulbs Out:	0



VCT.RC.M

Lighting Type:	LED
Case Length [ft]:	12.7
Bulb Length [ft]:	5
LEDs In:	5
LEDs Out:	0

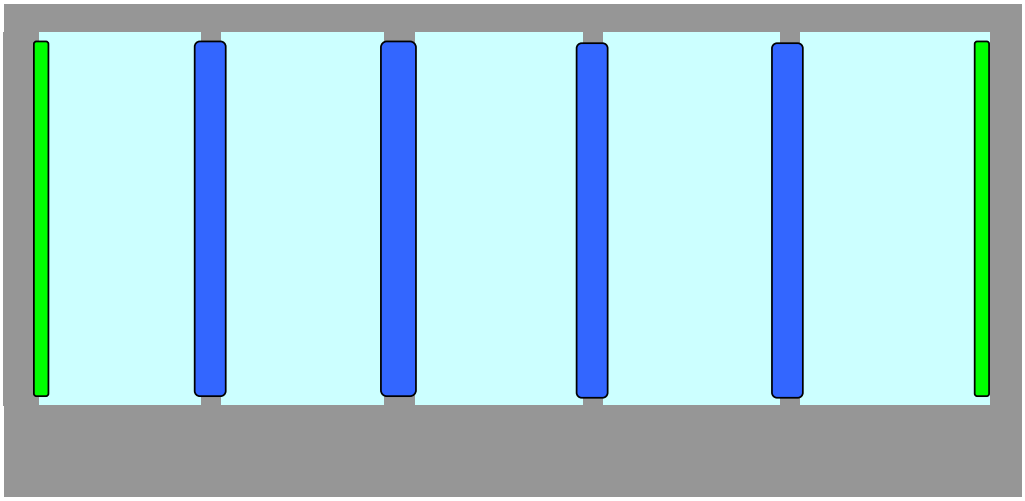
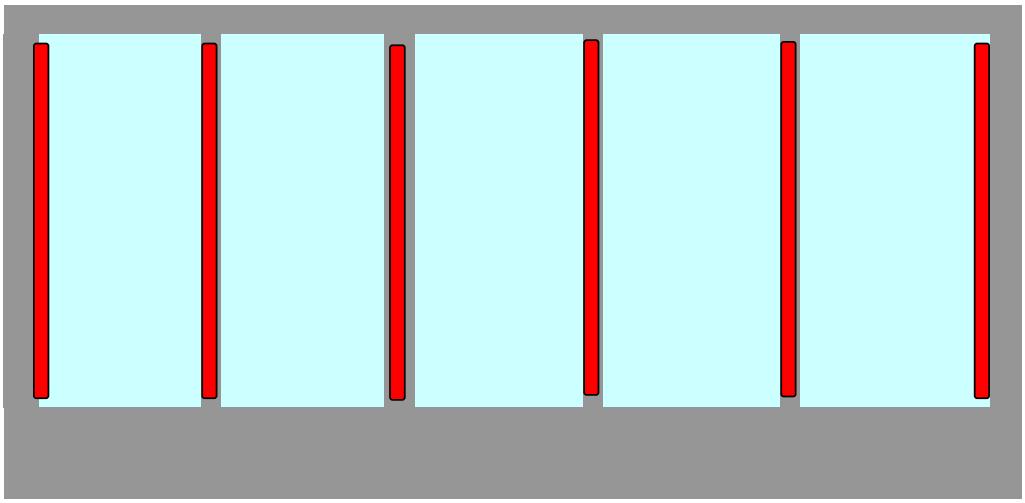


Figure B.3.1 Lighting Configurations for VCT.RC.M

VCT.RC.L

Lighting Type:	Fluorescent
Case Length [ft]:	12.7
Bulb Length [ft]:	5
Bulbs In:	6
Bulbs Out:	0



VCT.RC.L

Lighting Type:	LED
Case Length [ft]:	12.7
Bulb Length [ft]:	5
LEDs In:	5
LEDs Out:	0

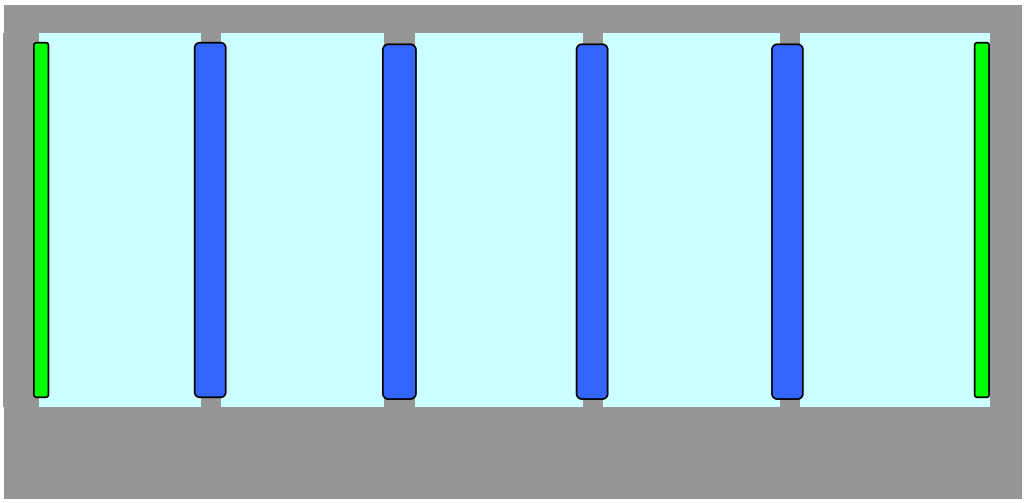


Figure B.3.2 Lighting Configurations for VCT.RC.L

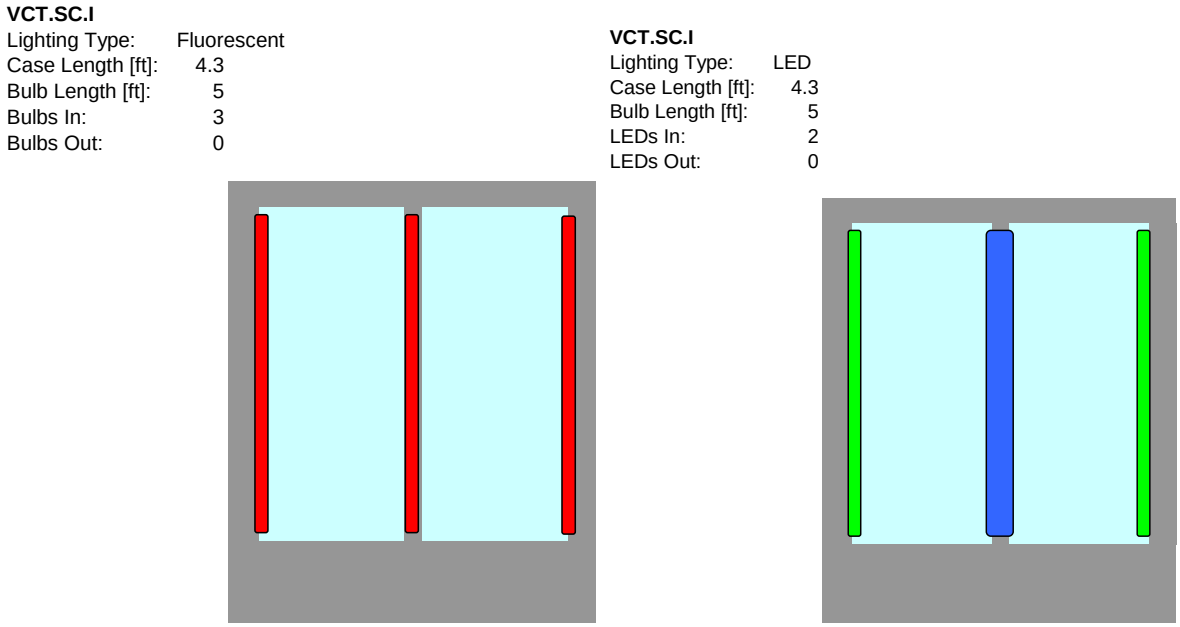


Figure B.3.3 Lighting Configurations for VCT.SC.I

For equipment classes without doors (i.e., VOP, SVO, SOC, and HZO equipment families), merchandise throughout the entire refrigerated volume is visible to the consumer. Therefore, the entire refrigerated volume must be illuminated.[1] For this application, the directional nature of LED lighting tends to be less effective than fluorescent lighting, which outputs light in all directions surrounding the bulb. Based on discussions with LED refrigerated display case lighting manufacturers and comments from commercial refrigeration equipment manufacturers, DOE determined that there are two different types of LED luminaires used in open cases. An LED shelf light is used to illuminate merchandise close to it. Due to the directional nature of the light output from an LED luminaire, DOE assumes that two LED shelf lights are used per shelf to provide the desired illumination throughout an entire shelf: one on the front of the shelf and one midway under the shelf. An LED canopy light is typically located on the canopy of a display case. An LED canopy light has effectively twice the light output, cost, and power consumption of an LED shelf light and is typically used to provide additional illumination of the product in the bottom well of the display case. DOE modeled the LED lighting for the VOP, SVO, and SOC equipment families using an LED shelf light (i.e., DOE used two LED shelf lights as an approximation of one LED canopy light). DOE also assumed that the number of LED lighting fixtures per shelf would have to be doubled from what was assumed for fluorescent lighting in order to provide adequate illumination for the merchandise displayed on each shelf. Illustrative cross-sections of lighting configurations for both fluorescent and LED lighting for the VOP, SVO, and SOC equipment

[1] DOE assumes that the HZO equipment family does not contain any lighting because the ambient light of the store provides adequate illumination of the displayed merchandise.

families are shown in Figure B.3.4 through Figure B.3.9. The green circles represent a fluorescent bulb or LED lighting fixture inside the refrigerated volume and the red circles represent a bulb or LED outside the refrigerated volume.

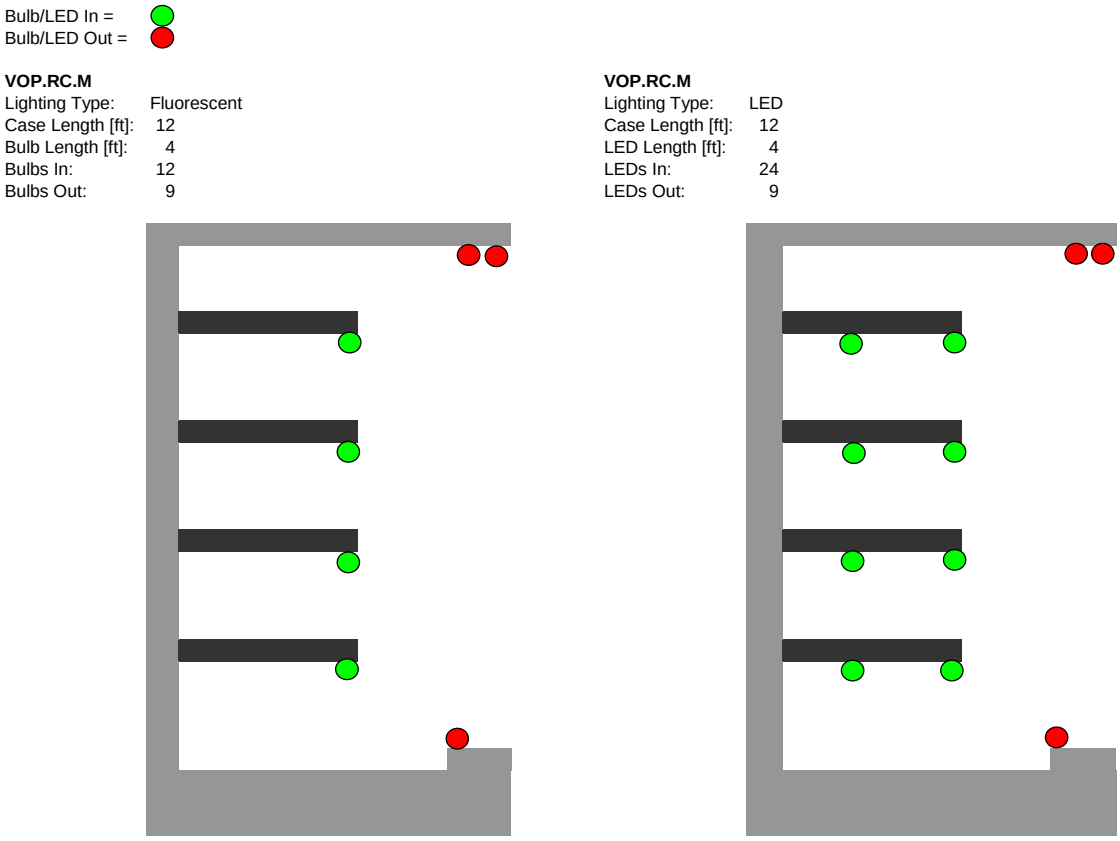
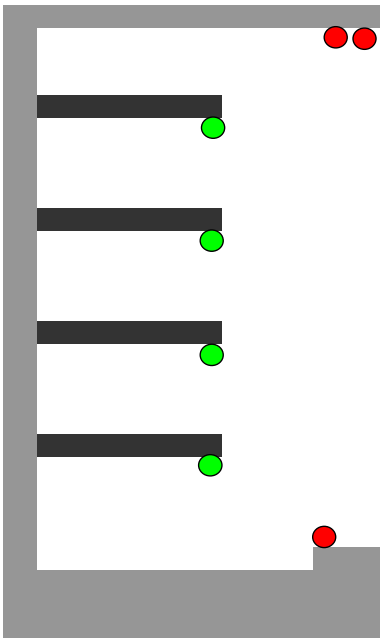


Figure B.3.4 Lighting Configurations for VOP.RC.M

VOP.SC.M

Lighting Type:	Fluorescent
Case Length [ft]:	4
Bulb Length [ft]:	4
Bulbs In:	4
Bulbs Out:	3



VOP.SC.M

Lighting Type:	LED
Case Length [ft]:	4
LED Length [ft]:	4
LEDs In:	8
LEDs Out:	3

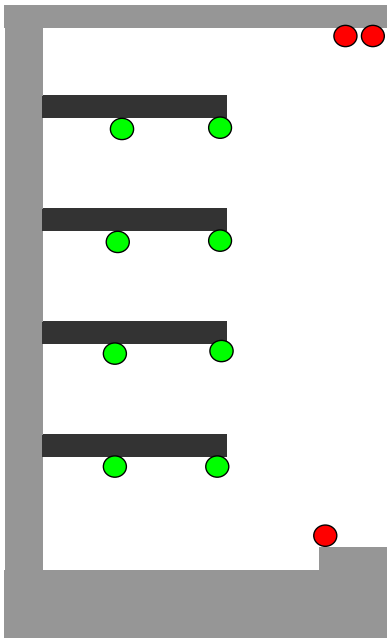
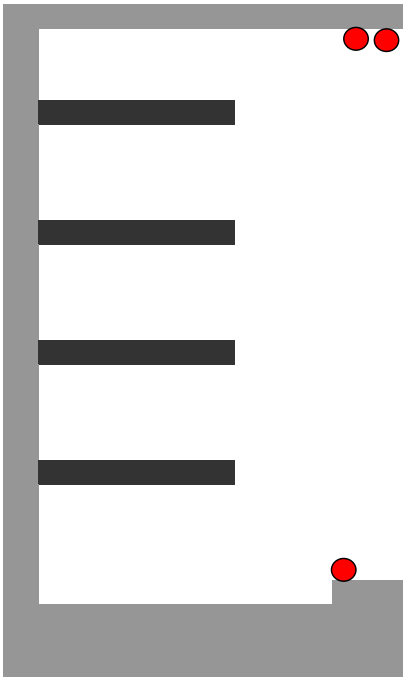


Figure B.3.5 Lighting Configurations for VOP.SC.M

VOP.RC.L

Lighting Type:	Fluorescent
Case Length [ft]:	12
Bulb Length [ft]:	4
Bulbs In:	0
Bulbs Out:	9



VOP.RC.L

Lighting Type:	LED
Case Length [ft]:	12
LED Length [ft]:	4
LEDs In:	0
LEDs Out:	9

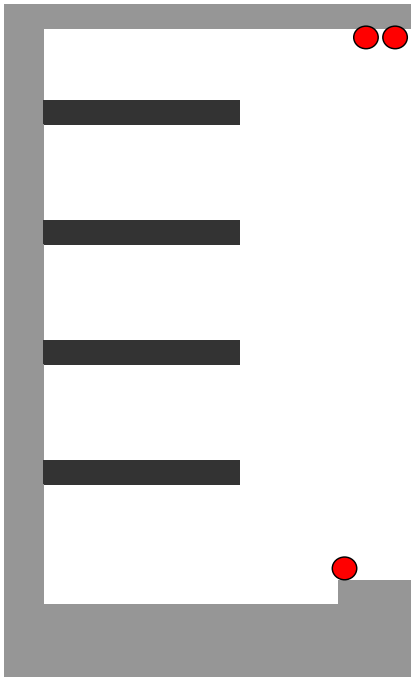
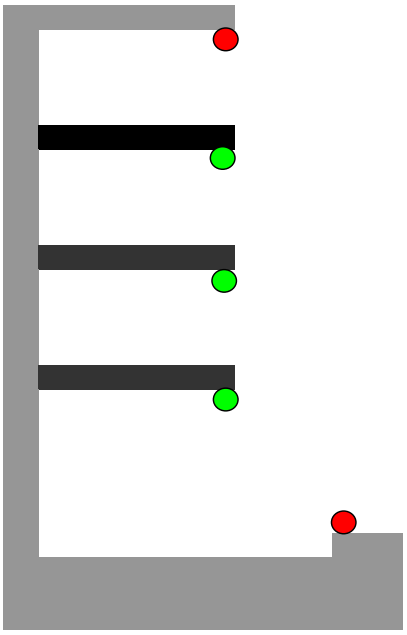


Figure B.3.6 Lighting Configurations for VOP.RC.L

SVO.RC.M

Lighting Type:	Fluorescent
Case Length [ft]:	12
Bulb Length [ft]:	4
Bulbs In:	9
Bulbs Out:	6



SVO.RC.M

Lighting Type:	LED
Case Length [ft]:	12
LED Length [ft]:	4
LEDs In:	18
LEDs Out:	6

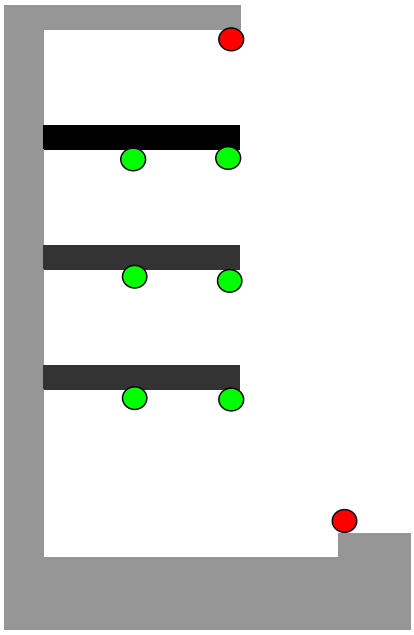
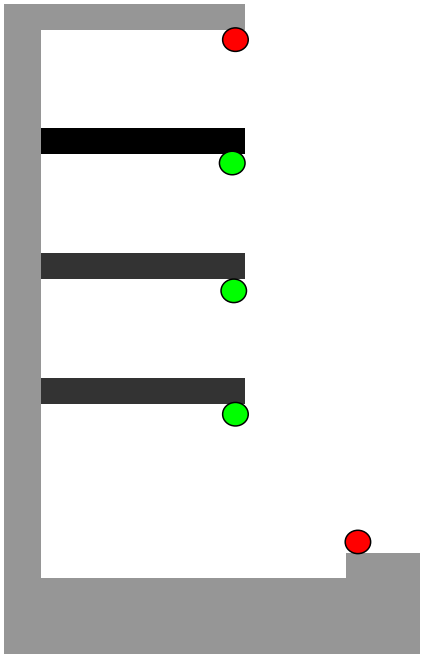


Figure B.3.7 Lighting Configurations for SVO.RC.M

SVO.SC.M

Lighting Type:	Fluorescent
Case Length [ft]:	4
Bulb Length [ft]:	4
Bulbs In:	3
Bulbs Out:	2



SVO.SC.M

Lighting Type:	LED
Case Length [ft]:	4
LED Length [ft]:	4
LEDs In:	6
LEDs Out:	2

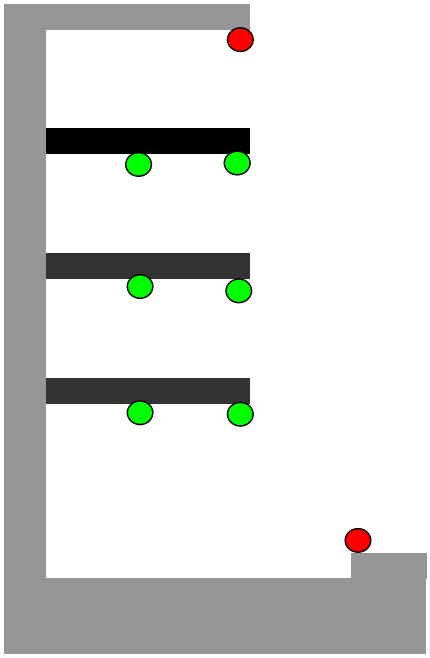
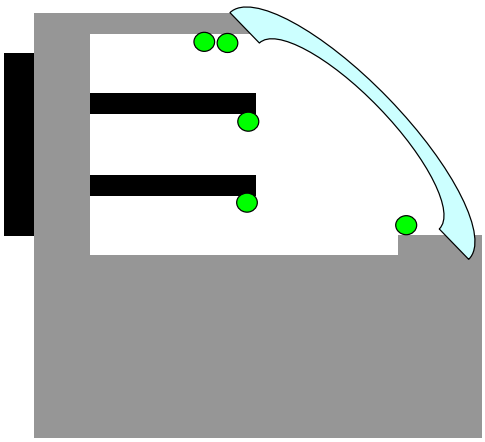


Figure B.3.8 Lighting Configurations for SVO.RC.M

SOC.RC.M

Lighting Type:	Fluorescent
Case Length [ft]:	12
Bulb Length [ft]:	4
Bulbs In:	15
Bulbs Out:	0



SOC.RC.M

Lighting Type:	LED
Case Length [ft]:	12
LED Length [ft]:	4
LEDs In:	18
LEDs Out:	0

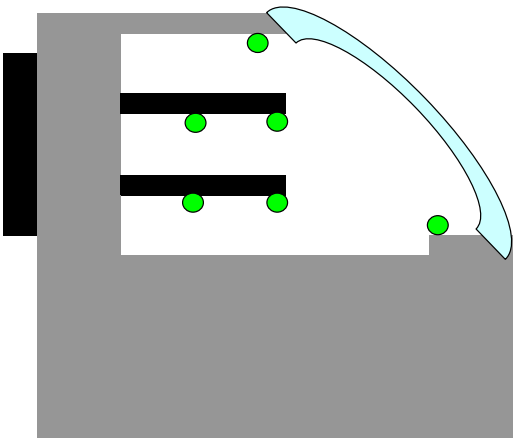


Figure B.3.9 Lighting Configurations for SOC.RC.M

Cost-Efficiency Results

For each of the fifteen CRE equipment classes analyzed in the engineering analysis, Figure B.3.10 through Figure B.3.24 show cost-efficiency curves and Table B.3.2 through Table B.3.16 show detailed cost-efficiency data. Included in each table are DOE analytically derived data and technology changes that occur above the baseline level. Levels above the baseline for analytically derived data ("design option levels") are labeled as "AD1", "AD2", and so forth.

Design option changes above the baseline are shown in Table B.3.2 through Table B.3.16 as additions to the previous design option level. Design options are implemented in order of lowest payback to highest and only one design option change is made per design option level.

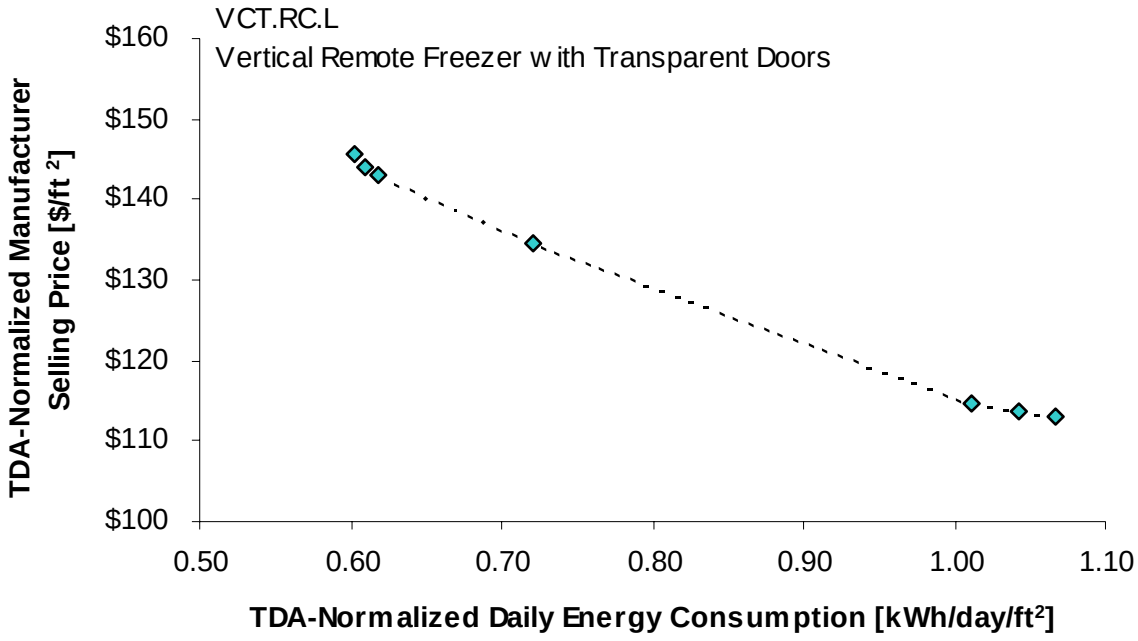


Figure B.3.10 Cost-Efficiency Curve for the VCT.RC.L Equipment Class

Table B.3.2 Cost-Efficiency Data and Design Options for the VCT.RC.L Equipment Class

DOE Analytically-Derived Data

Design Option Level	TDA-Normalized Daily Energy Consumption [kWh/day/ft^2]	TDA-Normalized Manufacturer Selling Price [$/ft^2]	Design Option Change Above the Baseline
AD1	1.07	113.17	-
AD2	1.04	113.61	AD1 + PSC Evaporator Fan Motors
AD3	1.01	114.67	AD2 + ECM Evaporator Fan Motors
AD4	0.72	134.42	AD3 + High-Performance Doors
AD5	0.62	143.16	AD4 + LED Lighting
AD6	0.61	143.98	AD5 + Additional 1/2" Insulation
AD7	0.60	145.70	AD6 + High-Performance Evaporator Coil

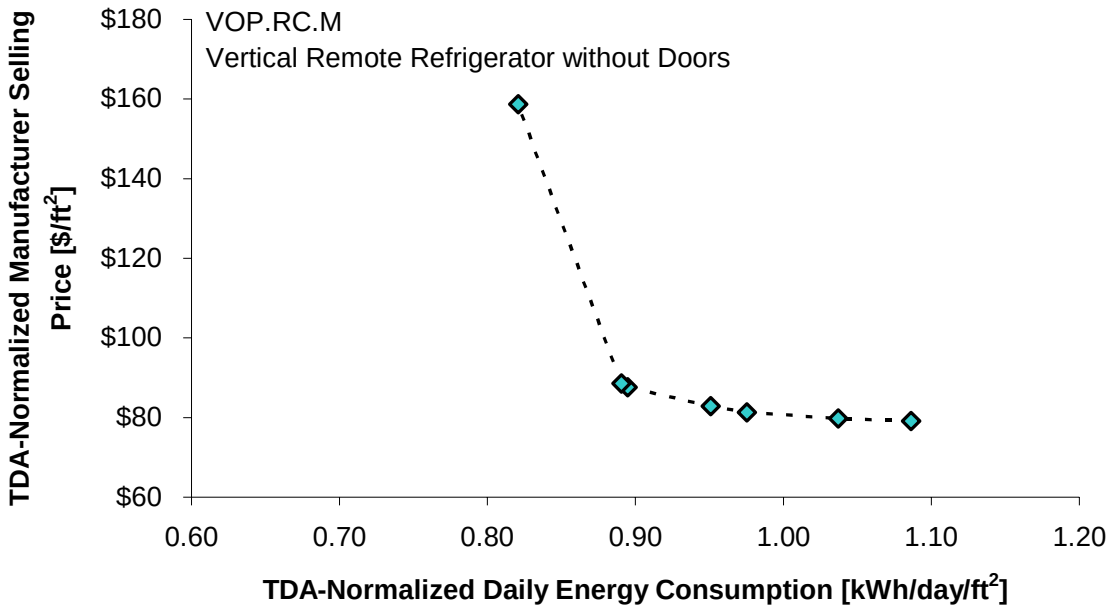


Figure B.3.11 Cost-Efficiency Curve for the VOP.RC.M Equipment Class

Table B.3.3 Cost-Efficiency Data and Design Options for the VOP.RC.M Equipment Class

DOE Analytically-Derived Data

Design Option Level	TDA-Normalized Daily Energy Consumption [kWh/day/ft^2]	TDA-Normalized Manufacturer Selling Price [$/ft^2]	Design Option Change Above the Baseline
AD1	1.09	79.12	-
AD2	1.04	79.76	AD1 + PSC Evaporator Fan Motors
AD3	0.98	81.30	AD2 + ECM Evaporator Fan Motors
AD4	0.95	82.90	AD3 + Super T8 Lighting
AD5	0.89	87.59	AD4 + High-Performance Evaporator Coil
AD6	0.89	88.58	AD5 + Additional 1/2" Insulation
AD7	0.82	158.71	AD6 + LED Lighting

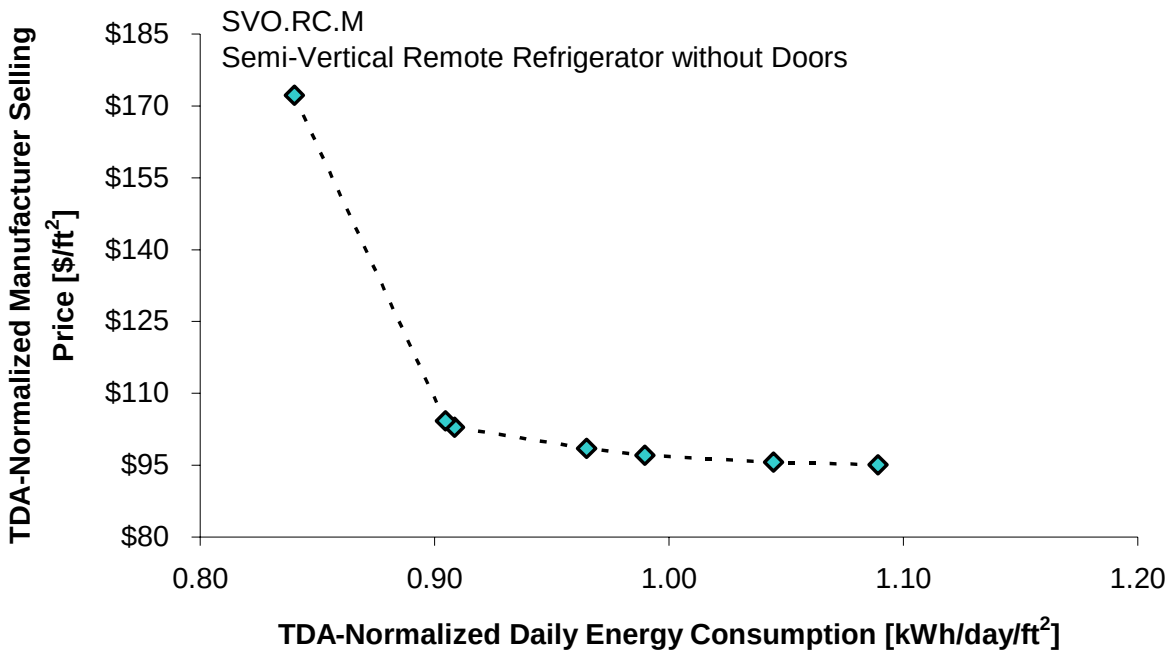


Figure B.3.12 Cost-Efficiency Curve for the SVO.RC.M Equipment Class

Table B.3.4 Cost-Efficiency Data and Design Options for the SVO.RC.M Equipment Class

DOE Analytically-Derived Data

Design Option Level	TDA-Normalized Daily Energy Consumption [kWh/day/ft^2]	TDA-Normalized Manufacturer Selling Price [$/ft^2]	Design Option Change Above the Baseline
AD1	1.09	95.10	-
AD2	1.04	95.67	AD1 + PSC Evaporator Fan Motors
AD3	0.99	97.04	AD2 + ECM Evaporator Fan Motors
AD4	0.96	98.56	AD3 + Super T8 Lighting
AD5	0.91	102.91	AD4 + High-Performance Evaporator Coil
AD6	0.90	104.24	AD5 + Additional 1/2" Insulation
AD7	0.84	172.27	AD6 + LED Lighting

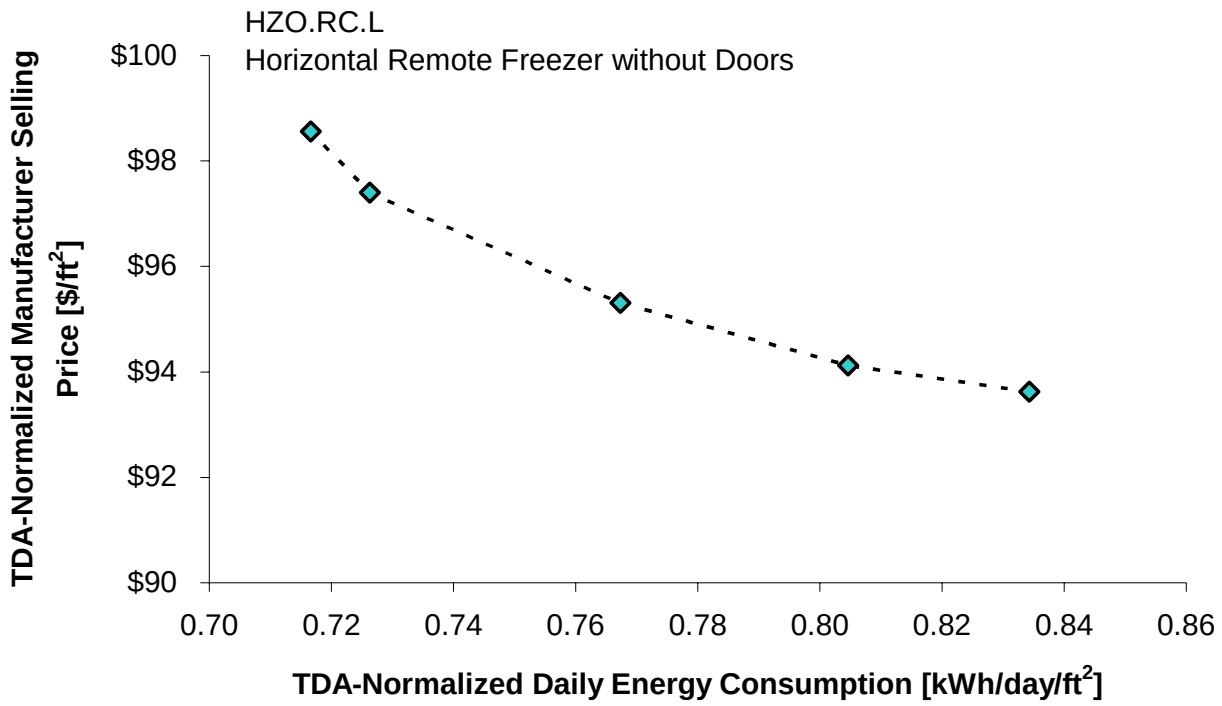


Figure B.3.13 Cost-Efficiency Curve for the HZO.RC.L Equipment Class

Table B.3.5 Cost-Efficiency Data and Design Options for the HZO.RC.L Equipment Class

DOE Analytically-Derived Data

Design Option Level	TDA-Normalized Daily Energy Consumption [kWh/day/ft^2]	TDA-Normalized Manufacturer Selling Price [$/ft^2]	Design Option Change Above the Baseline
AD1	0.83	93.63	-
AD2	0.80	94.12	AD1 + PSC Evaporator Fan Motors
AD3	0.77	95.31	AD2 + ECM Evaporator Fan Motors
AD4	0.73	97.40	AD3 + High-Performance Evaporator Coil
AD5	0.72	98.56	AD4 + Additional 1/2" Insulation

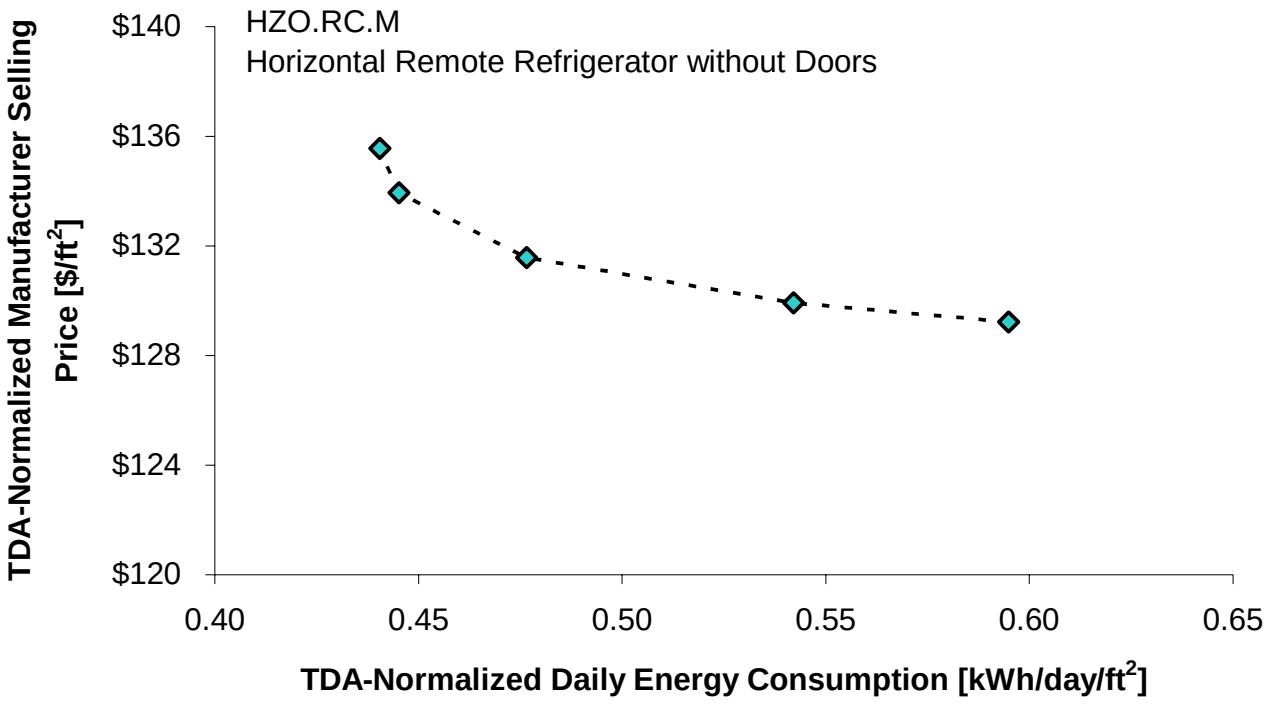


Figure B.3.14 Cost-Efficiency Curve for the HZO.RC.M Equipment Class

Table B.3.6 Cost-Efficiency Data and Design Options for the HZO.RC.M Equipment Class

DOE Analytically-Derived Data

Design Option Level	TDA-Normalized Daily Energy Consumption [kWh/day/ft^2]	TDA-Normalized Manufacturer Selling Price [$/ft^2]	Design Option Change Above the Baseline
AD1	0.59	129.23	-
AD2	0.54	129.92	AD1 + PSC Evaporator Fan Motors
AD3	0.48	131.58	AD2 + ECM Evaporator Fan Motors
AD4	0.45	133.95	AD3 + High-Performance Evaporator Coil
AD5	0.44	135.56	AD4 + Additional 1/2" Insulation

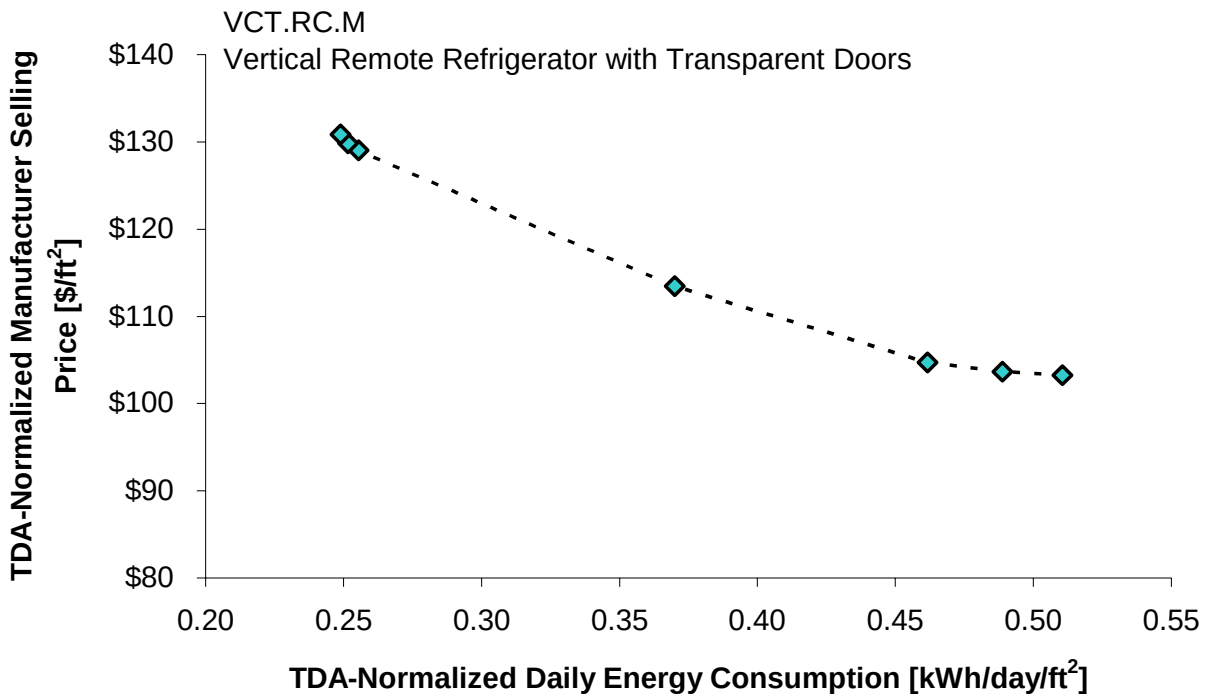


Figure B.3.15 Cost-Efficiency Curve for the VCT.RC.M Equipment Class

Table B.3.7 Cost-Efficiency Data and Design Options for the VCT.RC.M Equipment Class

DOE Analytically-Derived Data

Design Option Level	TDA-Normalized Daily Energy Consumption [kWh/day/ft^2]	TDA-Normalized Manufacturer Selling Price [$/ft^2]	Design Option Change Above the Baseline
AD1	0.51	103.23	-
AD2	0.49	103.67	AD1 + PSC Evaporator Fan Motors
AD3	0.46	104.72	AD2 + ECM Evaporator Fan Motors
AD4	0.37	113.47	AD3 + LED Lighting
AD5	0.26	129.02	AD4 + High-Performance Doors
AD6	0.25	129.84	AD5 + Additional 1/2" Insulation
AD7	0.25	130.86	AD6 + High-Performance Evaporator Coil

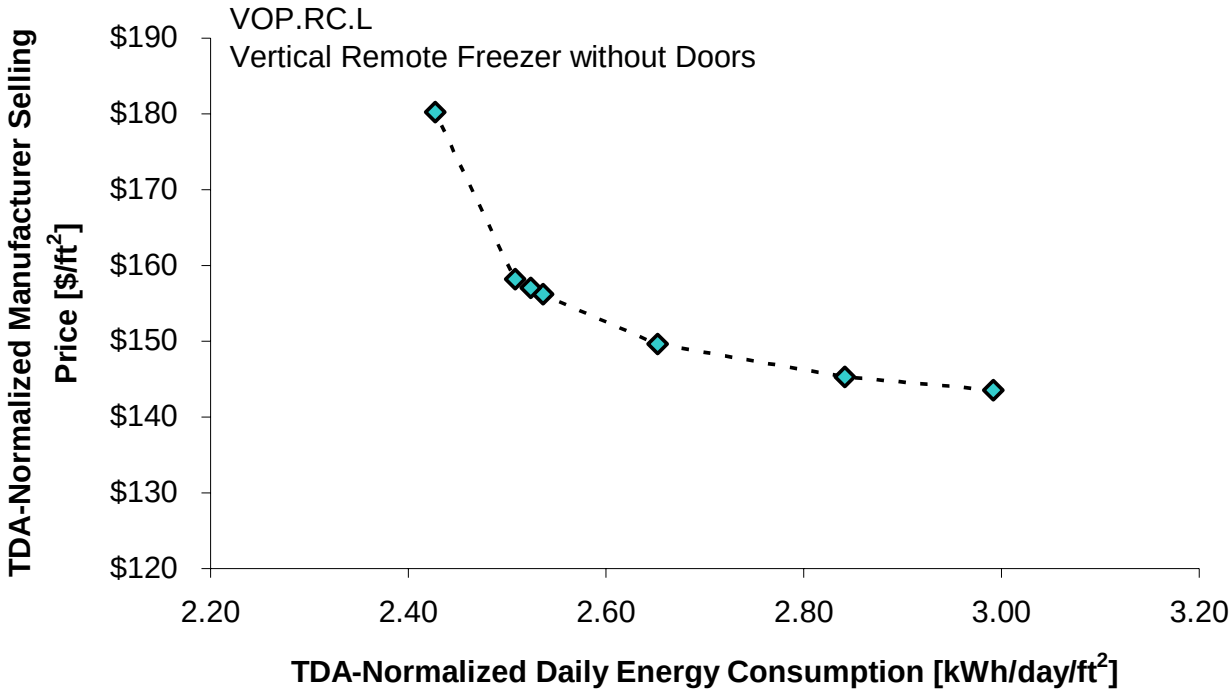


Figure B.3.16 Cost-Efficiency Curve for the VOP.RC.L Equipment Class

Table B.3.8 Cost-Efficiency Data and Design Options for the VOP.RC.L Equipment Class

DOE Analytically-Derived Data

Design Option Level	TDA-Normalized Daily Energy Consumption [kWh/day/ft^2]	TDA-Normalized Manufacturer Selling Price [$/ft^2]	Design Option Change Above the Baseline
AD1	2.99	143.54	-
AD2	2.84	145.32	AD1 + PSC Evaporator Fan Motors
AD3	2.65	149.62	AD2 + ECM Evaporator Fan Motors
AD4	2.54	156.20	AD3 + High-Performance Evaporator Coil
AD5	2.52	157.02	AD4 + Super T8 Lighting
AD6	2.51	158.21	AD5 + Additional 1/2" Insulation
AD7	2.43	180.22	AD6 + LED Lighting

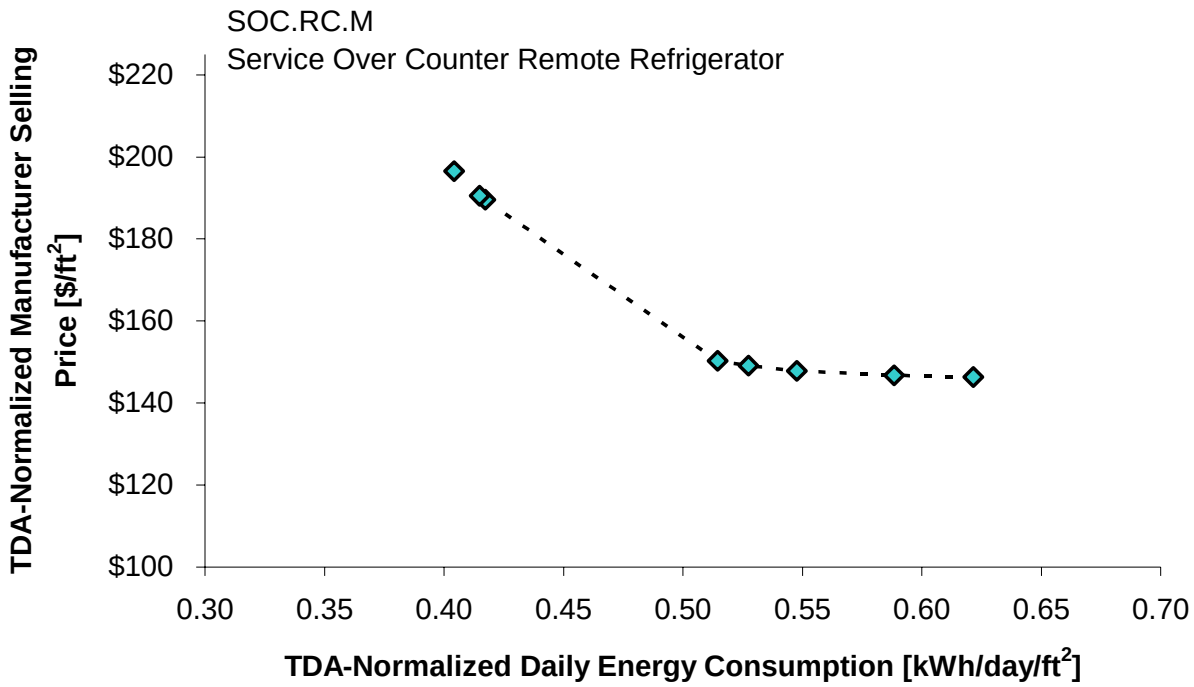


Figure B.3.17 Cost-Efficiency Curve for the SOC.RC.M Equipment Class

Table B.3.9 Cost-Efficiency Data and Design Options for the SOC.RC.M Equipment Class

DOE Analytically-Derived Data

Design Option Level	TDA-Normalized Daily Energy Consumption [kWh/day/ft^2]	TDA-Normalized Manufacturer Selling Price [$/ft^2]	Design Option Change Above the Baseline
AD1	0.62	146.36	-
AD2	0.59	146.81	AD1 + PSC Evaporator Fan Motors
AD3	0.55	147.88	AD2 + ECM Evaporator Fan Motors
AD4	0.53	149.08	AD3 + Super T8 Lighting
AD5	0.51	150.33	AD4 + High-Performance Evaporator Coil
AD6	0.42	189.53	AD5 + LED Lighting
AD7	0.41	190.57	AD6 + Additional 1/2" Insulation
AD8	0.40	196.55	AD7 + High-Performance Doors

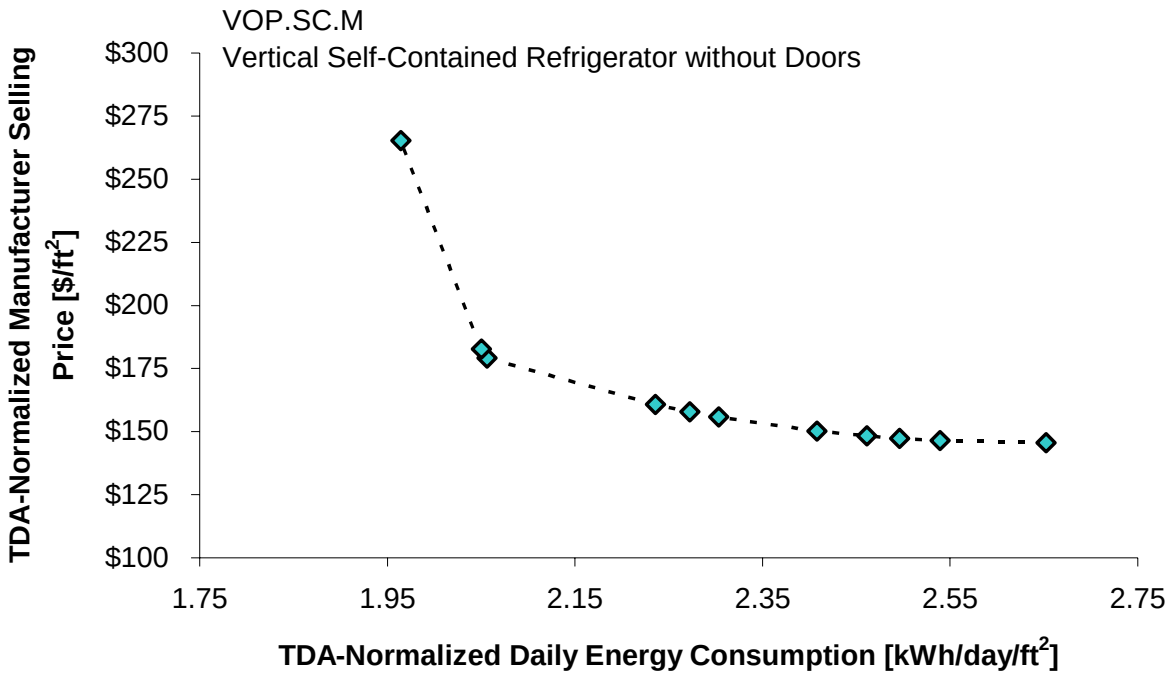


Figure B.3.18 Cost-Efficiency Curve for the VOP.SC.M Equipment Class

Table B.3.10 Cost-Efficiency Data and Design Options for the VOP.SC.M Equipment Class

DOE Analytically-Derived Data			
Design Option Level	**TDA-Normalized Daily Energy Consumption [kWh/day/ft^2]**	**TDA-Normalized Manufacturer Selling Price [$/ft^2]**	**Design Option Change Above the Baseline**
AD1	2.65	145.66	-
AD2	2.54	146.49	AD1 + High-Efficiency Compressor
AD3	2.50	147.25	AD2 + PSC Evaporator Fan Motors
AD4	2.46	148.39	AD3 + PSC Condenser Fan Motors
AD5	2.41	150.23	AD4 + ECM Evaporator Fan Motors
AD6	2.30	155.87	AD5 + High-Performance Evaporator Coil
AD7	2.27	157.96	AD6 + Super T8 Lighting
AD8	2.24	160.71	AD7 + ECM Condenser Fan Motors
AD9	2.06	179.11	AD8 + High-Performance Condenser Coil
AD10	2.05	182.67	AD9 + Additional 1/2" Insulation
AD11	1.96	265.29	AD10 + LED Lighting

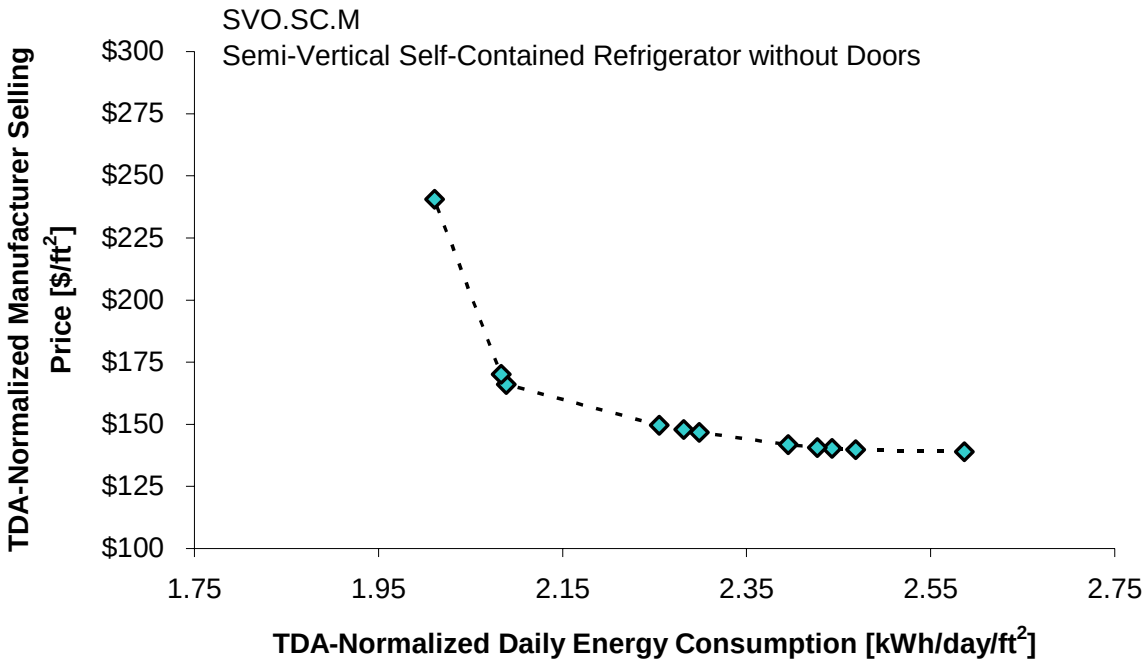


Figure B.3.19 Cost-Efficiency Curve for the SVO.SC.M Equipment Class

Table B.3.11 Cost-Efficiency Data and Design Options for the SVO.SC.M Equipment Class

DOE Analytically-Derived Data			
Design Option Level	**TDA-Normalized Daily Energy Consumption [kWh/day/ft^2]**	**TDA-Normalized Manufacturer Selling Price [$/ft^2]**	**Design Option Change Above the Baseline**
AD1	2.59	138.92	-
AD2	2.47	139.82	AD1 + High-Efficiency Compressor
AD3	2.44	140.27	AD2 + PSC Evaporator Fan Motors
AD4	2.43	140.71	AD3 + PSC Condenser Fan Motors
AD5	2.40	141.78	AD4 + ECM Evaporator Fan Motors
AD6	2.30	146.81	AD5 + High-Performance Evaporator Coil
AD7	2.28	147.88	AD6 + ECM Condenser Fan Motors
AD8	2.26	149.57	AD7 + Super T8 Lighting
AD9	2.09	165.98	AD8 + High-Performance Condenser Coil
AD10	2.08	170.13	AD9 + Additional 1/2" Insulation
AD11	2.01	240.51	AD10 + LED Lighting

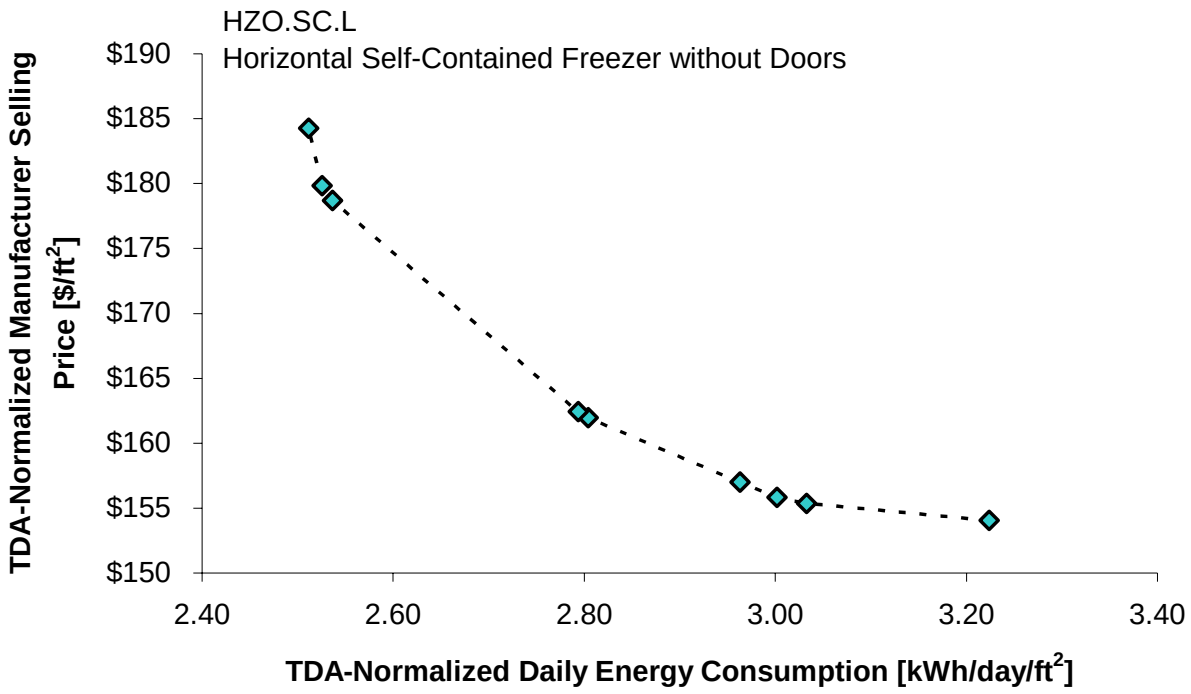


Figure B.3.20 Cost-Efficiency Curve for the HZO.SC.L Equipment Class

Table B.3.12 Cost-Efficiency Data and Design Options for the HZO.SC.L Equipment Class

DOE Analytically-Derived Data

Design Option Level	TDA-Normalized Daily Energy Consumption [kWh/day/ft^2]	TDA-Normalized Manufacturer Selling Price [$/ft^2]	Design Option Change Above the Baseline
AD1	3.22	154.04	-
AD2	3.03	155.38	AD1 + High-Efficiency Compressor
AD3	3.00	155.85	AD2 + PSC Evaporator Fan Motors
AD4	2.96	156.99	AD3 + ECM Evaporator Fan Motors
AD5	2.80	161.97	AD4 + High-Performance Evaporator Coil
AD6	2.79	162.44	AD5 + PSC Condenser Fan Motors
AD7	2.54	178.69	AD6 + High-Performance Condenser Coil
AD8	2.53	179.83	AD7 + ECM Condenser Fan Motors
AD9	2.51	184.26	AD8 + Additional 1/2" Insulation

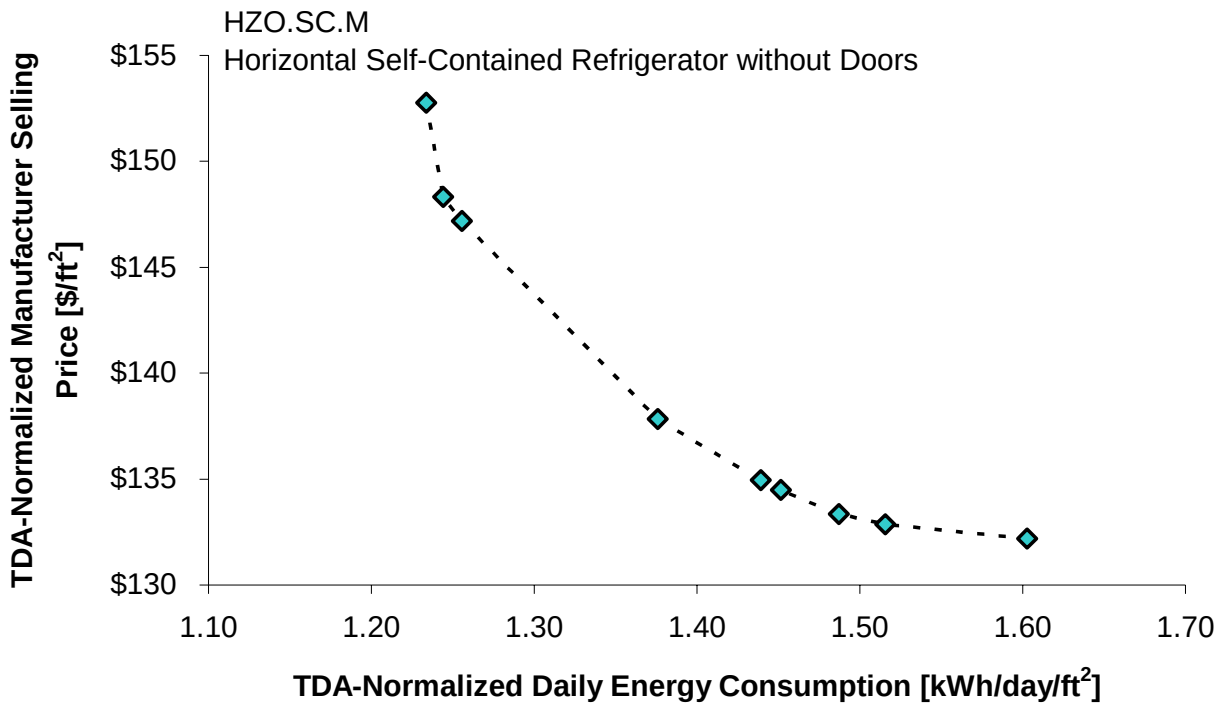


Figure B.3.21 Cost-Efficiency Curve for the HZO.SC.M Equipment Class

Table B.3.13 Cost-Efficiency Data and Design Options for the HZO.SC.M Equipment Class

DOE Analytically-Derived Data			
Design Option Level	**TDA-Normalized Daily Energy Consumption [kWh/day/ft^2]**	**TDA-Normalized Manufacturer Selling Price [$/ft^2]**	**Design Option Change Above the Baseline**
AD1	1.60	132.19	-
AD2	1.52	132.87	AD1 + High-Efficiency Compressor
AD3	1.49	133.34	AD2 + PSC Evaporator Fan Motors
AD4	1.45	134.48	AD3 + ECM Evaporator Fan Motors
AD5	1.44	134.96	AD4 + PSC Condenser Fan Motors
AD6	1.38	137.83	AD5 + High-Performance Evaporator Coil
AD7	1.26	147.19	AD6 + High-Performance Condenser Coil
AD8	1.24	148.33	AD7 + ECM Condenser Fan Motors
AD9	1.23	152.76	AD8 + Additional 1/2" Insulation

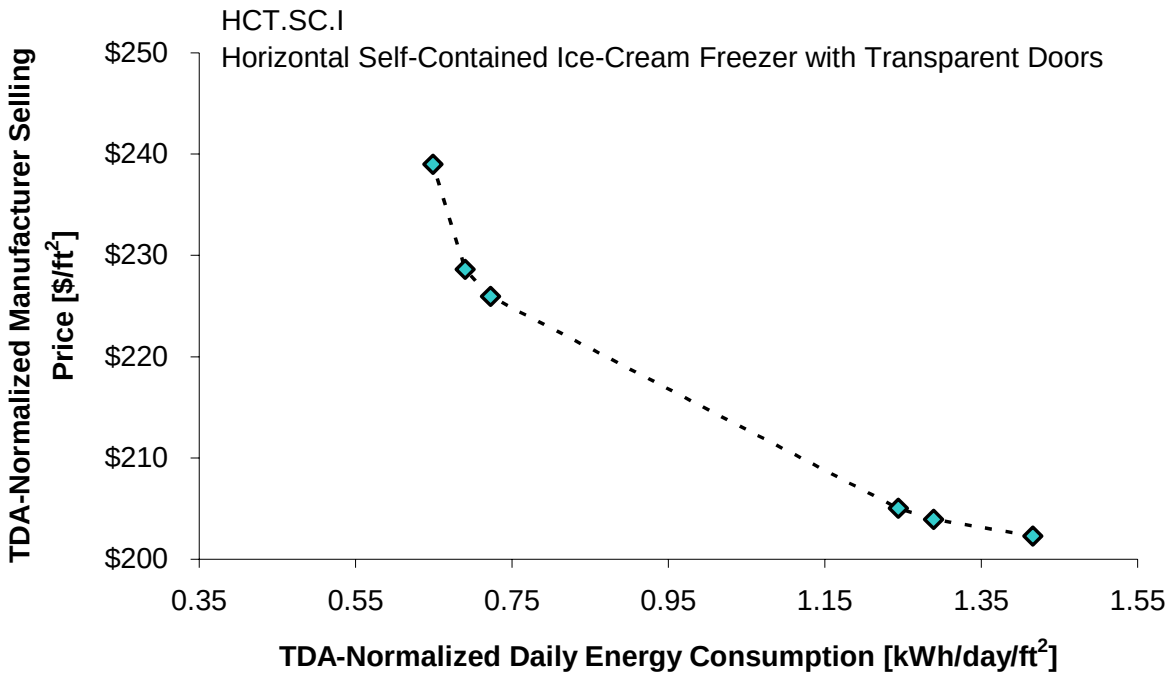


Figure B.3.22 Cost-Efficiency Curve for the HCT.SC.I Equipment Class

Table B.3.14 Cost-Efficiency Data and Design Options for the HCT.SC.I Equipment Class

DOE Analytically-Derived Data

Design Option Level	TDA-Normalized Daily Energy Consumption [kWh/day/ft^2]	TDA-Normalized Manufacturer Selling Price [$/ft^2]	Design Option Change Above the Baseline
AD1	1.42	202.29	-
AD2	1.29	203.93	AD1 + High-Efficiency Compressor
AD3	1.24	205.04	AD2 + PSC Condenser Fan motors
AD4	0.72	225.93	AD3 + High-Performance Doors
AD5	0.69	228.61	AD4 + ECM Condenser Fan motors
AD6	0.65	239.00	AD5 + Additional 1/2" Insulation

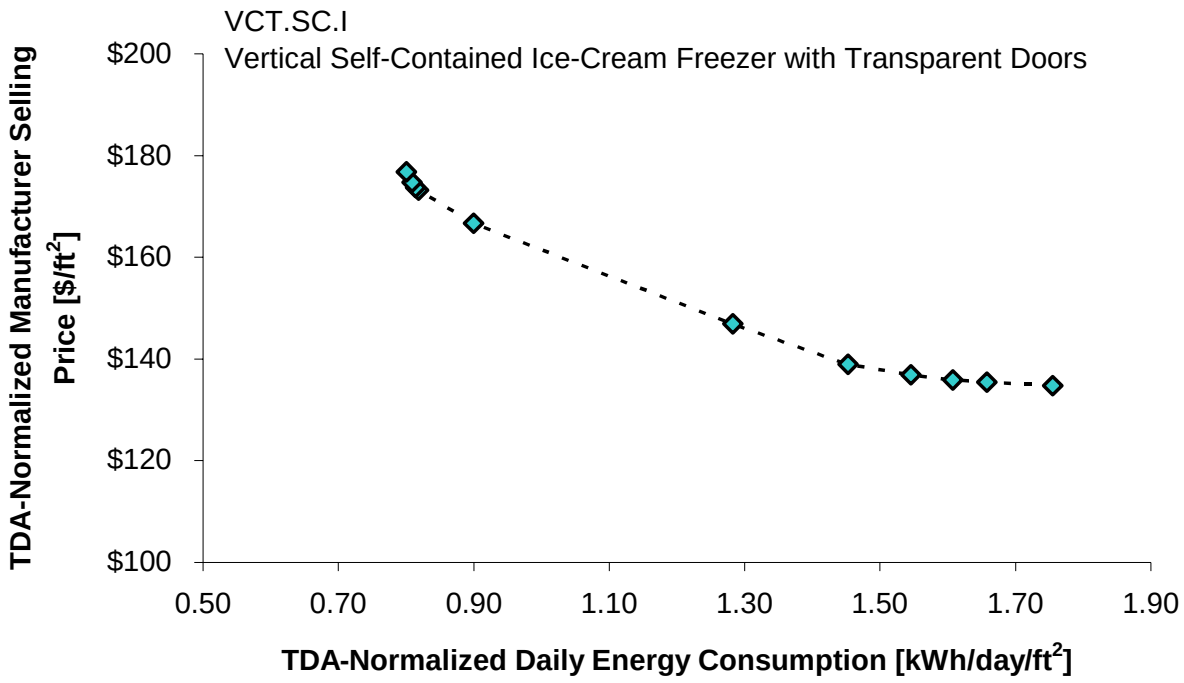


Figure B.3.23 Cost-Efficiency Curve for the VCT.SC.I Equipment Class

Table B.3.15 Cost-Efficiency Data and Design Options for the VCT.SC.I Equipment Class

DOE Analytically-Derived Data

Design Option Level	TDA-Normalized Daily Energy Consumption [kWh/day/ft^2]	TDA-Normalized Manufacturer Selling Price [$/ft^2]	Design Option Change Above the Baseline
AD1	1.76	134.76	-
AD2	1.66	135.45	AD1 + High-Efficiency Compressor
AD3	1.61	135.88	AD2 + PSC Evaporator Fan Motors
AD4	1.55	136.94	AD3 + ECM Evaporator Fan Motors
AD5	1.45	138.95	AD4 + High-Performance Evaporator Coil
AD6	1.28	146.92	AD5 + LED Lighting
AD7	0.90	166.68	AD6 + High-Performance Doors
AD8	0.82	173.24	AD7 + High-Performance Condenser Coil
AD9	0.81	173.67	AD8 + PSC Condenser Fan motors
AD10	0.81	174.73	AD9 + ECM Condenser Fan motors
AD11	0.80	176.77	AD10 + Additional 1/2" Insulation

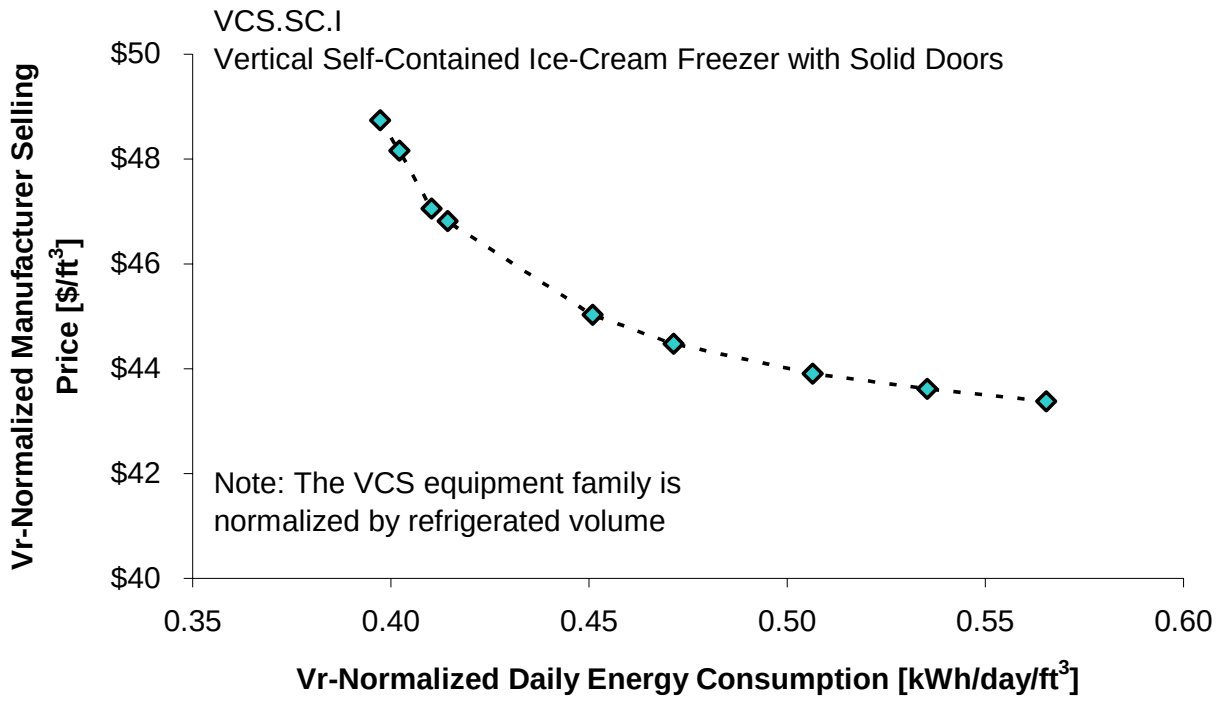


Figure B.3.24 Cost-Efficiency Curve for the VCS.SC.I Equipment Class

Table B.3.16 Cost-Efficiency Data and Design Options for the VCS.SC.I Equipment Class

DOE Analytically-Derived Data

Design Option Level	V-Normalized Daily Energy Consumption [kWh/day/ft^3]	V-Normalized Manufacturer Selling Price [$/ft^3]	Design Option Change Above the Baseline
AD1	0.57	43.38	-
AD2	0.54	43.61	AD1 + PSC Evaporator Fan Motors
AD3	0.51	43.91	AD2 + High-Efficiency Compressor
AD4	0.47	44.48	AD3 + ECM Evaporator Fan Motors
AD5	0.45	45.03	AD4 + High-Performance Evaporator Coil
AD6	0.41	46.82	AD5 + High-Performance Condenser Coil
AD7	0.41	47.06	AD6 + PSC Condenser Fan motors
AD8	0.40	48.17	AD7 + Additional 1/2" Insulation
AD9	0.40	48.74	AD8 + ECM Condenser Fan motors

REFERENCES

[1] U.S. Department of Energy, Solid-State Lighting Research and Development, Multi-Year Program Plan FY'08-FY'13.

[2] U.S. Department of Energy, Solid-State Lighting Research and Development, Multi-Year Program Plan FY'09-FY'14.