Patterns to Daylight Schools for People and Sustainability

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Lighting Research Center

Rensselaer

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Acknowledgments

The authors wish to thank the United States Green Building Council (USGBC) for their prescient recognition of the importance of studying the impact of daylighting in schools and for their generous sponsorship of the research and design leading to this book. Support for the work presented here was also given by the Trans-NIH Genes, Environment and Health Initiative Grant U01 DA023822.

Special thanks to Dennis Guyon for graphic design and to members of the Lighting Research Center for their substantial contributions to this publication: Jennifer Brons, Rosa Capó, Christine Kingery, Anna Lok, Sara Nonaka, Barbara Plitnick, Mark Rea, and Rinara Reh.

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Preface

Since the early 90's, the Lighting Research Center (LRC) has used pattern books as a means to accelerate the implementation of sustainable lighting practice. These pattern books offer model designs that can be adapted to your particular building and style. To have a large impact, lighting patterns should:

- Illustrate lighting solutions adaptable to many styles and applicable to common, rather than monumental or unique buildings
- Be clearly communicated in a format familiar to the intended audience
- Include pattern performance in a format that allows comparison among pattern alternatives
- Be widely distributed.

Here we continue this legacy of pattern books, merging daylighting design with a light and health perspective, two key research areas at the LRC. *Patterns to Daylight Schools for People and Sustainability* follows the four objectives above:

- Conceptual daylight approaches are offered for the three most common spaces in schools: classrooms, corridors, and gymnasiums.
- The designs and technical analyses are distilled to visual presentations for architects and school administrators.
- A "daylighting dashboard" is introduced, a graphic method to quickly compare the patterns. These comparisons include indicators of cost, comfort, the visual environment, and energy use.
- Partnering with the U.S. Green Building Council (USGBC), we offer wide electronic distribution to reach many daylighting decision makers.

Beyond direct application of these patterns, we hope that this approach encourages objective evaluation of daylight alternatives for all school buildings in all climates. Model your evaluations after the analyses contained on the following pages. Monitor the rapidly developing research in light and health to make student well-being a vested component of the analysis. Save energy while enjoying the beauty of daylight in schools.

Russell P. Leslie, AIA FIES

Introduction

Daylighting is the design of buildings to use light from the sun. Done properly, daylighting in schools creates interesting, dynamic interiors supportive of human health and activities while reducing energy demand. Done improperly, daylighting impedes vision, causes discomfort, and demands excessive energy.

The most critical decisions for a well daylit building come during the conceptual phase of architectural design, when the school's site, configuration, and fenestration are formulated. Therefore, this book emphasizes schematic patterns to daylight typical classrooms, corridors, and gymnasiums. Furthermore, exciting new science is demonstrating that lighting has a significant impact, not just on our visual system but, on our health and well-being. This book balances well-known daylight design approaches with new guidelines addressing these photobiological benefits of daylighting schools.

Background

There are many excellent guides for daylight design (see page 67). These guides often cite the benefits of daylight for saving energy, reducing peak electric load, allowing continued operation during power outages, and using view to connect people to their external environment. Further, frequent claims tout benefits of daylight for student productivity and health, but there has not been a well established basis for these claims.[1,2] New science, however, has now established a physiological basis that may explain these claims.

In response to the earth's 24-hour cycle, all species have evolved daily biological or circadian rhythms (for example, sleep/wake behavior) that repeat approximately every 24 hours. Circadian rhythms are generated and regulated by a biological clock located in the human brain. In the absence of external cues, human circadian rhythms will run with an average period of 24.2 hours. People are synchronized, or entrained, to the 24-hr solar day most strongly by the Earth's natural light/dark cycle.[3] Morning light will advance the biological clock, resulting in earlier bedtimes, while evening light will delay it, resulting in later bedtimes.[4] Since humans have a circadian clock that is slightly longer than 24 hours, we need a daily morning light dose to advance our biological clock and, therefore, keep us entrained with the solar day.

In 2008, the USGBC awarded the LRC a grant to study the impact of daylight design on students' well-being and performance in K-12 schools. Today's middle and high schools have rigid schedules requiring teenagers to be at school very early in the morning. These students are likely to miss the morning light because they often travel to school before the sun is up or as it is just rising; therefore, they may miss the light that promotes the entrainment of their biological clock to the external environment. Lack of entrainment between light and dark and the biological clock may lead to sleep deprivation, as well as symptoms of stress, mood disorders, and perhaps immune system deficiencies.[5-8] In adolescents, sleep deprivation has been linked to one's inability to fall asleep at appropriate evening hours and one's need to get up early for school the following morning.

The hypothesis posed by LRC researchers was that the students who were not exposed to morning light or daylight that would stimulate the circadian system would experience a more pronounced delayed circadian phase, which would result in later bedtimes, and possibly chronic sleep deprivation, stress or mood disorders. If the lighted environment in schools can promote circadian entrainment by delivering light that will shift the biological clock to an earlier time, students will fall asleep earlier at night and sleep deprivation will be reduced. In turn, students should feel better and perform better in school.

Having enough light in the classroom to read and study does not guarantee that there is sufficient light to stimulate our biological clocks. This is because the human visual system responds differently to light than the human circadian system, which is much more sensitive to short-wavelength (blue) light and needs more light to be activated than the visual system.[9-12] Most schools typically do not provide adequate electric light or daylight to fully stimulate the circadian system. However, if designers provide sufficient daylight, which contains ample, short-wavelength (blue) light, in classrooms, school buildings will be able to provide more circadian stimulation and therefore, better support for circadian entrainment.

The LRC's field studies found that insufficient exposure to daily morning light contributes to teenagers not getting enough sleep due to later bedtimes. Eleven eighth grade students, who wore special glasses that filtered out short-wavelength (blue) morning light, experienced a 30-minute delay in their dim light melatonin onset (DLMO) by the end of the five-day study. Melatonin is a hormone produced at night and under conditions of darkness. The onset of melatonin typically occurs about two hours prior to falling asleep. A later DLMO is generally associated with a later bedtime. Principal investigator Dr. Mariana Figueiro concluded, "These morning-light-deprived teenagers are going to bed later, getting less sleep and possibly under-performing on standardized tests."

Furthermore, exposure to early evening daylight in the springtime was found to have a similar effect on the biological clock. In the springtime, later sunset and extended daylight exposure in the evening can also delay bedtimes for teenagers. This research shows that exposure to short-wavelength (blue) light in the evening has just as much effect on the body as removing early morning light; both delayed sleep onset in students. For a more regular sleep pattern and earlier bedtimes, students should receive the light that activates the circadian system in the early morning and avoid that same light in the early evening.[13]

How then, should architects employ these findings in the design of schools? This book translates current light and health research findings to recommendations for school design. The patterns on the following pages merge these recommendations with well-established daylighting design principles to assist architects seeking to create healthy and sustainable schools.

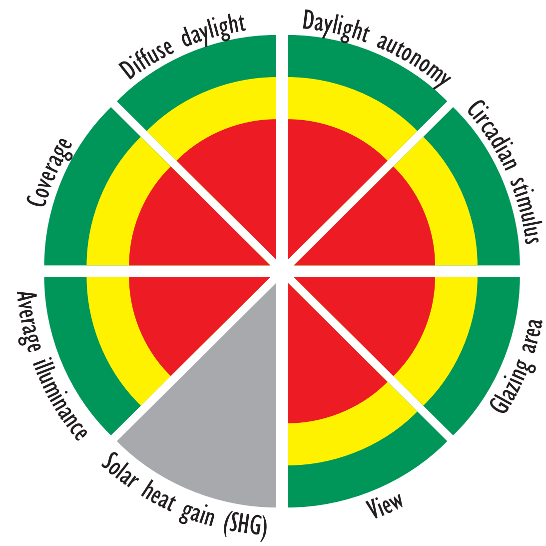
How to Use This Book

Architects should use this book to identify potential approaches, or "patterns," to daylight classrooms, gymnasiums, and corridors in schools. Similar to traditional architectural pattern books, this book gives model designs that can be adapted in configuration and style to a particular school project. To aid in the selection of patterns that meet the architect's design objectives, this book identifies positive attributes and flags potential shortcomings of each pattern, summarized in a color-coded diagram, a "daylighting dashboard," which represents eight goals for good daylighting design.

The daylighting dashboard, shown on the right, is divided into eight segments, each representing one of the daylighting goals described on pages 6-9. Each goal includes an associated metric. The daylighting dashboard summarizes a pattern's performance.

A red rating is a warning that the goal is unlikely to be met with the pattern; yellow indicates caution, for example careful evaluation or modification of the pattern is necessary to fully meet the goal; green indicates that the designer is well on the way to fully meeting that goal. The eight goals are evaluated with the following metrics: average illuminance, coverage, diffuse daylight, daylight autonomy, circadian stimulus potential, glazing area, view, and solar heat gain.

Architects may weigh the importance of the eight goals differently for different projects. Sometimes cost is the driver; other times view or energy savings most



The daylighting dashboard.

influences the building design. The daylighting dashboard described in this book provides an overview of the performance trade-offs of each pattern.

Consider this book as a conceptual tool. This guide allows comparison of the likely merits of generic daylighting approaches in schools. For a specific project, several candidate patterns should be identified for each room. Then, during schematic design, a site-specific analysis should be conducted to fine tune the performance ratings. In order to further improve the performance of the schematic design, ten principles for daylighting schools, listed on p. 10, should be considered. The References and Additional Resources sections offer further information that will aid in the school's daylighting design.

Goals and Metrics for Designing Daylighting for Schools

Daylighting design, like most design, must prioritize sometimes conflicting design goals. The patterns contained herein provide conceptual feedback on how well each pattern would meet a particular design goal. Thus, eight simple goals are evaluated for each design. Unlike other daylighting guides, these patterns also include the pattern's potential to stimulate the circadian system. It is up to the designer to weigh the relative importance of each goal and then to select candidate patterns for further analysis during design development. Eight goals that should be at the forefront of any good daylighting design and the metrics used for the daylighting dashboard are explained on the pages 6-9.

Each goal on the daylighting dashboard includes a metric for evaluating the pattern. The evaluation used AGi32† to analyze each pattern. Illuminance values in footcandles (fc) were calculated at each point of a horizontal grid located on the work plane 2.5 feet above the floor. Each pattern was evaluated under typical daylight conditions for the Albany, NY area. A day during each of the four seasons was chosen: March 21, June 21, September 21, and December 21 were each evaluated at 9:00 a.m., 12:00 p.m., and 3:00 p.m.

The building energy use analysis tool, eQUEST,‡ was used to evaluate the monthly and yearly solar heat gain for each pattern. Since the program is not able to separate clear and cloudy conditions, the daylighting dashboard reports a composite yearly average solar heat gain for clear and cloudy skies. Monthly averages for March, June, September, and December can be found in each pattern's data table.

Each pattern's performance during the 12 representative times was simulated under both clear and cloudy conditions. The data from each grid were used as the input for evaluating the illuminance, coverage, diffuse daylight, daylight autonomy, and circadian stimulus.

The evaluation results are shown with each pattern beginning on page 14.

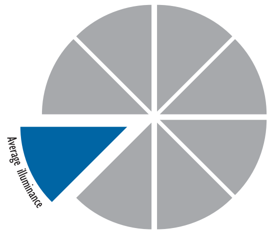
† - AGi32 version 2.13 lighting software, Lighting Analysts, Inc., Littleton, Colorado. Download available at www.agi32.com

‡ - eQUEST version 3.64 building energy simulation tool. eQUEST is a registered trademark of James J. Hirsch & Associates. Freeware is available at doe2.com/equest

Average Illuminance

Goal

Provide sufficient daylight to perform tasks.



Average illuminance on the horizontal work plane is an indicator of daylighting availability for performing visual tasks. Illuminance significantly below Illuminating Engineering Society (IES) recommended levels makes seeing difficult without supplementary electric light. Excessive illuminance may cause glare, fade materials, and could be an indicator that there is more glazing than necessary in the space.

Metric

Green indicates that the average illuminance from daylight is usually sufficient for all tasks typical of the space. Red indicates that there will often be insufficient daylight to perform tasks of small size and low contrast. Yellow indicates that daylight levels are often below the target illuminance or that there is excessive illuminance, which may produce uncomfortable glare.

Approach

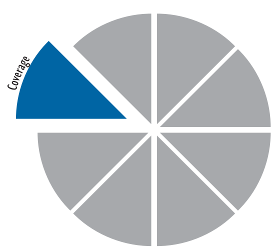
The target illuminance for sufficient daylight was guided by the IES recommended values.[14] The relative visual performance (RVP) model was used to select a low illuminance criterion based on the dominant tasks for each pattern.[15] The 500 fc high illuminance criterion was based on the LEED 2009 IEQ credit 8.1.[16]

	Classroom	Corridor	Gymnasium
Green	30-500 fc	10-500 fc	30-500 fc
Yellow	10-29 or greater than 500 fc	2-9 or greater than 500 fc	10-29 or greater than 500 fc
Red	Below 10 fc	Below 2 fc	Below 10 fc

Coverage

Goal

Avoid under-lit areas by distributing ambient light throughout the space.



Coverage is the percentage of the work plane that is above the low illuminance criterion. High coverage is an indicator that most parts of the room are receiving adequate amounts of daylight to perform visual tasks. Low coverage indicates under-lit areas from daylight. A space with under-lit areas juxtaposed with well-lit areas may contribute to visual discomfort.

Metric

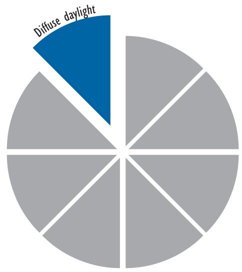
Green indicates that the entire space is above the low illuminance criterion. Yellow indicates that most of the space is above the low illuminance criterion. Red indicates that a significant portion of the space is under-lit.

Approach

The percentage of workplane calculation points was calculated above the low illuminance criteria, 10 fc for classrooms and gymnasiums, and 2 fc for corridors, was tabulated.

	Classroom	Corridor	Gymnasium
Green	100% above 10 fc	100% above 2 fc	100% above 10 fc
Yellow	80-99% above 10 fc	80-99% above 2 fc	80-99% above 10 fc
Red	Less than 80% above 10 fc	Less than 80% above 2 fc	Less than 80% above 10 fc

Diffuse Daylight



Goal

Control glare by minimizing direct sun in all spaces with critical visual tasks.

Diffuse daylight is the percentage of the work plane that has daylight without direct sunlight. Patches of direct sun may be welcome in corridors or lobbies, but direct sun in classrooms is an indicator of glare, uneven light distribution, and potential thermal discomfort. When daylight is not diffuse in classrooms, sun shading strategies should be considered by the designer that could include overhangs, window blinds, or louvers.

Metric

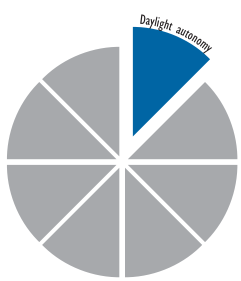
In classrooms, green indicates that the entire work plane has diffuse daylight without direct sun. Yellow and red indicate progressively more direct sun on the work plane. In gymnasiums, some direct sun is permissible, so gymnasiums with mostly diffuse daylight receive green and others receive yellow. For corridors, only green is shown since direct sunlight can be desirable as an aesthetic element.

Approach

It was assumed that all points exceeding 1000 fc in March, June, and September were the results of direct sun on the work plane. The direct sun threshold criterion for December was lowered to 500 fc to account for low sun angles in the winter months. Less stringent requirements for diffuse daylight in gymnasiums and corridors exist due to simpler visual tasks and greater occupant mobility within those spaces.

	Classroom	Corridor	Gymnasium
Green	100%	1-100%	80-100%
Yellow	80-99%		Less than 80%
Red	Less than 80%		

Daylight Autonomy



Goal

Save energy by maximizing time when electric lights can be turned off.

Daylight autonomy is the percentage of the work plane having an illuminance above the target illuminance, the IES recommended value, for the space. High daylight autonomy indicates a potential to save electric lighting energy if a suitable control system is designed to dim or switch off electric lights.

Metric

Green indicates a high energy savings potential because electric lights can be switched or dimmed during most of the school day. Red indicates that the potential for energy savings is much lower. Yellow indicates a moderate potential for energy savings.

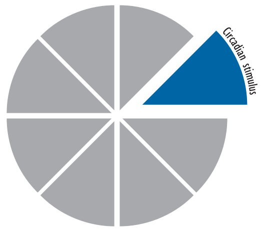
Approach

The percentage of work plane calculation points above the target illuminance was tabulated for each space.

	Classroom	Corridor	Gymnasium
Green	80% above 30 fc	80-100% above 10 fc	80-100% above 30 fc
Yellow	50-79% above 30 fc	50-79% above 10 fc	50-79% above 30 fc
Red	Less than 50% above 30 fc	Less than 50% above 10 fc	Less than 50% above 30 fc

Circadian Stimulus

Goal



Provide sufficient light to promote morning circadian stimulation in students.

Circadian stimulus is tabulated using a 0-24 point system to indicate daylight's probable impact on people's circadian systems. Light of certain illuminance, spectrum, and duration during the school day, especially during the morning hours, has the potential to improve sleep patterns in students (see Background, p. 3).

Criteria

Green indicates a high level of circadian stimulation throughout the year for a given sky condition, predicting sufficient illuminance at the eye to stimulate the circadian system of students. Red is an indication that students are more likely to be in "circadian darkness" while at school because they are not receiving enough light to stimulate their circadian systems. Yellow indicates moderate circadian stimulation potential.

Evaluation Approach

Each of the 12 simulated dates and times of year is assigned 0 to 2 points, yielding a maximum possible 24 points. Two points are given when the average circadian stimulus is above 35% (12 fc from daylight at the eye), one point is given when the average circadian stimulus is between 10% (4 fc from daylight at the eye) and 35%, and zero points are given when the circadian stimulus is below 10%.

Circadian stimulus is calculated using the model of human circadian phototransduction.[17] This model predicts nocturnal melatonin suppression by accounting for the light level at the cornea, the spectrum of light, the duration of exposure, and the pupil size. For this calculation, pupil size has been fixed at 2.3mm and the duration of exposure is one hour. The light level at the cornea (vertical illuminance at the eye) is conservatively estimated by taking the average horizontal illuminance on the work plane and dividing that value in half. Here, circadian stimulation equals predicted percent melatonin suppression and this percent suppression is being used as a surrogate for stimulation of the circadian system.

	Classroom, Corridor, Gymnasium
Green	Above 16 points
Yellow	9-16 points
Red	0-8 points

Glazing Area

Goal

Control construction costs by minimizing the area of windows or skylights.

Glazing area is the percent of window and skylight area compared to the floor area of the space. Windows and skylights generally cost more than solid walls, so a small glazing area can be an indicator of lower construction costs. Large glazing areas provide good views and daylight access, but they can also contribute to glare and higher heating or cooling costs.

Metric

Green , yellow, and red indicate increasingly high amounts of glazing, associated with increasingly high construction cost.

Approach

For each space, the total area of all skylights, monitors, and windows was divided by the floor area of the space.

	Classroom, Corridor, Gymnasium
Green	Below 10%
Yellow	10-20%
Red	Above 20%

View

Goal

Provide views to the outside.

People like a connection to the outdoors. Views provide information about what is happening in the environment. Views of just the sky are adequate, but interesting scenes with portions both above and below the horizon are preferable. Baffles or translucent glazing which inhibit view clarity are least preferred.[18]

Metric

Green indicates that the view is likely to include both the ground and the sky. Yellow indicates that there is a view of just the sky. Red indicates that there is no view at all. An example of a daylight aperture providing no view would be a translucent skylight.

Approach

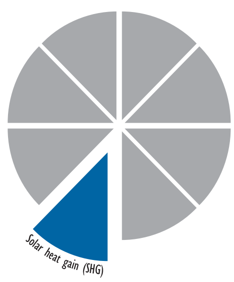
The assumption was made that skylights in the designs were translucent or had a diffuser, thus occluding view to the sky. Clerestory and roof monitor windows were considered to have views of the sky only and windows to have views of the sky and ground.

	Classroom, Gymnasium, Corridor
Green	View of sky and ground
Yellow	View of sky
Red	No view of sky and ground

Solar Heat Gain

Goal

Reduce building energy requirements and improve comfort by monitoring solar heat gain through glazing.



Solar heat gain is the daily average heat radiated from the sun into the space through the glazing, measured in British thermal units (Btu) per square foot of floor area. Solar heat gain is a good source of passive heating during cold months. However, many schools require cooling for most of the year due to warm climates and/or high internal loads from occupants. In these cases, high solar heat gain increases cooling equipment and operation costs. Designers need to match the solar heat gain strategy to their thermal design objectives. Solar heat gain is a function of climate and glazing area, materials, shading, tilt, and orientation.[18]

Metric

Since solar heat gain can be a benefit or a disadvantage no daylighting dashboard color ratings are given for the patterns. Rather, the amount of solar heat gain for each pattern is shown so that designers can have a simple comparison of the relative yearly solar heat gain resulting from alternative daylighting designs.

Approach

The average daily solar heat radiation per day into the space was calculated using the detailed *LS-L Management and Solar Summary* simulation (SIM) report generated by eQUEST, version 3.64. The result was divided by the floor area of each space to get the Btu/sf of floor area/day.

Ten Design Principles for Daylighting Schools

Good daylighting design should contribute to a comfortable, productive, healthy, environmentally responsive, and cost-effective school. Designers can improve the likelihood of meeting the goals described on pages 6-9 by following ten design principles:

1. Configure the room so that the floor area occupied by people is within "daylight zones." A typical daylight zone is about 15 feet (ft) from the window wall or the entire top floor of a school that is below skylights.
2. Elongate the wings of the school on an east-west axis to avoid glare and excessive solar heat gain.
3. Bring the light in high. Windows high on the wall will allow the light to penetrate further into the space.
4. Use skylights and roof monitors to daylight areas without easy access to windows.
5. Let daylight in from more than one side of the room when possible.
6. Provide views where appropriate, but diffuse or block direct sun
7. Use light-colored interior surfaces to reduce luminance contrast and improve coverage.
8. Control first costs by avoiding excessive glazing areas and oversized cooling systems.
9. Create a daylighting culture in the school. Educate teachers and students to open blinds and turn off electric lights when daylight is sufficient.
10. Dim or switch off electric lights when there is sufficient daylight.

Space Planning

Daylight, especially when distributed only from windows on one side of the classroom, creates areas of higher and lower illuminance within the classroom. The interior layout of classrooms can optimize the use of daylight by matching task areas to the daylight that is provided. For example, avoid placing desks and computer screens in a glary area adjacent to non-shaded windows, but place storage areas in the dimmer corners of the room. Arrange display screens and chalkboards on the walls perpendicular to the window walls; avoid putting the chalkboard or display screen on the same wall with windows to avoid visual discomfort. Projection screens or monitors should not be on the wall opposite the window to avoid reflected glare.

Classrooms should have the ability to be darkened in order to better view a television or electronic display if necessary. In some instances, daylighting controls such as shades or window blinds will be essential in order to manipulate the amount of light filtering into the space.

The classroom layout should also allow for some flexibility and teacher preference. Depending on the needs of the class, the desks in the room may be arranged in groups of seats, in a circle, or in rows. Good coverage from daylighting should allow for flexibility in the configuration of the space, but a design with poor daylight coverage will limit layout options.

Turn Off the Lights

Daylight is a key component of a comfortable school that supports human activity and health. However, to save energy, reduce building peak electric demand, and reduce power plant emissions that contribute to acid rain, air pollution, and global warming, electric lights must be dimmed or turned off when sufficient daylight is available. Critical decisions for saving lighting energy come during the design, specification, and commissioning of the electric lighting control systems.

Controls are the key to energy savings when daylighting. Expensive controls are not always more effective than simple ones. Stickers on the switches that remind occupants to turn off lights, coupled with encouragement from teachers and administrators, may be more cost-effective than automatic daylight control systems. Manual switching or dimming strategies must include readily accessible switches or dimmers for the lighting within the perimeter zone. The row of luminaires closest to the window walls should be controlled separately so that this row may be switched or dimmed when there is sufficient daylight and luminaires deeper in the space can remain on. Multi-lamp luminaires can be tandem-wired with adjacent luminaires and configured to allow users to switch off all, none, or some portion of the lamps within the row of luminaires. This "step dimming" avoids the higher cost of dimming ballasts (currently at least 50% higher than on/off ballasts) and can be controlled either manually or automatically in response to daylight.

Beyond Architectural Design

A school's luminous environment can be a positive factor in the circadian stimulation of its students, teachers, and other personnel. Operationally, people working or studying in the morning through mid-afternoon should be exposed to high light levels in the early morning and lower light levels (e.g., not more than those needed for simple visual tasks) in the evening to better entrain their sleep/wake cycle to their daily schedule. Although circadian stimulation can come from several sources, the patterns in this book use daylight because:

- It is available at the right times for school schedules.
- It uses less energy than electric lighting if done properly.
- It can provide higher light levels than energy codes or economics will allow from electric lighting.
- It has a cool spectrum (short-wavelength [blue]) light, which is particularly effective for circadian stimulation.

Thus, daylight can stimulate the circadian system in a shorter time and with less energy use than typical school electric lighting systems.

Nonetheless, there are other approaches to promote circadian stimulation in schools:

Electric Light

Electric light can also stimulate the circadian system. The energy required for effectively stimulating the circadian system can be minimized by:

- Using high correlated color temperature (CCT) (5000-8000 Kelvin [K]) light sources or blue-colored light emitting diodes (LED), which, for the same amount of watts, can more effectively stimulate the circadian system.
- Limiting the use of the electric lighting that stimulates the circadian system to 2-4 hours in the early morning. Studies have shown that stimulating the circadian system in the early evening may be counter-productive to entraining the circadian system to the 24-hour solar day.[13]

- Bringing the light source close to the individual student, which will provide the same illuminances at the eye but requires less electric power. This can be done with task lights on the desk or personal light treatment devices, such as blue LED light goggles.

Evening Light

The sleep/wake cycle is best entrained to the school day by circadian light stimulation in the early morning and no circadian light stimulation in the evening hours. Educating students and parents to minimize circadian-effective light exposures before bedtimes can help. In the evening, low level of a low CCT light, typical of incandescent lamps or other light sources with CCTs around 3000K, will be less likely to delay sleep.

Exposure Zones

In many schools, the desks near the window or under skylights or roof monitors provide the best areas for circadian light stimulation. If daylight is not uniform in the school, students could be rotated between the areas of better and worse circadian light stimulation. This could be done administratively by scheduling students each to spend at least one of the first few hours of the school day near the window, under a skylight, or outside (for example, at recess).

Material Choices

If tinted glazing is required, blue or blue-green glass that admits more short-wavelength (blue) light will be more effective in providing circadian light stimulation than an equivalent amount of light from a bronze glass. Interior finishes of high reflectance colors that are in the normal line of sight of the student will also help increase reflected light in the space and, therefore, increase the likelihood that students will be receiving adequate light at the eye for circadian stimulation.

Schedule

A later start to the school day will improve the likelihood that students will receive circadian light stimulation, especially in the winter when students with early schedules are less likely to be exposed to daylight on their way to school. Scheduling outdoor athletic activities in the morning could also offer health benefits to the participants.

Limitations

Following are some of the limitations of this book that designers should be aware of when designing a K-12 facility.

Electric Light

All the patterns included in this book are simulated under daylight alone. No electric light is factored into the illuminance, coverage, and circadian stimulus calculations.

Climate

The patterns and data provided in this book have been created and calculated specifically for the Albany, New York area. Regional climates, building materials, and aesthetic preferences will all affect the data generated by these patterns. For instance, solar heat gain numbers will be significantly higher if designing a classroom in Arizona as compared to in New York. When looking through this guide, keep in mind that any alterations made in order to accommodate a specific design scenario (for example, increasing the room size or window size) will alter the outcome of each pattern. Consequently, this publication is meant merely to provide a general overview but not a definitive, decision-making approach.

Glazing

This book does not consider different glazing types. In all patterns, all windows and clerestories use clear double-glazing; all skylights are translucent. Altering the glazing types will influence the outcome of each pattern.

Illuminance

This book only considers one average target illuminance needed in each environment. If a designer requires specialized lighting scenarios, for example in a wood shop or an art classroom, the illuminance needed on the work surface may vary.

Circadian Stimulation

The model of human circadian phototransduction by Rea and colleagues assumes a fixed pupil size of 2.3 mm, duration of exposure (1 hr) and does not take into account individual difference in response to light, age-related eye changes (i.e., increase light absorption), light history and photopigment regeneration, all of which could affect the light response.[9] Moreover, the calculations assume a relationship between acute melatonin suppression (calculated using the Rea et al. model) and entrainment. It is not known if acute melatonin suppression is a good surrogate for circadian stimulus sufficient to entrain students to the 24-hour solar day. Finally, the link between entrainment and health outcomes are only starting to be established. Much more work is needed to determine the impact of light exposure over the course of the 24-hour day on health and well-being.

Reflectance

The reflectance of the finishes will change the results of the pattern. This book assumes reflectances of:

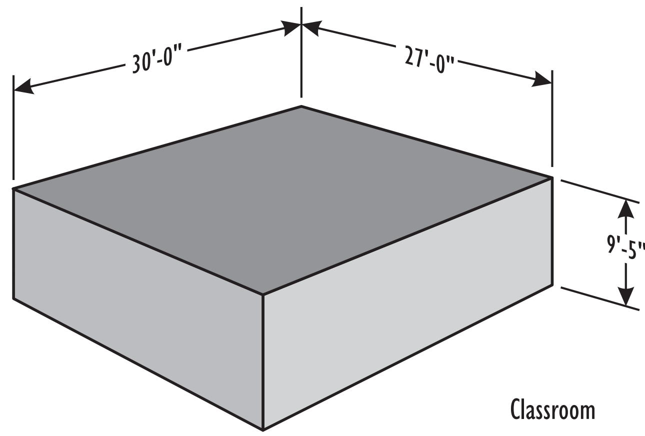
- 20% for the floor,
- 50% for the walls,
- 80% for the ceiling and roof monitor vertical walls.

Shading Systems

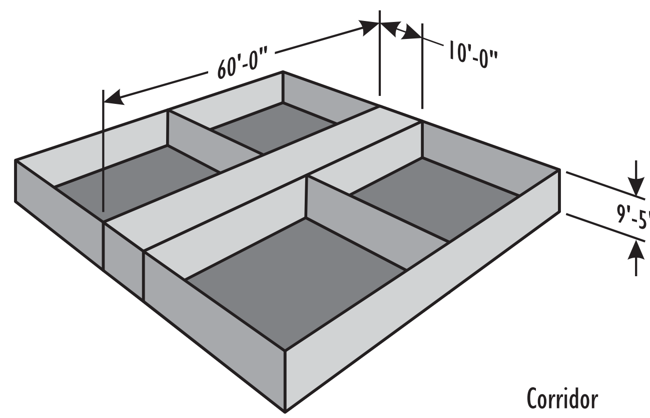
Some of the patterns have architectural shading systems such as light shelves, baffles under roof monitors, and overhangs. The patterns do not consider other direct sun control by interior shading systems such as window blinds or curtains. Often, blinds or other shading will be needed to mitigate the impact of direct sun. These should be considered as the design is developed. Illuminance levels indicate whether glare zones will need to be addressed.

Space Size

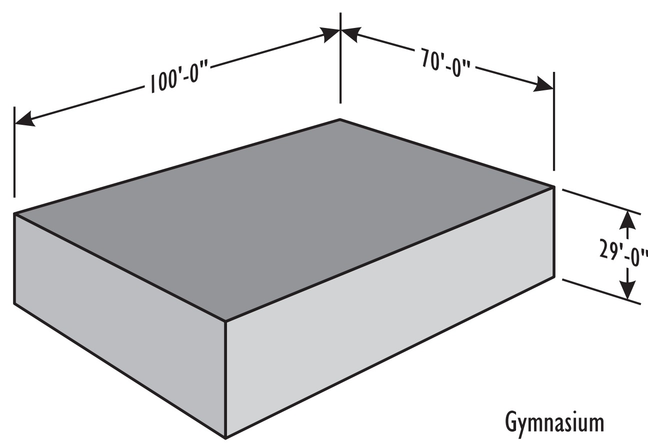
The patterns in this publication consider an average classroom, corridor, and gymnasium space. The way in which daylight illuminates the space will be altered if the considered building space is configured differently. The dimensions of the typical spaces analyzed in the book are shown below.



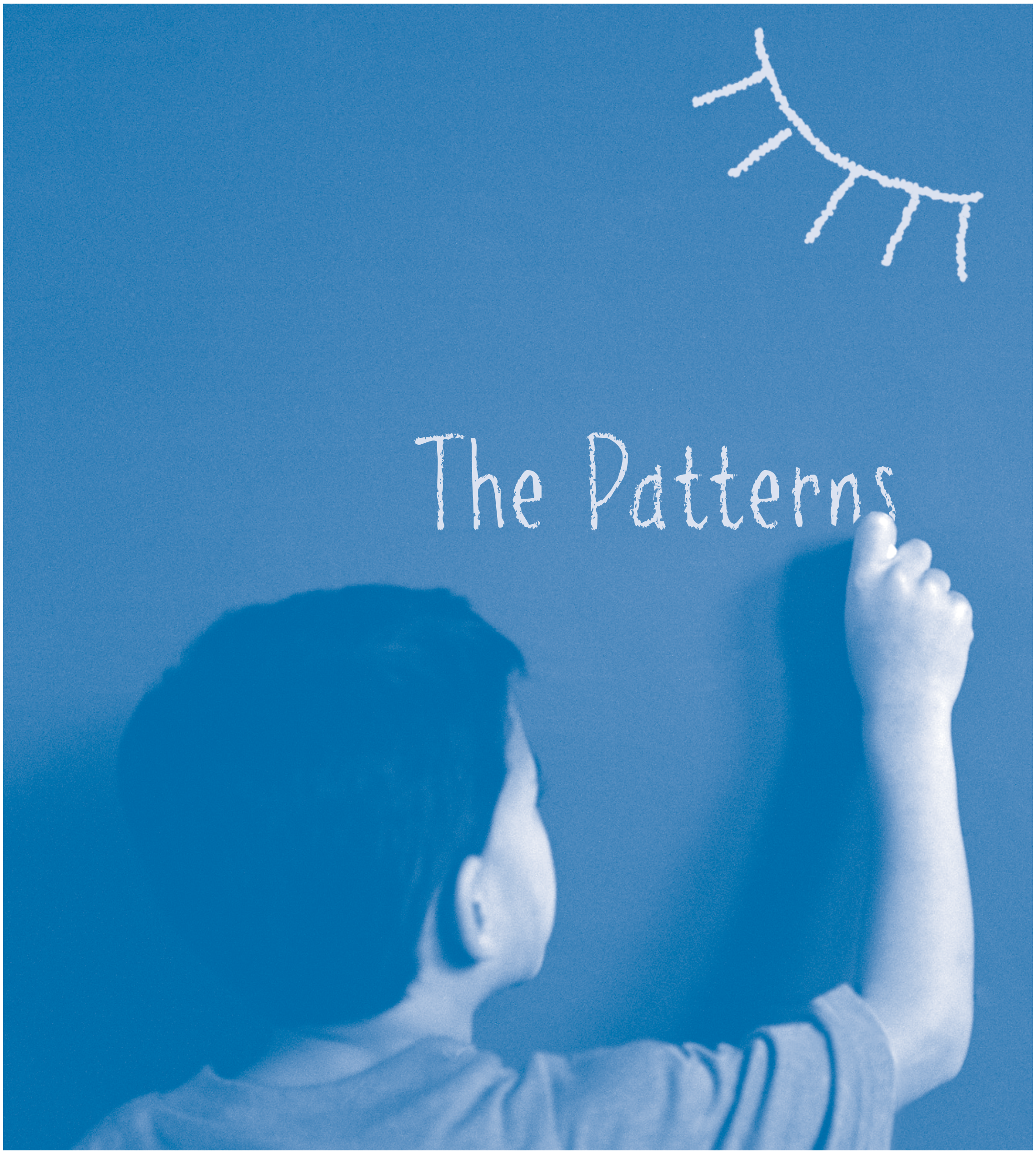
Classroom



Corridor



Gymnasium


The Patterns

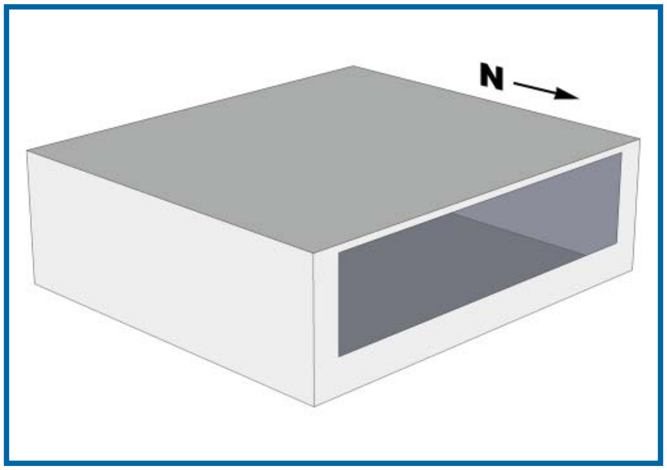
Patterns for Daylighting Schools

The following pages provide 25 patterns for classrooms, corridors, and gymnasiums, summarized below. Each pattern includes two daylighting dashboards, one for clear sky and one for cloudy sky conditions, representing the strengths and weaknesses of each pattern. The daylighting dashboards are based on the composite performance of the simulated dates and times of year listed on page 5. The tables separate the performance results for all the dates and times. Refer to the top-view room renderings to see the daylight quantity and distribution for September, representations of the median yearly conditions.

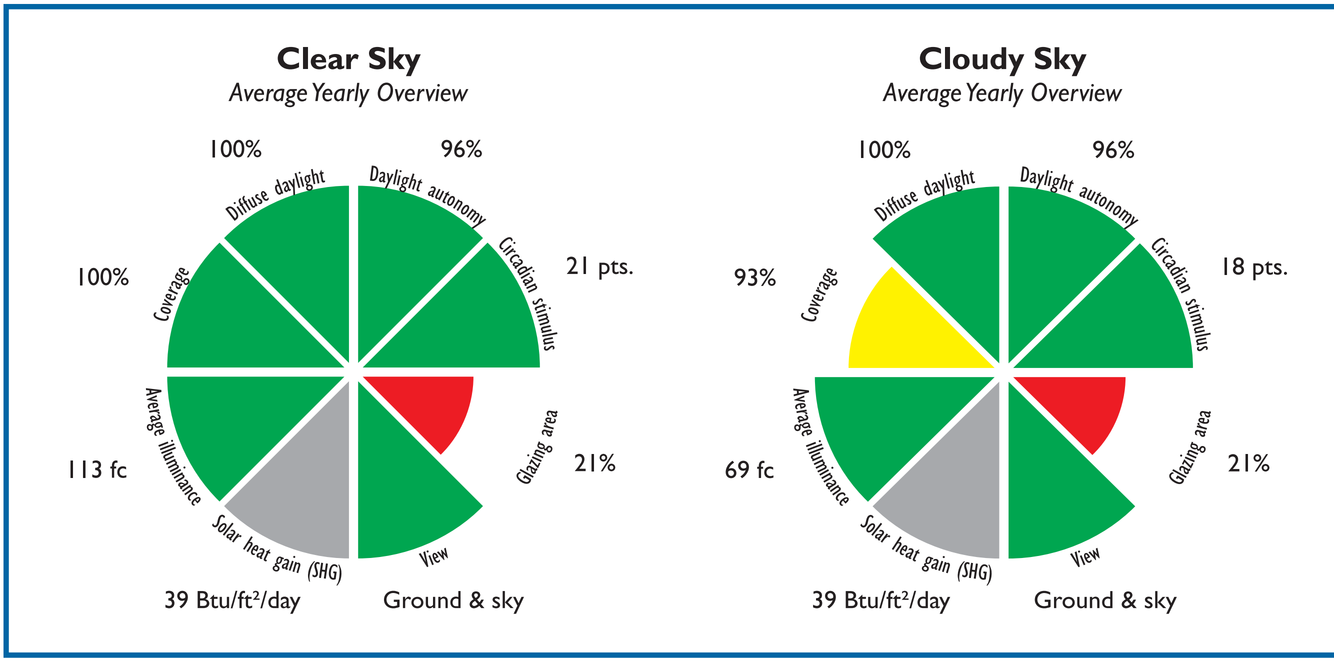
		Average illuminance (fc)		Coverage (%)		Diffuse daylight (%)		Daylight autonomy (%)		Circadian stimulus (pts.)		Glazing area (%)	View (G=ground; S=sky; N=none)	Solar heat gain (Btu/ft²/day)
Page	Space type	Clear	Cloudy	Clear	Cloudy	Clear	Cloudy	Clear	Cloudy	Clear	Cloudy			
—	All Rooms, No Daylight	0	0	0	0	0	0	0	0	0*	0*	0	N	0
	Classroom													
16	North Large Window	113	69	100	93	100	100	96	96	21	18	21	GS	39
18	South Large Window	752	70	100	94	81	100	100	58	24	18	21	GS	92
20	East Large Window	459	69	100	93	88	100	98	57	22	18	21	GS	71
22	West Large Window	385	69	100	93	92	100	98	57	22	18	21	GS	71
24	South Medium Window	336	34	100	76	92	100	98	33	23	12	10	GS	46
26	South Small Window	224	15	100	35	94	100	73	12	21	7	5	GS	23
28	South Large Window with Overhang	332	42	100	90	89	100	100	46	24	16	21	GS	52
30	South Large Window with Lightshelf	425	47	100	91	88	100	100	51	24	16	21	GS	68
32	Bilateral Large Windows	848	135	100	100	78	100	100	97	24	22	41	GS	132
34	Skylights	238	47	100	100	100	100	100	73	24	19	6	N	25
36	North Roof Monitor	47	40	99	89	100	100	71	49	18	16	12	S	22
38	South Roof Monitor with Baffles	85	11	99	42	100	100	77	2	19	4	8	S	52
40	North Large Window + Skylights	236	95	100	100	100	100	100	89	24	21	24	GS	52
42	South Large Window + Skylights	868	92	100	100	78	100	100	89	24	21	24	GS	105
44	North Small Window + Skylights	147	39	100	95	100	100	98	55	22	17	8	GS	22
46	South Small Window + Skylights	342	39	100	95	94	100	100	55	24	17	8	GS	35
	Corridor													
48	Clerestory Windows	21	4	100	81	100	100	99	0	10	0	50	N	0
50	Skylights	111	22	100	100	100	100	100	83	22	10	4	N	12
52	North Roof Monitors	12	13	100	90	100	100	47	36	3	7	7	S	9
54	Skylights with Clerestory Window	125	25	100	100	100	100	100	89	23	10	54	N	12
	Gymnasium													
56	North Clerestory Window	66	48	100	92	100	100	90	55	21	16	14	S	260
58	Skylights	132	26	100	93	100	100	94	39	22	10	4	N	140
60	North Roof Monitors	39	40	99	89	100	100	69	56	12	16	16	S	261
62	South Roof Monitor with Baffles	65	7	96	24	100	100	66	0	18	0	8	S	195
64	Skylights with Clerestory Window	154	66	100	100	100	100	100	82	23	19	17	S	353

* For reference, electric lighting without daylight designed for 30 fc on the workplane with 3500 K CCT results in 12 points.

Classroom:
North Large Window



This pattern features one 27 ft x 6 ft window on the north-facing wall. Due to the north orientation, controlling direct sunlight is not required. Electric lights will be needed to supplement daylight when the skies are overcast.



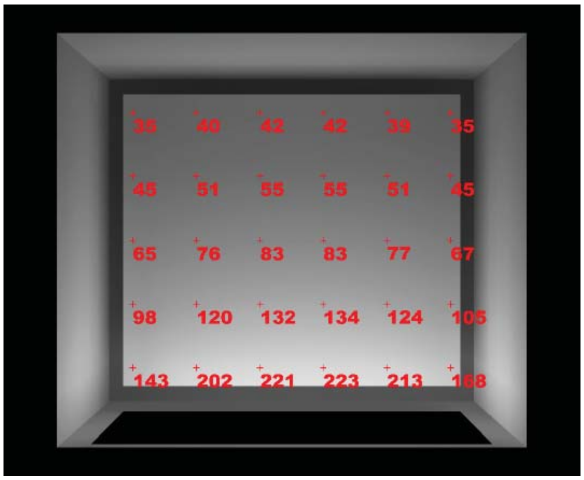
	Clear Sky												Cloudy Sky											
	Mar			Jun			Sep			Dec			Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	90	129	121	137	159	153	96	130	119	67	93	61	45	87	79	77	114	105	51	90	77	29	51	25
Coverage (%)	100	100	100	100	100	100	100	100	100	100	100	100	93	100	100	100	100	100	100	100	100	67	100	60
Diffuse daylight (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	100	100	100	100	100	100	100	100	100	80	100	73	40	73	60	60	87	80	47	73	60	33	47	27
Circadian stimulus (pts.)	2	2	2	2	2	2	2	2	2	1	1	1	2	2	2	2	2	2	2	2	2	0	0	0

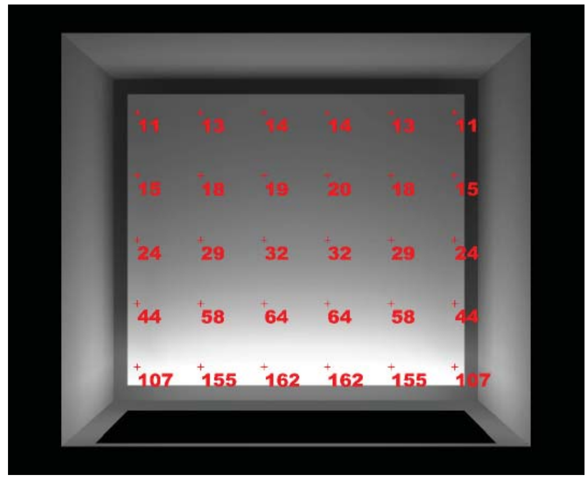
Glazing area: 21%
View: Ground & sky
SHG (Btu/ft²/day): March, 37; June, 63; September, 39; December, 17

Classroom:
North Large Window

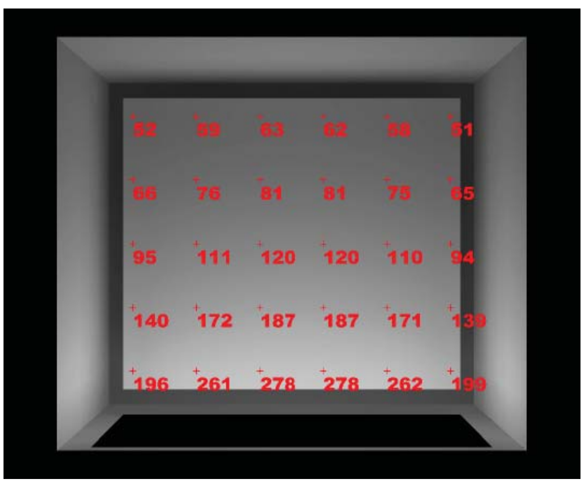
	Clear Sky September	**Cloudy Sky** September

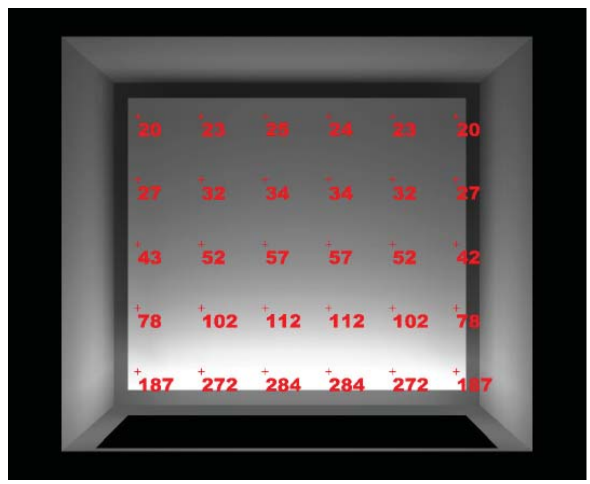
9:00 a.m.



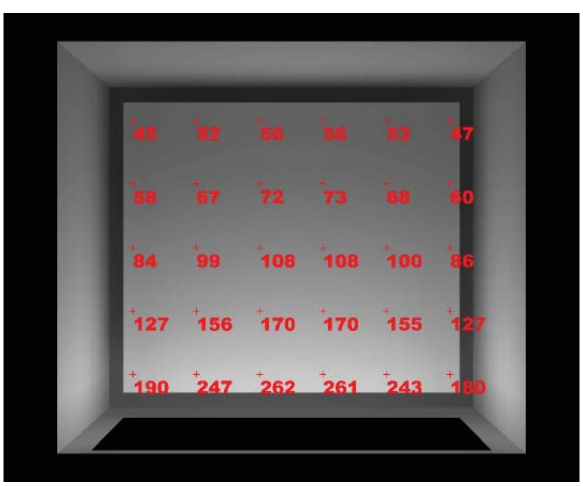


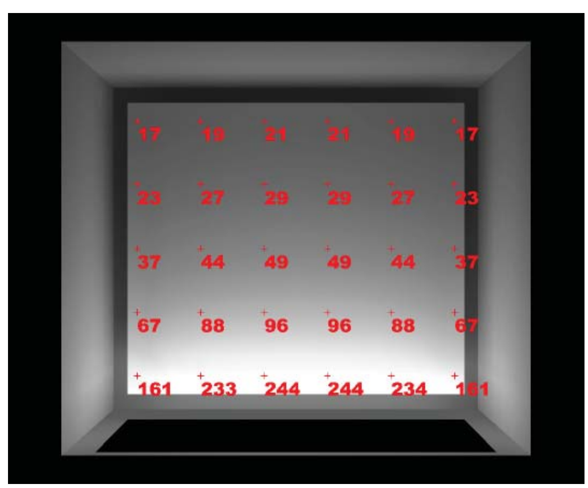
12:00 noon



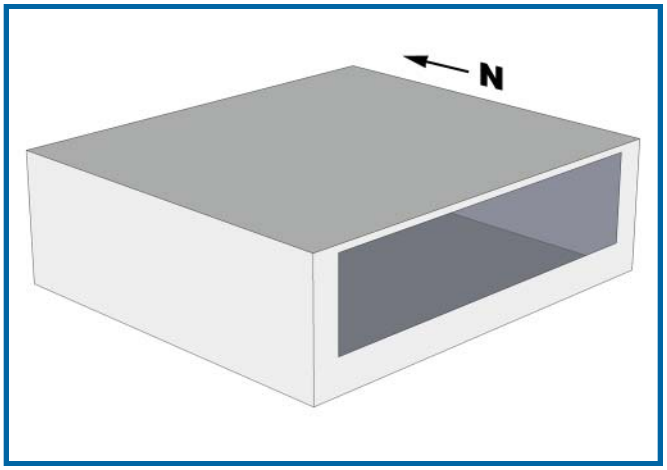


3:00 p.m.

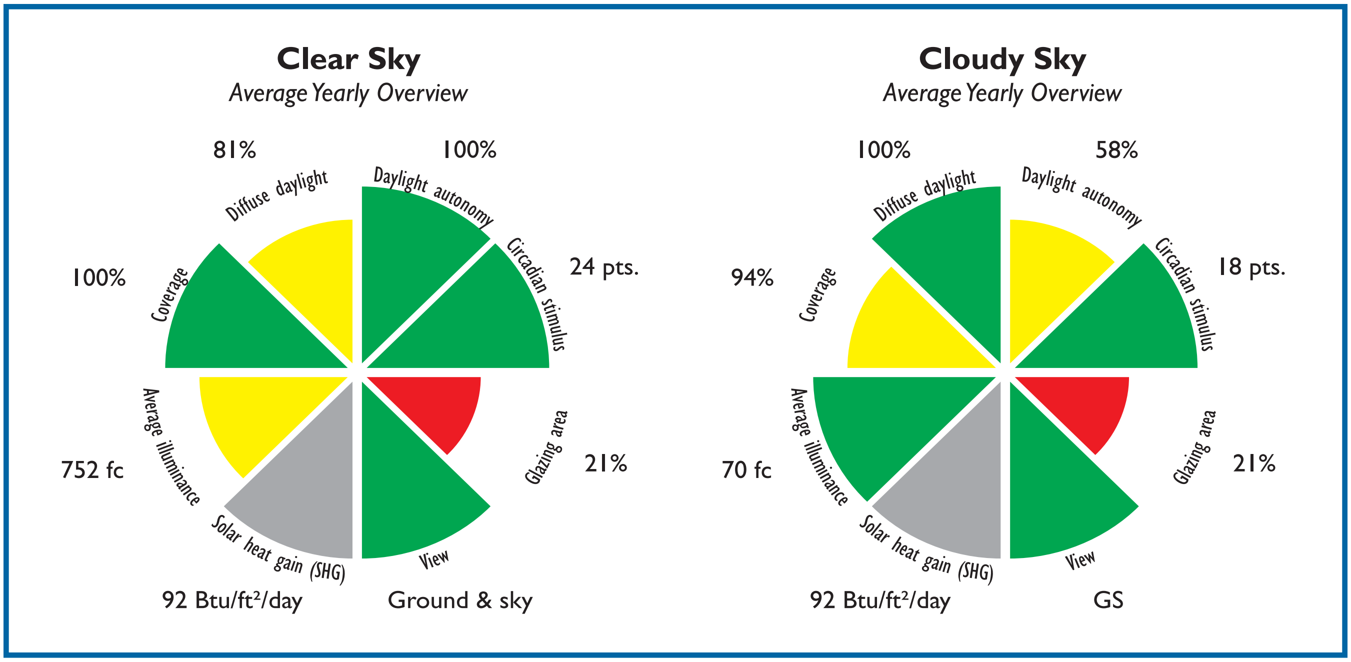




Classroom:
South Large Window



This pattern features a 26 ft x 6 ft window on the south wall. Blinds, louvers, or shades will be needed to control the direct sun. Rows of light fixtures should be arranged parallel to the windows and should be controlled separately.

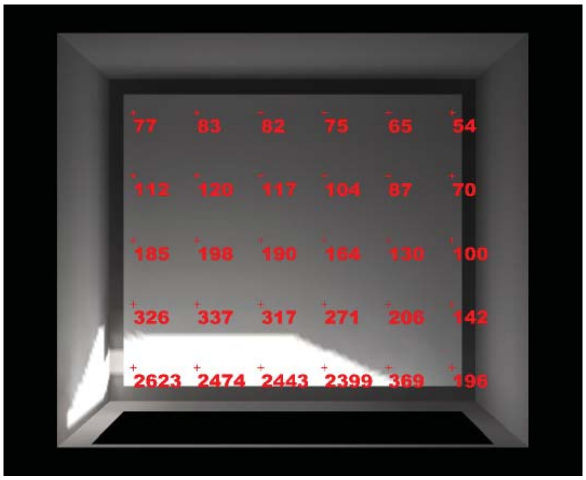
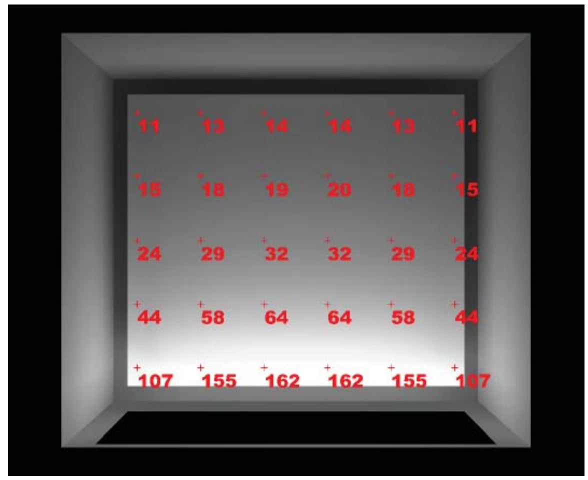
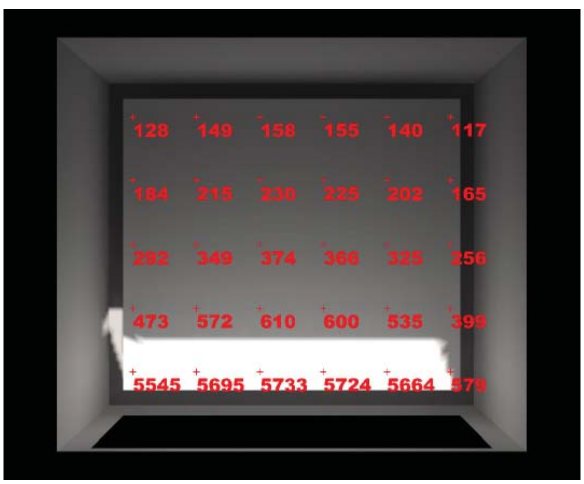
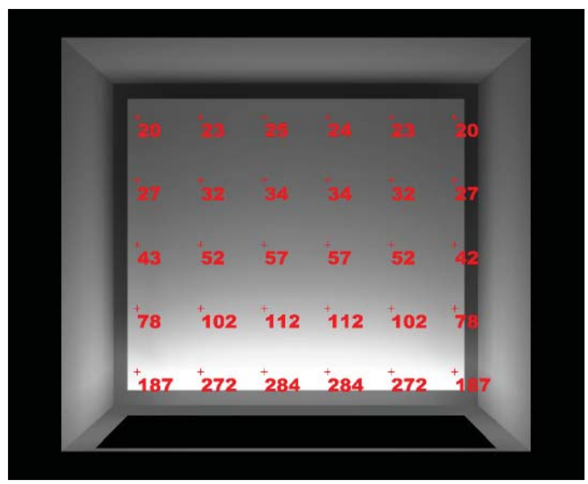
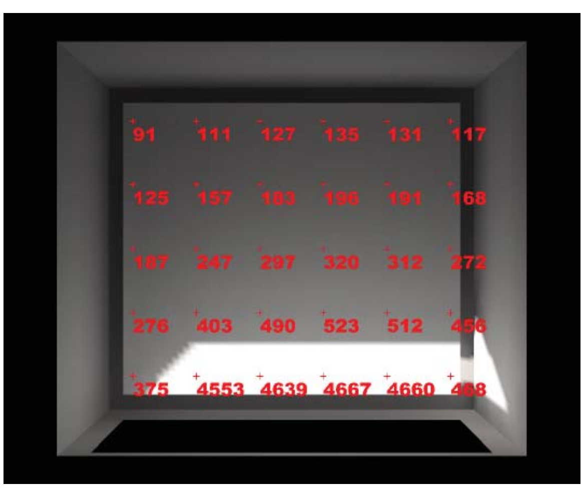
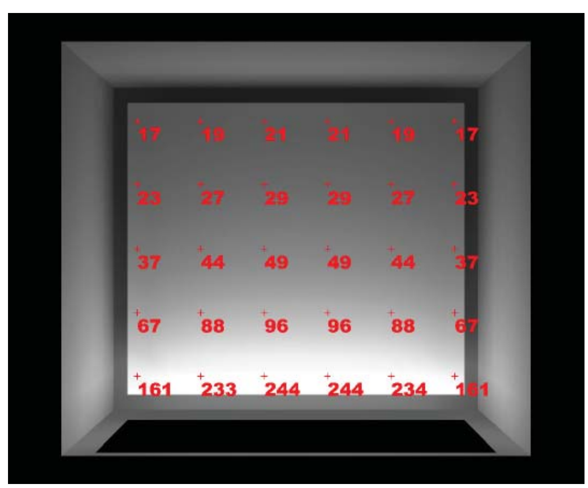


	Clear Sky												Cloudy Sky											
	Mar			Jun			Sep			Dec			Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	403	1183	1036	141	215	194	471	1205	987	733	1883	563	45	87	79	77	114	105	51	90	77	29	51	25
Coverage (%)	100	100	100	100	100	100	100	100	100	100	100	100	93	100	100	100	100	100	100	100	100	67	100	60
Diffuse daylight (%)	87	83	83	100	100	100	87	83	83	50	40	50	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	100	100	100	100	100	100	100	100	100	100	100	100	40	73	60	60	87	80	47	73	60	33	47	27
Circadian stimulus (pts.)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	0	0

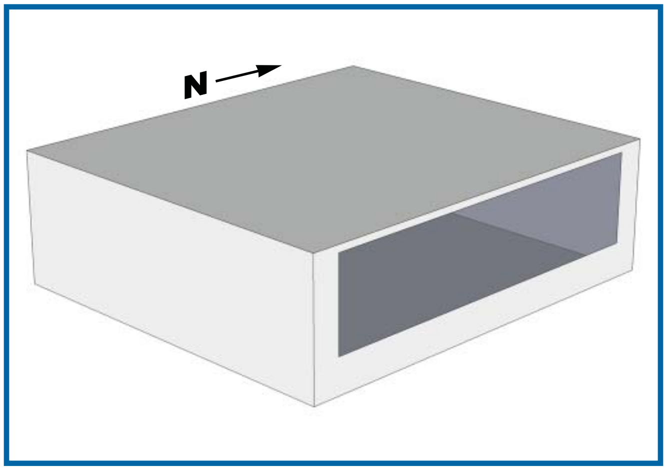
Glazing area: 21%
View: Ground & sky
SHG (Btu/ft²/day): March, 104; June, 76; September, 111; December, 78

Classroom:

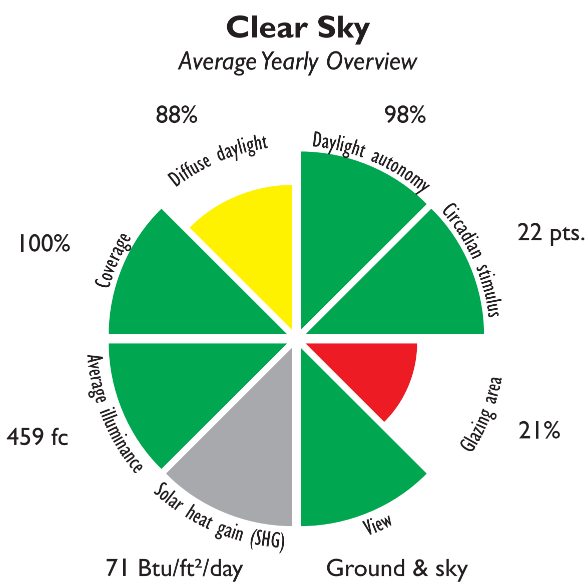
South Large Window

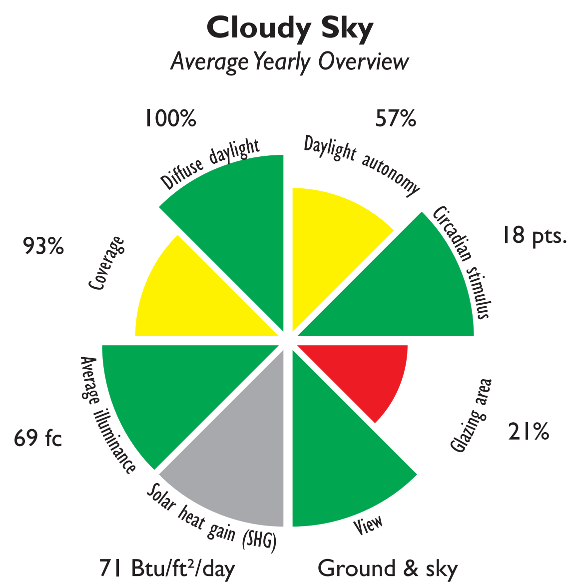
	Clear Sky September	Cloudy Sky September
9:00 a.m.		
12:00 noon		
3:00 p.m.		

Classroom:
East Large Window



This pattern features one 27 ft x 6 ft window on the east-facing wall. Blinds, louvers, or shades will be needed on sunny mornings; room occupants will need to make sure that the blinds are opened in the afternoon to capture daylight savings later in the day.





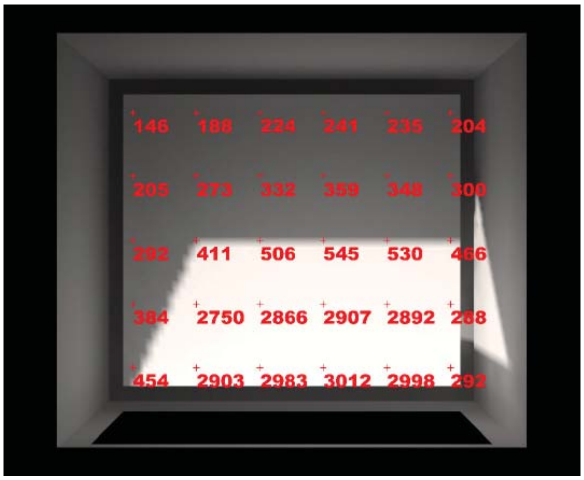
	Clear Sky												Cloudy Sky											
	Mar			Jun			Sep			Dec			Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	1377	186	123	1246	201	145	1192	179	120	568	109	61	45	87	79	77	114	105	51	90	77	29	51	25
Coverage (%)	100	100	100	100	100	100	100	100	100	100	100	100	93	100	100	100	100	100	100	100	100	67	100	60
Diffuse daylight (%)	50	100	100	80	100	100	67	100	100	63	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	100	100	100	100	100	100	100	100	100	100	100	73	40	73	60	60	87	80	47	73	60	33	47	27
Circadian stimulus (pts.)	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2	2	2	2	2	2	0	0	0

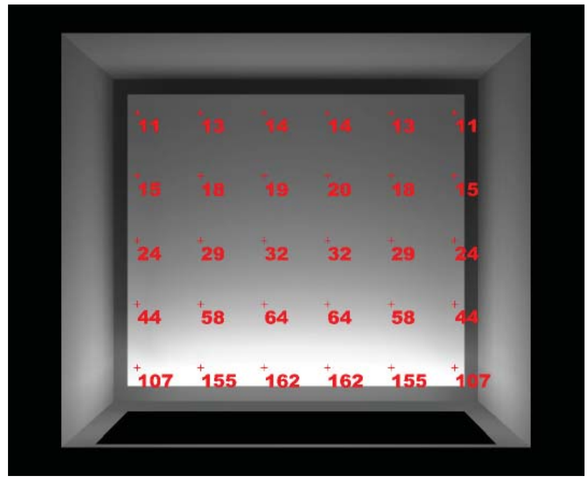
Glazing area: 21%
View: Ground & sky
SHG (Btu/ft²/day): March, 67; June, 107; September, 80; December, 29

Classroom:
East Large Window

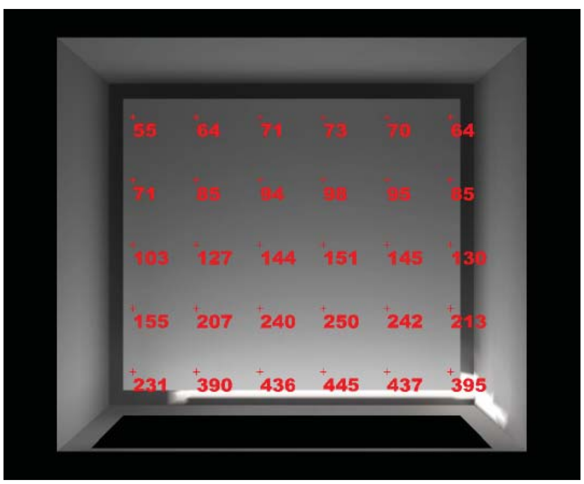
	Clear Sky September	Cloudy Sky September

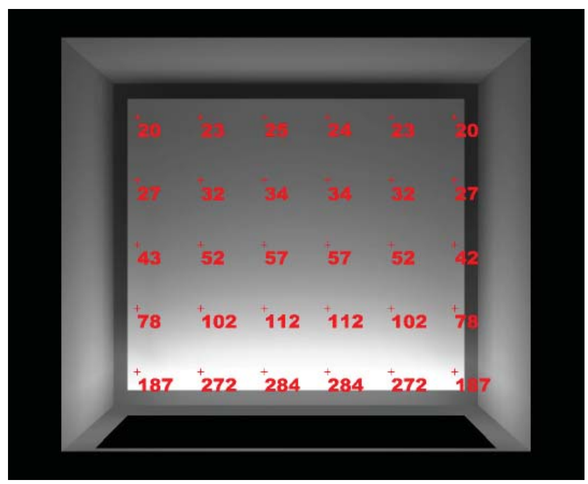
9:00 a.m.



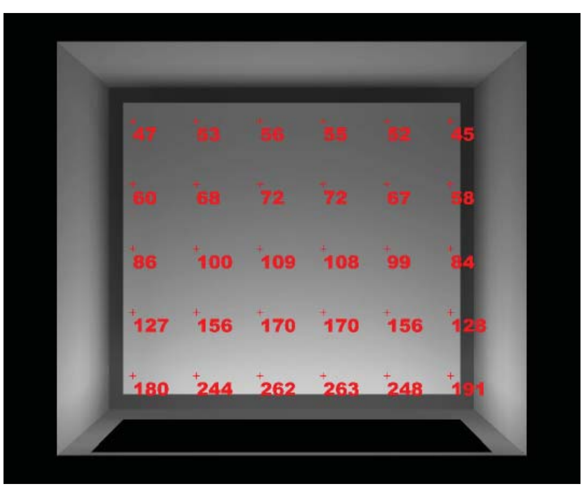


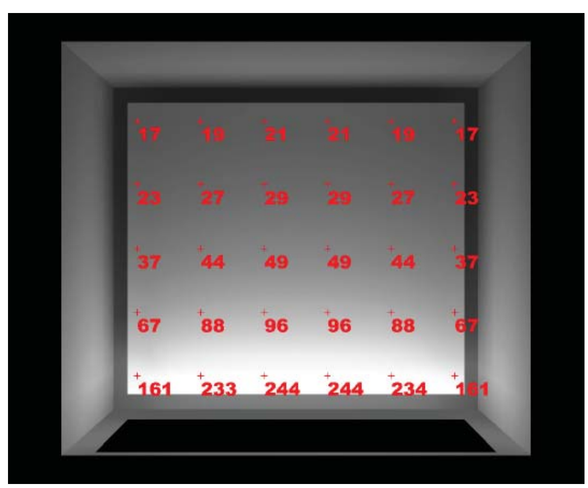
12:00 noon



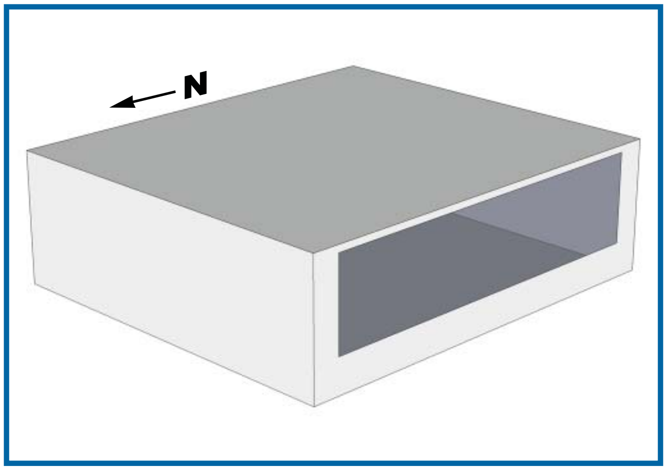


3:00 p.m.

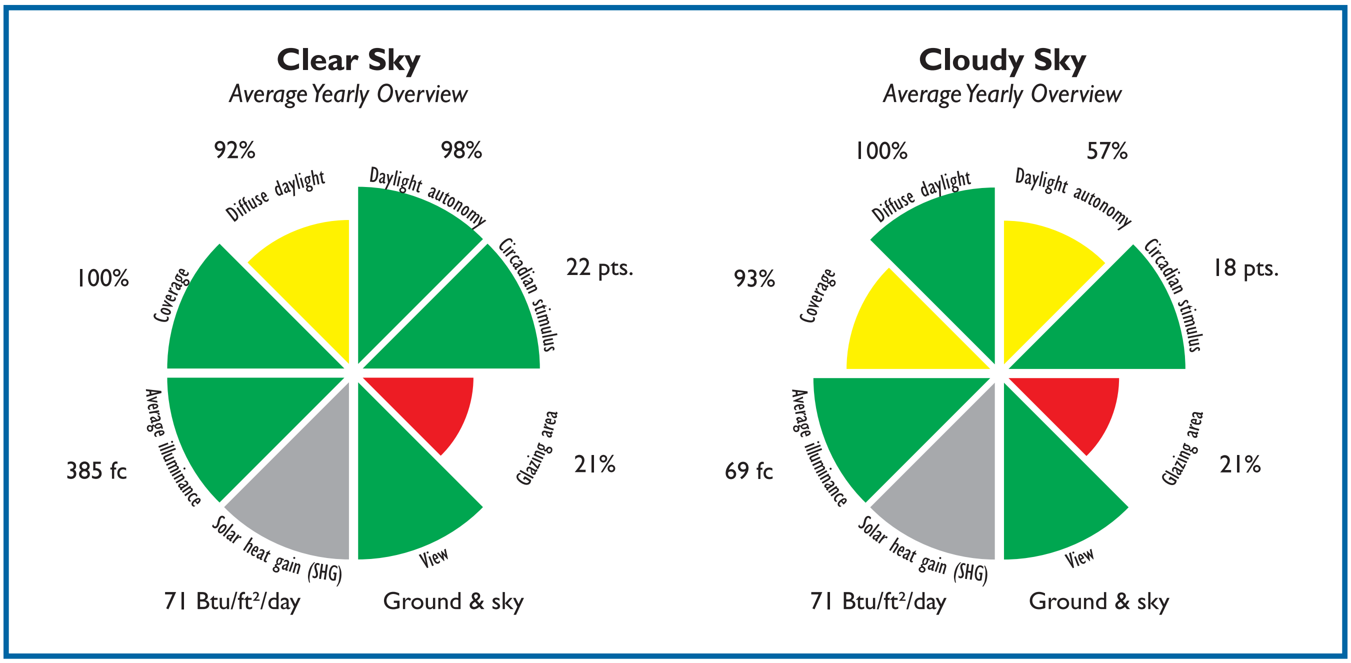




Classroom:
West Large Window



This pattern features one 27 ft x 6 ft window on the west-facing wall. Supplementary light will be needed when the skies are overcast. Blinds, louvers, or shades are needed to control direct sunlight in the afternoon.



Clear Sky

	Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	86	137	967	116	162	1226	92	142	979	67	113	530
Coverage (%)	100	100	100	100	100	100	100	100	100	100	100	100
Diffuse daylight (%)	100	100	83	100	100	83	100	100	83	100	100	53
Daylight autonomy (%)	100	100	100	100	100	100	100	100	100	77	100	100
Circadian stimulus (pts.)	2	2	2	2	2	2	2	2	2	1	1	2

Cloudy Sky

	Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	45	87	79	77	114	105	51	90	77	29	51	25
Coverage (%)	93	100	100	100	100	100	100	100	100	67	100	60
Diffuse daylight (%)	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	40	73	60	60	87	80	47	73	60	33	47	27
Circadian stimulus (pts.)	2	2	2	2	2	2	2	2	2	0	0	0

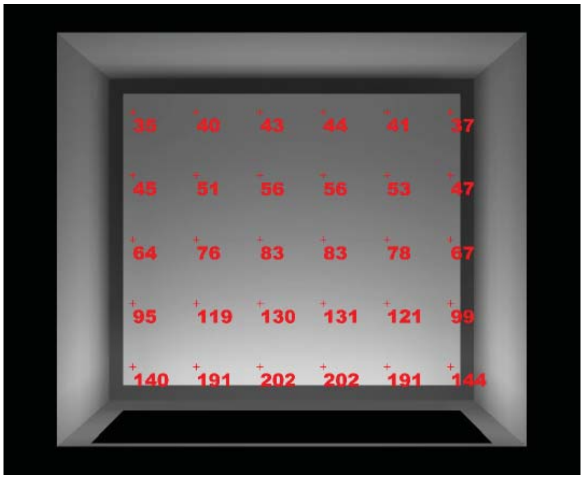
Glazing area: 21%
View: Ground & sky
SHG (Btu/ft²/day): March, 70; June, 105; September, 83; December, 27

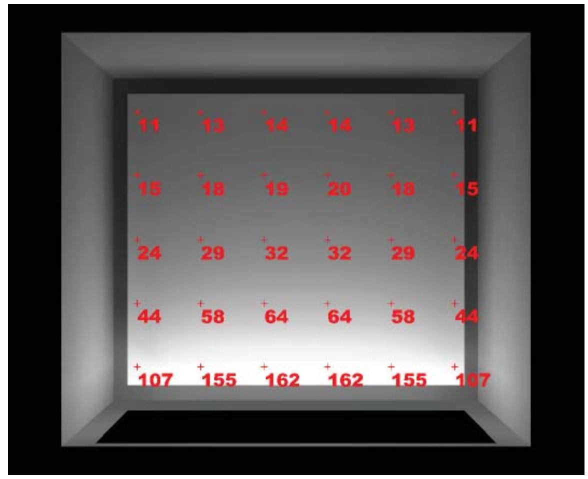
Classroom:
West Large Window

Clear Sky
September

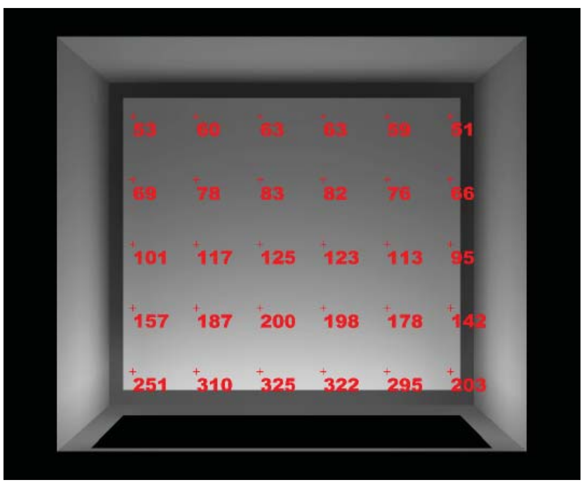
Cloudy Sky
September

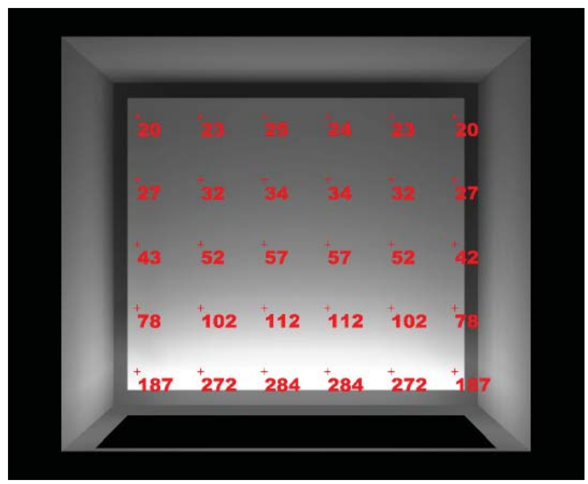
9:00 a.m.



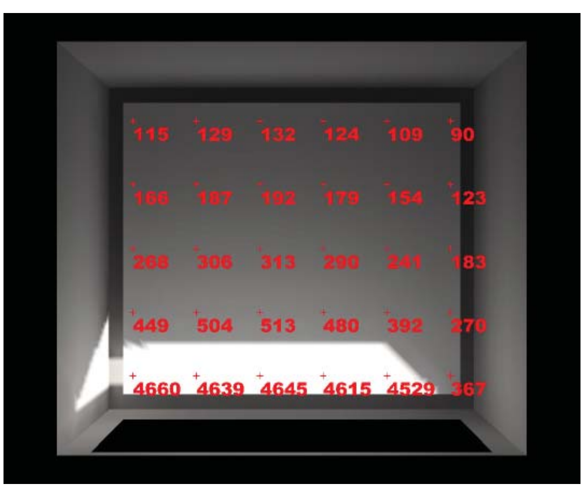


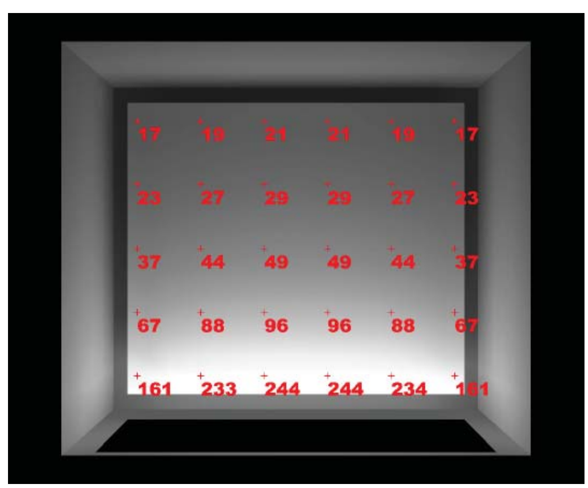
12:00 noon



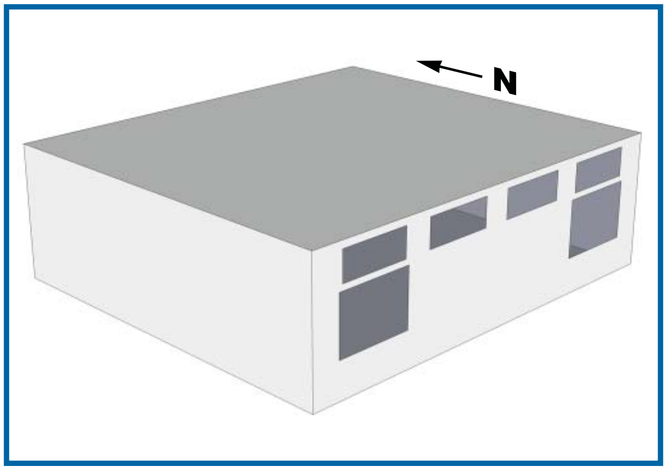


3:00 p.m.

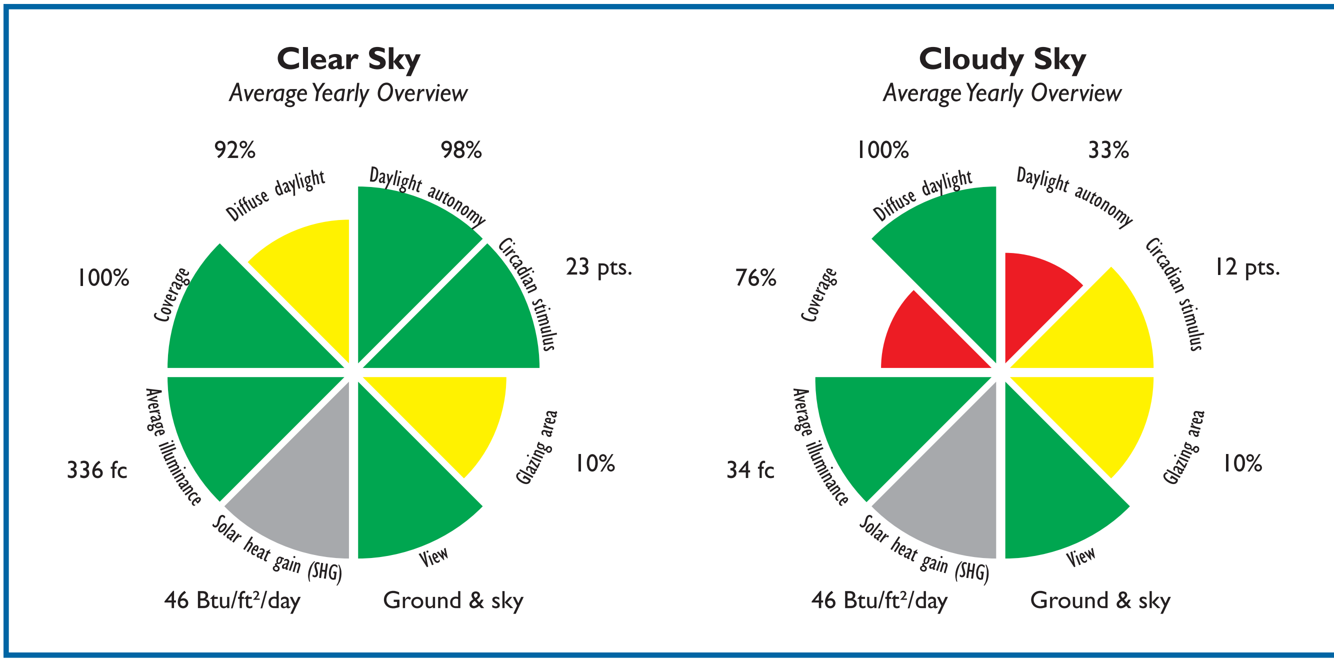




Classroom:
South Medium Windows



This pattern features four 5 ft x 2 ft clerestory windows located 7 feet above the floor and two 6 ft x 4 ft view windows on the south-facing wall. The clerestory windows allow reduced glazing area with reasonable daylight penetration under clear skies. Electric lights will be needed to supplement daylight when the skies are overcast. Blinds, louvers, or shades will be needed to control the direct sun.



	Clear Sky												Cloudy Sky											
	Mar			Jun			Sep			Dec			Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	154	526	462	69	108	97	178	535	439	305	880	276	23	44	40	40	39	53	26	46	39	15	26	13
Coverage (%)	100	100	100	100	100	100	100	100	100	100	100	100	60	93	90	90	87	100	60	100	87	40	60	40
Diffuse daylight (%)	97	93	93	100	100	100	97	93	93	83	73	77	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	97	100	100	77	100	100	100	100	100	100	100	100	20	40	40	40	40	53	27	40	40	13	27	13
Circadian stimulus (pts.)	2	2	2	2	2	2	2	2	2	2	2	1	1	2	1	1	1	2	1	2	1	0	0	0

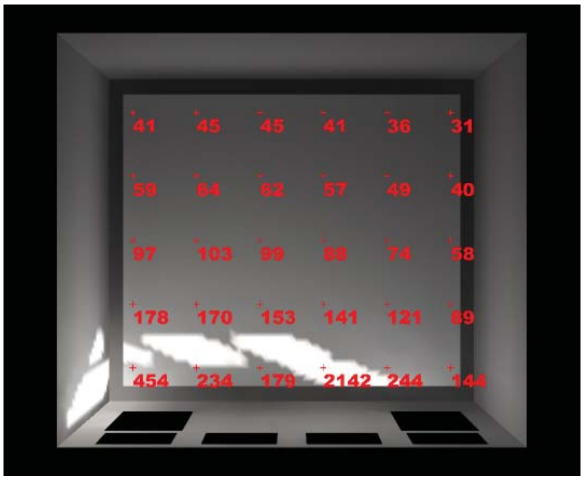
Glazing area: 10%
View: Ground & sky
SHG (Btu/ft²/day): March, 52; June, 38; September, 55; December, 39

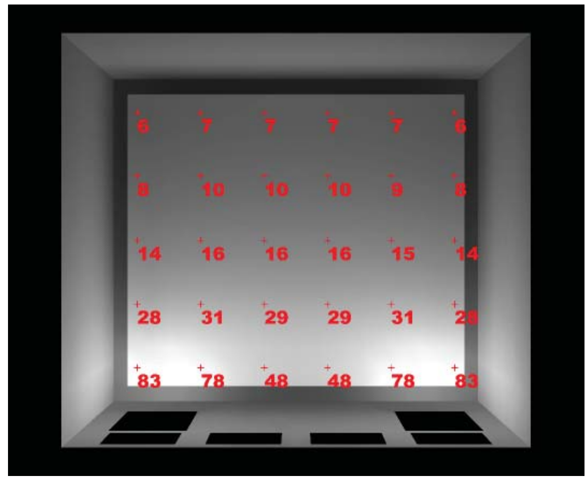
Classroom:
South Medium Windows

Clear Sky
September

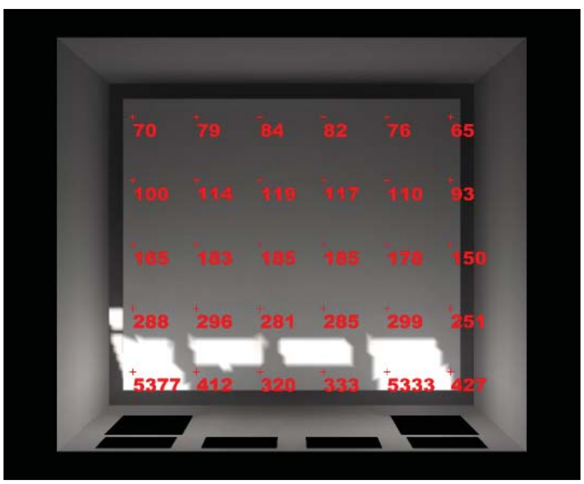
Cloudy Sky
September

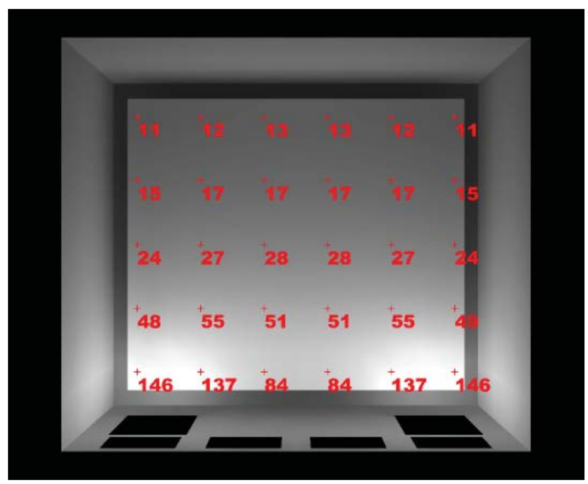
9:00 a.m.



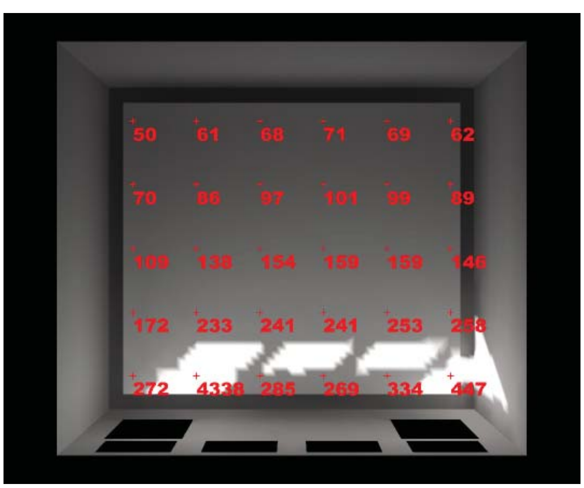


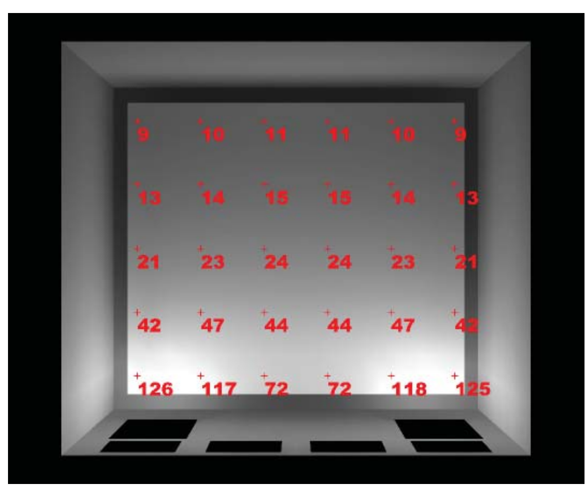
12:00 noon



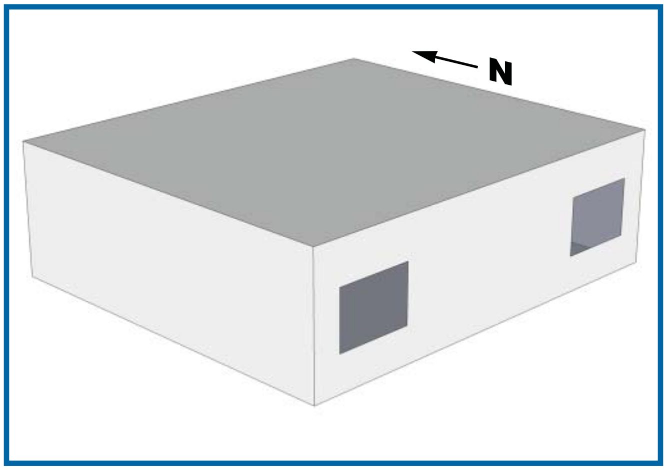


3:00 p.m.



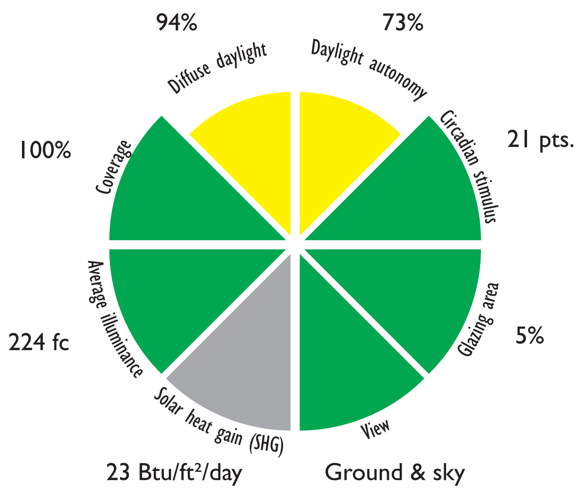


Classroom:
South Small Windows

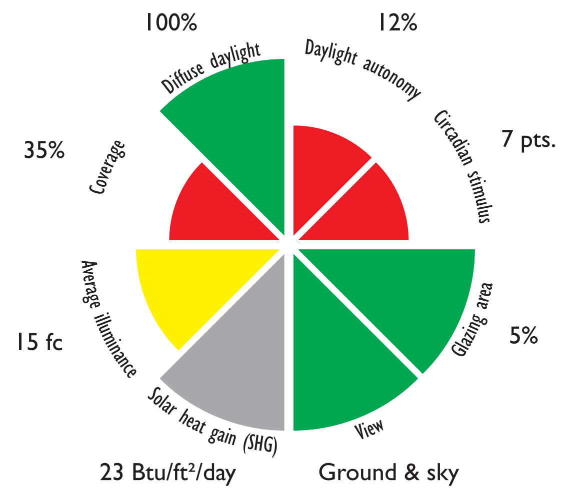


This pattern has two 6 ft x 4 ft windows on the south-facing wall. There is plenty of wall space left for educational materials due to the small glazing area, but electric lights will be needed most of the time when the skies are overcast.

Clear Sky
Average Yearly Overview



Cloudy Sky
Average Yearly Overview



	Clear Sky												Cloudy Sky											
	Mar			Jun			Sep			Dec			Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	99	407	356	35	53	48	116	415	338	164	506	148	10	20	18	17	25	23	12	20	17	7	12	6
Coverage (%)	100	100	100	100	100	100	100	100	100	100	100	100	20	40	40	40	60	60	27	40	40	13	27	13
Diffuse daylight (%)	97	93	93	100	100	100	97	93	93	90	83	87	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	57	87	80	40	60	60	57	87	80	90	100	77	13	13	13	13	13	13	13	13	13	7	13	0
Circadian stimulus (pts.)	2	2	2	1	2	2	2	2	2	1	2	1	0	1	1	1	1	1	0	1	1	0	0	0

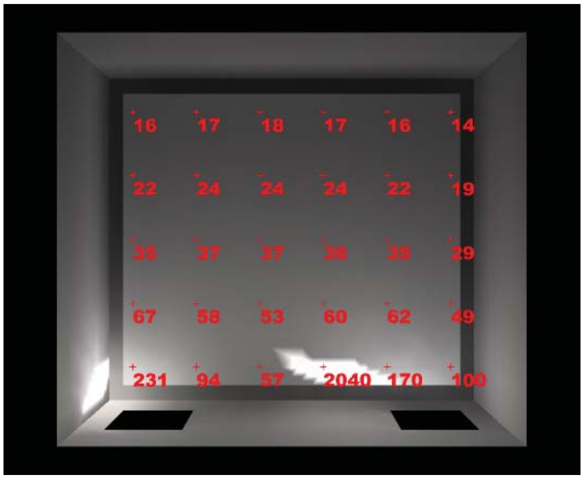
Glazing area: 5%
View: Ground & sky
SHG (Btu/ft²/day): March, 25; June, 18; September, 27; December, 19

Classroom:
South Small Windows

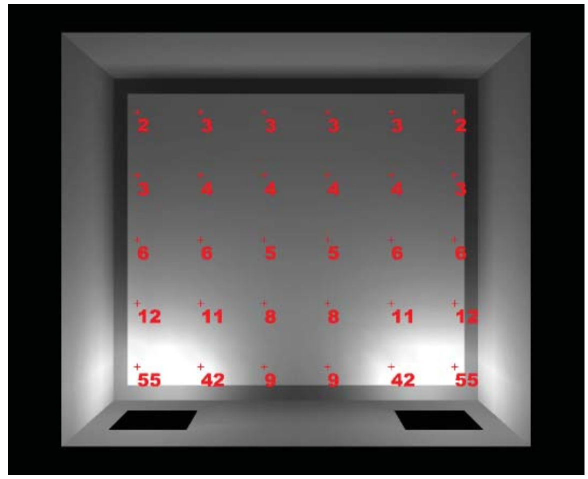
	Clear Sky September	**Cloudy Sky** September

9:00 a.m.

Clear Sky, September

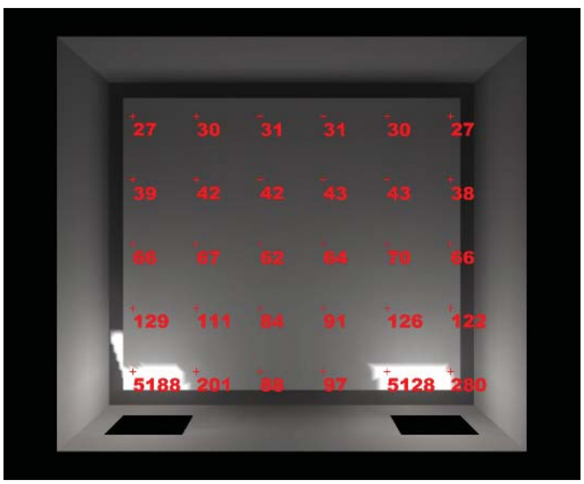


Cloudy Sky, September

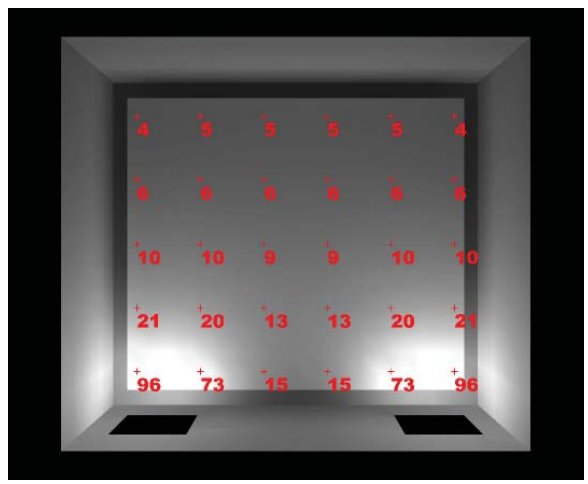


12:00 noon

Clear Sky, September

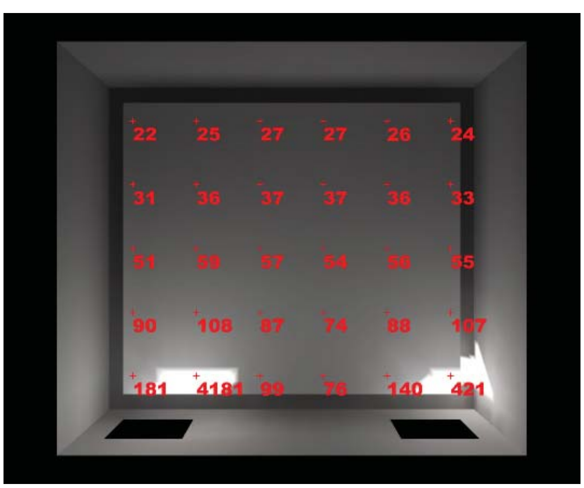


Cloudy Sky, September

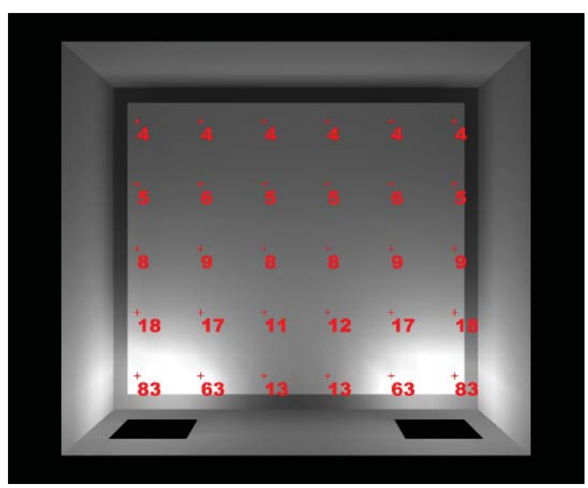


3:00 p.m.

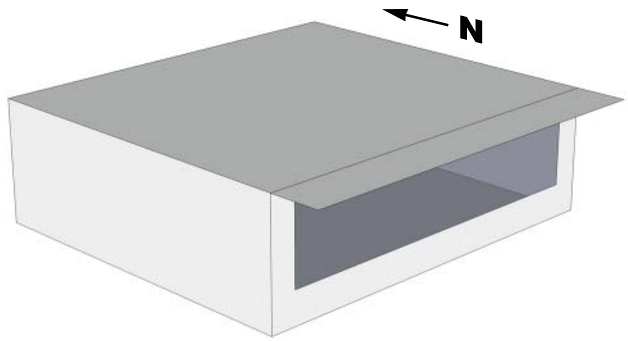
Clear Sky, September



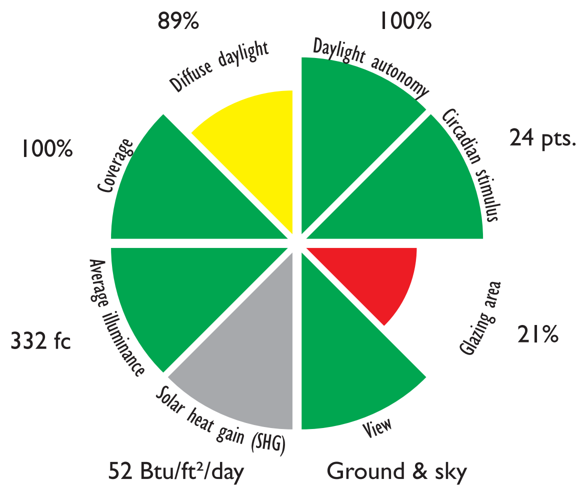
Cloudy Sky, September

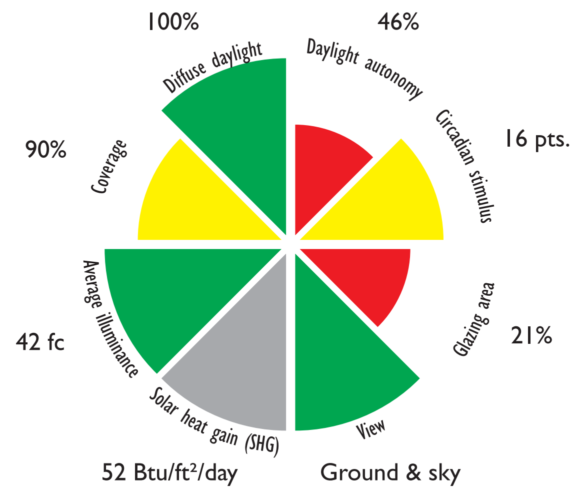


Classroom:
South Large Window with Overhang



This pattern features a 4 ft continuous overhang added to the Large South Window pattern. The overhang reduces glare and solar heat gain under clear skies, but also restricts the energy saving potential under overcast skies. The underside of the overhang should be a light color to help direct light reflected from the ground into the classroom.





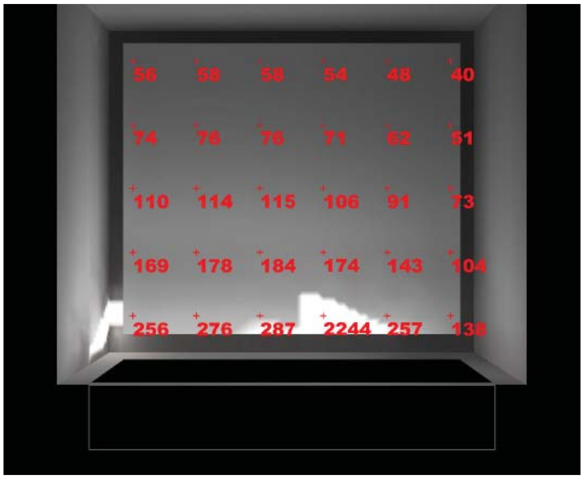
	Clear Sky												Cloudy Sky											
	Mar			Jun			Sep			Dec			Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	173	199	185	114	162	150	191	189	173	630	1316	506	27	53	47	46	69	63	31	54	47	18	31	15
Coverage (%)	100	100	100	100	100	100	100	100	100	100	100	100	83	100	100	100	100	100	93	100	100	60	93	53
Diffuse daylight (%)	97	100	100	100	100	100	97	100	100	57	60	53	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	100	100	100	100	100	100	100	100	100	100	100	100	33	60	53	53	73	67	33	60	53	20	33	13
Circadian stimulus (pts.)	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	1	2	2	0	0	0

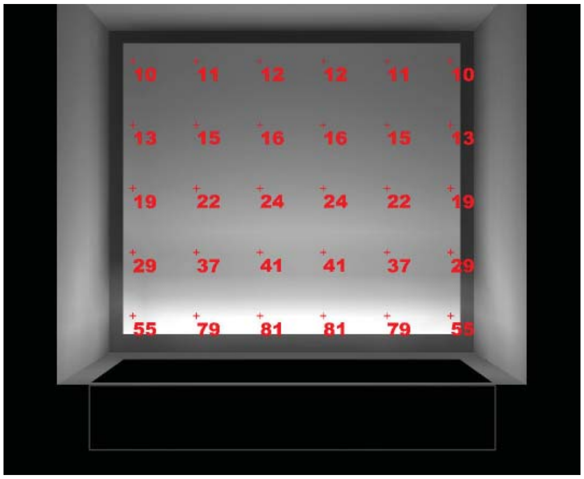
Glazing area: 21%
View: Ground & sky
SHG (Btu/ft²/day): March, 61; June, 45; September, 49; December, 54

Classroom:
South Large Window with Overhang

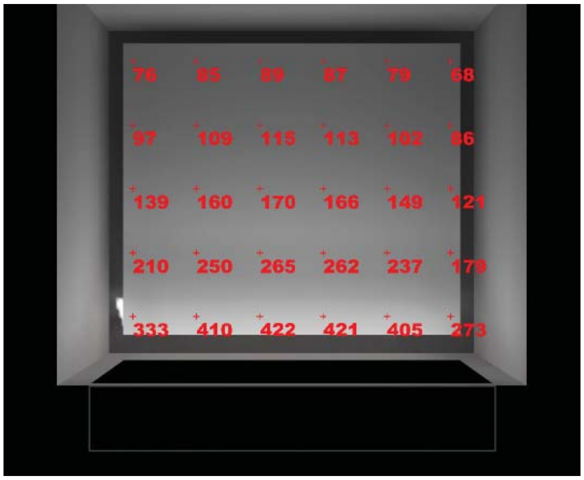
Clear Sky September | **Cloudy Sky** September

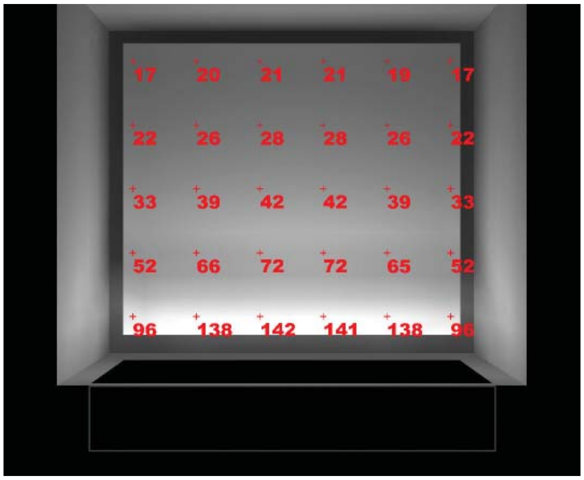
9:00 a.m.



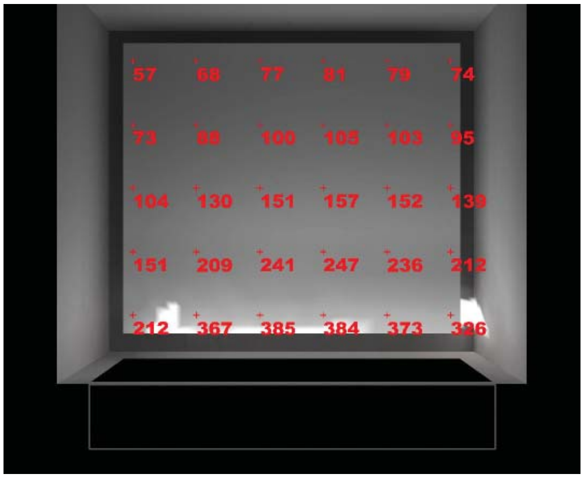


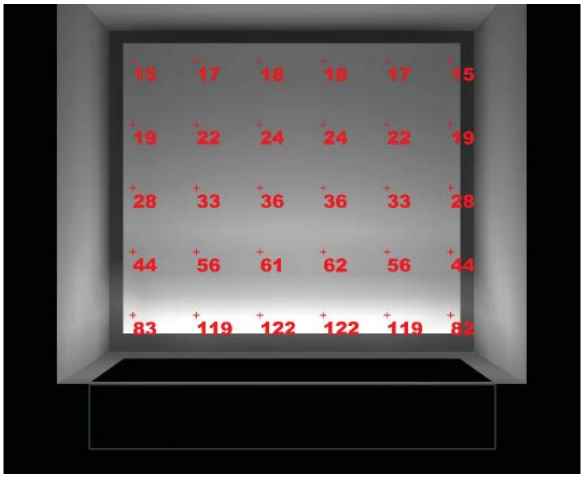
12:00 noon



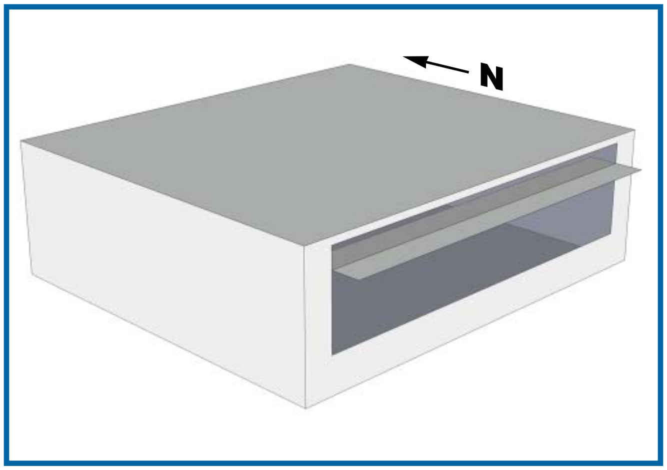


3:00 p.m.

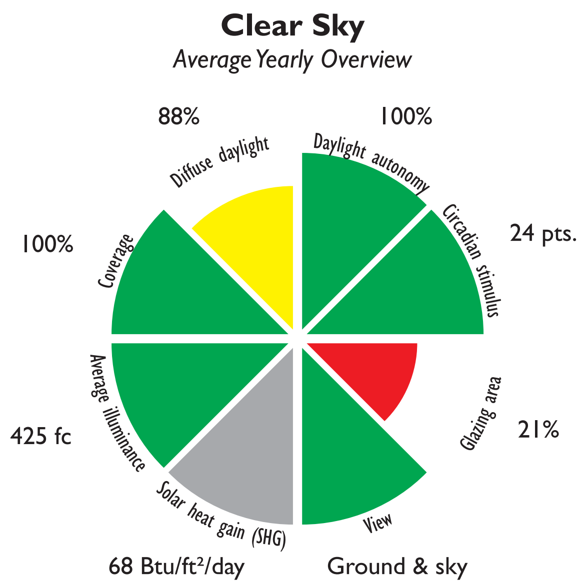


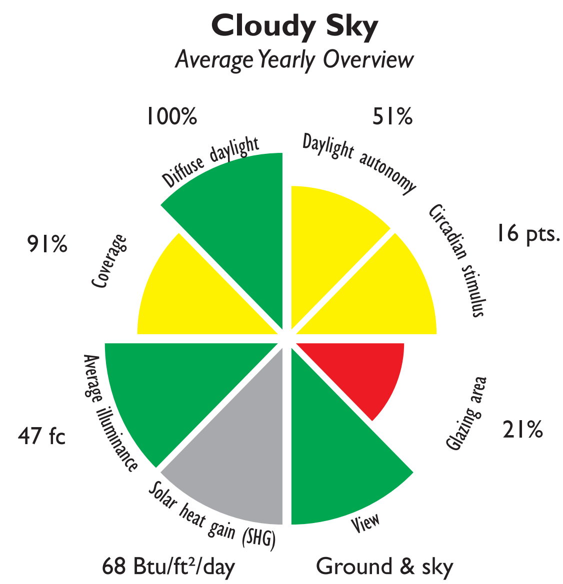


Classroom:
South Large Window with Light Shelf



This pattern divides the 27 ft x 6 ft Large South Window pattern with a 4 ft deep light shelf, located 5 feet above the window sill. Half of the light shelf is inside the classroom; half extends outside as an overhang. It helps to spread the daylight deeper in the space under clear skies while reducing glare and solar heat gain. The upper surface of the light shelf should be white to increase light reflected to the ceiling.





	Clear Sky												Cloudy Sky											
	Mar			Jun			Sep			Dec			Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	214	346	301	140	206	189	181	339	285	610	1800	493	31	59	53	52	77	71	35	61	52	20	35	17
Coverage (%)	100	100	100	100	100	100	100	100	100	100	100	100	93	100	100	100	100	100	93	100	100	60	93	53
Diffuse daylight (%)	97	100	100	100	100	100	100	100	100	60	40	57	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	100	100	100	100	100	100	100	100	100	100	100	100	33	60	60	60	80	73	40	60	60	20	40	20
Circadian stimulus (pts.)	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	1	2	2	0	0	0

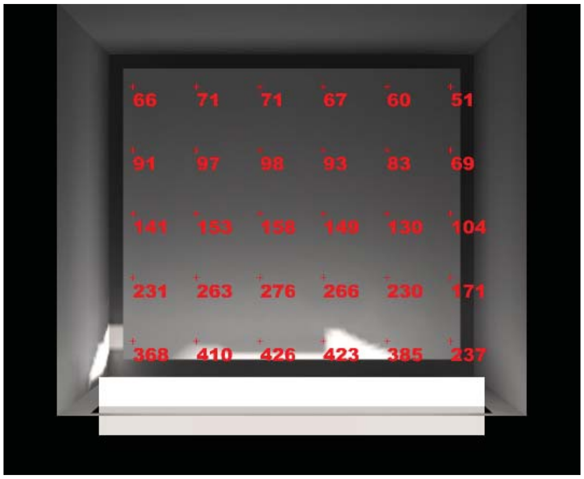
Glazing area: 21%
View: Ground & sky
SHG (Btu/ft²/day): March, 79; June, 54; September, 75; December, 65

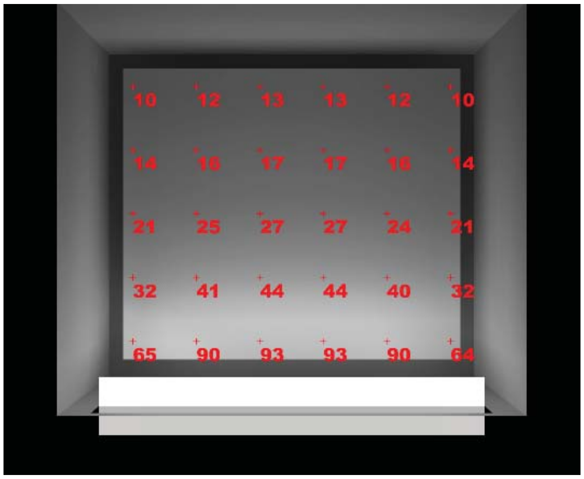
Classroom:

South Large Window with Light Shelf

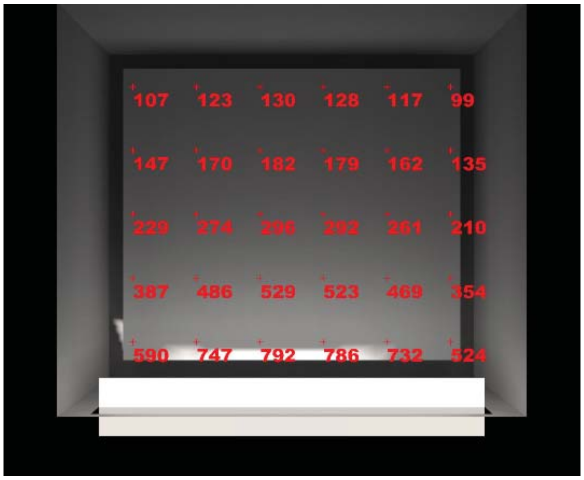
Clear Sky — September | **Cloudy Sky** — September

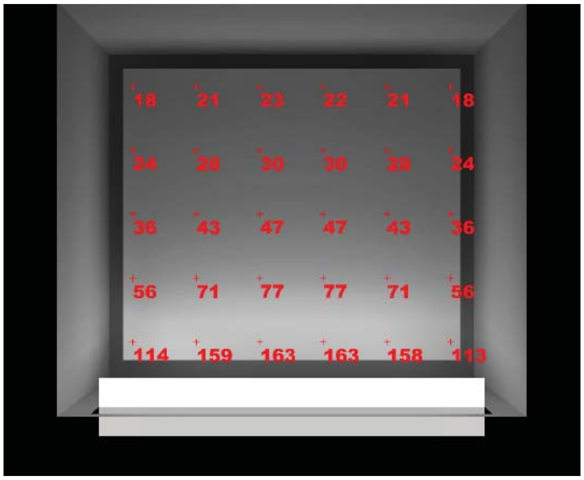
9:00 a.m.



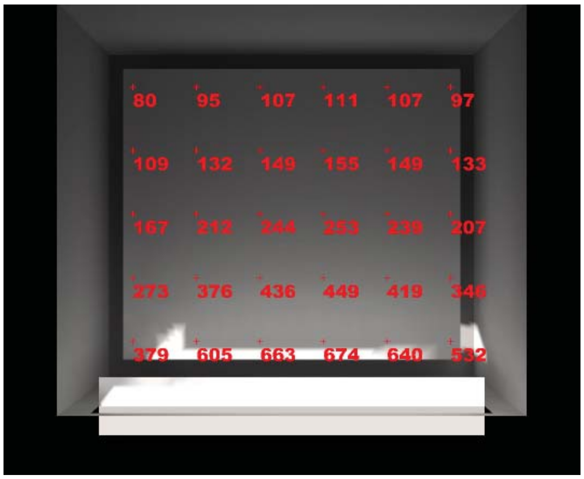


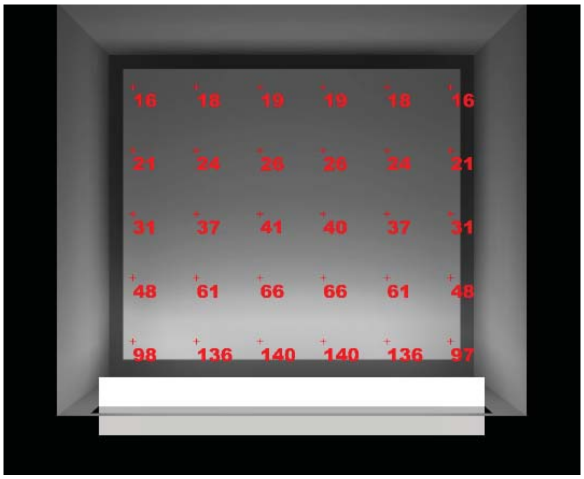
12:00 noon



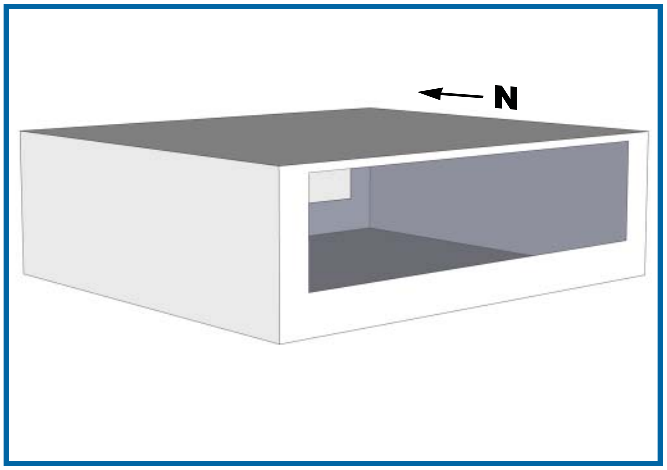


3:00 p.m.

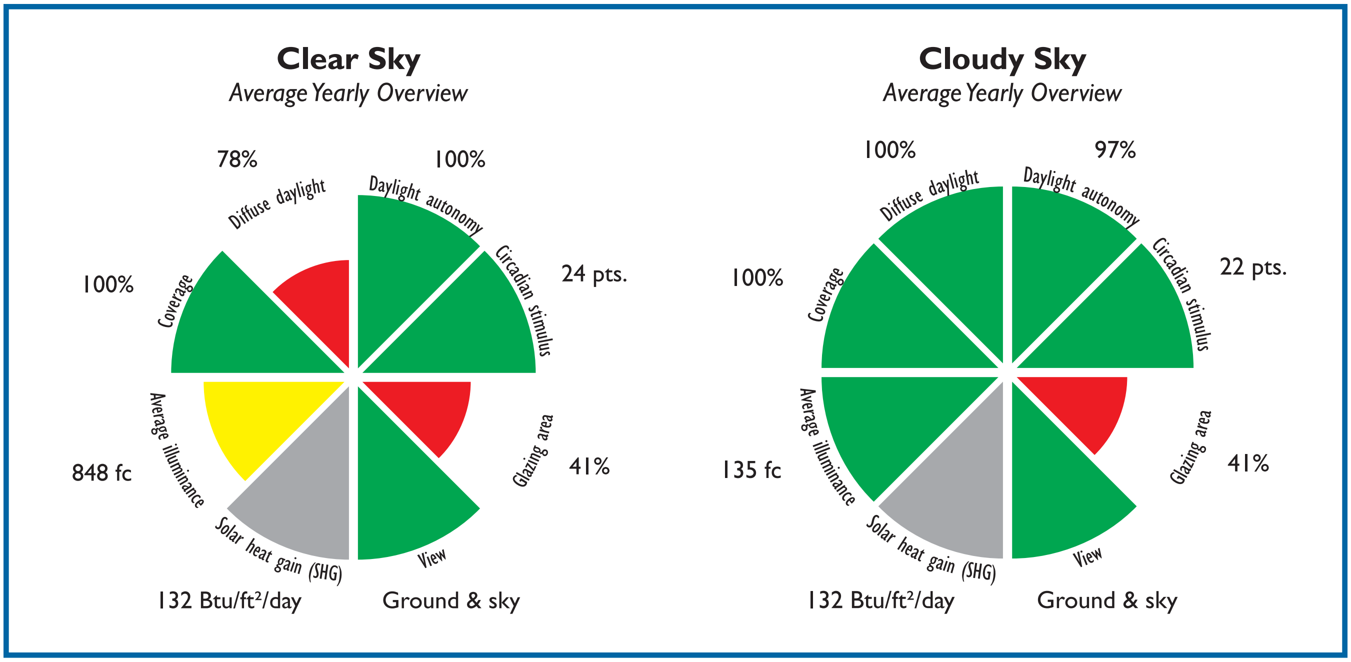




Classroom:
Bilateral Large Windows



This pattern features two 27 ft x 6 ft windows, one north-facing and one south-facing. The energy savings potential, and circadian stimulus are excellent, but at the expense of high solar heat gain, reduction of wall space for educational materials, and glare under clear skies. Blinds, louvers, or shades will be needed to control the direct sun.



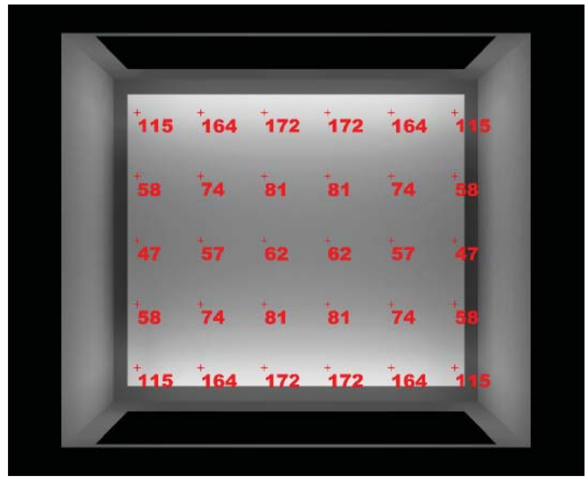
	Clear Sky												Cloudy Sky											
	Mar			Jun			Sep			Dec			Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	482	1293	1141	265	355	331	555	1318	1091	783	1953	609	88	170	154	150	222	204	100	175	150	57	99	48
Coverage (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Diffuse daylight (%)	87	83	83	100	100	100	87	83	83	50	33	50	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	93	100	67
Circadian stimulus (pts.)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	1

Glazing area: 41%
View: Ground & sky
SHG (Btu/ft²/day): March, 141; June, 139; September, 151; December, 96

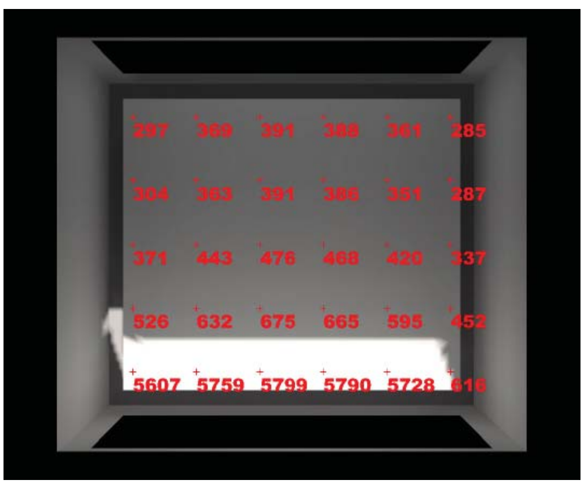
Classroom:
Bilateral Large Windows

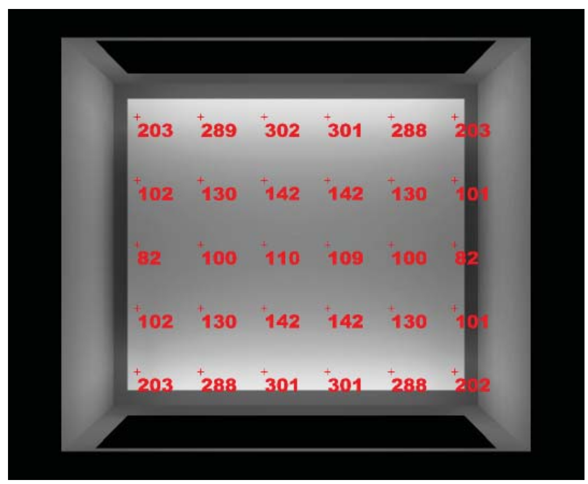
	Clear Sky September	Cloudy Sky September

9:00 a.m.

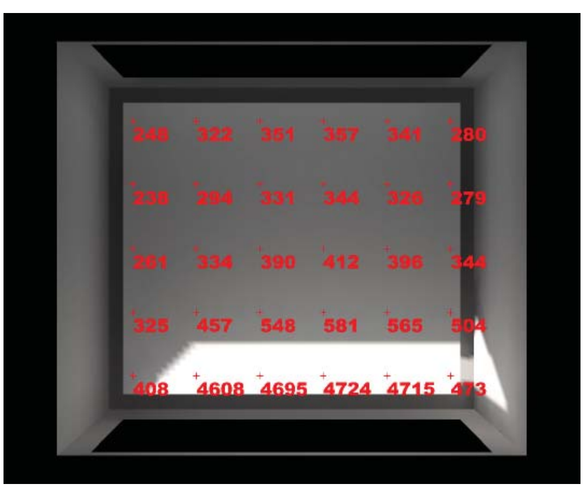


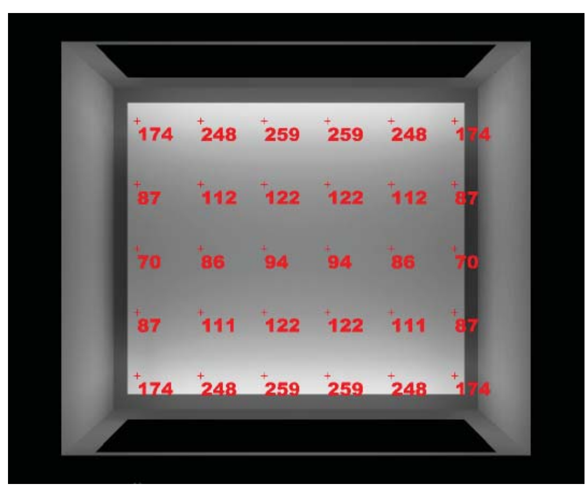
12:00 noon



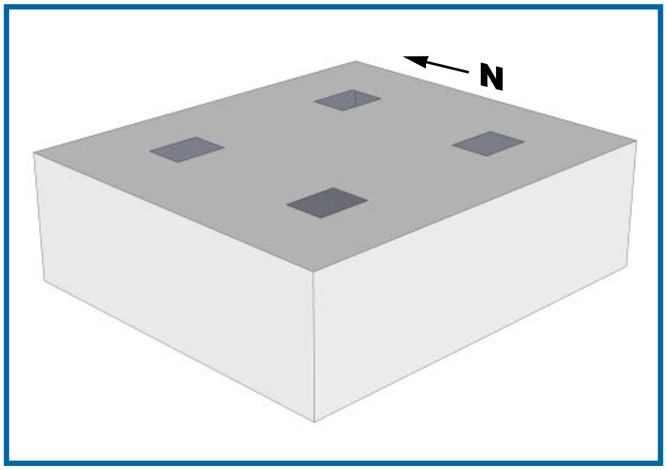


3:00 p.m.

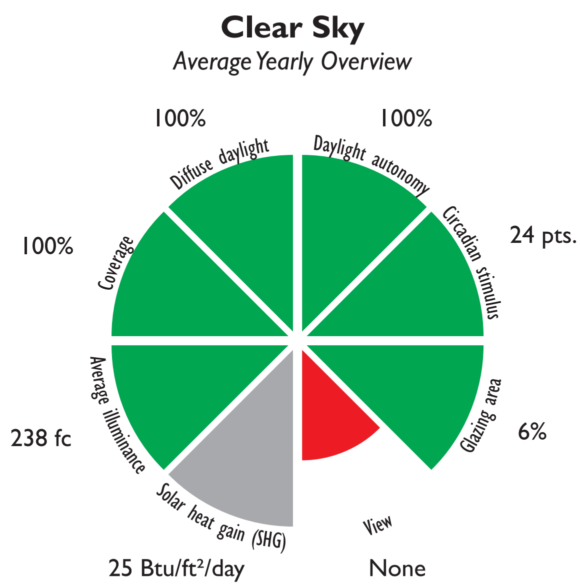


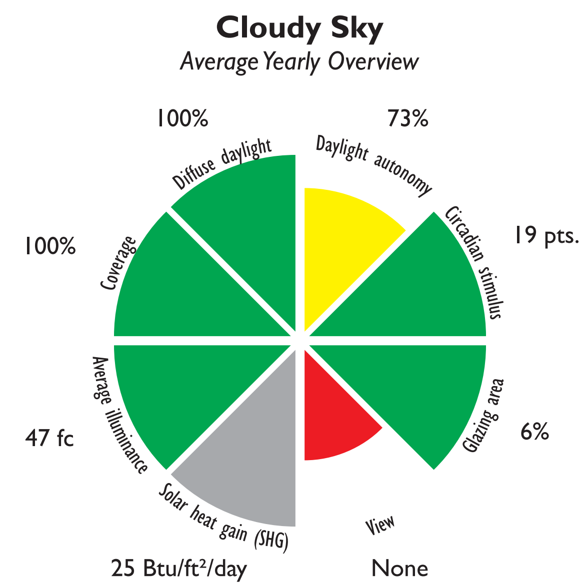


Classroom:
Skylights



This pattern is daylit entirely with four 3 ft x 4 ft skylights. All of the wall space is available for educational materials and glare is controlled by the diffuse glazing of the skylights. Supplementary electric lighting will be needed only during some winter overcast days. The primary drawback is the lack of exterior views.





	Clear Sky											
	Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	140	317	281	263	417	378	163	324	270	78	167	62
Coverage (%)	100	100	100	100	100	100	100	100	100	100	100	100
Diffuse daylight (%)	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	100	100	100	100	100	100	100	100	100	100	100	100
Circadian stimulus (pts.)	2	2	2	2	2	2	2	2	2	2	2	2

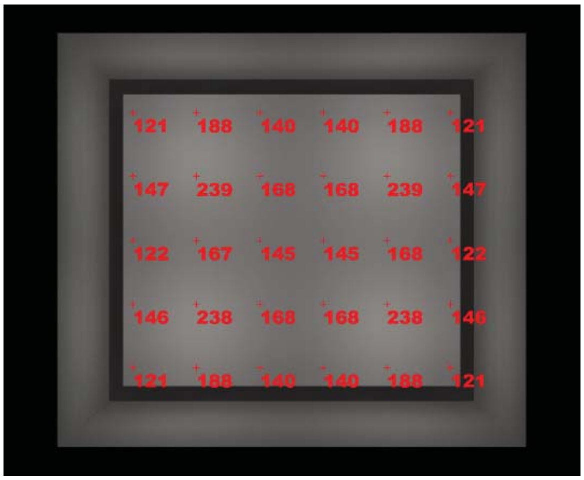
	Cloudy Sky											
	Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	31	60	54	52	78	71	35	61	53	20	35	17
Coverage (%)	100	100	100	100	100	100	100	100	100	100	100	100
Diffuse daylight (%)	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	47	100	100	100	100	100	67	100	100	0	67	0
Circadian stimulus (pts.)	1	2	2	2	2	2	1	2	2	1	1	1

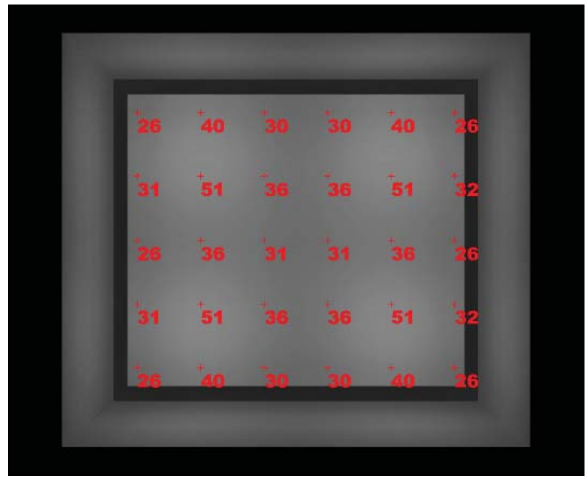
Glazing area: 6%
View: None
SHG (Btu/ft²/day): March, 23; June, 40; September, 28; December, 9

Classroom:
Skylights

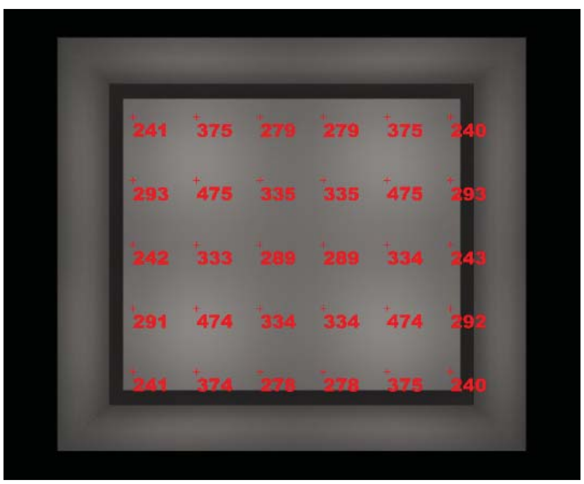
	Clear Sky September	**Cloudy Sky** September

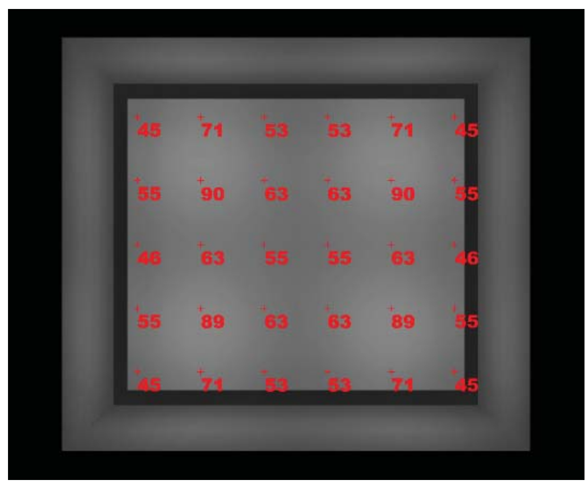
9:00 a.m.



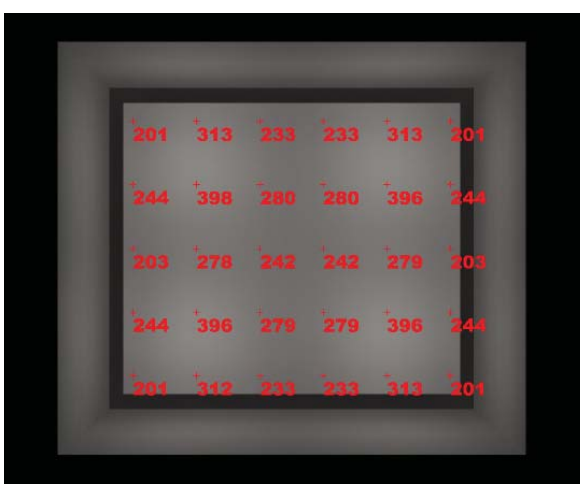


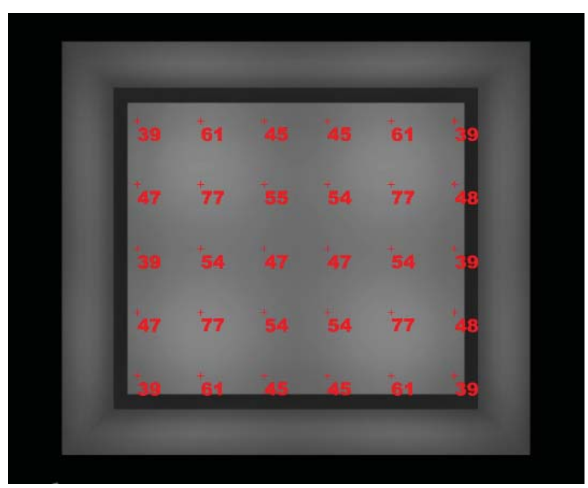
12:00 noon



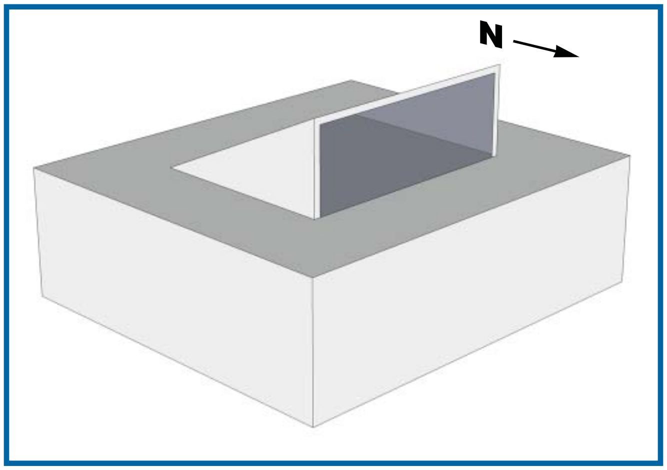


3:00 p.m.

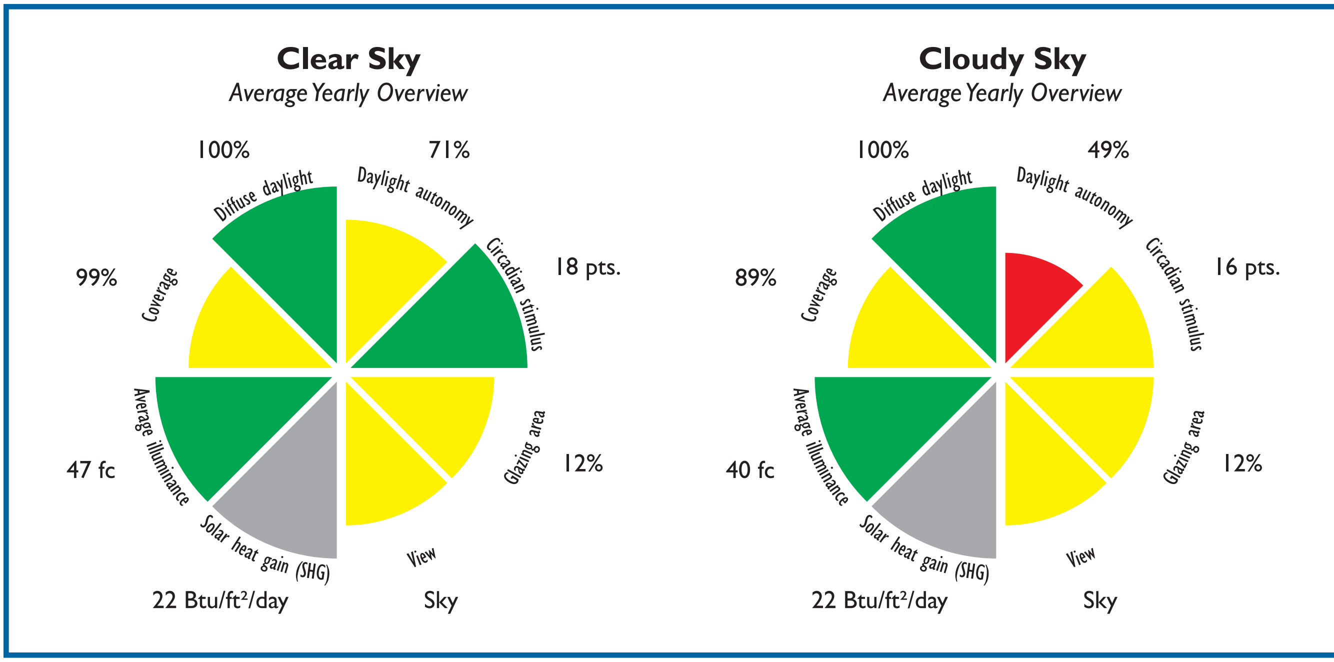




Classroom:
North Roof Monitor



This pattern has a 17 ft x 13 ft opening in the ceiling under a north-facing 16 ft x 6 ft roof monitor. Diffuse light is well distributed throughout the classroom without glare. There is a view of the sky and maximum wall area available for educational materials. Supplementary electric lighting will be needed.



Clear Sky	Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	39	51	49	59	63	62	41	51	48	30	39	28
Coverage (%)	100	100	100	100	100	100	100	100	100	93	100	93
Diffuse daylight (%)	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	60	80	73	87	93	93	67	80	73	40	60	40
Circadian stimulus (pts.)	1	2	2	2	2	2	2	2	2	0	1	0

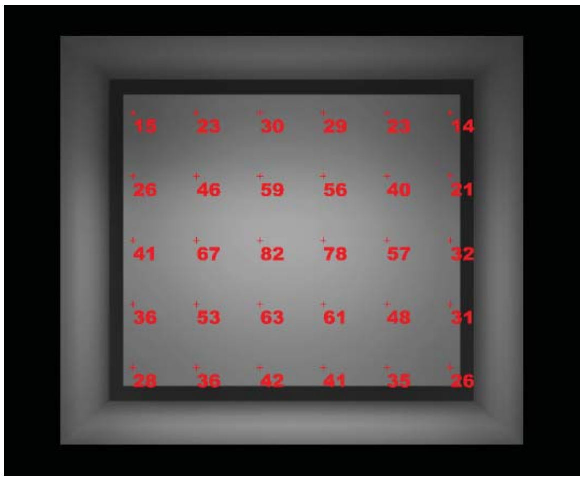
Cloudy Sky	Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	26	50	45	44	65	60	29	52	44	17	29	14
Coverage (%)	83	100	93	93	100	100	87	100	93	67	87	67
Diffuse daylight (%)	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	33	67	67	67	73	73	33	67	67	7	33	7
Circadian stimulus (pts.)	1	2	2	2	2	2	1	2	2	0	0	0

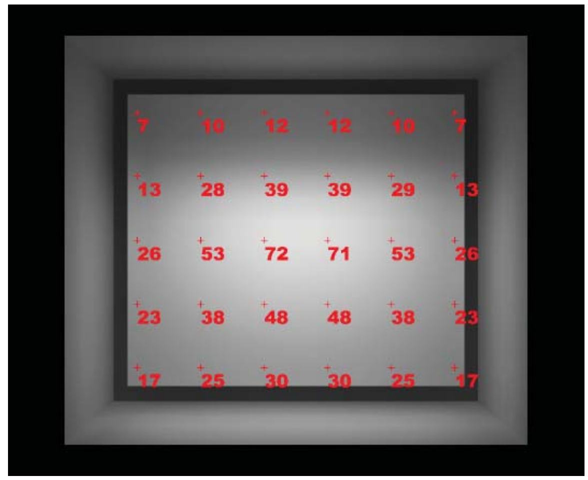
Glazing area: 12%
View: Sky
SHG (Btu/ft²/day): March, 21; June, 36; September, 22; December, 10

Classroom:
North Roof Monitor

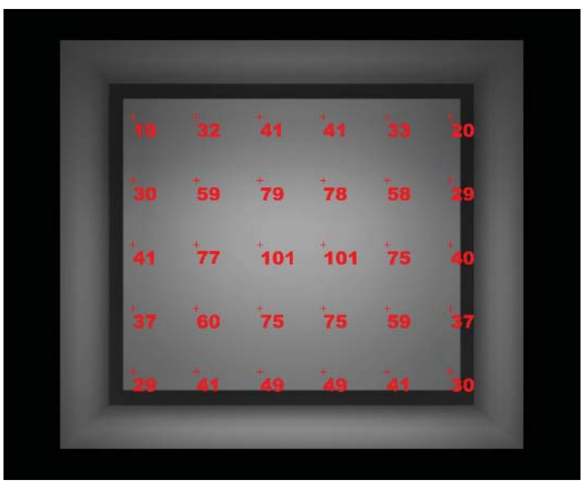
	Clear Sky September	Cloudy Sky September

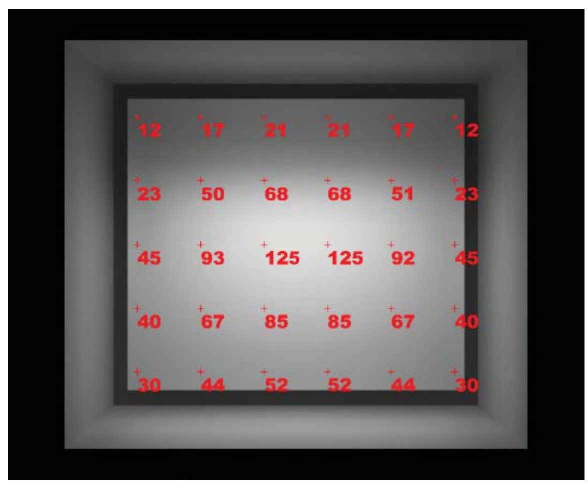
9:00 a.m.



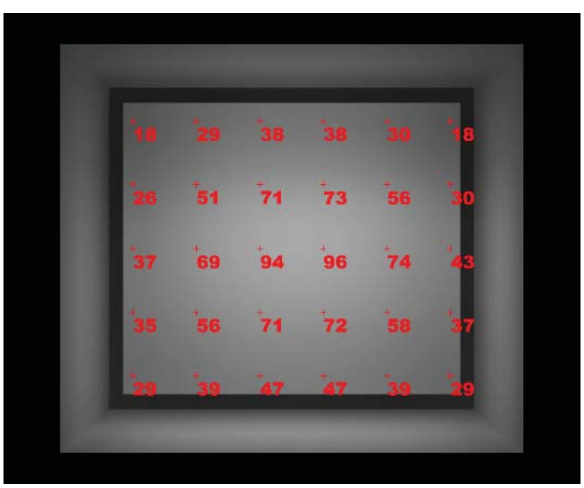


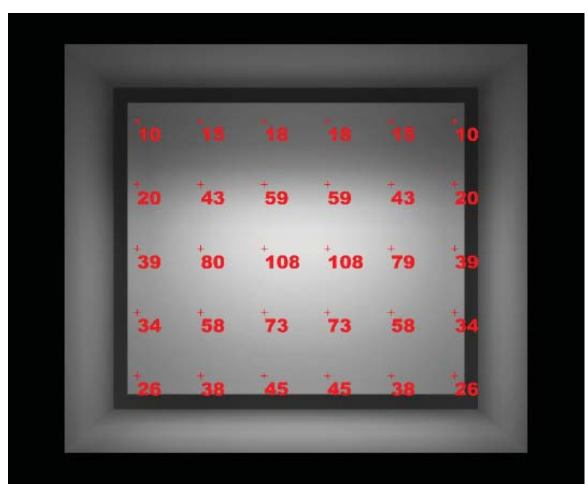
12:00 noon



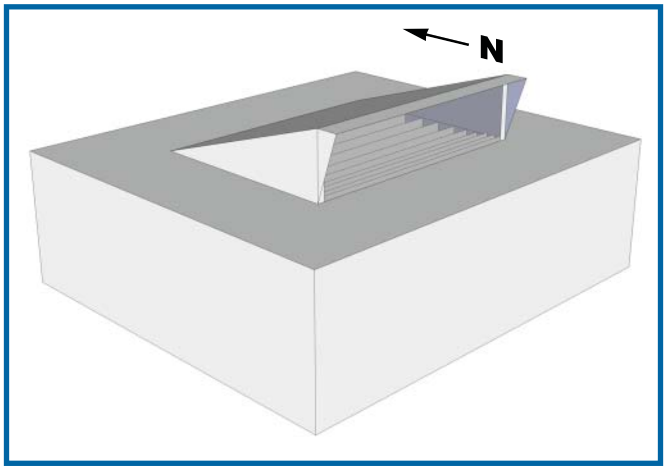


3:00 p.m.

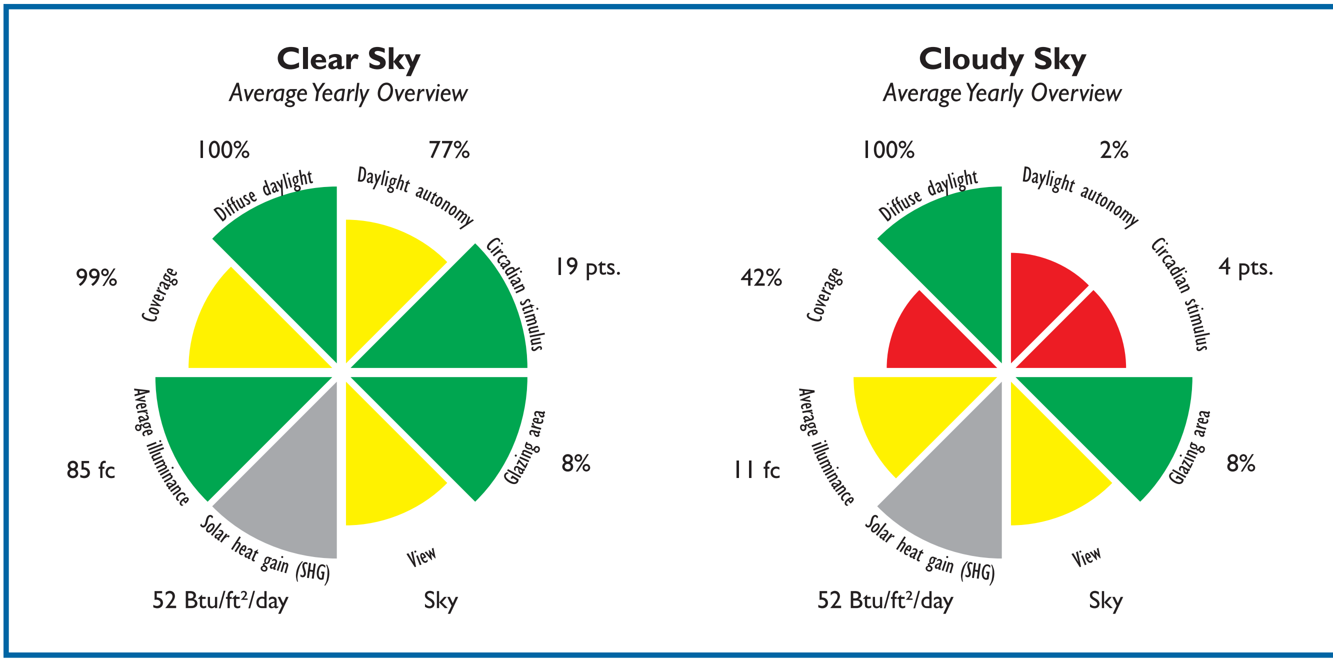




Classroom:
South Roof Monitor with Baffles



This pattern has a 17 ft x 13 ft opening in the ceiling under a south facing 16 ft x 4 ft roof monitor. The monitor includes a 2 ft overhang and fixed baffles at the ceiling level. With only 2/3 of the glass area of the North Roof Monitor pattern, it provides more light and energy savings potential under clear skies, but much less under overcast skies. The baffles are effective at eliminating direct sun. Electric lights will be needed to supplement daylight when the skies are overcast.



Clear Sky

	Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	49	117	104	24	33	30	54	150	100	100	192	73
Coverage (%)	100	100	100	93	100	100	100	100	100	100	100	100
Diffuse daylight (%)	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	63	100	97	30	47	37	70	100	97	97	100	90
Circadian stimulus (pts.)	2	2	2	1	1	1	2	2	2	1	2	1

Cloudy Sky

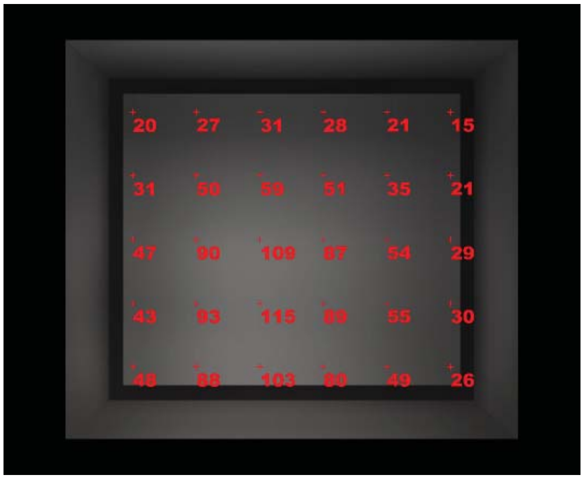
	Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	7	14	13	13	19	17	8	15	13	5	8	4
Coverage (%)	13	60	53	53	80	73	33	60	53	0	30	0
Diffuse daylight (%)	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	0	0	0	0	13	7	0	0	0	0	0	0
Circadian stimulus (pts.)	0	1	0	0	1	1	0	1	0	0	0	0

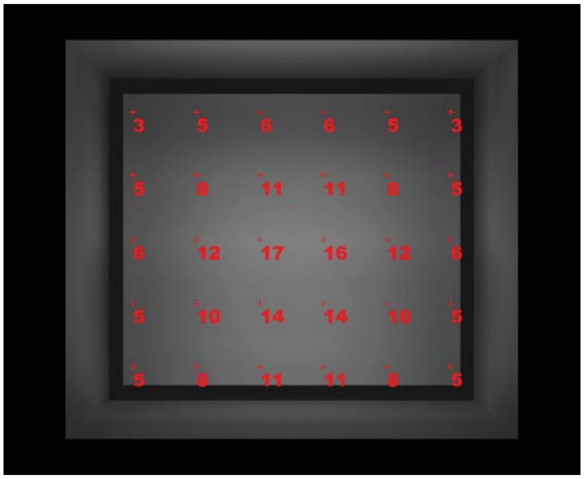
Glazing area: 8%
View: Sky
SHG (Btu/ft²/day): March, 59; June, 43; September, 63; December, 44

Classroom:
South Roof Monitor with Baffles

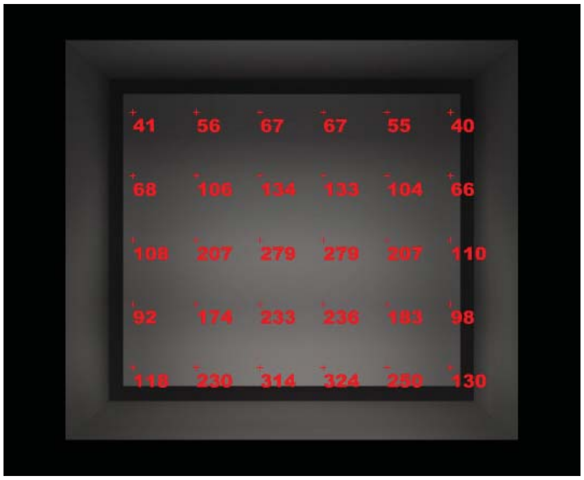
	Clear Sky September	Cloudy Sky September

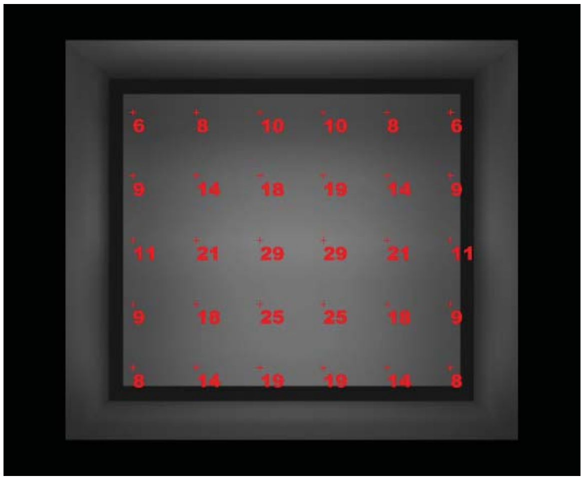
9:00 a.m.



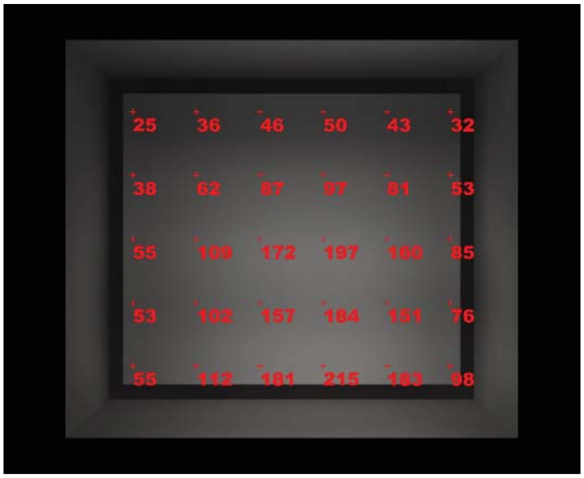


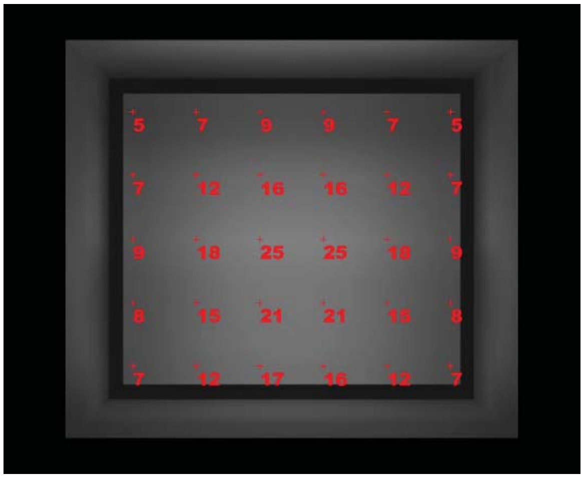
12:00 noon



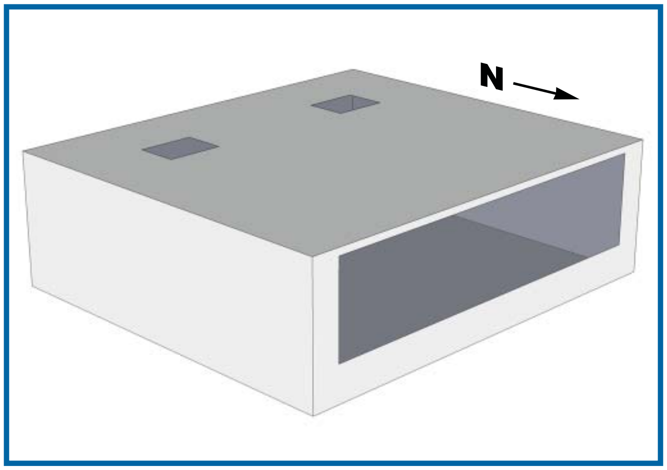


3:00 p.m.

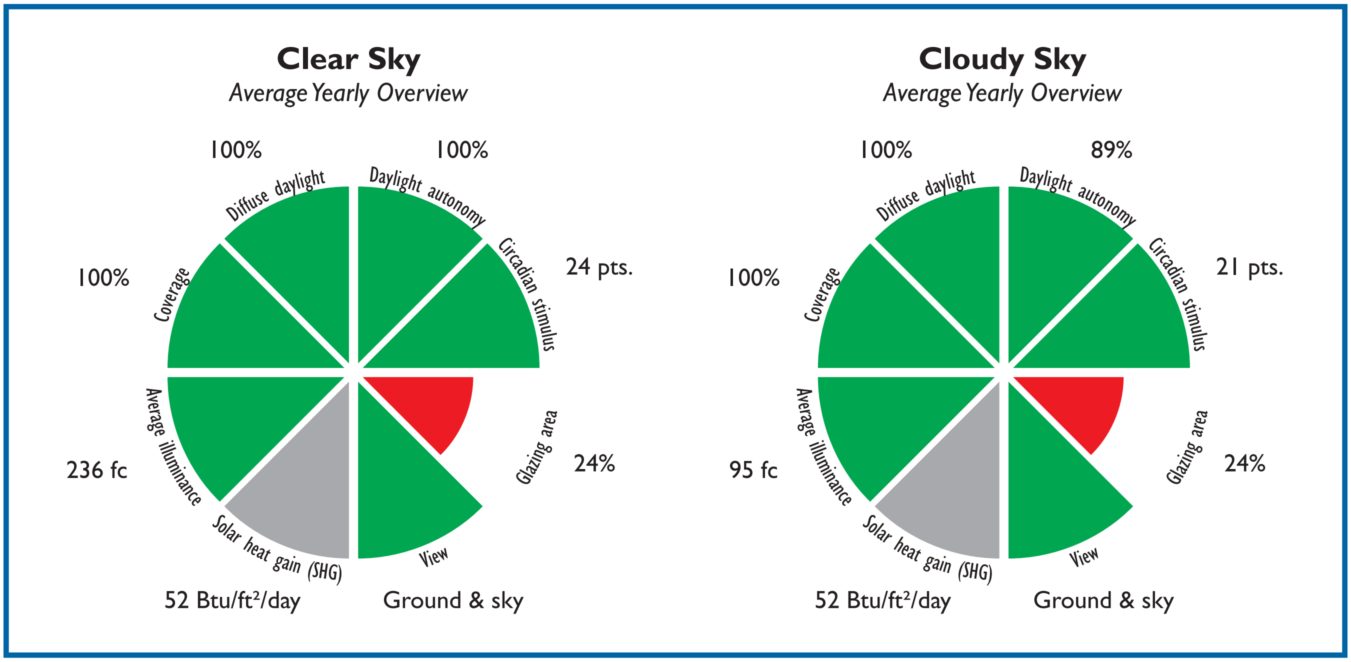




Classroom:
North Large Window + Skylights



This pattern features two 3 ft x 4 ft diffusing skylights added to the south half of the Large North Window pattern. The skylights add enough light for high potential energy savings under all sky conditions. Blinds, or louvers, or shades should not be needed.



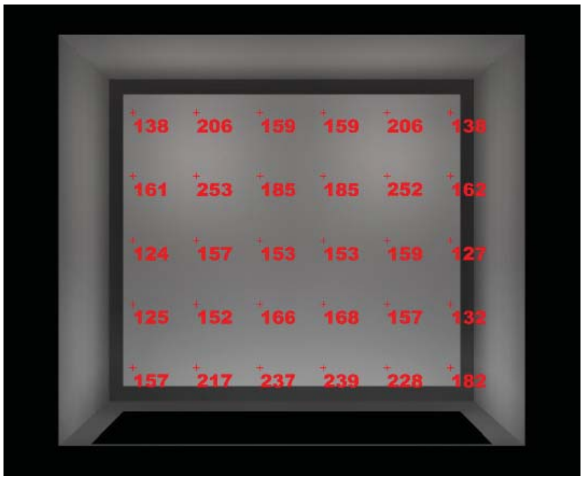
	Clear Sky												Cloudy Sky											
	Mar			Jun			Sep			Dec			Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	158	283	258	265	362	337	175	288	251	105	174	174	91	116	105	102	152	139	68	120	103	39	68	33
Coverage (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Diffuse daylight (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	40	100	33
Circadian stimulus (pts.)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1

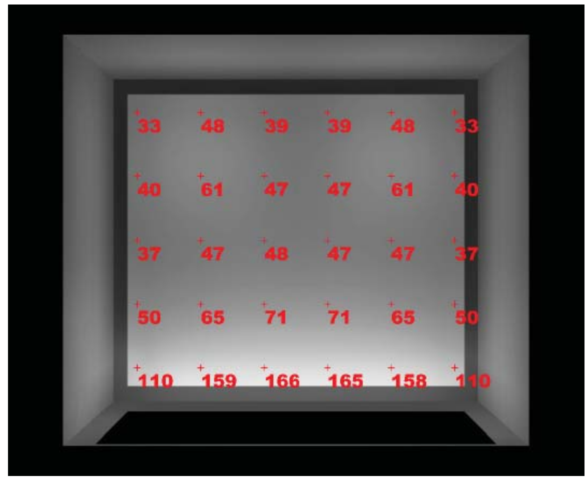
Glazing area: 24%
View: Ground & sky
SHG (Btu/ft²/day): March, 49; June, 83; September, 53; December, 22

Classroom:
North Large Window + Skylights

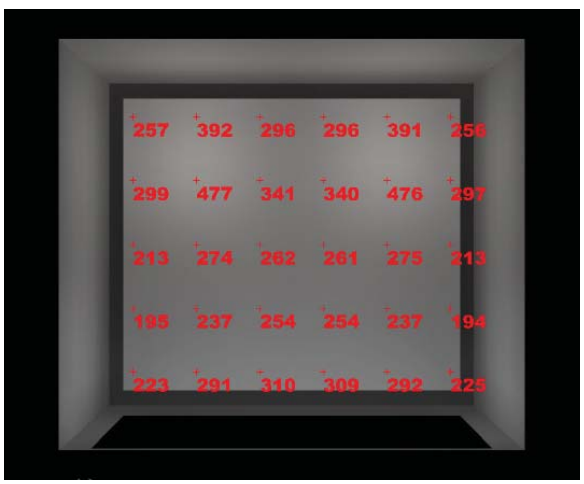
	Clear Sky September	Cloudy Sky September

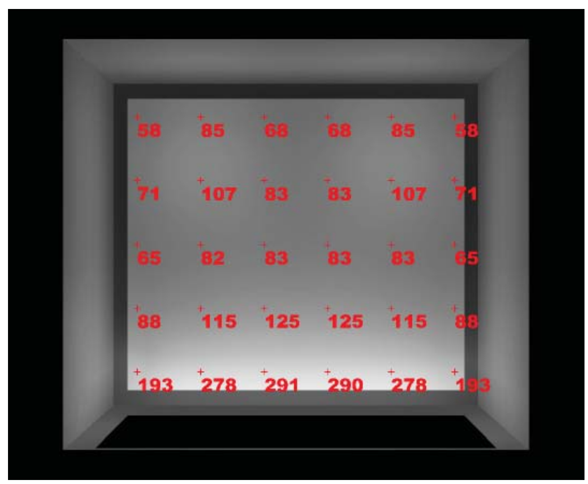
9:00 a.m.



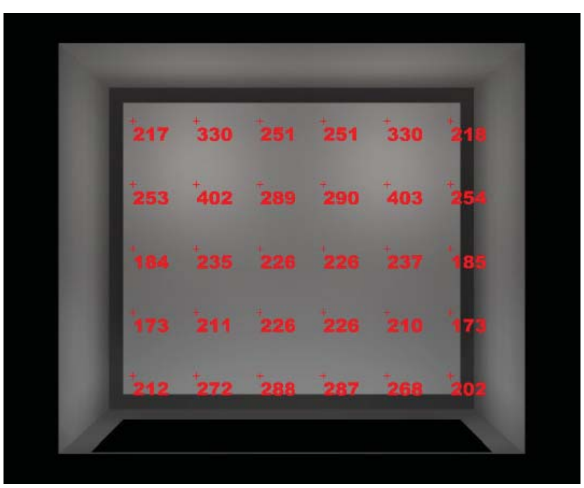


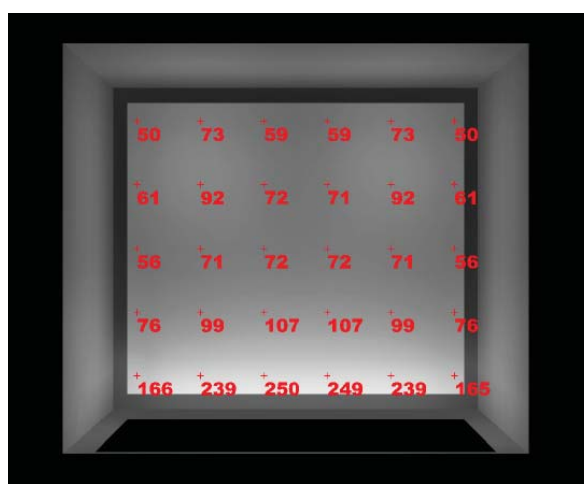
12:00 noon



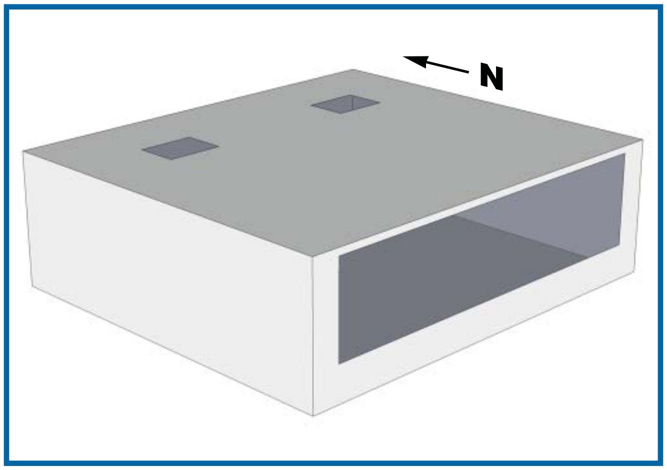


3:00 p.m.

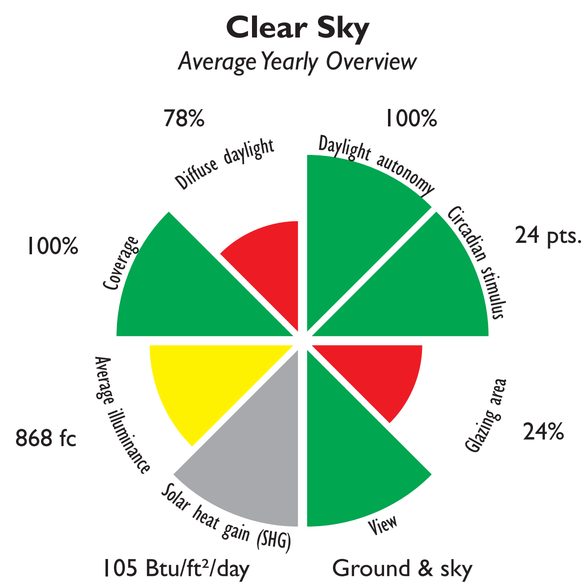


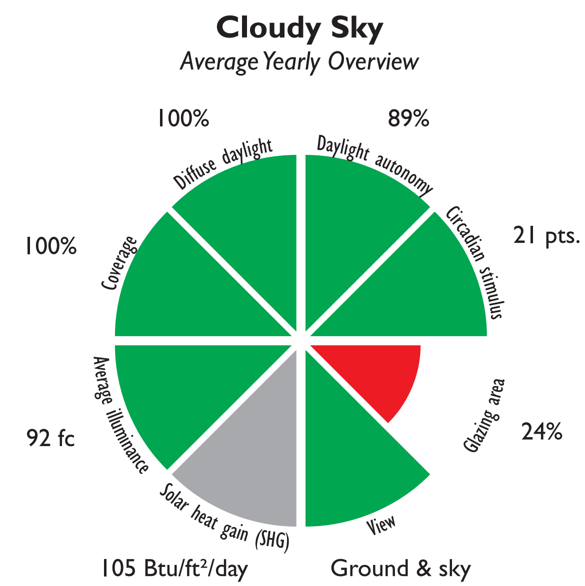


Classroom:
South Large Window + Skylights



This pattern features two 3 ft x 4 ft diffusing skylights added to the north half of the Large South Window pattern. The classroom is daylit very well under overcast skies yielding high energy savings potential. However, the large south window will need blinds, louvers, or shades to reduce glare under clear skies.





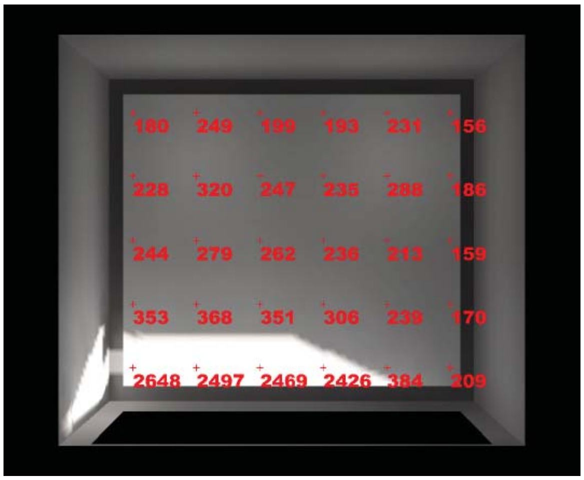
	Clear Sky												Cloudy Sky											
	Mar			Jun			Sep			Dec			Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	471	1341	1175	269	418	379	551	1366	1121	769	1964	591	60	116	105	102	152	139	68	120	103	39	68	33
Coverage (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Diffuse daylight (%)	87	83	83	100	100	100	87	83	83	50	27	50	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	100	100	100	100	100	100	100	100	100	100	100	100	93	100	100	100	100	100	100	100	100	40	100	33
Circadian stimulus (pts.)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1

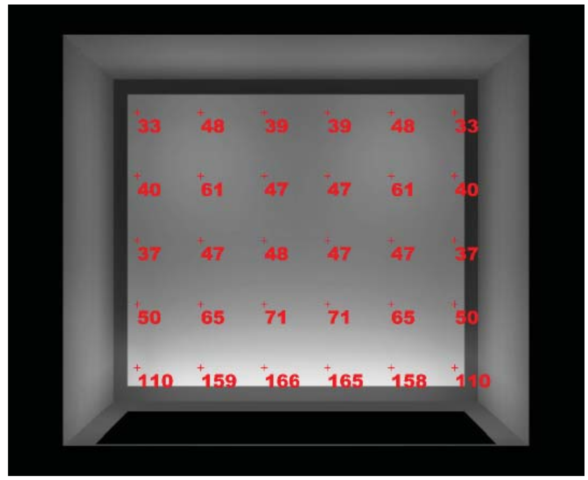
Glazing area: 24%
View: Ground & sky
SHG (Btu/ft²/day): March, 116; June, 96; September, 125; December, 83

Classroom:
South Large Window + Skylights

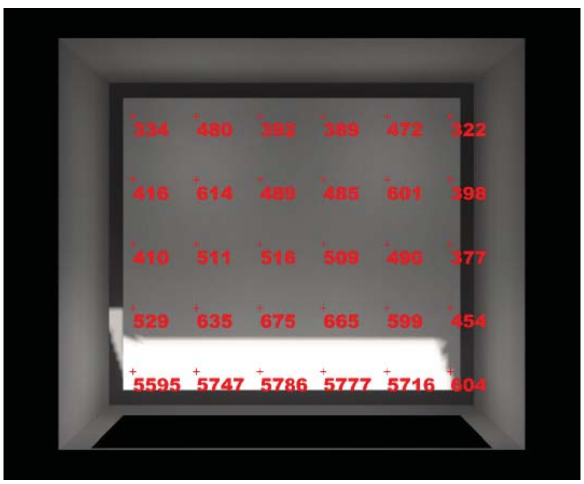
	Clear Sky September	Cloudy Sky September

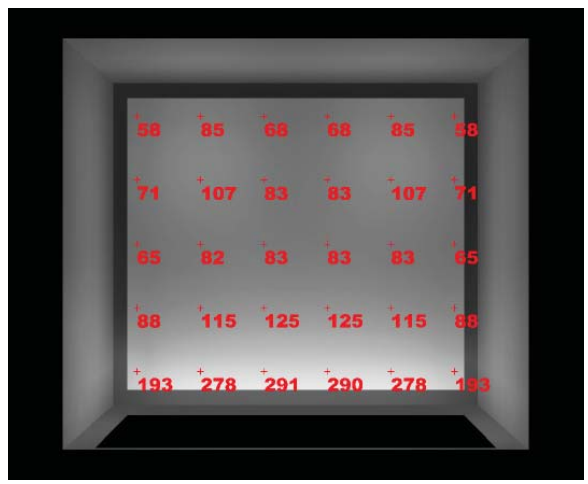
9:00 a.m.



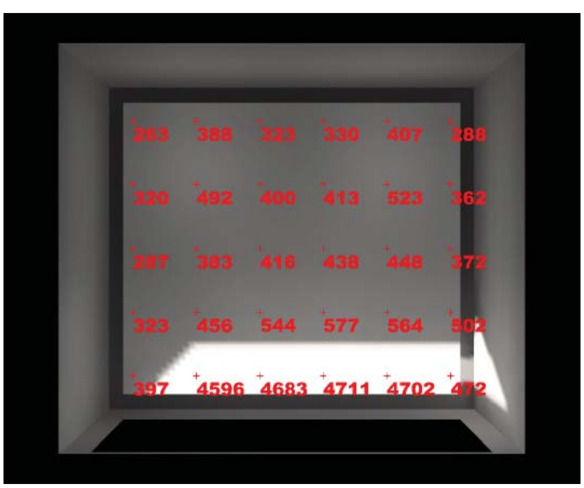


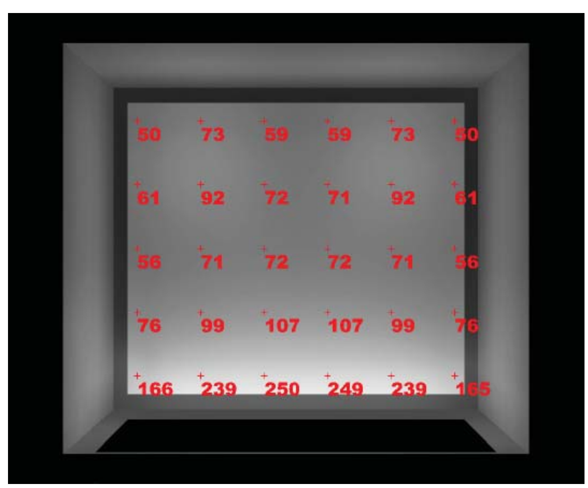
12:00 noon



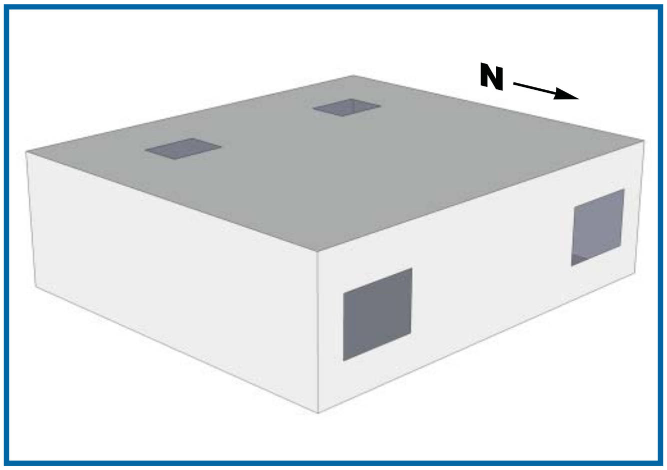


3:00 p.m.



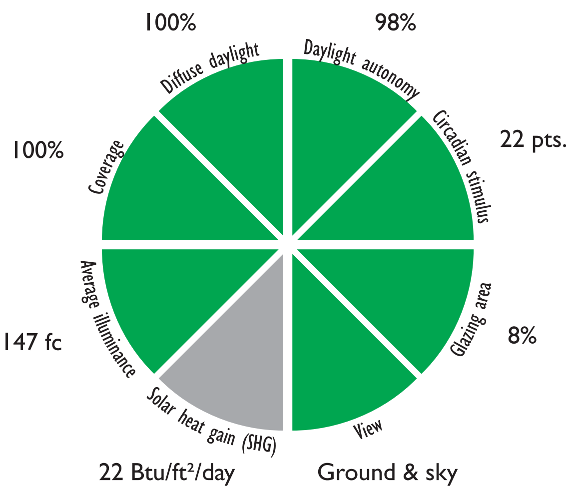


Classroom:
North Small Windows + Skylights

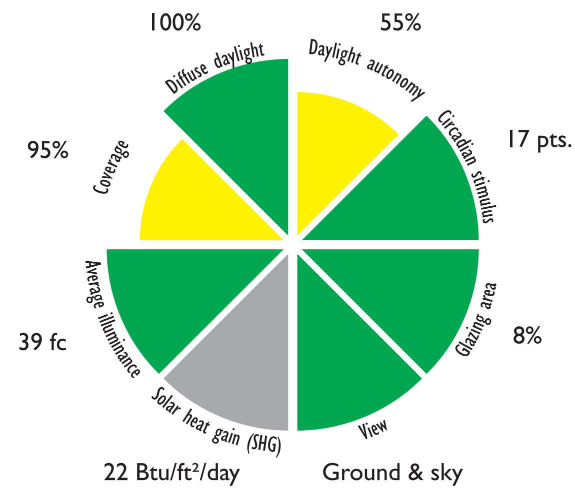


This pattern features two 6 ft x 4 ft north-facing windows and two 3 ft x 4 ft diffusing skylights over the south half of the classroom. The small amount of glazing affords a view and wall space for educational materials. Blinds, or louvers, or shades should not be needed. There is a high potential for energy savings, especially under clear sky conditions.

Clear Sky
Average Yearly Overview



Cloudy Sky
Average Yearly Overview



Clear Sky

	Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	92	191	171	165	248	227	105	195	165	56	107	47
Coverage (%)	100	100	100	100	100	100	100	100	100	100	100	100
Diffuse daylight (%)	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	100	100	100	100	100	100	100	100	100	93	100	83
Circadian stimulus (pts.)	2	2	2	2	2	2	2	2	2	1	2	1

Cloudy Sky

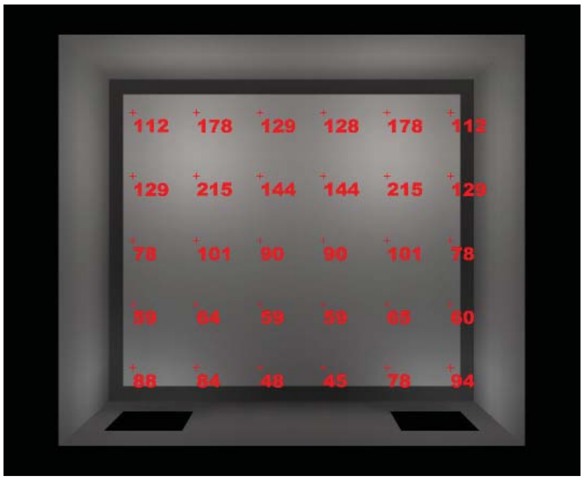
	Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	25	49	44	43	64	59	29	51	43	16	29	14
Coverage (%)	100	100	100	100	100	100	100	100	100	80	100	60
Diffuse daylight (%)	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	27	87	67	67	93	93	33	87	67	7	33	0
Circadian stimulus (pts.)	1	2	2	2	2	2	1	2	2	0	1	0

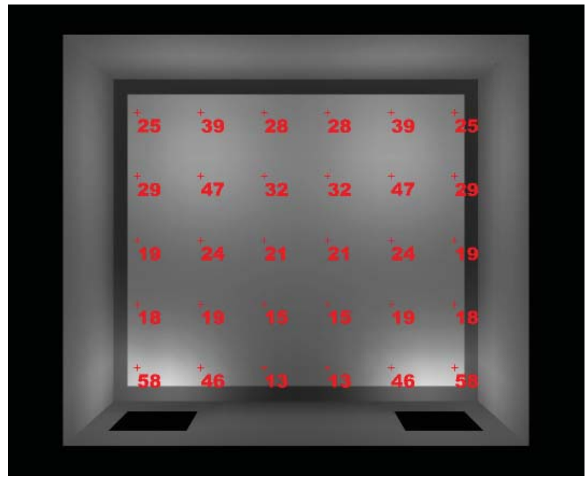
Glazing area: 8%
View: Ground & sky
SHG (Btu/ft²/day): March, 21; June, 35; September, 24; December, 9

Classroom:
North Small Windows + Skylights

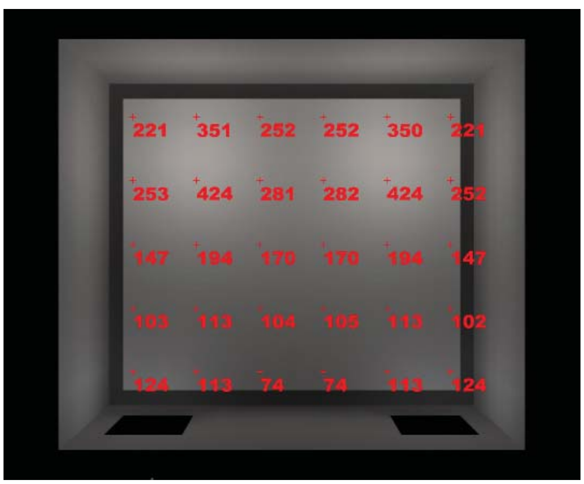
	Clear Sky September	Cloudy Sky September

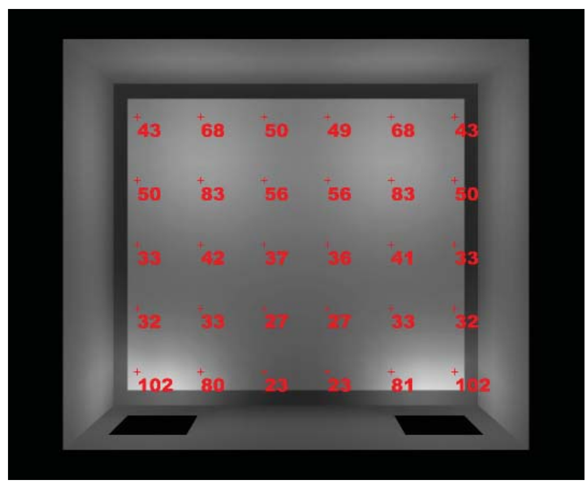
9:00 a.m.



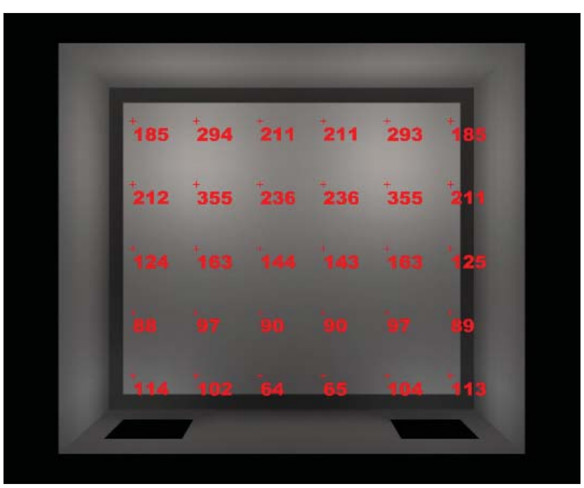


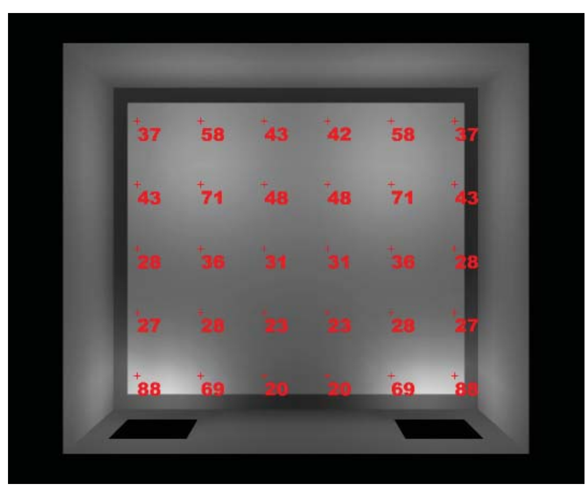
12:00 noon



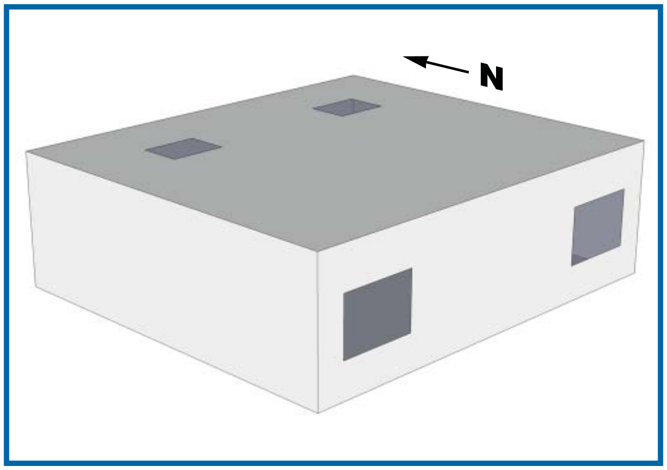


3:00 p.m.



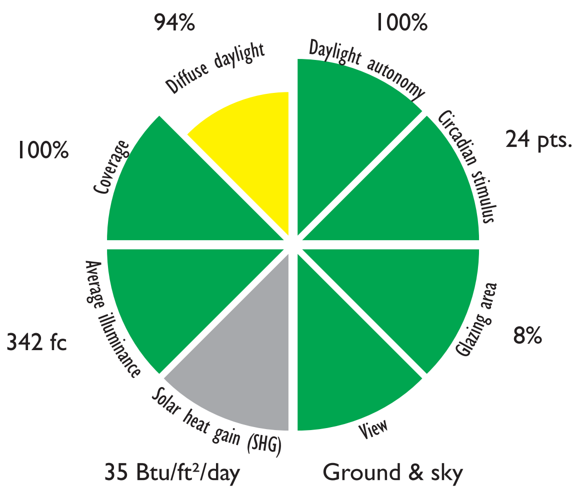


Classroom:
South Small Windows + Skylights

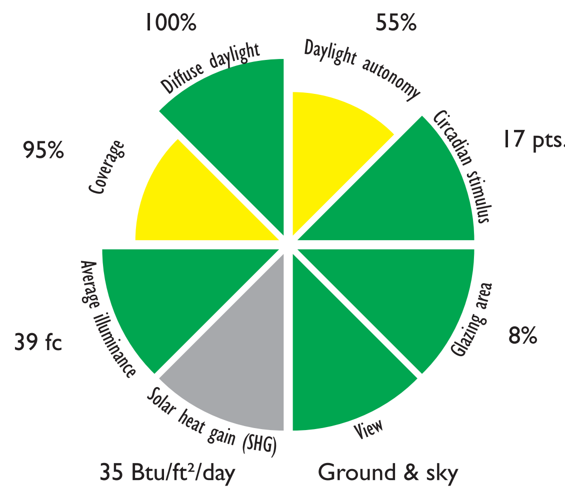


This pattern features two 6 ft x 4 ft south-facing windows and two 3 ft x 4 ft diffusing skylights over the north half of the classroom. The small amount of glazing affords a view and wall space for educational materials. Blinds, or louvers, or shades will be needed on the south windows to prevent glare. There is a high potential for energy savings, especially under clear sky conditions.

Clear Sky
Average Yearly Overview



Cloudy Sky
Average Yearly Overview



Clear Sky

	Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	169	565	496	166	261	237	197	577	473	202	588	179
Coverage (%)	100	100	100	100	100	100	100	100	100	100	100	100
Diffuse daylight (%)	97	93	93	100	100	100	97	93	93	90	83	87
Daylight autonomy (%)	100	100	100	100	100	100	100	100	100	100	100	100
Circadian stimulus (pts.)	2	2	2	2	2	2	2	2	2	2	2	2

Cloudy Sky

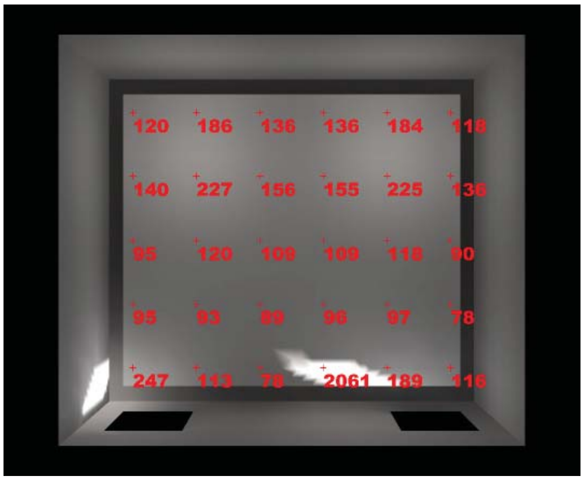
	Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	25	49	44	43	64	59	29	51	43	16	29	14
Coverage (%)	100	100	100	100	100	100	100	100	100	80	100	60
Diffuse daylight (%)	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	27	87	67	67	93	93	33	87	67	7	33	0
Circadian stimulus (pts.)	1	2	2	2	2	2	1	2	2	0	1	0

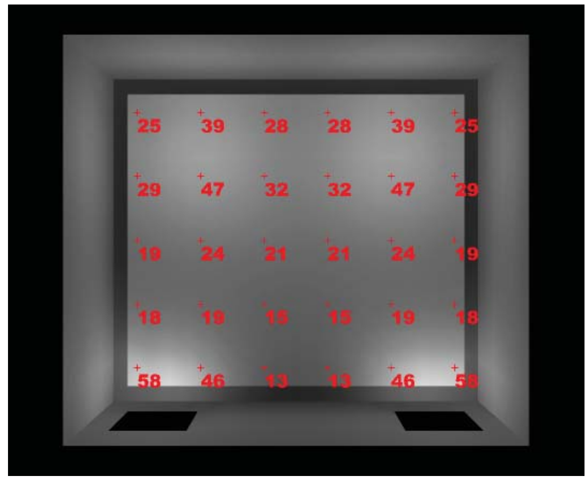
Glazing area: 8%
View: Ground & sky
SHG (Btu/ft²/day): March, 37; June, 38; September, 41; December, 24

Classroom:
South Small Windows + Skylights

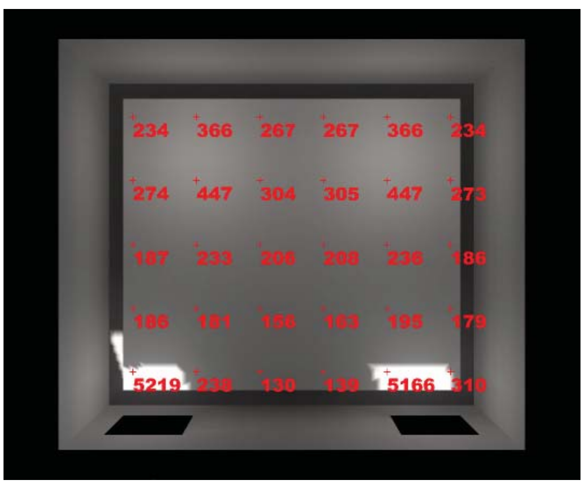
	Clear Sky September	**Cloudy Sky** September

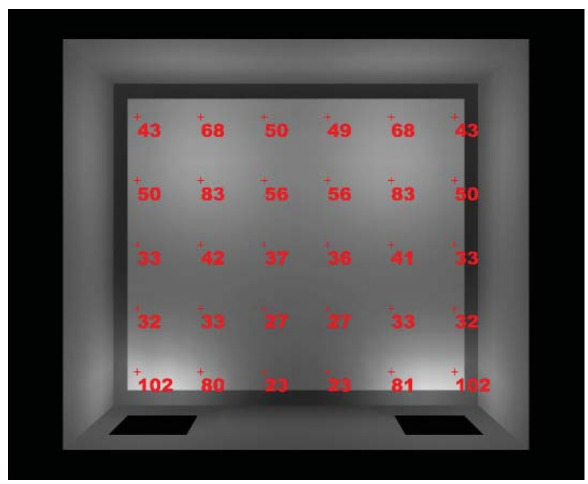
9:00 a.m.



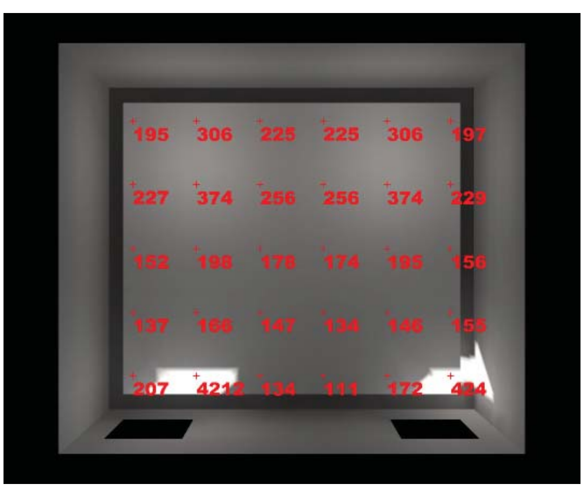


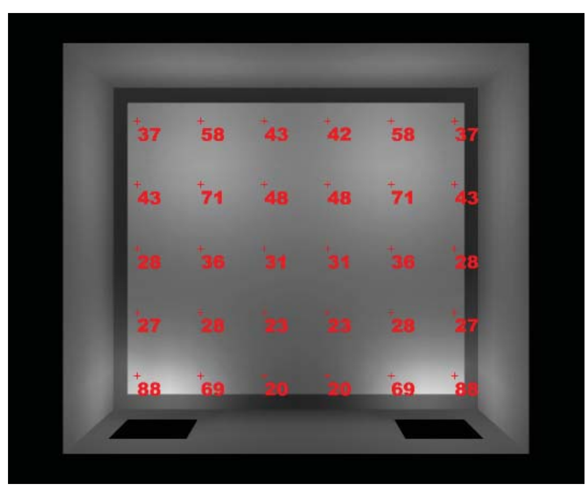
12:00 noon



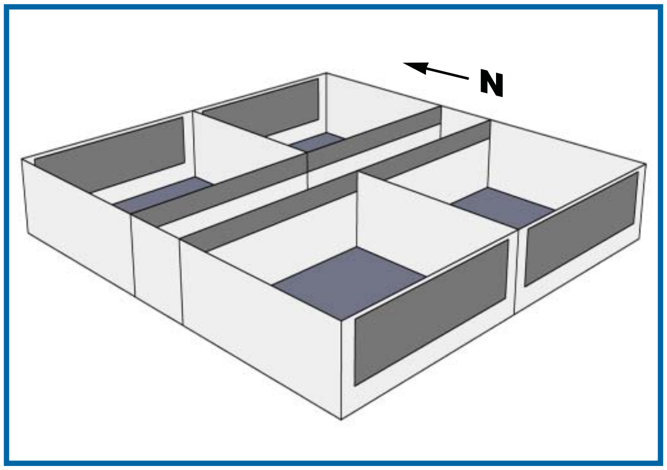


3:00 p.m.

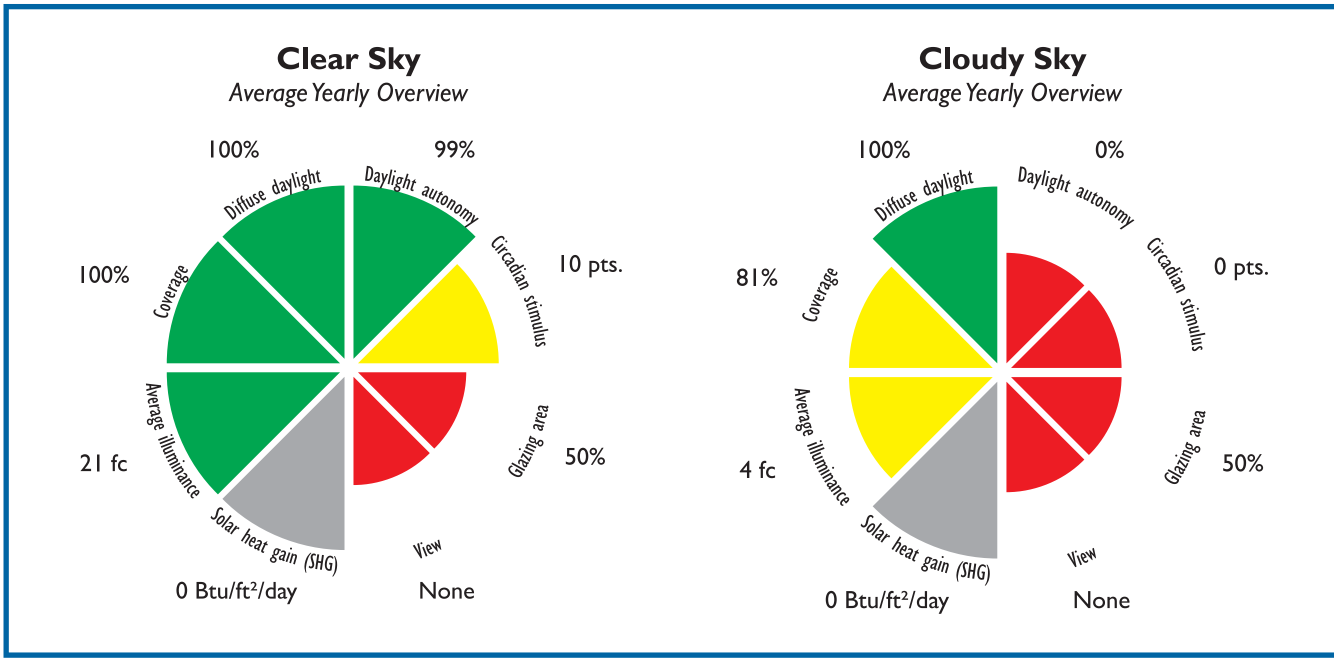




Corridor:
Clerestory Windows



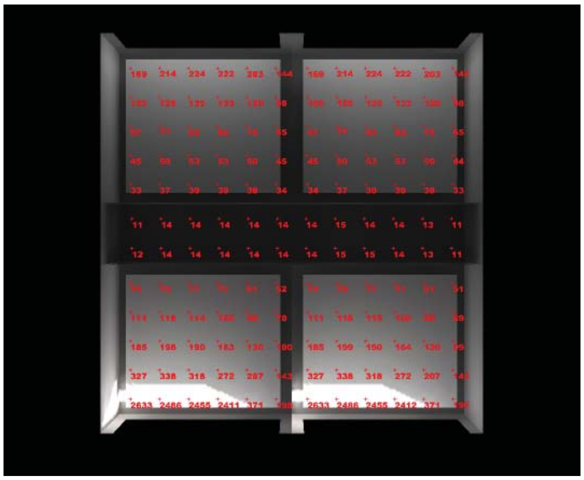
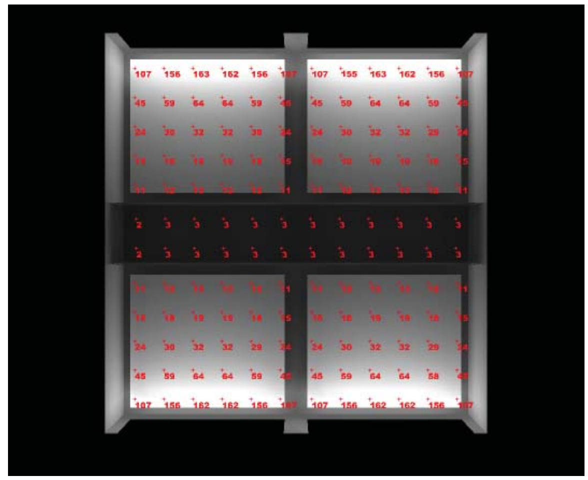
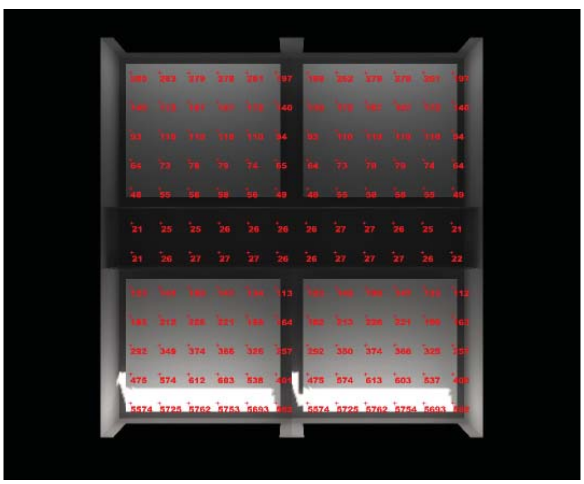
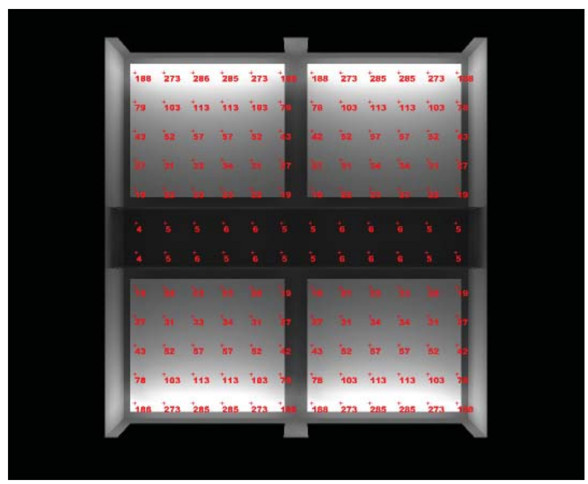
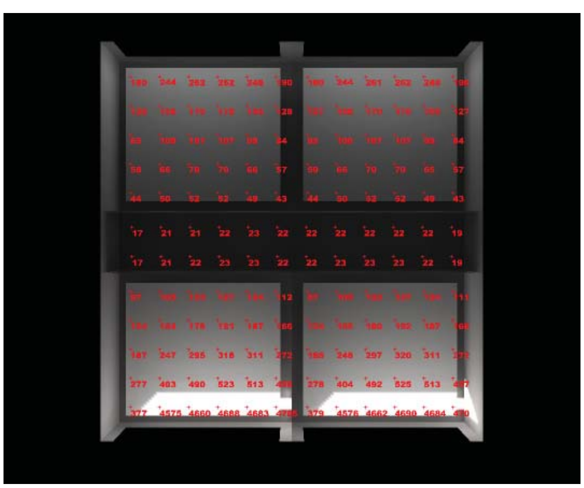
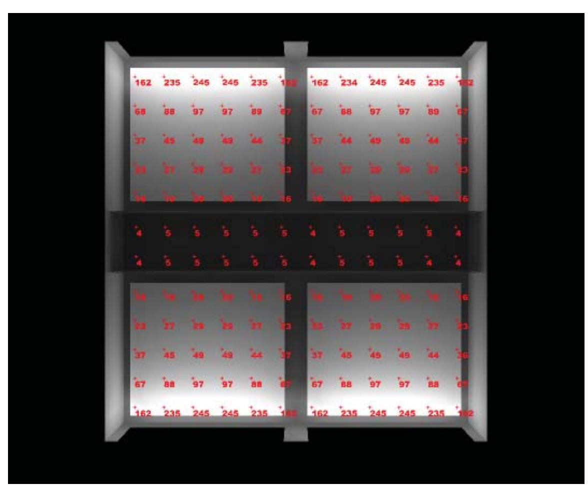
This pattern uses continuous 3 ft tall interior clerestory windows between the corridor and the classrooms. The corridor "borrows" enough daylight from the classroom to allow the corridor electric lights to be turned off most of the time under clear skies, but supplementary electric lighting will be needed under overcast skies.



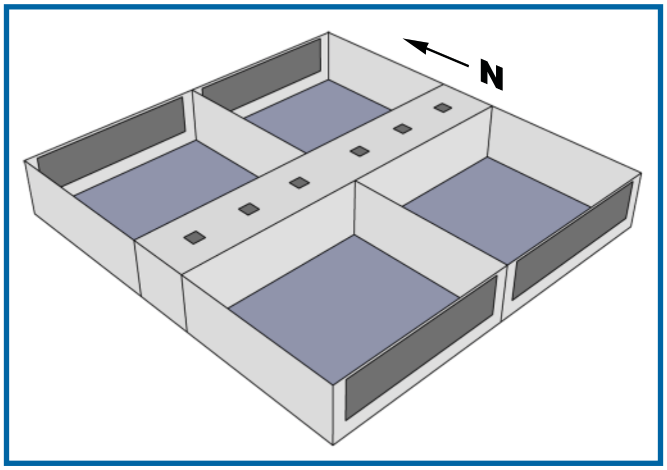
	Clear Sky												Cloudy Sky											
	Mar			Jun			Sep			Dec			Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	12	25	22	14	20	19	14	25	22	22	34	19	3	5	5	5	7	6	3	5	5	2	3	2
Coverage (%)	100	100	100	100	100	100	100	100	100	100	100	100	83	100	100	100	100	100	92	100	100	0	92	0
Diffuse daylight (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	88	100	100	100	100	100	100	100	100	100	100	100	0	0	0	0	0	0	0	0	0	0	0	0
Circadian stimulus (pts.)	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0

Glazing area: 50%
View: None
SHG (Btu/ft²/day): March, 0; June, 0; September, 0; December, 0

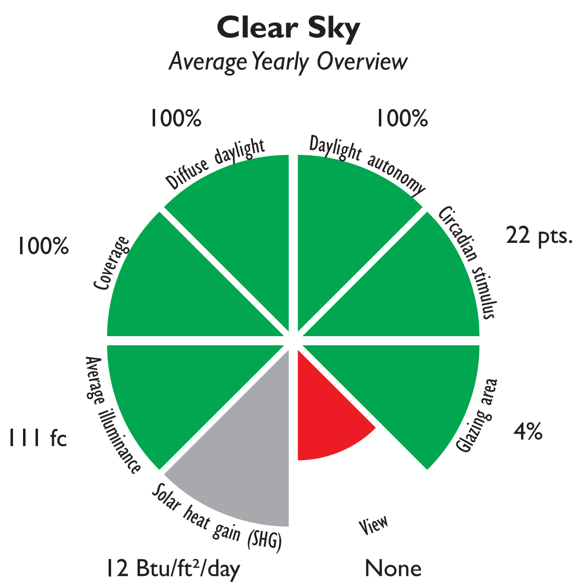
Corridor:
Clerestory Windows

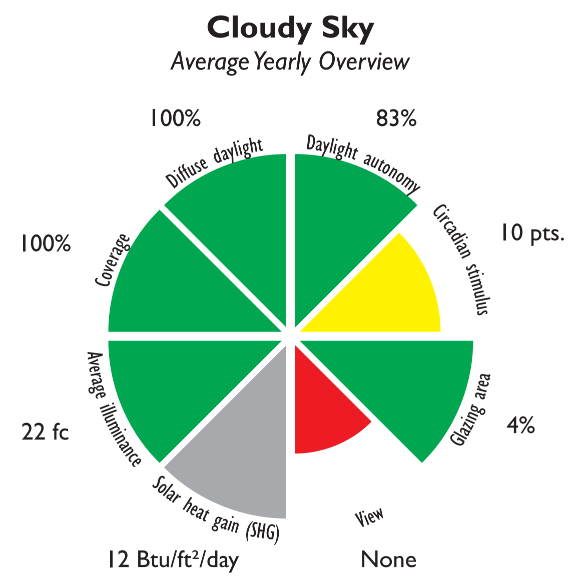
	Clear Sky September	Cloudy Sky September
9:00 a.m.		
12:00 noon		
3:00 p.m.		

Corridor:
Skylights



This pattern features 2 ft x 2 ft skylights on 8-12 ft centers to daylight most school days. These skylights can be diffusing to eliminate direct sun or clear to provide additional light and visual interest during clear skies.

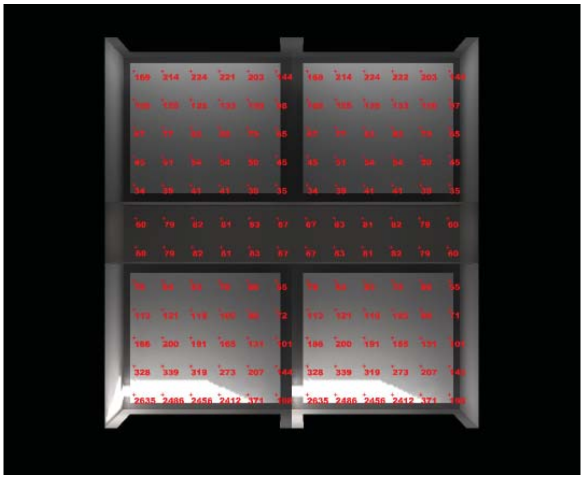
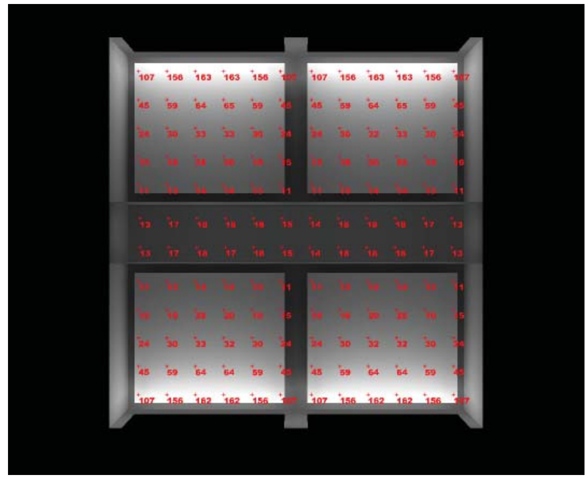
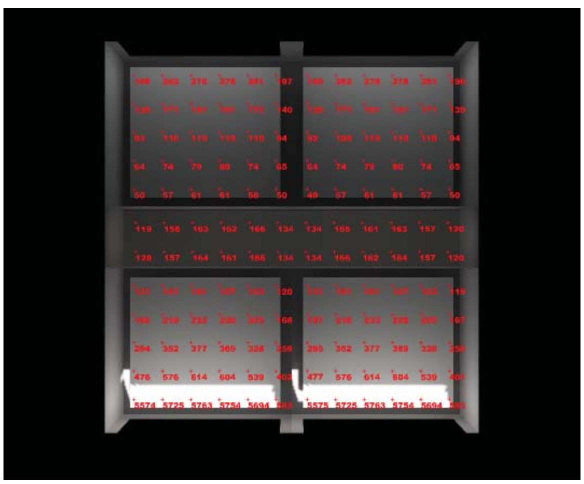
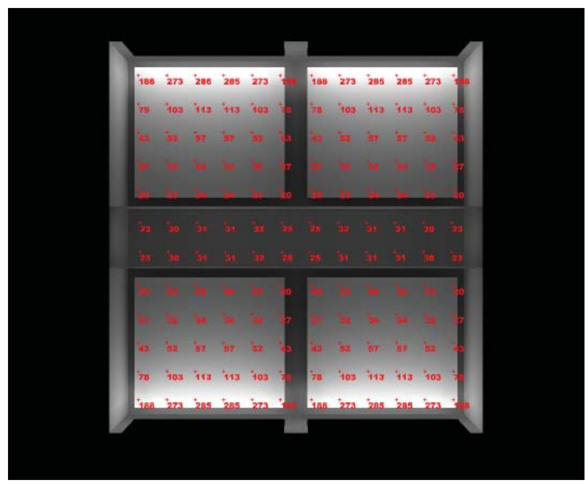
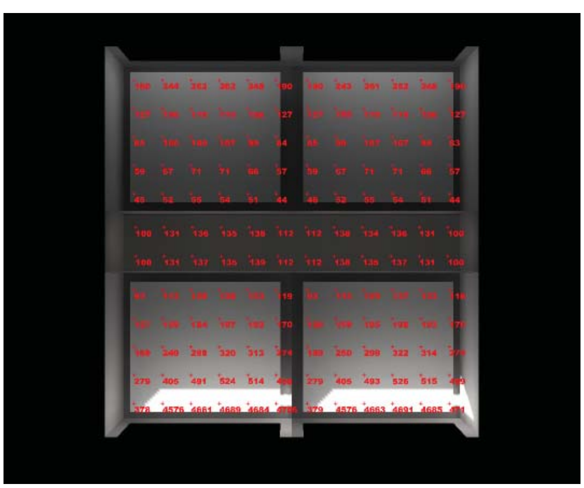
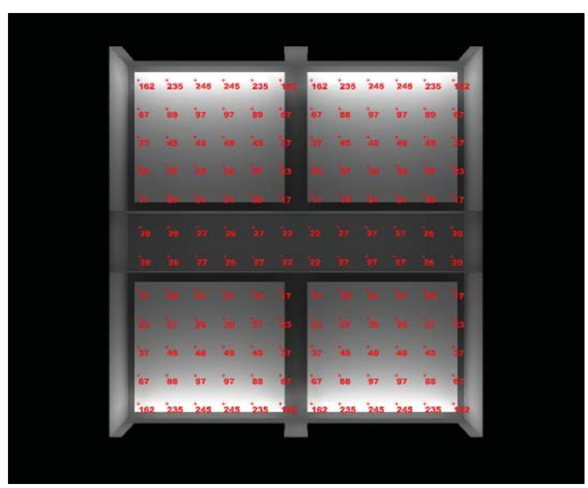




	Clear Sky												Cloudy Sky											
	Mar			Jun			Sep			Dec			Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	65	147	130	123	195	177	75	150	125	36	77	29	15	28	25	25	36	34	16	29	25	9	16	8
Coverage (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Diffuse daylight (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0	100	0
Circadian stimulus (pts.)	2	2	2	2	2	2	2	2	2	1	2	1	1	1	1	1	1	1	1	1	1	0	1	0

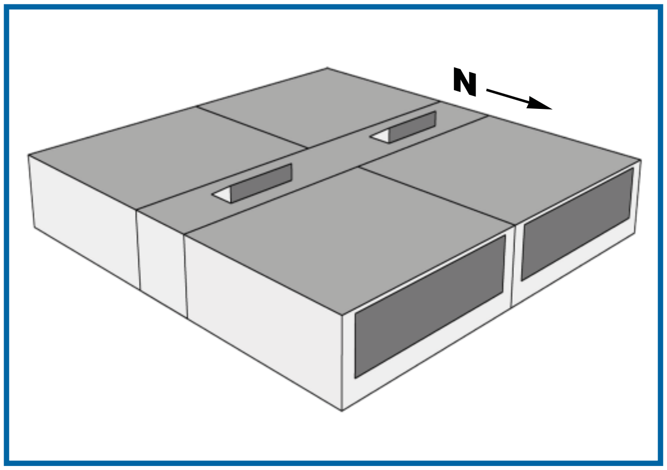
Glazing area: 4%
View: None
SHG (Btu/ft²/day): March, 12; June, 20; September, 14; December, 5

Corridor: Skylights

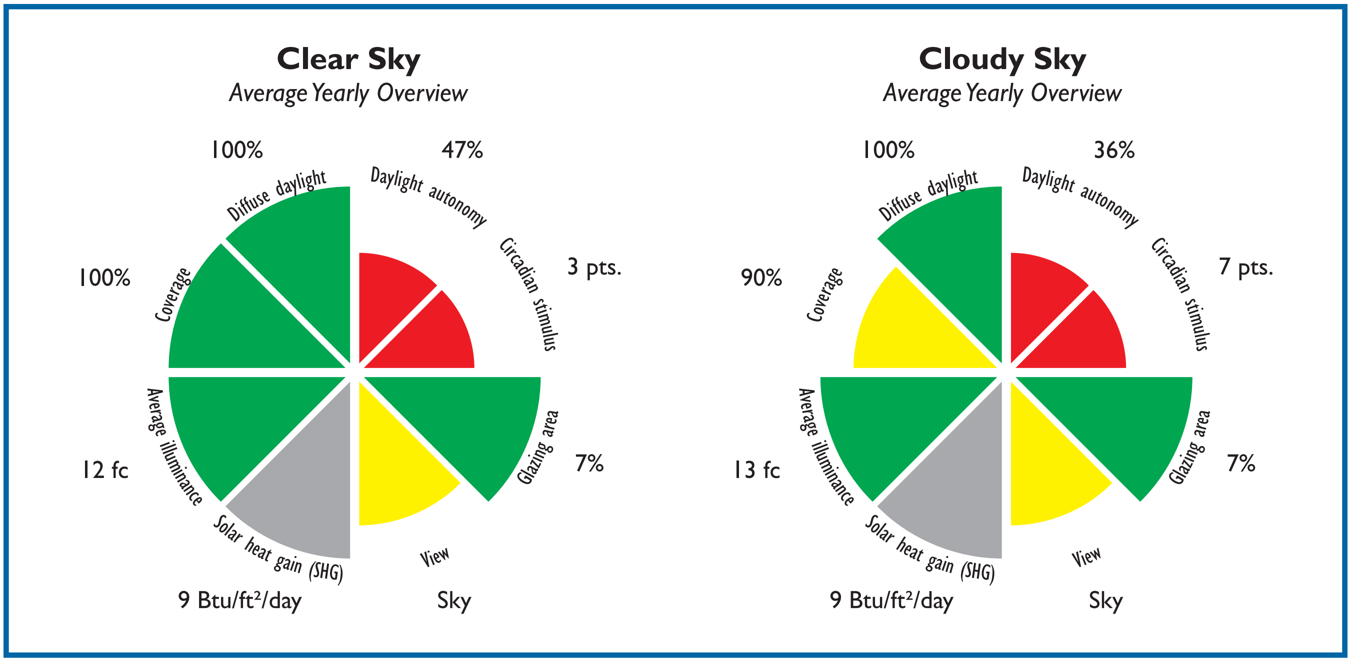
	Clear Sky September	Cloudy Sky September
9:00 a.m.		
12:00 noon		
3:00 p.m.		

Corridor:

North Roof Monitors



This pattern features a corridor with a 4 ft x 2 ft opening in the ceiling under a north facing 11 ft x 2 ft roof monitor between each pair of classrooms. Daylight usually provides sufficient illumination for movement through the corridor, but supplementary electric lighting will be needed.



Clear Sky

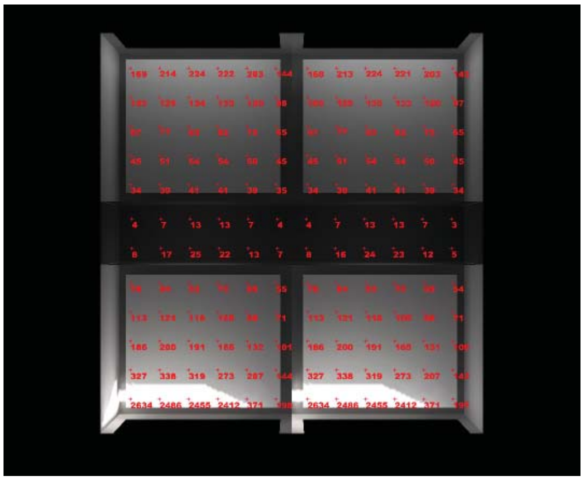
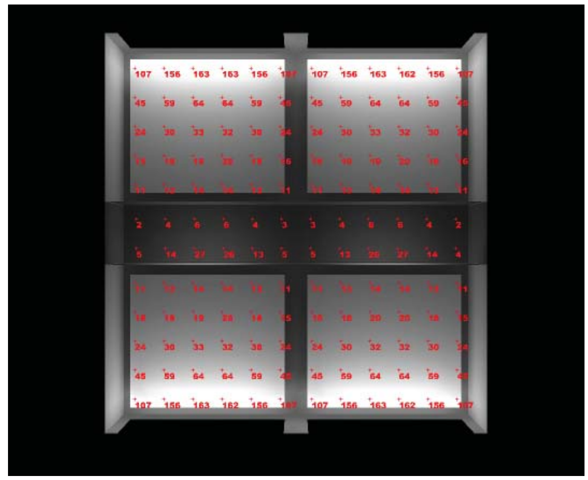
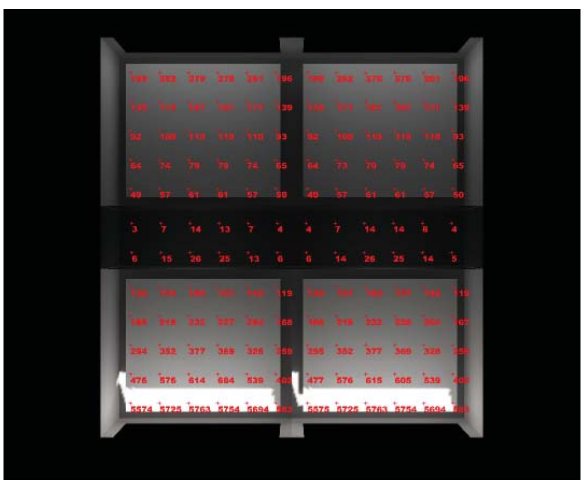
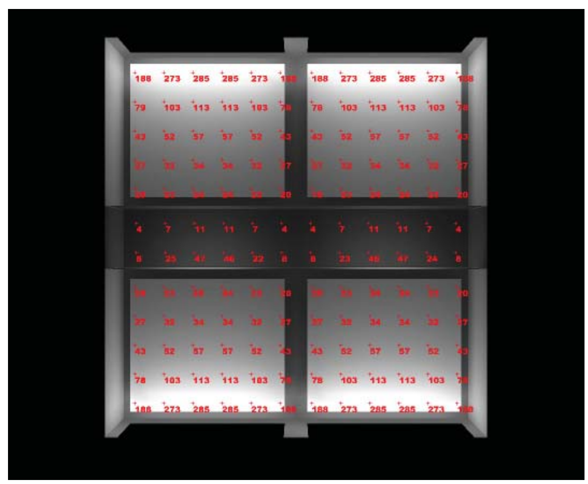
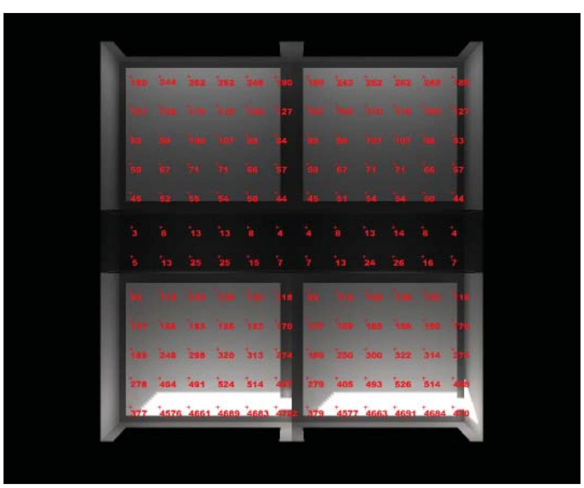
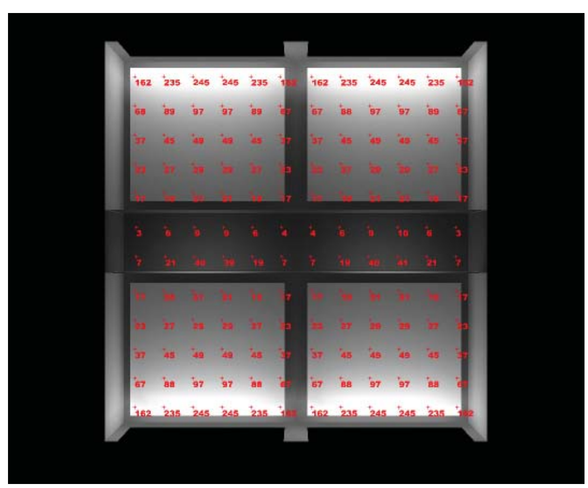
Time	Mar 9a	Mar 12p	Mar 3p	Jun 9a	Jun 12p	Jun 3p	Sep 9a	Sep 12p	Sep 3p	Dec 9a	Dec 12p	Dec 3p
Avg. illuminance (fc)	11	12	12	17	15	15	12	12	12	9	10	9
Coverage (%)	100	100	100	100	100	100	100	100	100	100	100	100
Diffuse daylight (%)	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	50	50	50	63	50	50	50	50	50	33	50	17
Circadian stimulus (pts.)	0	0	0	1	1	1	0	0	0	0	0	0

Cloudy Sky

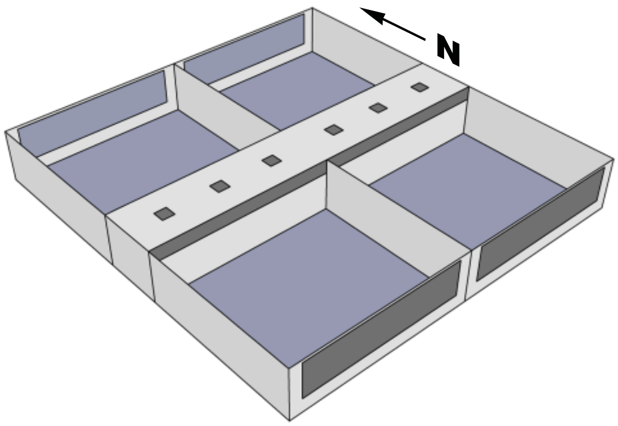
Time	Mar 9a	Mar 12p	Mar 3p	Jun 9a	Jun 12p	Jun 3p	Sep 9a	Sep 12p	Sep 3p	Dec 9a	Dec 12p	Dec 3p
Avg. illuminance (fc)	8	16	15	14	21	20	10	17	14	5	10	5
Coverage (%)	83	100	100	100	100	100	92	100	100	67	88	50
Diffuse daylight (%)	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	33	50	33	33	54	50	33	50	33	17	33	17
Circadian stimulus (pts.)	0	1	1	1	1	1	0	1	1	0	0	0

Glazing area: 7%
View: Sky
SHG (Btu/ft²/day): March, 8; June, 14; September, 9; December, 4

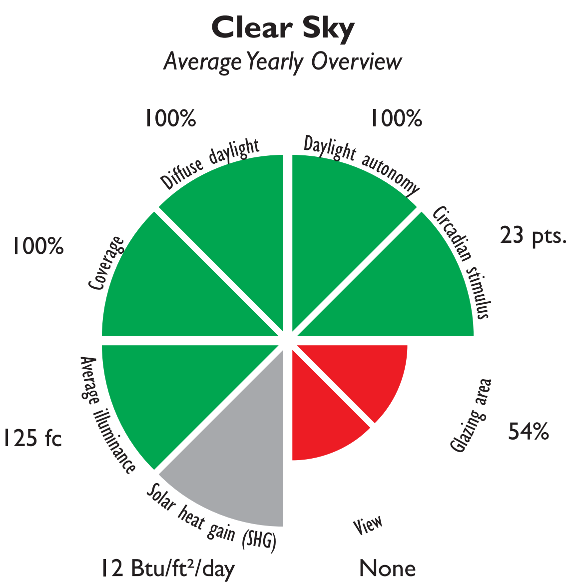
Corridor:
North Roof Monitors

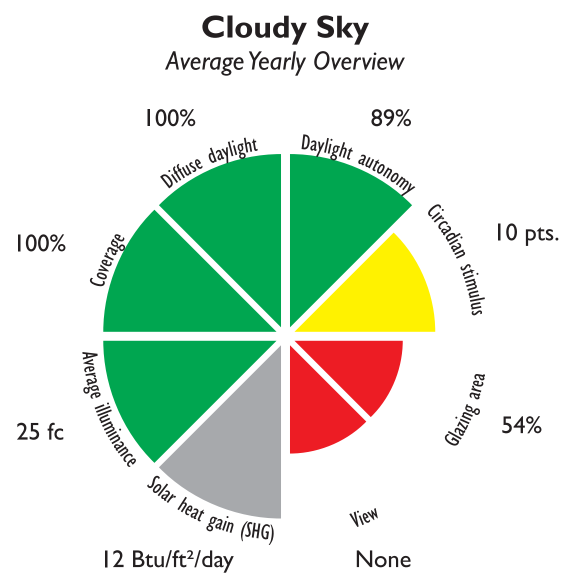
	Clear Sky September	Cloudy Sky September
9:00 a.m.		
12:00 noon		
3:00 p.m.		

Corridor:
Skylights with Clerestory Windows



This pattern combines the Corridor: Skylights and the Corridor: Clerestory Windows patterns. Compared to skylights alone, the illuminance levels and energy saving potential improve slightly, but more glazing is required.

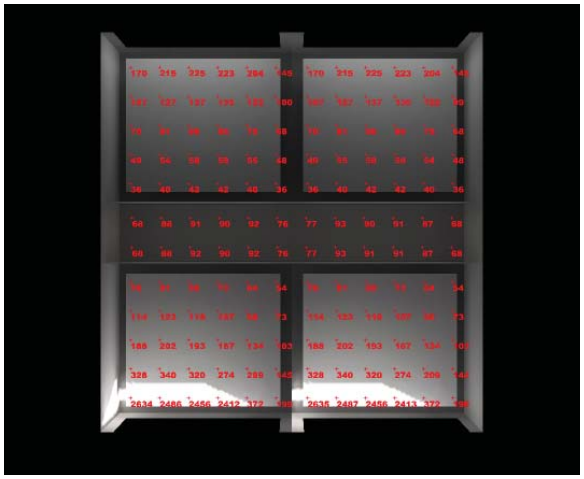
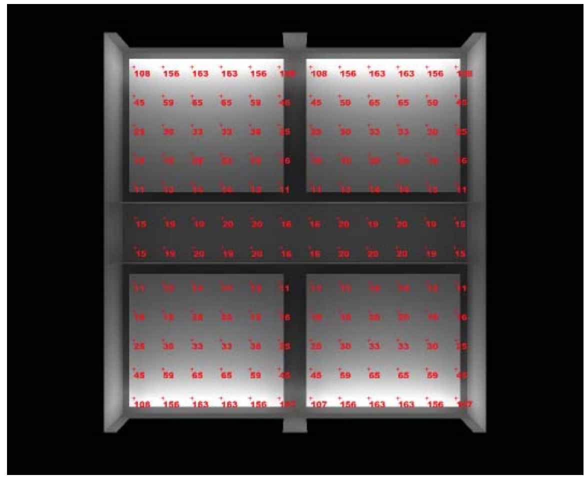
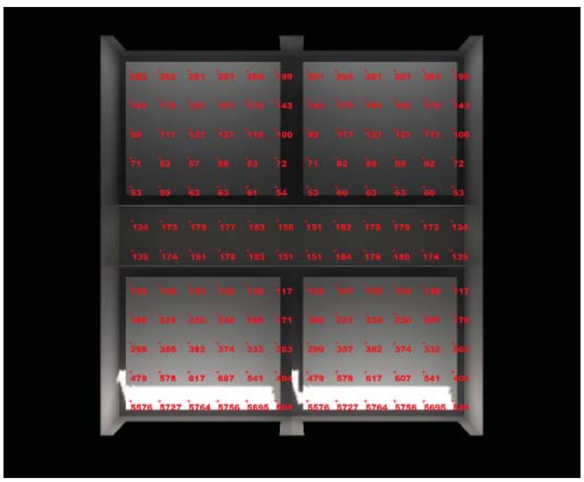
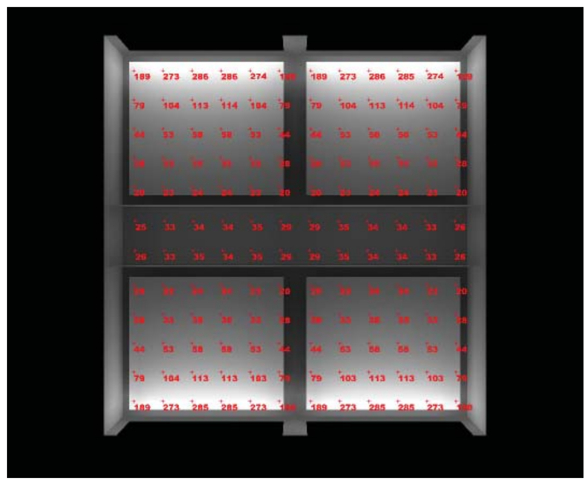
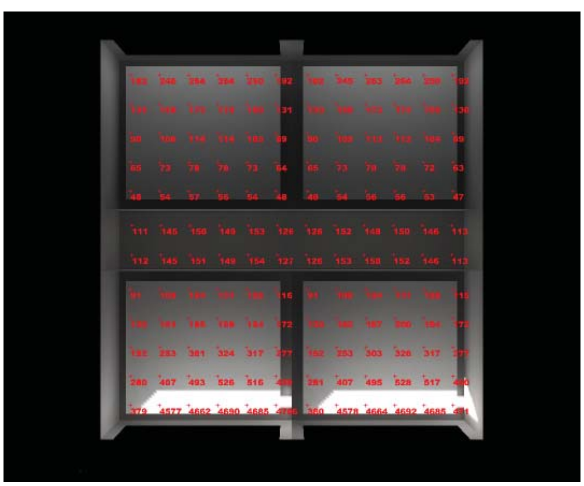
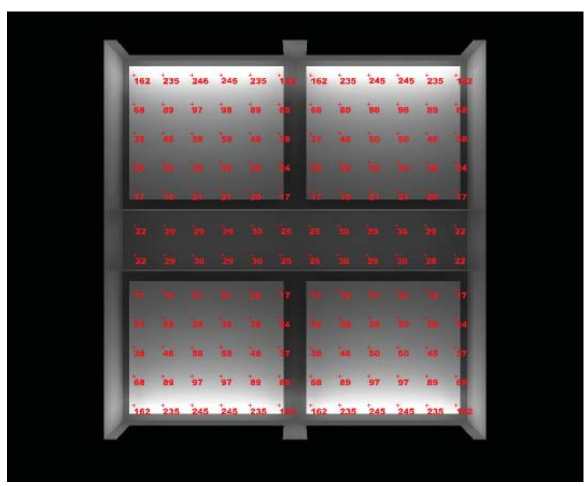




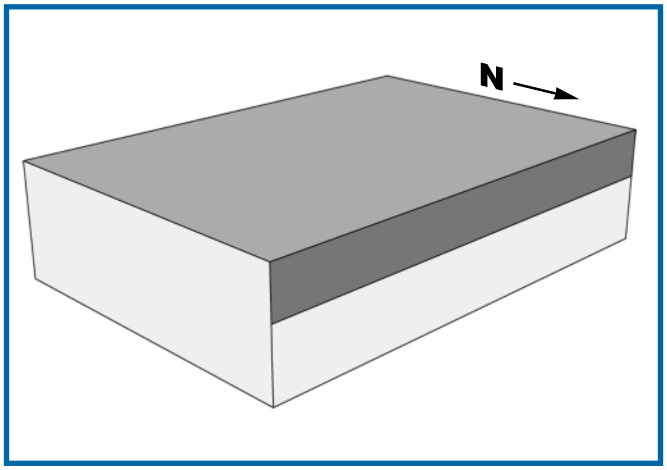
	Clear Sky												Cloudy Sky											
	Mar			Jun			Sep			Dec			Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	73	163	145	130	203	185	84	167	140	56	107	46	16	31	28	27	41	37	18	32	27	10	18	9
Coverage (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Diffuse daylight (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	67	100	0
Circadian stimulus (pts.)	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	0	1	0

Glazing area: 54%
View: None
SHG (Btu/ft²/day): March, 12; June, 20; September, 14; December, 5

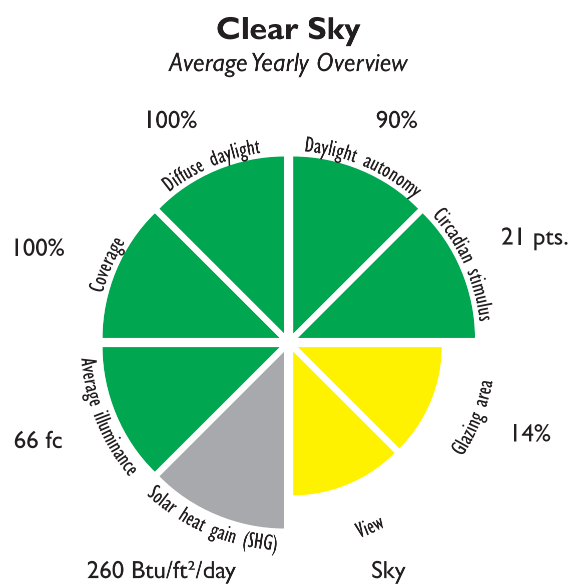
Corridor:
Skylights with Clerestory Windows

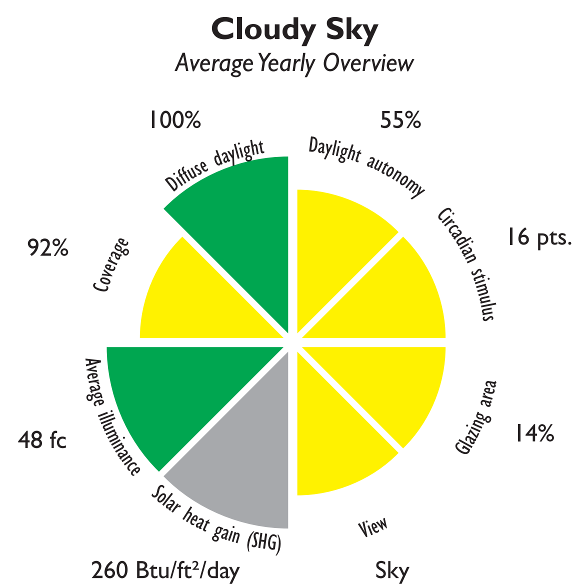
	Clear Sky September	**Cloudy Sky** September
9:00 a.m.		
12:00 noon		
3:00 p.m.		

Gymnasium:
North Clerestory Window



This pattern features a 100 ft x 10 ft north-facing clerestory window located 14 feet above the floor. Daylight is distributed well throughout the gymnasium, affording high energy-saving potential, especially under clear skies. Blinds, shades, or louvers should not be needed.





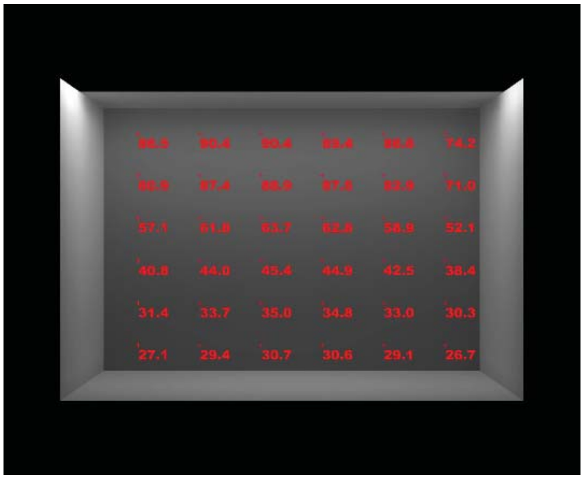
	Clear Sky												Cloudy Sky											
	Mar			Jun			Sep			Dec			Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	52	74	70	82	94	91	56	75	69	38	53	35	32	61	55	54	79	73	36	63	54	20	36	17
Coverage (%)	100	100	100	100	100	100	100	100	100	100	100	100	89	100	100	100	100	100	94	100	100	67	94	56
Diffuse daylight (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	78	100	100	100	100	100	89	100	100	64	94	58	44	67	61	61	78	69	44	67	61	33	44	28
Circadian stimulus (pts.)	2	2	2	2	2	2	2	2	2	1	1	1	1	2	2	2	2	2	1	2	2	0	0	0

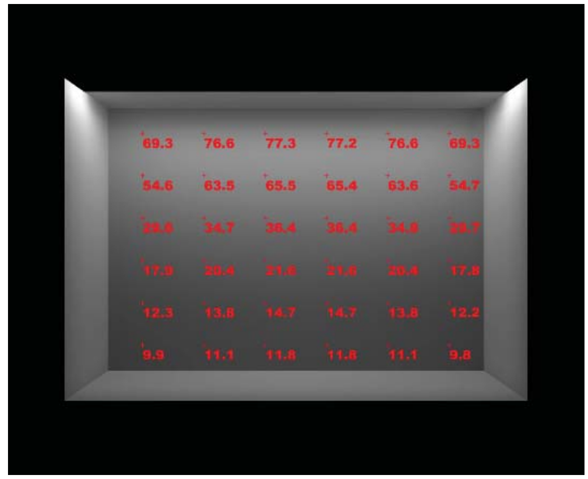
Glazing area: 14%
View: Sky
SHG (Btu/ft²/day): March, 245; June, 418; September, 262; December, 114

Gymnasium: North Clerestory Window

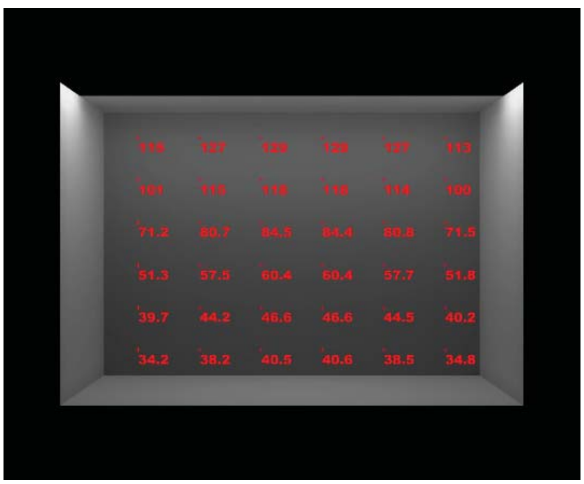
	Clear Sky September	**Cloudy Sky** September

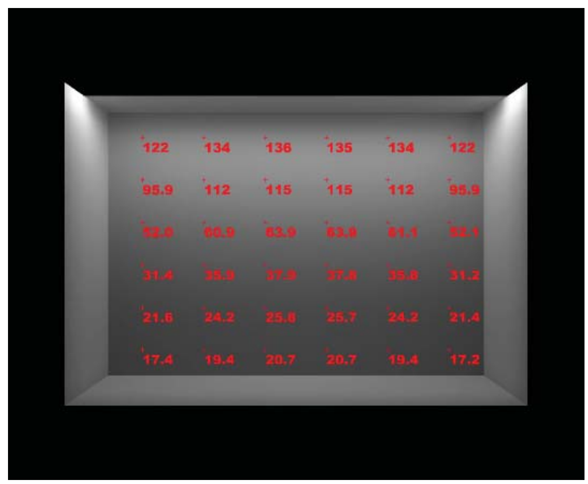
9:00 a.m.



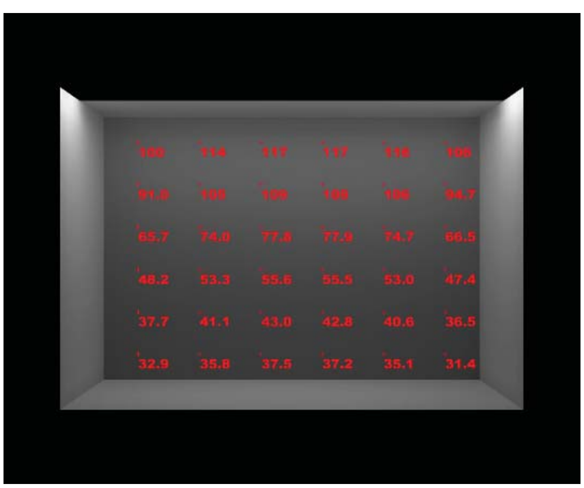


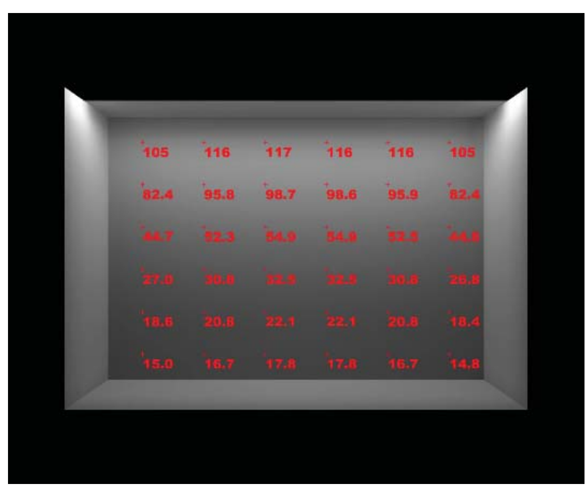
12:00 noon



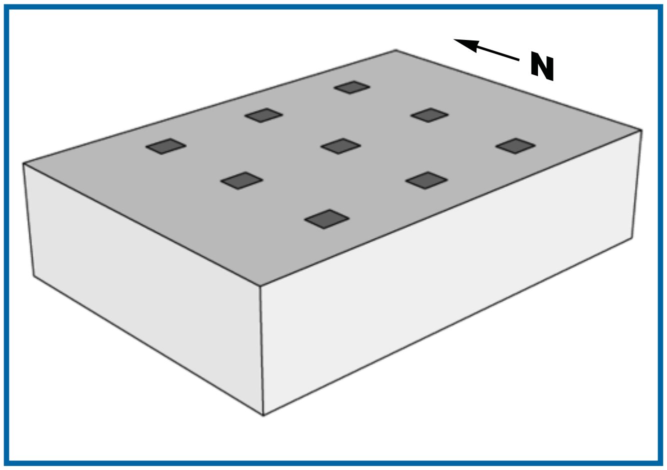


3:00 p.m.



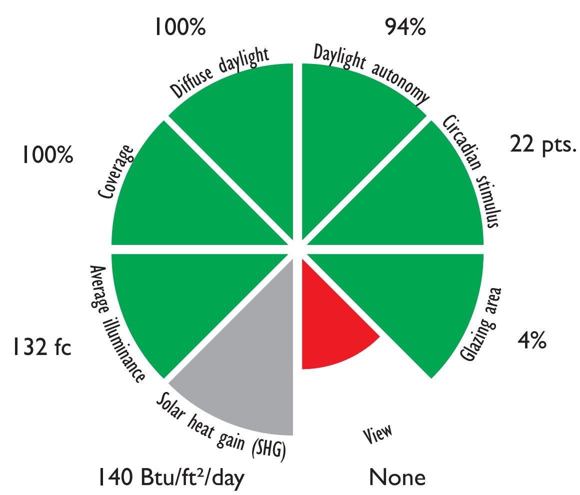


Gymnasium:
Skylights

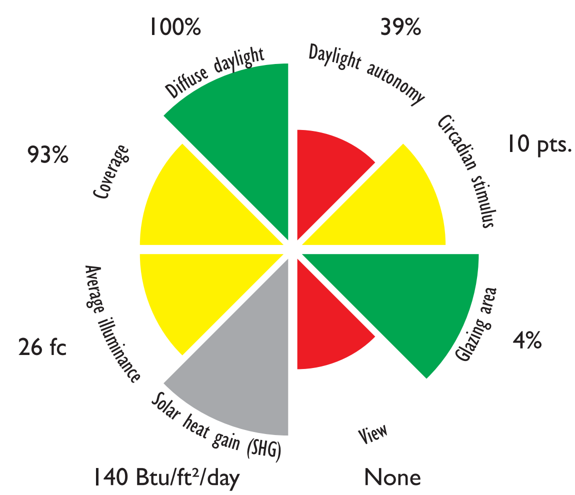


This pattern features nine 5 ft x 6 ft diffusing skylights spaced in three rows over the gymnasium. The small glazing area effectively daylights the gymnasium and supports circadian entrainment, especially under clear skies.

Clear Sky
Average Yearly Overview



Cloudy Sky
Average Yearly Overview



	Clear Sky											
	Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	78	176	156	146	231	210	90	179	150	43	92	35
Coverage (%)	100	100	100	100	100	100	100	100	100	100	100	100
Diffuse daylight (%)	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	100	100	100	100	100	100	100	100	100	67	100	67
Circadian stimulus (pts.)	2	2	2	2	2	2	2	2	2	1	2	1

	Cloudy Sky											
	Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	17	33	30	29	43	40	19	34	29	11	19	9
Coverage (%)	89	100	100	100	100	100	100	100	100	67	100	56
Diffuse daylight (%)	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	0	67	67	67	67	67	0	67	67	0	0	0
Circadian stimulus (pts.)	1	1	1	1	2	1	1	1	1	0	0	0

Glazing area: 4%
View: None
SHG (Btu/ft²/day): March, 131; June, 223; September, 157; December, 51

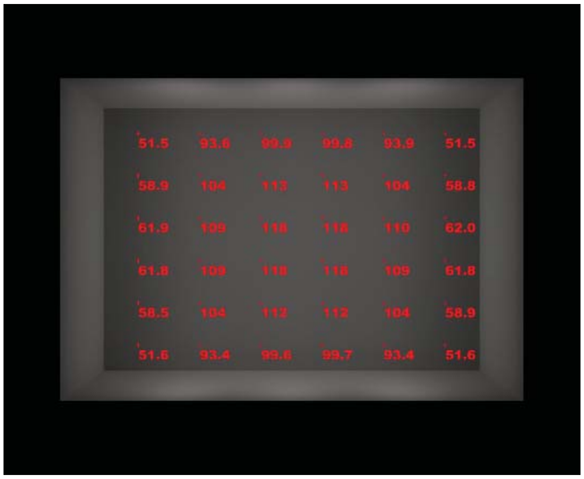
Gymnasium:

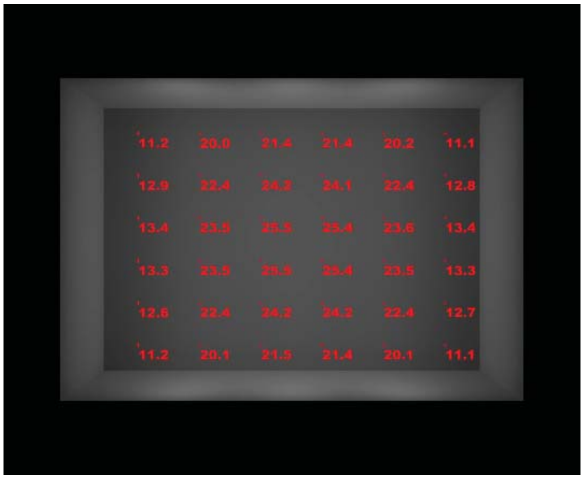
Skylights

Clear Sky
September

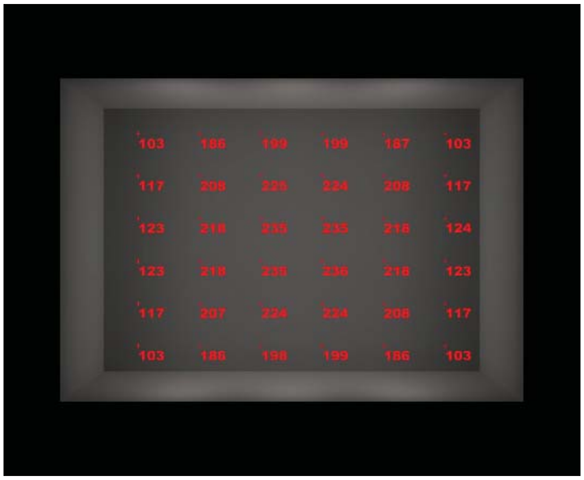
Cloudy Sky
September

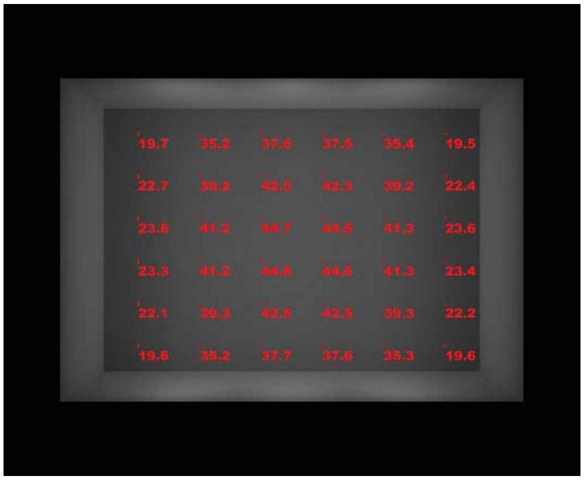
9:00 a.m.



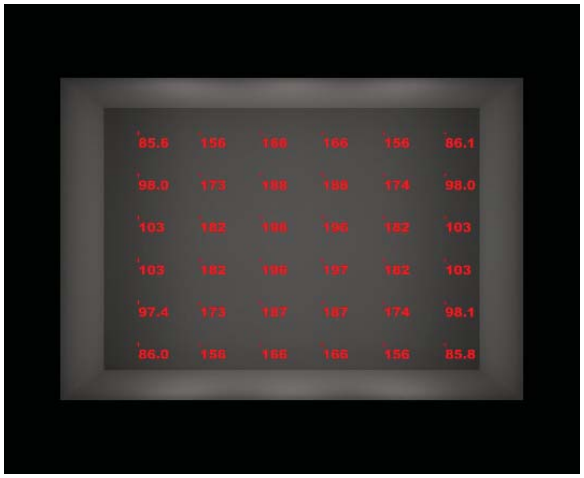


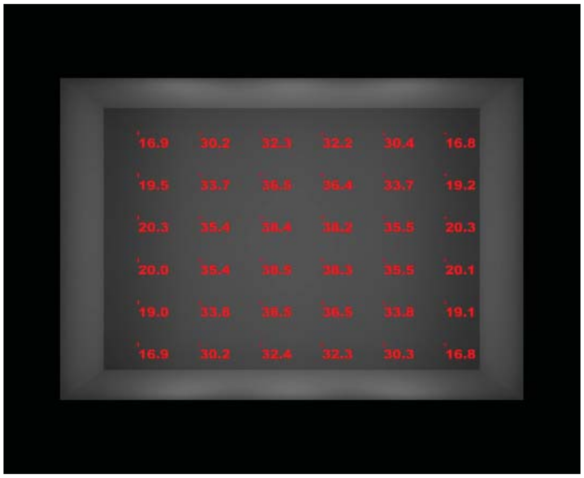
12:00 noon



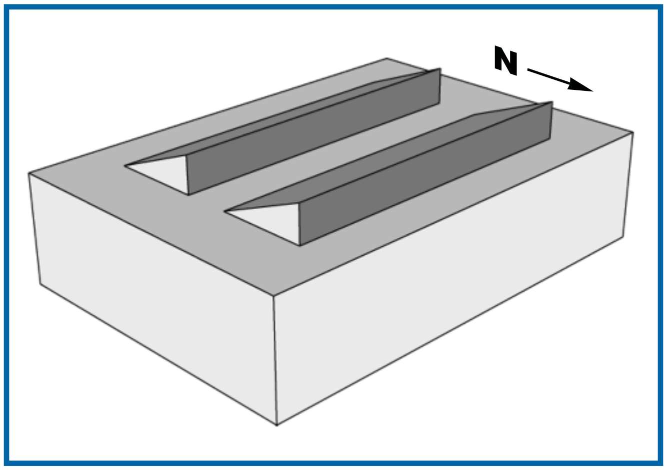


3:00 p.m.





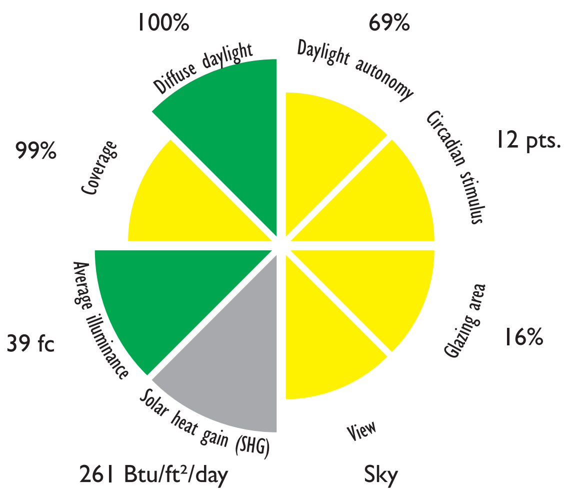
Gymnasium:
North Roof Monitors



This gymnasium roof has two 20 ft x 70 ft openings in the ceiling under north-facing 8 ft x 70 ft roof monitors. There is reasonable daylight and energy-saving potential under both clear and overcast skies without glare.

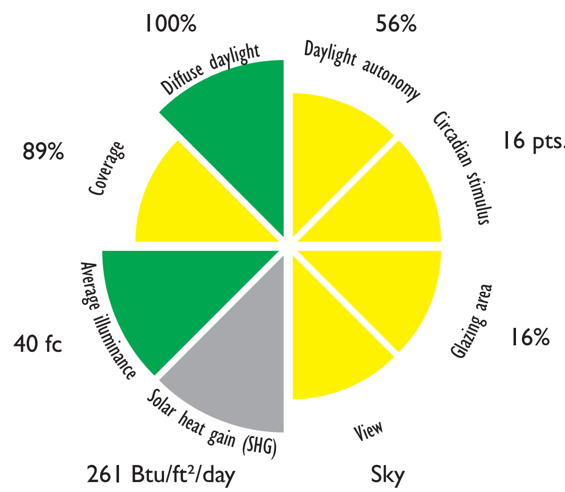
Clear Sky

Average Yearly Overview



Cloudy Sky

Average Yearly Overview

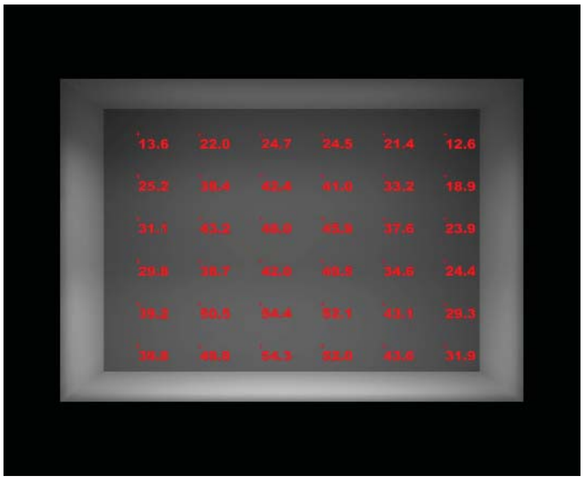
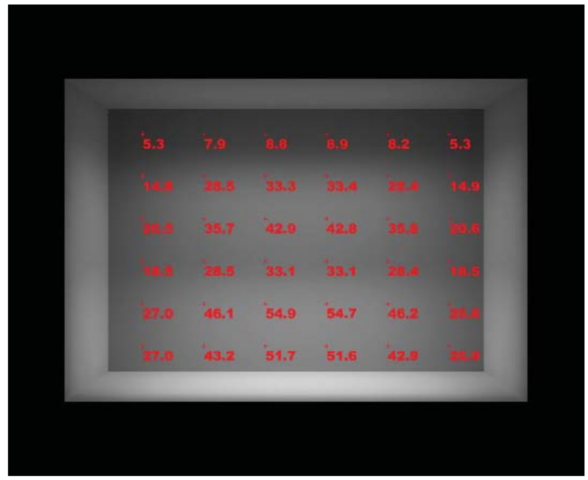
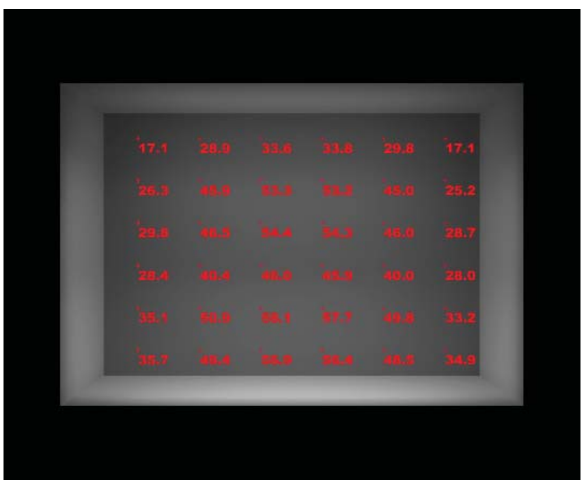
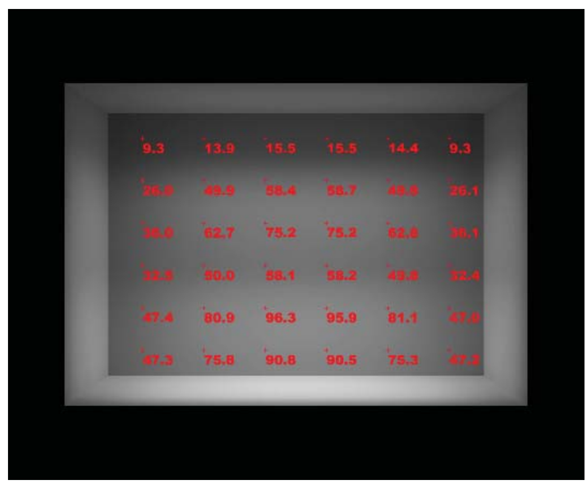
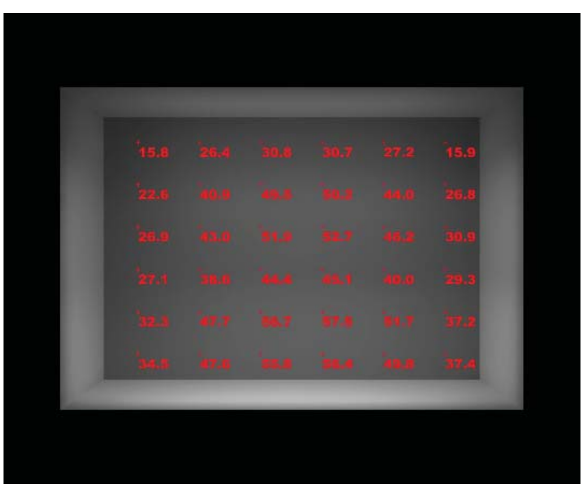
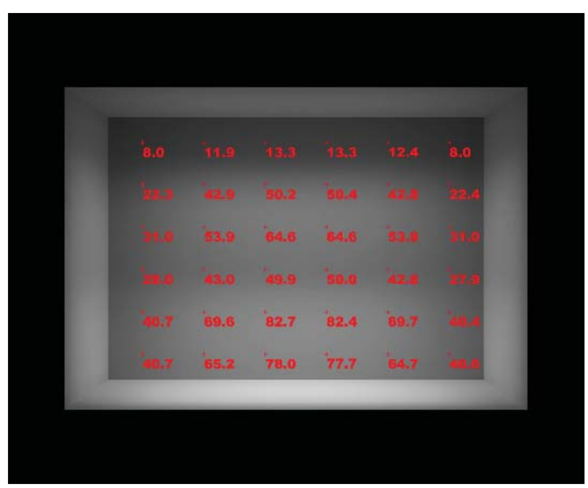


	Clear Sky											
	Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	35	40	40	52	51	51	36	41	40	27	33	25
Coverage (%)	100	100	100	100	100	100	100	100	100	94	100	94
Diffuse daylight (%)	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	67	72	75	83	94	92	67	72	75	33	61	33
Circadian stimulus (pts.)	1	1	1	2	2	2	1	1	1	0	0	0

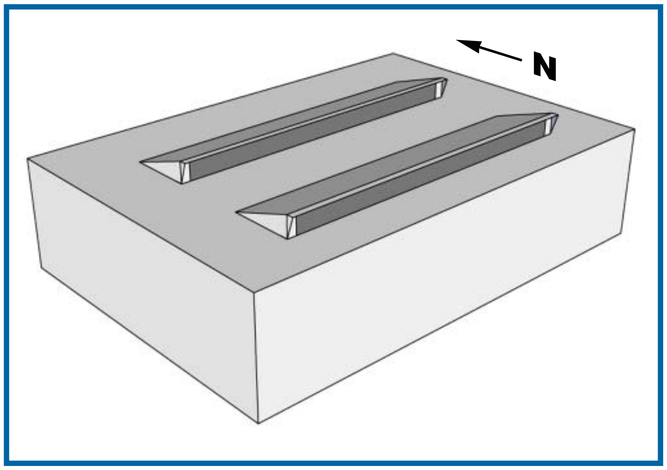
	Cloudy Sky											
	Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	26	50	45	44	65	60	29	51	44	17	29	14
Coverage (%)	83	94	94	94	100	100	83	94	94	78	83	67
Diffuse daylight (%)	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	33	78	72	72	83	83	44	78	72	6	44	0
Circadian stimulus (pts.)	1	2	2	2	2	2	1	2	2	0	0	0

Glazing area: 16%
View: Sky
SHG (Btu/ft²/day): March, 247; June, 420; September, 263; December, 115

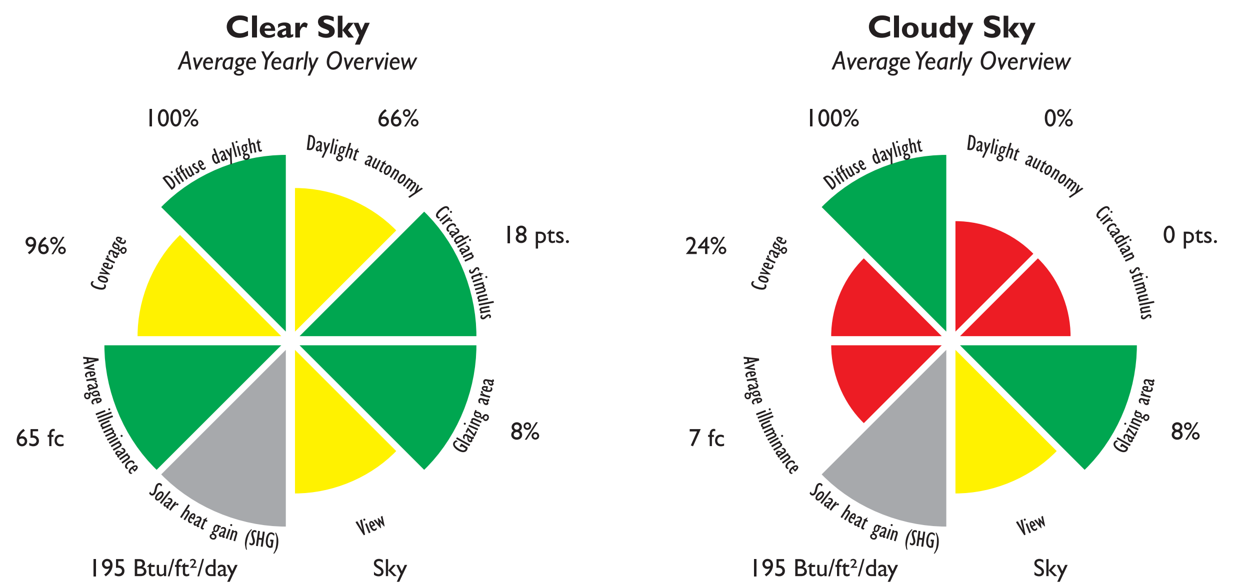
Gymnasium:
North Roof Monitors

	Clear Sky September	Cloudy Sky September
9:00 a.m.		
12:00 noon		
3:00 p.m.		

Gymnasium:
South Roof Monitors with Baffles



This gymnasium roof has two 13 ft x 66 ft openings in the ceiling under south-facing 4 ft x 66 ft roof monitors. Baffles should be added to control glare if the design intent is to avoid direct sun on the gymnasium floor. Compared to the Gymnasium: North Roof Monitors pattern, this pattern uses half the glazing area, but does not perform as well under overcast skies.



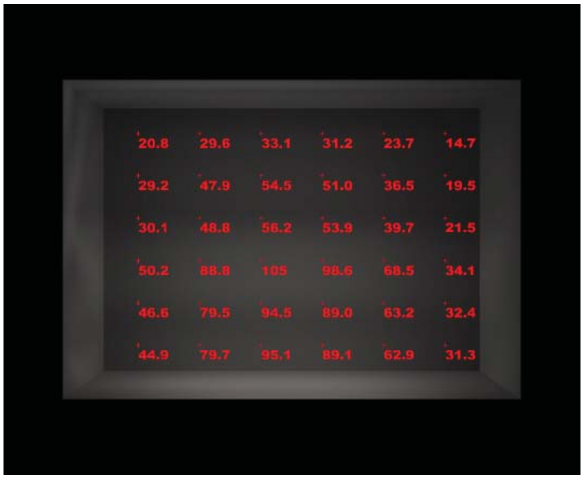
	Clear Sky												Cloudy Sky											
	Mar			Jun			Sep			Dec			Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	46	113	100	14	19	18	53	96	94	43	155	33	5	9	8	8	12	11	6	10	8	3	6	3
Coverage (%)	100	100	100	75	89	83	100	100	100	100	100	100	0	39	33	33	56	50	0	39	33	0	0	0
Diffuse daylight (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	64	100	97	0	17	6	81	100	97	75	100	53	0	0	0	0	0	0	0	0	0	0	0	0
Circadian stimulus (pts.)	2	2	2	1	1	1	2	2	2	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0

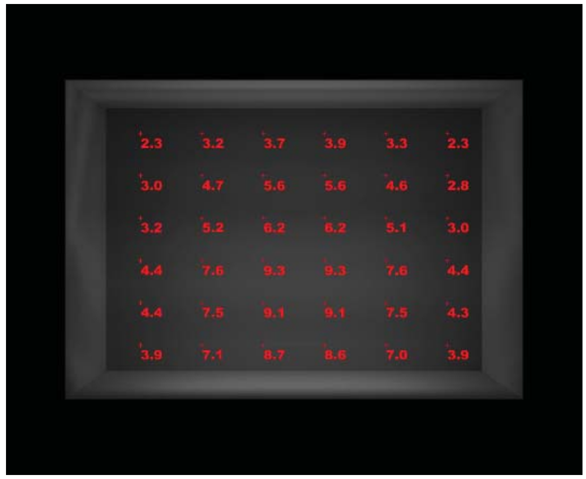
Glazing area: 8%
View: Sky
SHG ($Btu/ft^2/day$): March, 230; June, 152; September, 208; December, 191

Gymnasium:
South Roof Monitors with Baffles

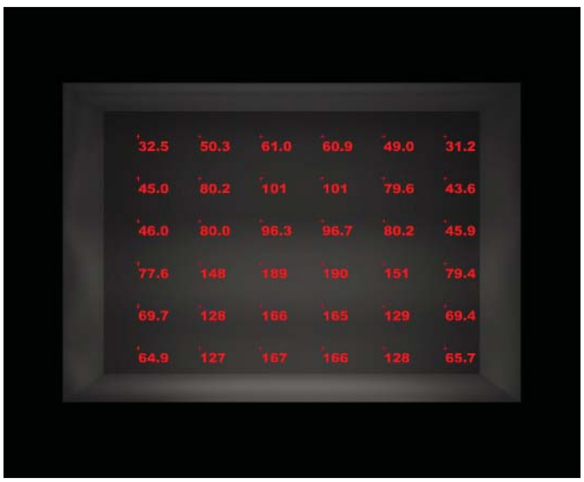
	Clear Sky September	Cloudy Sky September

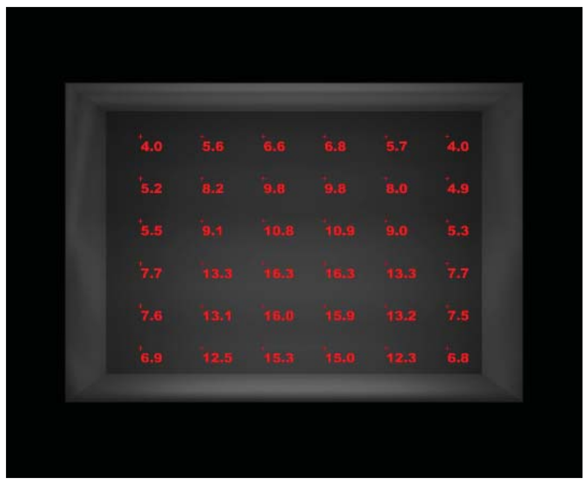
9:00 a.m.



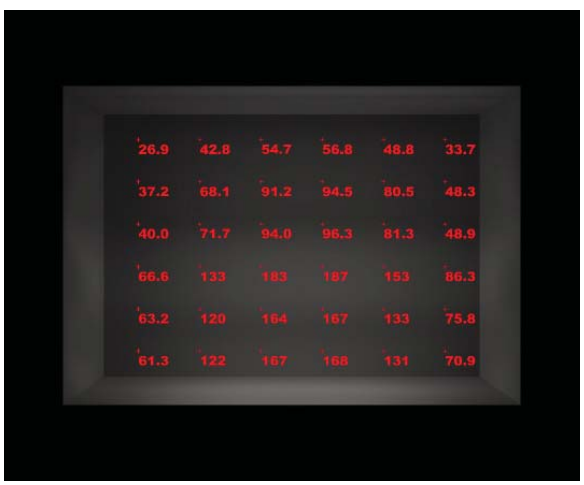


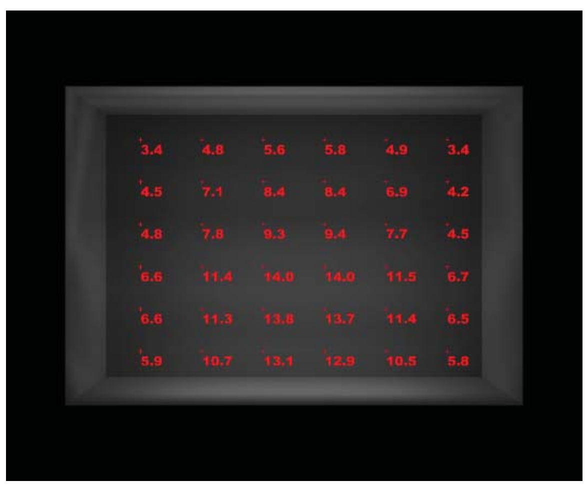
12:00 noon



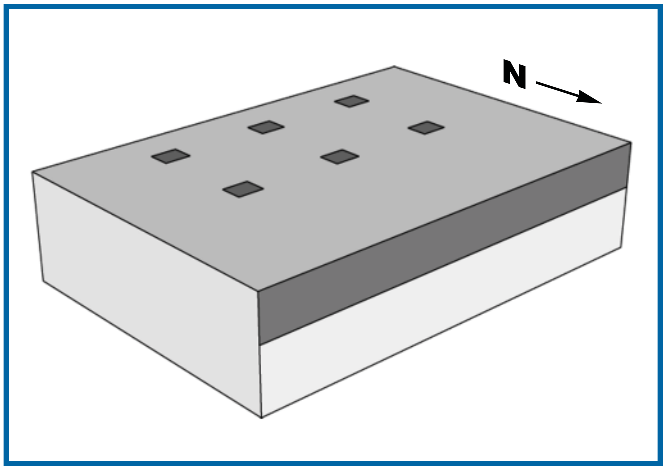


3:00 p.m.

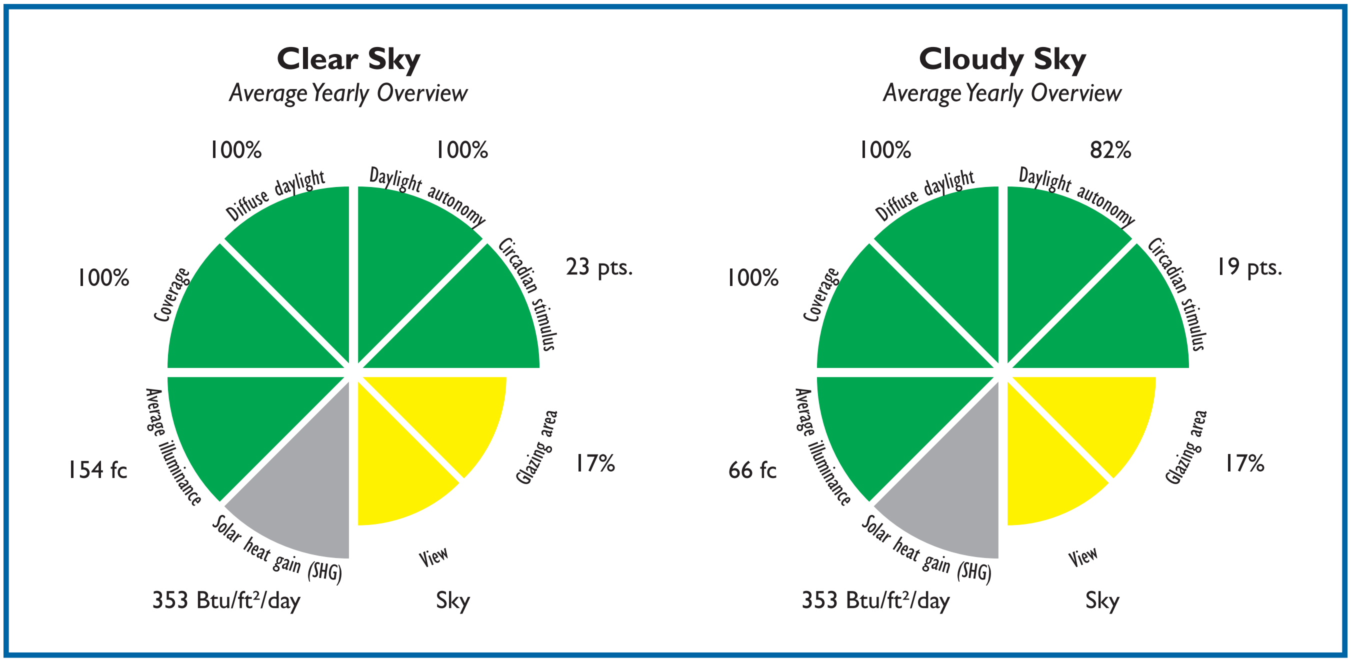




Gymnasium:
Skylights with North Clerestory Window



This pattern combines a 100 ft x 10 ft north-facing clerestory window located 14 feet above the floor with six 5 ft x 6 ft diffusing skylights over the south half of the gymnasium. Daylight provides excellent coverage, energy-savings potential, and circadian stimulation without glare.



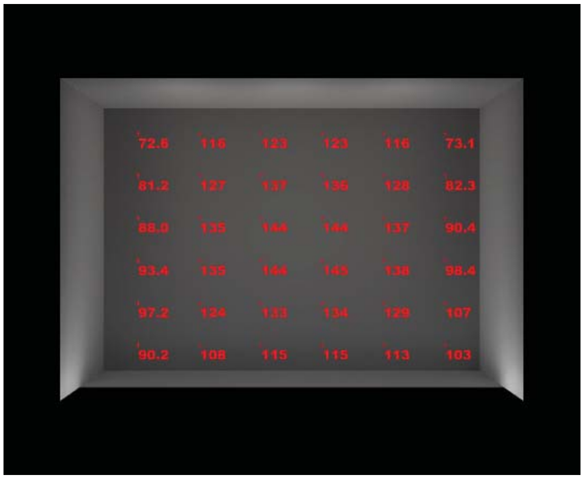
	Clear Sky												Cloudy Sky											
	Mar			Jun			Sep			Dec			Mar			Jun			Sep			Dec		
Time	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p	9a	12p	3p
Avg. illuminance (fc)	104	192	174	180	249	232	116	196	170	67	115	58	43	83	75	73	108	99	49	85	73	28	48	24
Coverage (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	94
Diffuse daylight (%)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Daylight autonomy (%)	100	100	100	100	100	100	100	100	100	100	100	100	72	100	100	94	100	100	78	100	94	39	78	28
Circadian stimulus (pts.)	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	0	1	0

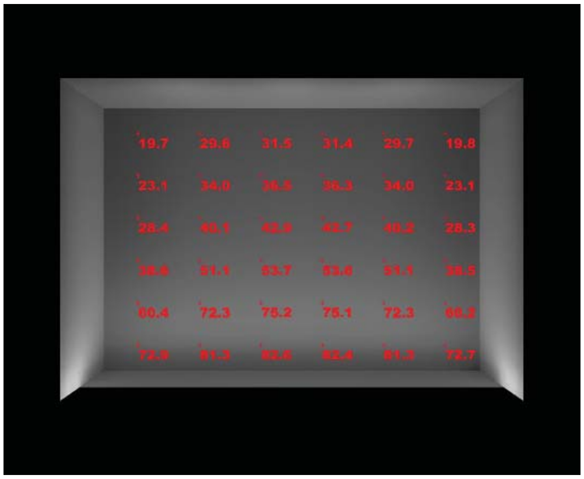
Glazing area: 14%
View: Sky
SHG (Btu/ft²/day): March, 245; June, 418; September, 262; December, 114

Gymnasium:
Skylights with North Clerestory Window

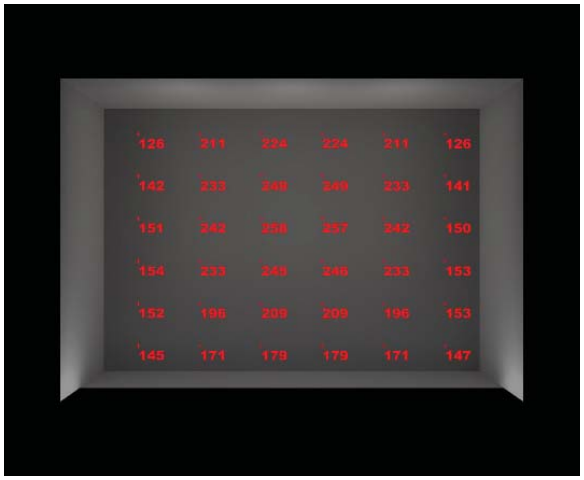
	Clear Sky September	**Cloudy Sky** September

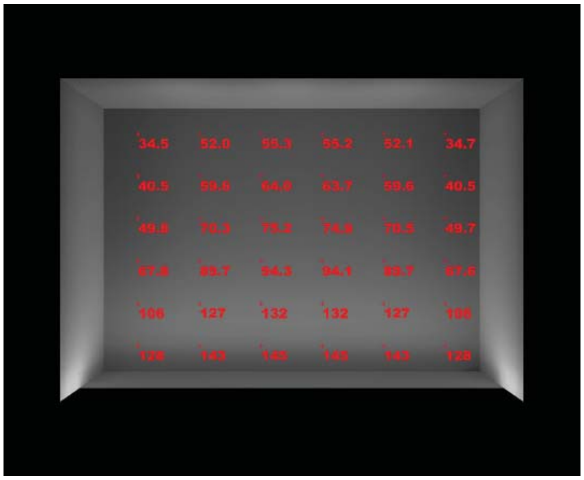
9:00 a.m.



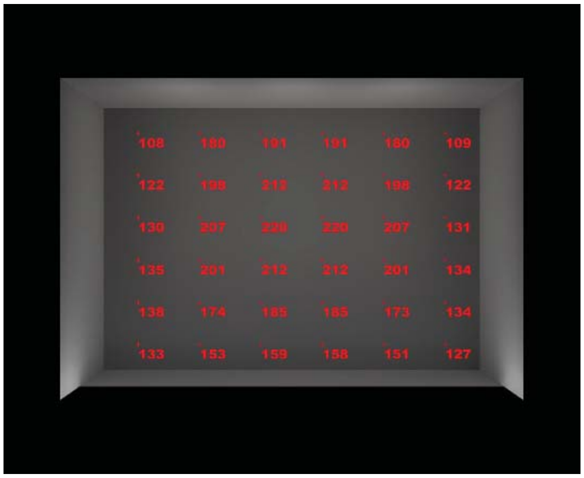


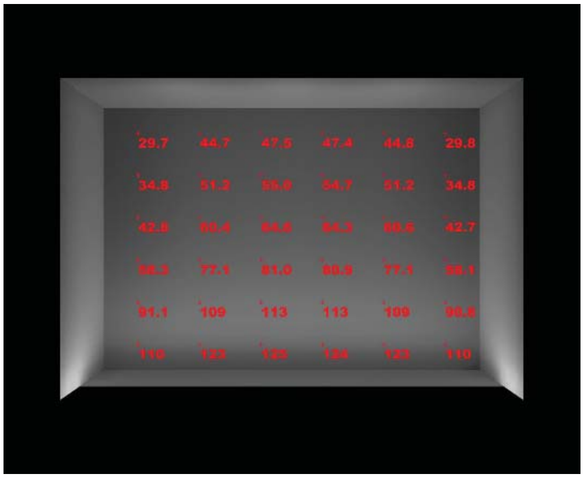
12:00 noon





3:00 p.m.





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