Daylighting Design
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Bozeman, MT
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INTEGRATED Design Lab
Bozeman
Montana State University
School of Architecture
College of Engineering
Learning Objectives

WHAT WE WILL COVER:

• WHY DAYLIGHTING IS THE CORNERSTONE OF ENERGY-EFFICIENT DESIGN

• PROVIDE TECHNIQUES FOR MEETING AND VERIFYING LEED DAYLIGHT AND VIEW CREDITS

• DEMONSTRATE EARLY DESIGN ASSISTANCE TOOLS FOR EFFECTIVE DAYLIGHTING SOLUTIONS

• PRESENT THE USE AND BENEFITS OF THE “MONTANA DAYLIGHT DESIGN MANUAL”
Montana Daylight Design Manual

PART 1: WHY DAYLIGHT?

PART 2: HOW TO DAYLIGHT

PART 3: DAYLIGHTING DESIGN

PART 4: TOOLS FOR DAYLIGHTING

PART 5: CASE STUDIES

AVAILABLE ON-LINE:
WWW.IDLBOZEMAN.COM
Part 1: Why Daylighting?

BUILDING THE CASE FOR DAYLIGHTING

“I use light abundantly, as you may have suspected; light for me is the fundamental basis of architecture.

I compose with light.”

Le Corbusier
Benefits of Daylighting

ENERGY BENEFITS

BETTER LIGHTING ENVIRONMENT

HEALTH BENEFITS
Daylight Benefits in the Office

• Benefits include better health, reduced absenteeism, increased productivity, financial savings, and preference.

• In some European countries, workers cannot be further than 27 feet from a window.

• Health: decrease headaches, reduce SAD, reduce stress, and eye strain when designed properly.

• In general, daylighting may contribute to a more positive mood in the office place.
Benefits of Daylight: Schools

DAYLIGHT BENEFITS IN SCHOOLS

• REDUCED UTILITY COSTS
• IMPROVED ATTENDANCE
• IMPROVED ACADEMIC PERFORMANCE
• REDUCED FATIGUE FACTORS
• IMPROVED STUDENT HEALTH
DAYLIGHT BENEFITS IN RETAIL

RETAILERS USING DAYLIGHTING TO:

• ENHANCE STORE ENVIRONMENT
• INCREASE SALES
• CREATE MORE PLEASANT SHOPPING
• ATTRACT CUSTOMERS
• IMPROVE COLOR RENDERING AND LIGHT LEVELS
Benefits of Daylight: Health Care

Benefits in Health Care

1. **Improved physiological and psychological state of both patients and staff**

2. **Reduced mental and physical strain of patients, doctors, and nurses**

3. **Patients recover faster in daylit recovery areas**

4. **Daylight and views have a psychotherapeutic quality**
Part 2: How to Daylight

1. Sources of Daylight
2. Sky Conditions
3. Montana Conditions
4. Programming for Daylight
5. Sunlighting & Daylighting Strategies
6. Planning for Solar Access
7. Sidelighting
8. Toplighting
9. Atria
10. Integration with Electric Lighting
Sources of Daylight

**DAYLIGHT**
- **DIFFUSE LIGHT FROM THE SKY DOME**
- **AREA LIGHT SOURCE**

**SUNLIGHT**
- **DIRECT BEAM SUNLIGHT**
- **POINT LIGHT SOURCE**

**REFLECTED LIGHT**
- **MAN-MADE OR NATURAL SURFACES**
Sky Conditions

OVERCAST SKY

CLEAR SKY

PARTLY CLOUDY SKY

Illumination

2,500 footcandles

10,000 footcandles

4/7/2017 Integrated Design Lab, Bozeman, MT
Montana Sky Conditions

GENERAL CONDITIONS

- **HIGH ALTITUDE**
- **LOW ATMOSPHERIC TURBIDITY**
- **INTENSE SUNLIGHT**
- **DEEP BLUE SKIES**
What is Your Dominant Sky Condition?

SUNNY OR SUNNY WITH SOME CLOUDY:

- Optimize for SUNLIGHT
- PROVIDE GLARE CONTROL
- POINT SOURCE LIGHTING

OVERCAST OR OVERCAST WITH CLOUDY:

- Optimize for DAYLIGHT
- AREA SOURCE LIGHTING
FOR EACH SPACE ASK THE FOLLOWING QUESTIONS…

• HOW IMPORTANT IS DAYLIGHT?

• HOW IMPORTANT IS VIEW?

• WHEN IS THE SPACE OCCUPIED?

• HOW IMPORTANT IS DIRECT SUN AND GLARE CONTROL?

• WHAT IS THE APPROPRIATE SOLAR ORIENTATION?

• WHAT IS THE BEST STRATEGY FOR PROVIDING DAYLIGHT?
5 Sunlighting Strategies

1. SHADE
2. REDIRECT
3. CONTROL
4. EFFICIENCY
5. INTEGRATE
1. Shade

PREVENT GLARE AND HEAT GAIN

NORTH/SOUTH OPENINGS:
• ILLUMINATE HORIZONTAL SURFACES

EAST/WEST OPENINGS:
• ILLUMINATE VERTICAL SURFACES
2. Redirect

- Put the light where needed
- Create proper distribution
- Spread light over large area:
  - Balance brightness
- Reduce contrast:
  - Window and surrounding surfaces
3. Control

PROVIDE THE RIGHT AMOUNT OF LIGHT AT THE RIGHT TIME

DO NOT OVERLIGHT THE SPACE
SHAPE INTERIOR TO USE THE LIGHT
USE HIGH REFLECTANCE SURFACES
REDUCE THE TOTAL SUNLIGHT NEEDED
5. Integrate

COORDINATE WITH THE ARCHITECTURE

PROVIDE FOR VIEWS OR OTHER ESSENTIAL CHARACTERISTICS
5 Daylighting Strategies

REMEMBER: THE SKY IS THE LIGHT SOURCE

1. MAXIMIZE SKY VIEW

2. SHADE FOR GLARE

3. DO NOT BLOCK DAYLIGHT

4. HIGH OPENINGS

5. SHAPE SPACE
1. Sky View

MAXIMIZE SOLID ANGLE OF SKY SEEN FROM TASK

SIDELIGHTING DEPTH = 2.5 TIMES WINDOW HEAD HEIGHT
2. Shade

SHADE TO PREVENT GLARE

DIRECT VIEW OF SKY CAN BE GLARING
FOR DAYLIGHTING DO NOT USE LIGHTSHELVES OR OVERHANGS THAT BLOCK TASK VIEW OF THE SKY
4. Locate Openings High

**Higher Opening: Deeper Daylight Penetration**

**Sidelighting Depth = 2.5 Times Window Head Height**
5. Shape Space

USE HIGH REFLECTANCE FINISHES

PROVIDE HIGH CEILINGS AT WINDOWS
Planning for Solar Access

TOPOGRAPHY

• Land Forms and Vegetation

BUILDING SHADING

• Obstruction and Reflection

SOLAR ENVELOPES

• Zoning to Preserve Solar Access
Forms for Admitting Daylight

1. SIDELIGHTING
2. TOPLIGHTING
3. ATRIA
1. Sidelighting

CEILING REFLECTANCE

CEILING IS THE MOST IMPORTANT LIGHT-REFLECTING SURFACE

1. SHOULD BE UNOBSERVED, HIGHLY REFLECTIVE, “SEEN” BY THE TASKS

2. SHOULD BE AS HIGH AS POSSIBLE BUT NOT HIGHLY ARTICULATED
1. Sidelighting

WINDOW OPENINGS

IN A VERTICAL SECTION:

- UPPER SECTION: BEST FOR OVERCAST CONDITIONS, HIGH SUN AND GLARE POTENTIAL, NEED TO PROPERLY BAFFLE

- MIDDLE SECTION: BEST FOR VIEW ORIENTATION, AVOID REFLECTED GLARE PROBLEMS

- LOWER SECTION: OPTIMAL FOR REFLECTED SUNLIGHT, BUT CAN BE A SOURCE OF REFLECTED GLARE
SUNLIGHT REDIRECTING

LIGHT SHELVES

• HORIZONTAL SHADING AND REDIRECTING DEVICE

• MOST EFFECTIVE ON SOUTH ELEVATION

• REDUCES ILLUMINATION NEAR WINDOW WHILE PUSHING LIGHT DEEPER INTO THE SPACE

• DEPTH IS DETERMINED BY SHADING NEEDS

APPLIES TO DIRECT SUNLIGHTING, NOT APPROPRIATE FOR OVERCAST CONDITIONS
1. Sidelighting

GLARE AND THERMAL CONTROL STRATEGIES

• AUTOMATED EXTERIOR SHADING SYSTEM
• FIXED EXTERIOR SHADING SYSTEM
• EXTERIOR FABRIC AWNING
• HIGH PERFORMANCE GLAZING
• OPERABLE WINDOW
• AUTOMATIC INTERIOR SHADING SYSTEM/DOUBLE SKIN
• MANUAL INTERIOR SHADING SYSTEM
2. Toplighting

CHARACTERISTICS

• LONG HISTORY IN ARCHITECTURE
• VIEWS ARE OF SUNLIT SURFACES
• LESS GLARE POTENTIAL
• PROVIDES MORE LIGHT PER UNIT AREA OF OPENING THAN SIDELIGHTING
• CAN BE ORIENTED INDEPENDENTLY OF BUILDING ORIENTATION
2. Toplighting

DESIGN OPTIONS

- CLERESTORY
- MONITOR
- SAWTOOTH
- SKYLIGHT
2. Toplighting

SHAPE

- SHAPE, REFLECTANCE AND PROPORTIONS ARE CRITICAL
- HIGHER CEILINGS PROVIDE BETTER LIGHT DISTRIBUTION
- USE SUNLIGHT INDIRECTLY: USE WALLS OR DEEP WELLS FOR LIGHT RECEIVING SURFACES
- DEEP SPLAYED LIGHT WELLS: IMPROVE LIGHT DISTRIBUTION, REDUCE CONTRAST, AND INCREASE APPARENT SIZE OF SOURCE
3. Atria

CHARACTERISTICS

- CENTRAL SPACE: ATRIA, COURTYARD, LIGHT WELL, LIGHT COURT
- COMBINES TOPLIGHTING AND SIDELIGHTING
- ALLOWS MULTIPLE LEVELS TO BE ILLUMINATED
- CREATES A STRONG ARCHITECTURAL FEATURE
- MAY BE THERMALLY ISOLATED OR CONNECTED TO ADJACENT SPACE
3. Atria

**Types**

- Atria as “holes” to create thinner floor plates
- Atria as “winter garden” for tempered space

**Shape**

- Atrium: visual relief and interest of an outdoor space
- Litrium: optimized to provide natural light of adjacent spaces, usually wider at top floors
3. Atria

OPENINGS

- HORIZONTAL SKYLIGHT TYPE: GOOD FOR OVERCAST SKIES, EXCESSIVE SUMMER HEAT GAIN, MAY HAVE MOVABLE ROOF

- SLANTED OR CLERESTORY: BALANCES LIGHTING WITH THERMAL GAINS IN A TEMPERATE CLIMATE

- ATRIA PROVIDE A SECOND FILTER WHICH CAN MODIFY THE LIGHT

- LIGHT AT PERIMETER MAY BE DIFFUSED OR REDIRECTED WITH SUNCATHERS OR LIGHTSHELVES
3. Atria

LIGHT WELLS

• LARGE, WIDE WELLS WILL PRODUCE MORE ILLUMINATION

• USE HIGH REFLECTANCE OR MIRRORED WALL FINISHES

• ALLOWS LIGHT TO BE BROUGHT DEEP INTO THE INTERIOR
Integration with Electric Lighting

TOP TEN COMMON CONTROL FAILURES

1. INAPPROPRIATE OR UNEXPECTED TRANSITIONS
2. EMERGENCY FIXTURES ALWAYS ON
3. CULTURAL RESISTANCE
4. WHAT THE PHOTOCELL SEES IS NOT REPRESENTATIVE OF THE SPACE
5. NO SPECIFICATION OF REFERENCE LOCATION FOR CALIBRATION
6. NO SPECIFIED LIGHT LEVELS
7. NOT COMMISSIONED OR PROPERLY DONE
8. COMMISSIONING NOT IN ANYONE’S SCOPE
9. INSUFFICIENT RELAYS OR POWER LOSS IN LONG RUNS
10. INAPPROPRIATE ZONING THAT DOES NOT RELATE TO DAYLIGHT PATTERNS
Daylight Checklist

1. **Determine Availability of Natural Light and the Dominant Sky Condition**

2. **Identify Visual Program Needs**

3. **Choose the Appropriate Strategy**

4. **Use Design Strategy Effectively**

5. **Check and Test Design**

6. **Integrate with Electric Lighting System**
Part 3: Daylighting Design

Montana Solar Angles

Window Wall Ratio

Shading Systems

Glazing Properties
Montana Solar Angles

SOUTHERN BORDER

45 North

NORTHERN BORDER

49 North
LONG AXIS NORTH-SOUTH

- Morning and afternoon exposure
- More light and solar in summer
- Difficult to shade direct sunlight
- Fine for top lighting

LONG AXIS EAST-WEST

- Winter: greater solar on south
- Summer greater solar on roof
- South façade easy to shade
Horizontal Shading

SHADING DEVICES

1. HORIZONTAL:
   - SHADE BASED ON SOLAR ALTITUDE ANGLES
   - EFFECTIVE ON SOUTH ELEVATION
   - GOOD SEASONAL SUNLIGHT CONTROL
Vertical Shading

SHADING DEVICES

2. VERTICAL:

• SHADE BASED ON SOLAR AZIMUTH ANGLES

• EFFECTIVENESS CHANGES DIURNALLY

• PROVIDES LOW ANGLE SUN CONTROL: EAST AND WEST ELEVATIONS

• MIGHT ALSO BLOCK VIEW

• MAY NEED TO BE ADJUSTABLE
Glazing Properties

SHADING COEFFICIENT

SOLAR HEAT GAIN COEFFICIENT

U-VALUE

VISIBLE LIGHT TRANSMITTANCE (VT)

LIGHT TO SOLAR GAIN (LSG)
Part 4: Tools for Daylighting

TARGETS

RULES OF THUMB

COMPUTER SIMULATIONS
LEED v4, 2013 Daylight Credit

3 OPTIONS TO DEMONSTRATE COMPLIANCE:

1. SIMULATION: SPATIAL DAYLIGHT AUTONOMY (SDA) & ANNUAL SUN EXPOSURE (ASE)

2. SIMULATION: ILLUMINANCE CALCULATIONS

3. MEASUREMENT
OPTION 1: SIMULATION – SDA & ASE

- REQUIRED: MANUAL OR AUTOMATED (WITH MANUAL OVERRIDE) GLARE CONTROL DEVICES
- LOCATION BASED AND ANNUALIZED
- SDA OF AT LEAST 55%, 75% OR 90%
- ASE OF NO MORE THAN 10%

SEFAIRA TUTORIAL EXAMPLE
OPTION 2: SIMULATION

- PROVIDE A MINIMUM OF 300 LUX AND A MAXIMUM OF 3000 LUX

- AT LEAST 75% OF REGULARLY OCCUPIED AREA SHOULD BE WITHIN LUX RANGE

- CLEAR SKY CONDITIONS, SEPTEMBER 21 AT 9 AM AND 3 PM (EQUINOX)

- VIEW-PRESERVING AUTOMATED SHADES FOR GLARE CONTROL
OPTION 3: MEASUREMENT

- INDOOR LIGHT MEASUREMENT: PROVIDE A MINIMUM OF 300 LUX AND A MAXIMUM OF 3000 LUX

- MEASUREMENT TAKEN ON 10-FOOT GRID

- MEASURED AT APPROPRIATE WORK PLANE HEIGHT
**LEED v4, 2013 Views Credit**

<table>
<thead>
<tr>
<th>VIEW TYPES</th>
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<tbody>
<tr>
<td>1. Multiple lines of sight to vision glazing in different directions at least 90 degrees apart</td>
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<tr>
<td>2. Views that include at least two of the following</td>
</tr>
<tr>
<td>- Flora, fauna or sky</td>
</tr>
<tr>
<td>- Movement</td>
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<tr>
<td>- Objects at least 25 feet from exterior of glazing</td>
</tr>
<tr>
<td>3. Unobstructed views located within distance of 3 times head height of vision glazing</td>
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<tr>
<td>4. Views with view factor of 3 or greater</td>
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1. **Provide occupants with a connection to the outdoors**

2. **Achieve direct line-of-sight to outdoors via vision glazing between 30” and 90” above finished floor in 75% of all regularly-occupied areas.

Views to include at least two of the view types.
LEED v4, 2013 Views Credit

LEED V4 VIEWS CREDIT EXAMPLE

JAKE JABS HALL
MONTANA STATE UNIVERSITY, BOZEMAN, MT

View 1 & 2
View 2 & 3
View 2 & 4
Not Qualified
1. **THE 2.5H GUIDELINE**

- Assumes clear glazing
- Overcast skies
- No obstructions
- Window area about half of exterior wall area

2. **THE 15/30 GUIDELINE**

Next 15 feet is partially daylit, needs electric light supplement beyond 30 feet, very little daylight.
**Rules of Thumb**

**DAYLIGHT FACTOR (DF) GUIDELINES**

\[
DF\% = \left(\frac{\text{INT. ILLUM.}}{\text{EXT. ILLUM.}}\right) \times 100
\]

<table>
<thead>
<tr>
<th>DF RECOMMENDATIONS</th>
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<tbody>
<tr>
<td>Minimum for circulation</td>
<td>0.5</td>
</tr>
<tr>
<td>Ordinary visual tasks:</td>
<td>1.5 to 2.5</td>
</tr>
<tr>
<td>Moderately difficult tasks</td>
<td>2.5 to 4.0</td>
</tr>
<tr>
<td>Difficult prolonged tasks</td>
<td>4.0 to 8.0</td>
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Computer Simulations

Computer Programs Provide:

- Daylight and Electric Lighting Calculations

  Illumination, Luminance, and Daylight Factor Calculations

  Electric Lighting Using Standard IES Photometric Files

- Radiosity and Ray Tracing Visualizations
MANY PROGRAMS TO CHOOSE FROM:

VELUX DAYLIGHT VISUALIZER  HTTP://VIZ.VELUX.COM
RADIANCE  HTTP://WWW.RADIANCE-ONLINE.ORG/
DAYSIM  HTTP://DAYSIM.NING.COM/
DIVA FOR RHINO  HTTP://DIVA4RHINO.COM
DIAL+  HTTP://WWW.ESTIA.CH
IESVE  HTTP://WWW.IESVE.COM/
DIALUX  HTTP://DIAL.DE/
RELUX  HTTP://WWW.RELUX.BIZ/
AGI32  HTTP://WWW.AGI32.COM
ECOTECT  HTTP://USA.AUTODESK.COM/ECOTECT-ANALYSIS/
EVALGLARE  HTTP://WWW.ISE.FRAUNHOFER.DE
LIGHTSOLVE  HTTP://LIGHTSOLVE.EPFL.CH
3DS MAX DESIGN  HTTP://WWW.AUTODESK.COM
GROUNDHOG  HTTP://GROUNDHOGPROJECT.ORG/
Computer Simulations

DIVA FOR RHINO

WEB: [http://solemma.net/TrainingRhino.html](http://solemma.net/TrainingRhino.html)

DAYLIGHT AUTONOMY

FALSE COLOR

Occupied hours %

0%

100%
Part 5: Resource

Daylighting Pattern Guide

Introduction
New Buildings Institute in partnership with the University of Idaho and University of Washington has developed a freely available interactive tool for the design of proven daylighting strategies in a variety of building types. Users will be introduced to the Daylighting Pattern Guide while exploring the inter-relationship of key site, aperture, and space planning. The guide uses a combination of built examples and advanced simulation to set the stage for substantial reductions in lighting power consumption and overall energy use through successful daylighting design.