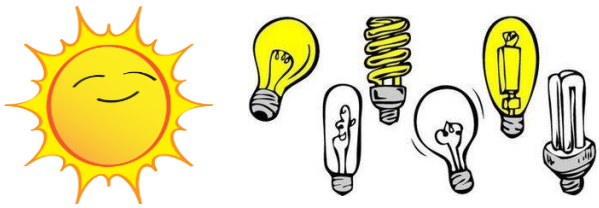
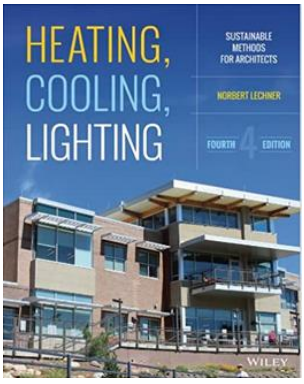


JT Wunderlich PhD

LIGHTING DESIGN

Including:



(CH 12) LIGHT
(CH 13) DAYLIGHTING
(CH 14) ELECTRIC LIGHTING

Illuminating Engineering Society (IES) Lighting handbook, 10th edition, 2011

Purchased for Elizabethtown College Library to compliment J Wunderlich Lighting Design lecture series in ERG/ART499A&B Architecture Studio I & II, 2018

Architectural Lighting

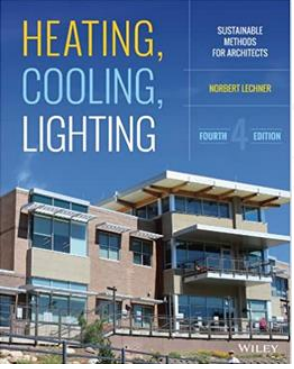
Use the sun as much as possible !

Rome, Italy 2011
Photo by J Wunderlich PhD

Architectural Lighting

Use the sun as much as possible !

Rome, Italy 2011
Photo by J Wunderlich PhD



CH 13 DAYLIGHTING

- RE-READ CH 7 HVAC-PASSIVE-Solar-*Heating*
- RE-READ Roman-A&E(pptx-audio pdf **mp4**)

HISTORY

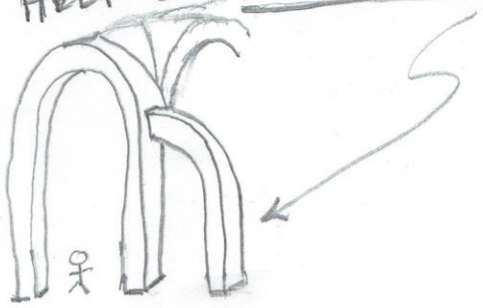
→ UNTIL 1800's, NO ARTIFICIAL LIGHTING DURING DAY

→ WESTERN CIVILIZATION → 50AD, FIRST GLASS WINDOWS → SUNROOMS → PANTHEON OCCULUS (GOOGLE IMG.)

700BC-500AD ROMAN → GROIN VAULT REPLACES BARREL VAULT

ALSO INCA'S (PURU) AND AMERICAN INDIANS CHANELED SUNLIGHT AND ORIENTED BUILDINGS SOUTH

~1300's GOTHIC ARCHITECTS USE GROIN VAULT AND MADE THEM HUGE, WITH THE HELP OF FLYING BUTTRESSES (GOOGLE IMG.)



~1400 TO ~1700AD RENAISSANCE WINDOWS DOMINATE WALLS

Pre-1900's

FLOOR PLANS (PRE-1900's)

→ HIGH SURFACE-AREA-TO-VOLUME RATIO
→ CALLED ENVELOPE DOMINATED BUILDING (E.D. BUILDING)
→ MAX LIGHT IN !!
→ ALSO YIELDS GOOD VENTILATION

EX'S

A good idea to mitigate the adverse effects of pandemics! – perhaps do now !!

JT Wunderlich PhD

~ 1860's TO PRESENT

INDUSTRIAL REVOLUTION 1860's + → "MODERNISM" 1900's

STEEL, MASS PRODUCTION

- → CURTAIN WALLS OF GLASS
- → SKYLIGHTS
- → HUGE SUN-SPACES
- → GLASS BLOCK

NON-WESTERN

ASIA FOR 1000's OF YEARS

→ SUN INTIGRATED INTO WAY OF LIFE

FENG SHUI (Chinese, 6000 years old!)

SOURCE:
http://www.homeonline.com/hol/home-tips/6-feng-shui-effects-of-sunlight-on-homes.html

Exposure to sun is vital for living. Hence it is important that the house is designed in such a way that it gets sufficient sunlight or else the good energies start to dissipate with the passage of time. Vastu and feng shui consultant Rashi Gaur points out the effects of sunlight on the energies of the house, the feng shui way.

In the northern hemisphere, the sun rises in the east. In the morning hours, it's the east zone of your house that gets maximum sunshine. This is good energy, the healing energy, and every household needs it. The energy that is soaked in through sunlight continues to stay there throughout the day. Hence it is vital to have an open zone in this area. Have windows, a balcony or garden, anything that allows the sun to enter. If you have plants in this zone, ensure that they don't grow so tall that they start blocking the good energy.

1. The sun moves to the South East zone from East and by afternoon, it is at its peak in the South zone. In the winter months, when the weather is cold, it is a good idea to allow sunlight in through these zones. While summer and sunlight is yang (positive energy) in nature, winter and night are yin (negative energy) in nature. Yang denotes life and yin denotes death. A balance of both is vital. Just like night and day are equally important, it is important to ensure that the amount of sunlight in the house is maintained to balance yin and yang.

2. In summer, the sun energy is anyway too strong and keeping the sun out is probably a good idea. Similarly if a room has way too much sunlight and you tend to feel restless there all the time, you need to tone down the energy. Use curtains and drapes as a solution.

3. If a particular room in the house gets too little or no sun at all itwould lead to dampness and stagnation. Switch on bright lights and play music at least for a few hours each dayto create artificial yang energy here. Pets are also a great source to uplift energy. This way you can ensure that there is more yang energy than yin energy to maintain balance in the house.

4. In a house where all windows are facing North, chances are that the house will have no direct sunlight and there may be a feeling of depression, bad mood or slowdown. People in such houses could face many problems in life. So it is vital to create parallel sources of light. Try and see if provision can be made for a skylight in the East, North East or South East. If skylight is not possible, see if a real fireplace can be placed . Adding candles and other sources of artificial lighting will also help.

5. If the longer length of your home faces east or west, chances are you will have most windows or openings there. Sunrise will energize your life helping you with new beginnings and getting you new projects. That's why east facing houses are always preferred. Sunset will make you more mellow and romantic. So a relaxation room with windows in the w[illegible]uld be a good choice.

JAPAN

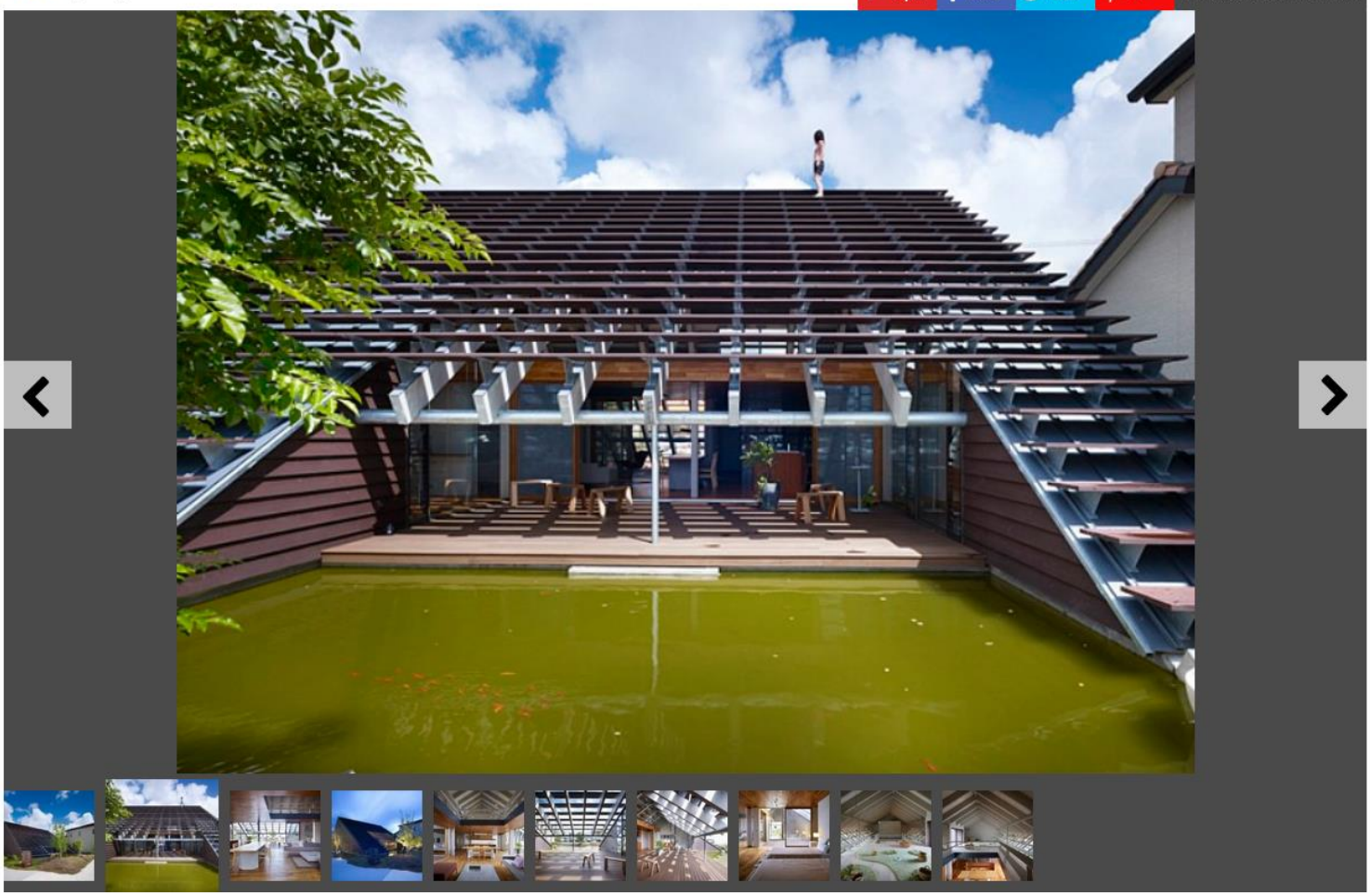
(recently)

INHABITAT NEWS DESIGN LIFESTYLE ENVIRONMENT

Cocage: Japanese Stepped Mountain Home Incorporates Light, Wind, Water & Shadows

08/15/2011
by Bridgette Meinhold

Flip It Share Tweet Pin PAUSE SLIDESHOW



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https://inhabitat.com/cocage-**stepped-mountain-home**-incorporates-light-wind-water-shadows/volumesmy-booksuppose_kochitiff_16-suu8806-tif/

JAPAN

(recently)

https://inhabitat.com/cocage-**stepped-mountain-home**-incorporates-light-wind-water-shadows/volumesmy-booksuppose_kochitiff_16-suu8806-tif/

JT Wunderlich 1989,90

School Lane Remodel

Wayne Pennsylvania, U.S.A.

Design/Builder

JT Wunderlich 1989,90

School Lane Remodel

Wayne Pennsylvania, U.S.A.

Design/Builder

LAWS FOR SUNLIGHT

TO 500 AD → ROMAN "SUN RIGHTS"

~1200 AD → ENGLAND DAYLIGHT-ACCESS LAWS

1900's → NEW YORK CITY ZONING
MINIMUM-LEVELS OF DAYLIGHT

PRESENT → MANY U.S. LOCAL ZONING LAWS
FOR BUILDING HEIGHT RESTRICTIONS
(∴ DON'T BLOCK SUNLIGHT TO
ADJACENT PROPERTIES)

ONE
3FT x 3FT WINDOW = 100 60 WATT LAMPS
AND CAN ILLUMINATE A FLOOR AREA = 450 (OVERCAST DAY) TO 2250 S.F. (SUNNY DAY)

LEED CREDITS FOR DAYLIGHTING

1	FOR 75% OF BUILDING DAYLIT
2	FOR 90% OF BUILDING DAYLIT
1 TO 10	FOR DAYLIGHT IMPROVING ENERGY EFFICIENCY OF BUILDING (ACTIVE AND PASSIVE)
1	FOR 90% OF OCCUPANTS HAVING GOOD VIEWS

REFLECTANCE

→ CHANNEL LIGHT WHERE YOU WANT IT
→ INTO BUILDING
→ WHITE PATIO
→ THROUGHOUT INTERIOR
→ LIGHT-COLORED WALLS

MATERIAL	REFLECTANCE
ASPHALT	10
CONCRETE	30 TO 50
GRASS	10 TO 35
BLACK PAINT	4
WHITE PAINT	70-90

DF

DAYLIGHT FACTOR %

"TYPICAL" BEFORE ANY SPECIAL MEASURES DESIGNED

→ RATIO OF ILLUMINATION GETTING INDOORS TO SUN OUTDOORS ON OVERCAST DAY

SPACE	DAYLIGHT FACTOR (%)
STUDIO	4-6%
FACTORY, LAB	3-5%
OFFICE, CLASSROOM GYM, KITCHEN	2%
LOBBY, LOUNGE LIVING ROOM, CHURCH	1%
HALLWAY, BEDROOM	0.5%

VARIATIONS DUE TO TYPICAL FLOOR PLANS

→ SO, NOT MUCH GETS IN ON OVERCAST DAYS

→ SO, MUST TAKE EXTRA MEASURES TO CHANNEL SUN INTO BUILDINGS!

BUT, CONSIDER A ~ COST/BENIFIT TYPE RATIO:

BENIFIT: SUNLIGHT-IN vs. ~COST IF YOU DON'T WANT IT: HEAT FROM SUN-IN

$$LSG = \frac{VT}{SHGC}$$

LSG: LIGHT TO SOLAR GAIN RATIO

VT: VISABLE TRANSMITTANCE

SHGC: SOLAR HEAT GAIN COEFFICIENT

CLEAR GLASS	1.20	=	0.82 / 0.75	ALL LIGHT AND HEAT GETTING IN
REFLECTIVE GLASS	1.25	=	0.20 / 0.16	EVERYTHING BLOCKED
SPECTARLY SELECTIVE LOW-E GLASS	1.52	=	0.70 / 0.46	LET MOST LIGHT IN BUT BLOCK MOST HEAT

JT Wunderlich PhD

RECALL lecture on CH 9, 10 PASSIVE Cooling & Shading (pdf **mp4** a b)

GLAZING TREATMENTS

	SC (SHADING COEFFICIENT)	SHGC (SOLAR HEAT GAIN COEFF)
CLEAR GLASS	1.0	0.86
REFLECTIVE GLASS	0.4	0.4
BLINDS	0.4	N.A.
TREES	0.4	N.A
GLASS BLOCK	0.1 TO 0.7	~0.6

EX "REFLECTIVE GLASS"
→ BLUE, GOLD, BLACK, ETC
→ POPULAR IN U.S SOUTHWEST

This type glass is now also typically Low-e

→ GLASS BLOCK
→ CAN BE VERY ESTHETIC
→ PRIVACY

JT Wunderlich 1984,85 — *"Project Manager" / Architectural-Designer*

West Lake Oaks Office Park (13 buildings)
Doerring Development Company
Austin TX

One of two IBM360 Computer Centers

Need Low-e Glass in places that get very hot for long periods of time, like Texas and California

JT Wunderlich PhD

I selected and ordered $1,200,000 *(in 2020 dollars)* of **"Ford Reflective Blue Glass"** for this building

JT Wunderlich 1985,86 — *"Director of Projects" / Architectural Designer*

High-tech office complex in San Diego CA
JDC inc *(Development Company)*, La Jolla CA

- On Architectural Design Team *(as Owner's Representative)*
- Added significant Architectural Design
- Project nominated for annual San Diego "Orchid Award"

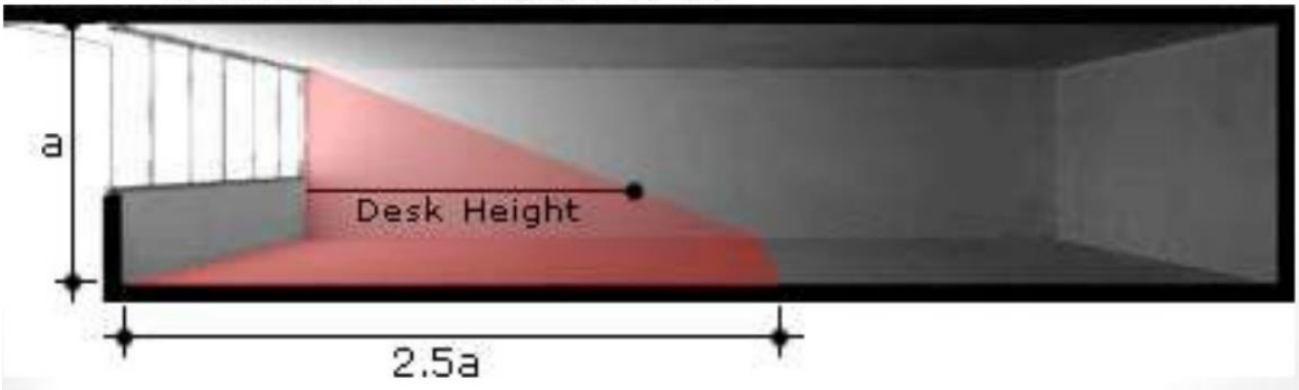
SOURCE: https://www.slideshare.net/pathyapustak/**light-and-architecture**/1

Lighting by use of natural sunlight-DAYLIGHTING :

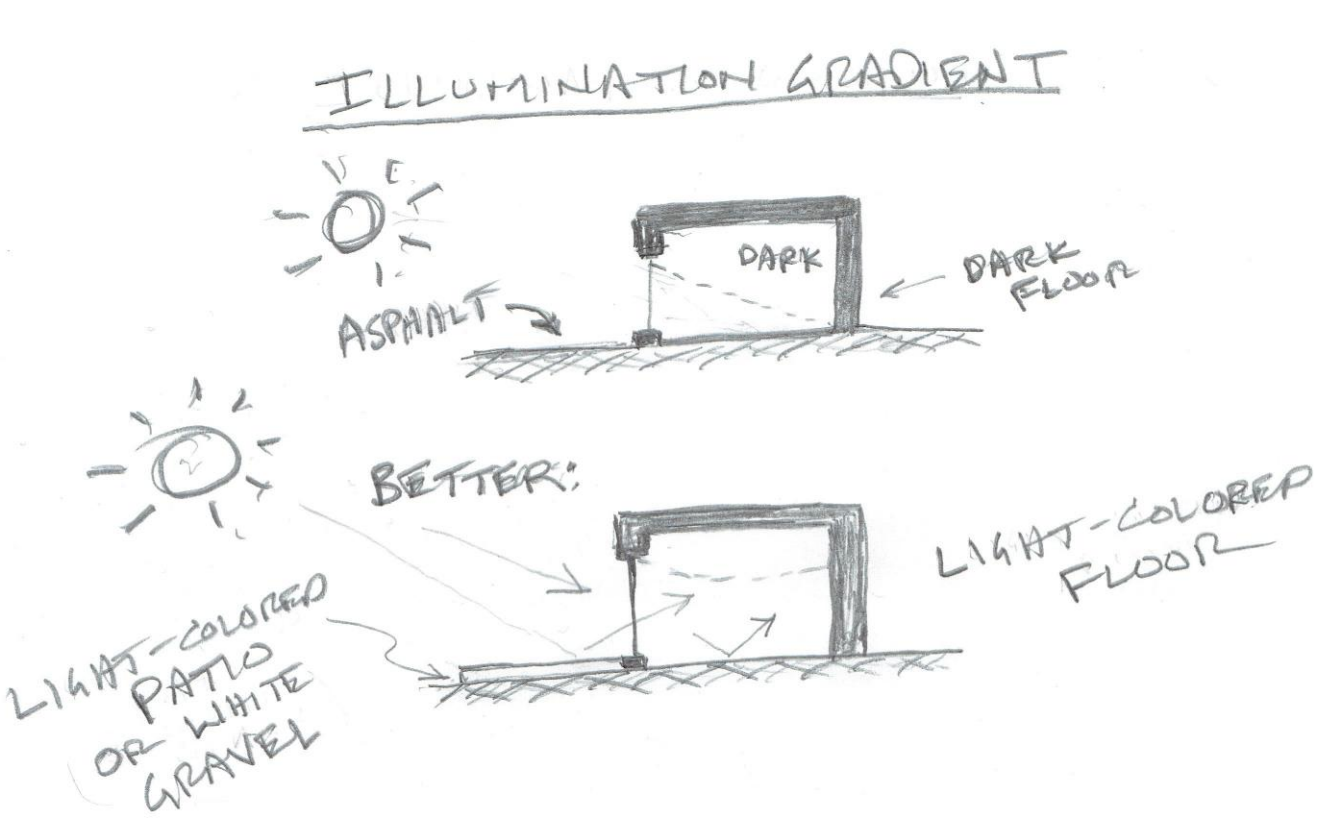
The daylight *factor*

From a subjective perspective, the following user responses to daylight factors have been suggested:

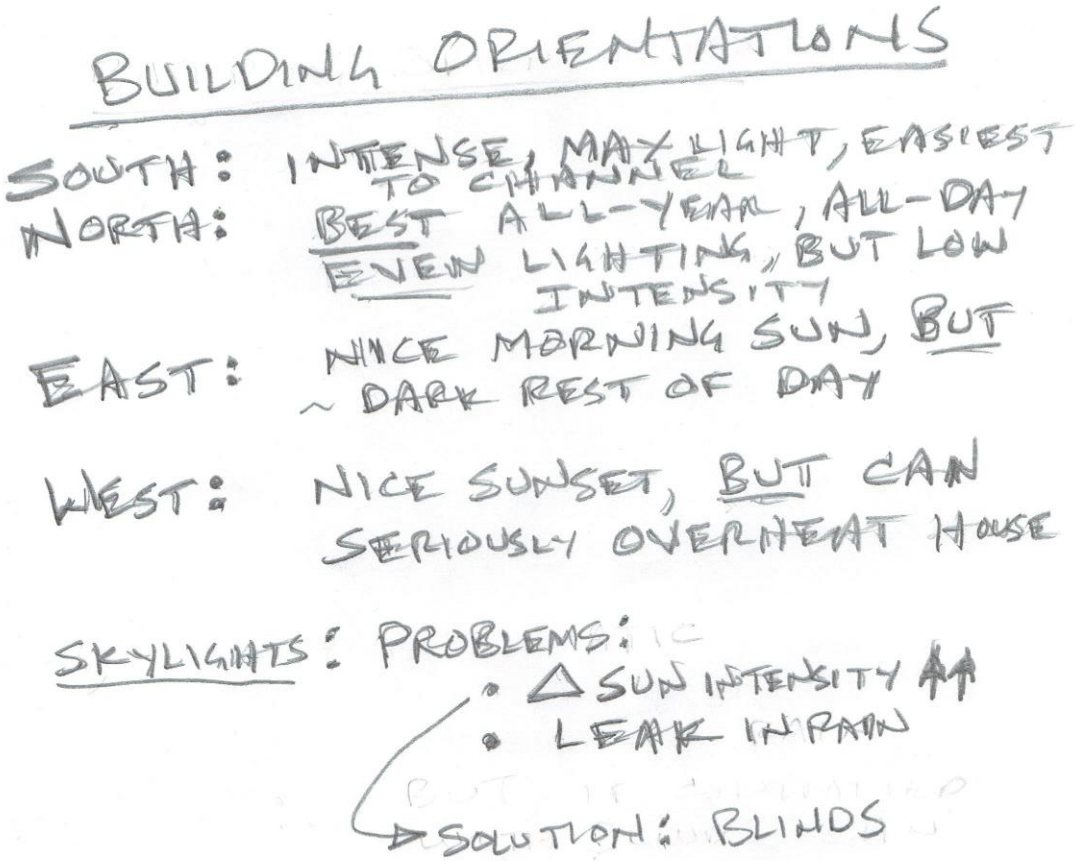
- With a DF of less than 2%, a room will seem gloomy. Electric lighting will be required for most of the daylight hours.
- With a DF between 2% and 5%, a room will feel that it is daylit, although supplementary electric lighting may be needed.
- With a DF greater than 5%, a room will feel vigorously daylit. Depending upon the task at hand, electric lighting may not be necessary during daylight hours.



Cross section showing lighting distribution from a single-sided window



Recall Lecture: CH 5,11 [Climate&Site-Design]

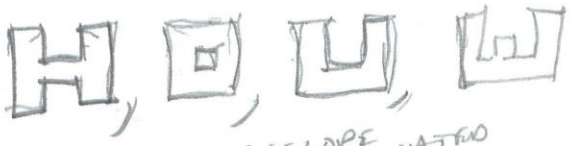


RECALL lecture on CH 9, 10
PASSIVE Cooling & Shading
(pdf **mp4** **a** **b**)

HOW TO GET LIGHT DEEP INTO BUILDING

Common building footprints prior to 20th century – for MAX Daylight and VENTILATION

1. MAX SURFACE AREA SHAPES (BUILDING FOOTPRINTS)



FOR E.D. (ENVELOPE DOMINATED) BUILDINGS

2. FOR I.D. (INTERNALLY DOMINATED) BUILDINGS, USE
   - SKYLIGHTS
   - LIGHT-TUBES
   - CLEAR-STORY WINDOWS
   - LIGHT "SCOOPS"
   - CURTAIN WALLS

   - EVENLY DISTRIBUTED ON TALL CEILINGS
   - CHANNEL LIGHT WITH REFLECTORS AND CEILINGS/WALLS

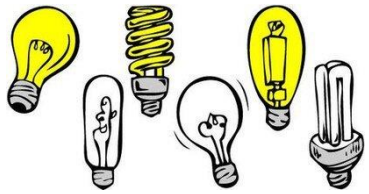
3. TALL CEILINGS, TALL WINDOWS
4. DISTRIBUTE WINDOWS EVENLY
5. LIGHT-COLORED WALLS CLOSE TO WINDOWS TO CHANNEL LIGHT
6. TRANSLUSCENT DRAPES
7. CHANNEL LIGHT WITH OPERABLE LOUVERS (ON WINDOWS, ETC.)
   → VENITIAN BLINDS
8. CHANNEL LIGHT IN WITH REFLECTIVE WINDOW SILLS (OR EVEN "LIGHT SHELVES")
9. GLASS FLOORS
10. HELIOSTAT → BIG DISH COLLECTS LIGHT

→ DISTRIBUTE LIGHT WITH FIBRE OPT

JT Wunderlich PhD

(11) TRANSLUSCENT WALLS + WINDOWS
→ LIKE TENTS
EX! LANCASTER, PA MALL
"PARK CITY"

https://www.tripadvisor.com/Attraction_Review-g52970-d4115576-Reviews-Park_City_Center-Lancaster_Lancaster_County_Pennsylvania.html

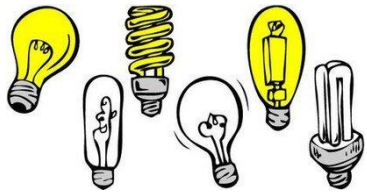


MIX OF NATURAL & ARTIFICIAL

PSYCHOLOGICAL CONSIDERATIONS

1. SPACIAL ORIENTATION
2. TIME "
3. FORM IDENTIFICATION (EDGES) → DETECTION
4. ACTIVITY ENHANCEMENT
5. DEFINE PERSONAL SPACE
6. HAPPINESS (WE NEED DAYLIGHT) REAL OR SIMULATED
7. VISUAL DIVERSITY NEEDS
8. ORDER "
9. SECURITY "
10. LIGHT POETRY
    - SUNSET / SUNRISE
    - SUNLIGHT ON A STREAM
        - → FOUNTAINS
        - → WATER FALLS
        - → KOY PONDS
    - UPLIGHTING ON STATUES + BLDGS + TREES
    - SPOTS ON PAINTINGS
11. COMBING SOURCE-TYPES WITH WALL/CEILING/FLOOR COLORS + TEXTURES
12. MAXIMUM NATURAL DAYLIGHT

JT Wunderlich PhD



MIX OF NATURAL & ARTIFICIAL

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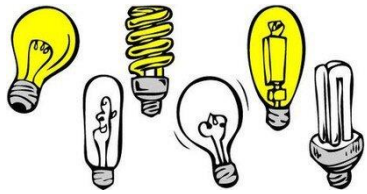


CASE STUDY: ART GALLERIES

MIX OF NATURAL & ARTIFICIAL

Synthesized by J Wunderlich, from Chapters 11 to 16, and 21

1. Lighting is for artwork more than observer

2. Use northern sunlight, including from north-facing skylights, to provide evenly distributed soft light, free of glare

3. Don't allow direct sunlight on art (to prevent damage)

4. Fill space with daylight without damaging art, then highlight art only as needed. This provides high-quality light, and energy efficiency, and earn LEED points

5. Control magnitude and spectra *(intensity of light over a range of energies)* of all light on art, to prevent damage

6. Consider thermal effects of light on art

7. Identify art as "high", "low", or "no" sensitivity; Then control light accordingly

8. Use only "subtle" or "soft" accent lighting on art

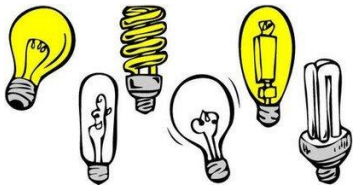
9. Accent lighting not on art, But to provide way-finding, and highlight architecture

10. Minimize impact on gallery from adjacent high-illuminance spaces such as hallways, lobbies, and restrooms. If necessary, use a "Light Lock" (a vestibule to separate transition space, like in a theater)

11. Use low reflectance ceilings, walls, and floors in low-illuminance gallery; and in adjacent high-illuminance spaces

12. Use indirect lighting to enhance ambient light, and provide way-finding and highlighted architecture; Using wall-sconces, pendants, chandeliers, up-lighting

JT Wunderlich PhD



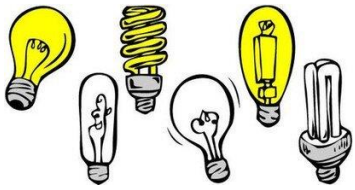
CASE STUDIES:
ART GALLERIES

MIX OF NATURAL & ARTIFICIAL LIGHTING

Venice

http://admore.it/2013/02/10/waiting-the-venice-art-biennal-2013/

JT Wunderlich PhD

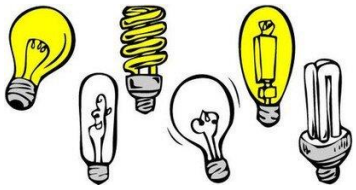


CASE STUDIES:
ART GALLERIES

MIX OF NATURAL & ARTIFICIAL LIGHTING

Venice

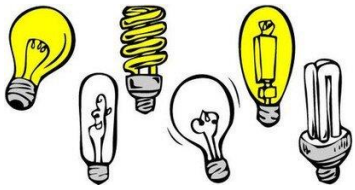
https://www.artsy.net/artwork/carla-chaim-project-to-resize-the-room



CASE STUDIES:
ART GALLERIES

MIX OF NATURAL & ARTIFICIAL LIGHTING

Venice
http://www.karenlamonte.com/keyword/Venice/

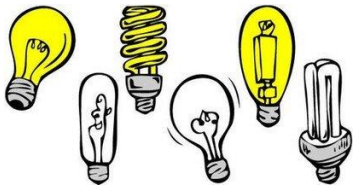


CASE STUDIES:
ART GALLERIES

MIX OF NATURAL & ARTIFICIAL LIGHTING

Venice

http://www.elleuk.com/life-and-culture/articles/g31780/six-best-art-venice-biennale-2017/

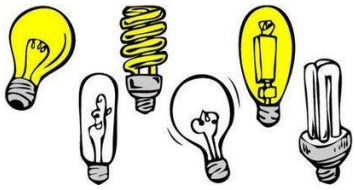


CASE STUDIES:
ART GALLERIES

MIX OF NATURAL & ARTIFICIAL LIGHTING

Venice

https://www.tripsavvy.com/top-venice-museums-1548030

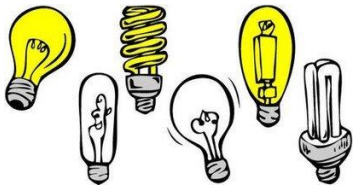


CASE STUDIES:
ART GALLERIES

MIX OF NATURAL & ARTIFICIAL LIGHTING

Venice

https://www.venetoinside.com/attraction-tickets-in-veneto/tickets/correr-museum/

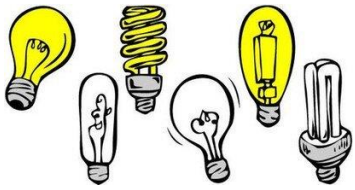


CASE STUDIES:
ART GALLERIES

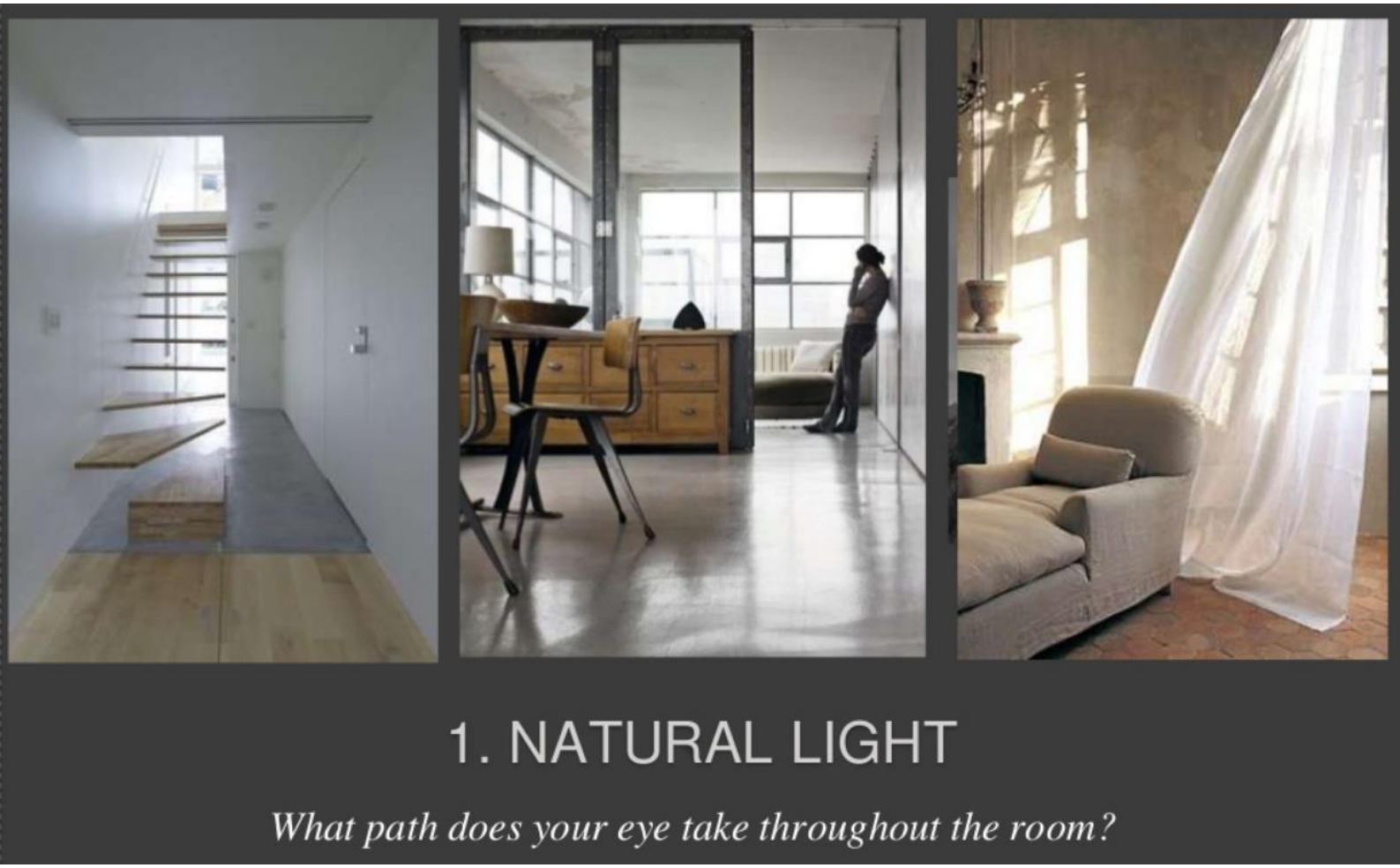
MIX OF NATURAL & ARTIFICIAL LIGHTING

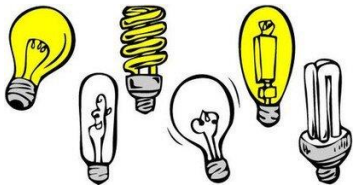
Venice

http://www.europeanbestcities.com/venice-art-museums.html



Source:
https://www.slideshare.net/PaulaMcHugh/architectural-color-and-light-questions-to-consider





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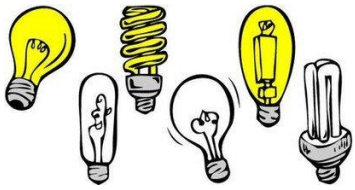


3. WALL PAINT COLOR

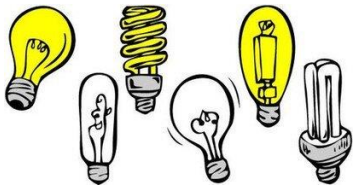
How does wall color set the mood?

Slide Source: https://www.**slideshare**.net/PaulaMcHugh/architectural-color-and-light-questions-to-consider

4. COLORED LIGHT

What can create ambiance in a simple space?

Slide Source: https://www.**slideshare**.net/PaulaMcHugh/architectural-color-and-light-questions-to-consider



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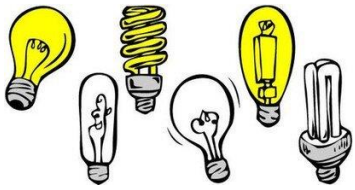
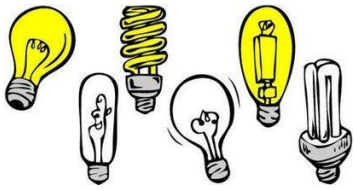
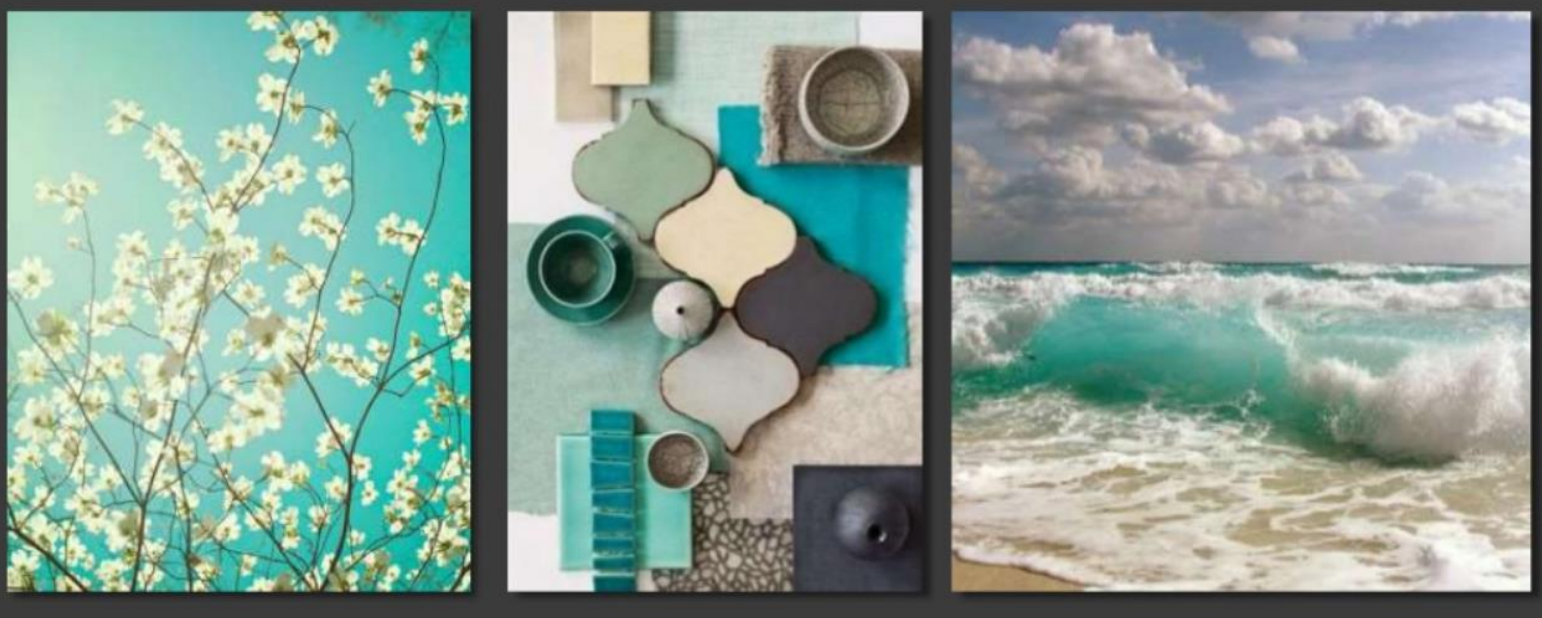


6. COLOR & EMOTION

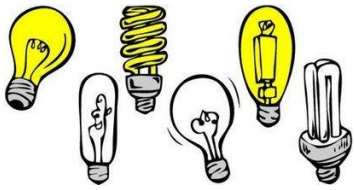
If blue is a bus, where does it take you?

Slide Source: https://www.**slideshare**.net/PaulaMcHugh/architectural-color-and-light-questions-to-consider





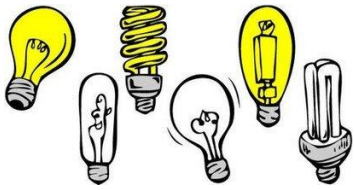
Slide Source: https://www.**slideshare**.net/PaulaMcHugh/architectural-color-and-light-questions-to-consider



8. COLOR & EMOTION

If yellow's a song, what are the words?

Slide Source: https://www.**slideshare**.net/PaulaMcHugh/architectural-color-and-light-questions-to-consider



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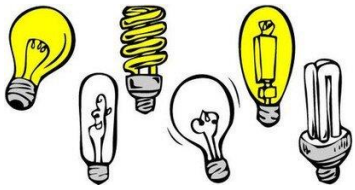
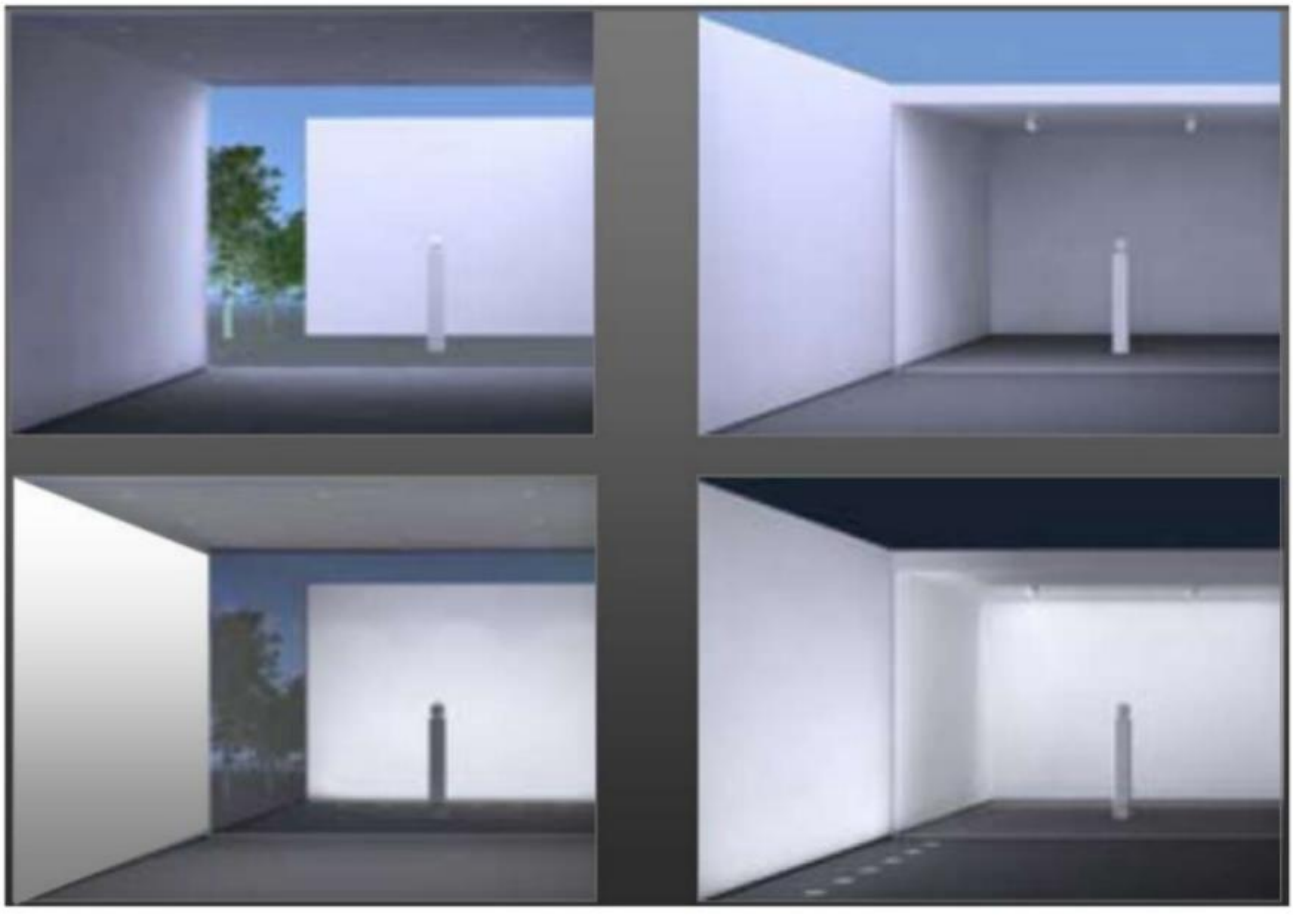
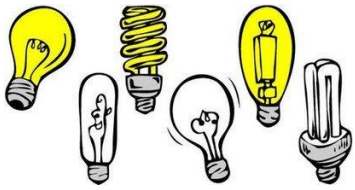


SOURCE: https://www.slideshare.net/pathyapustak/**light-and-architecture**/1

Forming functional zones: Distinct contrasts between individual zones and their surroundings remove them from their spatial context.

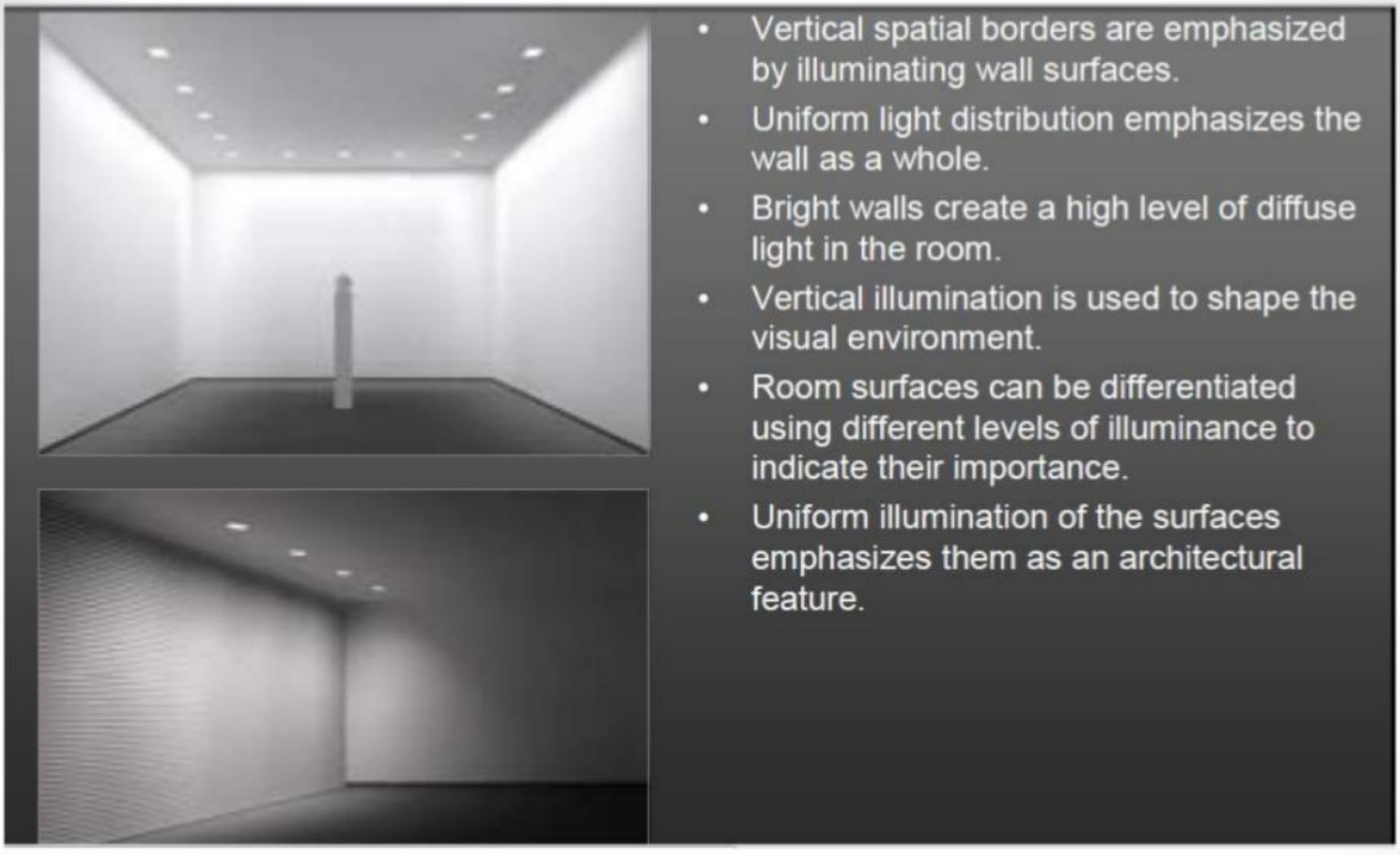


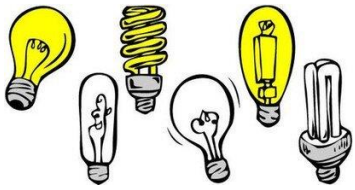


SOURCE: https://www.slideshare.net/pathyapustak/**light-and-architecture**/1

Forming spatial borders:

a)Vertical:

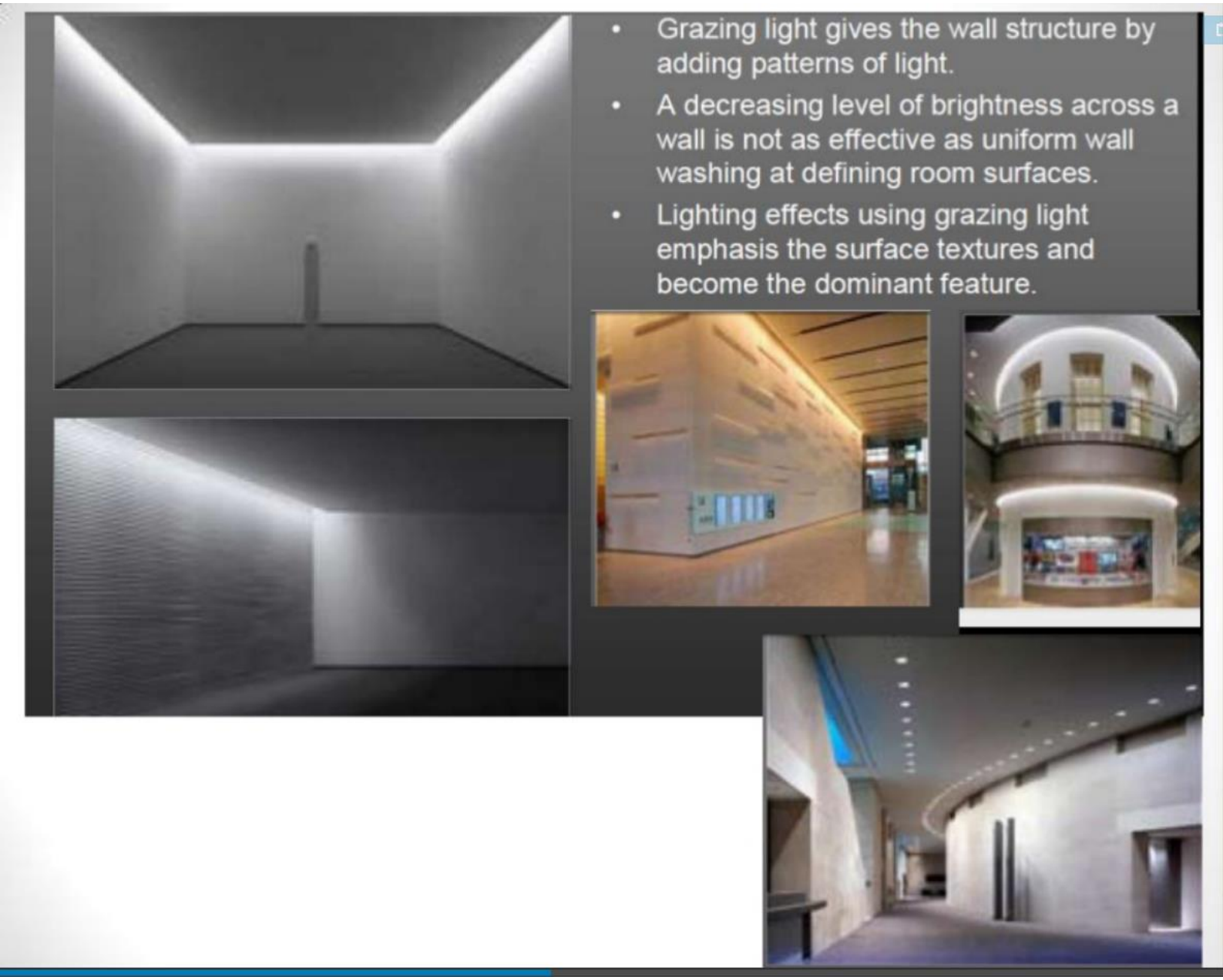


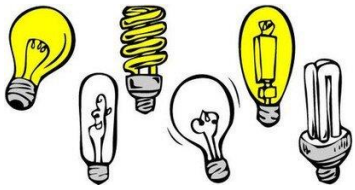


SOURCE: https://www.slideshare.net/pathyapustak/**light-and-architecture**/1

Forming spatial borders:

a)Vertical:





SOURCE: https://www.slideshare.net/pathyapustak/**light-and-architecture**/1

Forming spatial borders:

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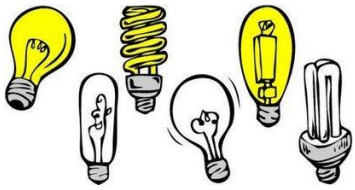
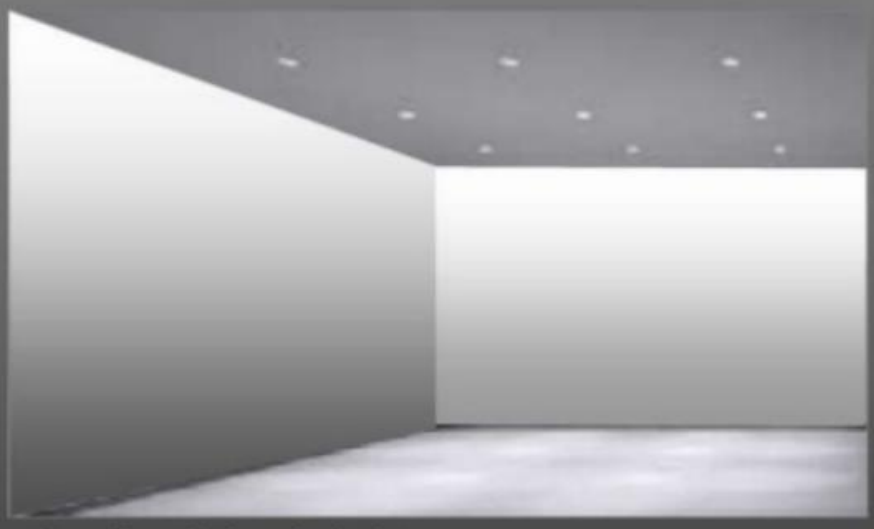


SOURCE: https://www.slideshare.net/pathyapustak/**light-and-architecture**/1

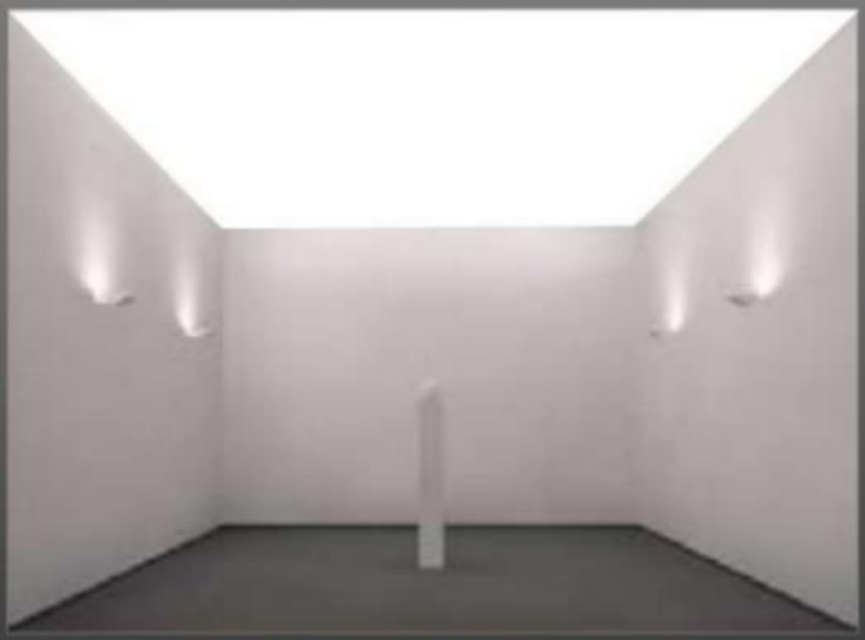
Forming spatial borders:

b) Horizontal



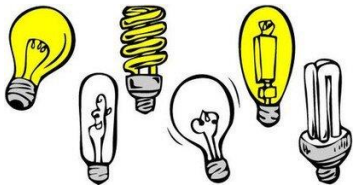
floor lit with downlight fixtures

- Floor illumination emphasizes objects and pedestrian surfaces.



ceiling uniformly lit with uplight wall fixtures

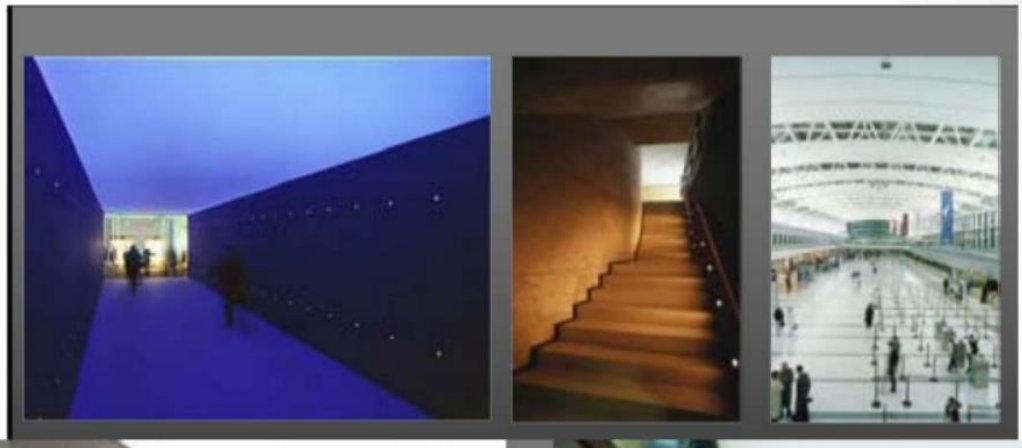
- Indirect lighting of a ceiling creates diffuse light in the room with the lighting effect being influenced by the reflectance and color of its surface.

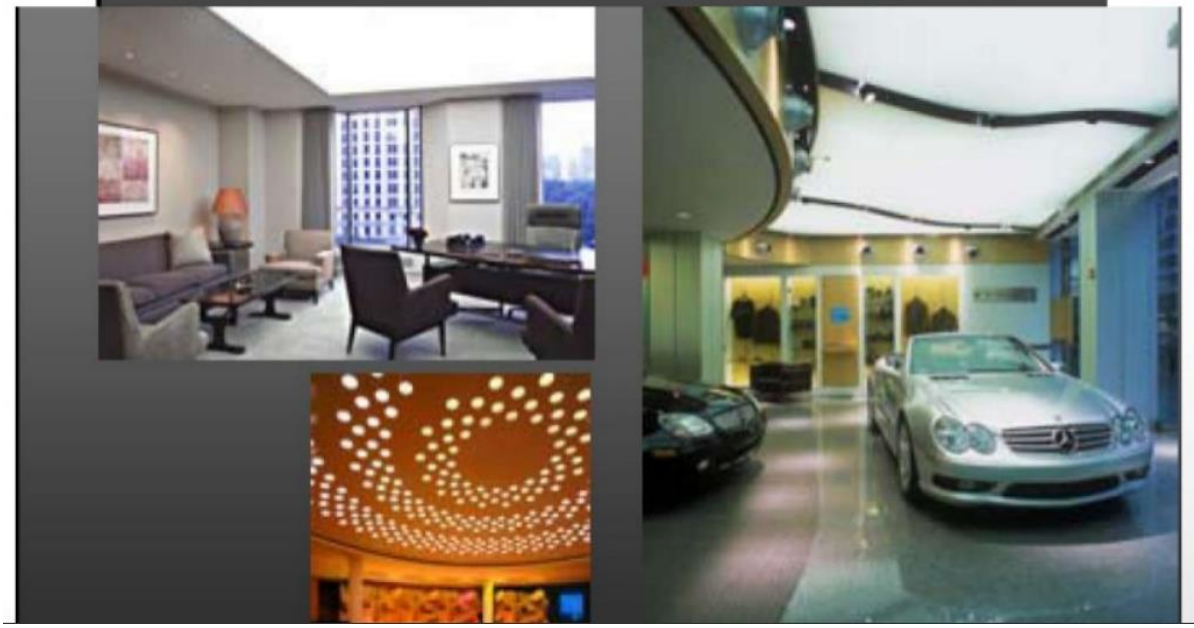


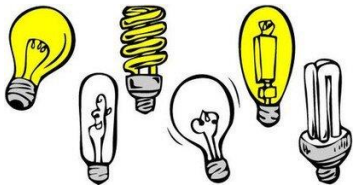
SOURCE: https://www.slideshare.net/pathyapustak/**light-and-architecture**/1

Forming spatial borders:

b) Horizontal



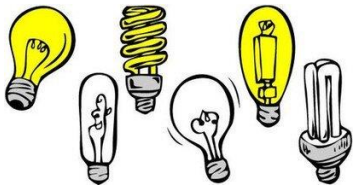




SOURCE: https://www.slideshare.net/pathyapustak/**light-and-architecture**/1

Emphasizing architectural feature:

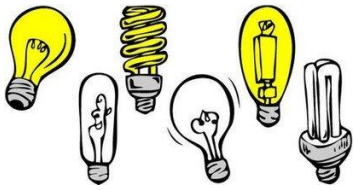
- Grazing light accentuates individual elements or areas and brings out their form and surface texture.
- Grazing light can cause highly three-dimensional features to cast strong shadows.
- By using different levels of illuminance, different parts of a room can be placed in a visual hierarchy.



SOURCE: https://www.slideshare.net/pathyapustak/**light-and-architecture**/1

Layout and Pattern :

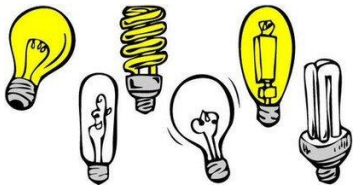
a) For clarity



SOURCE: https://www.slideshare.net/pathyapustak/**light-and-architecture**/1

Layout and Pattern :

b) For architectural Relationship:



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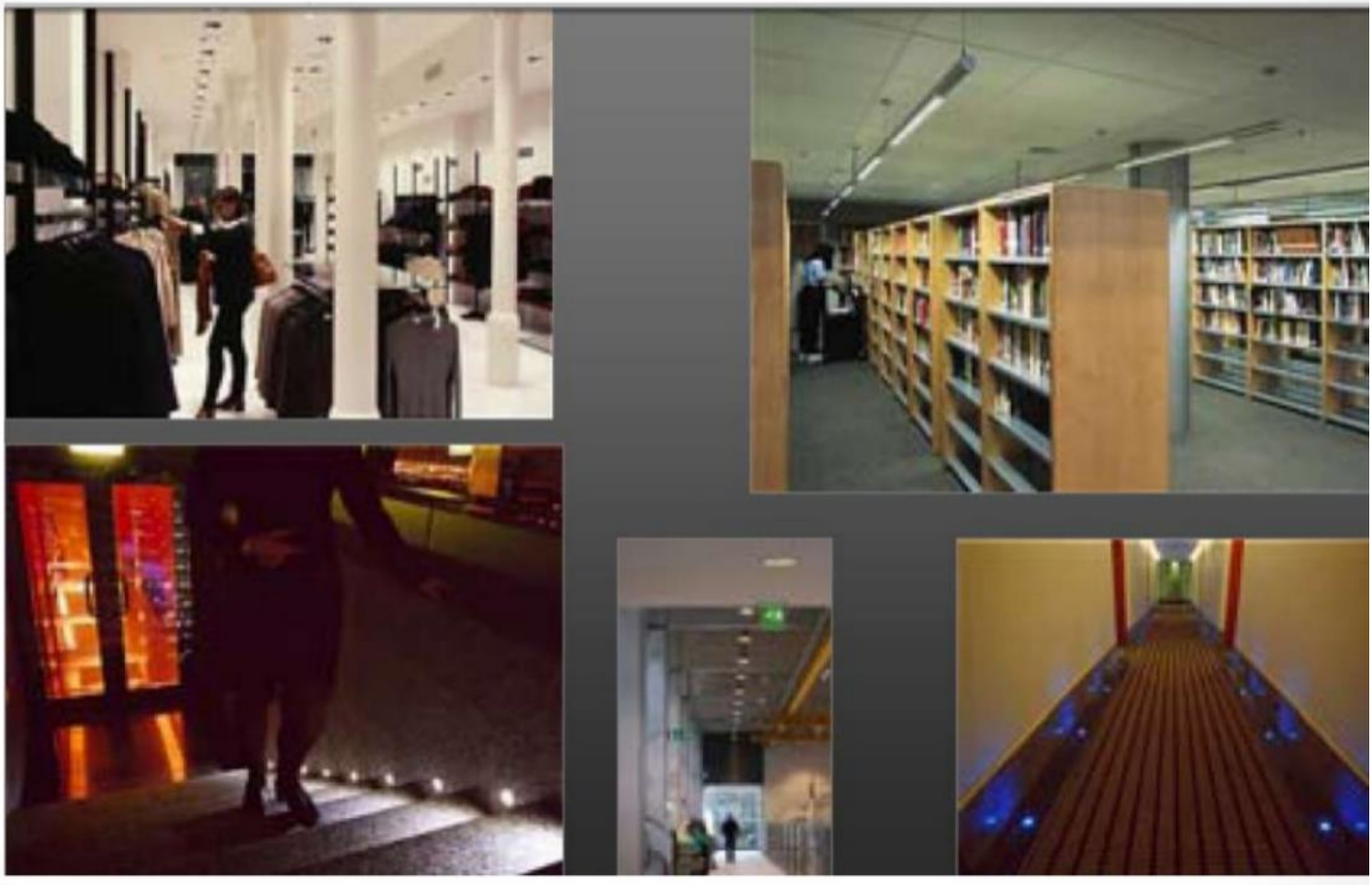
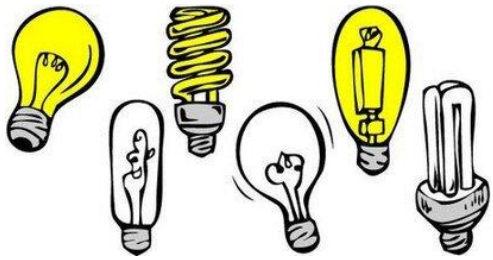
Layout and Pattern :

c) For function



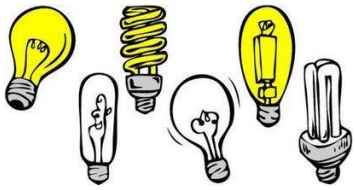
CASE STUDY:
THEATRE DESIGN



SOURCE: https://www.slideshare.net/pathyapustak/**light-and-architecture**/1

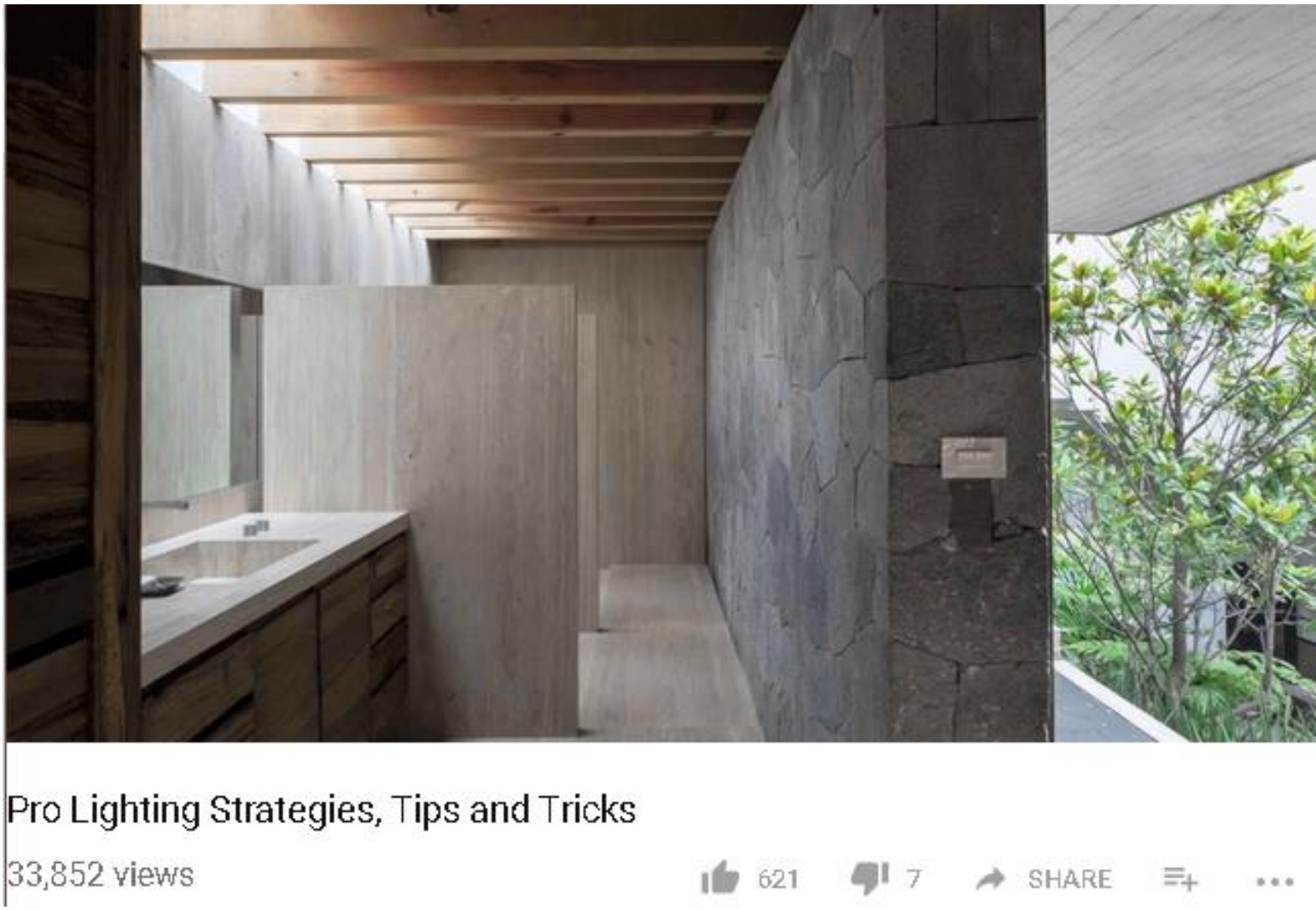
Lightning for stages and theatres:

- Luminance contrast between the object and the surroundings
- Beam spread of the luminaires – polar curve
- Type of the lamp
- Position or location of projectors
- Background luminance
- Nature of surface to be lit
- Atmospheric losses
- Maintenance factor
- Glare



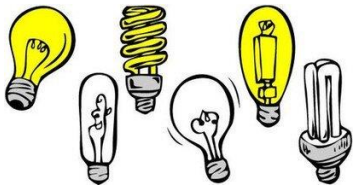
Architectural Lighting

WATCH: https://www.youtube.com/watch?v=aVXoOuzGA0I



Pro Lighting Strategies, Tips and Tricks

33,852 views 621 7 SHARE



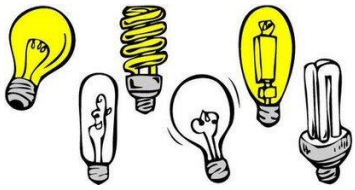
Architectural Lighting Nighttime Lighting

WATCH: https://www.youtube.com/watch?v=slEvHTzAXhE

Exterior Lighting Concepts (An Architect's Guide)

41,372 views 666 7 SHARE

Color Temperature

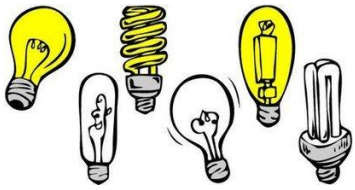


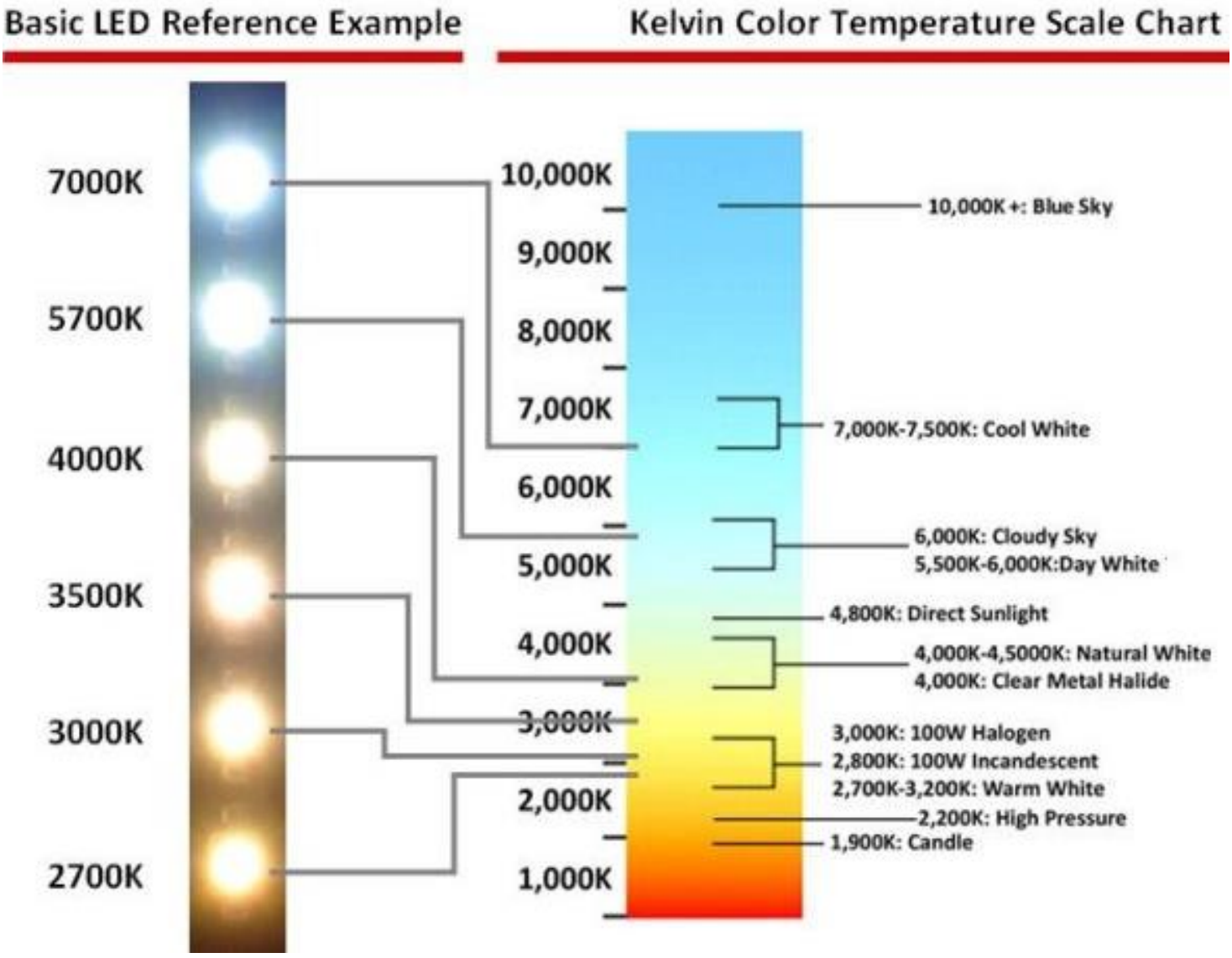
2000-3000K 3100-4500K 4600-6500K

Color Temperature (KELVIN)	2000K - 3000K	3100K - 4500K	4600K - 6500K
Light Appearance	Warm White	Cool White	Daylight
Ambience	Cozy, calm, inviting, intimate	Bright, vibrant	Crisp, invigorating
Best for	Living room, kitchens, bedrooms, bathrooms, restaurant/commercial ambient lighting, decorative outdoor lighting	Basements, garages, work environments, task lighting, bathrooms	Display areas, security lighting, garages, task lighting

Source: http://www.westinghouselighting.com/color-temperature.aspx

Color Temperature

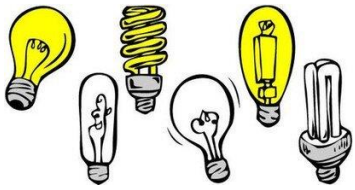




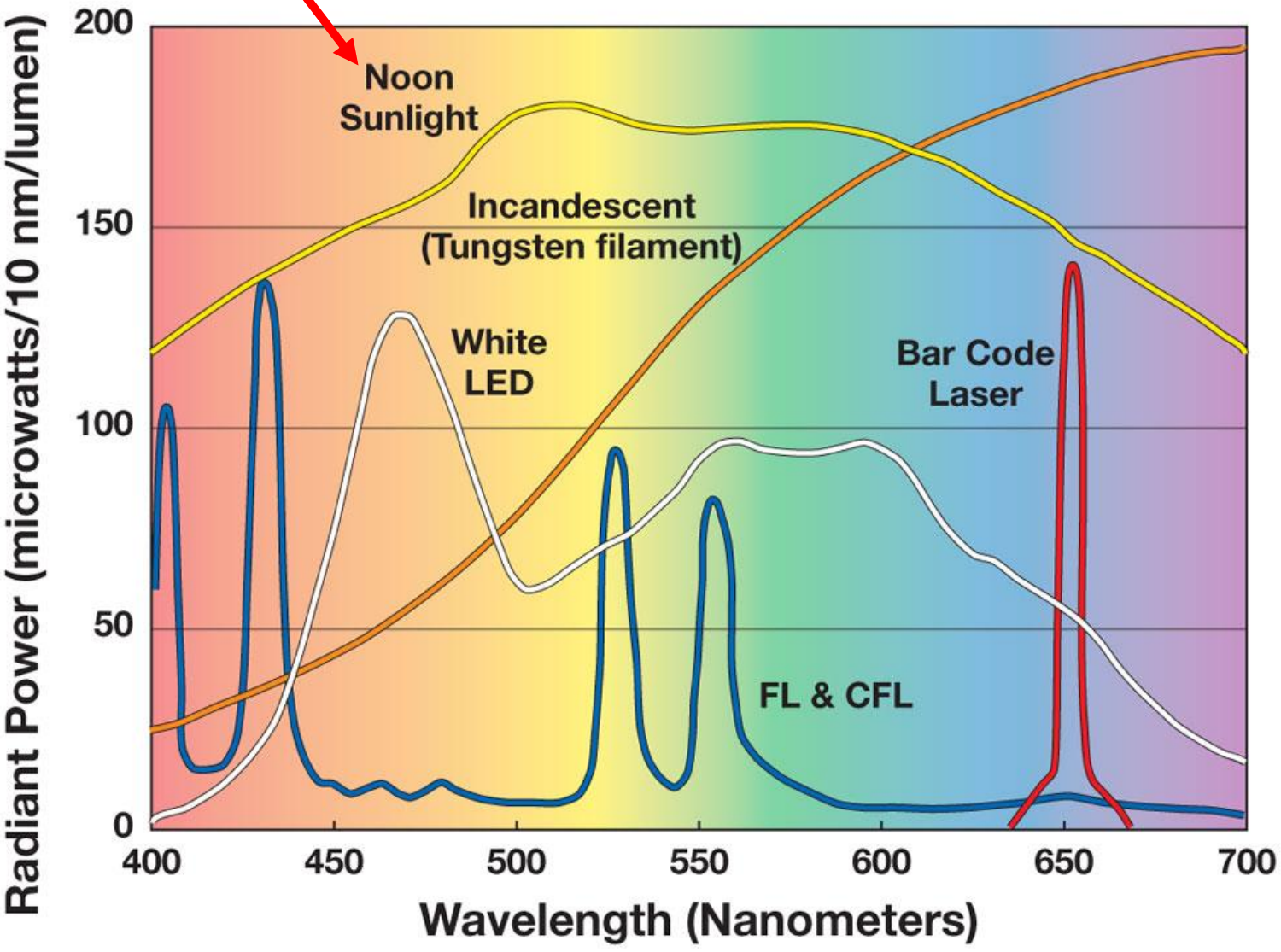
Source: https://ledcorporations.com/kelvin-aka-cct-correlated-color-temperature/

Color Temperature

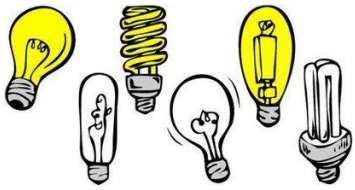
Source: https://www.pinterest.com.au/pin/392446555010416740/



Color Temperature



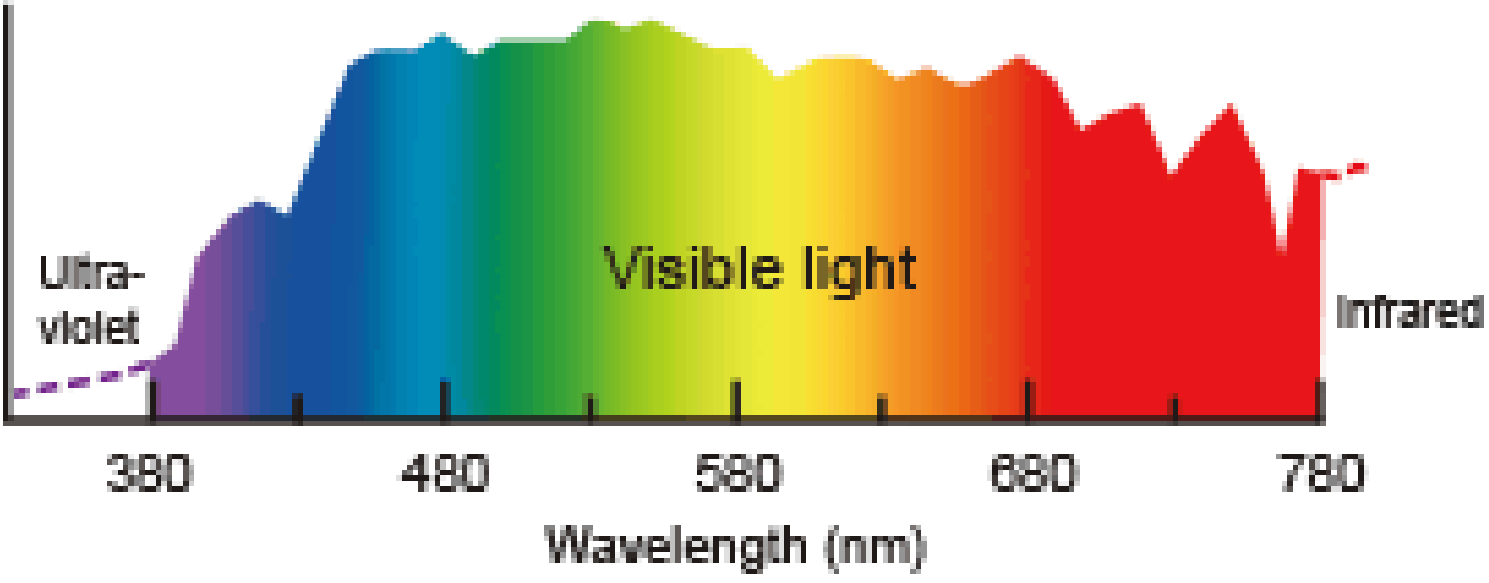
https://www.homepower.com/articles/home-efficiency/equipment-products/choosing-right-light/



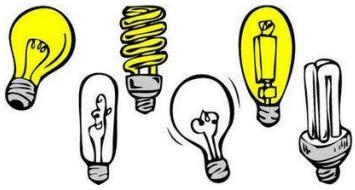
Color Rendering Index (CRI)

Quality of Light Source in how it makes an object's color **APPEAR**;
Scale: 0 to 100

DAYLIGHT. High power at all wavelengths ("full color spectrum"); highest level of color rendering across the spectrum. **CRI = 100**



http://lukeskaff.com/diy-sunlight-simulator-light-therapy-full-spectrum/

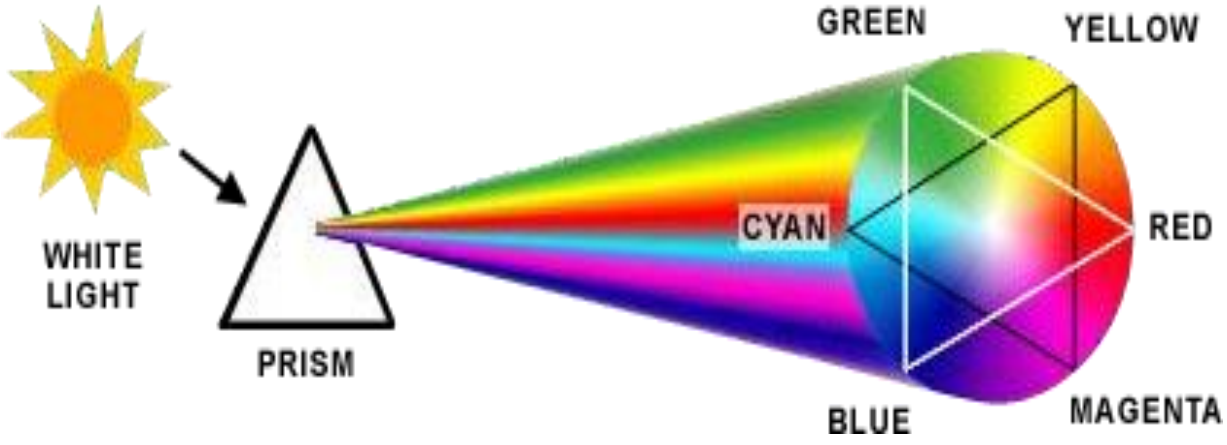


Color Rendering Index (CRI)

Quality of Light Source in how it makes an object's color **APPEAR**;
Scale: 0 to 100

Let's learn a little bit about additive and subtractive color before we go into color rendering

Excerpt from J Wunderlich Lecture: "Color-Physics/Display-Tech"

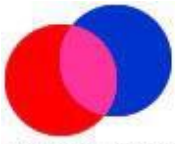


If the visible portion of the light spectrum is divided into thirds, the predominant colors are red, green and blue. These three colors are considered the primary colors of the visible light spectrum.

Primary colors can be arranged in a circle, commonly refered to as a color wheel. Red, green and blue (RGB) form a triangle on the color wheel. In between the primary colors are the secondary colors, cyan, magenta and yellow (CMY), which form another triangle.

The media and methods used to reproduce color include color paintings, printing presses, color film, color monitors, color printers, etc. There are only two basic ways, however, of reproducing color... additive and subtractive.

Additive Color System (RGB) (back to top)

 G+B LIGHT = CYAN	 R+B LIGHT = MAGENTA	 G+R LIGHT = YELLOW

The additive color system involves light emitted directly from a source, before an object reflects the light. The additive reproduction process mixes various amounts of red, green and blue light to produce other colors. Combining one of these additive primary colors with another produces the additive secondary colors cyan, magenta, yellow. Combining all three primary colors produces white.

COMPUTER MONITORS:

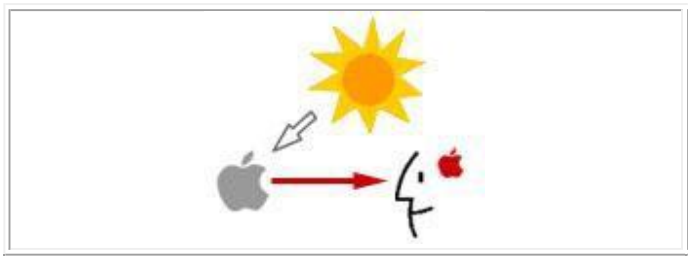
Television and computer monitors create color using the primary colors of light. Each pixel on a monitor screen starts out as black. When the red, green and blue phosphors of a pixel are illuminated simultaneously, that pixel becomes white. This phenomenon is called additive color.

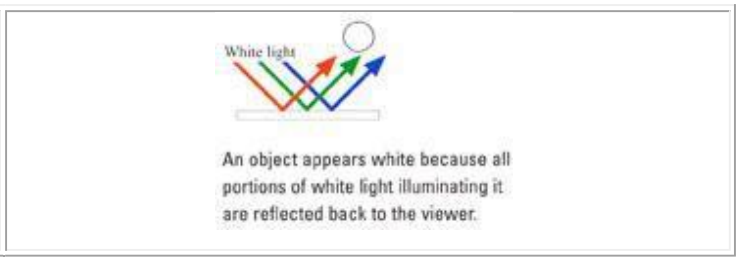
To illustrate additive color, imagine three spotlights, one red, one green and one blue focused from the back of an ice arena on skaters in an ice show. Where the blue and green spotlights overlap, the color cyan is produced; where the blue and red spotlights overlap, the color magenta is produced; where the red and green spotlights overlap the color yellow is produced. When added together, red, green and blue lights produce what we perceive as white light.

As mentioned before, television screens and computer monitors are examples of systems that use additive color. Thousands of red, green and blue phosphor dots make up the images on video monitors. The phosphor dots emit light when activated electronically, and it is the combination of different intensities of red, green and blue phosphor dots that produces all the colors on a video monitor. Because the dots are so small and close together, we do not see them individually, but see the colors formed by the mixture of light. Colors often vary from one monitor to another. This is not new information to anyone who has visited an electronics store with various brands of televisions on display. Also, colors on monitors change over time. Currently, there are no color standards for the phosphors used in manufacturing monitors for the graphics arts industry.

All image capture devices utilize Additive color

Subractive Color System (CMY) (back to top)



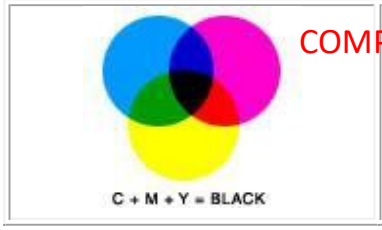


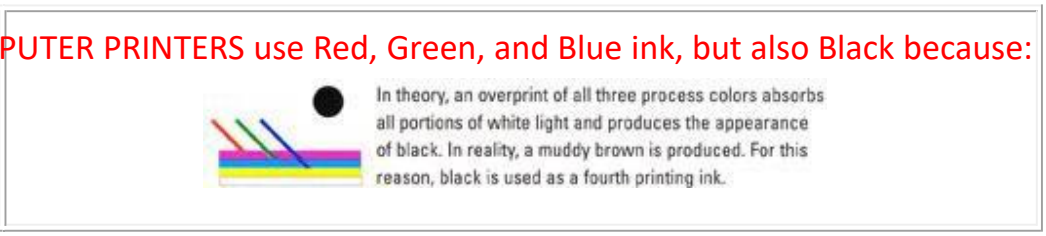
Photographs, magazines and other objects of nature such as an apple; create color by subtracting or absorbing certain wavelengths of color while reflecting other wavelengths back to the viewer.

A red apple is a good example of subtractive color; the apple has no light energy of its own, it merely reflects the wavelengths of white light that cause us to see red and absorbs most of the other wavelengths which evokes the sensation of red. The viewer (or detector) can be the human eye, film in a camera or a light-sensing instrument.

The subtractive color system involves colorants and reflected light. Subtractive color starts with an object (often a substrate such as paper or canvas) that reflects light and uses colorants (such as pigments or dyes) to subtract portions of the white light illuminating an object to produce other colors. If an object reflects all the white light back to the viewer, it appears white. If an object absorbs (subtracts) all the light illuminating it, no light is reflected back to the viewer and it appears black. It is the subtractive process that allows everyday objects around us to show color.

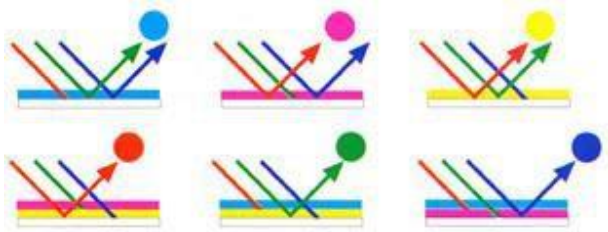
Color paintings, color photography and all color printing processes use the subtractive process to reproduce color. In these cases, the reflective substrate is canvas (paintings) or paper (photographs, prints), which is usually white.





Printing presses use color inks that act as filters and subtract portions of the white light striking the image on paper to produce other colors. Printing inks are transparent, which allows light to pass through to and reflect off of the paper base. It is the paper that reflects any unabsorbed light back to the viewer. The offset printing process uses cyan, magenta and yellow (CMY) process color inks and a fourth ink, black. The black printing ink is designated K to avoid confusion with B for blue. Overprinting one transparent printing ink with another produces the subtractive secondary colors red, green, and blue.

The illustrations below show process inks printed on white paper. Each process printing ink (cyan, magenta, yellow) absorbs or subtracts certain portions of white light and reflects other portions back to the viewer. Process printing inks are transparent. It is the paper that reflects unabsorbed light back to the viewer.



Ink Color	Absorbs	Reflects	Appears
C	Red light	Green and Blue light	Cyan
M	Green light	Red and Blue light	Magenta
Y	Blue light	Red and Green light	Yellow
M + Y	Green & Blue light	Red light	Red
C + Y	Red and Blue light	Green light	Green
C + M	Red and Green light	Blue light	Blue

To be reproducible on press, an original color image, such as a photograph, must first be converted into a pattern of small dots for each of the four colors (CMYK). When printed with ink on paper, the small dots fool the eye and give the visual appearance of the original Image.

To summarize: Subtractive color involves colorants and reflected light. It uses cyan, magenta and yellow pigments or dyes to subtract portions of white light illuminating an object to produce other colors. When combined in equal amounts, pure subtractive primary colors produce the appearance of black.

Computer Monitors

and some advice on making design decisions

J. Wunderlich PhD

PHYSICS:

Recall additive and subtractive colors from previous lecture, and watch this video: http://www.youtube.com/watch?v=Er7CM_RNFZ4

Computer Monitors use additive color mixing, and RGB (Red Green Blue) Hexadecimal (Base 16) numbers to specify the mixing. Each Hexadecimal number for each color is two Hex digits (00 to FF), representing 0 to 255 in Decimal (Base 10) or 0000 to1111 in Binary (Base 2):

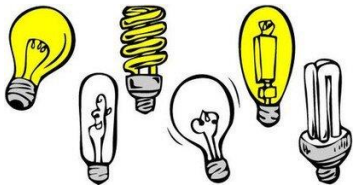
Hexadecimal (Base 16)	Decimal (Base 10)	Binary (Base 2)
#FF0000	RGB (255, 0, 0)	11111111, 00000000, 00000000
#FF7F00	RGB (255, 127, 0)	11111111, 01111111, 00000000
#FFFF00	RGB (255, 255, 0)	11111111, 11111111, 00000000
#FFFF00	RGB (0, 255, 0)	00000000, 11111111, 00000000
#0000FF	RGB (0, 0, 255)	00000000, 00000000, 11111111
#4B0082	RGB (75, 0, 130)	00101101, 00000000, 01000010
#8F00FF	RGB (143, 0, 255)	01001111, 00000000, 11111111

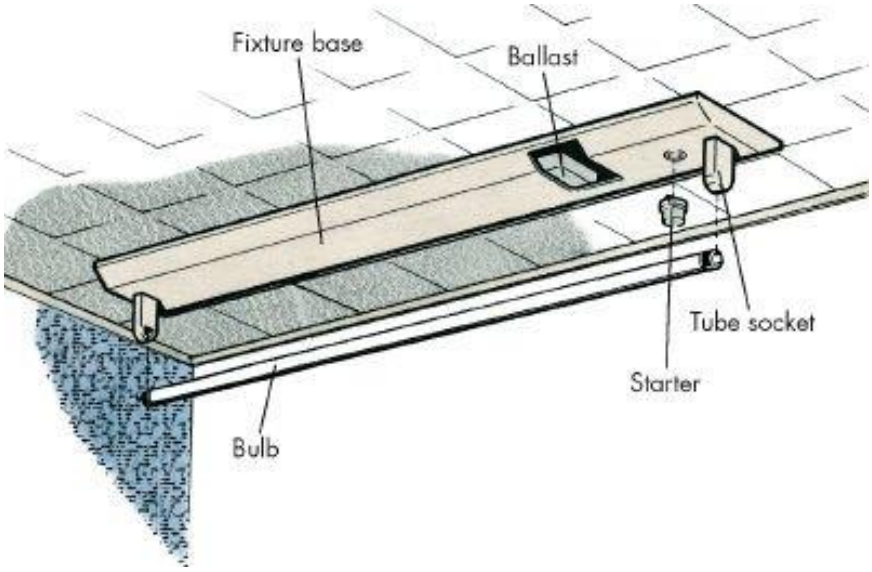
SuddenWhims.com

Image from: http://suddenwhims.com/wp-content/uploads/2012/10/rainbow-hex-rgb.png

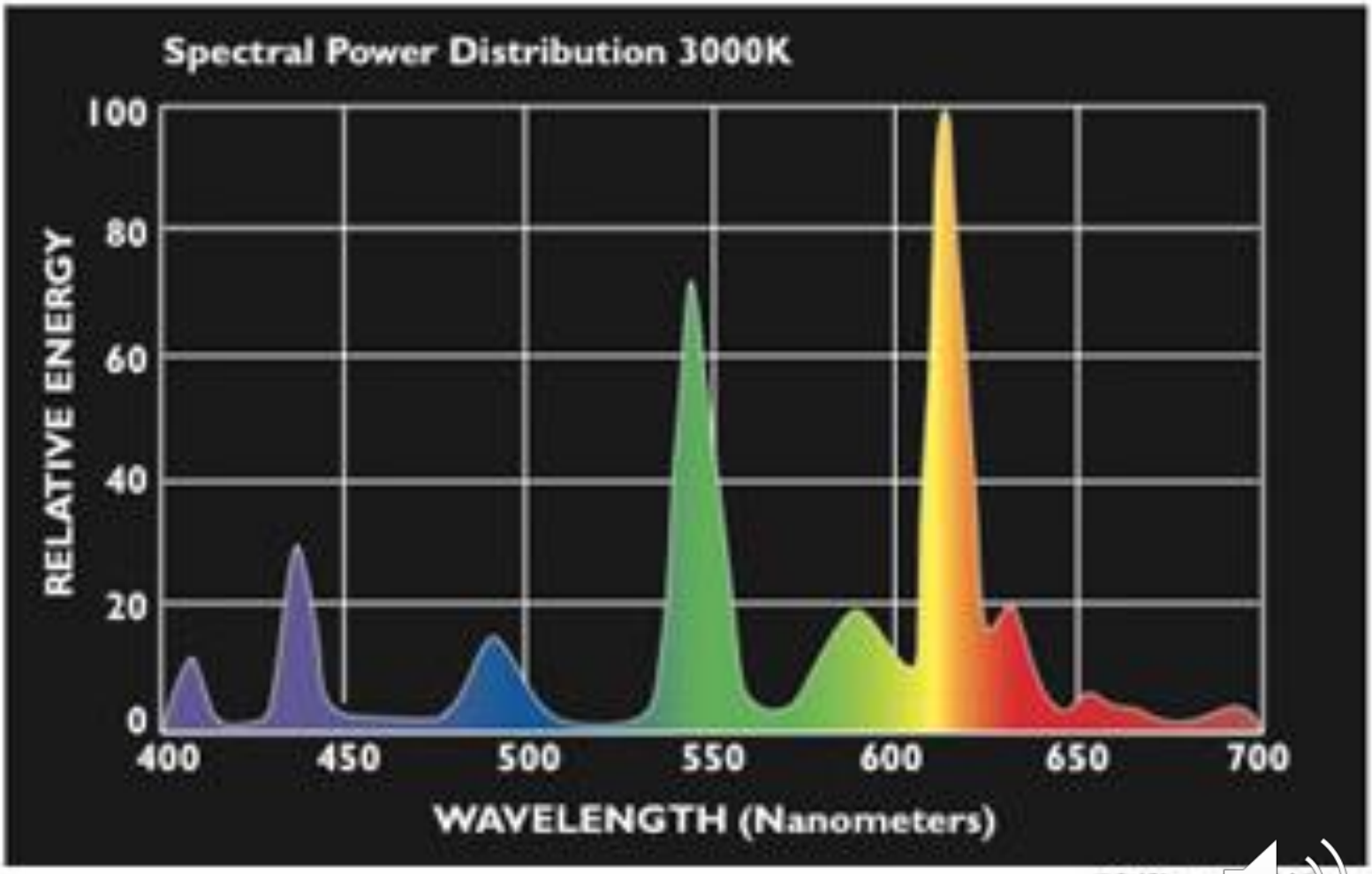
Color Rendering Index (CRI)

Quality of Light Source in how it makes an object's color **APPEAR**; Scale: 0 to 100





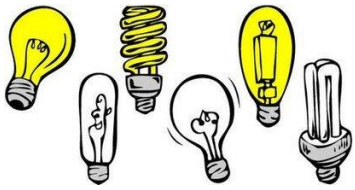
"WARM-WHITE FLUORESCENT" example with a CRI = 82, and Temp=3000K. All wavelengths ("full spectrum") present, but only certain wavelengths strong, and some wavelengths very low, near zero

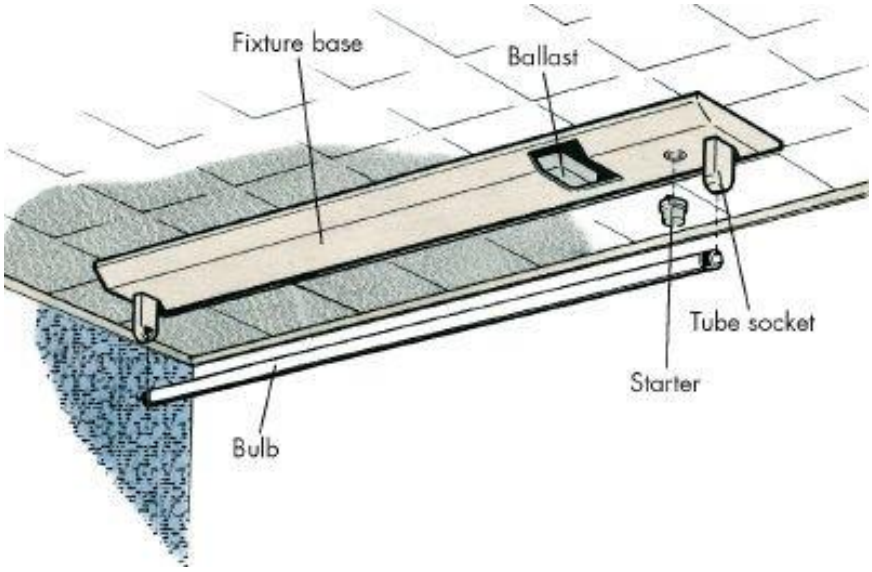


https://www.topbulb.com/color-rendering-index

Color Rendering Index (CRI)

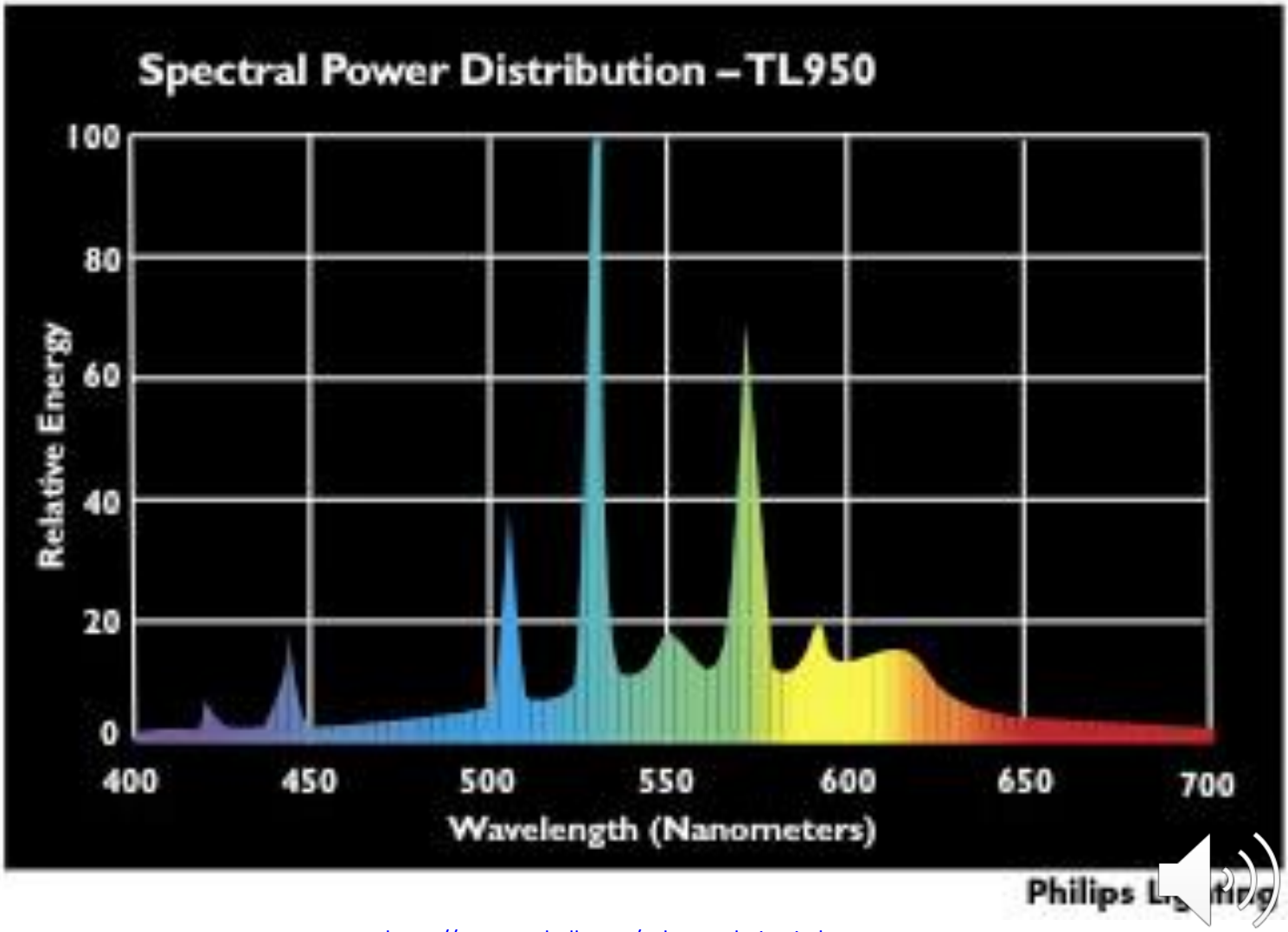
Quality of Light Source in how it makes an object's color **APPEAR**; Scale: 0 to 100





"COOL-WHITE **FLUORESCENT**" with a CRI = 98, Temp=5000K

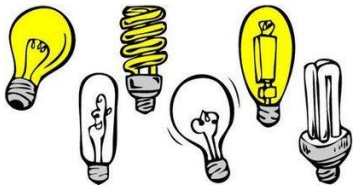
No low points in the curve close to zero power.



https://www.topbulb.com/color-rendering-index

Color Rendering Index (CRI)

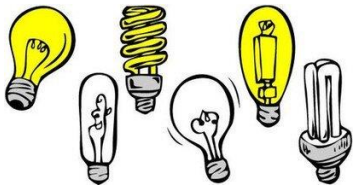
Quality of Light Source in how it makes an object's color **APPEAR**; Scale: 0 to 100

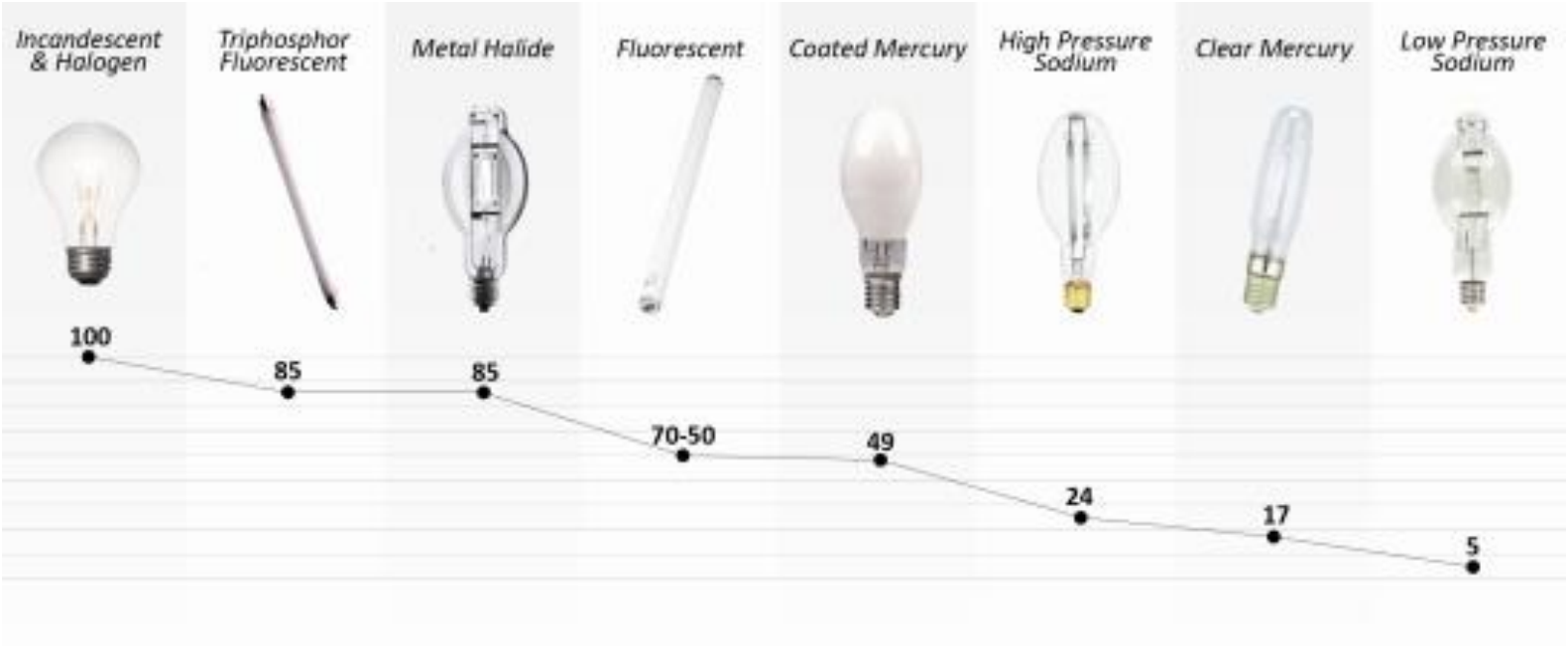


http://www.westinghouselighting.com/lighting-education/color-rendering-index-cri.aspx

Color Rendering Index (CRI)

Quality of Light Source in how it makes an object's color **APPEAR**; Scale: 0 to 100

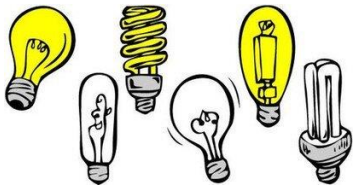




http://www.tesengineering.com/color-rendering-index-across-a-spectrum-of-options/

Color Rendering Index (CRI)

Quality of Light Source in how it makes an object's color **APPEAR**; Scale: 0 to 100



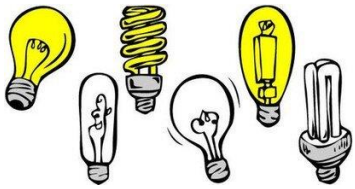
HALOGEN is often the best choice for Artwork

- It adds a special "sparkle"

https://www.youtube.com/watch?v=aVXoOuzGA0I

Color Rendering Index (CRI)

Quality of Light Source in how it makes an object's color **APPEAR**; Scale: 0 to 100

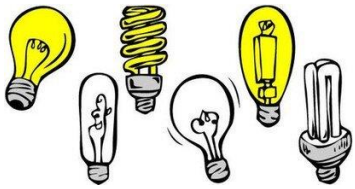


LED's are improving, but not yet replacing Halogen everywhere for lighting Artwork

http://www.getty.edu/conservation/our_projects/science/lighting/case.html

Color Rendering Index (CRI)

Quality of Light Source in how it makes an object's color **APPEAR**; Scale: 0 to 100



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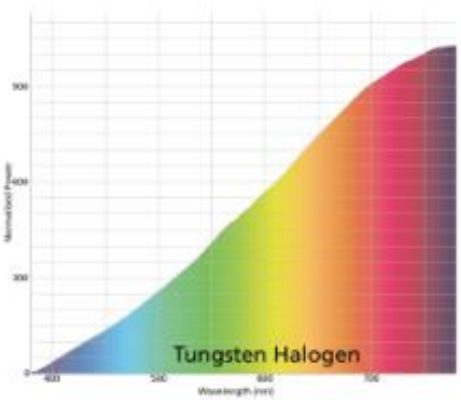
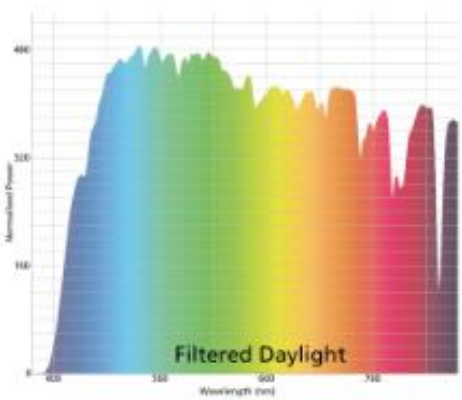
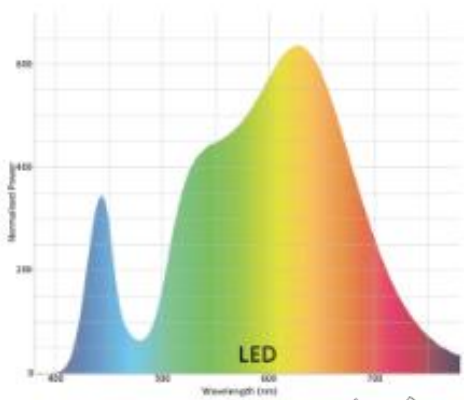
LED's are improving, but not yet replacing Halogen everywhere for lighting Artwork



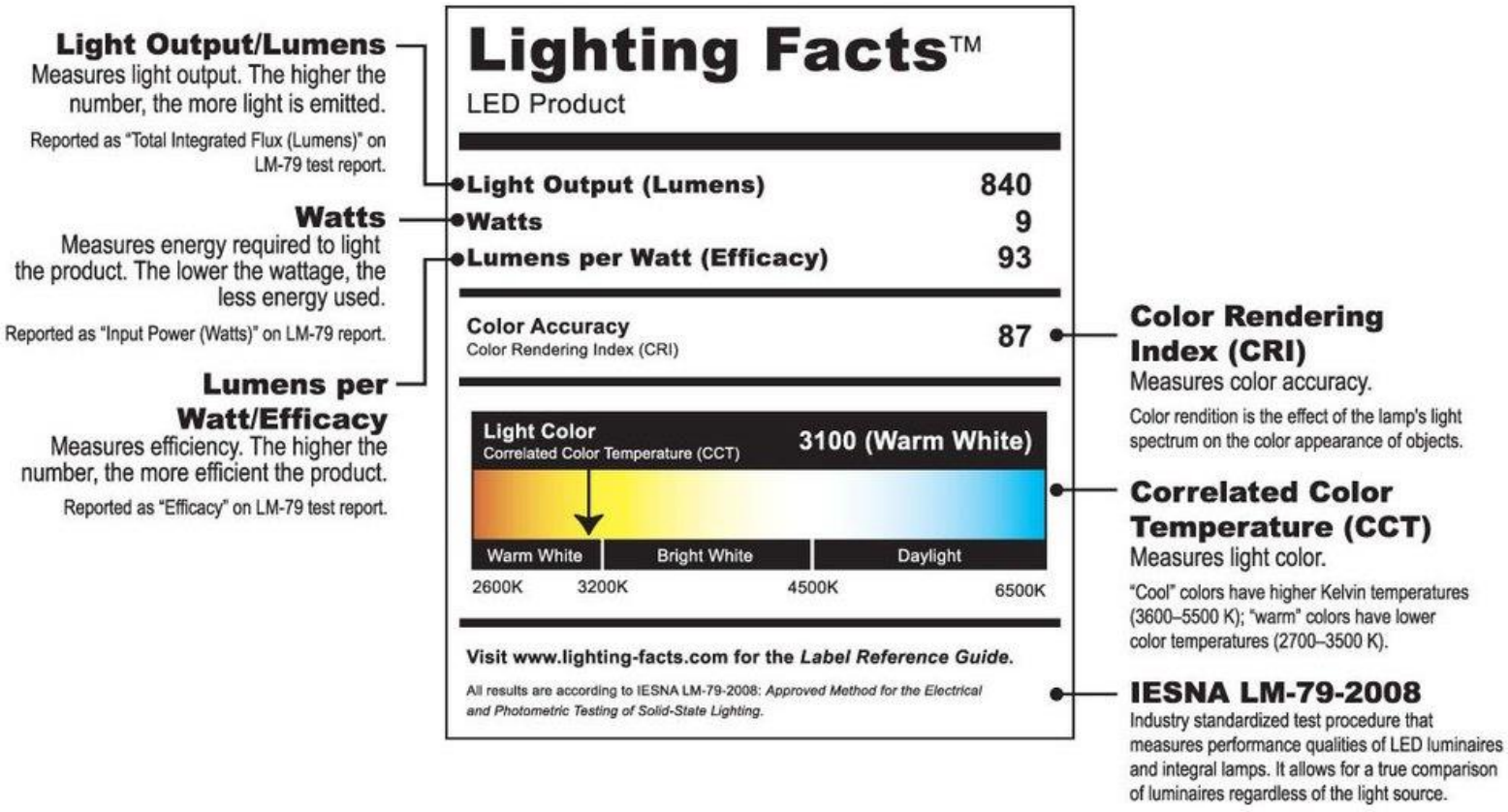




JT Wunderlich PhD

http://research.ng-london.org.uk/scientific/spd/?page=info

Label on Box



https://www.google.com/search?q=Daylight+bulb+CRI&source=lnms&tbm=isch&sa=X&ved=0ahUKEwiRu7_ujdPaAhVqhuAKHWuWATAQ_AUICygC&biw=1024&bih=1163#imgrc=GDysS2Z4Dvvd9M:

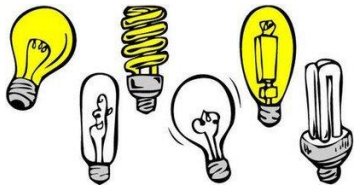


TABLE 14.2

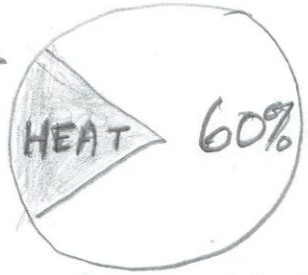
EFFICIENCY

= MAX WATTS PER SQUARE FOOT OF BUILDING

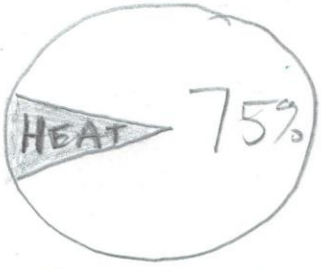
→ A STANDARD DESIGN GOAL

DIFFERENT THAN "EFFICACY" (LUMENS PER WATT)

BAD	5	BEFORE ANY CODES OR STANDARDS
	1.2	AMERICAN SOCIETY OF HEATING AND REFRIGERATION ENGINEERS STANDARD
	0,9	LEED
BEST	0.45	MAX POSSIBLE DURING DAY IF DAYLIGHTING USED

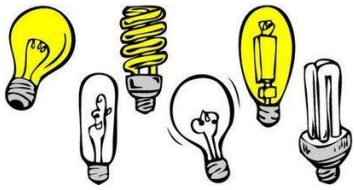


SUNLIGHT THROUGH CLEAR GLASS



SUNLIGHT THROUGH SPECTRALLY-SELECTIVE LOW-E GLAZING (GLASS)

CH 14 Electric Lighting



<u>VISIBLE LIGHT</u> is part of Electromagnetic (EM) Spectrum of WAVES

Which interact with matter like particles (PHOTONS)

with *"Effective Mass"*

*see Dr. W Active Solar lecture (**PV** **P**hoto**V**oltaics part)*

PPTX-w/audio PDF MP4

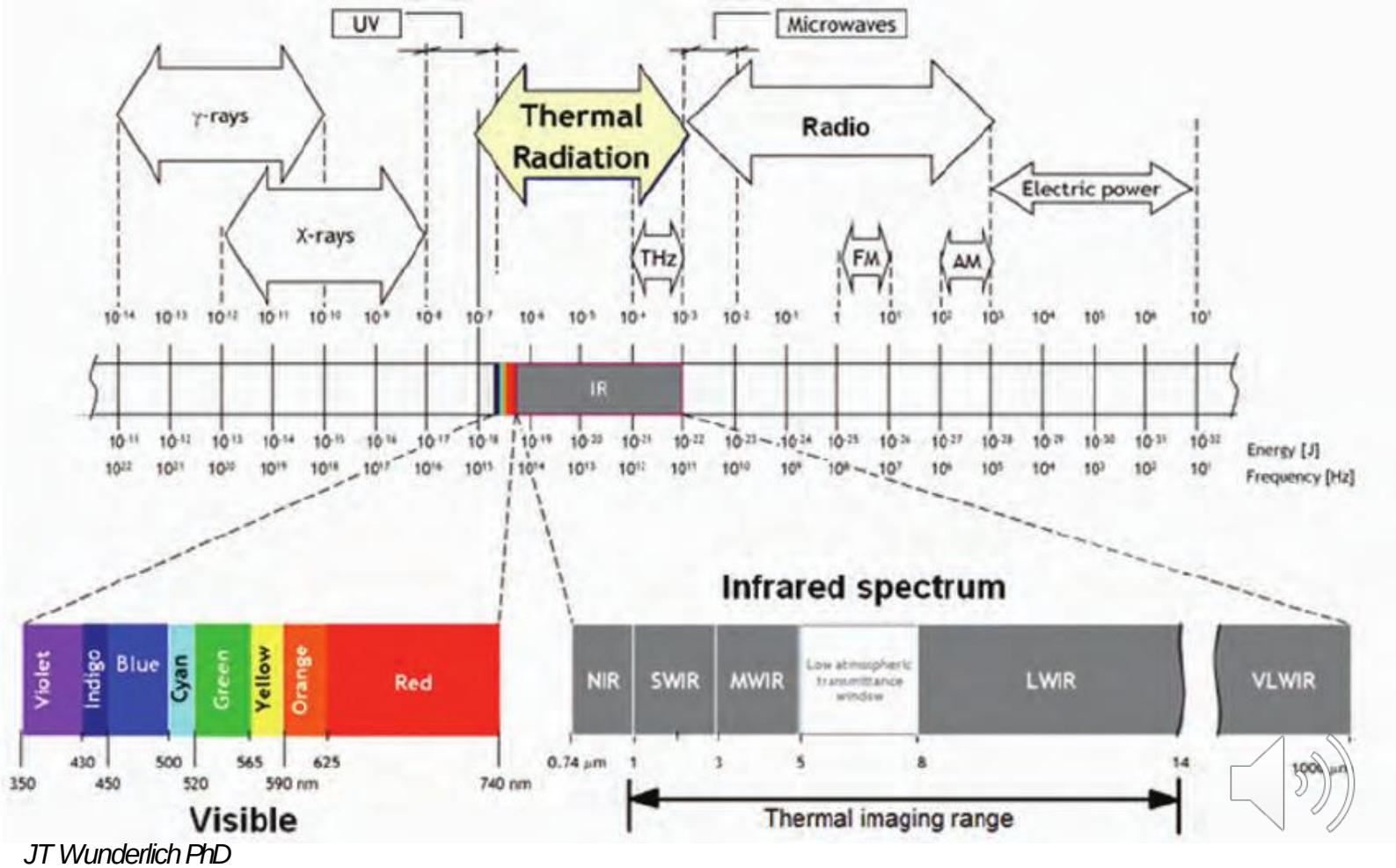
VISIBLE LIGHT is in a range of wavelengths directly related to the temperature of our sun (i.e. humans have adapted to its star)

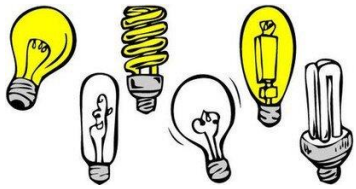
VISABLE LIGHT vs. **<u>THERMAL RADIATION</u> (HEAT)**

- See Dr W lecture on A&E Thermodynamics: **PDF**

The range of wavelengths of thermal radiation includes visible light, however we're most concerned with the heat loss associated with the infrared wavelengths outside of the range of visible light

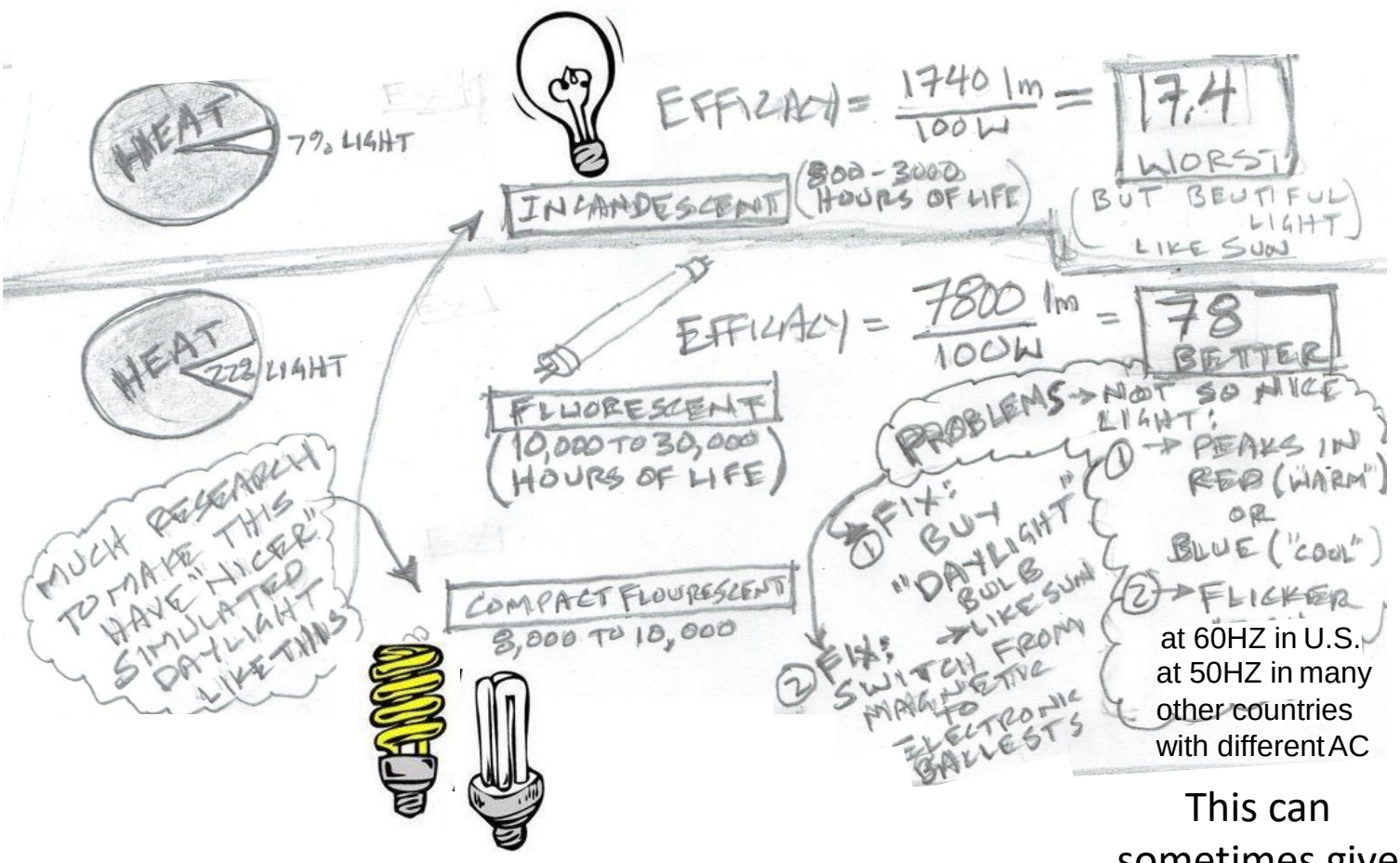
- This is where we do **<u>THERMAL IMAGING</u>** to measure **<u>HEAT LOSS</u>**





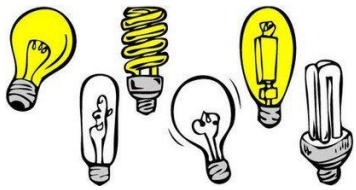
LUMEN (lm) = RATE SOURCE EMITS ENERGY (i.e. FLUX)

EFFICACY = LIGHT OUT / ENERGY-IN = LUMENS / WATTS = (lm)/(W)



CFL
Compact FLorescent

This can sometimes give people headaches after prolonged exposure



EFFICACY = $\frac{9500\,lm}{100\,W}$ = 95 BEST

HIGH-PRESSURE SODIUM
(24,000 TO 30,000 HOURS OF LIFE)

+ Very long Life
+ Wide Diffused Light
+ Good for big Gyms
- Requires 5 minutes to start

HALOGEN
2000 TO 5000 HOURS OF LIFE

EFFICACY = 12 TO 24 $\frac{lm}{W}$

GOOD SPOT LIGHTS ON PAINTINGS AND SCULPTURES

CERAMIC METAL HALIDE
10,000 TO 20,000 HOURS OF LIFE

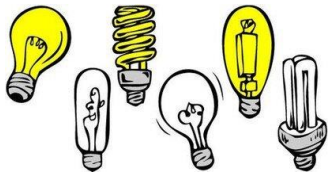
EFFICACY = 30 TO 95 $\frac{lm}{W}$

METAL HALIDE

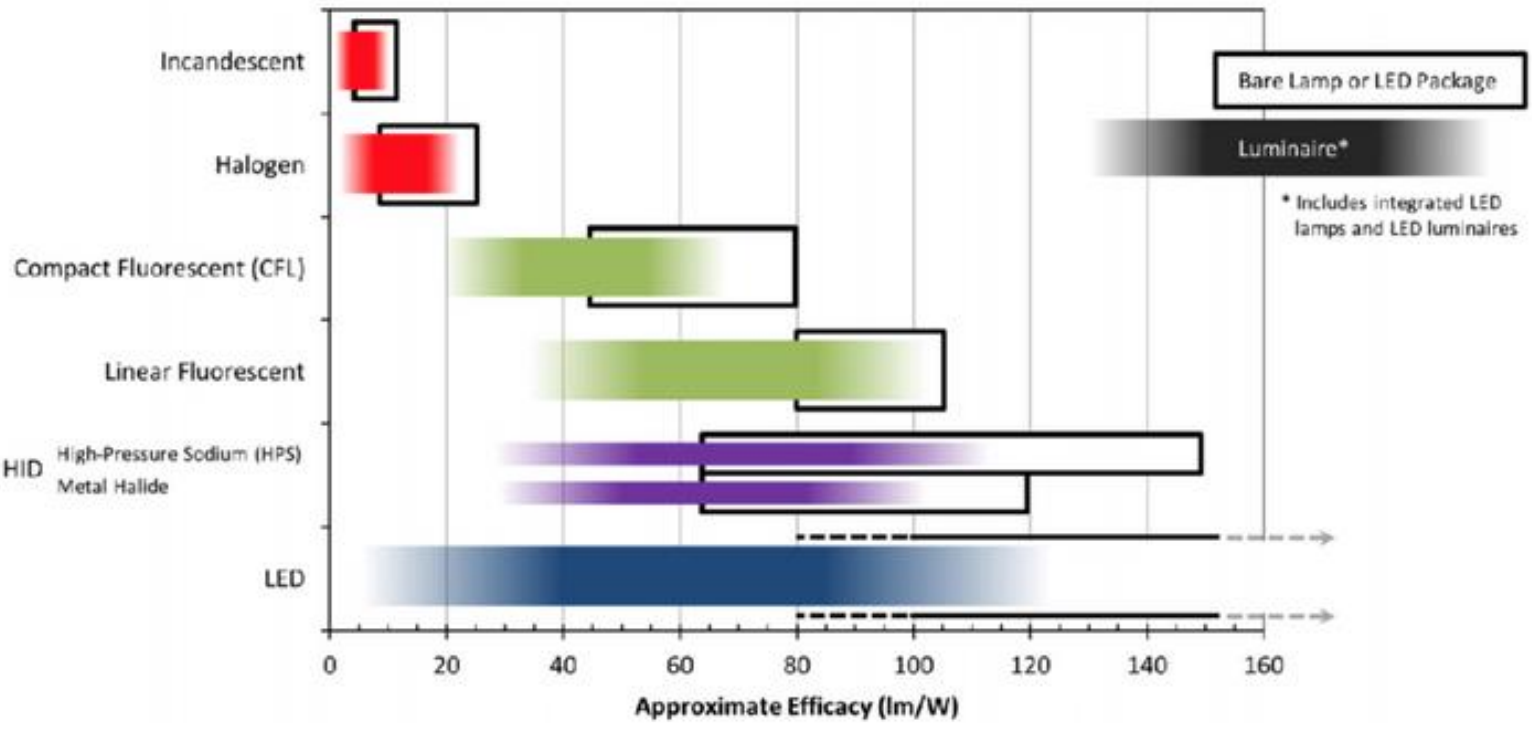
EFFICACY = 50 TO 115 $\frac{lm}{W}$

→ WIDE DIFFUSED LIGHT
→ USE IN GYMS
→ 5 MINUTES TO START

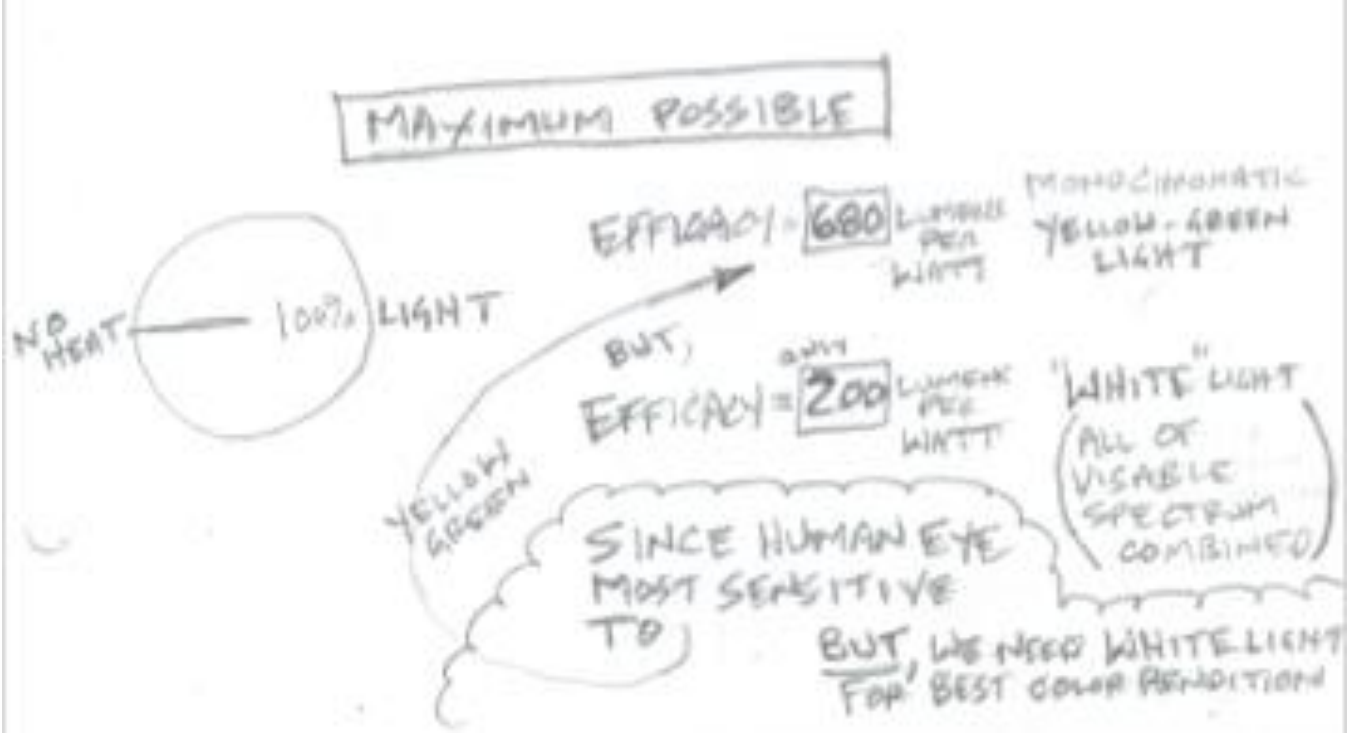
LED's (Light Emitting Diodes)



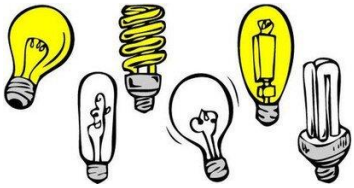
+ EFFICACY = Wide Range, from good to **great!**
+ LIFE = 10,000 to **50,000 HOURS !**
+ **Great Control** of Light Qualities

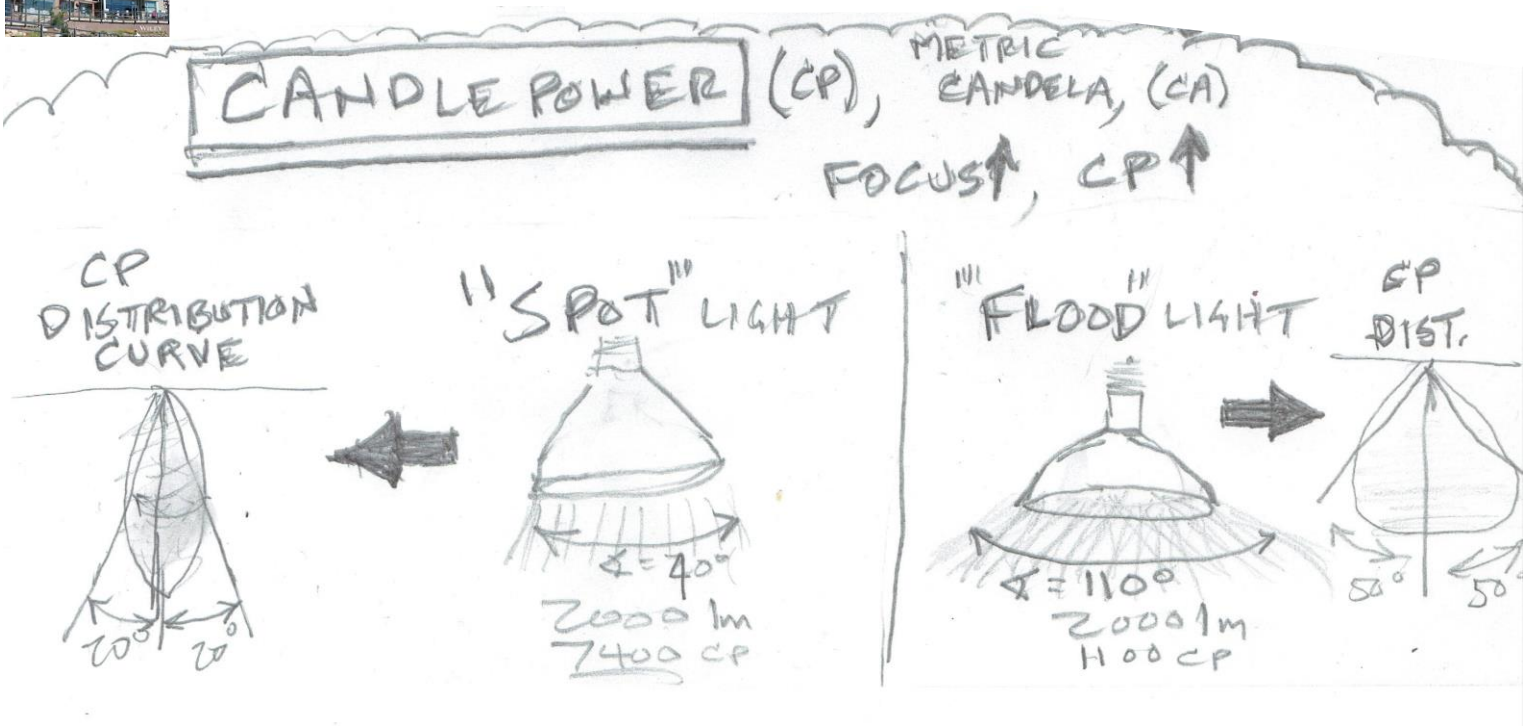


https://www.researchgate.net/figure/Range-of-efficacy-for-various-light-sources_fig1_262851515

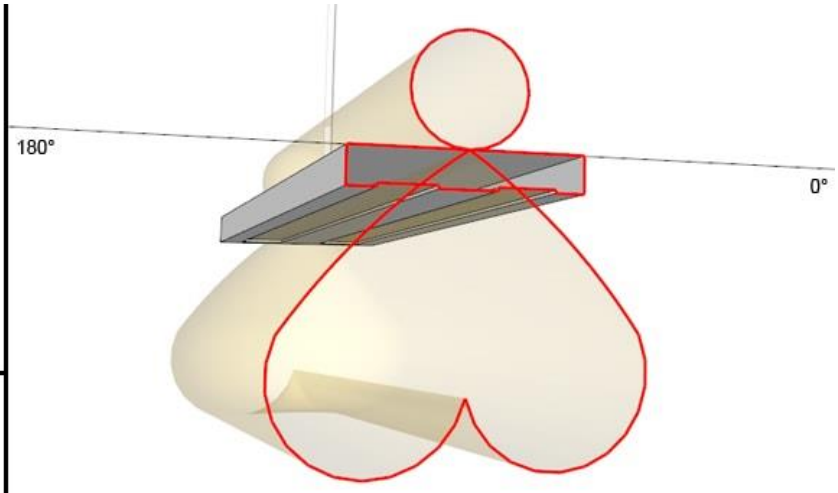


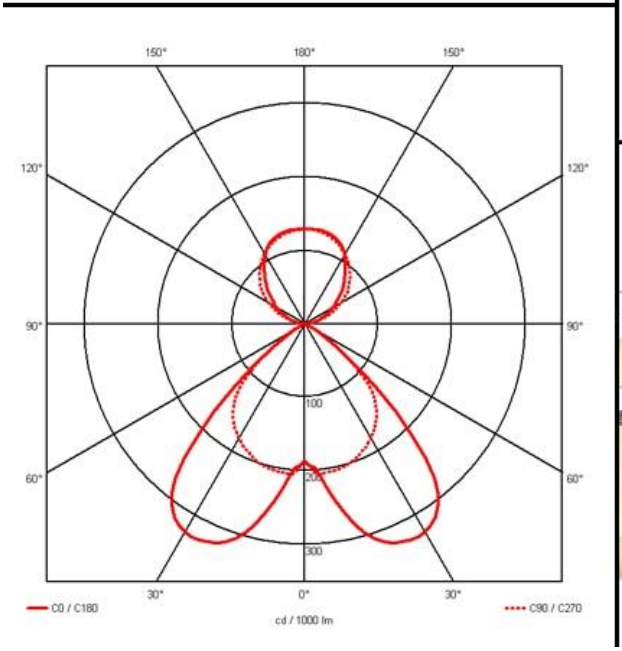
Light Distribution

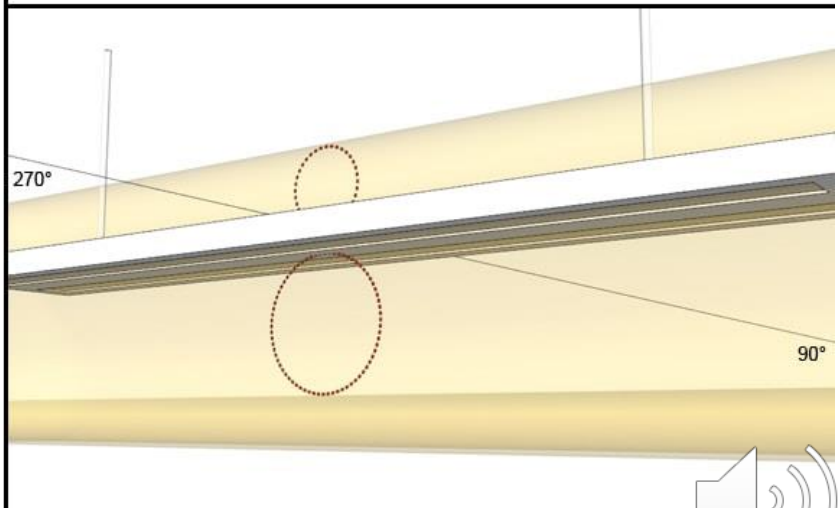




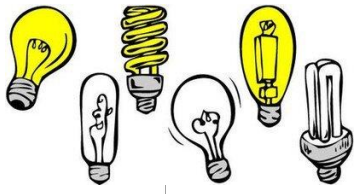
JT Wunderlich PhD







https://www.dmlights.com/blog/interpret-light-distribution-curve/



ILLUMINANCE / FOOTCANDLE (LUX) METHOD 2

LIGHT INCIDENT ON A UNIT AREA

EX)

80 lm SOURCE

4 FT^2 TABLE TOP

$\frac{80\ lm}{4\ ft^2}$ = 20 FOOTCANDLES OF ILLUMINATION

BRIGHTNESS VS. LUMINANCE

PERCEIVED

= f (EYE'S ADAPTATION)

= f (PSYCHOLOGY)

VIA LIGHT METER (OR EYE)

EX) BRIGHT LIGHT AT NIGHT,

EX) GLARE

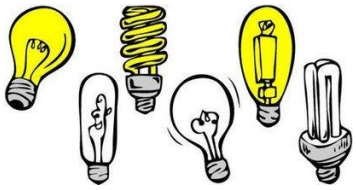
★ DESIGN FOR BOTH

= f ("REFLECTANCE")

LUMINANCE NEEDED = f (① TASK, ② EYE PERFORMANCE, ③ PSYCHOLOGY, ④ CONTRAST NEEDED)

TASK		FOOTCANDLES NEEDED
RESIDENTIAL	NO-WORK	8
	WORK	30
CLASSROOM		75

Reduce glare with:
- DIFFUSERS (lenses on fixtures)
- LAMPSHADES
- WALL & CEILING COLORS/TEXTURES



BRIGHTNESS RATIO

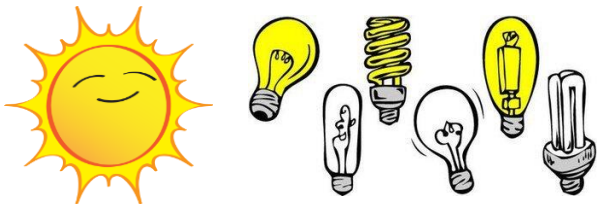
VARIATION IN BRIGHTNESS BETWEEN AREAS

AREAS	MAX RATIO
BOOK TO DESK	3:1
" " NEARWALL	5:1
" " FAR "	10:1
WINDOW TO ADJACENT WALL	20:1

Analogous to the LIGHTING RATIO in photography:

https://nofilmschool.com/2017/05/understanding-lighting-ratios-what-are-they-and-why-do-they-matter

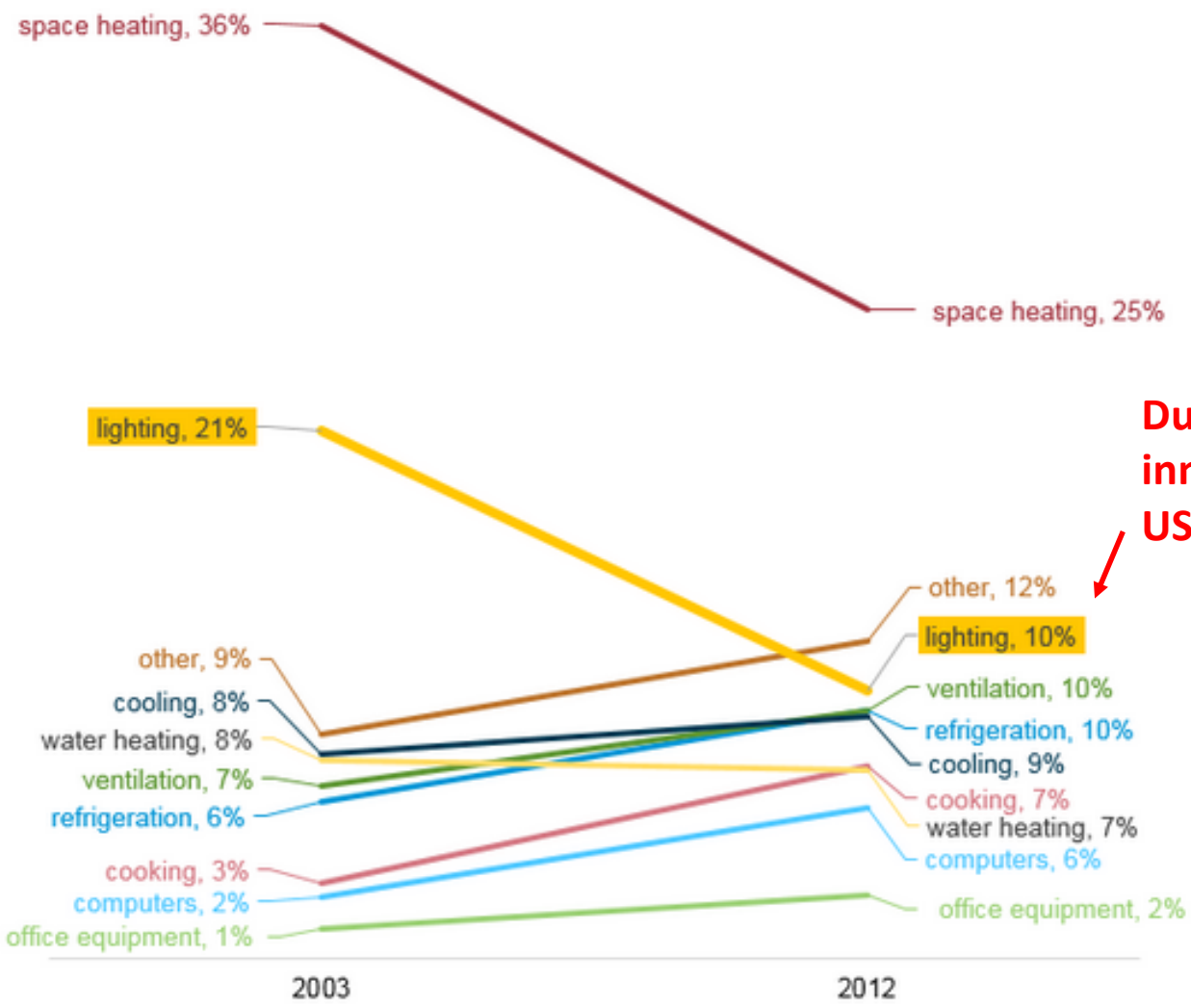
ENERGY USE and PRODUCTION



In UNITED STATES:

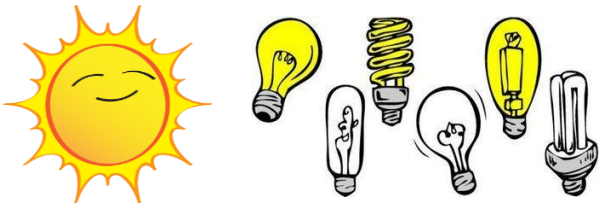
https://www.**eia.gov**/electricity/data/browser/

Figure 3: Lighting in the commercial sector has decreased as a share of total major fuel consumption

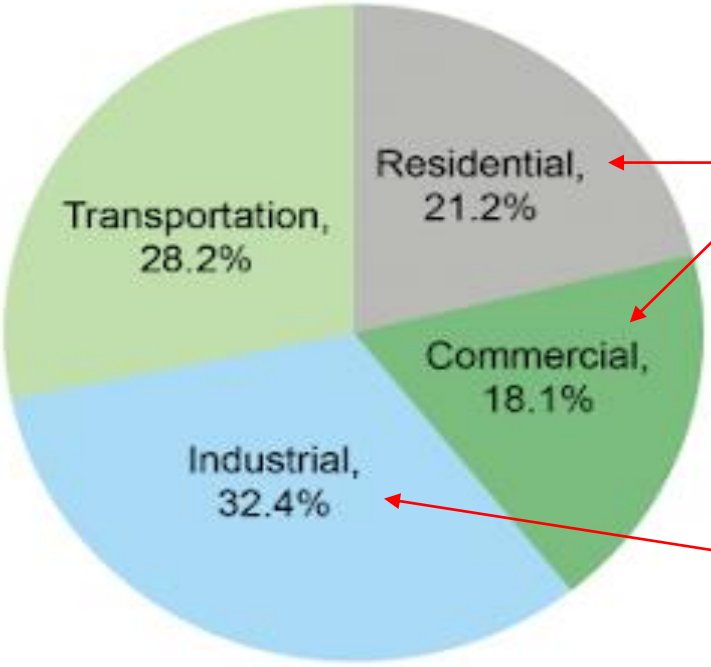


Due to great innovations in the US and elsewhere

When considering just electricity usage in commercial buildings, lighting accounted for 17% of electricity consumption in commercial buildings in 2012 (Figure 4), down from 38% in 2003. However, lighting remains one of the largest end uses of electricity, second only to the broad category of other electricity end uses. The *Other* category of electricity uses includes miscellaneous electric loads (MELs), process equipment, motors, and air compressors.



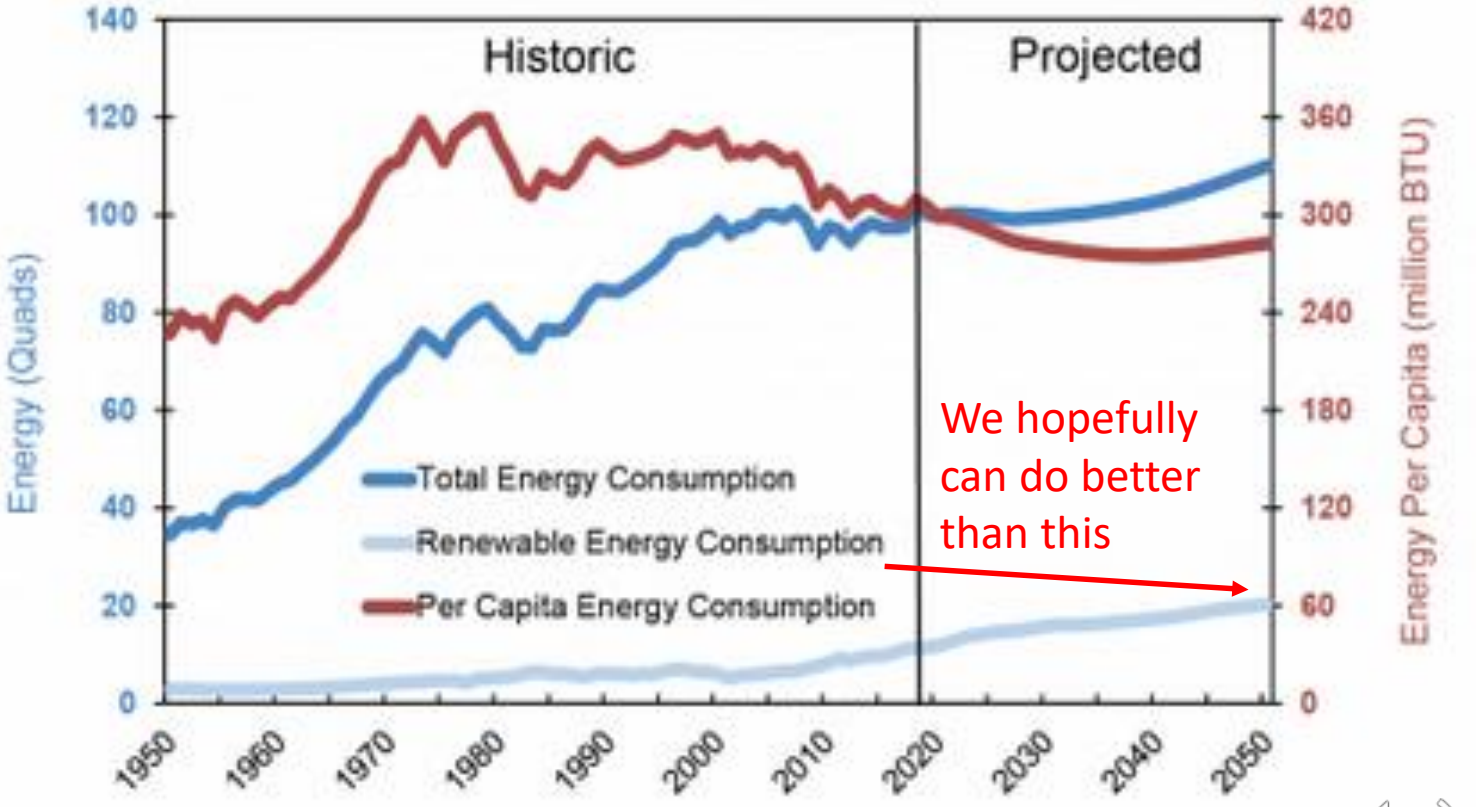
U. S. ENERGY **USE** (not just electrical) in 2019:

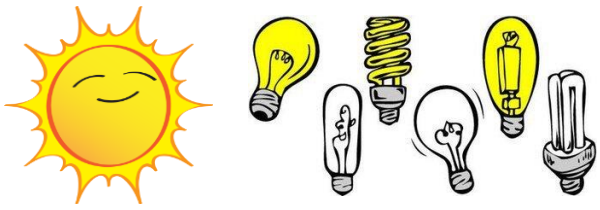


Buildings (39.3%)

Part in Buildings

http://css.umich.edu/factsheets/us-energy-system-factsheet





U. S. ENERGY **PRODUCTION** (not just electrical) in 2019:

https://www.**eia.gov**/electricity/data/browser/

eia Independent Statistics & Analysis U.S. Energy Information Administration

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thousand megawatthours

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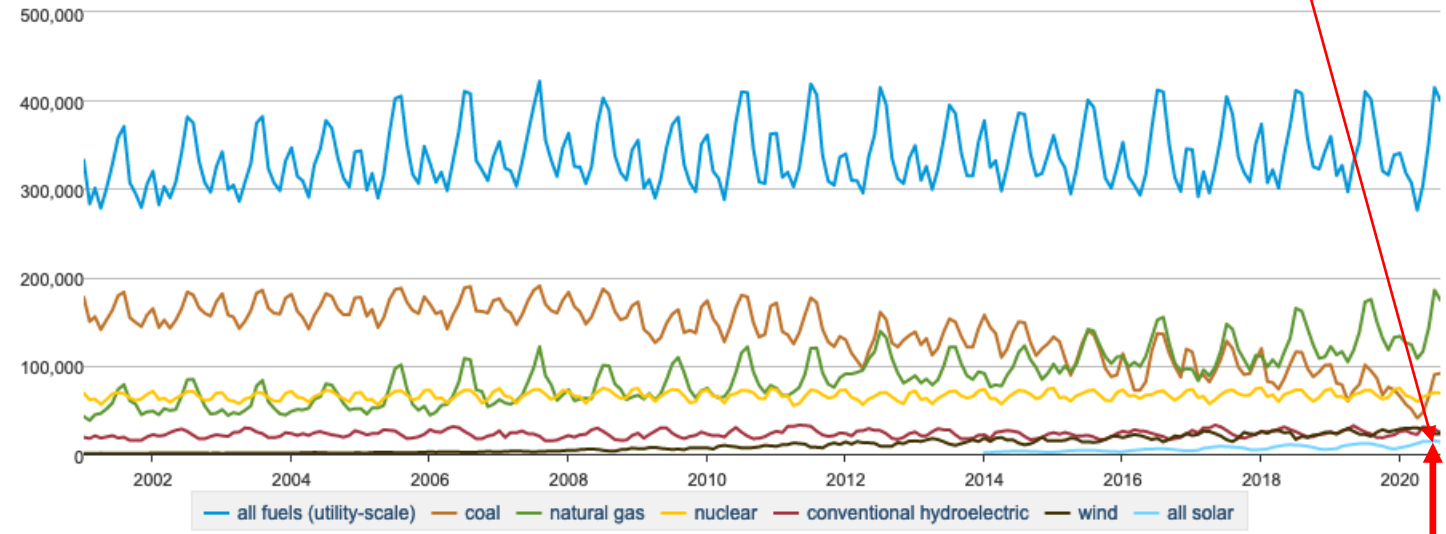

eia Source: U.S. Energy Information Administration

CHART INDEXING OPTIONS: None | Index to start as percent | Index to start as value

We can do much better than this !!

all fuels (utility-scale) coal natural gas nuclear conventional hydroelectric wind all solar

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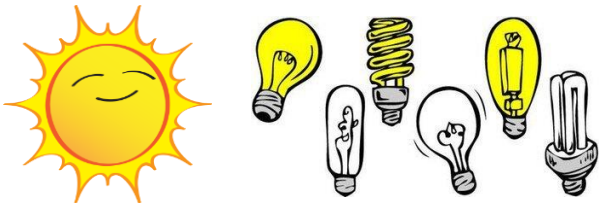
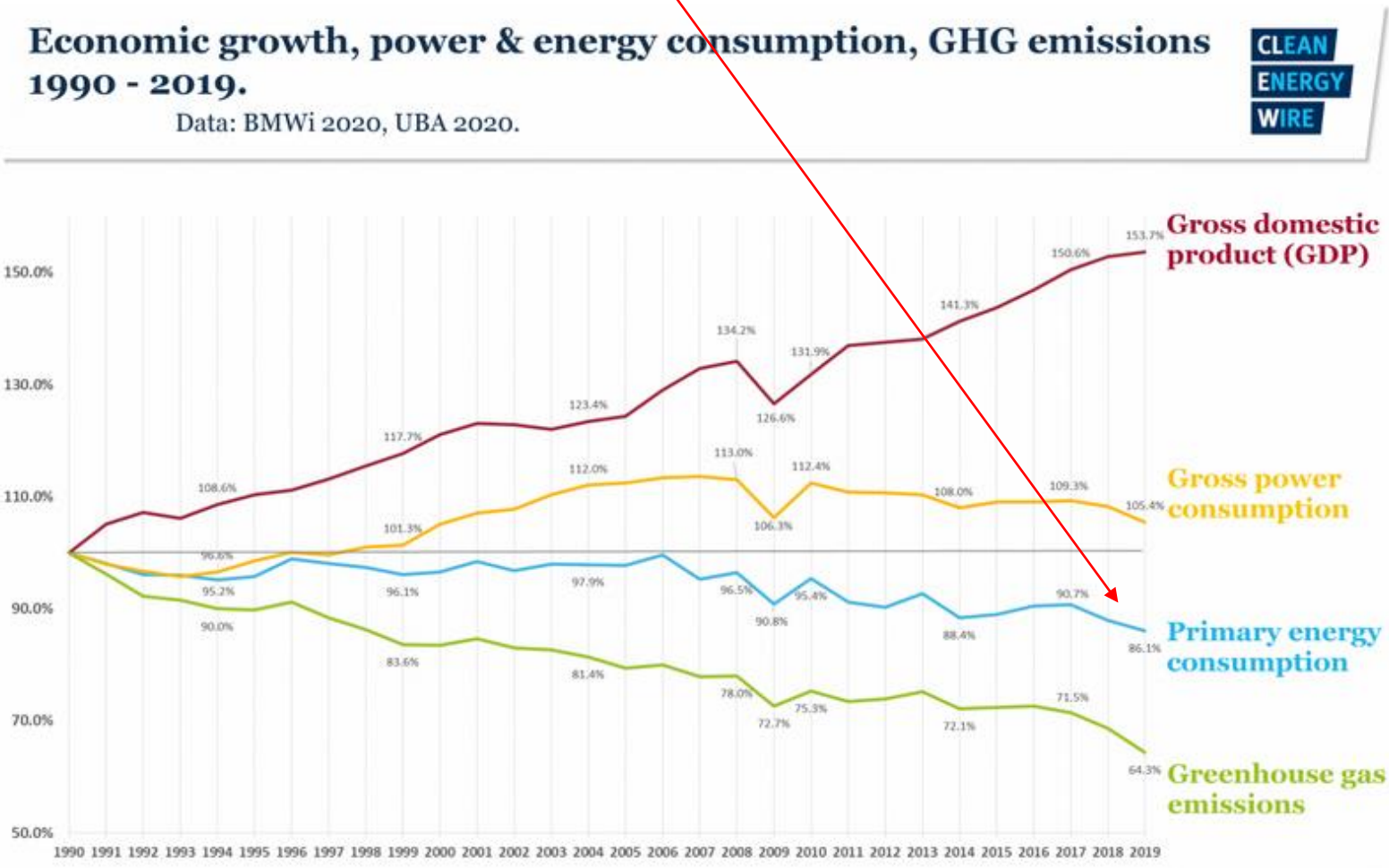


GERMANY ENERGY **USE** (not just electrical) in 2019:



https://www.cleanenergywire.org/factsheets/**germanys-energy-consumption-and-power-mix-charts**

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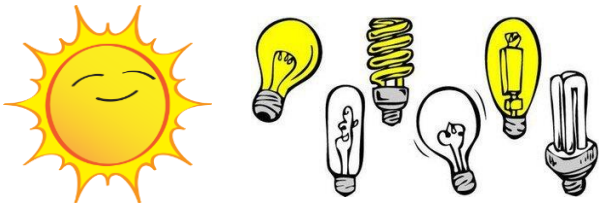
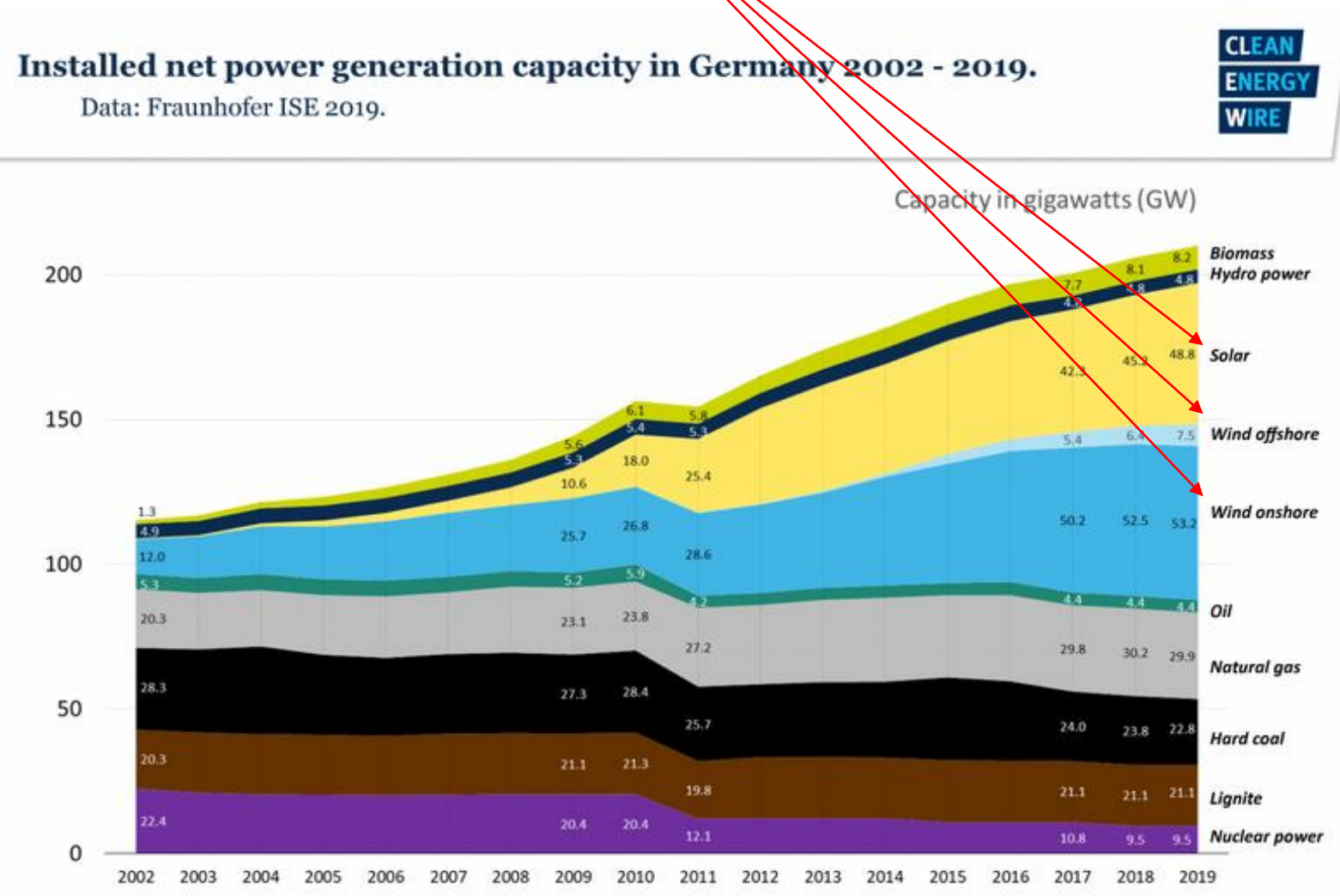


GERMANY ENERGY **PRODUCTION** in 2019:



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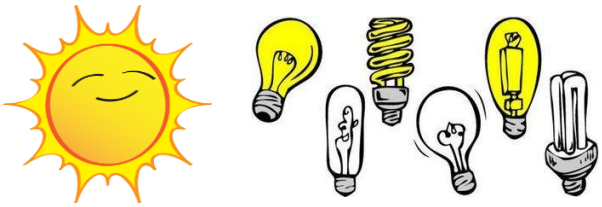
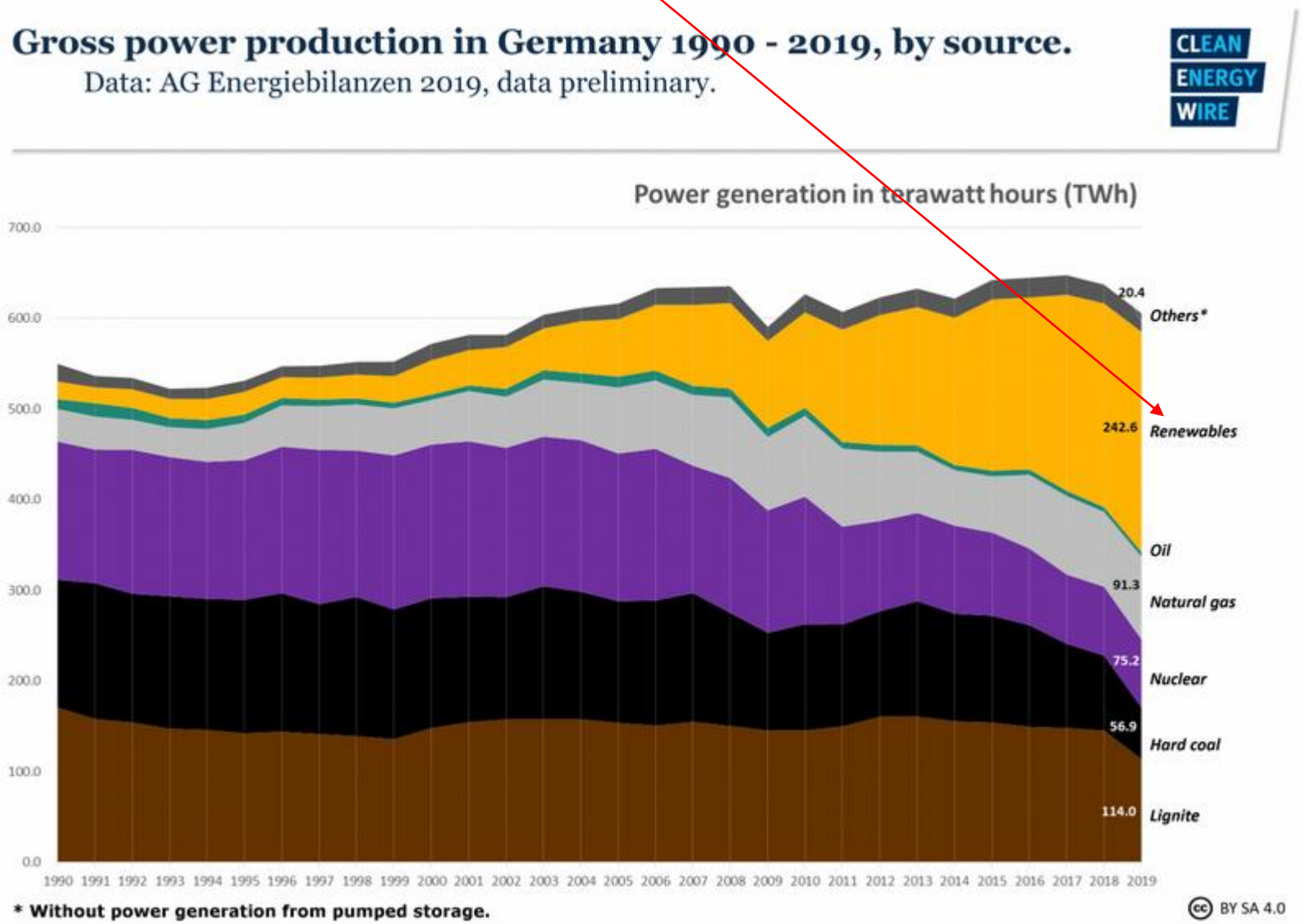


GERMANY ENERGY **PRODUCTION** in 2019:



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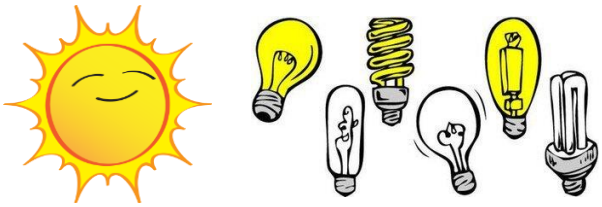
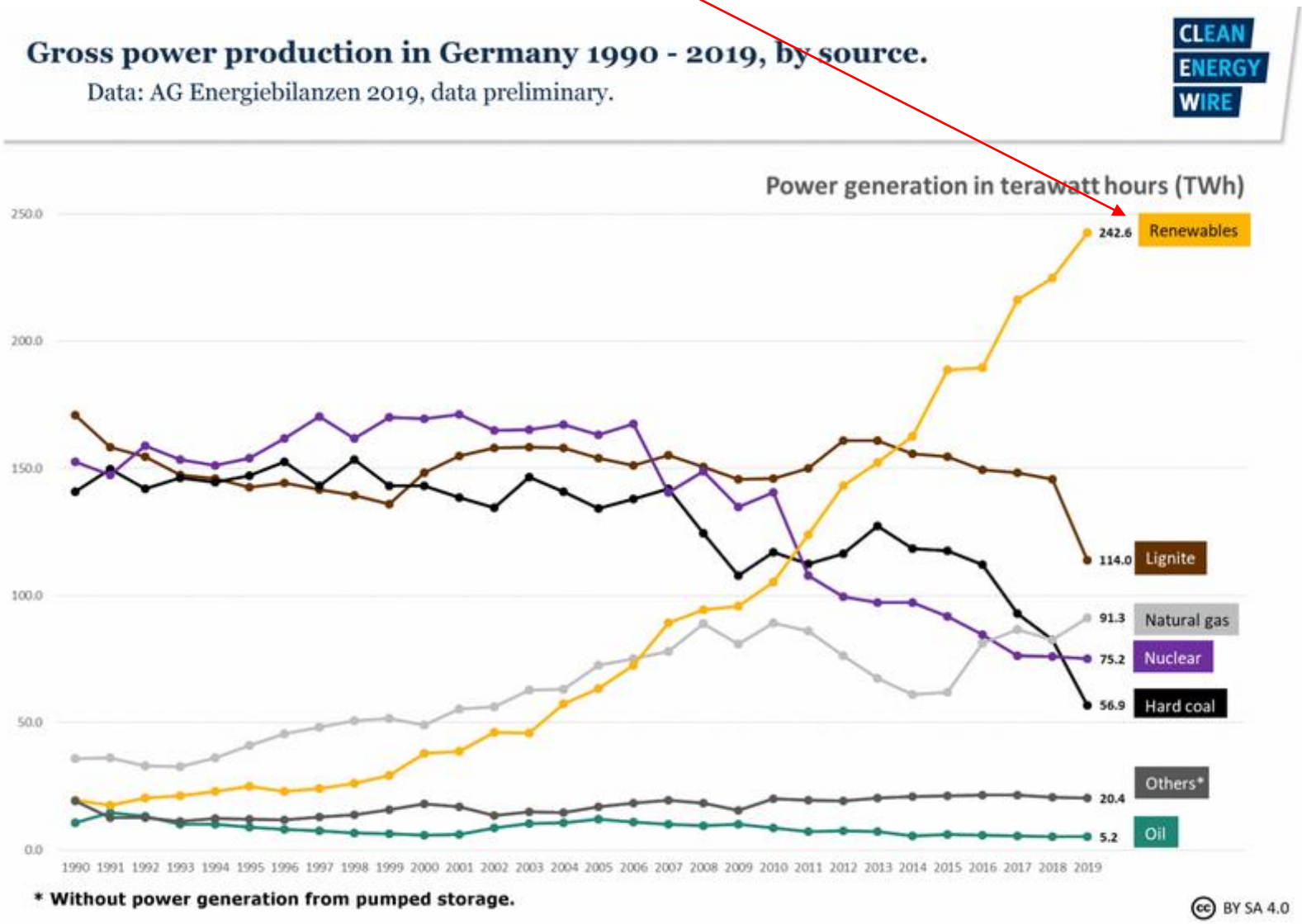


GERMANY ENERGY **PRODUCTION** in 2019:



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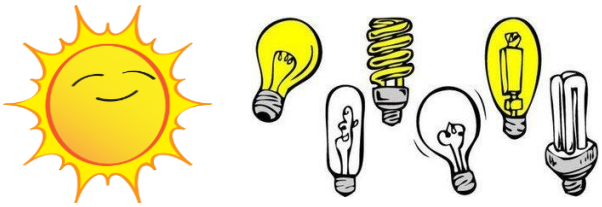
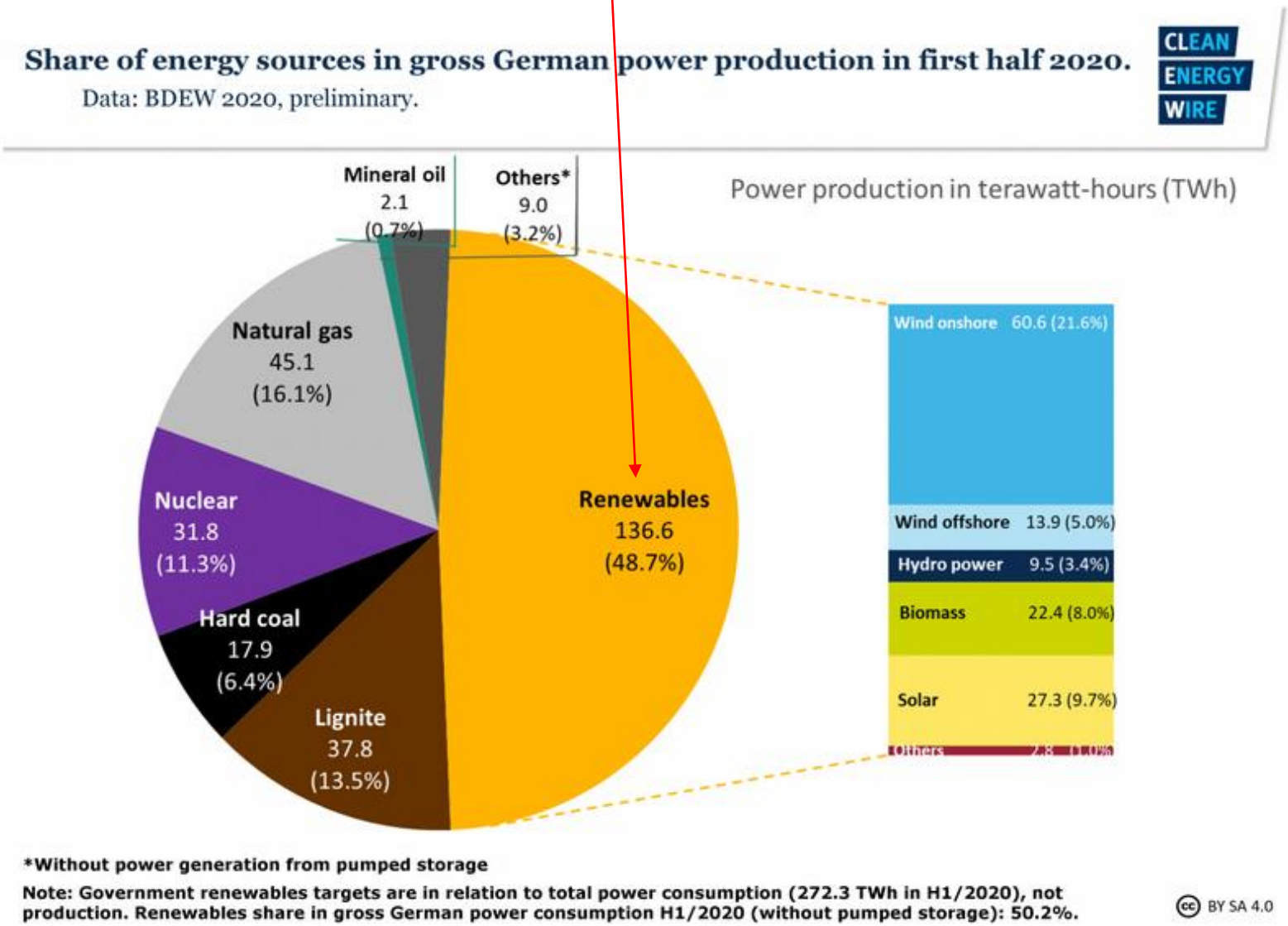


GERMANY ENERGY **PRODUCTION** in 2019:



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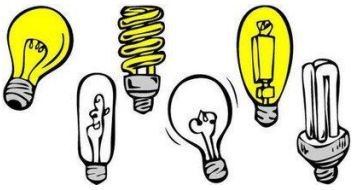
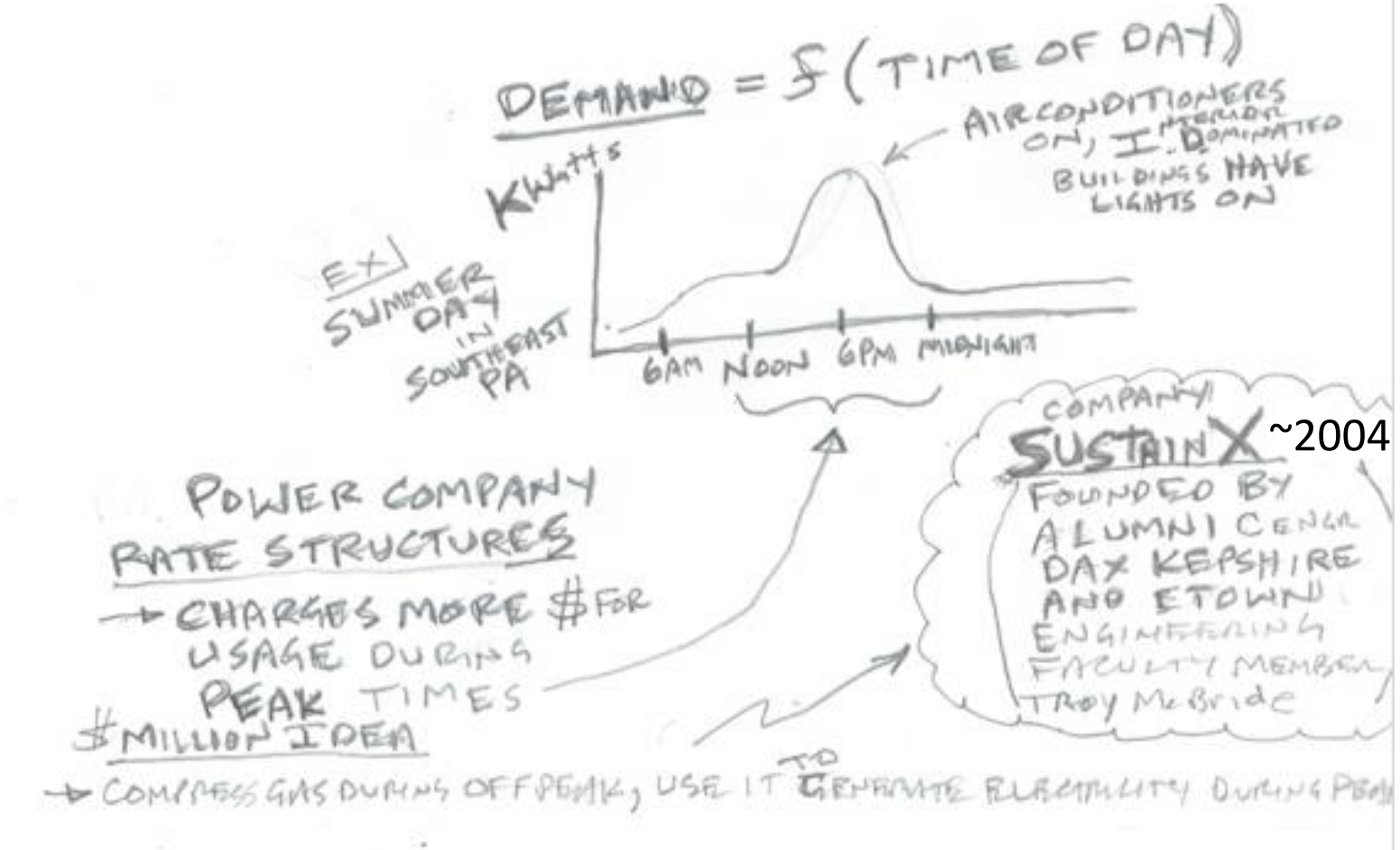
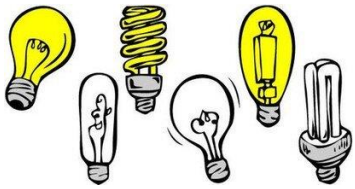


U.S. ENERGY **USE/PRODUCTION**

ELECTRICAL LOAD BALANCING



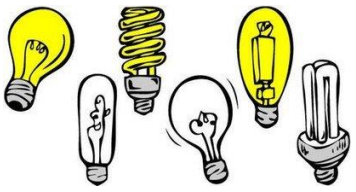


U.S. ENERGY USE/PRODUCTION ~2004 ++

Applications

Intelligent energy storage

Elizabethtown College Research with alumnus Dr. Dax Kepshire

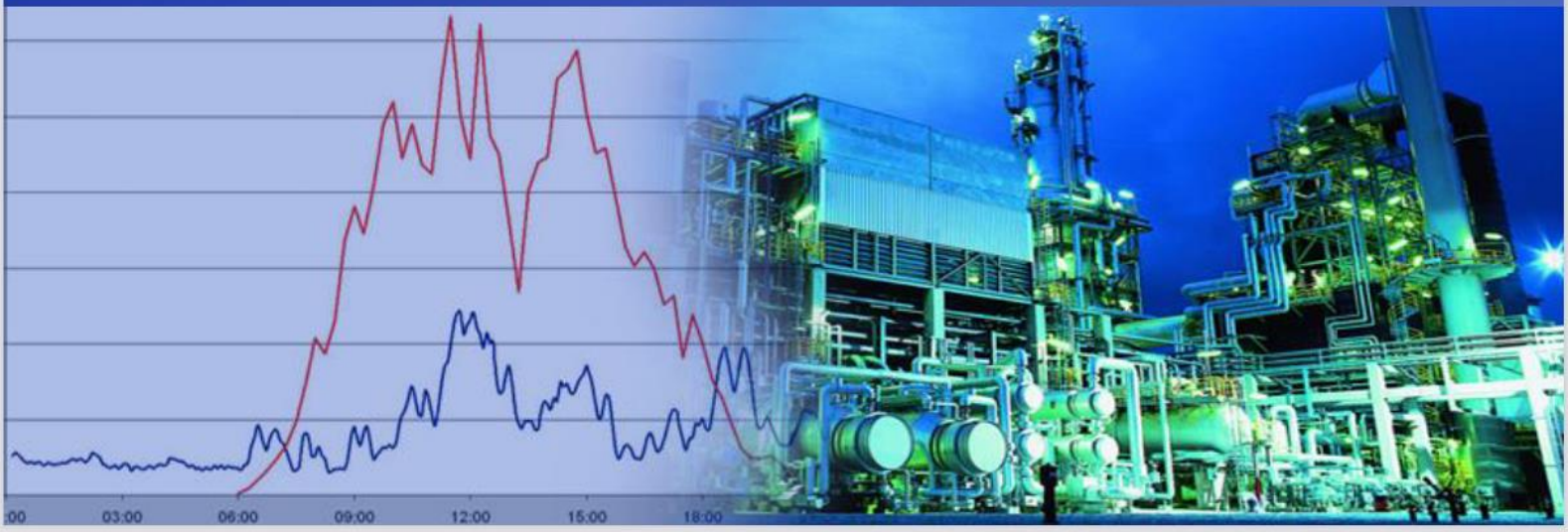


U.S. ENERGY USE/PRODUCTION ~2004 ++

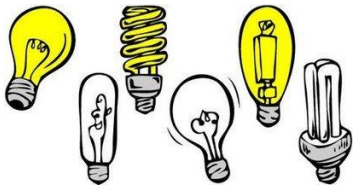
Applications

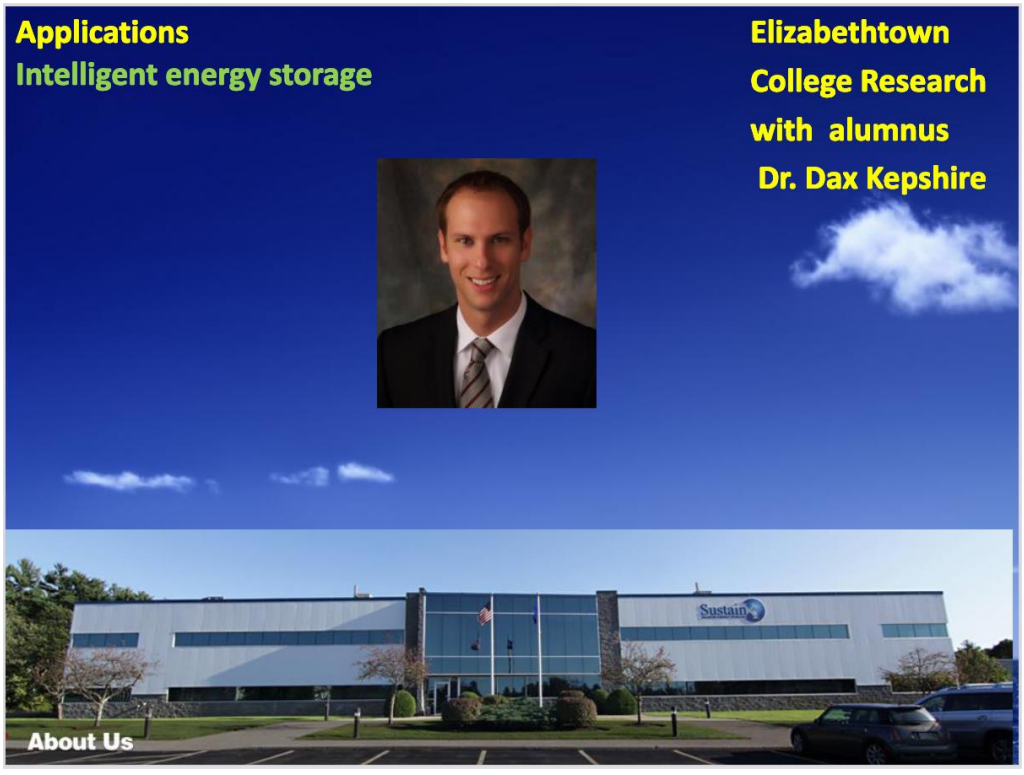
Energy load-shedding

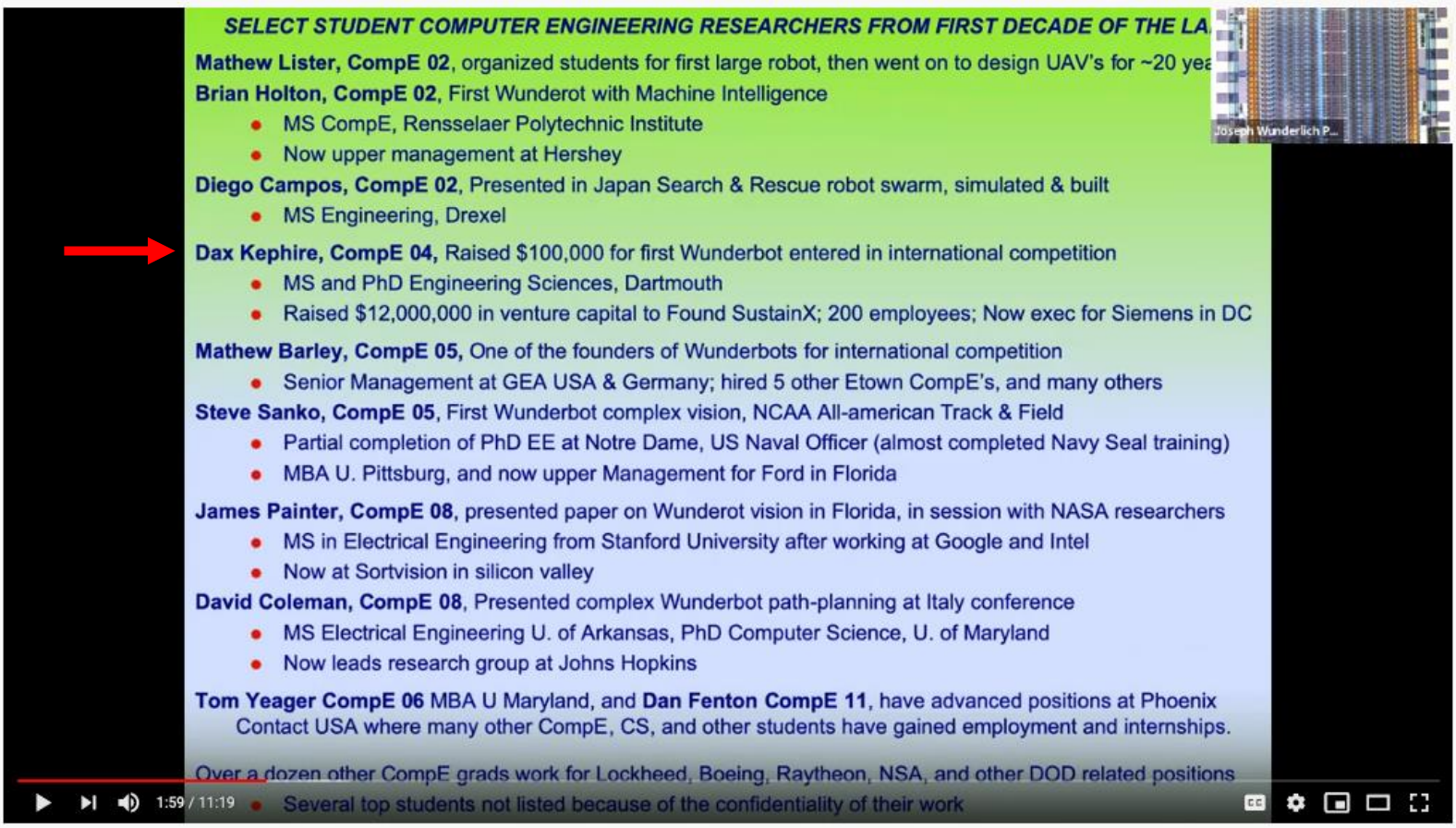
Elizabethtown College Research with alumnus Dr. Dax Kepshire



U.S. ENERGY USE/PRODUCTION ~2004 ++







2020 LECTURE: 21st year of Etown Robotics & Machine Intelligence Lab, and ARCHITECTURE STUDIO

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Watch: https://www.youtube.com/watch?v=Jk3kZ8qyS2M

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Vision - NonVisual-Effects
Vision - Performance&Perception

Human vs. Machine Vision
Color-Physics/Display-Tech
Computer-graphics
Graphics-boards