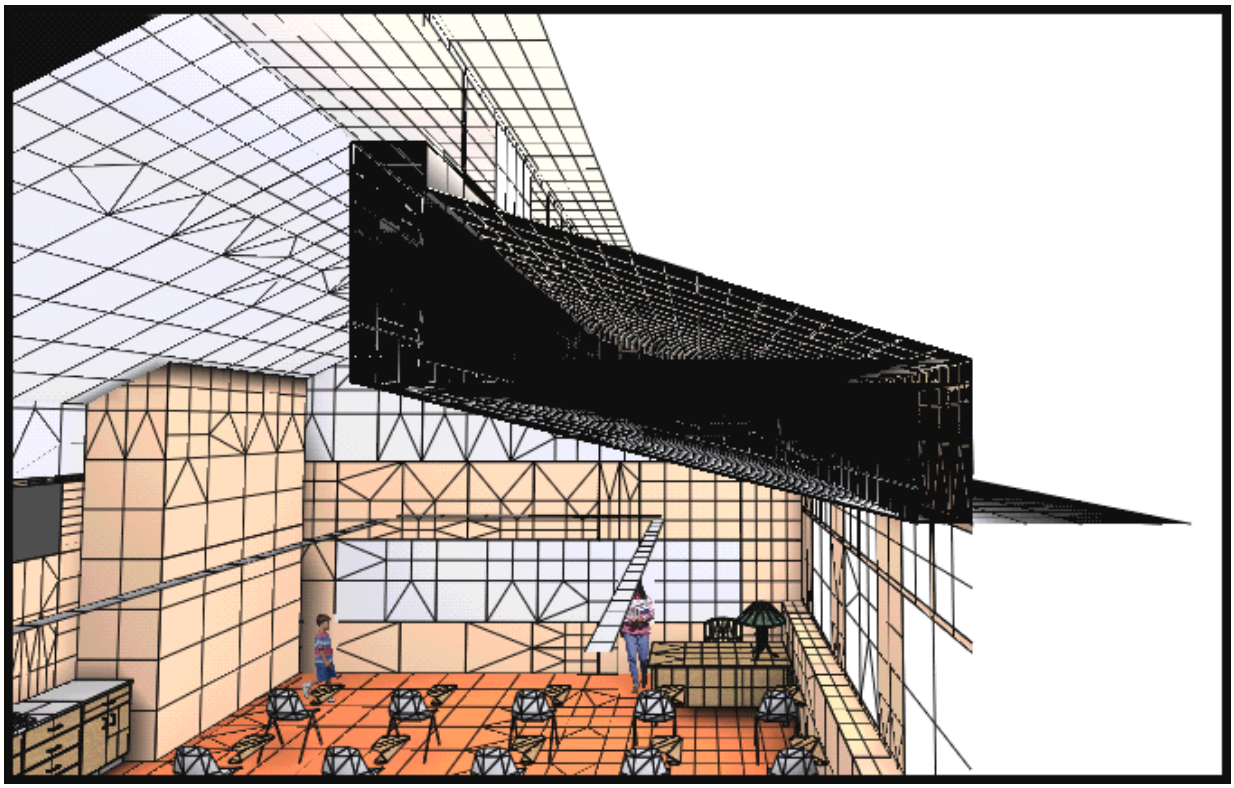
The Cool Daylighting™ Design Approach Workbook

Volume 2 – Schools



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The
Cool Daylighting™ Design Approach
Workbook:
Volume 2 – Schools

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Table of Contents

A. Overview

Welcome to the Cool Daylighting™ Design Approach Workbook Volume 1: Schools. The purpose of this Workbook is to facilitate quick economic and performance assessments of simple, yet very effective Cool Daylighting™ design strategies for all schools. The goal is to empower architects, engineers, building owners, etc., with concise information that suggests how no-cost and low-cost Cool Daylighting™ strategies can be included in all schools. This goal supports the Daylighting Collaborative's vision of making daylighting a mainstream building technology. For a detailed definition of the Cool Daylighting™ design approach, or further information on the Daylighting Collaborative's other products and resources, please visit our web site at www.daylighting.org.

The technique utilized in this Workbook is called Comparative Analysis. Comparative Analysis is based on the integrated whole-building environmental design approach developed by Steve Ternoey, et al, in The Design of Energy Responsive Commercial Buildings, John Wiley & Sons, 1985. In this workbook, comparative analysis documents the cost and performance of standard or "Base Case" classroom solutions, then compares the cost and performance of "Prototypical" daylighting solutions. Easy-to-use worksheets are provided to facilitate simple comparisons and choices by building designers and owners.

The Workbook summarizes the daylighting means and methodologies taught at the Daylighting Collaborative's School Building training seminar. Please review the Training Manual if you have questions about the design of the daylighting prototypes documented in this Workbook. The Workbook is also intended to compliment the Daylighting Collaborative Copy Rooms. While the Base Case classrooms presented here will be very familiar to everyone, the Prototypical Daylighting Solutions are beyond the physical experience of most people. Therefore, the Daylighting Collaborative has (will) scattered mock-ups of the Prototypes around the region for personal inspection and experience. We call these mock-ups "Copy Rooms", since the intent is to allow building designers and owners to review a "catalog" of real solutions, select the one(s) they desire, and "copy" those basic systems into their project. Granted, not every possibility can be demonstrated, so there are limits to this approach. However, copying simple mock-ups is an excellent place to begin daylighting every building. The approach cuts risk and insures a specific level of success from the very first project. For a list of Copy Room sites, please refer to the Daylighting Collaborative web site. (Note: This version of the Workbook is being released before Copy Room sites are in place in the State of Wisconsin. Watch our web site for Copy Room grand openings, and updated Prototype documentation for this workbook.)

As with the Copy Rooms, the Workbook Base Cases and Prototypes are presented on a per room basis. Typical classroom-related spaces, such as perimeter and core classrooms, are presented. Quite simply, one uses a "worksheet" to first document the number (or area) of typical classrooms included in your proposed building, and key performance and cost data. Next, select the Prototypical solutions you want to evaluate for use on your project. As with the Base Case, a worksheet is used to record performance and cost factors for the Prototype alternative. Simple math is used to compare the net differences in first cost, HVAC CFM & tons, peak kW, ductwork, etc., between the two solutions.

Two "Levels" of solutions are shown for most Prototypes. Level 1 solutions hold incremental cost to a minimum, and generally do not include higher price components such as overhangs and daylighting controls. Level 1 solutions represent no cost alternatives that can be used on most building, new or retrofit, without any cost premium over standard construction. Level 2 solutions generally represent higher quality cool daylighting systems where first cost is higher, but where partial to full first cost savings can be derived from HVAC downsizing and other cost reallocation methods. While we generally recommend Level 2 solutions where possible, both prototype solution levels increase human, environmental and economic performance compared to standard or Base Case classroom solutions.

Cost data for each Base Case and Prototype are based on the author's experience designing Cool Daylighting™ solutions over the last decade, and on widely available construction cost references, where noted. Refer to the Training Manual for additional data. Energy and HVAC capacity data is derived from calibrated Energy 10 simulations using an hourly Minneapolis TMY weather file. The Minneapolis weather file is used since it is representational for the region, while remaining relatively conservative in predicting the benefits of cooling load avoidance strategies. All simulated loads are based on typical conditions, NOT PEAK CONDITIONS. In other words, absolute values are not to be used alone; only the difference between two numbers is a valid estimate of improvement or benefit. Do not use this data to design or size HVAC equipment. Workbook data must only be used to approximate the **differences** between the Base Cases and Prototypes in values such as air-conditioning tonnage, CFM, peak kW, cost, etc. Additional modeling technique discussions will be eventually published as an Appendix to this Workbook, and will be available on our web site.

Use this workbook as a simple design tool to point out potentially useful design alternatives. Once options are selected, use your own design team to define cost and performance for your particular situation and circumstances. While this Workbook can be a useful tool, it is never intended to replace the need for a competent design team! Good luck!

B. Worksheets

For comparison, Base Cases and Prototypes are always studied as pairs. Likewise, Worksheets are divided into two sections. The front of each Worksheet is for the Base Case layout, while the back is for the Prototype solution. Each side of the Worksheet has an area to sketch the building layout, and a place to create a data table summarizing areas, cost and performance factors. Simple math is used to calculate overall results for each layout proposed by the user.

The data tables can be constructed in two ways. First, one can literally count the number of classrooms by orientation and type, and complete the form on a "per room" basis (as shown in the attached example). Alternately, one can use square foot data to approximate the same general answers, if the classrooms and support spaces on your project are somewhat different in size than the prototypes listed in this workbook. Base Case and Prototypical data is provided in Section C in both square foot and per classroom format.

Open classroom core zones are used to approximate all core functions (circulation, rest rooms, etc.). This is sufficient since our only desire is to approximate the benefits of daylighting and solar shading, factors that vary little by the exact space use.

Blank and sample Worksheets are attached. Photocopy the blanks for future use.

Cool Daylighting™ Design Approach Worksheet Page 1
Base Case Project Name:

Sketch

Description:

Space/ID	Number (or Area)	Tons Ea. (orTons/sf)	Tons Total	CFM Ea. (or CFM/sf)	CFM Total	kW Ea. (or kW/sf)	kW Total	$/yr (or $/sf)	$/yr Total

Summary/Conclusions:

Cool Daylighting™ Design Approach Worksheet Page 2

Proposed Solution Name:

Sketch

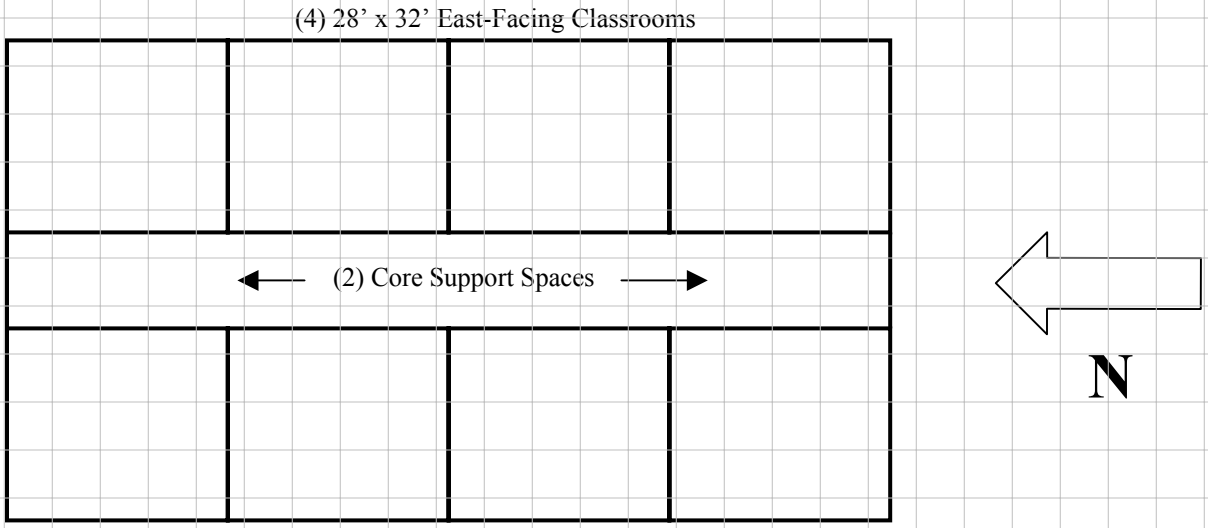
Description:

Space/ID	Number (or Area)	Tons Ea. (orTons/sf)	Tons Total	CFM Ea. (or CFM/sf)	CFM Total	kW Ea. (or kW/sf)	kW Total	$/yr (or $/sf)	$/yr Total

Summary/Conclusions:

Cool Daylighting™ Design Approach Worksheet Page 1

Base Case Project Name: Righi Elementary Classroom Wing Scheme A



Sketch

Description: **2-Story, 18,000 square foot gross.**
Classrooms - Lights: 1.36 W/sf Glass: 92 sf; SC=0.51
Corridors – Lights: 0.89 W/sf, no glass, 1 person/60 sf (Use Prototype 1.1 Core 2)

Space/ID	Number (or Area)	Tons Ea. (orTons/sf)	Tons Total	CFM Ea. (or CFM/sf)	CFM Total	kW Ea. (or kW/sf)	kW Total	$/yr (or $/sf)	$/yr Total
B1.1 East	8	3.44	27.52	1255	10040	6.40	51.2	881	7048
B1.1 West	8	3.35	26.80	1078	8624	6.58	52.6	892	7136
P1.1 Core 2	4	2.10	8.40	479	1916	4.50	18.0	621	2484
			62.72		20,580		121.8		$16,668

65 Ton Unit

Summary/Conclusions:

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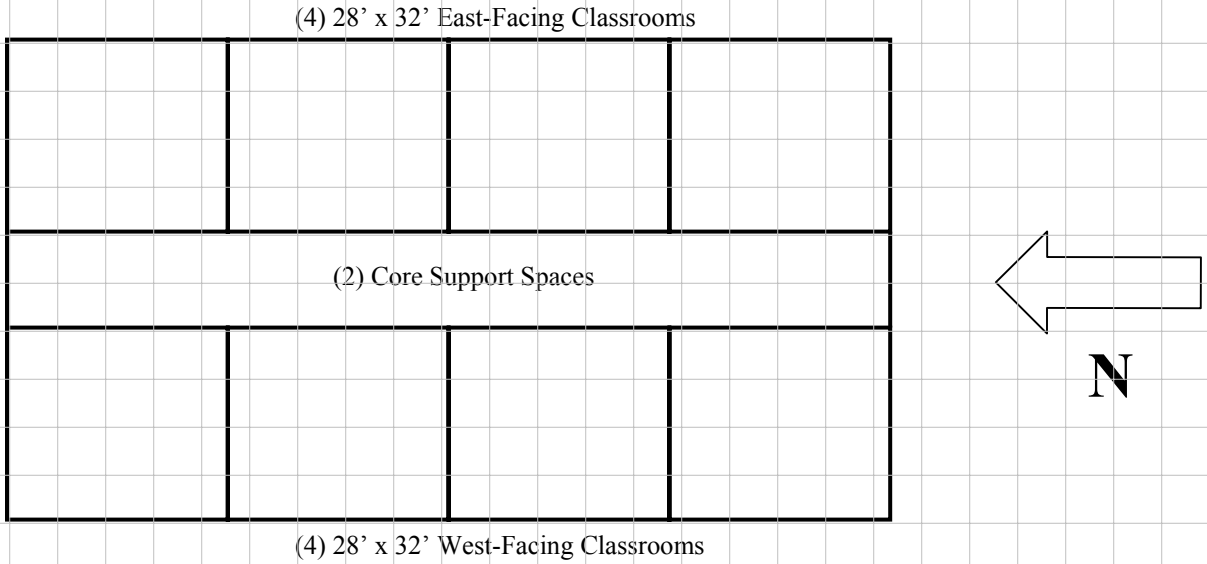
Cool Daylighting™ Design Approach Worksheet Page 2

Proposed Solution Name: Righi Elementary Classroom Wing Scheme B



Sketch

Description: Use Prototype 1.2 for each perimeter space.

Space/ID	Number (or Area)	Tons Ea. (orTons/sf)	Tons Total	CFM Ea. (or CFM/sf)	CFM Total	kW Ea. (or kW/sf)	kW Total	$/yr (or $/sf)	$/yr Total
P1.2 L1 East	8	2.69	21.52	859	6872	5.38	43.04	723	5784
P1.2 L1 West	8	2.69	21.52	750	6000	5.38	43.04	726	5808
P1.1 Core 2	4	2.10	8.40	479	1916	4.50	18.00	621	2484
			51.44		14,788		104.08		14,076
			55 ton unit (-15%)		**(-28%)**		**(-15%)**		**(-16%)**

10 ton reduction, for a multizone system, is worth about $2300 x 10 = $23,000
A 28% reduction in fan power is worth about .28/.50 x .33 x $1.15 x 18,000 sf = $3,825
(see training manual for cost factors)

Summary/Conclusions: The above results are achieved while reducing first cost by about $25,000 and greatly improving the quality of the luminous environment.

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C. Series 1 Base Case & Prototypical Designs: Overview

The Series 1 Base Case and Prototypical Classroom Designs presented here mirror the basic Cool Daylighting™ solutions recommended at the Daylighting Collaborative School Building Training. Series 2 and beyond, to be added later to this Workbook, will document additional solutions/variants demonstrated at Daylighting Collaborative Copy Room sites. It is highly recommended that both building owners and the design team visit Copy Room sites before implementing any solutions represented in this Workbook. Many of these solutions push existing design standards and, therefore, require owner approval before construction.

As overviewed below, Series 1 Classroom documentation includes: 1) 28' x 32' Base Case Classroom, 2) 28' x 32' Perimeter Classroom with Improved Glass & Dimming, 3) 28' x 32' Perimeter Classroom with Clerestories & Dimming, 4) 28' x 32' Perimeter Classroom with 10'-6" Ceiling, Clerestories & Direct/Indirect Luminaires, and 5) 28' x 32' Perimeter Classroom with Stepped Roof Form. Multiple Prototypical Designs are presented to bracket key cost and performance factors, and to provide choice. Designers are encouraged to interpolate between solutions to approximate the performance of variants not documented in this Workbook.

Base Case 1.1 - 28' x 32' Classroom: This design approximates the current standard for classroom design in Wisconsin. The Base Case Classroom has (12) 2x4 3" Parabolic 3-lamp Troffers (1.36 W/sf), 92 sf of tinted glass (S.C. = 0.51), and a 9'-0" ceiling. Occupancy is 28 people, and 1 W/sf of plug loads is included (diversified). Variants document Base Case performance for perimeter and windowless core classrooms and ancillary spaces.

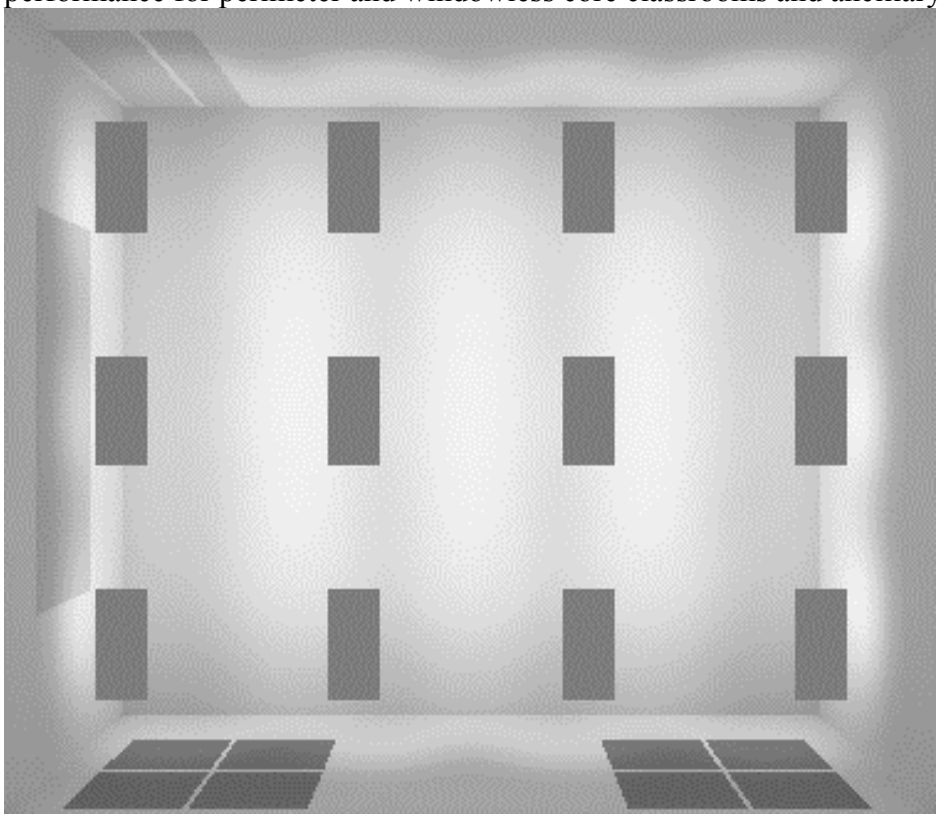


Figure C1: Base Case Classroom 1.1

Prototype 1.1 – 28' x 32' Perimeter Classroom with Improved Glass & Dimming: In this prototype, daylight is better distributed by utilizing four windows evenly placed along the perimeter. Viracon VE3-40 (S.C. = 0.22) is used. To prevent overall window costs from rising over the Base Case, total window area is 82 sf, an 11% reduction. The electric lighting system is changed to (12) 2-lamp 12-cell parabolic troffers with (12) Motorola dimming ballasts. By prescribing semi-annual lamp cleaning, and by using a higher ballast factor (0.96 vs 0.87), 50 fc is achieved with 0.89 W/sf lighting power density, a 35% reduction compared to the Base Case. Since glass and lighting revisions add no net cost, this solution is appropriate for all schools, including non-air-conditioned facilities. Variants document Prototype performance with & without a fixed exterior overhang, and with & without a photocell dimming control for the exterior row of luminaires. Core classroom and ancillary spaces of this electric lighting design are also documented.

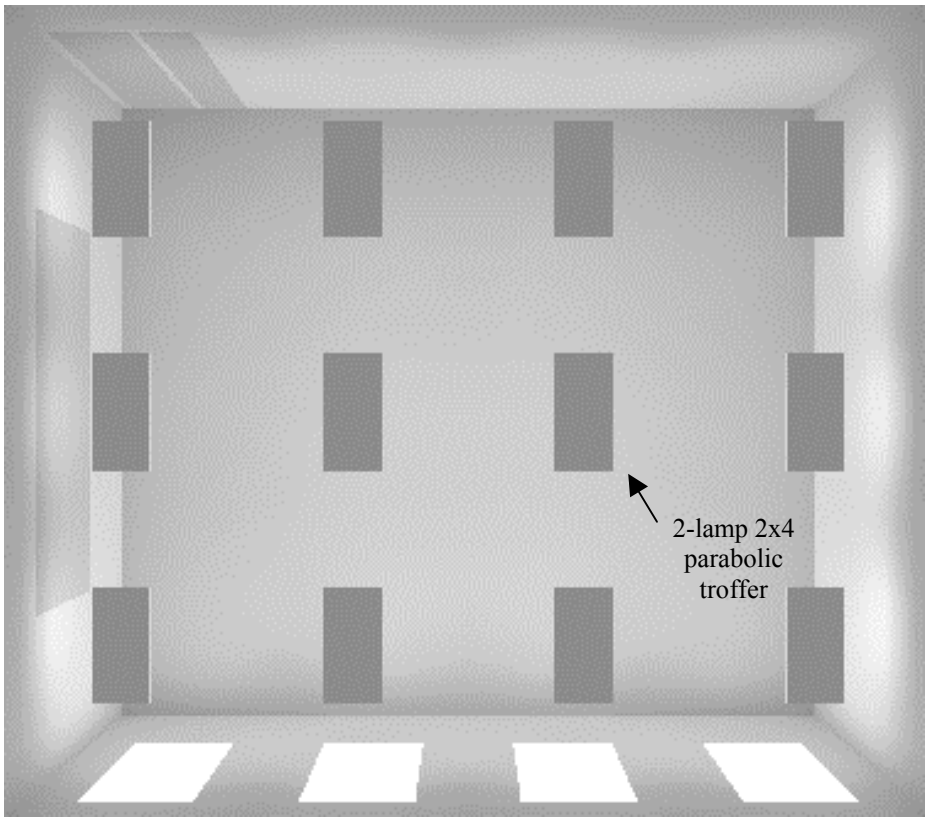


Figure C2: Prototype Classroom 1.1

Prototype 1.2 – 28' x 32' Perimeter Classroom with Clerestories & Dimming: As illustrated on the next page, Prototype 1.2 is identitcal to Prototype 1.1, except for window size and placement. To increase transparency, daylight quality, and useful daylight to augment photocell-based dimming, a 20" clerestory strip is added (area = 43 sf, S.C. = .26 unshaded, .38 shaded). View windows equal 48 sf, with a .22 Shading Coefficient. The total glass area is about 91 sf, matching the Base Case. Variants document Prototype performance without the overhang or photocell-based lighting controls (Level 1) and with overhangs and photocell-based lighting controls (Level 2).

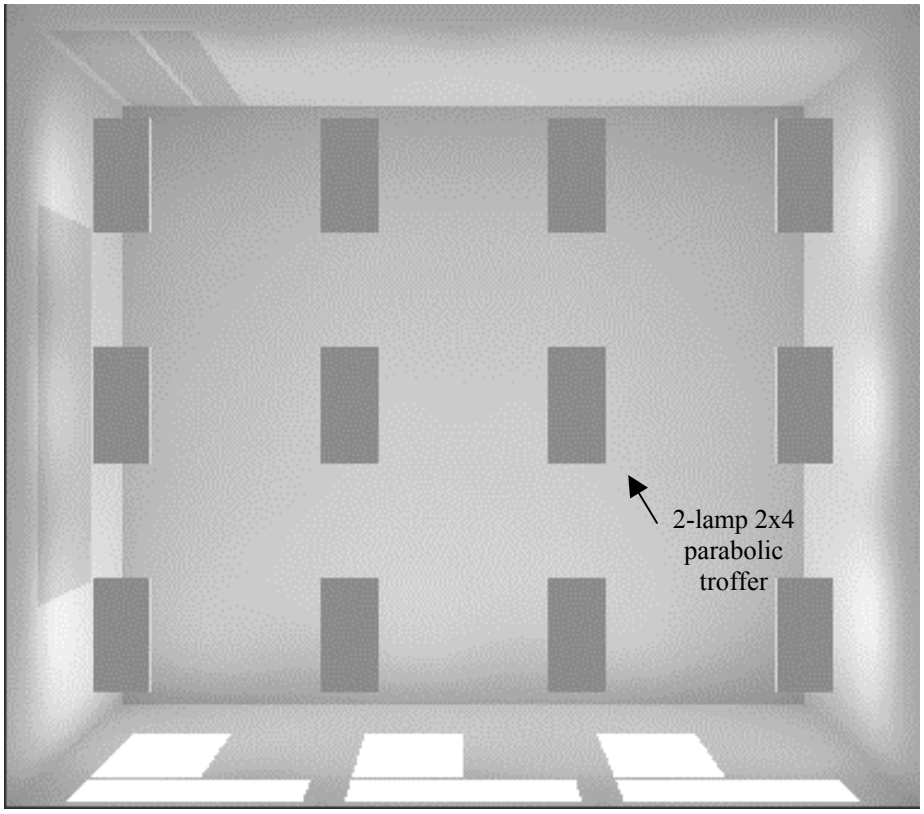


Figure C3: Prototype Classroom 1.2

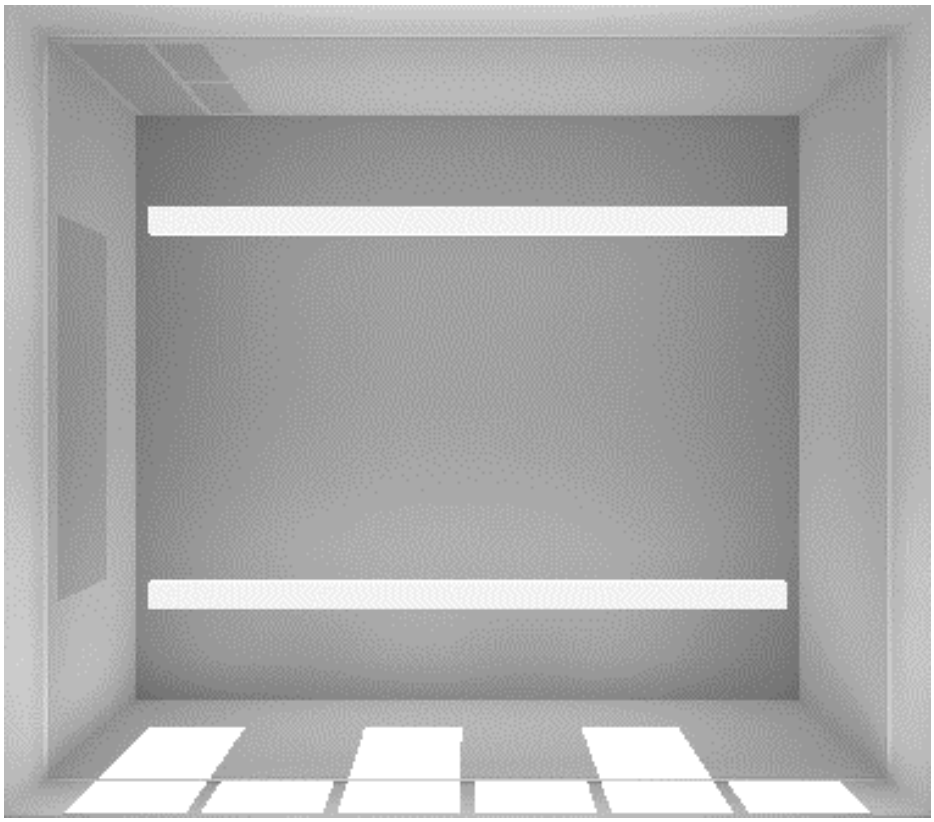


Figure C4: Prototype Classroom 1.3

Prototype 1.3 – 28’ x 32’ Perimeter Classroom with 10’-6” Ceiling, Clerestories & Direct/Indirect Luminaires: As illustrated on the previous page, the ceiling is raised to 10.5’ in height, and a 27” high clerestory (57 sf total) spans the exterior wall. Three large view windows are used, totaling 60 sf (Total glass area = 117 sf). Two rows of 24’ long 2-lamp direct/indirect Luminaires with Motorola dimming ballasts are placed 8’-0” above the finished floor (0.86 W/sf connected). Variants document Prototype performance without the overhang or photocell-based lighting controls (Level 1) and with overhangs and photocell-based lighting controls (Level 2).

Note: The 50% up/50% down, 92% efficient luminaires utilized in Prototype 1.3 provide much higher and more even vertical illuminance on the marker board than most standard parabolic downlighting solutions. However, some designers may prefer even more vertical illuminance when chalkboards are used. While not studied in detail in this workbook, Figure C5 below illustrates how three rows of direct/indirect luminaires can be used to augment vertical illuminance at the front of the room, while keeping total connected lighting load nearly the same. Luminaire selection criteria does change with this fixture orientation and location. Fixture luminance must be selected carefully!

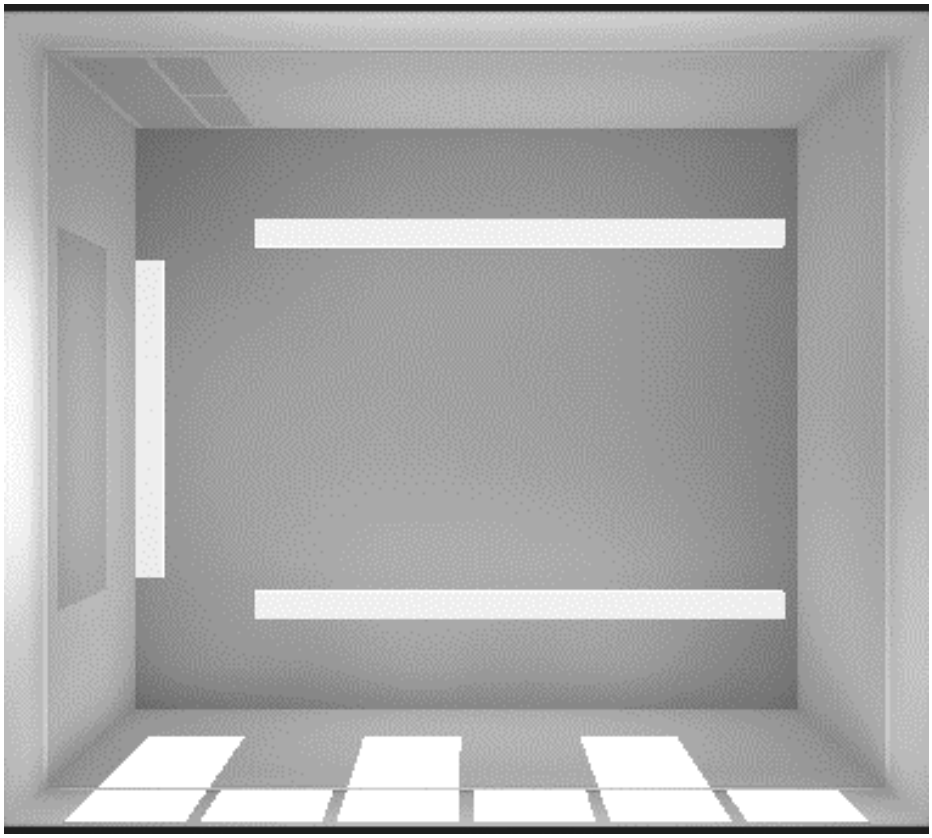


Figure C5: Prototype Classroom 1.3 – Revised for Chalkboards

Prototype 1.4 – 28’ x 32’ Perimeter Classroom with Stepped Roof Form: As illustrated below, this prototype matches Prototype 1.3, with the addition of a clerestory step near the centerline of the classroom. The 30” high shaded clerestory (63 sf total) spans the roof step. Total glass area = 180 sf). A 40” deep overhang shades the clerestory, since movable interior

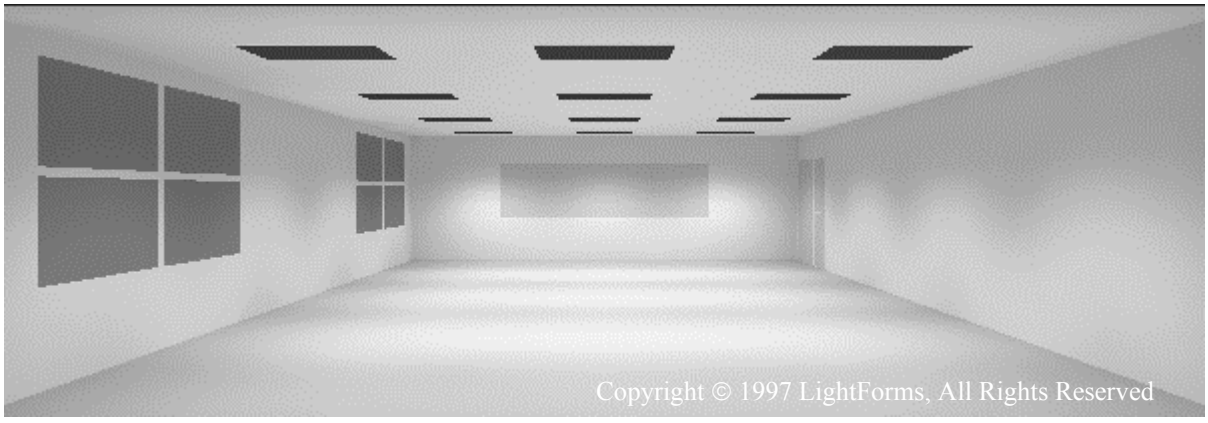
window treatments are never recommended at that height. This prototype is representational of classroom daylighting solutions that manipulate the roof to achieve higher daylight factors than achieveable with sidelighting alone. As a performance comparason to the preceeding prototype will show, environmental performance is not significantly increased compared to the added costs. The true purpose of such solutions is the creation of superior luminance environments for human performance and enjoyment reasons, a topic to be discussed at the Advanced Daylighting Tools and Techniques Training.

Figure C6: Prototype Classroom 1.4

All cost values cited in the detailed Base and Prototypical data which follows are as presented in the Daylighting Training. The lone exception is the cost for the above classroom roof pop-up. Past experience suggests the minimum added cost is about $250/linear foot of pop-up for a small (less than 3'-0" high) clerestory. Refer to the Training Manual for cost factors concerning glass, window treatments, overhangs and sun shades, electric lighting trade-offs, HVAC downsizing, etc.

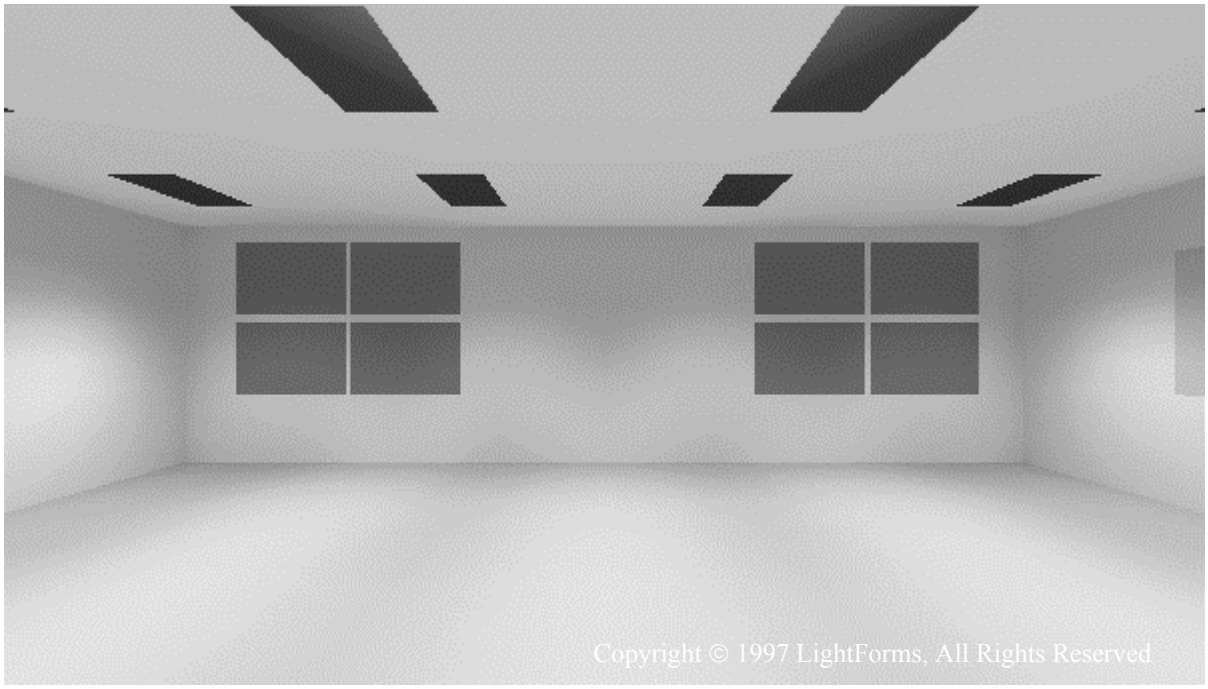
Each of the designs will now be presented in data sheet format. Performance factors will be tabulated for each Base Case and Prototype for the four cardinal directions for each variant. Variants include multiple levels of completeness for the Prototypes to bracket performance for even the most limited construction budgets.

Base Case #1.1
28’x32’ Classroom



Description: Base Case has (12) 2x4 3” Parabolic 2-lamp Troffers (1.36 W/sf) and 92 sf of tinted insulated glass (S.C. = 0.51) and mini-blinds. Nighttime average horizontal illuminance = 59.5 fc. Two zone Dual Switching is used to meet code (approximate cost is $310). Surface reflectances are 0.8 ceiling, 0.5 walls and 0.2 floor. Ceiling height is 9’– 0”. Occupancy is 28 people, full occupancy 9am to 3pm, partial occupancy 8am – 5pm, 12 months/yr. Also, 1 W/sf of diversified plug loads are included. Variants document Base Case performance for perimeter and windowless core classrooms and ancillary spaces as follows:

- Base Case 1.1A: Base Case Classroom performance data for windows oriented North, South, East and West.
- Base Case 1.1B: Base Case Classroom performance data for windowless core classrooms, and windowless core ancillary spaces (Half the people load, other loads the same)



Base Case #1.1A
28'x32' Classroom Performance Factors

Description	North Glass Orientation	South Glass Orientation	West Glass Orientation	East Glass Orientation[1]
CFM_{peak}	804	1006	1078	1255
CFM/Sq. Ft.	0.89	1.12	1.20	1.39
AC Tons	2.85	3.27	3.35	3.44
Sq. Ft./Ton	315	275	269	262
Tons/Sq. Ft.	.0032	.0036	.0037	.0038
kW_{peak}[2]	6.03	6.53	6.58	6.40
kW_{peak}/Sq. Ft.	.0067	.0073	.0073	.0071
$/Classrm-Yr[3]	843	884	892	881
$/Sq. Ft.-Yr[3]	.937	.983	.991	.979

[1] Typically, one would expect capacities to be higher for the West orientation than for the East. However, the West-side solar peak occurs after school is done for the day, which makes the East-side capacities slightly higher than the West-side. For schools with near-full occupancy to 5pm, use East classroom capacities for West classrooms, when larger.
[2] Room peak may not be same as building peak.
[3] Based on $0.025/kWh, and $9.50/kW, autosized HVAC equipment with average loads

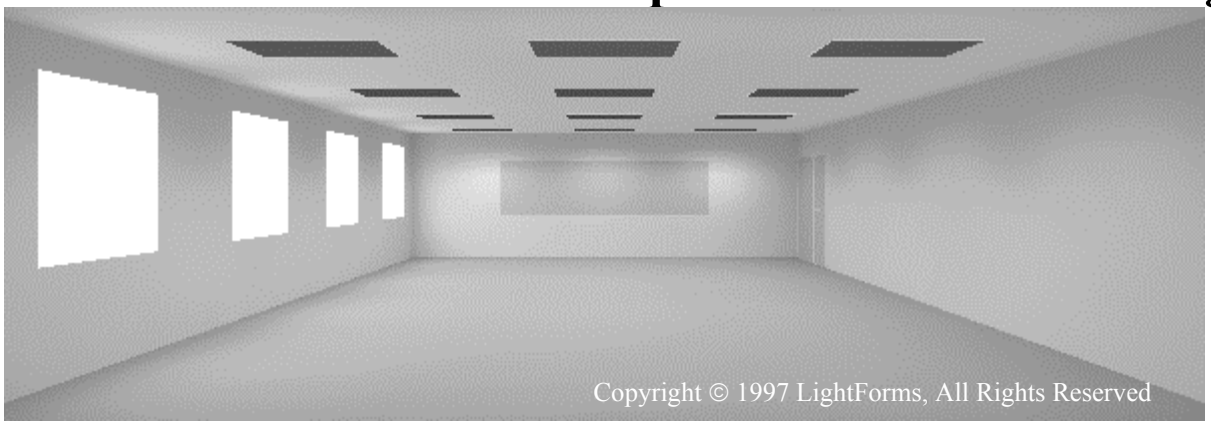
Base Case #1.1B
28'x32' Classroom Performance Factors

Description	Windowless Core 1 Classroom	Windowless Core 2w/ 50% Occupancy[1]		
CFM_{peak}	684	565		
CFM/Sq. Ft.	0.76	0.63		
AC Tons	2.60	2.27		
Sq. Ft./Ton	346	396		
Tons/Sq. Ft.	.0029	.0025		
kW_{peak}[2]	5.63	5.20		
kW_{peak}/Sq. Ft.	.0063	.0058		
$/Classrm-Yr[3]	769	732		
$/Sq. Ft.-Yr[3]	.854	.813		

[1] For classroom-like ancillary spaces with about 60 sf/person (half the people density of a classroom)
[2] Room peak may not be same as building peak.
[3] Based on $0.025/kWh, and $9.50/kW, autosized HVAC equipment with average loads

Prototype #1.1

28’ x 32’ Classroom with Improved Glass & Dimming

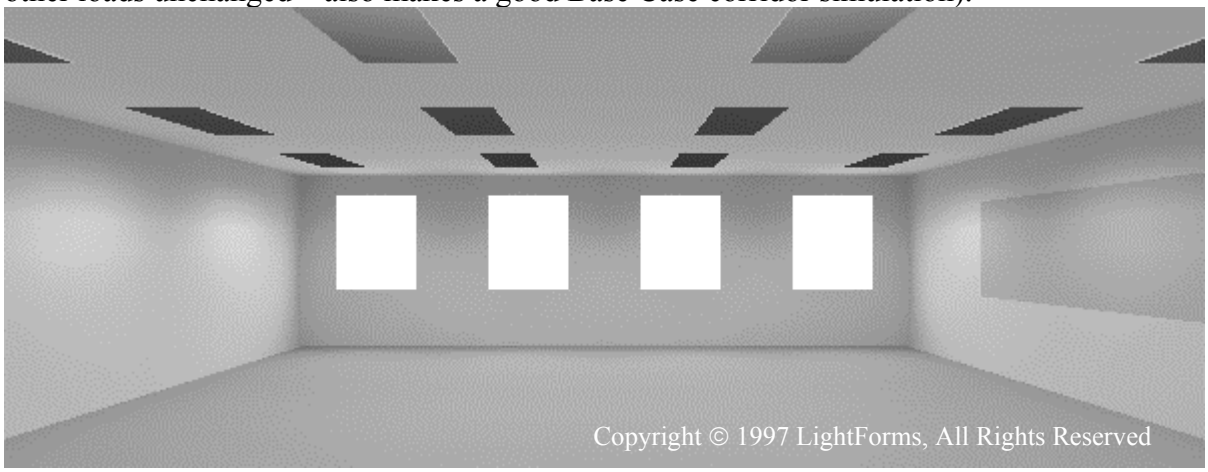


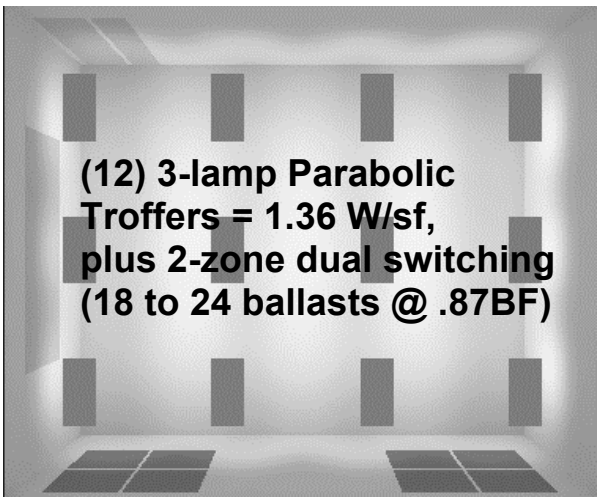
Description: Daylight is better distributed by utilizing four 4.2’x4.9’hi windows evenly placed along the perimeter. Viracon VE3-40 glazing (S.C. = 0.22) is used. To prevent window and glass costs from rising over the Base Case, total window area is 82 sf, an 11% reduction. Miniblinds are installed at each window. The electric lighting system is (12) 2-lamp 12-cell parabolic troffers with (12) Motorola dimming ballasts. By prescribing semi-annual lamp cleaning, and by using a higher ballast factor (0.96 vs 0.87), 50 fc maintained is achieved with 0.89 W/sf lighting power density, a 35% reduction compared to the Base Case. Starfield class 2 wiring and rotary dimmers (two per room) cost less than standard switch legs, resulting in a lighting cost adder of $0 (before including photosensor to dim the outside row - see next page). Variants are as follows:

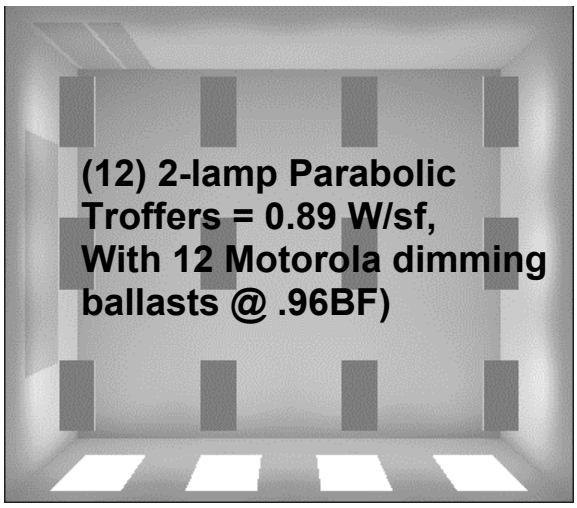
Level 1 - As above, without overhang and photosensor based lighting control. Since electric lighting, window and window treatment revisions have no significant 1st cost increase, this Prototype can be applied to all schools, even non-airconditioned facilities.

Level 2 – To Level 1 solution, add 36” wide East, South and West-side exterior solar shading (cost: about $100/Lin. Ft. for overhang, or $150/Lin. Ft. for applied sunshade). Level 2 solution includes one photosensor control at a net cost of $50/classroom (see next page).

As per the Base Case Classroom, performance data is also included for a windowless core classroom, and a windowless core ancillary space (Half the people load, 0.89 W/sf lights, other loads unchanged – also makes a good Base Case corridor simulation).







Prototype 1.1 - 28'x32' Classroom Cost Comparison: 3-Lamp, Dual Switch vs 2-Lamp Dimming

Base Case	**Materials**	**Prototype 1.1**
$70 ea.*	Fixture Cost	$74 ea.**
$840.00	Total Cost	$888.00
$66.00	Fixture Whips	$66.00
$72.00	Connect/J-box & conduit	$72.00
$1,051.35	Total plus 7.5% Distr. Markup	**$1,102.95**
	Labor	
2	Supports/unit	2
2.4hr.	6 min /support	2.4 hr.
3.0 hr.	Install Fixtures	3.0 hr.
3.0 hr.	Elec. Connect	3.0 hr.
$252.00	@ $30/hr	**$252.00**
	Contractor	
$1,303.35	**Cost**	$1,354.95
$409.70	Markup (100% labor + 15%materials	$417.44
$1,713.05	**Lighting Cost**	**$1,772.39**
	Controls	
$308	Switch Leg	$222
	Photosensors ea.	$74
$308	**Controls Cost**	**$296**
$2,021.05	**Total Cost**	**$2,068.39**
		+$47.34 (2%)
1.36	Watts/sq. ft.	.89 (-35%)

*Price includes multiple ballasts for dual switching (2@ $12 ea.)
**Price includes (1) $28 dim ballast

Prototype #1.1A
28'x32' Classroom Performance Factors

Description	North Glass Orientation	South Glass Orientation	West Glass Orientation	East Glass Orientation[1]
CFM_{peak}				
Level 1	663	747	726	820
Level 2	645	664	651	728
CFM/Sq. Ft.				
Level 1	.74	.83	.81	.91
Level 2	.72	.74	.72	.81
AC Tons				
Level 1	2.56	2.73	2.60	2.60
Level 2	2.52	2.54	2.52	2.52
Sq. Ft./Ton				
Level 1	341	330	346	346
Level 2	357	354	357	357
Tons/Sq. Ft.				
Level 1	.0028	.0030	.0029	.0029
Level 2	.0028	.0028	.0028	.0028
kW_{peak}[2]				
Level 1	5.18	5.40	5.30	5.33
Level 2	5.03	5.08	5.03	5.10
kW_{peak}/S.F.				
Level 1	.0058	.0060	.0059	.0059
Level 2	.0056	.0056	.0056	.0057
$/ClassrmYr[3]				
Level 1	706	721	718	716
Level 2	683	685	686	688
$/Sq. Ft.-Yr[3]				
Level 1	.784	.801	.798	.796
Level 2	.759	.761	.762	.765

[1] Typically, one would expect capacities to be higher for the West orientation than for the East. However, the West-side solar peak occurs after school is done for the day, which makes the East-side capacities slightly higher than the West-side. For schools with near-full occupancy to 5pm, use East classroom capacities for West classrooms, when higher.
[2] Room peak may not be same as building peak.
[3] Based on $0.025/kWh, $9.50/kW, autosized equipment with average loads

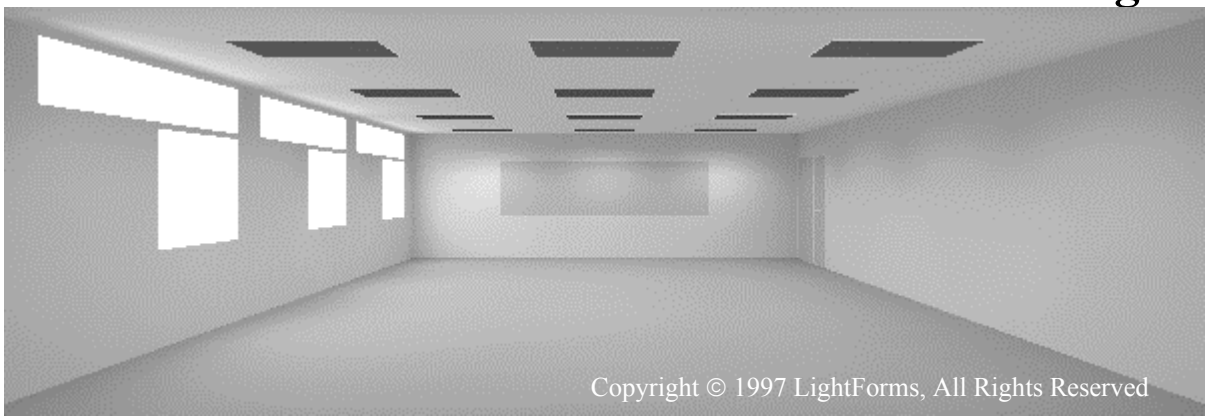
Prototype #1.1B
28'x32' Classroom Performance Factors

Description	Windowless Core 1 Classroom	Windowless Core 2w/ 50% Occupancy[1]		
CFM_{peak}	598	479		
CFM/Sq. Ft.	0.66	0.53		
AC Tons	2.42	2.10		
Sq. Ft./Ton	372	428		
Tons/Sq. Ft.	.0027	.0023		
kW_{peak}[2]	4.95	4.50		
kW_{peak}/Sq. Ft.	.0055	.0050		
$/Classrm-Yr[3]	645	621		
$/Sq. Ft.-Yr[3]	.726	.689		

[1] For classroom-like ancillary spaces with about 60 sf/person (half the people density of a classroom)
[2] Room peak may not be same as building peak.
[3] Based on $0.025/kWh, and $9.50/kW, autosized HVAC equipment with average loads

Prototype #1.2

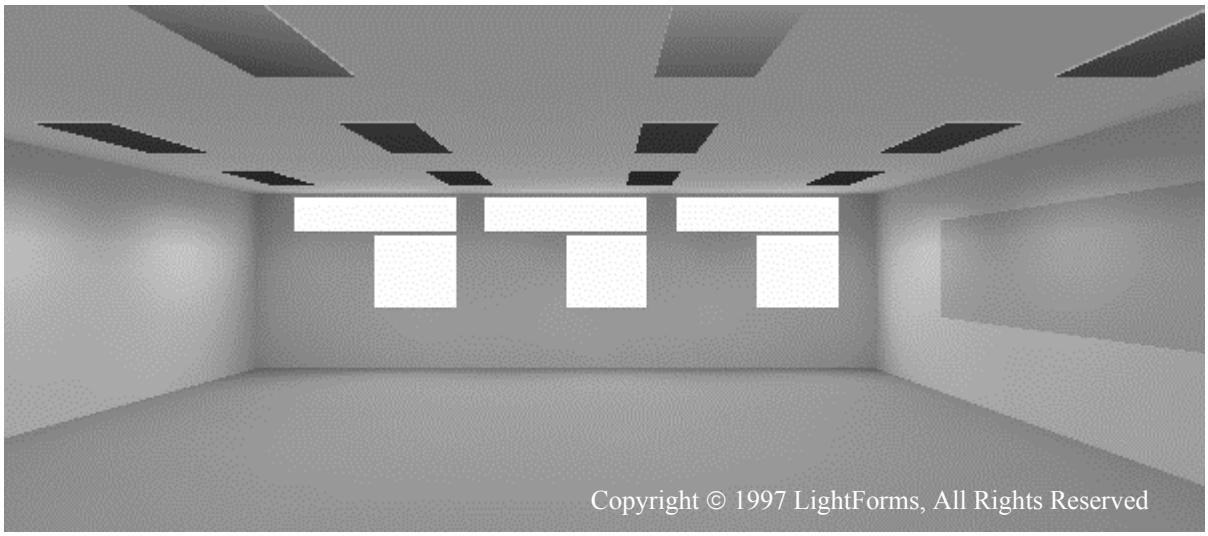
28’ x 32’ Classroom with Clerestories & Dimming



Prototype 1.2 is identitcal to Prototype 1.1, except for window size and placement. To increase transparency, daylight quality, and useful daylight to augment photocell-based dimming, a 20” clerestory strip is added (area = 43 sf, S.C. = .26 unshaded, .38 shaded). View windows equal 48 sf, with a .22 Shading Coefficient. The total glass area is about 91 sf, matching the Base Case. At about $1.50/sf more, the Viracon glass adds $137/classroom. Variants are as follows:

Level 1 - As above, without overhang and photosensor based lighting control. Six miniblinds are used, three at the clerestory and three at view windows, totalling 91 sf and matching the Base Case. Therefore, total incremental cost, before HVAC savings are considered, is approximately $137/classroom.

Level 2 – To Level 1 solution, add 36” wide East, South and West-side exterior solar shading (cost: about $100/Lin. Ft. for overhang, or $150/Lin. Ft. for applied sunshade). Level 2 solution includes two photosensor controls at a net cost of $148/classroom (see next page). Three perforated view window roller screens totalling 48 sf replace the 91 sf of miniblinds (net add of about $100). Undressed clerestories may require blackout shades.



Prototype 1.2 - 28'x32' Classroom Cost Comparison: 3-Lamp, Dual Switch vs 2-Lamp Dimming

Base Case	Materials	Prototype 1.2
$70 ea.*	Fixture Cost	$74 ea.**
$840.00	Total Cost	$888.00
$66.00	Fixture Whips	$66.00
$72.00	Connect/J-box & conduit	$72.00
$1,051.35	Total plus 7.5% Distr. Markup	**$1,102.95**
	Labor	
2	Supports/unit	2
2.4hr.	6 min /support	2.4 hr.
3.0 hr.	Install Fixtures	3.0 hr.
3.0 hr.	Elec. Connect	3.0 hr.
$252.00	@ $30/hr	**$252.00**
	Contractor	
$1,303.35	**Cost**	$1,354.95
$409.70	Markup (100% labor + 15%materials	$417.44
$1,713.05	**Lighting Cost**	**$1,772.39**
	Controls	
$308	Switch Leg	$308 (3 zones)
	2 Photosensors	$148
$308	**Controls Cost**	**$456**
$2,021.05	**Total Cost**	**$2,228.39**
		+$207.34 (10%)
1.36	Watts/sq. ft.	.89 (-35%)

*Price includes multiple ballasts for dual switching (2@ $12 ea.)
**Price includes (1) $28 dim ballast

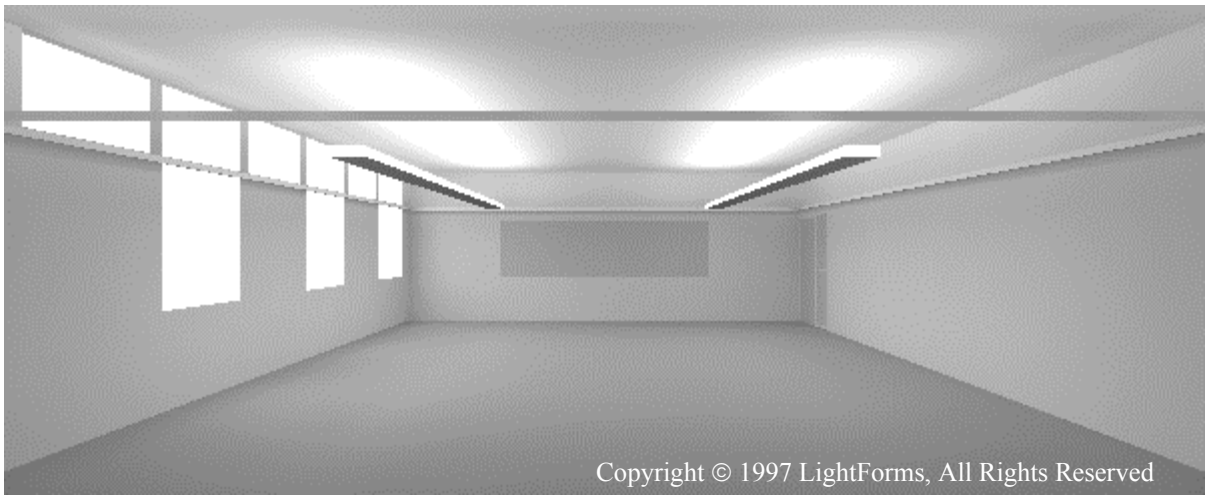
Prototype #1.2
28'x32' Classroom Performance Factors

Description	North Glass Orientation	South Glass Orientation	West Glass Orientation	East Glass Orientation[1]
CFM_{peak}				
Level 1	678	767	750	859
Level 2	653	670	657	694
CFM/Sq. Ft.				
Level 1	.75	.85	.83	.95
Level 2	.73	.74	.73	.77
AC Tons				
Level 1	2.58	2.77	2.69	2.69
Level 2	2.52	2.56	2.54	2.58
Sq. Ft./Ton				
Level 1	348	335	335	335
Level 2	357	351	354	348
Tons/Sq. Ft.				
Level 1	.0029	.0031	.0030	.0030
Level 2	.0028	.0028	.0028	.0029
kW_{peak}[2]				
Level 1	5.20	5.45	5.38	5.38
Level 2	5.00	5.05	5.00	5.08
kW_{peak}/S.F.				
Level 1	.0058	.0061	.0060	.0060
Level 2	.0056	.0056	.0056	.0056
$/ClassrmYr[3]				
Level 1	712	727	726	723
Level 2	680	679	681	684
$/Sq. Ft.-Yr[3]				
Level 1	.791	.808	.807	.803
Level 2	.756	.755	.757	.759

[1] Typically, one would expect capacities to be higher for the West orientation than for the East. However, the West-side solar peak occurs after school is done for the day, which makes the East-side capacities higher than the West-side. For schools with near-full occupancy to 5pm, use East classroom capacities for West classrooms, when higher.
[2] Room peak may not be same as building peak.
[3] Based on $0.025/kWh, $9.50/kW, autosized equipment with average loads

Prototype #1.3

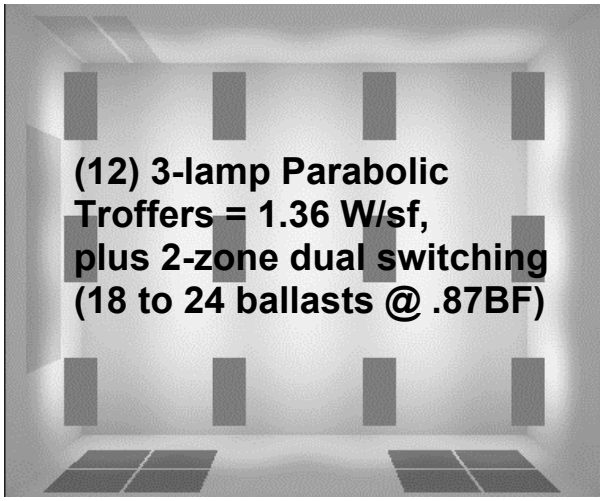
28’ x 32’ Perimeter Classroom with 10’-6” Ceiling, Clerestories & Direct/Indirect Luminaires



Description: Ceiling height is raised to 10’-6” for higher quality daylight distribution. This increase is achieved by reducing ductwork and plenum sizes, or exposing structure, not by increasing floor to floor height. A picture mold is placed at 8’-0”, with wall reflectance above this line being 0.80 to match the ceiling. Electric lighting switches to two rows of 24’ long 2-lamp direct/indirect Finelite Series 4 with 6 Motorola 4-lamp dimming ballasts (0.89 W/sf; 51.7 fc nighttime; without photosensors cost increment is about $44/classroom, with photosensors cost increment is about $192 - see next page). Luminaires are placed at 8’-0” AFF (a maintenance worry for some school districts, not for others). View glass area is 59.5 sf (S.C. = 0.22). Clerestory glass area is 57.4 sf (S.C. = 0.38 with an overhang; 0.24 without). Total Glass area is 116.9 sf, with an incremental cost of $175.35 to $647 compared to the Base Case (glass and masonry wall cost about the same, but contractor pricing for the window openings varies greatly). Variants are as follows:

Level 1 - As above, without overhang and without photosensor based lighting controls. Miniblinds cover clerestories and view windows (add $1.75/sf x 25sf = $44).

Level 2 – To Level 1 solution, add East, South and West-side 40” wide exterior solar shading (cost: about $100/Lin. Ft. for overhang, or $150/Lin. Ft. for applied sunshade). Level 2 solution includes 2 photosensor dimming controls at $148/classroom (see next page). With the overhang, window treatments are not necessary for the clerestory window (blackout roller shades still may be necessary). To increase transparency, a perforated roller screen is used at the view window. While perforated roller screens are about $3.75/Sq. Ft. more expensive than mini-blinds, fewer Sq. Ft. are required (not required on North view windows – net increase is about $100/classroom on the East, South and West orientations).



Prototype 1.3 - 28'x32' Classroom Cost Comparison: 3-Lamp, Dual Switch vs 2-Lamp Finelite Series 4 with Dimming

Base Case	**Materials**	Prototype 1.3
$70 ea.*	Fixture Cost	$25.25/ln. ft.*
$840.00	Total Cost	$1,212.00
$66.00	Fixture Whips	
$72.00	Connect/J-box & conduit	$22.00
$1,051.35	Total plus 7.5% Distr. Markup	**$1,326.55**
	Labor	
2	Supports/unit	Start + 1/12'
2.4hr.	6 min /support	.6 hr.
3.0 hr.	Install Fixtures	1.4 hr.
3.0 hr.	Elec. Connect	.5 hr.
$252.00	@ $30/hr	**$75.00**
	Contractor	
$1,303.35	**Cost**	$1,401.55
$409.70	Markup (100% labor + 15%materials	$273.98
$1,713.05	**Lighting Cost**	**$1,675.53**
	Controls	
$308	Switch Leg	$246
	Dim Ballast Add	$144
	(2) Photosensors	$148
$308	**Controls Cost**	**$538**
$2,021.05	**Total Cost**	**$2,213.53**
		+$192.48 (9%)
1.36	Watts/sq. ft.	.89 (-35%)

* Price includes multiple ballasts for dual switching

Prototype #1.3
28'x32' Classroom Performance Factors

Description	North Glass Orientation	South Glass Orientation	West Glass Orientation	East Glass Orientation[1]
CFM_{peak}				
Level 1	694	803	804	925
Level 2	613	628	617	728
CFM/Sq. Ft.				
Level 1	.77	.89	.89	1.03
Level 2	.68	.70	.69	.81
AC Tons				
Level 1	2.63	2.85	2.81	2.81
Level 2	2.44	2.48	2.46	2.40
Sq. Ft./Ton				
Level 1	343	316	320	320
Level 2	369	363	366	375
Tons/Sq. Ft.				
Level 1	.0029	.0032	.0031	.0031
Level 2	.0027	.0028	.0027	.0027
kW_{peak}[2]				
Level 1	5.25	5.55	5.53	5.48
Level 2	4.60	4.65	4.60	4.68
kW_{peak}/S.F.				
Level 1	.0058	.0062	.0061	.0061
Level 2	.0051	.0052	.0051	.0052
$/ClassrmYr[3]				
Level 1	723	741	743	736
Level 2	620	619	623	625
$/Sq. Ft.-Yr[3]				
Level 1	.803	.823	.825	.818
Level 2	.688	.687	.692	.695

[1] Typically, one would expect capacities to be higher for the West orientation than for the East. However, the West-side solar peak occurs after school is done for the day, which makes the East-side capacities higher than the West-side. For schools with near-full occupancy to 5pm, use East classroom capacities for West classrooms, when higher.
[2] Room peak may not be same as building peak.
[3] Based on $0.025/kWh, $9.50/kW, autosized equipment with average loads

Prototype #1.4

28’ x 32’ Perimeter Classroom with Stepped Roof Form

This prototype matches Prototype 1.3, with the addition of a clerestory step near the centerline of the classroom (also see cover photo). The 30” high shaded clerestory (63 sf total) spans the roof step. A 40” deep overhang shades the clerestory, since movable interior window treatments are never recommended at that height. Incremental cost is about $250/lin. ft. with overhangs, and $200/lin. ft. for the North-side without overhangs ($6,400 to $8,000/classroom, plus cost of perimeter components). Total glass area = 180 sf. This prototype is representational of classroom daylighting solutions that manipulate the roof to achieve higher daylight factors than achieveable with sidelighting alone. All such solutions fall very closely to these cost and the following performance factors. As a performance factor comparason to the preceeding prototype will show, environmental performance is not significantly increased compared to simple sidelighting systems. The true purpose of such solutions is the creation of superior luminance environments for human performance and enjoyment reasons, a topic to be further discussed at the Advanced Daylighting Tools and Techniques Training.

Only Level 2 performance factors are listed for this prototype. With this much added glass, overall performance will go down dramatically without proper shading.

Prototype #1.4
28'x32' Classroom Performance Factors

Description	North Glass Orientation	South Glass Orientation	West Glass Orientation	East Glass Orientation[1]
CFM_{peak}				
Level 1				
Level 2	626	636	633	813
CFM/Sq. Ft.				
Level 1				
Level 2	.69	.71	.70	.90
AC Tons				
Level 1				
Level 2	2.48	2.50	2.48	2.58
Sq. Ft./Ton				
Level 1				
Level 2	363	360	363	349
Tons/Sq. Ft.				
Level 1				
Level 2	.0028	.0028	.0028	.0029
kW_{peak}[2]				
Level 1				
Level 2	4.48	4.53	4.50	4.55
kW_{peak}/S.F.				
Level 1				
Level 2	.0050	.0050	.0050	.0051
$/ClassrmYr[3]				
Level 1				
Level 2	608	603	614	614
$/Sq. Ft.-Yr[3]				
Level 1				
Level 2	.675	.669	.682	.682

[1] Typically, one would expect capacities to be higher for the West orientation than for the East. However, the West-side solar peak occurs after school is done for the day, which makes the East-side capacities higher than the West-side. For schools with near-full occupancy to 5pm, use East classroom capacities for West classrooms, when higher.
[2] Room peak may not be same as building peak.
[3] Based on $0.025/kWh, $9.50/kW, autosized equipment with average loads