PG&E

CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

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Building Envelope Tradeoff Method

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Overview

The building envelope tradeoff method contained in Section 143(b) contains a building envelope tradeoff procedure whereby fenestration performance, insulation levels and cool roof properties may be traded off to achieve compliance with the standards. The current procedure includes two criteria that shall be met in order to achieve compliance. The heat loss (HL) of the proposed design shall be no greater than the HL of the standard design, and the heat gain (HG) of the proposed design shall be no greater than the HG of the standard design.

The building envelope tradeoff method was first developed in 1992 and has been tweaked and/or modified with each update cycle of the standards. The incremental changes have resulted in a procedure that is unnecessarily cumbersome. Furthermore, the currency for comparing energy performance changed from source energy to (time dependent valued) TDV energy with the 2005 update. An opportunity exists to simplify the procedure and base it on TDV energy rather than source energy.

The recommended tradeoff procedure will combine the heat loss and heat gain equations into a single tradeoff equation that calculates the annual TDV energy of space cooling and heating based on the thermal performance of envelope. Tradeoffs would be compared in TDV energy instead of source energy and this would allow for tradeoffs between cooling and heating aspects of the envelope. The new tradeoffs would also allow greater flexibility in envelope design while minimizing energy cost.

This proposal would also introduce a new coefficient for visual light transmittance in order to better model the different solar heat gain performance between single and multiple layered glazing. The pre-existing fenestration model is based on U-factor and SHGC (solar heat gain coefficient) only and takes no account of visible light transmittance or number of glazing layers. The SHGC is measured at normal (perpendicular) solar incidence. As the incident angle of sunlight increases, the fraction of transmitted solar heat (angular SHGC) decreases. As shown in Figure 1, the angular SHGC decreases more rapidly as incidence angle increases for multiple glazing layer windows than that for single glazed windows. Thus if one compares the solar heat gains over the course of a day between two windows with the same normal incidence SHGC, but one window is single pane and the other is multiple pane; the single glazed window has greater heat gains over the course of the day because its angular SHGC drops off less quickly for high incidence angles.

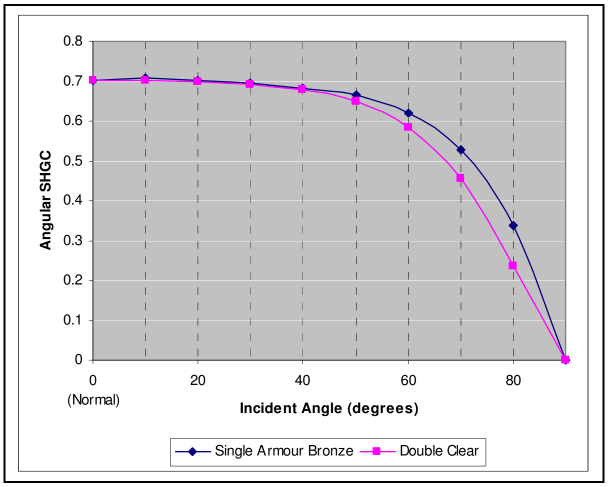

Figure 1:Angular SHGC With Respect to Incident Angle For a Single Pane and Double Pane Window

Since the current overall envelope model considers only normal incidence SHGC for solar gains regardless of number of glazing layers, the solar gains of single glazed fenestration is under-estimated relative to that of multiple layered glazings. The revised model proposed here would better model the solar heat gains at various sun angles that occur during a day in the base case glazing (double low-e glass) and thus require more mitigating features in a building when single glazed fenestration is used. Fixing this problem will yield a net energy savings for the State of California. For a given SHGC, higher visible light transmittance corresponds to either more glazing layers or more films both of which reduce angular SHGC more quickly than single glazed windows as incident angle increases.

As proposed here a building may use the envelope tradeoff method to show compliance with the standard as long as the calculated TDV of the proposed design is no greater than the TDV of the standard design using prescriptive envelope requirements.

Description

The proposed change is a modification to Section 143(b) of the standards. This section of the standards would be replaced in its entirety by the recommendations of this CASE report. The new tradeoff equation simplifies the way cool roofs are taken into account by introducing separate coefficients for reflectance and emittance of the roof surfaces. A new term is introduced for the VLT of fenestrations to better represent their performance.

Given the quantity of the coefficient tables, we recommend that the coefficients be moved back to the Standards Nonresidential Appendix.

Energy Benefits

The recommended measure is a change to an existing compliance option. In so far as the changes close existing loopholes in the compliance option, energy benefits may result, otherwise the changes will be neutral in terms of energy savings. Overall the recommended measure is an improved method of making energy trade-offs. In general this method is energy neutral. However, the old method underestimated the negative energy impacts of replacing double low-e glass (the basis of the prescriptive requirements) with single glazed low transmittance glass. By improving this glass model to account for the increased high incident angle heat gains through single glazed windows than is now calculated, this measure will save energy when single glazed fenestration is specified.

In addition, peak demand will be reduced by switching the envelope tradeoff equation from source energy to TDV. Since TDV weights peak hours more heavily than non-peak hours, the new tradeoff equation should weight those features that reduce peak demand more favorably. As a result, users of the tradeoff equation would be more inclined to chose features that reduce peak demand.

Non-energy Benefits

As described above, this new method discourages the use of single windows by more accurately modeling the increase in energy consumption that results from replacing the base case window (double low-e) with a single glazed window. To the extent that single glazed windows are discouraged, occupant comfort is increased. During cold winter months, the inside surface temperature of single glazed windows is lower which leads to convective currents (cold drafts) and an asymmetric radiant temperature field for the occupant sitting by windows[1]. Both mechanisms contribute to occupant discomfort even when space temperature is normally considered comfortable by occupants not sitting by the windows. The double low-e windows which are the basis of the standard would have less of these effects and result in a more comfortable environment for the occupant.

Statewide Energy Impacts

Statewide energy impacts are estimated by calculating the savings per square foot that results from the new method better calculating the energy impacts of single fenestration. Since single glazed fenestration is calculated as consuming 5.84% more TDV energy than it used to, greater efficiency has to be built into buildings when singled fenestration is used. We estimate that approximately 2.65 million ft² of single pane windows is installed in California nonresidential and high-rise residential buildings each year[2]. Given that, on average, the new energy estimates for single glazing will be 0.191938 kWh/ ft² , 5.892785 TDV kBtu/ft² and $0.860182/ft² higher. Assuming 20% of the Title 24 compliances uses overall envelope tradeoff approach[3], this new methodology will have the savings shown in Table 1.

Table 1: Annual Energy, TDV and Present Value Cost Savings

	MWh/yr	TDV kBtu/yr	PV $
First year savings	101.7	3,123,000	456,000
10th year savings	1,017	31,230,000	4,560,000

Environmental Impact

The proposed changes/measures will not result in any adverse environmental impact. This proposal does not impact the materials that are installed in building envelopes.

The energy savings that result from the improved single glazed window trade-off procedure will yield a relatively small energy savings as compared to the status quo. As a result a positive environmental impact is the reduction in air emissions from power plants due to reduced electricity consumption. We will base these estimates of reduced emissions by multiplying the statewide energy savings by the emissions factor values generated by the California Energy Commission for evaluating the environmental impacts of the 2005 standards as shown in Table 2 below.[4]

[1] 2005 ASHRAE Handbook of Fundamentals, p. 8.13 “Thermal Nonuniform Conditions and Local Discomfort.”

[2] In 1999, California has about 20.4 million ft² of total commercial windows built, according to the 2000 AAMA/WDMA North American Industry Market Studies – Fenestration Products. About 13% of the windows is single pane, according to the 2002 Eley Associate study – A Characterization of the Nonresidential Fenestration Market.

[3] About 20% of Title 24 compliance applications use overall envelope tradeoff, based on personal communicate with EnergySoft, the developer of EnergyPro.

[4] Table 1, Appendix B page 2, Initial Study/Proposed Negative Declaration for the 2005 Building Energy Efficiency Standards for Residential and Nonresidential Buildings September 2003 P400-03-018 http://www.energy.ca.gov/reports/2003-09-12_400-03-018.PDF Values provided by the CEC System Assessment and Facilities Siting Division.

Table 2: Emissions Factors used to calculate the air emissions reductions resulting from end-use reductions in electricity and natural gas consumption

Emissions factors	NOx	CO	CO2	PM10
Natural Gas, California (lbs/MMBtu)	0.094	0.03	115	0.01
Electricity, Western States (lbs/MWh)	0.383	0.23	1200	0.06

Table 3: Estimate of Statewide Emissions Reduction in pounds

	NOx	CO	CO2	PM10
First year savings	39.04	23.46	122,055	6.16
10^{th} year savings	390.4	234.6	1,220,550	61.6

Type of Change

The proposed measure would change an existing compliance option, the building envelope tradeoff method that is contained in Section 143(b) of the standards.

Technology Measures

This is not a technology measure.

Methodology

Approach

The approach for developing the overall envelope tradeoff procedure is to develop a database of results from the DOE-2.1E reference method. A separate database is created for each climate zone and occupancy type. Three occupancy types are considered, as defined in the nonresidential ACM manual. These include daytime occupancy, 24-hour occupancy, and retail occupancy. For each of these occupancies, the nonresidential ACM manual defines schedules of operation for building occupants, plug loads, and lighting. The ACM manual also defines outside air ventilation rates and other modeling assumptions.

The overall envelope tradeoff procedure is designed to permit tradeoffs among the following building envelope features:

- Fenestration properties, including U-factor, SHGC, VLT, area, orientation, and shading from overhangs.
- Construction class, U-factor, and area of roofs, walls, and floors exposed to ambient conditions.
- The reflectance and emittance of roof outside surfaces.

A regression analysis is performed on the database of results to determine a table of coefficients for the overall envelope tradeoff procedure. The coefficients are listed by climate zone and occupancy type. For fenestration, orientation is also considered in the tradeoff equation. These coefficients will become the basis of the new envelope tradeoff procedure.

Energy Model and Assumptions

DOE-2.1E version 119, developed by Lawrence Berkeley Laboratory, was used to create a database of TDV energy of space heating and cooling for a wide variety of inputs. For all cases, a simple five-zone energy model (Figure 2) was used. The arrangement for thermal zoning was intentionally designed so that perimeter zones are connected only to the interior zone and not to other perimeter zones. This tends to isolate solar effects on the building. Windows are modeled only on each perimeter zone.

A set of coefficients is developed for each class of construction and fenestration, climate zone and occupancy type. These are important features in the energy model:

- Geometry
    - A five-zone model
    - Four exterior zones (100 ft X 15 ft) with windows on the long facades, no skylights
    - One interior zone (100 ft X 100 ft) without windows
    - Space height 13 ft, no plenum
- Fenestration

  The fenestration area is set to 30% of gross external wall area, i.e., window to wall ratio (WWR) is 30%, for daytime and 24-hour occupancy, and 10% for retail occupancy. The fenestration used is double tint bronze with a U-factor of 0.48 and a SHGC of 0.49, the DOE-2 code is 2204 in the window library. These glass properties represent similar complying properties to those of the current California Standards. The fenestration is varied only when performing the regression analysis for fenestration coefficients.

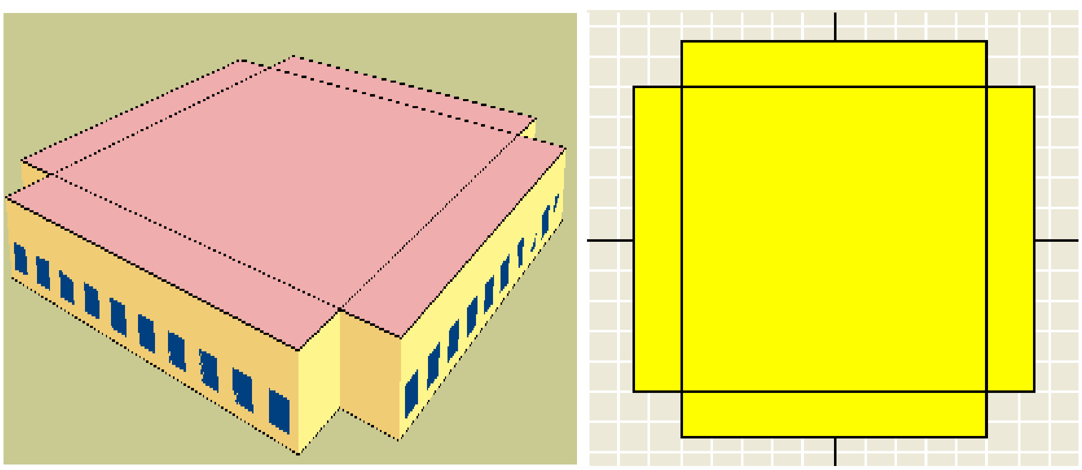

Figure 2 – The Five-Zone Energy Model

- Internal loads

Table 4 – Internal Loads

Internal Loads	Daytime	Retail	24-hour
Lighting Power Density (W/ft^2)	1.25	1.5	0.50
Equipment Power Density (W/ft^2)	0.75	0.94	0.50
Occupancy (persons / 1,000 ft^2)	29	29	5

- HVAC systems
  - One packaged single zone (PSZ) system for each zone. No plenum.
  - Cooling EER 9.5, fan power at 0.35 W/cfm
  - Integrated air-side economizer
  - Outside air 15 cfm/person
  - Heating temperature is set to 70°F; cooling temperature is set to 73°F
  - Electricity is used for cooling and gas is used for heating
- Operation schedules
  - Daytime only (typical for office buildings) with annual operating hours of 4300
  - Retail (typical for retail stores) with annual operating hours of 5475
  - 24-hour (typical high-rise residential) with annual operating hours of 8760
- Envelope construction assemblies

Table 5 – Roof Construction Assemblies Modeled

Roof Class	ID	DOE-2 Construction Materials	U-factor (Btu/h-ft^2-°F)
Light	Low	(AR02, BP01, PW03, RWF49, GP01)	0.020
Light	Medium	(AR02, BP01, PW03, RWF19, GP01)	0.045
Light	High	(AR02, BP01, PW03, AL33, GP01)	0.285
Mass	Low	(RG01, BR01, CC14, IN47, GP01)	0.037
Mass	Medium	(RG01, BR01, CC14, IN74, GP01)	0.130
Mass	High	(RG01, BR01, CC14, AL33, GP01)	0.324
Attic	Low	Roof: (RG01, BR01, PW05) Ceiling: (GP02, RWF49)	0.019
Attic	Medium	Roof: (RG01, BR01, PW05) Ceiling: (GP02, RWF19)	0.043
Attic	High	Roof: (RG01, BR01, PW05) Ceiling: (GP02)	0.284

Table 6 – Wall Construction Assemblies Modeled

Wall Class	ID	DOE-2 Materials	U-factor (Btu/h- ft²-°F)
Light	Low	(SC01, BP01, WWF30, GP01)	0.032
Light	Medium	(SC01, BP01, WWF11, GP01)	0.076
Light	High	(SC01, BP01, WMF00, GP01)	0.417
Mass7	Low	(SC01, CB49, IN36)	0.065
Mass7	Medium	(SC01, CB49, IN33)	0.143
Mass7	High	(SC01, CB29)	0.379
Mass15	Low	(SC01, CB32, IN36)	0.066
Mass15	Medium	(SC01, CB32, IN33)	0.147
Mass15	High	(CC05)	0.510

Table 7 – Floor Construction Assemblies Modeled

Floor Class	ID	DOE-2 Materials	U-factor (Btu/h- ft²-°F)
Light	Low	(RWF49, PW04, CP01)	0.019
Light	Medium	(RWF19, PW04, CP01)	0.042
Light	High	(RWF00, PW04, CP01)	0.151
Mass	Low	(RWF49, CC14, CP01)	0.019
Mass	Medium	(RWF11, CC14, CP01)	0.063
Mass	High	(RWF00, CC14, CP01)	0.162

Table 8 –Roof Outside Surfaces Modeled

Reflectance	Emittance
0.90	0.75
0.90	0.50
0.90	0.90
0.70	0.75
0.70	0.50
0.70	0.90
0.50	0.75
0.50	0.50
0.50	0.90
0.30	0.75
0.30	0.50
0.30	0.90
0.10	0.75
0.10	0.50
0.10	0.90

Table 9 – Window Overhangs Modeled for Four Orientations

Projection Factor
0
0.25
0.50
0.75
1

Table 10 – Fenestrations Modeled

Window	DOE-2 GTC Code	Panels	U-factor (Btu/h-ft²-°F)	SHGC	VLT
ATB 1 Clr - 6 mm	5010	1	0.992	0.715	0.754
ATB 1 Bronze – 6 mm	5011	1	0.992	0.548	0.455
ATB 2 Clear - 6 mm	5012	2	0.563	0.618	0.671
ATB 1 Silver - 6 mm	5013	1	0.795	0.232	0.123
ATB 1 Stainless - 6mm	5014	1	0.849	0.282	0.171
ATB 2 SS Tint – 6 mm	5015	2	0.563	0.358	0.498
ATB 2 SS Low-E - 6 mm	5016	2	0.389	0.341	0.599
ATB 2 Bronze – 6 mm	5017	2	0.563	0.446	0.403
A - Clear 1, AL	5000	1	1.158	0.706	0.708
B - Clear 2, ATB	5001	2	0.586	0.591	0.629
C - Bronze Tint 2, ATB	5002	2	0.586	0.425	0.382
D - Reflective 2, ATB	5003	2	0.532	0.172	0.105
E - Low-E Bronze 2, ATB	5004	2	0.484	0.387	0.355
F - Sepctrally Selective Low-E Tint 2, ATB	5005	2	0.456	0.265	0.418
G - Sepctrally Selective Low-E Clear 2, ATB	5006	2	0.456	0.332	0.562

Fenestration Constructions

The 206 fenestration assemblies in DOE-2 are modeled in order to determine whether new variables and coefficients are necessary for the current trade-off procedure. The results show various outliers that include electrochromic glass and heat mirror glass that are either not available or not commonly available in the market place. As a result, these glass types are removed from our analysis. The analysis shows that including the variable Tvis may account for some discrepancy between the percent differences in TDV. A negative percent difference in TDV shows the U-factor and shading coefficient (U/SC) method under-represents the TDV value when compared to the glass code type method. The introduction of a new Tvis variable in the trade-off procedure should help account for this under-representation. Table 37 in the Appendix shows the results of percent difference in TDV for the glass types used in the analysis.

Figure 3 shows the relatively high correlation of Tvis with the amount of error between a building simulated as a function of SHGC alone (shading coefficient method) and the more exact optical method (glass type code or Window6 layers method) that accounts for the number of glazing layers. From this correlation, the calculation of solar heat gains is modified by both the SHGC and VLT. The greater the SHGC, the greater the solar heat gain and the greater the VLT, the lower the solar heat gain. For two glazing assemblies with the same SHGC, the assembly with the higher VLT is likely to have more glazing layers or more coatings - both which increase off angle reflections..

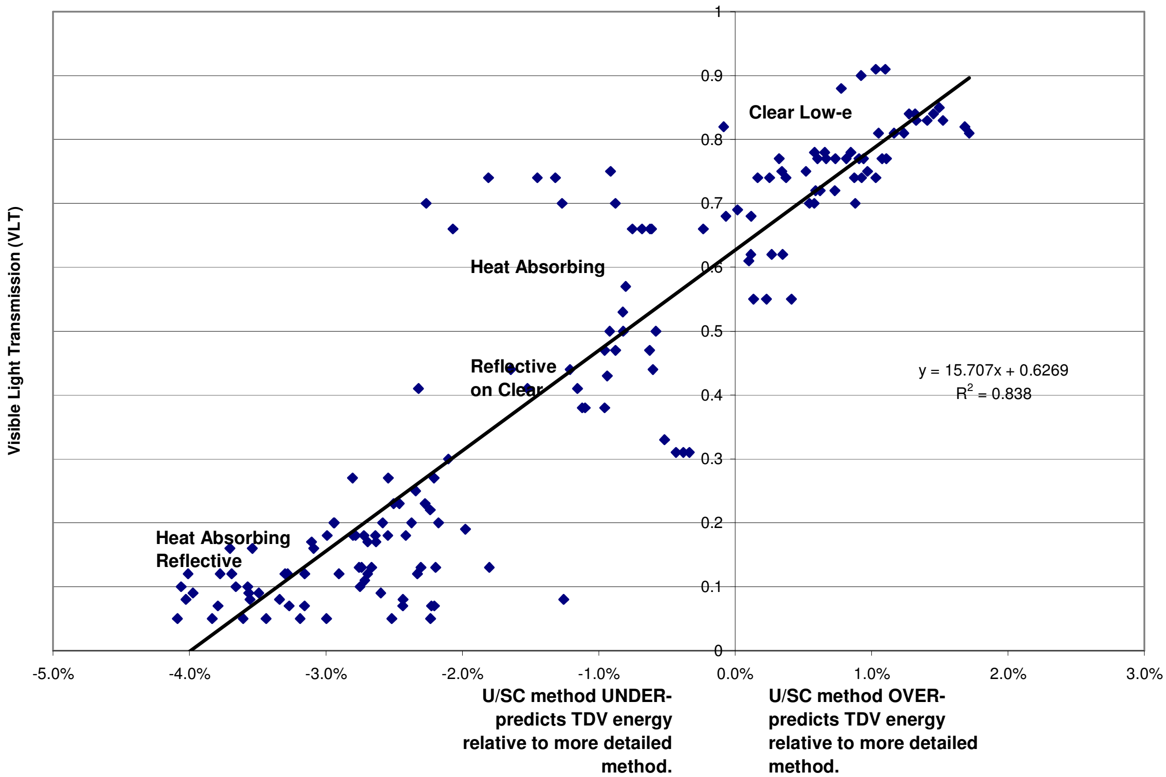

Figure 3 – Percent Difference in Whole Building TDV from Shading Coefficient Method versus Layers and Glass Type Code Method with Respect to VLT for Climate Zone 12

Results

Simulations were described as above. A multivariate regression was performed in the form of the equation described in the Recommendation sections. Descriptive statistics show that this form of the equation predicts energy impacts of envelope trade-off within 4%.

The accuracy to combine the heat loss and heat gain equation into one tradeoff procedure was performed for two climate zones. Note that these results were performed using the 2005 TDV curves, however, we anticipate that the 2008 TDV curves will not affect the accuracy of the new tradeoff equation since the methodology is the same and new coefficients were determined for the 2008 TDV curves as listed below.

The results from this trade-off procedure is compared to the actual TDV heating and cooling energy consumption and detailed below. The heating and cooling energy consumption does not include fan energy, lighting, receptacle, process, hot water and miscellaneous loads since it is an envelope trade-off procedure.

Table 11 – Modeling Assumptions

Case	Roof	Wall	Floor	SHGC	U-factor
Case 1	Base Case	Base Case	Base Case	Base Case	Base Case
Case 2	Base Case with 14.4ci Rigid	Base Case with 14.4ci Rigid	Base Case with 14.4ci Rigid	0.8	1.28
Case 3	R-0	R-0	R-0	0.15	0.21
Case 4	Base Case	Base Case with 14.4ci Rigid	Base Case with 14.4ci Rigid	0.15	0.21
Case 5	R-0	R-0	R-0	0.8	1.28
Case 6	Base Case with 5.4ci Rigid	Base Case with 5.4ci Rigid	Base Case with 5.4ci Rigid	0.47	0.47
Case 7	R-19 Built-up with 0.30 Reflectance	R-19 Metal	R-19 Metal	0.75	0.75
Case 8	R-19 Built-up with 0.30 Reflectance	R-11 Metal	R-19 Metal	0.21	0.15
Case 9	R-19 Built-up with 0.30 Reflectance	R-19 Metal	R-30 Metal	0.75	0.75
Case 10	R-30 Metal Rafter with 14.4ci Rigid	R-30 Metal	R-30 Metal	0.55	0.55
Cases 1-5 use wood framing and cases 6-10 use metal framing.					

Table 12 – Energy Consumption Results for Climate Zone 3

Case	TDV SF	TDV Total	Wall UA	Floor UA	Roof UA	Glazing UA	Cool Roof UA	SHGC
Case 1	29.14	291400	8624	19880	14280	25872	24290	65848
Case 2	30.12	301200	3336	9830	8233	43008	14005	120960
Case 3	67.92	679200	27912	66640	83160	7056	141455	22680
Case 4	21.26	212600	3336	9830	8233	7056	14005	22680
Case 5	74.87	748700	27912	66640	83160	43008	141455	120960
Case 6	26.87	268700	5412	14370	11196	15792	19045	71064
Case 7	30.19	301900	14348	24080	13154	15792	43258	71064
Case 8	26.63	266300	17560	24080	13154	7056	43258	22680
Case 9	33.66	336600	14348	20440	13154	25200	43258	113400
Case 10	29.22	292200	12308	20440	9830	18480	16721	83160

Table 13 – Regression Results for Climate Zone 3

Intercept	145974.5218	Multiple R	0.999768
Wall Coefficient	2.568817322	R Square	0.999537
Floor Coefficient	-0.557530169	Adjusted R Square	0.998611
Roof Coefficient	5.926244844	Standard Error	6889.75
Glazing Coefficient	0.018727521	Observations	10
Cool Roof Coefficient	-0.129931666		
SHGC Coefficient	0.812962277		

Table 14 – Accuracy of Combined Trade-off Procedure for Climate Zone 3

Case	TDV Heat and Cool	Regression Results	Difference	% Difference
Case 1	291400	292531.4973	1131.497325	0%
Case 2	301200	295176.006	-6023.994038	-2%
Case 3	679200	673538.7037	-5661.296276	-1%
Case 4	212600	214604.7815	2004.781525	1%
Case 5	748700	754109.9282	5409.928162	1%
Case 6	268700	273809.0376	5109.037638	2%
Case 7	301900	299807.9233	-2092.076736	-1%
Case 8	266300	268560.9941	2260.994056	1%
Case 9	336600	336431.0926	-168.9074334	0%
Case 10	292200	290230.0358	-1969.964223	-1%

Table 15 – Energy Consumption Results for Climate Zone 6

Case	TDV SF	TDV Total	Wall UA	Floor UA	Roof UA	Glazing UA	Cool Roof UA	SHGC
1	44.18	441800	8624	19880	21280	25872	35335	62110
2	50.05	500500	3336	9830	10160	43008	16871	118080
3	66.25	662500	27912	66640	83160	7056	138087	22140
4	36.63	366300	3336	9830	8233	7056	13672	22140
5	77.88	778800	27912	66640	83160	43008	138087	118080
6	44.34	443400	5412	14370	11196	15792	18592	69372
7	47.47	474700	14348	24080	13154	15792	42228	69372
8	40.69	406900	17560	24080	13154	7056	42228	22140
9	53.92	539200	14348	20440	13154	25200	42228	110700
10	46.28	462800	12308	20440	9830	18480	16323	81180

Table 16 – Regression Results for Climate Zone 6

Intercept	301764.4796	Multiple R	0.998483
Wall Coefficient	1.049287975	R Square	0.996969
Floor Coefficient	-0.966082106	Adjusted R Square	0.990908
Roof Coefficient	2.78007914	Standard Error	11902.8
Glazing Coefficient	-1.801948888	Observations	10
Cool Roof Coefficient	0.953036216		
SHGC Coefficient	1.925615672		

Table 17 – Accuracy of Combined Trade-off Procedure for Climate Zone 6

Case	TDV Heat and Cool	Regression Results	Difference	% Difference
Case 1	441800	457423.4134	15623.41341	4%
Case 2	500500	489971.0761	-10528.92393	-2%
Case 3	662500	659384.3669	-3115.633103	0%
Case 4	366300	361605.1995	-4694.800465	-1%
Case 5	778800	779344.2681	544.2680704	0%
Case 6	443400	447532.6752	4132.675233	1%
Case 7	474700	475497.8143	797.814281	0%
Case 8	406900	403659.2733	-3240.726693	-1%
Case 9	539200	541643.4625	2443.462512	0%
Case 10	462800	460838.4507	-1961.549309	0%

Sample Calculation

The following sample calculation is for a nonresidential building in climate zone 12 and uses the coefficients in the section below.

Table 18 – Accuracy of Combined Trade-off Procedure for Climate Zone 12

		Proposed Design (WWR = 23%)					Standard Design				
Case	Area	U-Factor	Reflectance	Emittance	SHGC	VLT	U-Factor	Reflectance	Emittance	SHGC	VLT
Wall (light)	3640	0.032					0.059				
Floor (light)	16000	0.151					0.071				
Roof (attic)	16000	0.045	0.70	0.75			0.039	0.70	0.75		
North Glazing	273	0.492			0.49	0.473	0.47			0.47	0.473
East Glazing	273	0.492			0.49	0.473	0.47			0.36	0.473
South Glazing	273	0.492			0.49	0.473	0.47			0.36	0.473
West Glazing	273	0.492			0.49	0.473	0.47			0.36	0.473

$$\mathrm{TDV} = \sum_{i=1}^{nW} c_W \left(A_W \times U_W\right) + \sum_{i=1}^{nF} c_F \left(A_F \times U_F\right) + \sum_{i=1}^{nR} c_R \left(A_R \times U_R \times M_{CR}\right)$$
$$+ \sum_{i=1}^{nG} A_G \left[\left(c_{Gu} \times U\right) + \left(c_{Gs} \times \mathrm{SHGC} \times M_{OH}\right) + \left(c_{Gt} \times \mathrm{VLT}\right)\right]$$

TDVproposed = 137.8381(3,640 * 0.032) + 90.65458(16,000 * 0.151) + 173.688(16,000 * 0.045) + 273(43.81912 * 0.492 + 172.20811 * 0.49 + -14.82019 * 0.473) + 273(31.59824 * 0.492 + 356.3808 * 0.49 + -9.85456 * 0.473) + 273(48.62256 * 0.492 + 356.93819 * 0.49 + -8.09810 * 0.473) + 273(40.89670 * 0.492 + 473.68683 * 0.49 + -17.47074 * 0.473)

TDVproposed = 16055.38 + 219021.5 + 125055.4 + 27008.17 + 50644.7 + 53232.71 + 66602.19

TDVproposed = 557620.1 or 34.85125 TDV/sf

TDVstandard = 137.8381(3,640 * 0.059) + 90.65458(16,000 * 0.071) + 173.688(16,000 * 0.039) + 273(43.81912 * 0.47 + 172.20811 * 0.47 + -14.82019 * 0.473) + 273(31.59824 * 0.47 + 356.3808 * 0.36 + -9.85456 * 0.473) +

273(48.62256 * 0.47 + 356.93819 * 0.36 + -8.09810 * 0.473) + 273(40.89670 * 0.47 + 473.68683 * 0.36 + -17.47074 * 0.473)

TDVstandard = 29602.11 + 102983.6 + 108381.3 + 25804.74 + 37806.97 + 40272.95 + 49545.42

TDVstandard = 394397.1 or 24.64982 TDV/sf

As TDVproposed > TDVstandard, the proposed building does not comply with Title 24-2008 with the Overall Envelope Tradeoff approach.

Recommendations

The tradeoff approach, Section 143(b) of Title 24-2005, should be replaced with the following:

(b) The total TDV Energy of the overall envelope of the proposed building, TDVprop, shall be no greater than the total TDV Energy of the overall envelope of a standard building, TDVstd, as calculated in Standards Nonresidential Appendix "Overall Envelope Trade-off calculations". In making the calculations, it shall be assumed that the orientation and area of each envelope component of the standard building are the same as in the proposed building. If the proposed building has Window-Wall-Ratio greater than 40% or Skylight-Roof-Ratio greater than 5%, the area of walls and windows or roofs and skylights will be adjusted accordingly in the standard building to cap the WWR at 40% and SRR at 5%.

The following will be added to the Standards Nonresidential Appendix:

Overall Envelope Approach
The total TDV Energy of the overall envelope of the proposed building, TDVprop, shall be no greater than the total TDV Energy of the overall envelope of a standard building, TDVstd, as calculated in the following equations. In making the calculations, it shall be assumed that the orientation and area of each envelope component of the standard building are the same as in the proposed building. If the proposed building has Window-Wall-Ratio greater than 40% or Skylight-Roof-Ratio greater than 5%, the area of walls and windows or roofs and skylights will be adjusted accordingly in the standard building to cap the WWR at 40% and SRR at 5%.

TDV Energy of the Standard Building

$$
\begin{aligned}
TDV_{std} = & \sum_{i=1}^{nW} c_W \times \left(A_W \times U_{W,std}\right) + \sum_{i=1}^{nF} c_F \times \left(A_F \times U_{F,std}\right) + \sum_{i=1}^{nR} c_R \times \left(A_R \times U_{R,std}\right) \\
& + \sum_{i=1}^{nG} A_G \times \left[\left(c_{Gu} \times U_{G,std}\right) + \left(c_{Gs} \times SHGC_{G,std}\right) + \left(c_{Gt} \times VLT_{G,std}\right)\right] \\
& + \sum_{i=1}^{nS} A_S \times \left[\left(c_{Su} \times U_{S,std}\right) + \left(c_{Ss} \times SHGC_{S,std}\right) + \left(c_{St} \times VLT_{S,std}\right)\right]
\end{aligned}
$$

Where:

TDV_{std} = TDV energy of the standard building, for space cooling and heating only.

i = Each wall type, floor/soffit type, roof/ceileing type, window type and orientation, and skylight type

nW, nF, nR, nG, nS = Number of components of the applicable envelope feature of the standard building.

c_W = Coefficient for the wall.

A_W = Exterior wall area (net area) on the north, east, south, and west orientations of the standard building (in ft^2). Each orientation has as many walls as there are HC categories.

$U_{W,std}$ = The wall U-factor in Btu/h- ft^2-°F for the corresponding A_W.

c_F = Coefficient for the floor.

A_F = Exterior floor/soffit area of the standard building (in ft^2). There are as many floors/sofits as there are HC categories.

$U_{F,std}$ = The floor/soffit U-factor in Btu/h- ft^2-°F for the corresponding A_F.

c_R = Coefficient for the roof.

A_R = Exterior roof/ceiling area (net area) of the standard building (in ft^2).

$U_{R,std}$ = The roof/ceiling U-factor in Btu/h- ft^2-°F for the corresponding A_R.

A_G = Window area for each window type and window orientation of the standard building (in ft^2).

c_{Gu} = Coefficient for the glazing U-factor.

$U_{G,std}$ = The window U-factor in Btu/h- ft^2-°F for the corresponding A_G.

c_{Gs} = Coefficient for the glazing SHGC.

$SHGC_{G,std}$ = The window SHGC for the corresponding A_G.

C_{Gt} = Coefficient for the window visible light transmittance.

$VLT_{G,std}$ = The window visible light transmittance for the corresponding A_G.

A_S = Skylight area for each skylight type of the standard building (in ft^2).

c_{Su} = Coefficient for the skylight U-factor.

$U_{S,std}$ = The skylight U-factor in Btu/h- ft^2-°F for the corresponding A_S.

c_{Ss} = Coefficient for the skylight SHGC.

$SHGC_{S,std}$ = The skylight SHGC for the corresponding A_S.

C_{St} = Coefficient for the skylight visible light transmittance.

$VLT_{S,std}$ = The skylight visible light transmittance for the corresponding A_S.

Area of each building envelope component of the standard building is the same as that of the proposed building, except when the window-wall-ratio of the proposed building (WWR_{prop}) is more than 40% and/or the skyligt-roof-ratio of the proposed building (SRR_{prop}) is more than 5%, the area of each window/skylight and its parent wall/roof needs to be adjusted accordingly:

$$A_{Gi,adj} = A_{Gi,prop} \times \frac{0.40}{WWR_{prop}}$$

$$A_{Wi,adj} = A_{Wi,prop} + \left(A_{Gi,prop} - A_{Gi,adj}\right)$$

$$A_{Si,adj} = A_{Si,prop} \times \frac{0.05}{SRR_{prop}}$$

$$A_{Ri,adj} = A_{Ri,prop} + \left(A_{Si,prop} - A_{Si,adj}\right)$$

TDV Energy of the Proposed Building

$$\begin{aligned} TDV_{prop} = & \sum_{i=1}^{nW} c_W \times \left(A_W \times U_{W,prop}\right) + \sum_{i=1}^{nF} c_F \times \left(A_F \times U_{F,prop}\right) + \sum_{i=1}^{nR} c_R \times \left(A_R \times U_{R,prop} \times M_{CR}\right) \\ & + \sum_{i=1}^{nG} A_G \times \left[\left(c_{Gu} \times U_{G,prop}\right) + \left(c_{Gs} \times SHGC_{G,prop} \times M_{OH}\right) + \left(c_{Gt} \times VLT_{G,prop}\right)\right] \\ & + \sum_{i=1}^{nS} A_S \times \left[\left(c_{Su} \times U_{S,prop}\right) + \left(c_{Ss} \times SHGC_{S,prop}\right) + \left(c_{St} \times VLT_{S,prop}\right)\right] \end{aligned}$$

Where:

TDV_{prop} = TDV energy of the proposed building, for space cooling and heating only.

i = Each wall type, floor/soffit type, roof/ceileing type, window type and orientation, and skylight type

nW, nF, nR, nG, nS = Number of components of the applicable envelope feature of the proposed building.

c_W = Coefficient for the wall.

A_W = Exterior wall area on the north, east, south, and west orientations of the proposed building (in ft^2). Each orientation has as many walls as there are HC categories.

$U_{W,prop}$ = The wall U-factor in Btu/h- ft^2-°F for the corresponding A_W.

c_F = Coefficient for the floor.

A_F = Exterior floor/soffit area of the proposed building (in ft^2). There are as many floors/sofits as there are HC categories.

$U_{F,prop}$ = The floor/soffit U-factor in Btu/h- ft^2-°F for the corresponding A_F.

c_R = Coefficient for the roof.

A_R = Exterior roof/ceiling area of the proposed building (in ft^2).

$U_{R,prop}$ = The roof/ceiling U-factor in Btu/h- ft^2-°F for the corresponding A_R.

M_{CR} = $1 + c_{\mathrm{Re}f} \times (\mathrm{Re}f - 0.70) + c_{Emit} \times (Emit - 0.75)$

Where:

c_{Ref} = Coefficient for the reflectance of the roof.

Ref = Reflectance of the roof outside surface. Use the initial value of a new roof.

C_{Emit} = Coefficient for the emittance of the roof.

Emit = Emittance of the roof outside surface.

A_G = Window area for each window type and window orientation of the proposed building (in ft^2).

c_{Gu} = Coefficient for the glazing U-factor.

$U_{G,prop}$ = The window U-factor in Btu/h- ft^2-°F for the corresponding A_G.

c_{Gs} = Coefficient for the glazing SHGC.

$SHGC_{G,prop}$ = The window SHGC for the corresponding A_G.

M_{OH} = Window shading multiplier. M_{OH} = $1 + a \times PF + b \times PF^2$

Where:

a = First coefficient for the projection factor

b = Second coefficient for the projection factor

PF = Projection Factor. $PF = \frac{H}{V}$

H = Horizontal projection of the overhang from the surface of the window in feet, but no greater than *V*

V = Vertical distance from the window sill to the bottom of the overhang, in feet.

C_{Gt} = Coefficient for the window visible light transmittance.

$VLT_{G,prop}$ = The window visible light transmittance for the corresponding A_G.

A_S = Skylight area for each skylight type of the proposed building (in ft^2).

c_{Su} = Coefficient for the skylight U-factor.

$U_{S,prop}$ = The skylight U-factor in Btu/h- ft^2-°F for the corresponding A_S.

c_{Ss} = Coefficient for the skylight SHGC.

$SHGC_{S,prop}$ = The skylight SHGC for the corresponding A_S.

C_{St} = Coefficient for the skylight visible light transmittance.

$VLT_{S,prop}$ = The skylight visible light transmittance for the corresponding A_S.

Nonresidential Coefficients

Table 19 – Coefficients for Opaque Construction Assemblies (Nonresidential)

	Floors		Roofs			Walls		
CZ	C_F (light)	C_F (mass)	C_R (attic)	C_R (light)	C_R (mass)	C_W (light)	C_W (mass, HC>7)	C_W (mass, HC>15)
1	73.394	54.094	116.493	100.031	82.853	72.488	58.269	46.275
2	98.241	50.227	181.542	172.080	82.192	135.264	58.053	33.040
3	43.409	10.680	115.848	101.524	56.838	79.890	35.097	18.597
4	55.583	10.901	140.758	134.555	58.338	105.293	35.112	15.065
5	47.250	9.603	114.805	105.403	45.128	87.013	18.390	2.803
6	9.708	-31.662	90.706	83.898	24.177	69.494	8.102	-7.575
7	13.888	-13.619	94.637	94.399	32.667	75.524	11.965	12.063
8	25.688	-18.439	117.991	113.673	40.206	104.300	25.050	5.544
9	45.160	-13.094	130.995	127.797	37.331	119.134	29.004	4.300
10	65.722	16.731	156.421	155.297	56.144	142.743	44.352	18.436
11	104.705	57.416	180.358	163.506	100.031	153.460	92.081	68.889
12	90.655	40.409	173.688	159.380	89.761	137.838	74.851	51.092
13	89.402	44.735	171.473	158.475	91.748	148.521	81.197	58.693
14	120.371	69.080	207.357	191.355	113.762	169.934	97.675	66.673
15	118.030	65.808	191.525	187.166	96.060	201.127	105.307	76.147
16	161.722	125.780	224.180	198.468	142.004	164.155	122.084	98.428

Table 20 – Coefficients for North-facing Windows and Overhangs (Nonresidential)

	North Windows			North Overhangs	
CZ	C_{GU} (U-factor)	C_{GS} (SHGC)	C_{GT} (VLT)	a	b
1	30.51128	60.86041	-8.69389	-0.28720	0.11517
2	47.11697	131.94871	-12.18333	-0.31603	0.14522
3	20.82913	94.92615	-3.30028	-0.31270	0.14667
4	18.32581	147.24242	-6.61103	-0.33586	0.16368
5	16.50418	115.89062	-6.32757	-0.31677	0.14294
6	-0.05739	138.85517	4.05348	-0.41806	0.19790
7	4.97141	151.31538	0.67166	-0.43214	0.20967
8	9.86929	173.12131	-2.46967	-0.39459	0.18865
9	19.34245	183.40885	-6.50787	-0.35711	0.16457
10	20.02160	207.76621	-22.40067	-0.38294	0.18410
11	53.05770	188.47535	-16.82636	-0.24976	0.12007
12	43.81912	172.20811	-14.82019	-0.26234	0.12561
13	42.90161	194.07587	-15.45374	-0.27939	0.13746
14	62.07302	206.89059	-14.29912	-0.27873	0.13921
15	54.48698	303.70211	-20.18653	-0.30869	0.14387
16	81.90300	137.30353	-28.12008	-0.16744	0.09156

Table 21 – Coefficients for East-facing Windows and Overhangs (Nonresidential)

	East Windows			East Overhangs	
CZ	C_{GU} (U-factor)	C_{GS} (SHGC)	C_{GT} (VLT)	a	b
1	27.93105	50.79329	-5.10254	-0.66945	0.51664
2	30.85984	256.16316	-18.76135	-0.73484	0.29162
3	16.34532	170.33418	2.55125	-0.72227	0.31992
4	15.64723	293.90897	-11.89494	-0.76852	0.30860
5	12.73199	238.38579	-1.11048	-0.76659	0.32588
6	-4.83060	297.25003	7.67995	-0.78286	0.31696
7	1.81457	279.82029	5.40337	-0.78414	0.31556
8	5.24963	367.47168	-7.11105	-0.76653	0.28679
9	11.31512	376.80775	-6.51354	-0.73133	0.27107
10	20.26027	411.90728	-24.04314	-0.76414	0.30280
11	43.74473	378.10812	-10.29843	-0.67736	0.28638
12	31.59824	356.38080	-9.85456	-0.70933	0.29100
13	30.32513	418.51235	-16.06071	-0.72814	0.31032
14	48.65486	431.91401	-21.53964	-0.71024	0.28316
15	40.08348	666.00861	-28.85875	-0.71671	0.30448
16	69.96470	220.11336	-18.99129	-0.63319	0.27159

Table 22 – Coefficients for South-facing Windows and Overhangs (Nonresidential)

	South Windows			South Overhangs	
CZ	C_{GU} (U-factor)	C_{GS} (SHGC)	C_{GT} (VLT)	a	b
1	32.53609	69.67267	-5.14186	-1.53478	1.16393
2	44.29611	312.07070	-23.27442	-0.98421	0.52884
3	26.07305	203.97691	6.30980	-1.16547	0.68003
4	28.80816	313.43871	-6.32024	-1.09211	0.61697
5	23.63508	319.52695	3.84676	-1.15173	0.60890
6	1.71913	319.30203	12.56991	-1.03562	0.56088
7	60.43132	-20.69075	127.19281	-0.97886	-0.04047
8	32.56079	367.01164	4.61099	-0.77474	0.38497
9	18.35005	493.58746	-8.78841	-0.87367	0.41351
10	24.02994	520.66898	-30.05995	-1.00219	0.45741
11	57.44029	406.32407	-12.54416	-1.07567	0.62051
12	48.62256	356.93819	-8.09810	-1.02071	0.56712
13	45.21754	403.74937	-19.63289	-1.15044	0.67153
14	56.48661	395.22465	-26.04500	-0.97797	0.54491
15	32.84172	586.58036	-33.07435	-1.00045	0.42981
16	81.44858	247.62683	-21.98690	-1.13695	0.70970

Table 23 – Coefficients for West-facing Windows and Overhangs (Nonresidential)

	West Windows			West Overhangs	
CZ	C_{GU} (U-factor)	C_{GS} (SHGC)	C_{GT} (VLT)	a	b
1	29.06222	85.68015	-7.74086	-0.69736	0.29916
2	41.18875	340.91390	-18.68043	-0.73019	0.27154
3	20.45075	206.01058	8.33799	-0.75580	0.29085
4	20.47890	364.57486	-3.19770	-0.69649	0.23149
5	13.64550	239.59397	-3.62150	-0.73229	0.30053
6	-6.21354	340.91048	9.80756	-0.76927	0.30027
7	2.92001	348.89066	1.89487	-0.77506	0.31905
8	4.00599	483.19737	-10.69322	-0.69631	0.32099
9	16.78148	468.45615	-11.13374	-0.73521	0.29981
10	19.85401	492.08798	-30.03276	-0.68842	0.25925
11	50.45293	555.64881	-57.41079	-0.64614	0.22432
12	40.89670	473.68683	-17.47074	-0.68429	0.24355
13	39.45424	544.07781	-27.50665	-0.69839	0.24313
14	59.06447	560.23612	-32.00602	-0.67906	0.23771
15	51.41251	713.08539	-30.11675	-0.70611	0.05070
16	81.01195	292.21037	-33.79706	-0.66361	0.21803

Table 24 – Coefficients for Skylights and Cool Roofs (Nonresidential)

	Skylight			Cool Roofs	
CZ	C_{GU} (U-factor)	C_{GS} (SHGC)	C_{GT} (VLT)	C_{Ref} (Reflectance)	C_{Emit} (Emittance)
1	34.66529	190.85346	-5.87447	-0.60100	0.02202
2	32.96460	683.06062	-0.17024	-1.28815	-0.31486
3	7.38391	514.21127	18.67796	-1.49561	-0.27844
4	10.34543	742.41151	26.57442	-1.80626	-0.42959
5	15.98041	428.13139	78.44023	-1.73881	-0.37710
6	-42.39175	773.31823	29.41717	-2.16167	0.19269
7	-22.06848	1022.94127	68.03387	-3.27052	-0.93154
8	-26.98849	912.54783	13.06346	-2.88793	-0.95624
9	-18.66154	881.50629	14.78926	-2.51592	-0.83924
10	-1.38267	908.10099	3.45777	-2.29951	-0.78034
11	38.87433	888.35212	21.95954	-1.69524	-0.46048
12	33.85265	852.55088	23.89755	-1.67621	-0.41811
13	18.62398	947.90450	8.56803	-2.07280	-0.65907
14	44.69635	942.22595	20.69210	-1.69028	-0.47577
15	-81.19288	1871.93109	-198.50784	-2.54137	-0.89709
16	91.84067	605.52958	-10.99830	-0.95261	-0.18181

Retail Coefficients

Table 25 – Coefficients for Opaque Construction Assemblies (Retail)

	Floors		Roofs			Walls		
CZ	C_F (light)	C_F (mass)	C_R (attic)	C_R (light)	C_R (mass)	C_W (light)	C_W (mass, HC>7)	C_W (mass, HC>15)
1	11.804	-15.216	107.400	97.078	79.979	73.604	59.366	52.214
2	59.116	13.546	194.258	183.928	88.203	159.342	86.247	58.170
3	-14.241	-49.086	108.651	95.293	51.608	76.792	39.153	24.773
4	10.770	-42.835	145.193	136.060	55.172	117.598	54.948	32.822
5	-19.520	-61.540	99.995	97.488	34.459	90.201	22.707	7.661
6	-63.098	-89.613	70.896	68.503	22.456	60.812	16.447	5.646
7	-57.058	-69.708	87.229	85.557	25.961	60.419	21.763	5.259
8	-26.670	-66.682	116.127	105.289	34.018	112.376	45.193	20.838
9	5.022	-58.469	137.896	128.794	34.525	136.111	56.464	28.924
10	31.071	-31.832	167.331	163.368	62.038	172.290	81.748	49.671
11	84.213	23.953	201.408	186.480	118.963	192.525	131.910	105.896
12	63.893	11.685	186.527	174.280	100.449	166.395	104.667	78.833
13	70.651	13.621	192.124	184.926	108.395	189.650	122.296	93.480
14	111.249	43.827	235.276	220.368	135.663	213.966	144.649	107.521
15	110.584	51.696	219.811	222.202	114.011	253.958	167.488	136.995
16	141.891	86.003	250.006	232.472	179.756	202.870	167.589	145.053

Table 26 – Coefficients for North-facing Windows and Overhangs (Retail)

	North Windows			North Overhangs	
CZ	C_{GU} (U-factor)	C_{GS} (SHGC)	C_{GT} (VLT)	a	b
1	-0.40156	18.26787	2.87092	-1.18851	0.60793
2	7.04654	56.91502	-1.80710	-0.79874	0.42020
3	-3.91590	32.75558	3.72290	-1.00695	0.53459
4	0.19684	56.77242	2.85943	-0.85003	0.44875
5	-4.07917	38.00557	4.00361	-1.06279	0.55374
6	-10.79192	48.13604	5.95043	-1.18016	0.62431
7	-7.24597	53.60031	4.58083	-1.05354	0.55564
8	-4.60096	64.88238	3.10789	-0.98954	0.52179
9	-0.68715	70.30827	2.08609	-0.93507	0.49020
10	4.12396	93.07568	-5.58091	-0.80406	0.42369
11	13.70471	74.59673	-1.78569	-0.62814	0.32998
12	9.41536	68.89827	-1.19026	-0.70917	0.37732
13	11.30294	78.50707	-2.05869	-0.68405	0.36451
14	16.59715	83.72108	-3.97944	-0.61430	0.32980
15	17.75895	123.49779	-5.00659	-0.72049	0.38251
16	22.69753	55.37465	-5.01594	-0.55136	0.28544

Table 27 – Coefficients for East-facing Windows and Overhangs (Retail)

	East Windows			East Overhangs	
CZ	C_{GU} (U-factor)	C_{GS} (SHGC)	C_{GT} (VLT)	C_{GU} (U-factor)	C_{GS} (SHGC)
1	-1.15559	7.13606	3.22327	0.26399	-0.24639
2	7.49401	112.23476	-0.18626	-2.15609	1.04657
3	-2.34192	52.92849	7.83744	-1.44500	0.70777
4	0.54088	114.81447	3.50517	-2.10621	0.98852
5	-2.29661	87.54786	6.02656	-1.92643	0.89473
6	-9.12473	91.42506	8.53762	-1.74280	0.74159
7	-5.97990	100.53587	5.93940	-2.04920	1.04879
8	-3.18152	133.72441	4.57921	-2.09397	1.00088
9	-1.13937	150.73323	2.68858	-2.04130	0.99161
10	4.91956	172.34048	-2.65727	-2.07498	0.99960
11	12.22623	169.06718	0.19143	-1.84662	0.83325
12	7.68863	149.59807	1.72958	-2.09894	0.99554
13	9.73357	176.98809	-0.95666	-2.08340	0.95561
14	14.14785	183.08118	-4.93853	-2.21173	1.00260
15	18.72997	270.90945	-2.97271	-1.92169	0.90769
16	19.62065	96.00684	-1.16660	-1.95637	0.86971

Table 28 – Coefficients for South-facing Windows and Overhangs (Retail)

	South Windows			South Overhangs	
CZ	C_{GU} (U-factor)	C_{GS} (SHGC)	C_{GT} (VLT)	C_{GU} (U-factor)	C_{GS} (SHGC)
1	1.91360	19.93050	6.09047	-5.19671	4.44874
2	10.61172	140.60700	-1.65809	-2.36318	1.25455
3	-0.13432	79.21267	8.41837	-2.96708	1.87945
4	4.97011	131.37567	4.79800	-2.89349	1.75472
5	0.22696	107.70805	6.56282	-3.00914	1.73702
6	0.98110	47.14660	40.94104	-6.23748	3.92757
7	-3.23505	122.22584	7.58355	-2.58212	1.48828
8	42.55272	-105.31969	102.92825	-3.40647	1.36672
9	2.83355	197.44384	4.77315	-2.30780	1.22499
10	7.52914	219.92186	-0.87733	-2.28921	1.12727
11	18.99232	186.53870	2.85491	-2.66391	1.55859
12	13.22552	163.25501	3.10483	-2.81714	1.64230
13	14.80172	182.41277	-1.13299	-2.80387	1.61371
14	20.02102	183.10946	-2.90889	-2.67987	1.56819
15	17.55192	311.65287	-7.90221	-2.12832	1.03571
16	24.92895	115.10732	-2.02336	-2.92889	1.78824

Table 29 – Coefficients for West-facing Windows and Overhangs (Retail)

	West Windows			West Overhangs	
CZ	C_{GU} (U-factor)	C_{GS} (SHGC)	C_{GT} (VLT)	C_{GU} (U-factor)	C_{GS} (SHGC)
1	0.39017	32.06153	4.19663	-2.43902	1.35868
2	8.28848	152.29161	-4.54207	-1.99257	0.84398
3	0.20372	96.81758	-0.41752	-2.02853	0.78052
4	5.88093	126.75727	15.93059	-2.43026	1.02702
5	-4.68219	94.78738	2.82662	-2.02140	0.91043
6	-1.62383	108.38909	-16.53218	-2.08019	4.23615
7	-5.84771	139.66420	6.49671	-2.09751	0.93532
8	-1.19692	179.00316	8.34808	-2.03638	0.89554
9	1.03807	195.98962	0.00806	-1.92495	0.81884
10	6.04859	210.12176	-1.32988	-1.83428	0.81739
11	15.01058	220.23524	-6.86815	-1.94313	0.74458
12	10.88080	201.58093	-1.22418	-1.92485	0.75937
13	20.55020	196.28407	-2.66262	-2.23341	1.22683
14	18.90466	251.91024	-7.13802	-1.84341	0.67923
15	21.33861	297.46464	-6.93970	-1.85411	0.75006
16	23.88413	132.57331	-7.95237	-1.92469	0.77247

Table 30 – Coefficients for Skylights and Cool Roofs (Retail)

	Skylight			Cool Roofs	
CZ	C_{GU} (U-factor)	C_{GS} (SHGC)	C_{GT} (VLT)	C_{Ref} (Reflectance)	C_{Emit} (Emittance)
1	-2.73848	213.30569	11.12775	-0.79686	-0.19753
2	-8.64831	800.48649	13.33811	-1.67638	-0.56766
3	-45.49778	636.93410	6.65611	-2.08489	-0.55146
4	-39.86801	918.22500	50.68249	-2.38078	-0.74018
5	-43.20921	614.02516	34.65605	-2.31509	-0.81148
6	-61.17058	742.36868	57.08760	-4.75891	-1.58765
7	-53.11051	833.45463	50.78243	-4.05236	-1.04702
8	-30.92046	946.53799	118.53241	-4.04518	-1.33319
9	-48.36775	1011.98088	46.93004	-3.06811	-1.11845
10	-36.13256	1091.93732	20.76329	-2.77185	-1.02236
11	-6.87408	1073.15643	41.10879	-1.92649	-0.63502
12	-19.28049	1030.57126	39.97124	-1.96260	-0.61348
13	-14.97594	1207.87943	-6.88119	-2.33193	-0.81018
14	3.50477	1220.95146	20.47496	-2.00518	-0.71624
15	-27.31066	1570.86101	35.87891	-2.47500	-1.00232
16	45.99441	731.66147	3.71644	-1.11605	-0.29893

High-rise Residential Coefficients

Table 31 – Coefficients for Opaque Construction Assemblies (High-rise Residential)

	Floors		Roofs			Walls		
CZ	C_F (light)	C_F (mass)	C_R (attic)	C_R (light)	C_R (mass)	C_W (light)	C_W (mass, HC>7)	C_W (mass, HC>15)
1	271.874	265.552	218.709	241.174	213.095	170.515	158.571	144.367
2	242.470	190.182	267.291	315.449	190.509	215.979	111.640	85.713
3	195.460	176.409	191.986	218.065	167.967	160.682	108.558	89.782
4	175.146	130.666	215.079	257.773	153.935	182.304	89.877	66.339
5	192.000	161.913	181.954	222.348	148.229	162.295	79.047	60.490
6	111.378	94.937	140.698	181.955	113.991	125.384	55.769	40.674
7	90.069	72.351	132.268	171.949	96.466	122.176	44.858	42.950
8	111.941	77.345	163.283	199.831	109.885	155.911	54.810	32.174
9	124.221	77.351	175.638	213.388	107.066	171.917	63.883	37.514
10	153.715	109.938	217.562	263.871	134.273	217.443	90.758	58.236
11	225.654	183.941	270.929	288.291	205.921	253.215	164.418	138.326
12	212.816	161.276	258.224	286.433	186.456	227.713	133.547	102.566
13	195.343	157.651	246.211	268.750	184.104	232.080	146.340	118.116
14	247.836	203.101	300.353	324.851	229.380	269.208	165.758	131.671
15	193.394	131.403	256.904	282.168	175.334	284.474	163.642	137.530
16	346.760	296.438	345.318	371.781	287.740	300.857	220.437	196.090

Table 32 – Coefficients for North-facing Windows and Overhangs (High-rise Residential)

	North Windows			North Overhangs	
CZ	C_{GU} (U-factor)	C_{GS} (SHGC)	C_{GT} (VLT)	a	b
1	115.96486	-58.34647	-42.92907	-1.54554	0.69740
2	96.82798	97.29212	-38.96852	-0.06242	0.04426
3	93.03419	20.14148	-34.72318	1.60601	-0.72330
4	76.90661	108.58410	-26.94060	-0.15311	0.07606
5	85.00643	22.47909	-33.54803	0.52373	-0.18144
6	54.01370	65.25369	-17.04307	-0.16996	0.09202
7	42.62191	106.48506	-13.36235	-0.34073	0.16905
8	51.94844	140.10941	-19.23026	-0.31103	0.15187
9	57.11317	167.06623	-19.71432	-0.30721	0.14788
10	70.11778	193.29749	-26.89629	-0.30628	0.14724
11	111.99552	180.33029	-33.98904	-0.13435	0.06954
12	101.92555	149.42606	-32.02433	-0.14250	0.07712
13	93.13227	188.06607	-30.64324	-0.16679	0.08506
14	116.60644	194.13234	-38.94480	-0.19274	0.10354
15	89.97437	335.65441	-37.50176	-0.27572	0.12926
16	169.17001	116.98490	-52.46648	0.10675	-0.02776

Table 33 – Coefficients for East-facing Windows and Overhangs (High-rise Residential)

	East Windows			East Overhangs	
CZ	C_{GU} (U-factor)	C_{GS} (SHGC)	C_{GT} (VLT)	a	b
1	123.08745	-220.04346	-33.13291	-0.89924	0.25349
2	94.63118	106.37880	-23.19813	-0.45418	0.36266
3	88.88018	-44.30914	-25.04499	-2.32883	0.77446
4	75.43392	146.31582	-17.18378	-0.62032	0.38568
5	79.34784	26.74283	-24.27829	-0.61119	1.57657
6	50.85615	145.21311	-9.63048	-1.25935	0.84859
7	38.34106	181.28076	-8.39786	-0.73186	0.38925
8	47.44827	267.11272	-17.29904	-0.74166	0.34858
9	49.60498	312.11163	-13.55353	-0.67700	0.29468
10	61.27902	371.67328	-32.71251	-0.68113	0.28992
11	107.09370	287.83564	-23.26511	-0.51343	0.20796
12	97.41953	232.53481	-21.58328	-0.53952	0.26294
13	83.16070	357.10040	-27.24638	-0.59098	0.22490
14	103.58315	349.92867	-34.44078	-0.60697	0.25511
15	76.27309	752.40553	-41.35184	-0.67247	0.26618
16	167.89451	62.80959	-38.94532	0.32917	0.11692

Table 34 – Coefficients for South-facing Windows and Overhangs (High-rise Residential)

	South Windows			South Overhangs	
CZ	C_{GU} (U-factor)	C_{GS} (SHGC)	C_{GT} (VLT)	a	b
1	116.15724	-224.68284	-26.78996	-0.96284	0.19761
2	98.96722	171.07484	-26.68188	-1.13793	0.91324
3	84.66182	10.17517	-31.56119	-2.18060	7.87344
4	74.35611	207.70722	-15.73033	-1.31317	0.94753
5	72.94670	88.04744	-34.75209	-1.48843	1.49464
6	43.88019	162.72015	-7.91402	-0.83695	0.71006
7	60.49534	-21.62365	69.32543	6.68377	-4.07717
8	70.25614	264.41682	-7.61121	-0.74393	0.25350
9	33.00660	526.65085	-56.83526	-0.94011	0.54343
10	57.94822	436.65063	-34.25191	-1.07069	0.57065
11	115.89049	351.28643	-24.43467	-1.04468	0.64888
12	102.93596	323.49959	-47.00019	-0.92227	0.62012
13	110.85654	362.70928	1.75554	-1.06540	0.63791
14	105.66968	381.46134	-39.62178	-0.96369	0.61260
15	72.92425	871.09986	-62.58491	-0.76575	0.32580
16	169.09704	94.34305	-47.18113	-1.51152	1.66488

Table 35 – Coefficients for West-facing Windows and Overhangs (High-rise Residential)

	West Windows			West Overhangs	
CZ	C_{GU} (U-factor)	C_{GS} (SHGC)	C_{GT} (VLT)	a	b
1	120.44594	-218.96662	-30.33049	-0.87856	0.15276
2	87.80444	201.76472	-39.34868	-0.69538	0.47561
3	81.96725	23.53511	-36.99004	-0.73299	1.51244
4	63.43676	242.73262	-22.89375	-0.91212	0.53905
5	79.44431	9.65797	-35.93622	0.12177	1.90658
6	36.04386	165.33575	-30.52046	-0.42771	0.21515
7	34.27107	258.31653	-13.14974	-0.80067	0.35105
8	42.83319	359.98535	-20.91995	-0.46257	0.11943
9	51.83597	424.09050	-24.35961	-0.72485	0.27151
10	57.70913	461.66238	-43.40259	-0.58600	0.20484
11	115.34131	403.62745	-27.87098	-0.70493	0.21646
12	95.23214	379.28015	-34.29311	-0.65176	0.20828
13	86.54790	514.35260	-38.39796	-0.64675	0.23577
14	105.27378	541.92129	-48.38151	-0.62950	0.23989
15	29.62898	1259.13780	-213.10627	-0.44408	0.02921
16	166.61275	146.50308	-57.33755	-0.51194	0.30767

Table 36 – Coefficients for Skylights and Cool Roofs (High-rise Residential)

	Skylight			Cool Roofs	
CZ	C_{GU} (U-factor)	C_{GS} (SHGC)	C_{GT} (VLT)	C_{Ref} (Reflectance)	C_{Emit} (Emittance)
1	166.28047	-511.66796	-51.54146	0.95162	0.51569
2	117.60487	289.49165	-29.37376	-0.11502	0.14956
3	105.42078	32.50766	-39.74930	0.27952	0.29444
4	64.11914	562.51134	12.83457	-0.53530	0.01227
5	92.02527	91.92126	-60.27149	0.20296	0.26575
6	117.35461	-5.02420	162.56622	-0.49565	0.14630
7	31.65031	555.72685	7.51420	-1.24202	-0.10453
8	21.47317	818.11908	-40.07116	-1.14682	-0.20149
9	42.05243	800.55491	11.11348	-1.12724	-0.27171
10	67.75575	761.49684	-4.26899	-1.04266	-0.25981
11	122.25604	734.20444	7.75878	-0.67191	-0.10524
12	110.91871	687.39718	-2.22641	-0.56093	-0.03761
13	86.07728	801.76964	-8.09962	-0.83986	-0.16925
14	115.49288	771.68879	-10.95906	-0.55582	-0.04762
15	111.68330	819.19735	214.90674	-1.38280	-0.61388
16	207.95033	251.99931	-47.41279	-0.06557	0.10347

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Table 37 – Percent Difference in TDV for Climate Zone 12

GTC Code	Doe-2 Glass Library Entry Name	U TB	TDV GTC	TDV USC	%Diff TDV	Panes
2430	Double Ref-B Tint-L	0.530	1407459	1349920	-4.1%	2
2453	Double Ref-C Tint-M	0.552	1443324	1384696	-4.1%	2
2413	Double Ref-A Tint-M	0.541	1418894	1361778	-4.0%	2
2456	Double Ref-D Tint-H	0.562	1455048	1396694	-4.0%	2
2416	Double Ref-A Tint-H	0.552	1442008	1384696	-4.0%	2
2410	Double Ref-A Tint-L	0.530	1403717	1349920	-3.8%	2
2450	Double Ref-C Tint-L	0.541	1421287	1367407	-3.8%	2
2433	Double Ref-B Tint-M	0.541	1438234	1383941	-3.8%	2
2436	Double Ref-B Tint-H	0.573	1468818	1414416	-3.7%	2
2457	Double Ref-D Tint-H	0.465	1431358	1378537	-3.7%	2
2454	Double Ref-C Tint-M	0.454	1418209	1366318	-3.7%	2
2411	Double Ref-A Tint-L	0.433	1374912	1325331	-3.6%	2
2455	Double Ref-C Tint-M	0.411	1407253	1356977	-3.6%	2
2417	Double Ref-A Tint-H	0.465	1417677	1367131	-3.6%	2
2414	Double Ref-A Tint-M	0.443	1392093	1342578	-3.6%	2
2437	Double Ref-B Tint-H	0.476	1447034	1395820	-3.5%	2
2418	Double Ref-A Tint-H	0.422	1407026	1357876	-3.5%	2
2431	Double Ref-B Tint-L	0.433	1378097	1330721	-3.4%	2
2415	Double Ref-A Tint-M	0.411	1380404	1334293	-3.3%	2
2434	Double Ref-B Tint-M	0.443	1411675	1365094	-3.3%	2
2458	Double Ref-D Tint-H	0.422	1421174	1374560	-3.3%	2
2451	Double Ref-C Tint-L	0.443	1393773	1348202	-3.3%	2
2432	Double Ref-B Tint-L	0.389	1364954	1321422	-3.2%	2
2452	Double Ref-C Tint-L	0.389	1381342	1337730	-3.2%	2
2435	Double Ref-B Tint-M	0.400	1400011	1355845	-3.2%	2
2443	Double Ref-C Clear-M	0.552	1452058	1406974	-3.1%	2
2438	Double Ref-B Tint-H	0.443	1437630	1393212	-3.1%	2
2412	Double Ref-A Tint-L	0.389	1362241	1321422	-3.0%	2
2406	Double Ref-A Clear-H	0.562	1445209	1401977	-3.0%	2
2447	Double Ref-C Clear-H	0.465	1454464	1411686	-2.9%	2
2446	Double Ref-C Clear-H	0.562	1474040	1430731	-2.9%	2
2440	Double Ref-C Clear-L	0.541	1414162	1373096	-2.9%	2
2426	Double Ref-B Clear-H	0.573	1491401	1449562	-2.8%	2
1410	Single Ref-B Tint-H	0.991	1550654	1507209	-2.8%	1
2420	Double Ref-B Clear-L	0.562	1442090	1401977	-2.8%	2
2403	Double Ref-A Clear-M	0.541	1412010	1373096	-2.8%	2
1405	Single Ref-A Tint-H	0.950	1511922	1470333	-2.8%	1
1416	Single Ref-C Tint-H	0.960	1529627	1487743	-2.7%	1
2421	Double Ref-B Clear-L	0.476	1423379	1384636	-2.7%	2
1415	Single Ref-C Tint-M	0.940	1510833	1469820	-2.7%	1
2445	Double Ref-C Clear-M	0.411	1423059	1384729	-2.7%	2

GTC Code	Doe-2 Glass Library Entry Name	U TB	TDV GTC	TDV USC	%Diff TDV	Panes
2441	Double Ref-C Clear-L	0.443	1391160	1353690	-2.7%	2
2404	Double Ref-A Clear-M	0.443	1390753	1353690	-2.7%	2
2408	Double Ref-A Clear-H	0.433	1418478	1381067	-2.6%	2
2444	Double Ref-C Clear-M	0.454	1431772	1394072	-2.6%	2
1404	Single Ref-A Tint-M	0.919	1478399	1439996	-2.6%	1
2448	Double Ref-C Clear-H	0.422	1445873	1408509	-2.6%	2
2407	Double Ref-A Clear-H	0.476	1426565	1390245	-2.5%	2
2427	Double Ref-B Clear-H	0.476	1473919	1436434	-2.5%	2
1408	Single Ref-B Tint-L	0.889	1457154	1420477	-2.5%	1
2470	Double Ref-D Tint	0.606	1526410	1488208	-2.5%	2
2471	Double Ref-D Tint	0.519	1513487	1476214	-2.5%	2
2400	Double Ref-A Clear-L	0.530	1377975	1344406	-2.4%	2
1414	Single Ref-C Tint-L	0.899	1474539	1438637	-2.4%	1
2422	Double Ref-B Clear-L	0.433	1415236	1381067	-2.4%	2
1406	Single Ref-B Clear-L	0.981	1514144	1478223	-2.4%	1
1418	Single Ref-D Tint	1.103	1629162	1591016	-2.3%	1
2442	Double Ref-C Clear-L	0.389	1381235	1349071	-2.3%	2
2666	Double Low-E (e2=.04) Tint	0.480	1477256	1442975	-2.3%	2
1409	Single Ref-B Tint-M	0.909	1496471	1461999	-2.3%	1
2472	Double Ref-D Tint	0.487	1508047	1473760	-2.3%	2
3601	Triple Low-E (e5=.1) Clear	0.400	1672162	1634285	-2.3%	3
1413	Single Ref-C Clear-H	0.960	1545768	1511202	-2.2%	1
1403	Single Ref-A Tint-L	0.889	1452910	1420477	-2.2%	1
2401	Double Ref-A Clear-L	0.433	1355504	1325331	-2.2%	2
2428	Double Ref-B Clear-H	0.443	1466260	1433912	-2.2%	2
2402	Double Ref-A Clear-L	0.389	1345797	1316118	-2.2%	2
2405	Double Ref-A Clear-M	0.411	1381445	1351118	-2.2%	2
1402	Single Ref-A Clear-L	0.970	1516313	1483345	-2.2%	1
1407	Single Ref-B Clear-H	0.991	1569803	1536800	-2.1%	1
3621	Triple Low-E (e2=e5=.1) Clear	0.338	1581998	1549280	-2.1%	3
1412	Single Ref-C Clear-M	0.940	1516535	1486562	-2.0%	1
3001	Triple Clear	0.446	1743242	1711718	-1.8%	3
1411	Single Ref-C Clear-L	0.899	1465026	1438637	-1.8%	1
2636	Double Low-E (e2=.1) Tint	0.491	1530029	1504868	-1.6%	2
2667	Double Low-E (e2=.04) Tint	0.331	1441302	1419372	-1.5%	2
3002	Triple Clear	0.331	1729507	1704437	-1.4%	3
3002	Triple Clear	0.366	1729507	1706704	-1.3%	3
3602	Triple Low-E (e5=.1) Clear	0.288	1647478	1626577	-1.3%	3
1400	Single Ref-A Clear-L	0.878	1420638	1402769	-1.3%	1
2637	Double Low-E (e2=.1) Tint	0.354	1500774	1482606	-1.2%	2
2668	Double Low-E (e2=.04) Tint	0.263	1424087	1407622	-1.2%	2
2216	Double Tint Grey	0.519	1579790	1562086	-1.1%	2
2215	Double Tint Grey	0.606	1591368	1573864	-1.1%	2
2203	Double Tint Bronze	0.606	1601418	1586099	-1.0%	2
2217	Double Tint Grey	0.487	1575083	1560019	-1.0%	2

GTC Code	Doe-2 Glass Library Entry Name	U TB	TDV GTC	TDV USC	%Diff TDV	Panes
1205	Single Tint Grey	1.113	1703720	1687752	-0.9%	1
2218	Double Tint Blue	0.606	1600829	1586099	-0.9%	2
1203	Single Tint Green	1.113	1715409	1699732	-0.9%	1
3603	Triple Low-E (e5=.1) Clear	0.238	1637310	1622941	-0.9%	3
2205	Double Tint Bronze	0.487	1586160	1572270	-0.9%	2
1201	Single Tint Bronze	1.113	1713837	1699732	-0.8%	1
2220	Double Tint Blue	0.487	1585282	1572270	-0.8%	2
1206	Single Tint Blue	1.113	1713481	1699732	-0.8%	1
2210	Double Tint Green	0.519	1592558	1580561	-0.8%	2
2209	Double Tint Green	0.606	1603204	1592254	-0.7%	2
2204	Double Tint Bronze	0.519	1590536	1580561	-0.6%	2
3622	Triple Low-E (e2=e5=.1) Clear	0.213	1555866	1546147	-0.6%	3
2211	Double Tint Green	0.487	1588226	1578491	-0.6%	2
2638	Double Low-E (e2=.1) Tint	0.297	1487105	1478129	-0.6%	2
2219	Double Tint Blue	0.519	1589783	1580561	-0.6%	2
1417	Single Ref-D Clear	1.103	1629224	1620788	-0.5%	1
2460	Double Ref-D Clear	0.606	1543832	1537164	-0.4%	2
2461	Double Ref-D Clear	0.519	1537208	1531375	-0.4%	2
2462	Double Ref-D Clear	0.487	1534328	1529175	-0.3%	2
3623	Triple Low-E (e2=e5=.1) Clear	0.175	1546982	1543372	-0.2%	3
1202	Single Tint Green	1.134	1775453	1773948	-0.1%	1
2664	Double Low-E (e3=.04) Clear	0.331	1512727	1511693	-0.1%	2
1200	Single Tint Bronze	1.134	1779727	1780034	0.0%	1
1204	Single Tint Grey	1.134	1772152	1773948	0.1%	1
2200	Double Tint Bronze	0.617	1676883	1678815	0.1%	2
2665	Double Low-E (e3=.04) Clear	0.263	1504605	1506366	0.1%	2
2214	Double Tint Grey	0.498	1656926	1659148	0.1%	2
2207	Double Tint Green	0.530	1664621	1667357	0.2%	2
2212	Double Tint Grey	0.617	1668910	1672737	0.2%	2
2208	Double Tint Green	0.498	1661194	1665391	0.3%	2
2201	Double Tint Bronze	0.530	1668992	1673477	0.3%	2
2642	Double Low-E (e3=.1) Clear	0.297	1671823	1677207	0.3%	2
2633	Double Low-E (e2=.1) Clear	0.491	1622421	1627969	0.3%	2
2202	Double Tint Bronze	0.498	1665723	1671531	0.3%	2
2206	Double Tint Green	0.617	1672598	1678815	0.4%	2
2213	Double Tint Grey	0.530	1660493	1667357	0.4%	2
2634	Double Low-E (e2=.1) Clear	0.354	1610404	1618752	0.5%	2
2660	Double Low-E (e2=.04) Clear	0.480	1532707	1541056	0.5%	2
2662	Double Low-E (e2=.04) Clear	0.274	1510905	1519654	0.6%	2
2005	Double Clear	0.487	1716715	1726704	0.6%	2
2613	Double Low-E (e3=.2) Clear	0.514	1693525	1703506	0.6%	2
2641	Double Low-E (e3=.1) Clear	0.366	1671652	1681750	0.6%	2
2614	Double Low-E (e3=.2) Clear	0.400	1692127	1702673	0.6%	2
2004	Double Clear	0.519	1717282	1728567	0.7%	2
2640	Double Low-E (e3=.1) Clear	0.503	1673068	1684207	0.7%	2

GTC Code	Doe-2 Glass Library Entry Name	U TB	TDV GTC	TDV USC	%Diff TDV	Panes
2615	Double Low-E (e3=.2) Clear	0.331	1692082	1704437	0.7%	2
2602	Double Low-E (e3=.4) Clear	0.411	1734280	1747002	0.7%	2
1001	Single Clear	1.113	1830757	1844993	0.8%	1
2630	Double Low-E (e2=.1) Clear	0.503	1639903	1653257	0.8%	2
2003	Double Clear	0.606	1719065	1733656	0.8%	2
2611	Double Low-E (e3=.2) Clear	0.400	1731184	1746303	0.9%	2
2661	Double Low-E (e2=.04) Clear	0.343	1517680	1531038	0.9%	2
2600	Double Low-E (e3=.4) Clear	0.571	1734477	1750224	0.9%	2
1000	Single Clear	1.134	1859814	1876991	0.9%	1
2610	Double Low-E (e3=.2) Clear	0.526	1731573	1747619	0.9%	2
2601	Double Low-E (e3=.4) Clear	0.469	1734112	1750449	0.9%	2
2635	Double Low-E (e2=.1) Clear	0.297	1605366	1620930	1.0%	2
2612	Double Low-E (e3=.2) Clear	0.343	1731358	1749210	1.0%	2
1003	Single Low Iron	1.124	1880874	1900279	1.0%	1
2000	Double Clear	0.617	1758993	1777460	1.0%	2
2631	Double Low-E (e2=.1) Clear	0.366	1626910	1644409	1.1%	2
1002	Single Low Iron	1.134	1886425	1907182	1.1%	1
2632	Double Low-E (e2=.1) Clear	0.297	1621654	1639640	1.1%	2
2002	Double Clear	0.498	1756481	1776947	1.2%	2
2001	Double Clear	0.530	1757132	1778872	1.2%	2
2008	Double Low Iron	0.498	1797625	1820569	1.3%	2
2007	Double Low Iron	0.530	1798541	1822254	1.3%	2
2011	Double Low Iron	0.487	1790070	1813824	1.3%	2
2010	Double Low Iron	0.530	1790833	1816035	1.4%	2
2006	Double Low Iron	0.617	1800934	1827107	1.5%	2
1600	Single Low-E Clear (e2=.4)	0.899	1783153	1809819	1.5%	1
2009	Double Low Iron	0.606	1792975	1820270	1.5%	2
1601	Single Low-E Clear (e2=.2)	0.776	1761989	1791663	1.7%	1
1602	Single Low-E Clear (e2=.2)	0.766	1730826	1760538	1.7%	1