Daylighting and Compliance:
Are current standards sufficient?

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Mail Online

Pupils pass out in £25million PFI schools as new classrooms overheat

By Laura Clark
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Children passed out from heat exhaustion at three £25million schools as ventilation problems sent temperatures soaring to 38C, teachers claimed yesterday.

One pupil from each of school had to be sent home after collapsing during recent hot weather and staff also became ill

Teaching unions warned that the opposite could happen this winter, with classrooms becoming freezing cold.

Heat wave targets: Tong High was among the three flagship schools where children passed out last month

guardian.co.uk

£35bn revamp will produce generation of mediocre schools

Government body criticises 80% of new building designs

BBC NEWS

LIVE BBC NEWS CHANNEL

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Many new-built schools 'mediocre'

Half of a sample of 52 secondary schools built in England in the last five years were at best "mediocre", government design advisers say.

The design quality was "not good enough to secure the government's ambition to transform our children's education".

One of the best designs: Caroline Chisholm School, Northants

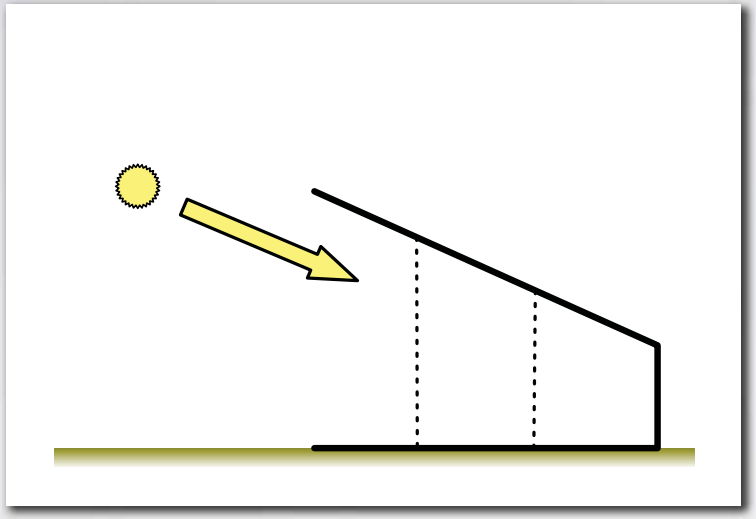
Flagship schools: On shaky foundations

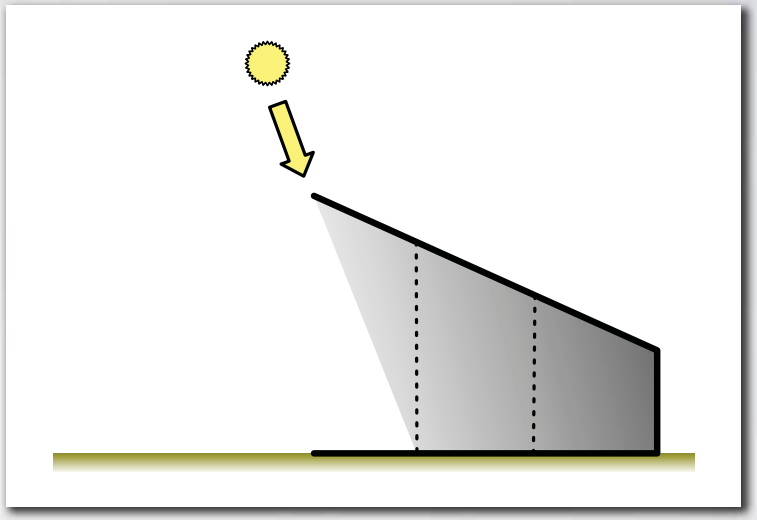
THE INDEPENDENT

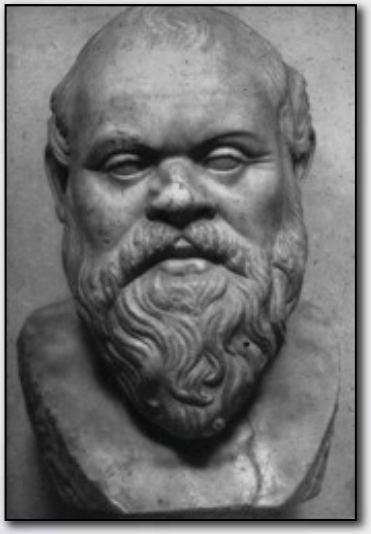
Billions of pounds are being spent on rebuilding the nation's secondary schools. But many - including two from top architect Lord Foster - have attracted criticism.

Key failings identified in the CABE report:

“… classrooms which are too dark or prone to overheating on sunny afternoons”

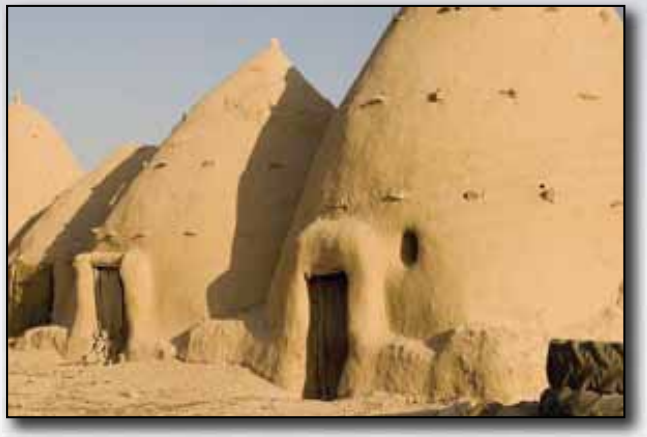






"Now in the houses with a south aspect, the Sun's rays penetrate into the porticoes in the winter, but in summer the path of the Sun is right over our heads and above the roof so that there is shade."

Quoted by Xenophon in *Memorabilia Socrates*



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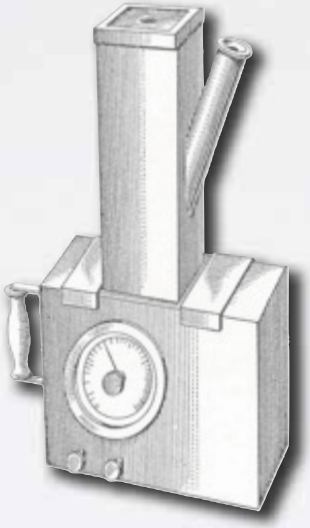

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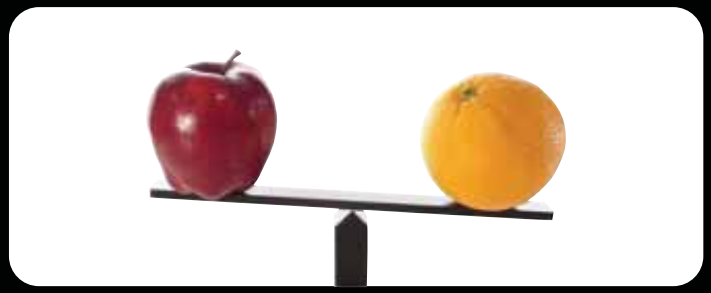
Units + Measurements ➔ Standards



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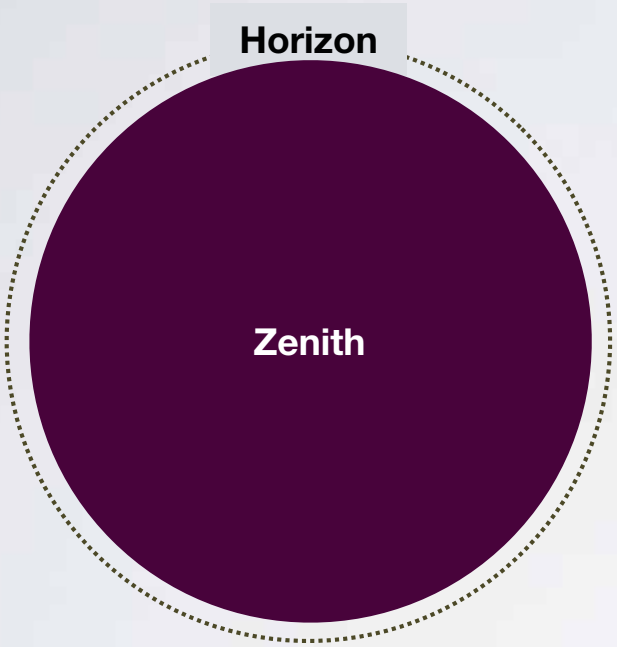
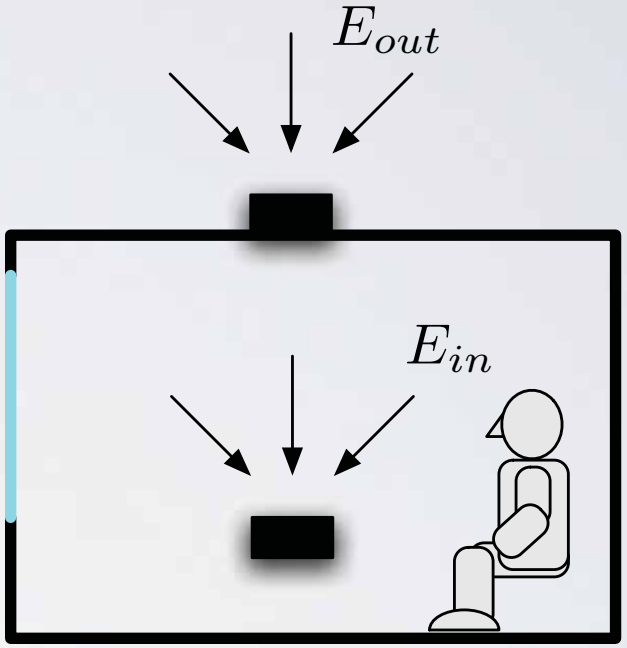
✓

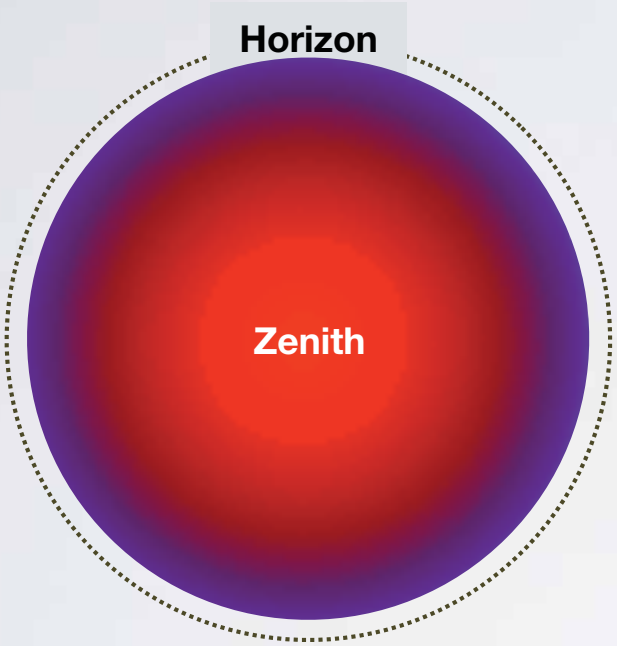
The sky factor

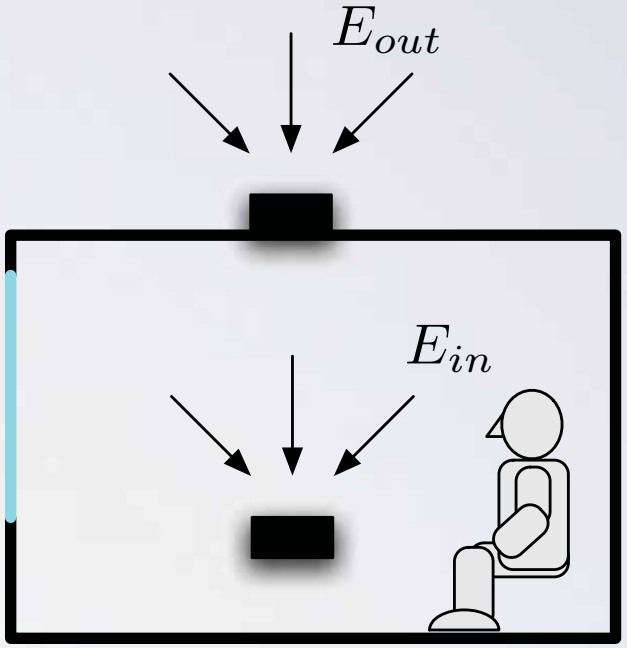




$$SF = \frac{E_{in}}{E_{out}} 100\%$$

The daylight factor



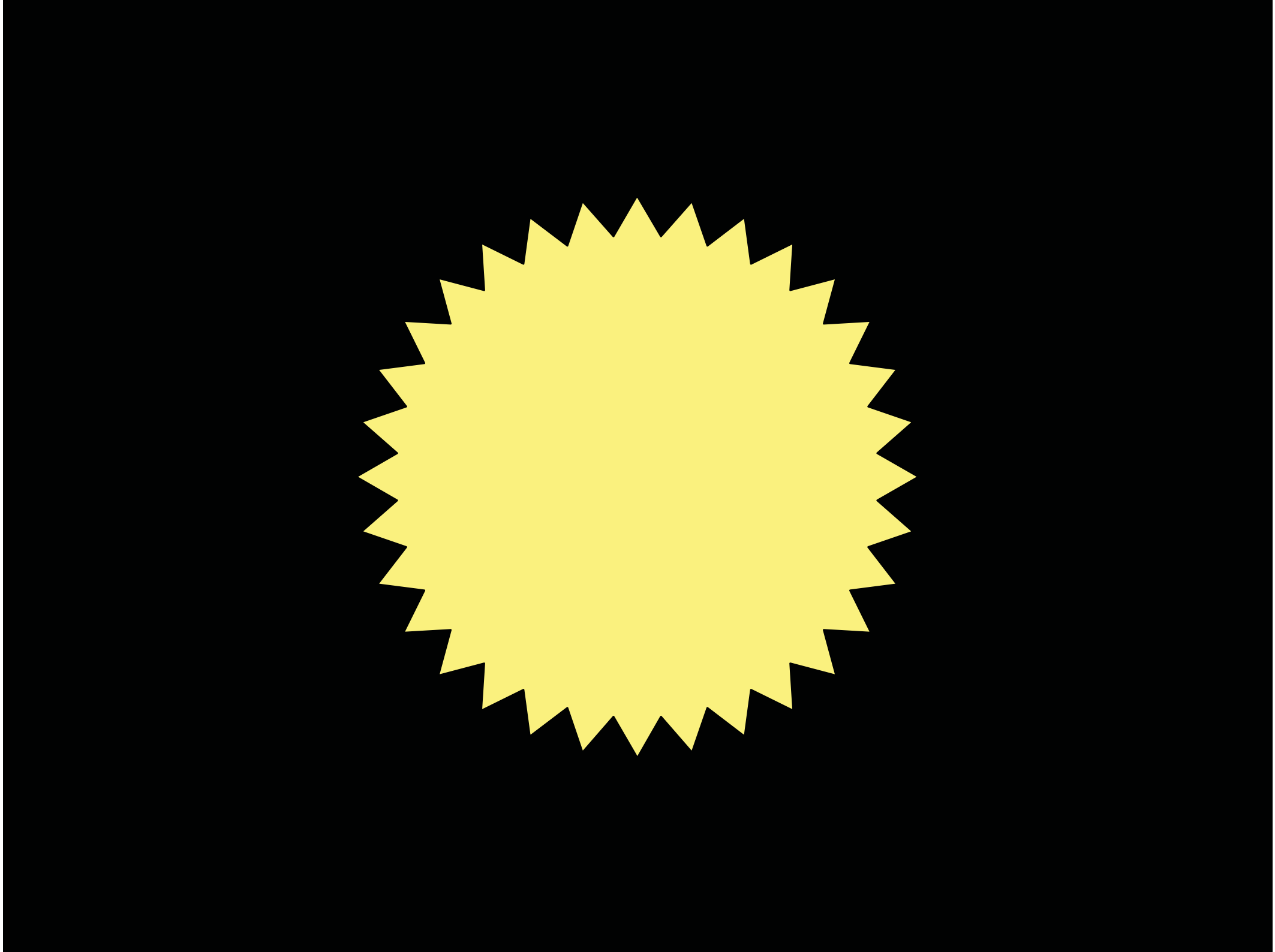


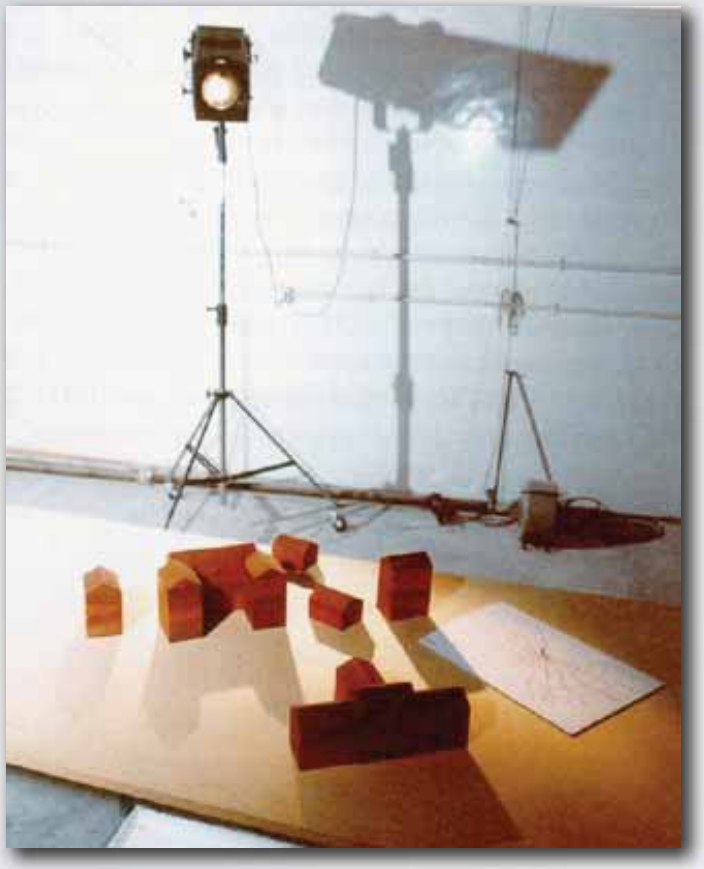
$$DF = \frac{E_{in}}{E_{out}} 100\%$$

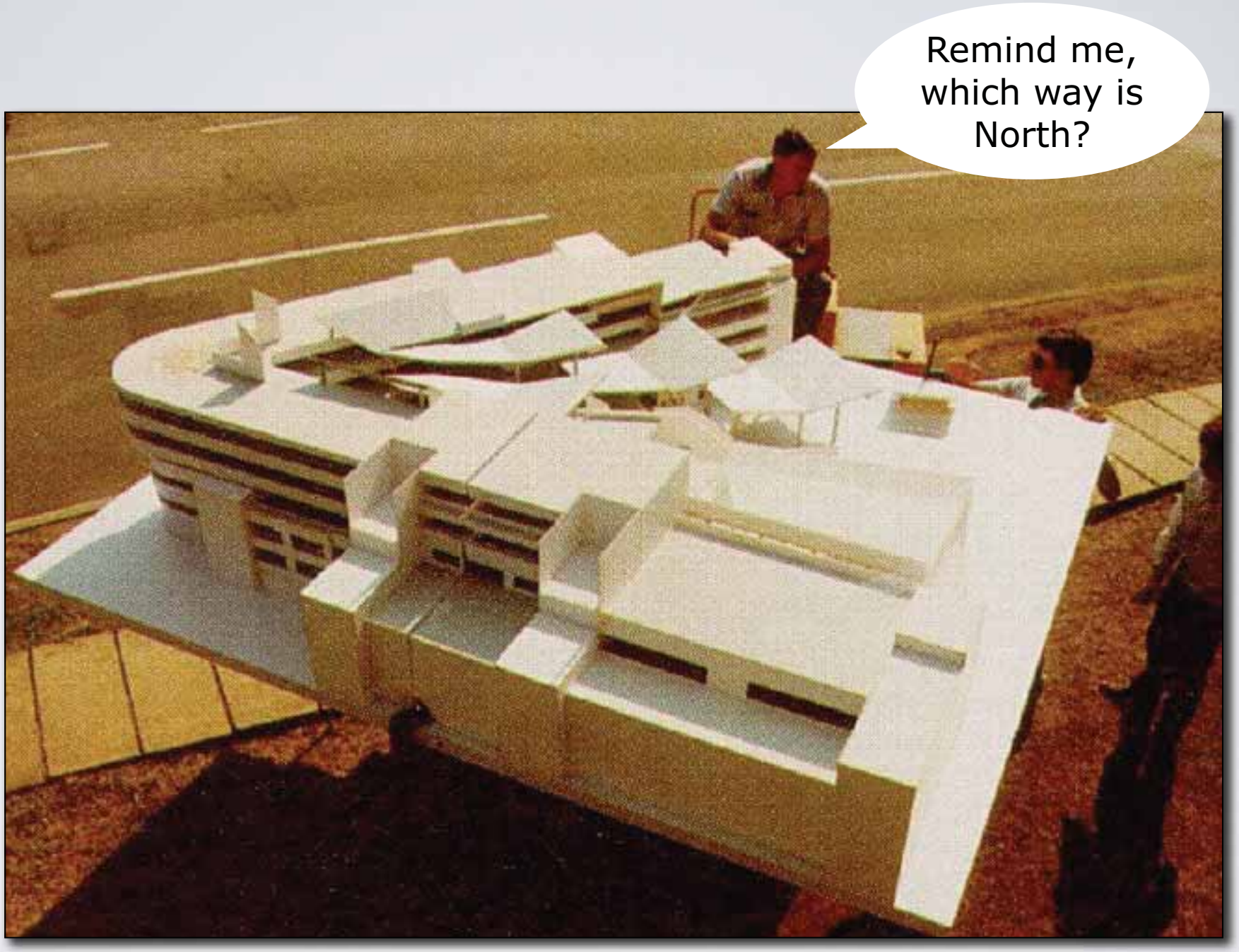
The daylight factor is insensitive to climate/location and orientation

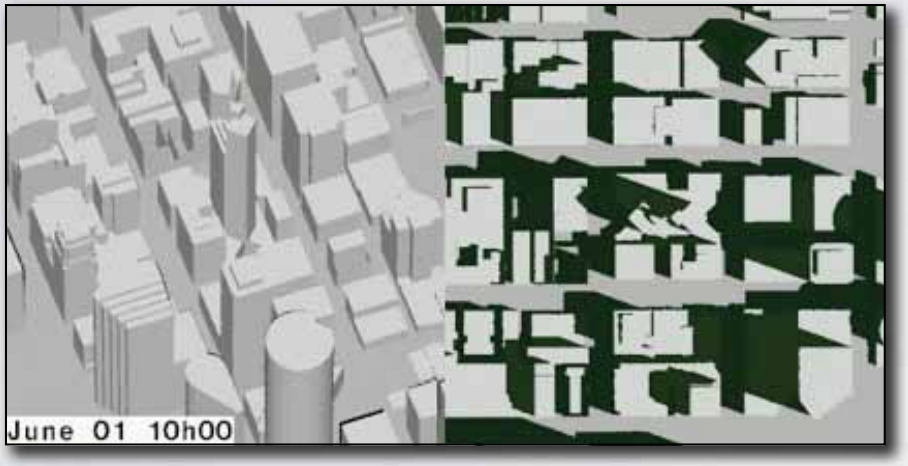
North-facing in St. Petersburg or South-facing in Miami?

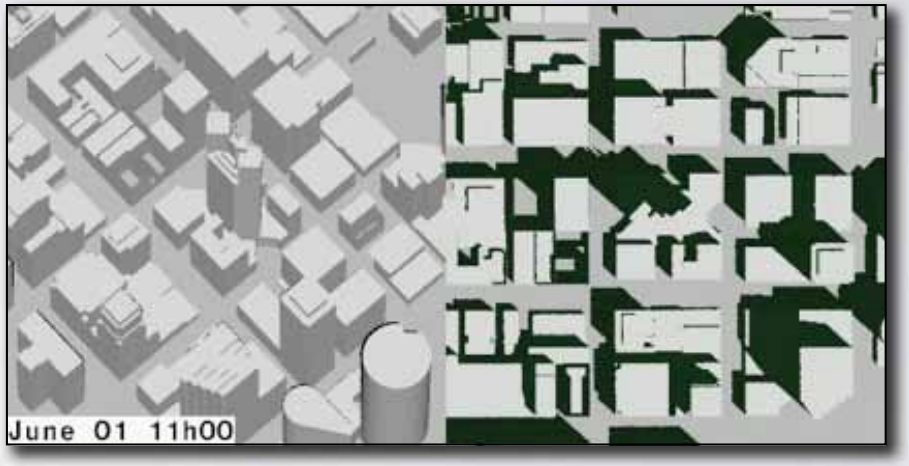
For a given design you get the <u>same</u> daylight factor either way

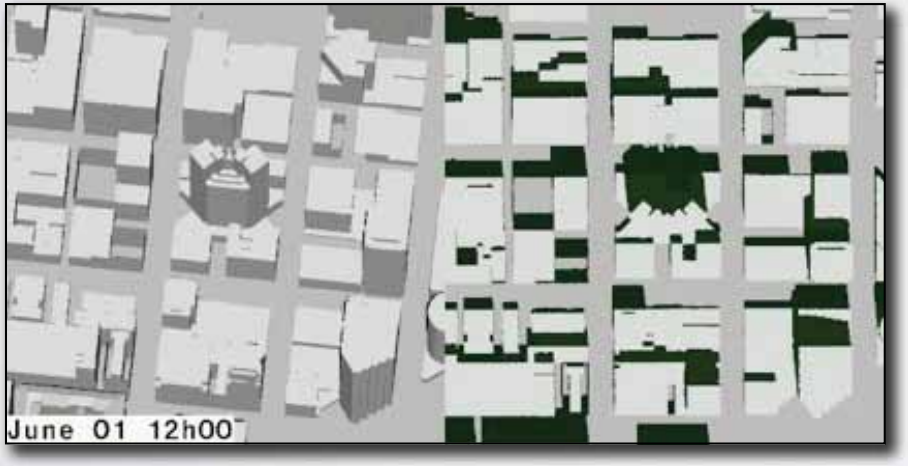


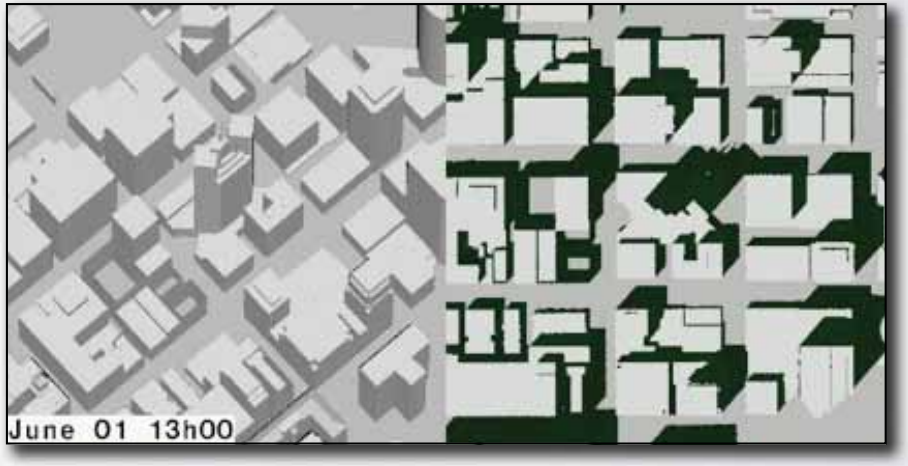



Remind me, which way is North?


June 01 10h00

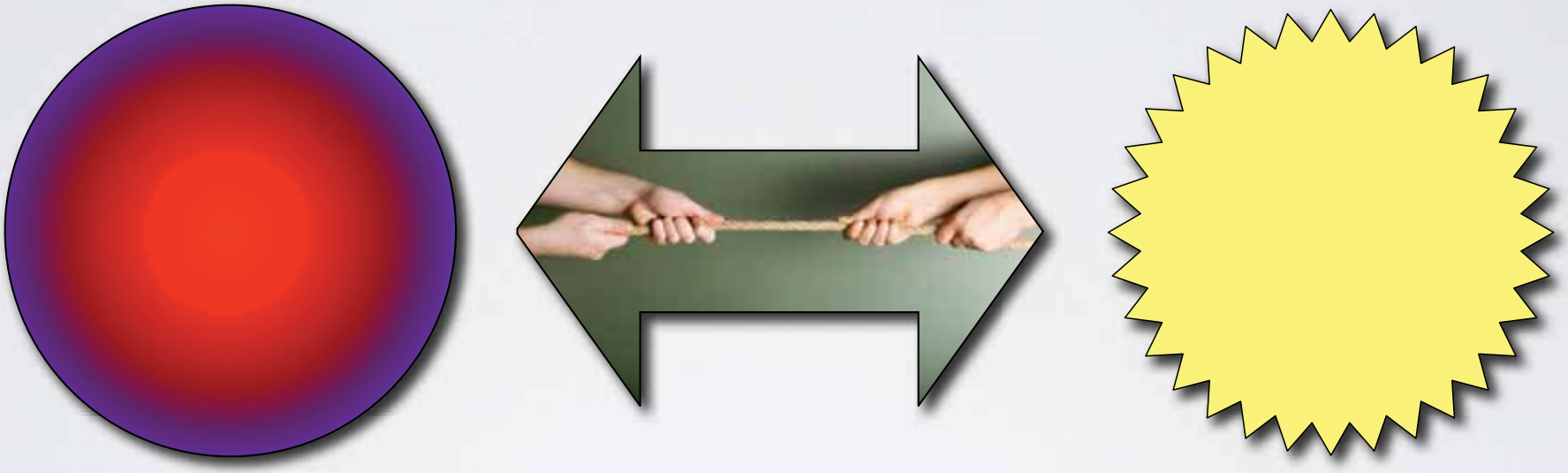

June 01 11h00


June 01 12h00


June 01 13h00

Daylight factor

Shadow pattern



Incompatible methodologies - often giving contradictory advice

The decline of climate-adapted building design

The development of:

- curtain wall technology;
- float glass;
- fluorescent lighting; and,
- HVAC.

Higher occupant densities in deeper-plan spaces.

Modernist architecture became preoccupied with vaguely defined notions of ‘light’ and ‘transparency’.

Daylight and Compliance

Drivers

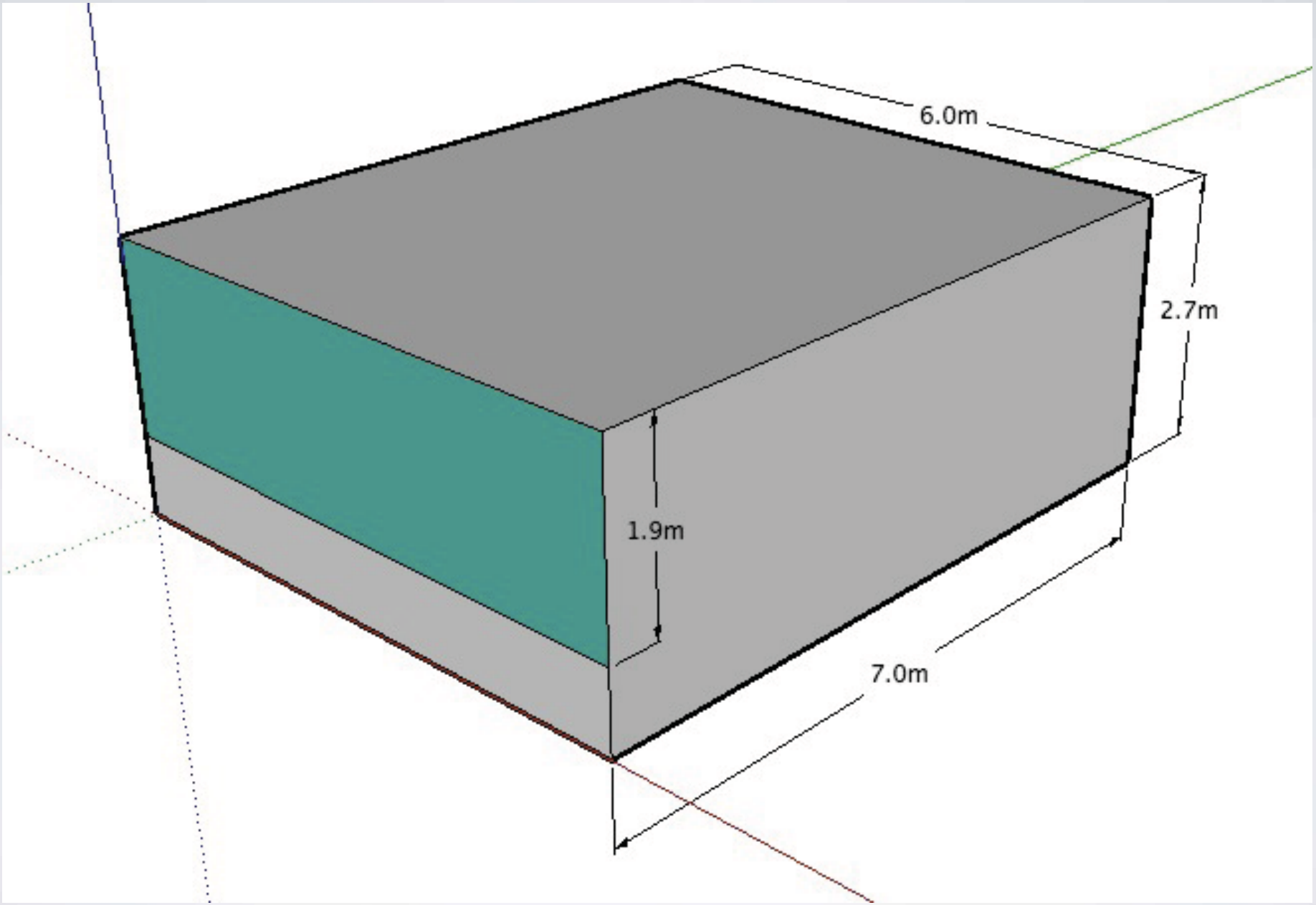
- A belief that *good* daylighting can reduce energy consumption.
- A belief that a *well-daylit* environment is preferred by occupants.
- Data *suggesting* that there might be positive health, well-being and productivity outcomes associated with good daylighting.
- The discovery of the non-visual effects of daylight, e.g. the function of the suprachiasmatic nucleus (SCN) in circadian entrainment.

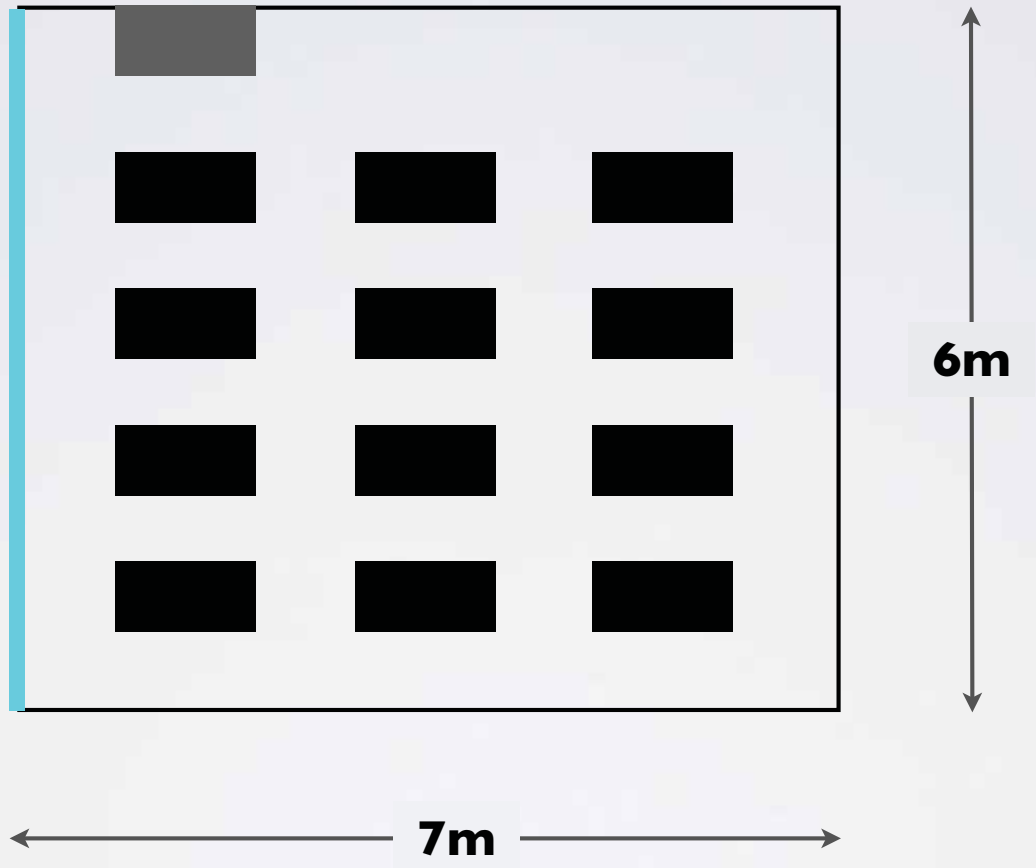
BS 8206

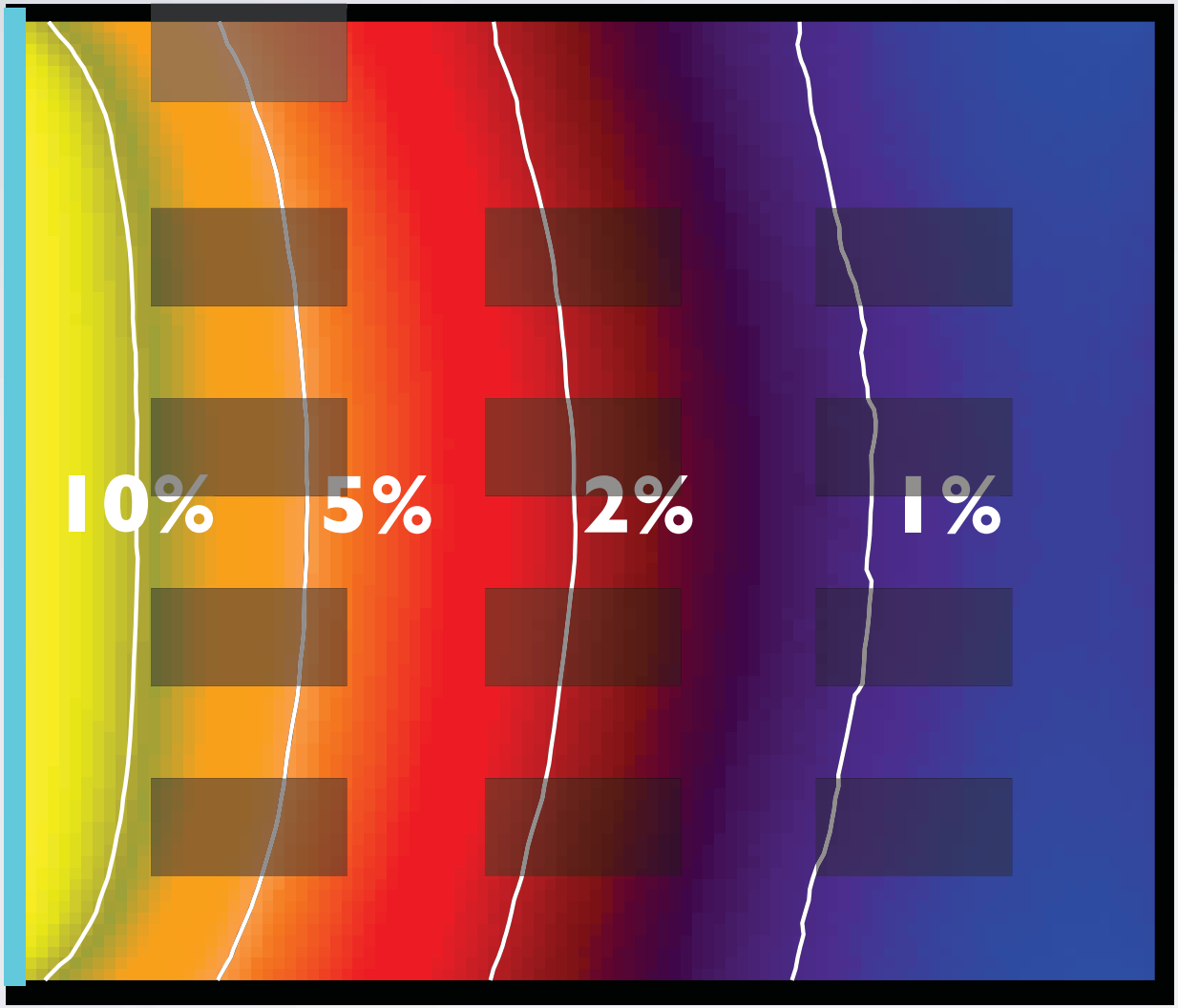
"... the average daylight factor should be at least 2%. If the average daylight factor in a space is at least 5% then electric lighting is not normally needed during the daytime, provided the uniformity is satisfactory."

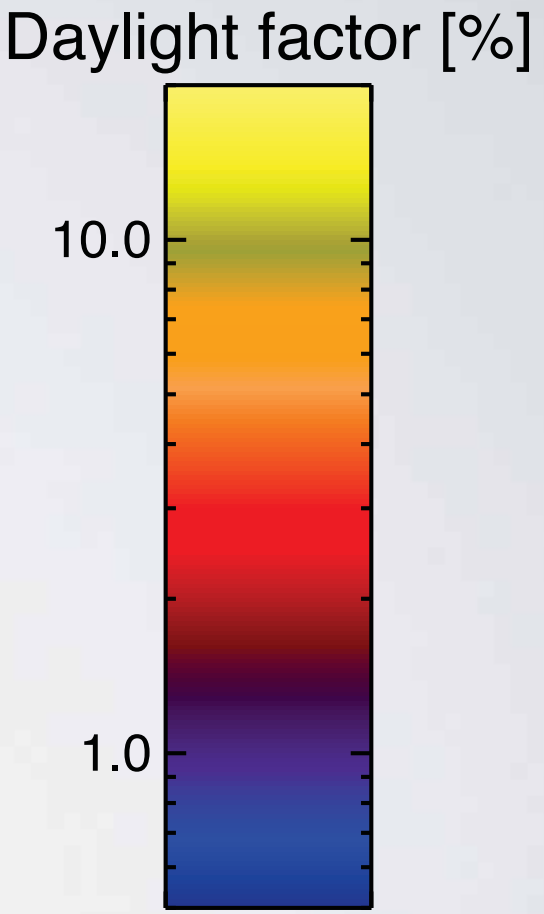
"... the minimum illuminance on a particular task area should not fall below 0.7 times the average illuminance on that task area."

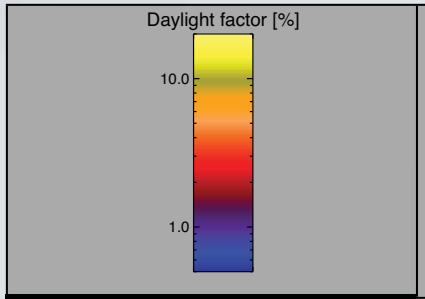
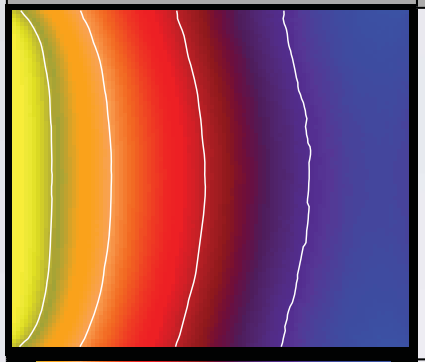
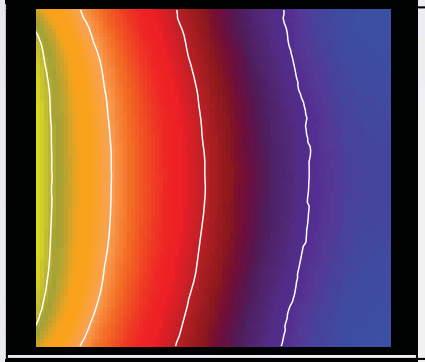
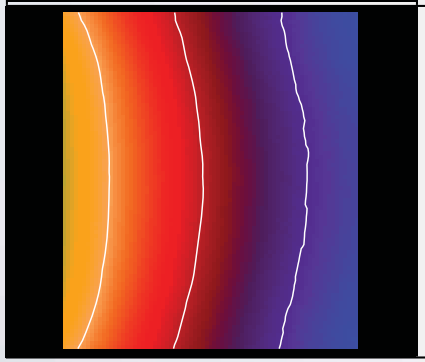
- Carbon Trust / BSF: Daylight factor not less than 4%. Preferably 6%.
- BREEAM: Where at least 80% of occupied spaces will be adequately daylit with an average daylight factor exceeding 2% [1 credit]
- BREEAM: Where all spaces will be adequately daylit with an average daylight factor exceeding 4% in single storey and 3% in multi-storey buildings. [2 credits]


6.0m
2.7m
1.9m
7.0m


6m
7m


10%
5%
2%
1%


Daylight factor [%]
10.0
1.0

	Border F/B	Mean	Median	Uniformity
	0.1m	3.4%	1.7%	0.20
	0.5m	2.9%	1.7%	0.23
	1.0m	2.5%	1.7%	0.28

LEED and daylight muddle

- Daylight factor based (v2.1)
- Glazing factor based (v2.2)
- ‘Snapshot’ clear sky option with lower limit (v2.2)
- ‘Snapshot’ clear sky option with lower and upper limit (v3.0)
- Prescriptive - similar to glazing factor (v3.0)

Clear sky options

“Demonstrate, through computer simulation, that a minimum daylight illumination level of 25 footcandles has been achieved in a minimum of 75% of all regularly occupied areas. Modeling must demonstrate 25 horizontal footcandles under clear sky conditions, at noon, on the equinox, at 30 inches above the floor.”

No normalisation?

ASHRAE 189.1 draft

"The design for the building project shall demonstrate an illuminance of at least 30 fc (300 lux) on a plane 3 ft (1 m) above the floor, within 75% of the area of the daylight zones. The simulation shall be made at noon on the equinox using an accurate physical or computer daylighting model. Simulation is to be done using ***either*** *the CIE Overcast Sky Model* ***or*** *the CIE Clear Sky Model."*


No normalisation?
CIE clear or CIE overcast?

Sky type	**Radiance** command	Diffuse horizontal illuminance	Equivalent daylight factor for 300 lux
CIE Overcast Sky	`gensky 3 20 12 -c`	14,679 lux	2.04%
CIE Clear Sky	`gensky 3 20 12 -s`	8,454 lux	3.55%

```
echo "0 0 0 0 0 1" | rtrace -w -h -I+ -ab 1 -ad 4096 sky.oct \
        | rcalc -e '$1=($1*0.265+$2*0.670+$3*0.065)*179'
```

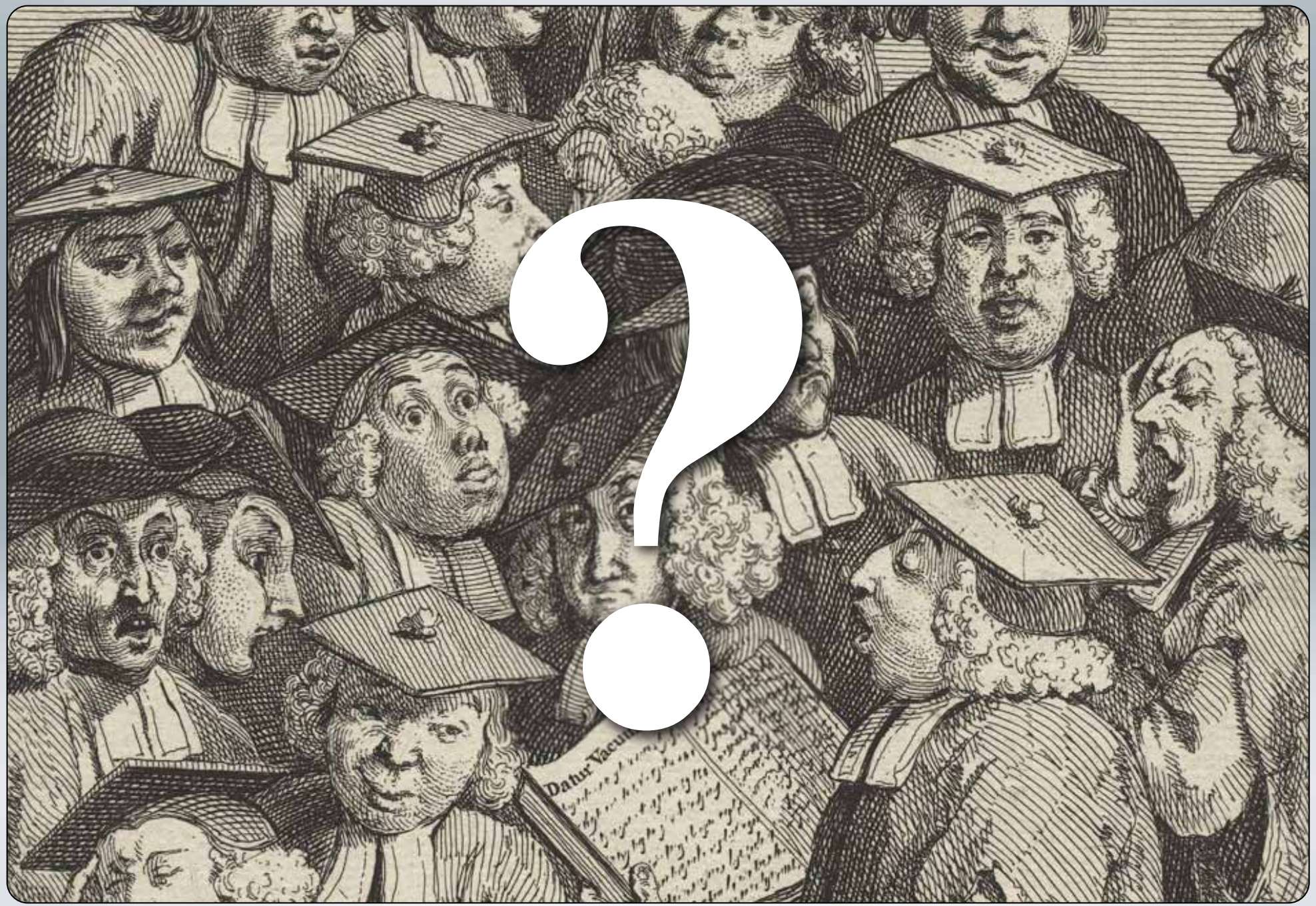
or

?

*“Regarding **gensky**, default behavior uses some rule-of-thumb calculation based on SF weather data as compiled by LBNL decades ago, and probably isn't appropriate for anywhere.”*

Greg Ward

Originator of the **Radiance** Lighting Simulation System



Expert daylight practitioner

Non-expert "compliance chaser"

Experience
Intuition
Advice

Software
Simulation
Targets

In the race to demonstrate compliance...

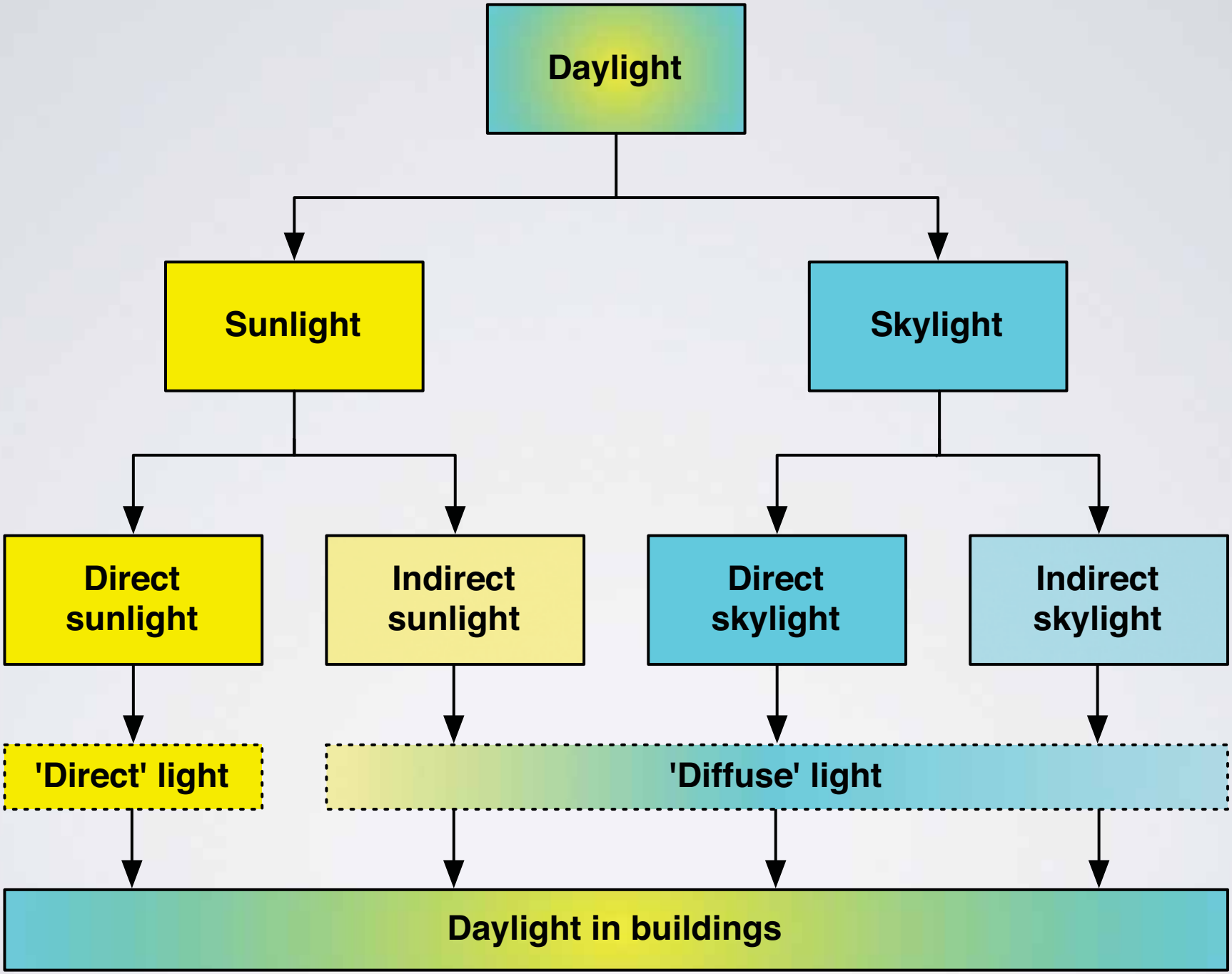
Experience
Intuition
Advice

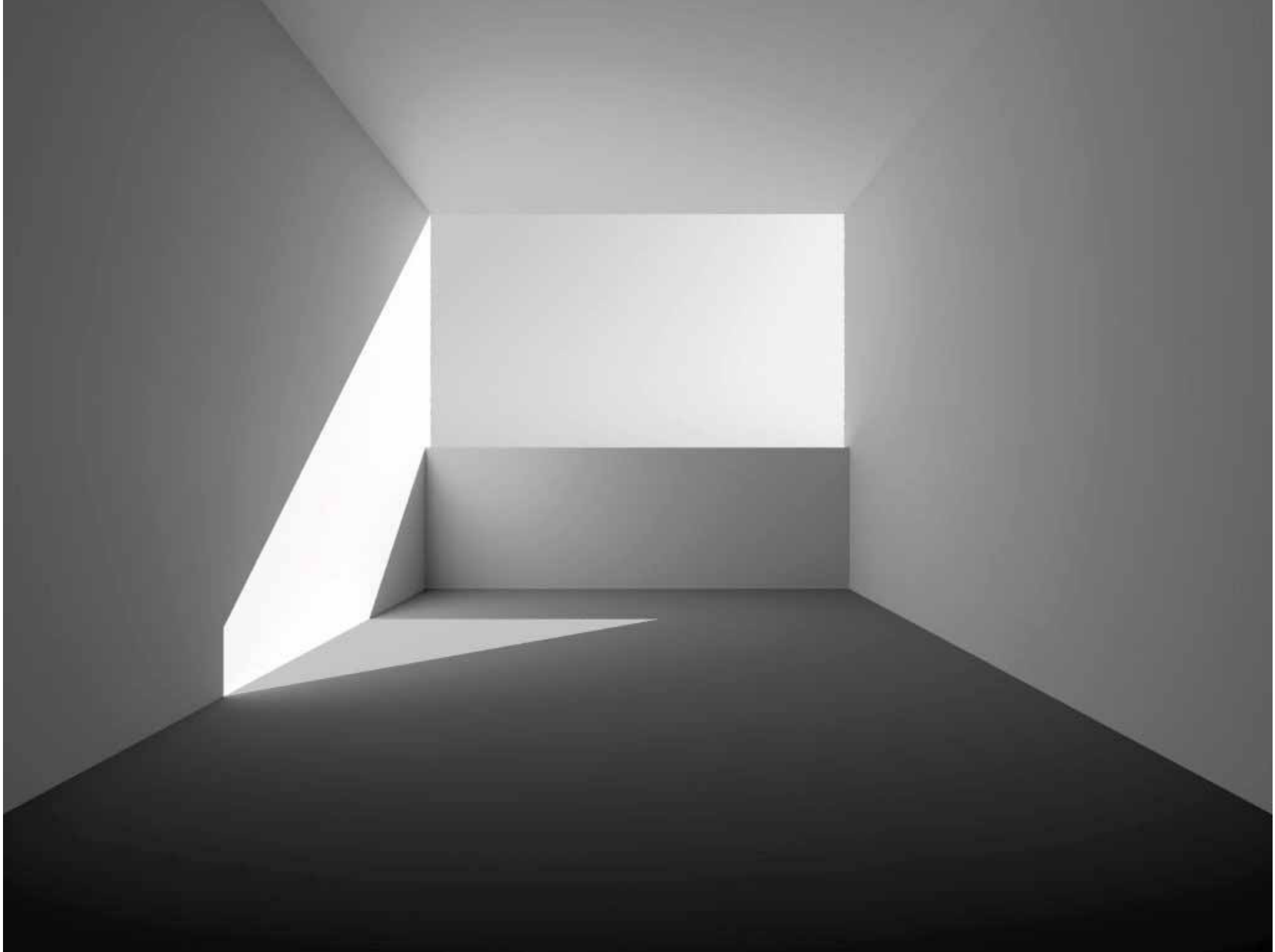
Software
Simulation
Targets

The expert practitioner's advice is invaluable

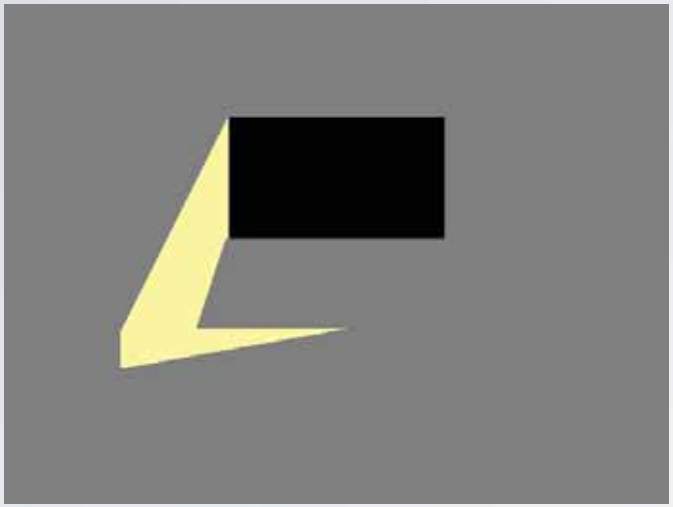
However, this knowledge can only be acquired through on-the-job apprenticeship; it does not lend itself to wide dissemination through classroom teaching, nor can it be codified in standards.

We need better measures of daylighting performance than currently exist - realistic measures of illumination that are objective, repeatable and thus suitable for codification in standards.

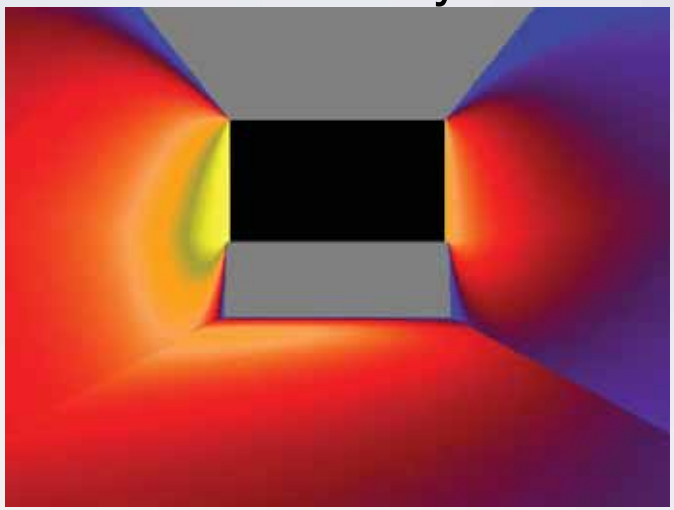

Daylight
Sunlight
Skylight
Direct sunlight
Indirect sunlight
Direct skylight
Indirect skylight
'Direct' light
'Diffuse' light
Daylight in buildings



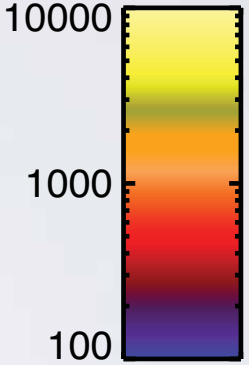
Direct sun



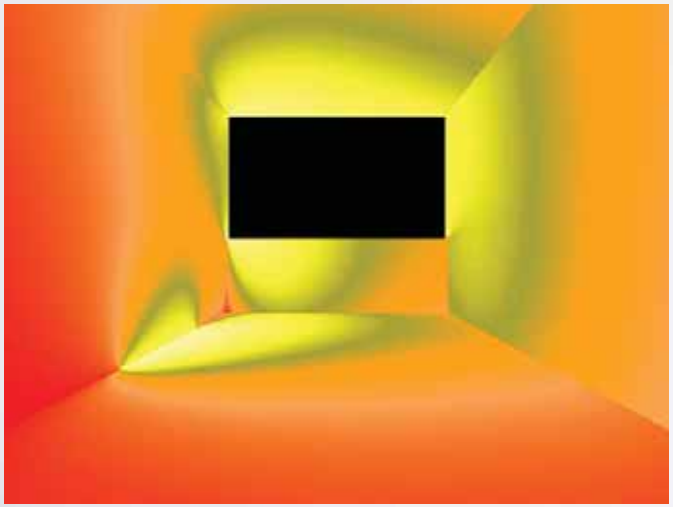
Direct sky



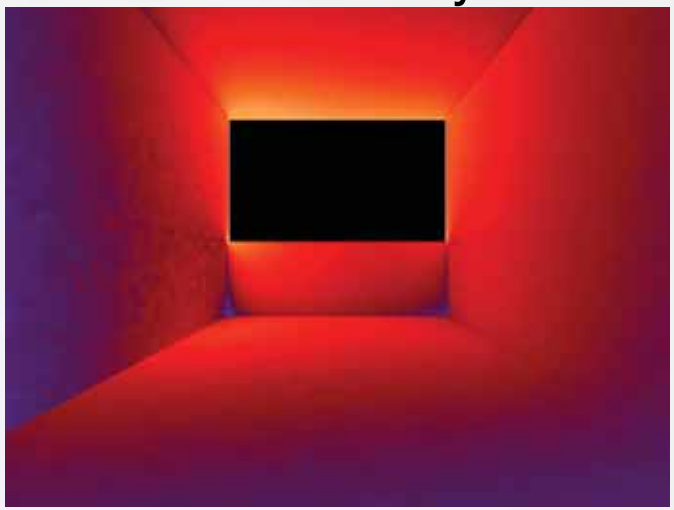
Illuminance [lux]



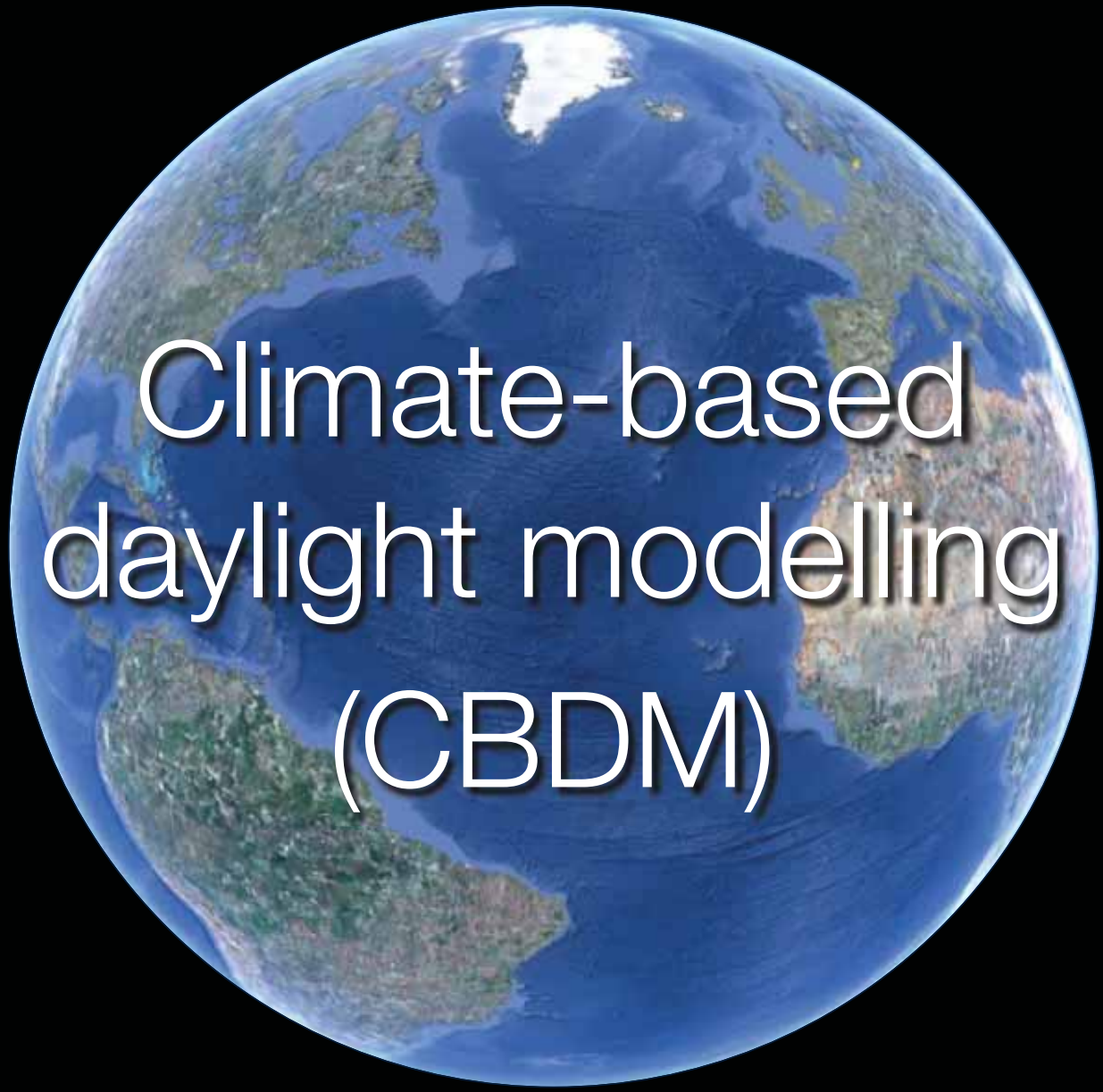
Indirect sun



Indirect sky

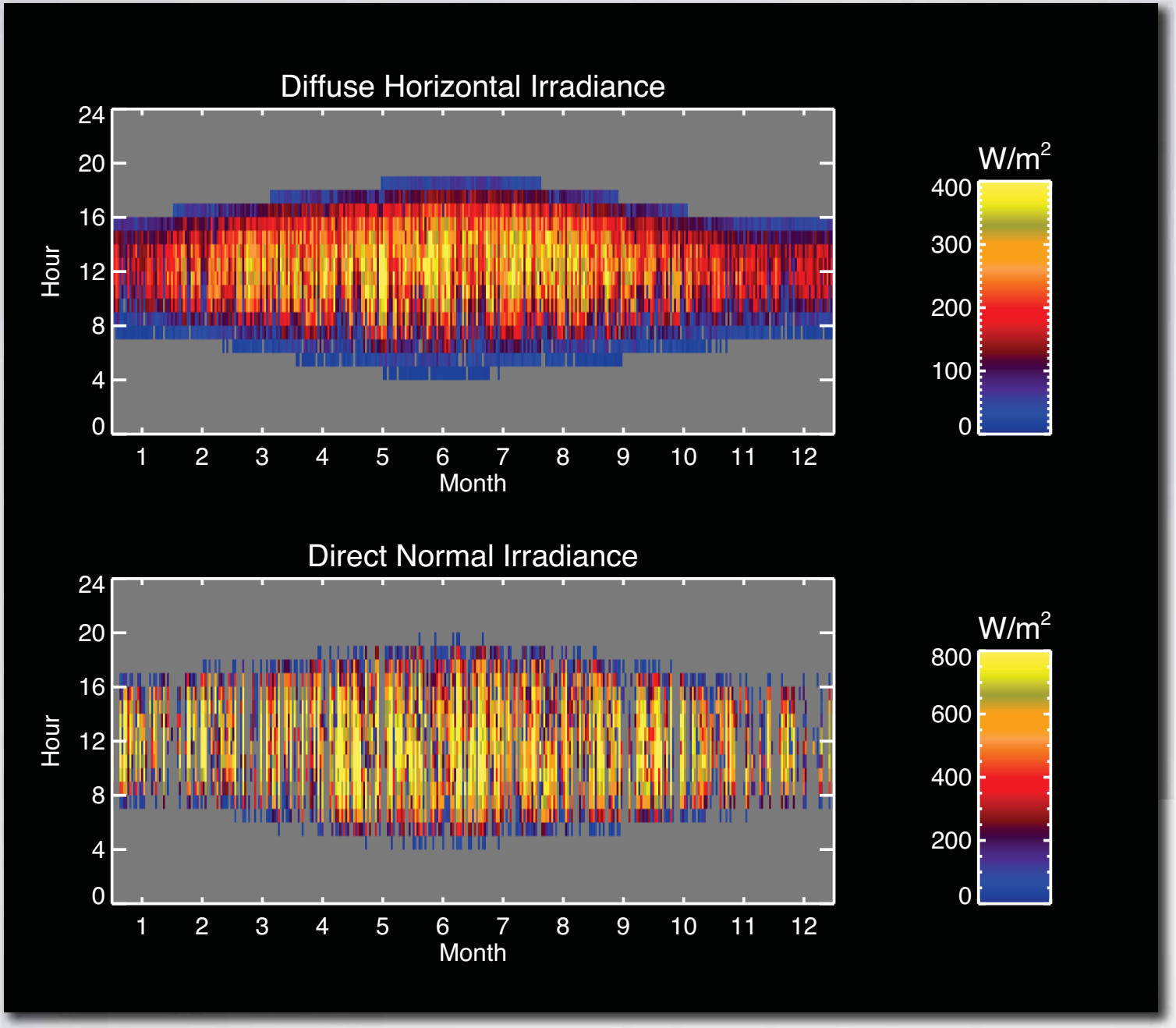


Total illumination


Climate-based
daylight modelling
(CBDM)

Why climate-based daylight modelling?

- Predicts absolute values of luminous quantities, e.g. illuminance, luminance, etc.
- Uses realistic sky and sun conditions.
- Founded on standardised climate files.
- Allows ‘holistic’ evaluation of daylighting combined with solar shading.



Standard climate file: Chicago TMY2 94846

Realistic sky model patterns derived from climate data

Quantities that can be predicted using CBDM

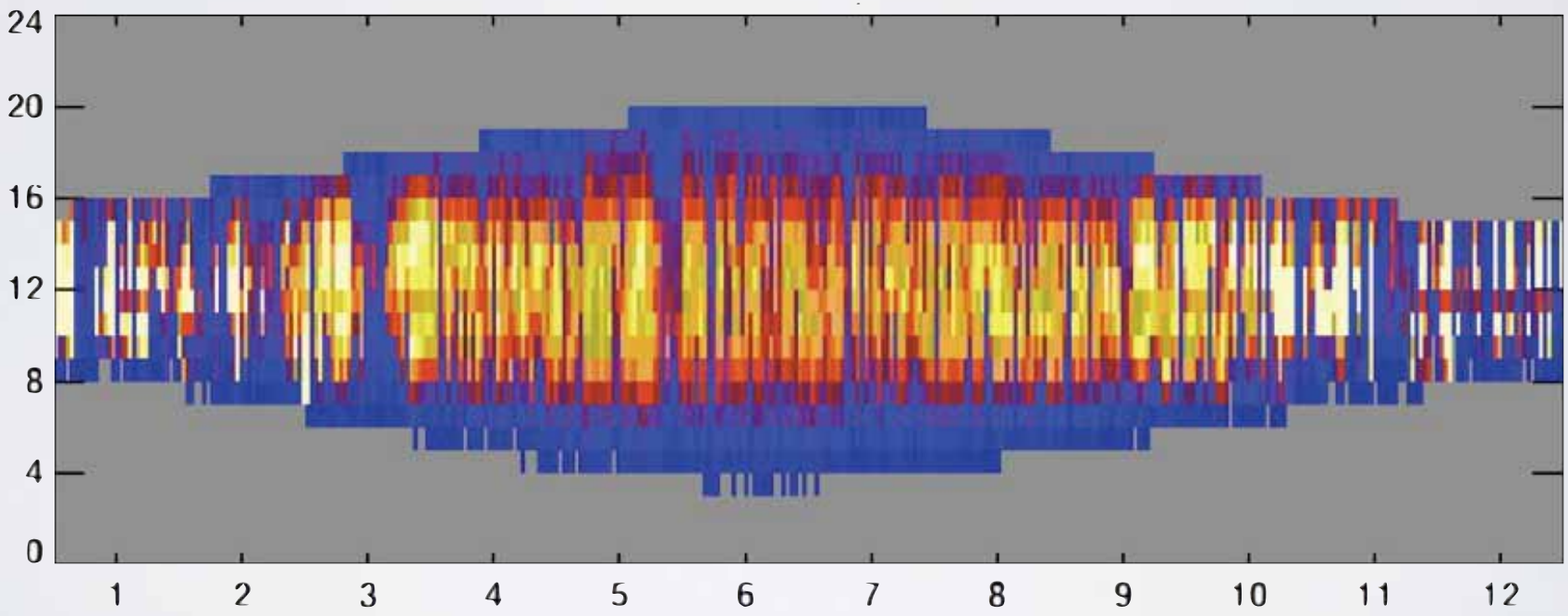
- Illuminance on the horizontal plane
- Field of view luminance
- Ceiling-level grid
- Photosensor response

Projects where CBDM has been used:

- Art Students League (New York) daylight injury study.
- Hermitage Museum (St. Petersburg) daylighting design and long-term exposure of art works.
- New York Times HQ Buildings evaluation and calibration of active daylighting systems.
- Performance of Serraglaze light redirecting material.
- Residential study for VELUX.
- Daylighting performance of school buildings.

1 daylight factor value per point

•



~4380 hourly illuminance values per point

CBDM generates lots of data!

Useful Daylight Illuminance

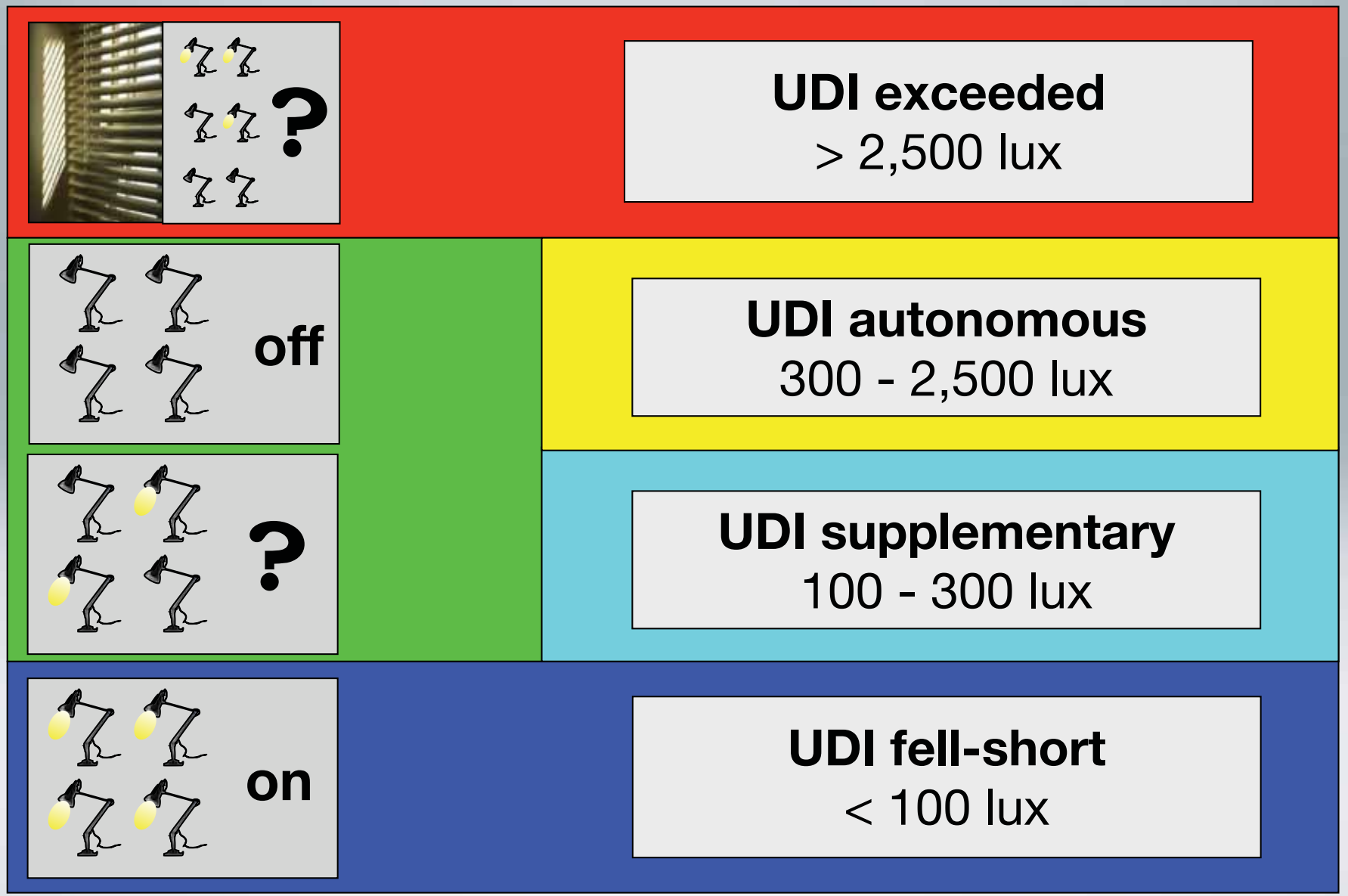
A human-factors based daylight metric

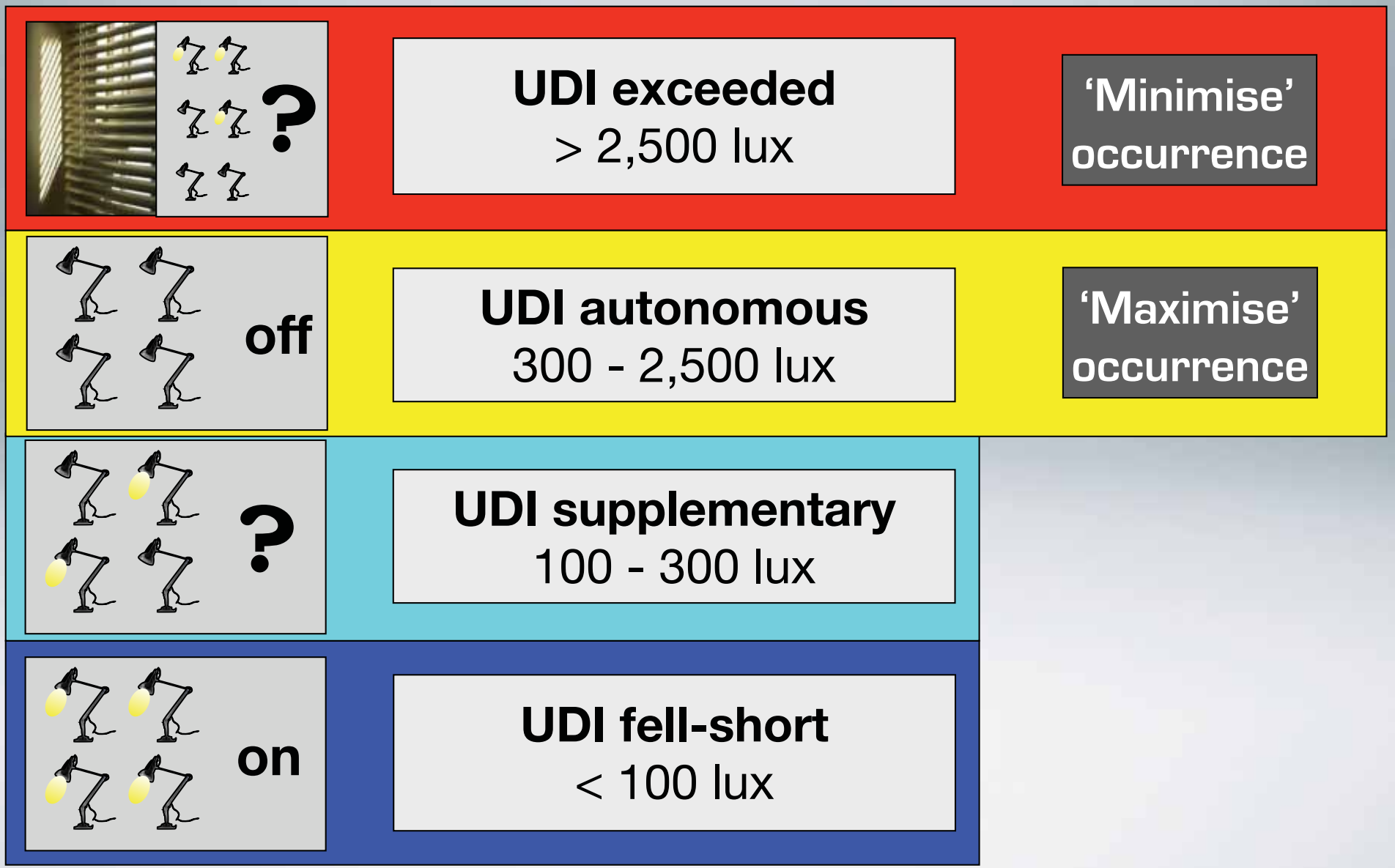
UDI exceeded
> 2,500 lux

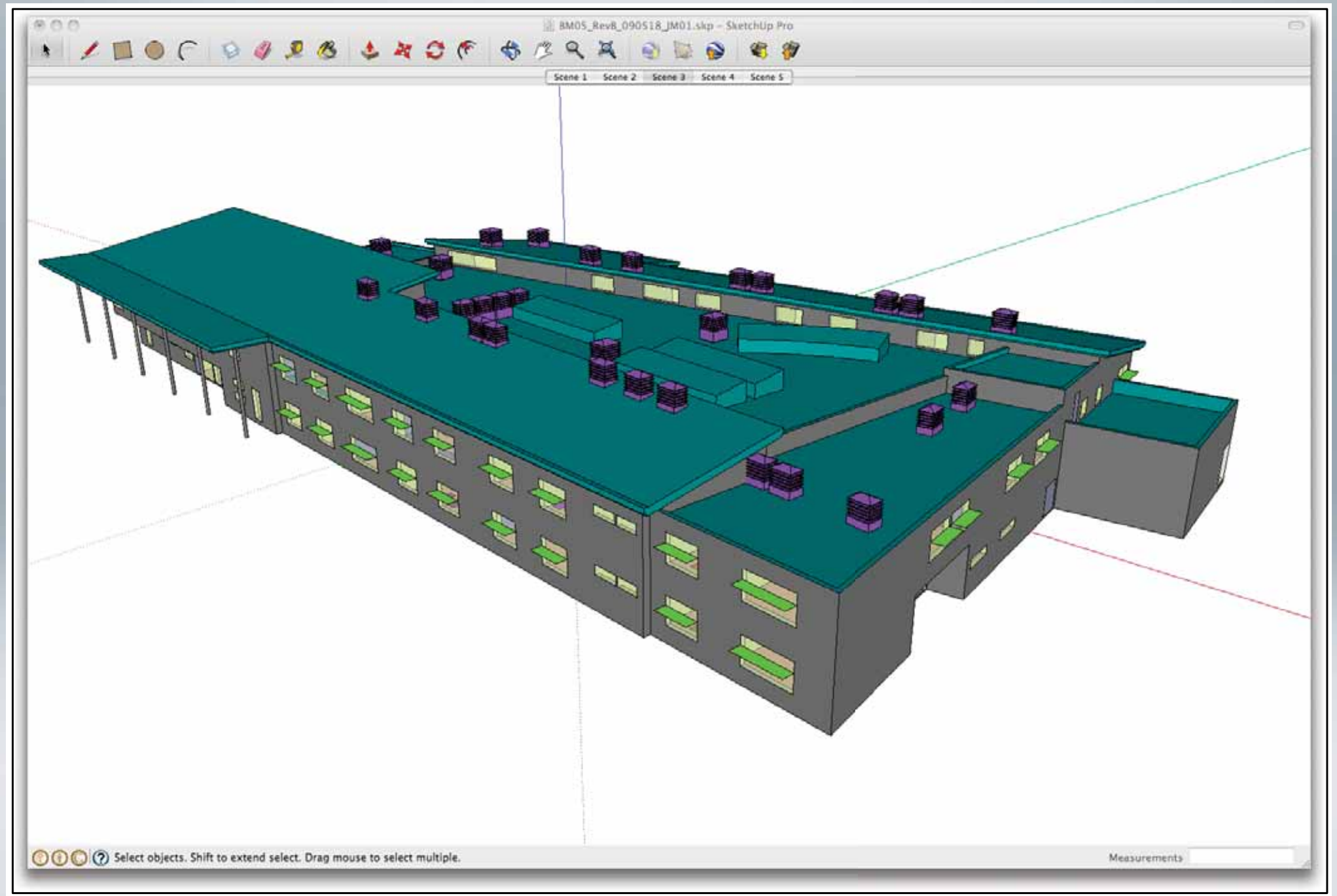
UDI achieved
100 - 2,500 lux

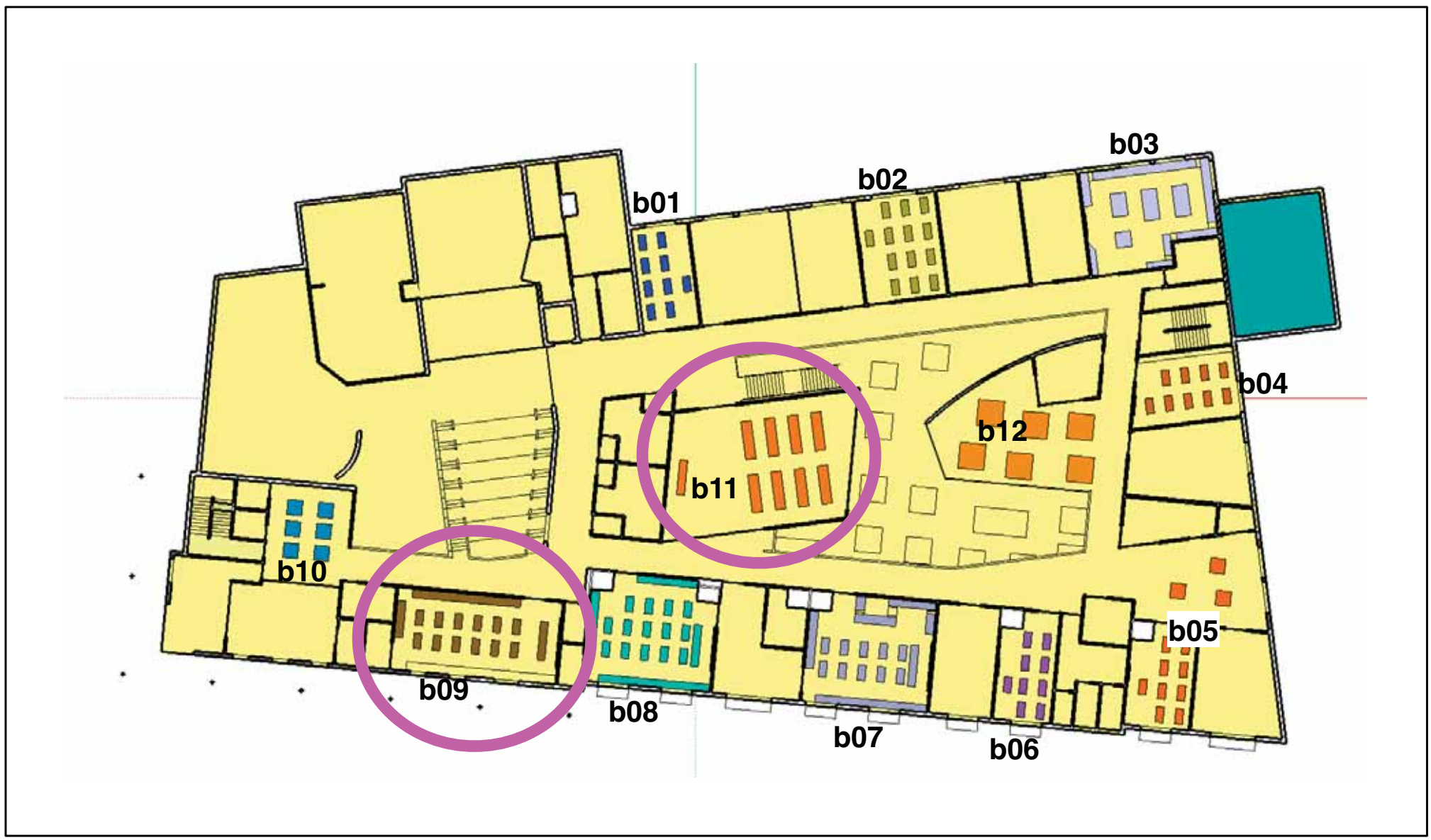
UDI fell-short
< 100 lux

The principle is not new...

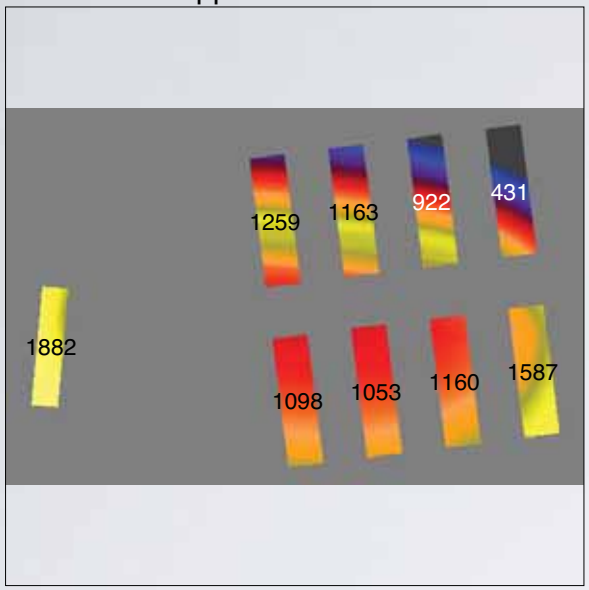

?
UDI exceeded
> 2,500 lux
off
UDI autonomous
300 - 2,500 lux
?
UDI supplementary
100 - 300 lux
on
UDI fell-short
< 100 lux


?
UDI exceeded
> 2,500 lux
'Minimise' occurrence
off
UDI autonomous
300 - 2,500 lux
'Maximise' occurrence
?
UDI supplementary
100 - 300 lux
on
UDI fell-short
< 100 lux

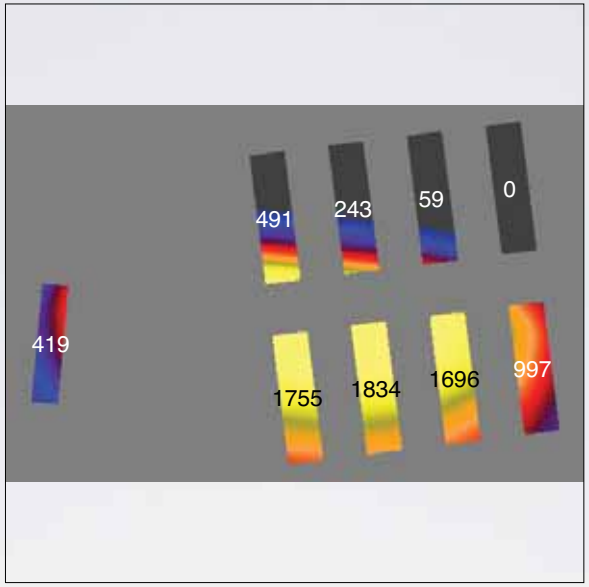

BM05_Rev8_090518_JM01.skp – SketchUp Pro
Scene 1
Scene 2
Scene 3
Scene 4
Scene 5
Select objects. Shift to extend select. Drag mouse to select multiple.
Measurements


b01
b02
b03
b04
b05
b06
b07
b08
b09
b10
b11
b12

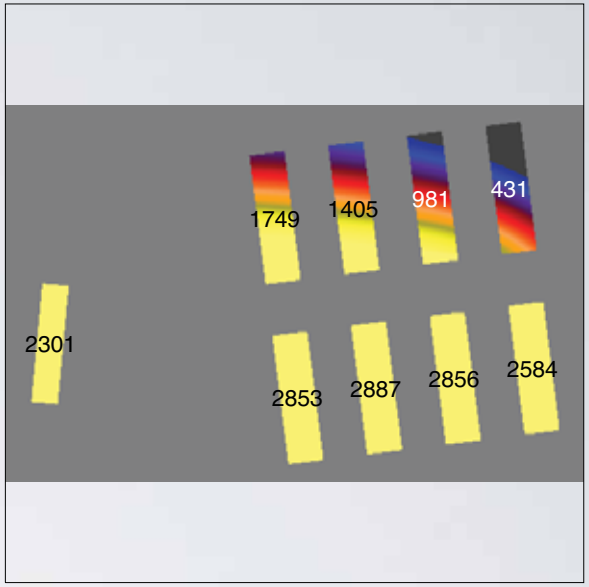
UDI supp: 100 < E < 300 lux



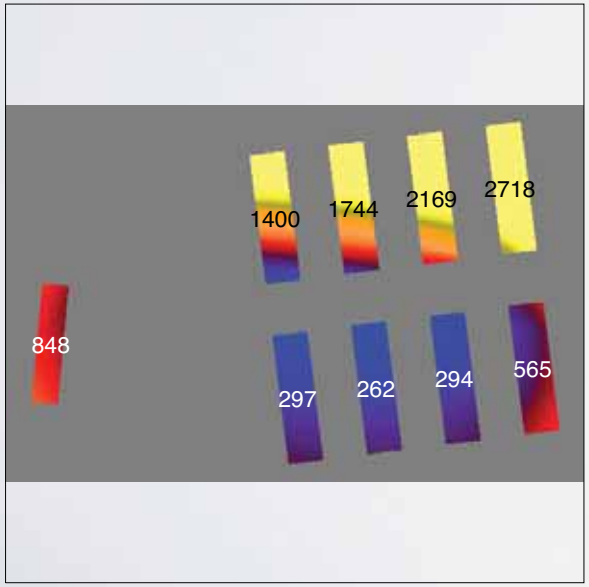
UDI auto: 300 < E < 2000 lux



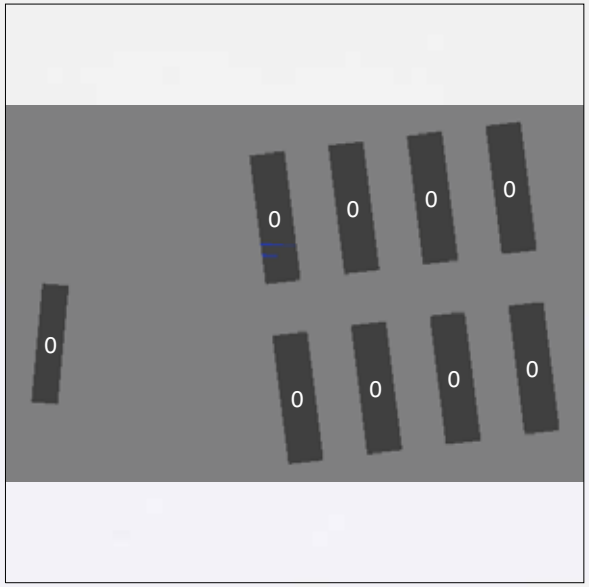
UDI: 100 < E < 2000 lux



UDI fell-short: E < 100 lux

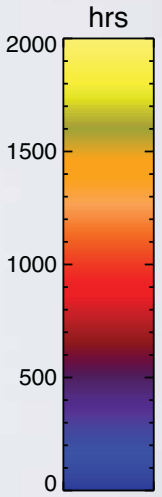


UDI exceeded: E > 2000 lux



UDI metrics

mod1/wpb11
wpb11
Hours:08-17



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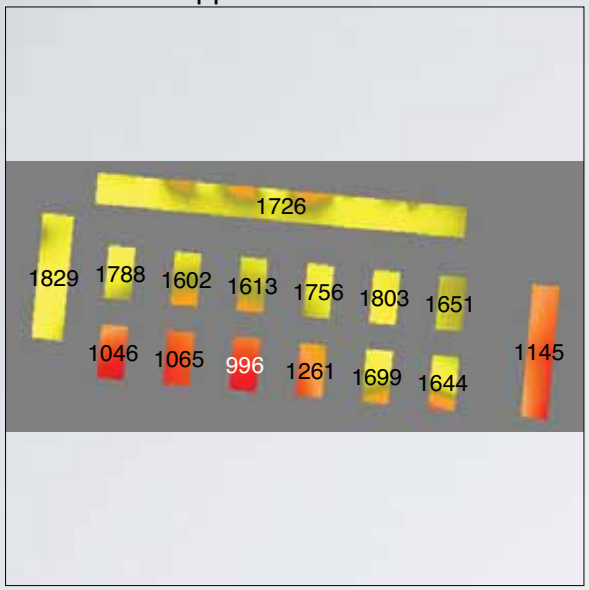
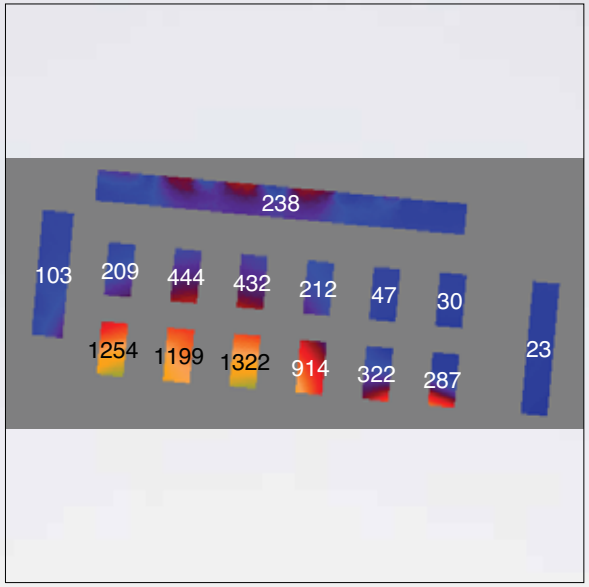
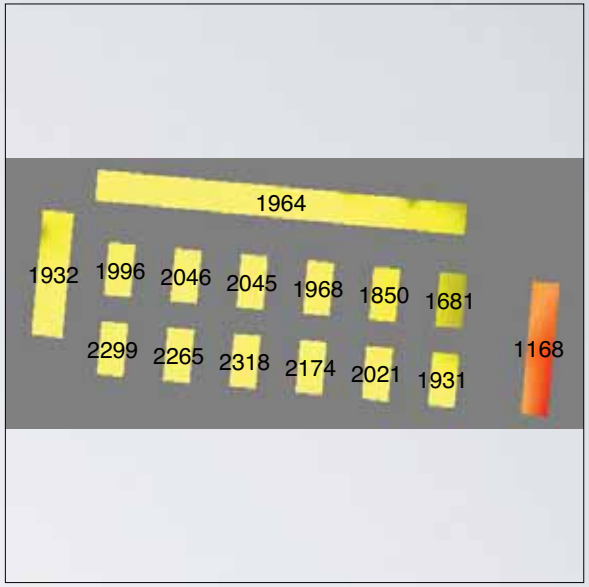
UDI supp: 100 < E < 300 lux



UDI auto: 300 < E < 2000 lux

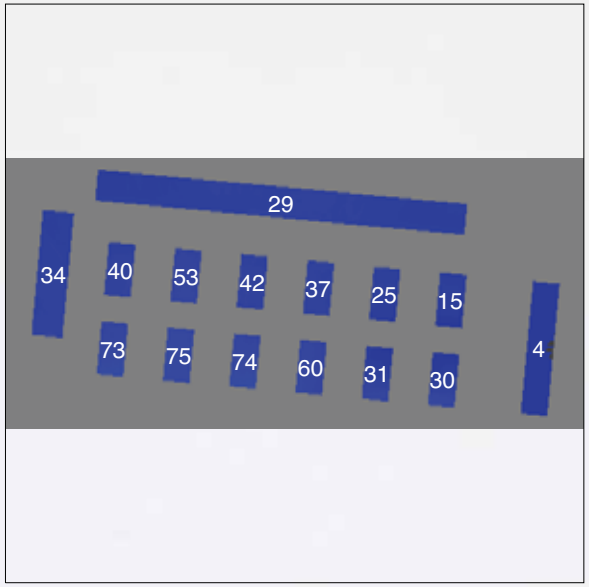


UDI: 100 < E < 2000 lux



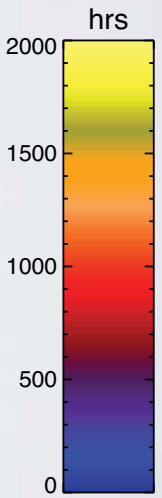
UDI fell-short: E < 100 lux

UDI exceeded: E > 2000 lux



UDI metrics

mod1/wpb09
wpb09
Hours:08-17



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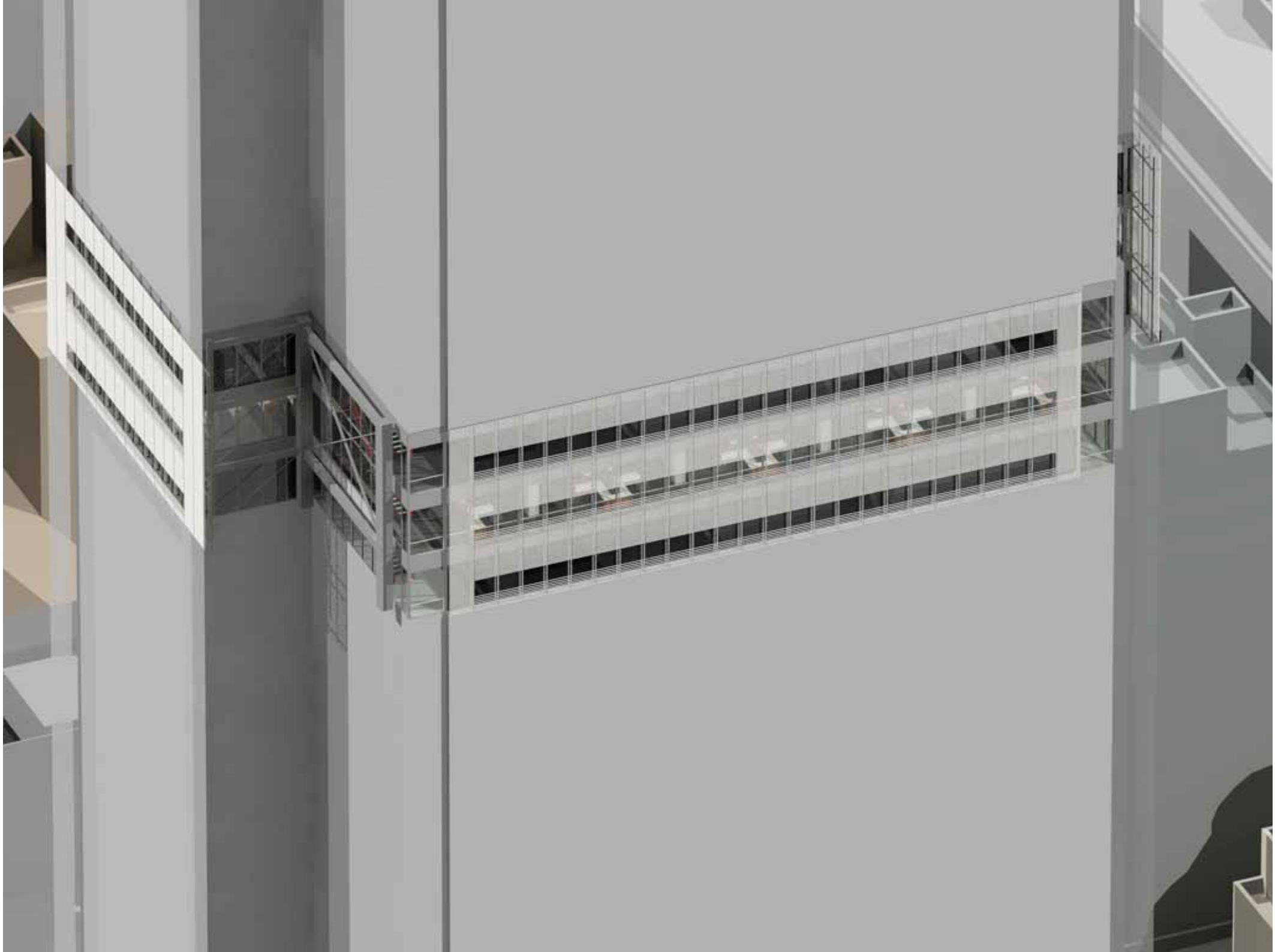
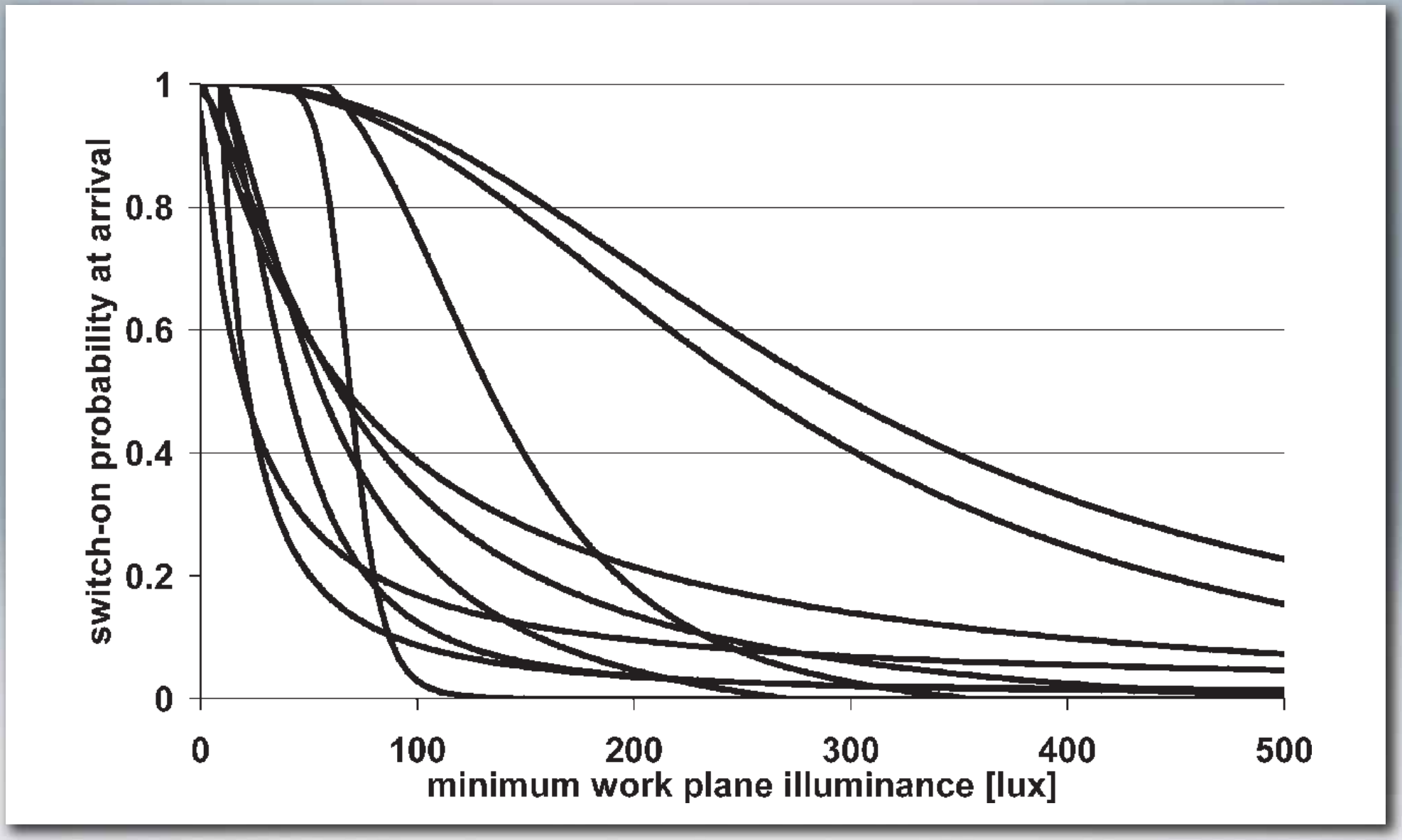
New York Times HQ Building

To create a competitive marketplace for daylighting systems and to address owner concerns about risk

- A full-scale mockup to evaluate commercially-available daylighting products.
- Simulation used to quantify window luminance and illuminance frequencies resulting from various control algorithms.
- Develop and use commissioning tools and procedures to insure that the automated daylighting control systems operate as intended prior to occupancy.



Actual building performance often differs from what was predicted



C. F. Reinhart and K. Voss. Monitoring manual control of electric lighting and blinds. *Lighting Research and Technology*, 35(3):243–258, 2003.

Similar uncertainties exist in models of user behaviour for:

- Lowering of blinds / shades.
- Raising of blinds / shades.
- Switching-off of lights.

Models tend to be based on measurements taken in small, side-lit office spaces. Ensemble behaviour in large open-plan spaces is even more uncertain.

Should a daylight performance metric be predicted for:

- The unoccupied building, i.e. the fixed or static architectural form?
- The building with occupants actively (or not) operating the shading devices? Special case of a building with a fully automatic shading system, e.g. New York Times.

Should the metric account also for the use of electric lighting?

Arguments against including building occupants:

- There is no consensus regarding occupant's use of shading devices (or lights), i.e. no single model.
- It's not certain that any one model would be suitable for the full range of devices and scenarios, e.g. side-lit closed office, open-plan, daylight from multiple directions, etc.
- Whatever the model, the parameterisation is likely to have some associated uncertainty.

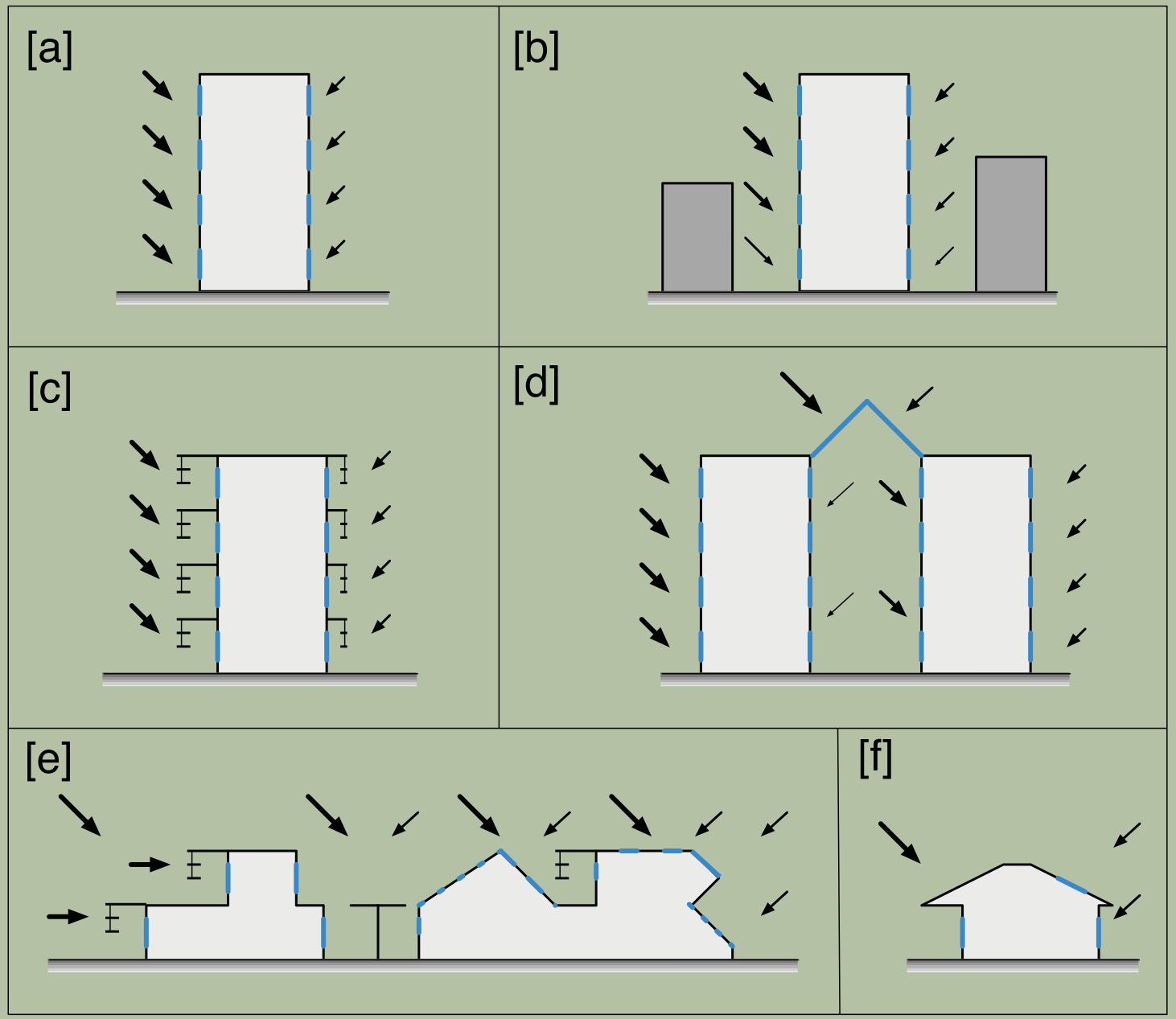
Perhaps the most compelling argument against including occupants is:

- The predicted daylighting performance (i.e. some metric) may well turn out to be largely dependant on the model and parametrisation used for the shading devices.

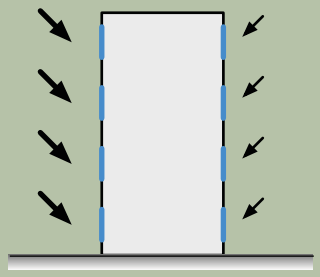
Thus, there is the very real danger of overlooking the potential for the **fixed** architectural form to temper the daylit luminous environment.

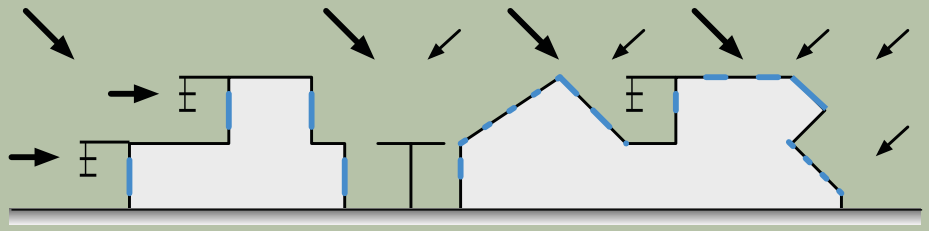
This potential varies according to building type.

The ‘Well-tempered’ Daylit Environment



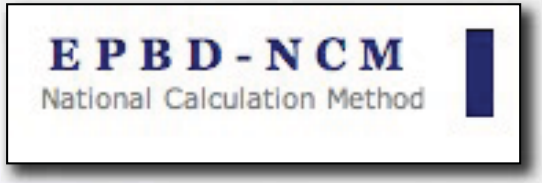
Daylighting evaluation





Less reliable?

More reliable?



Rating systems are now a key driver of building design

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- VELUX Corporation, Denmark.
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“Climate-Based Daylight Modelling”