LIGHTING BY PASSIVE & ACTIVE SOLAR USE DESIGN

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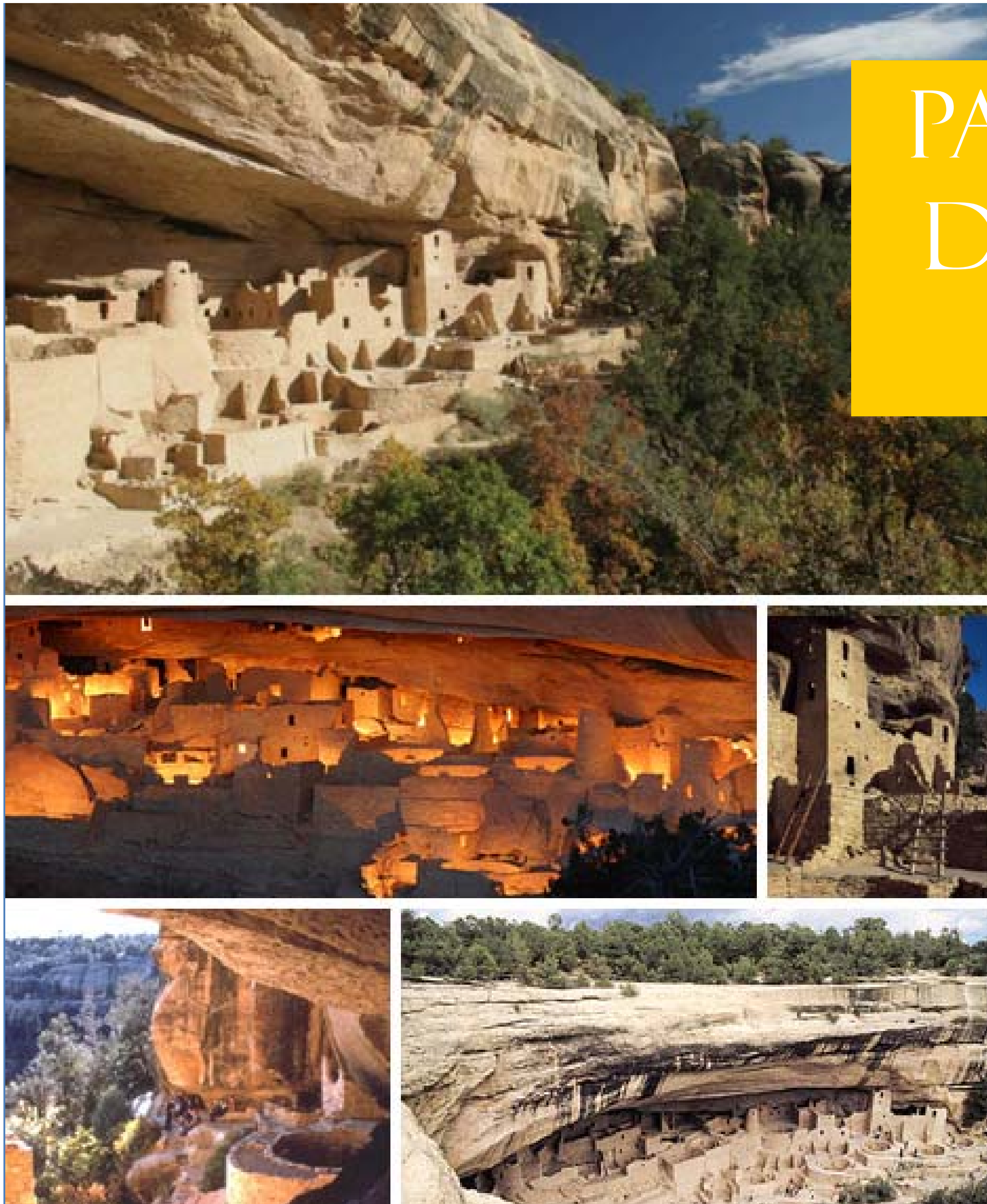
Burnham-Moores Center, University of San Diego MSRE February 25, 2014



Passive Solar Design Came First…

Ancient Egyptians, Greeks, Romans and Native Americans utilized passive solar design for heating, cooling and combating fuel shortages.

Historical Source: http://webecoist.momtastic.com/2009/01/25/ancient-green-architecture-alternative-energy-design/

Today

Solar design continues to be relevant because…

1 the negative environmental impact of burning fossil fuels

2 solar energy is the most abundant energy resource we have in the entire universe.

and **3 electric lighting accounts for 35-50% of electrical energy consumption**.

Today's Relelvance Source: http://homeguides.sfgate.com/difference-between-active-passive-solar-collectors-79681.html & http://www.wbdg.org/resources/daylighting.php

PASSIVE VS. ACTIVE DESIGN

How energy is collected and distributed
is the difference between active and passive solar design.

Passive solar design

No mechanical systems

No external sources of energy to power technologies.

Passive Solar Design Systems

- Simpler
- Redirect light & heat into rooms by design
- Shading features reduce unwanted light and heat
- =Daylighting

Passive vs Active Source: http://homeguides.sfgate.com/difference-between-active-passive-solar-collectors-79681.html

Passive vs. Active Design

How energy is collected and distributed
is the difference between active and passive solar design.

Active solar design

Uses both mechanical systems & external sources of energy to power technologies that turn solar energy into other useful energy.

Active Solar Design Systems

- Are more complex
- Collect, store and convert solar energy into electricity.
- =Daylight Harvesting

Passive vs Active Source: http://homeguides.sfgate.com/difference-between-active-passive-solar-collectors-79681.html

PASSIVE DESIGN

Solutions

Image Source: http://www.solatube.com/showcase/commerical-showcase

Building Orientation

Construction of site to maximize sun exposures
which change with time of day and season

The building's two wings are elongated on the east-west axis to make the most of sunlight for interior illumination.

Image & Caption Source: http://www.ecofriend.com/rnl-design-creates-sustainable-rsf-building-for-nrel-and-doe.html

Building Orientation

Optimized Building Footprint

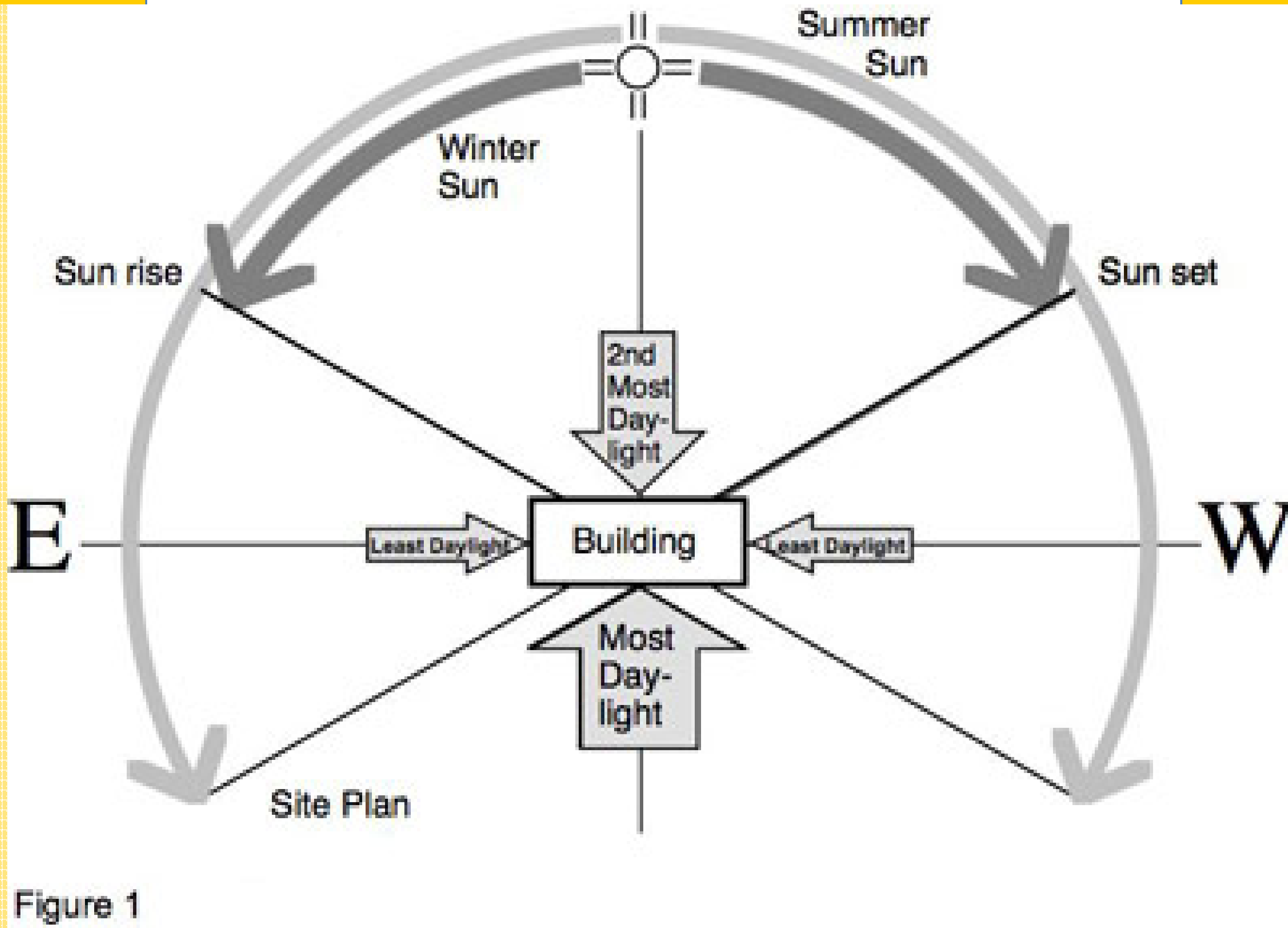


Image Source: http://www.wbdg.org/references/mou_daylight.php

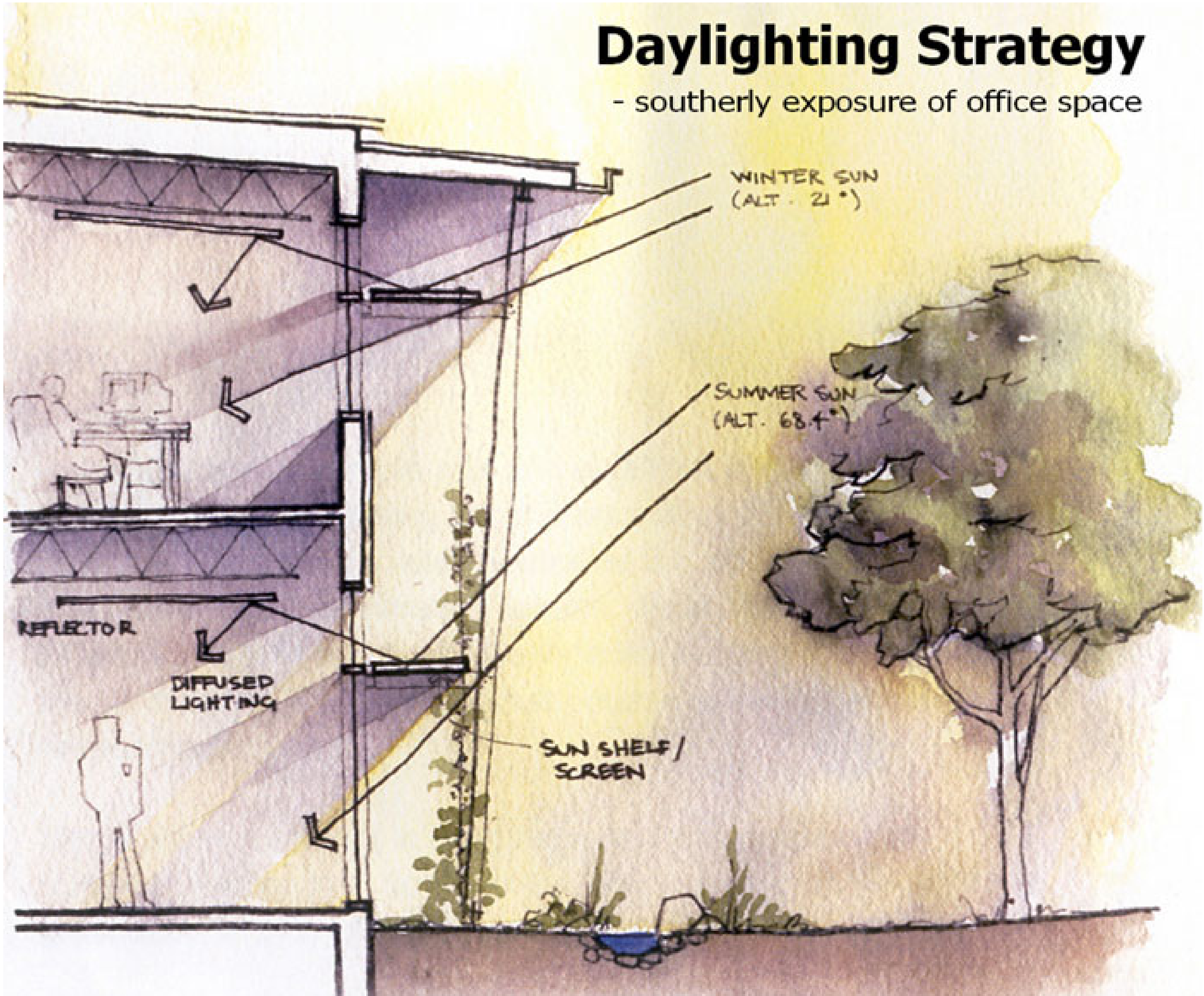


Image Source: http://www.rvca.ca/new_building/2008_RVCA_Conservation_Centre/green/index.html

Fenestration

- The design and placement of windows, doors & top lights
- Considers window to wall ratio
- Balances insulation (no energy gets in or out) and desire for shaded spaces with natural light transmittance.

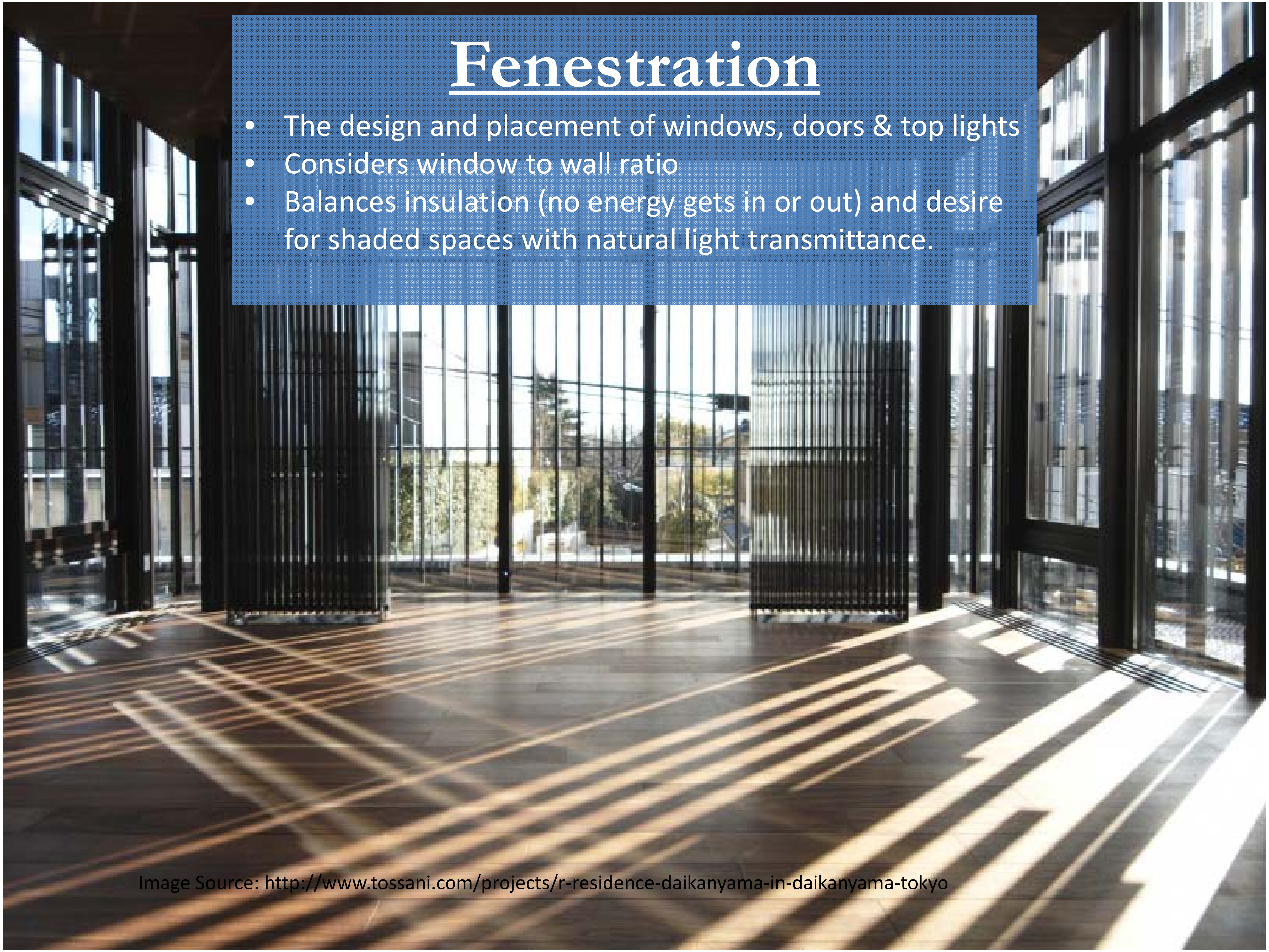
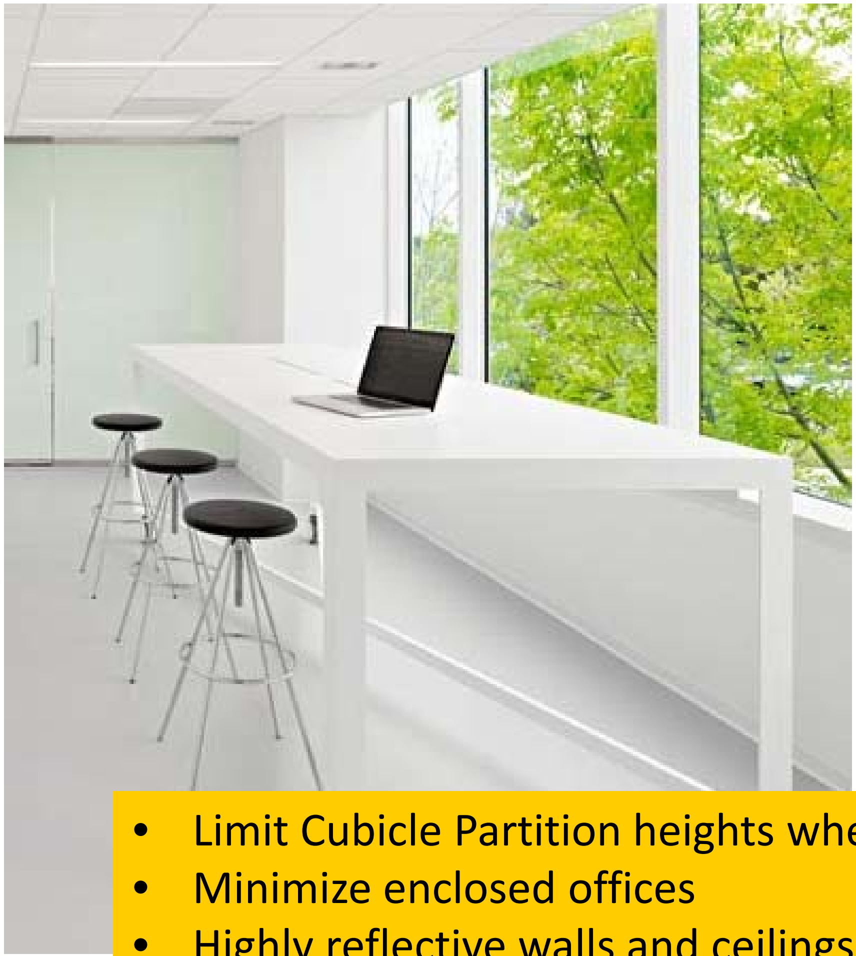
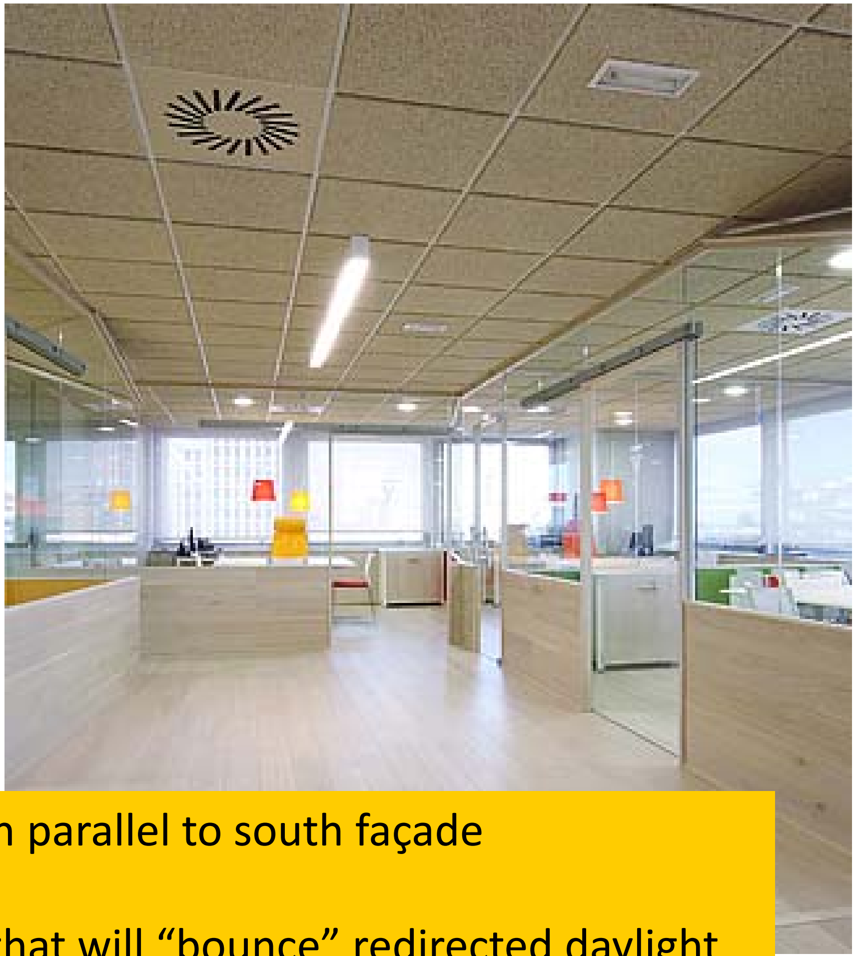


Image Source: http://www.tossani.com/projects/r-residence-daikanyama-in-daikanyama-tokyo

Interior Design

Furniture design, space planning and room surface finishes





- Limit Cubicle Partition heights when parallel to south façade
- Minimize enclosed offices
- Highly reflective walls and ceilings that will “bounce” redirected daylight

Image Source: http://prsarahevans.com/category/office-workspace/ http://worldhousedesign.com/interior-design/white-office-interior-design-by-garcia-tamjidi-open-office-areas-with-maximize-natural-light/

Architecture

Lighting Shelves

Image Source: http://besthomeinspirations.com/home-lighting-alternative-beside-skylight/
Image Source #2: http://www.architectureweek.com/2010/0922/

Dynamic Glass

- Glazing
- Curtain Wall
- Highly energy efficient
- Switches between clear and tinted states on demand
- Provides glare and heat control with unobstructed views
- Generally admits more light and less heat than a typical window.

Image Source: http://www.glassolutions.at/en/unternehmen/saint-gobain/quantum.aspx

Solar Tubes

- Top lighting devices
- Use a highly reflective film on the interior of a tube
- Channels light from a lens at roof to a lens at ceiling plane.
- Tend to be much smaller than a typical skylight
- Still deliver sufficient daylight for dimming of electric lighting.

Image Source: http://inhabitat.com/solar-tube/

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TUBES

Image Source: http://www.solatube.com/showcase/commerical-showcase

Skylights –

Top lighting
Most are passive, but can be active
Have a clear or diffusing medium (usually acrylic)
Allows daylight to penetrate an opening in the roof
Double layer of material, for increased insulation.

Image Source: http://www.unicelarchitectural.com/en/skylights.php

ACTIVE DESIGN
Solutions

Automatic Shading

- Devices with timers and sensors to shade building from unwanted sun exposure aka solar gains & glare
- Typically employed around windows with daylighting design
- Also known as overhangs

Image Source: http://unicelarchitectural.com/en/louvers.php

Daylight-Responsive Electric Lighting Controls

Photocells sense natural light illumination and reduce artificial light consumption accordingly by dimming electric lights and storing daylight.

Day

Night

Daylight Harvesting

Stored solar energy used to power artificial lights used when natural light is not available.

Image Source: http://www.lightingcontrols.com/design/innovative/daylight/overview/overview.asp

Daylight Harvesting

Photovoltaic Cells, Photocells, PV cells, PVs—store and distribute solar energy where it can be efficiently used

Image Source: http://www.hope-project.org/energy/advantages-and-disadvantages-of-solar-panels/

CLIMATE CATEGORY MATTERS

A Net Zero requirement & energy efficiency guideline…
decrease need for space conditioning aka artificial heating and cooling through HVAC systems.

Determine climate category:

(1) Cooling-dominant-- average temperature per day above 80F,
(2) Heating dominant-- average temperature per day below 65F
or (3) both cooling and heating dominant aka major energy consumption climate

Examples of California climate categories 1 -3:

Cooling-dominant: Brawley, CA Zone 15

Heating-dominant: Eureka, CA Zone 1, Bishop, CA Zone 16

Cooling & Heating-dominant: Riverside, CA Zone 10, Fresno Zone 13, Barstow Zone 14

San Diego is Zone 7 which requires both cooling and heating, but minimally thus low in terms of energy consumption.

Source: http://task40.iea-shc.org/data/sites/1/publications/DC-TP8-Cory-2011-11%20.pdf California Climates Source: http://www.pge.com/includes/docs/pdfs/about/edusafety/training/pec/toolbox/arch/climate/california_climate_zones_01-16.pdf

Solar Design Energy Performance Standards

- **Energy Star**—U.S. Government backed (Environmental Protection Agency) program helping businesses and individuals protect the environment through superior energy efficiency.
  - ❖ Commercial buildings must earn 75 pts on 1-100 scale.
  - ❖ Enter your own data on interactive online tool

- **LEED**—Green building certification through U.S. Green Building Council.
  - ❖ International certification
  - ❖ Must be verified through 3rd party

- **Title 24**—California's Building Energy Efficiency Code enacted 1977
  - ❖ Purpose to provide California with an adequate, reasonably-priced, and environmentally-sound supply of energy.
  - ❖ The standards are updated periodically by the California Energy Commission to allow for new energy efficiency technologies and methods.
  - ❖ Stricter regulations effective July 1, 2014

- **ASHRAE & IESNA**—A LEED certification prerequisite specific to lighting.
- **National Fenestration Rating Council (NFRC)**—An Energy Star prerequisite specific to the placement of windows, doors & top lights.

See Slide 30 for Solar Design Energy Performance Standards Sources

Most Common Window Performance Metrics

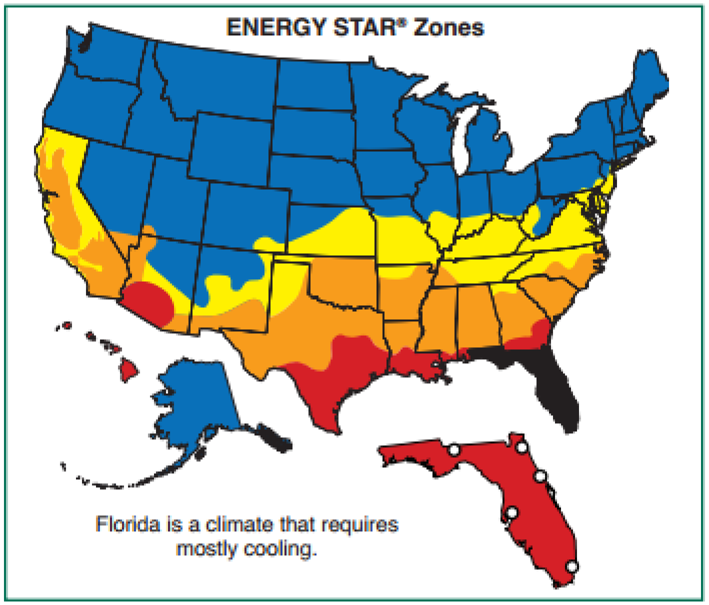
- U-factor
  - An insulation measurement of windows
  - Rate of non-solar heat transfer in or out through windows
  - Important when comparing to HVAC system
  - Lower is better if you need to keep heat where it is – less transference. Higher is acceptable in climates that don't require as much insulation. See Graphic for optimal ratings.

- Solar Heat Gain Coefficient (SHGC)
  - Measures solar heat transference.
  - Ratings between 0 and 1. A rating of 1 means the sun is completely blocked out. See graphic for optimal ratings.

- Visible Transmittance (VT) aka Light transmission coefficient (LT)
  - Measures visible light passing through glazed windows.
  - Important for daylighting.
  - The higher the ratio the less need for artificial lighting systems.

Ratings Source: http://energy.gov/energysaver/articles/energy-performance-ratings-windows-doors-and-skylights
(2) http://efficientwindows.org/performance.php

Metrics + Climate Category



Northern Zone U-factor	Northern Zone SHGC
Windows: $U \leq 0.30$ **Skylights: $U \leq 0.55$** If windows provide good access to winter solar heat gain (SHGC 0.40 or higher and southern orientation), a U-factor of 0.32 is also acceptable. For superior energy performance, use windows with a U-factor of 0.25 or less.	**No requirement.** If air conditioning is not a concern, look for a high SHGC (0.30–0.60) so winter solar heat can help offset the heating energy need. If cooling is a significant concern and no shading is available, select windows with a SHGC less than 0.40.
North/Central Zone U-factor	**North/Central Zone SHGC**
Windows: $U \leq 0.32$ **Skylights: $U \leq 0.55$** The larger your heating bill, the more important a low U-factor becomes. For superior energy performance, use windows with a U-factor of 0.25 or less.	**Windows: SHGC ≤ 0.40** **Skylights: SHGC ≤ 0.40** Windows with low SHGC values help reduce summer cooling demand, but they also reduce free winter solar heat gain. If you have significant air conditioning costs or summer overheating issues, look for SHGC values of 0.30 or less.
South/Central Zone U-factor	**South/Central Zone SHGC**
Windows: $U \leq 0.35$ **Skylights: $U \leq 0.57$** A low U-factor is useful during cold days when heating is needed and is also helpful during hot days when it is important to keep the heat out.	**Windows: SHGC ≤ 0.30** **Skylights: SHGC ≤ 0.30** Windows with low SHGC values help reduce summer cooling demand, but they also reduce free winter solar heat gain.
Southern Zone U-factor	**Southern Zone SHGC**
Windows: $U \leq 0.60$ **Skylights: $U \leq 0.70$** A low U-factor is useful during cold days when heating is needed and is also helpful during hot days when it is important to keep the heat out.	**Windows: SHGC ≤ 0.27** **Skylights: SHGC ≤ 0.30** A low SHGC is an important window property in warm climates. For superior energy performance, use windows with a SHGC of 0.25 or less.

Source: http://efficientwindows.org/factsheets/Florida.pdf

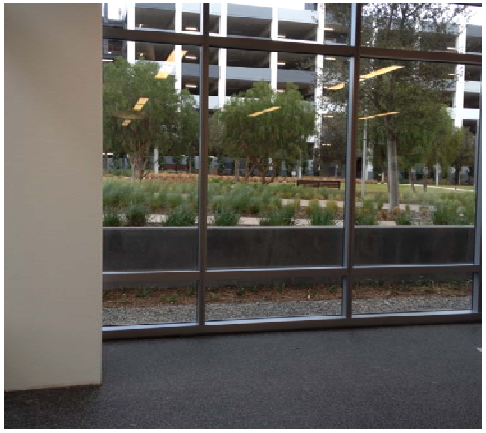
Benefits & Costs of Solar Design

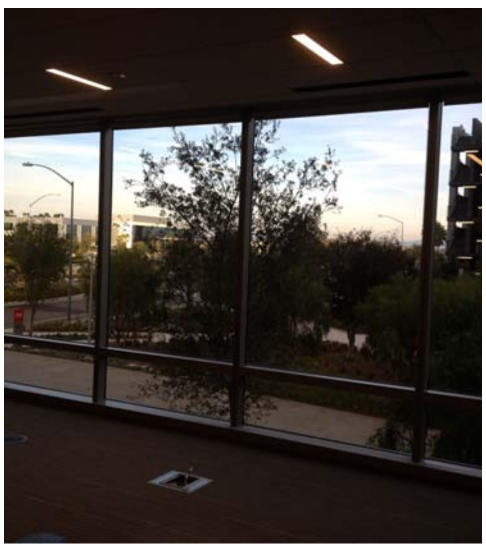
- Total Energy *Costs* can be reduced by 1/3
- Government financial incentives to include in construction
- Energy efficient points toward certification
- Daylight reduces greenhouse gases
- Slows fossil fuel depletion

- Daylighting *costs* $0.50 – 0.75 per sqft to implement
- Savings can be $0.05-0.20 per sqft annually.
- Increase worker productivity and decrease absenteeism in daylit commercial bldgs
- Boost test scores in daylit classrooms
- Accelerate recovery and shorten stays in daylit hospitals

Source: http://www.wbdg.org/resources/daylighting.php

La Jolla Commons Tower II





- **Viracon® Glass Curtain wall** integral to building design /selected early. Reduces the cooling load by lowering the amount of solar radiation admitted, heat.

- **Floor to ceiling windows** provide natural light, improve employee productivity and the quality of work environment.

- "**Title 24** standards are becoming much more stringent starting July 1, 2014. The solar heat gain co-efficient at LJC II is .28. The new standards require .25, sounds small but that is actually quite a large jump."

Source: Shaughnessy, Samantha. Group Tour. 11 Feb. 2014.

Reading Room
Kroon Hall at Yale

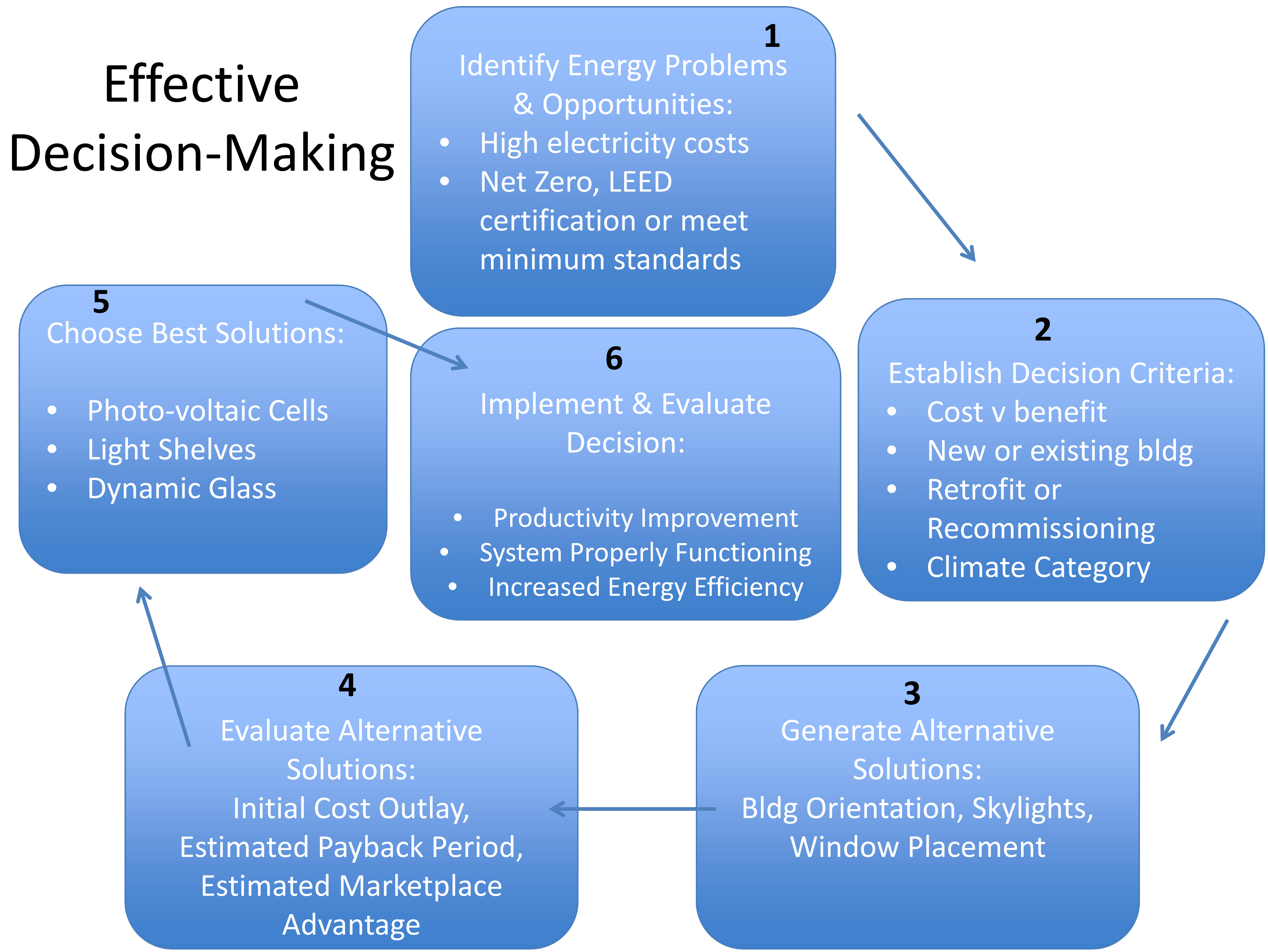
- Overhead skylights use photovoltaic panels to capture solar power
- Highly Insulated Façade with High Performance Windows & External Shading.
- Most used areas get maximum sun exposure: Top floors have reading room, classrooms and a café/ bottom floors have conference rooms.

Image Source: http://www.boston.com/bostonglobe/ideas/brainiac/2010/02/yale_building_w.html

Largest Solar-Powered Office Building in World

- Building located in China is modeled after the sun dial structure.
- The building will procure 95% of its energy needs from alternative energy sources.
- 5000 square meter solar panel array on the building complex.

Image Source: http://www.strengthconstructionlimited.com/tag/solar-energy


Effective Decision-Making
1
Identify Energy Problems & Opportunities:
• High electricity costs
• Net Zero, LEED certification or meet minimum standards
2
Establish Decision Criteria:
• Cost v benefit
• New or existing bldg
• Retrofit or Recommissioning
• Climate Category
3
Generate Alternative Solutions:
Bldg Orientation, Skylights, Window Placement
4
Evaluate Alternative Solutions:
Initial Cost Outlay, Estimated Payback Period, Estimated Marketplace Advantage
5
Choose Best Solutions:
• Photo-voltaic Cells
• Light Shelves
• Dynamic Glass
6
Implement & Evaluate Decision:
• Productivity Improvement
• System Properly Functioning
• Increased Energy Efficiency

Eco-Effectiveness

- “[Y]ou might start to envision the difference between eco-efficiency and eco-effectiveness as the difference between an airless, fluorescent-lit gray cubicle and a sunlit area full of fresh air, natural views, and pleasant places to work, eat and converse."

Source: William McDonough & Michael Braungart, *Cradle to Cradle*, New York: North Point Press, 2002, 76.

Sources for Solar Design Energy Performance Standards

- ASHRAE Sources: https://www.ashrae.org http://www.facilitiesnet.com/green/article/Energy-Modeling-ASHRAE-901-and-LEED--11188#
- Energy Ratings Source: http://www.nfrc.org/windowratings/Energy-ratings.html
- EnergyStar Source: https://www.energystar.gov/
- Energy v LEED Source: https://www.thgenergy.com/energymanagement/blog/12-03-16/ENERGY_STAR_vs_LEED_What_s_the_Difference.aspx

Thank you