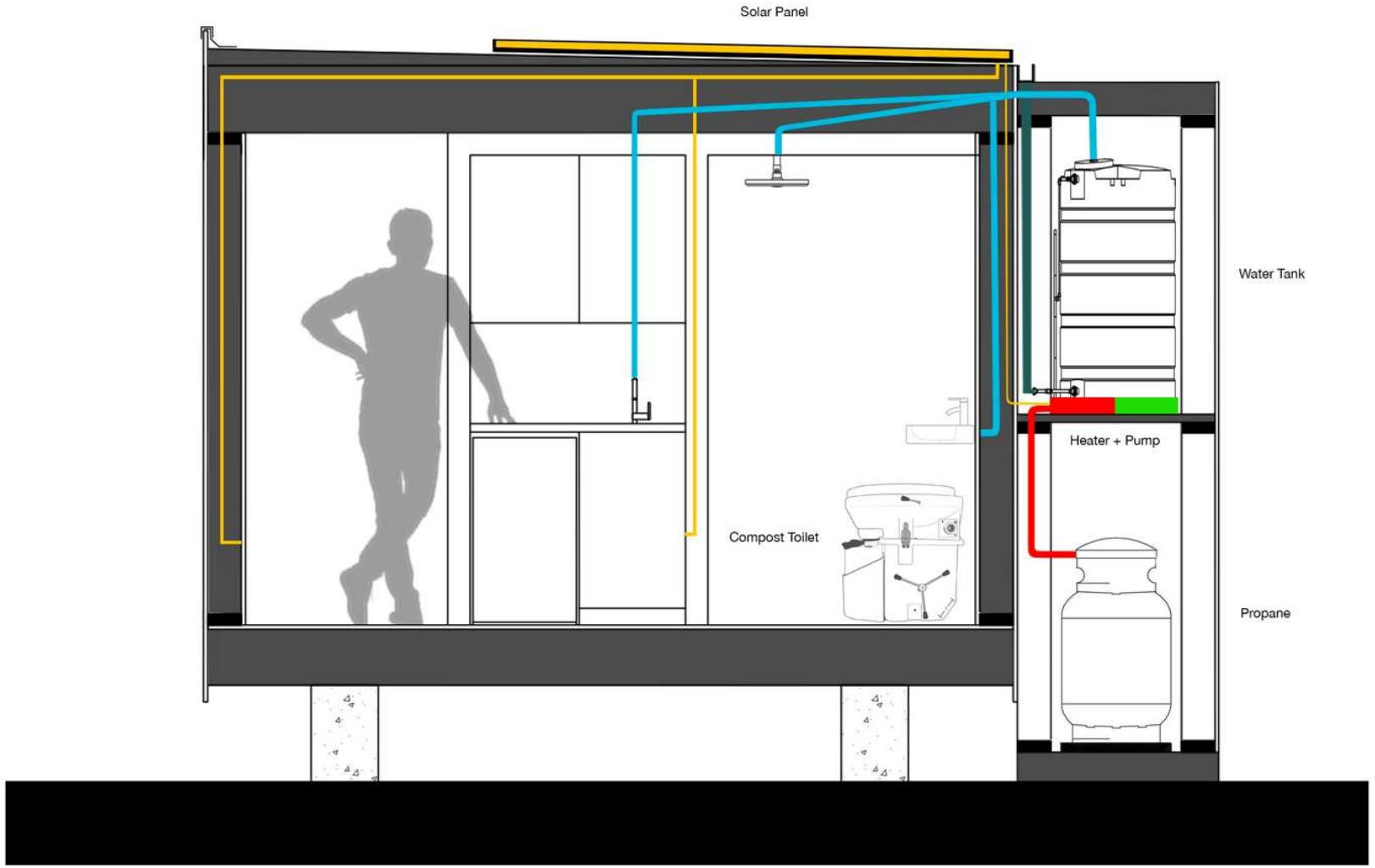
Lecture 1 –
Principles of bioclimatic construction

Magistère de Physique Fondamentale
Université Paris-Saclay
2019-2020

Edifice, Marc Thorpe Design, 2019



Edifice, Marc Thorpe Design, 2019

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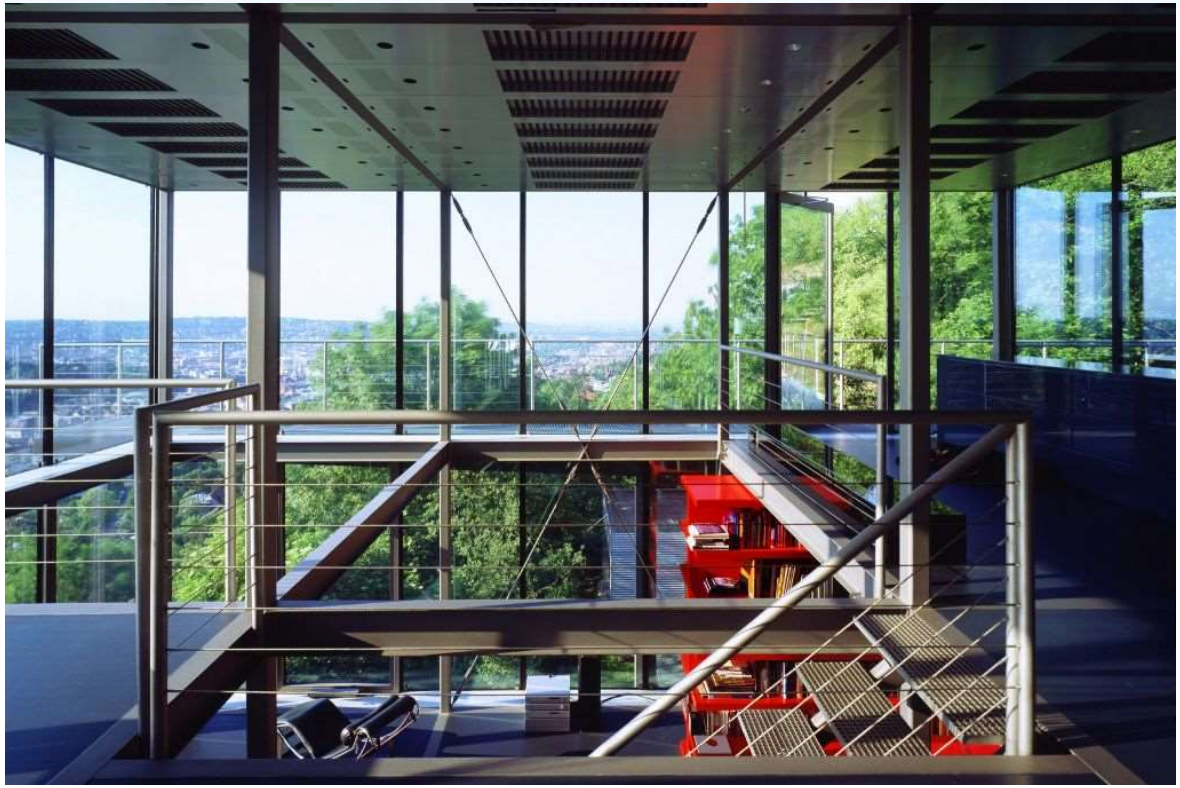
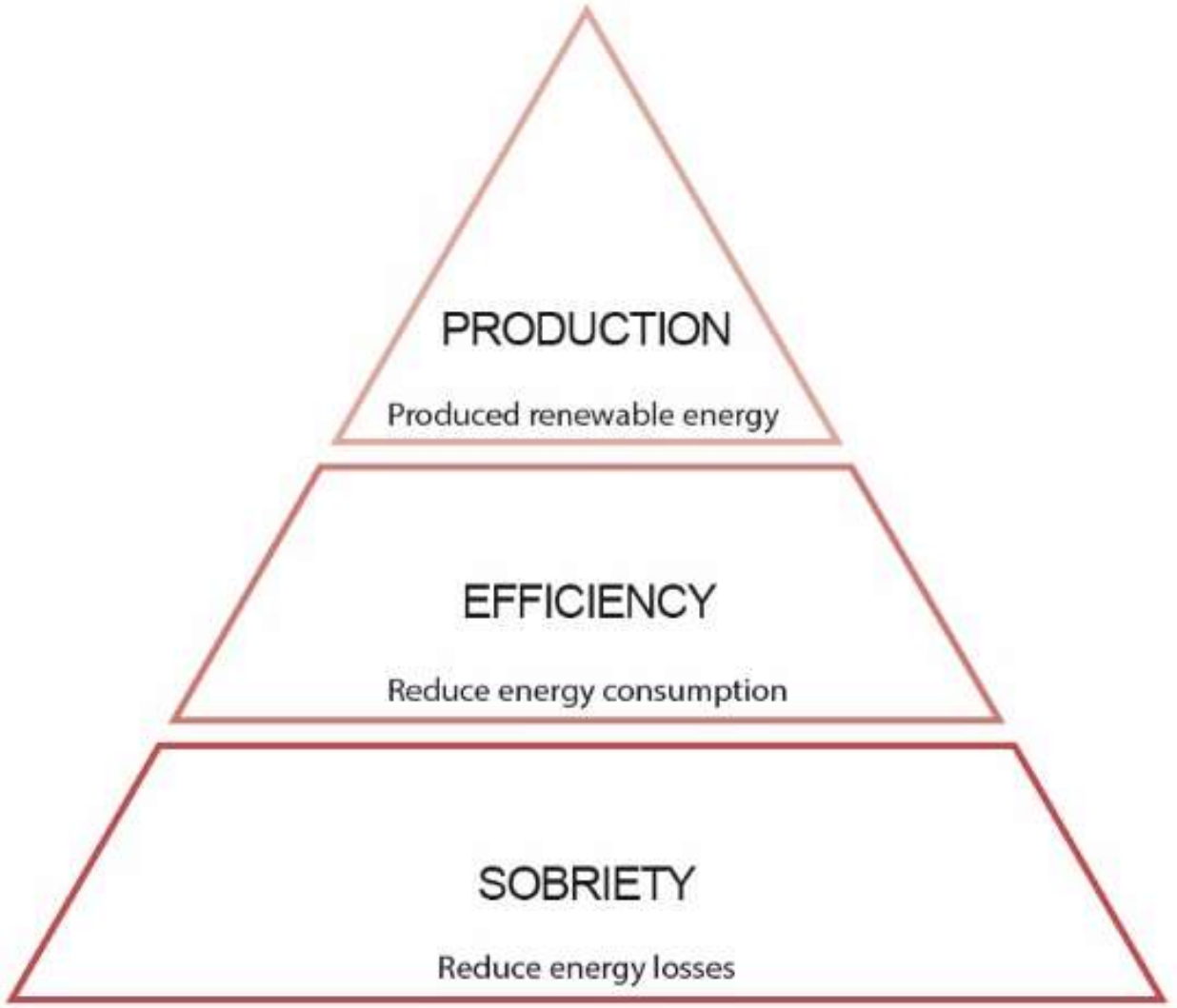


"This four-storey building is completely recyclable, produces no emissions and is self-sufficient in terms of heating energy requirement. The completely glazed building has high quality triple glazing panels featuring a k-value of 0.4. Its design is modular.
Because of its assembly by means of mortice-and-tenon joints and bolted joints, it cannot only be assembled and dismantled easily but is also completely recyclable. The electrical energy required for the energy concept and control engineering is produced by solar cells."

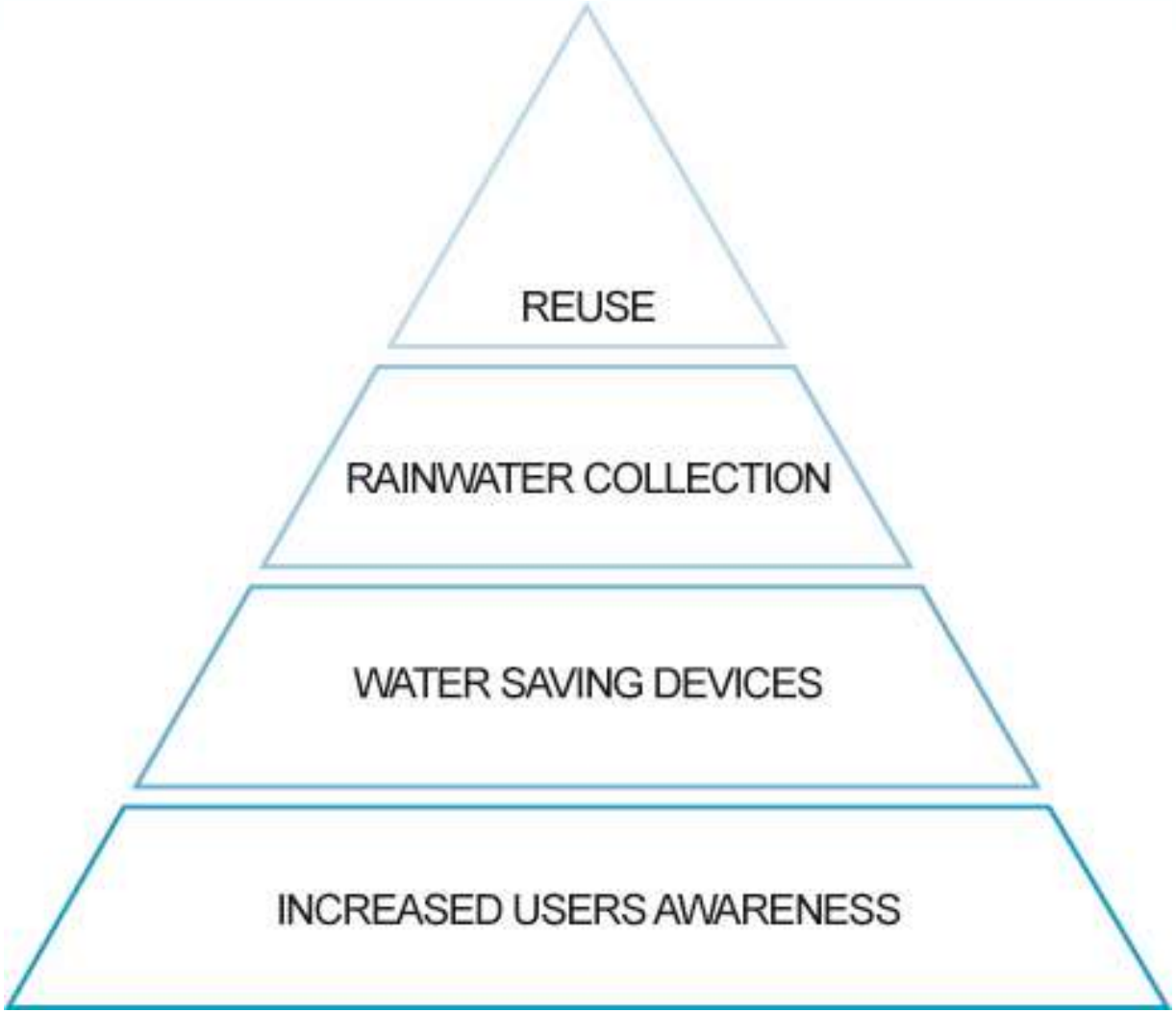
1. DEFINITION OF BIOCLIMATIC/SUSTAINABLE CONSTRUCTION

1. Energy
2. Water
3. Waste

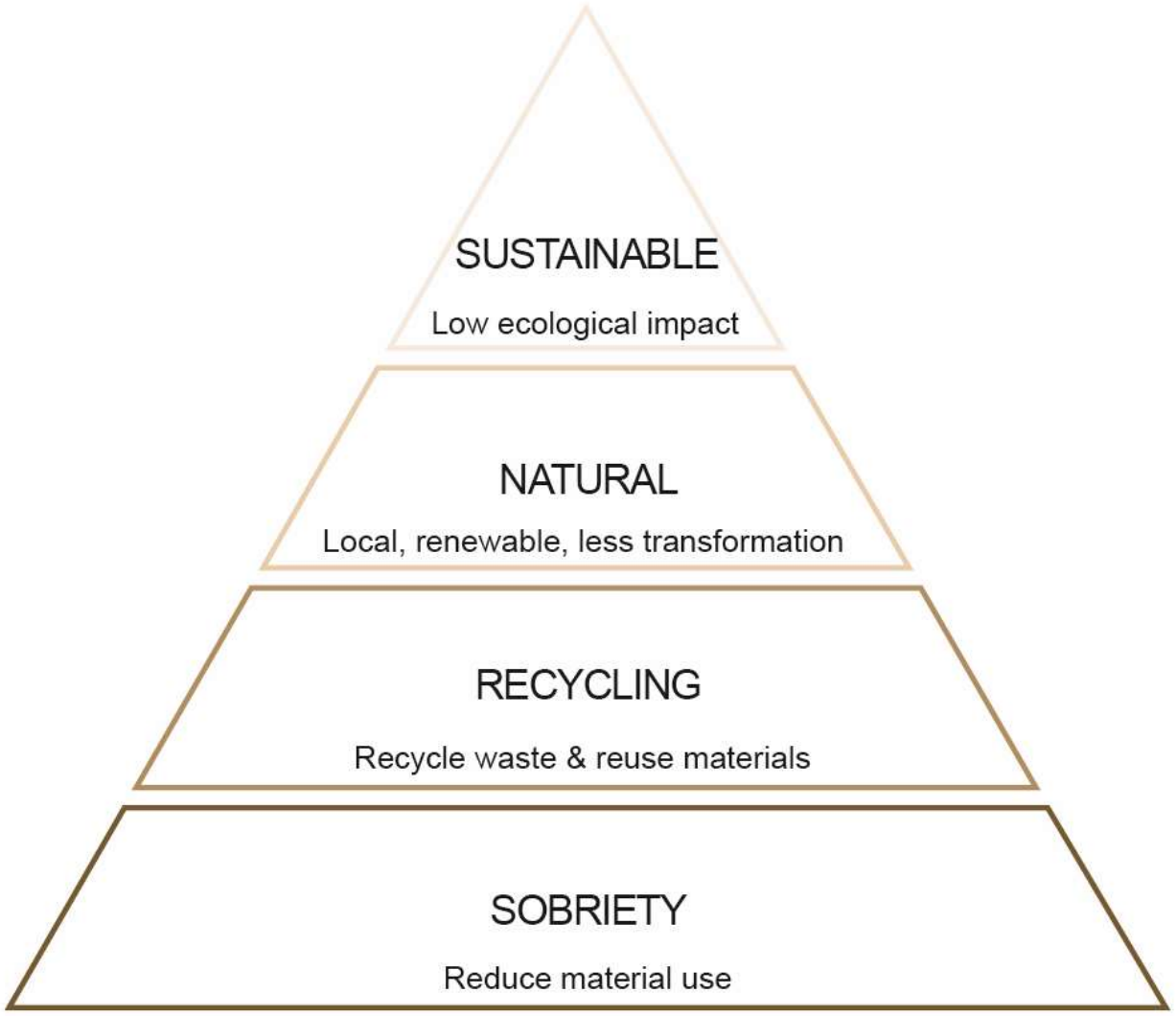
1. Energy


PRODUCTION
Produced renewable energy
EFFICIENCY
Reduce energy consumption
SOBRIETY
Reduce energy losses

2. Water


REUSE
RAINWATER COLLECTION
WATER SAVING DEVICES
INCREASED USERS AWARENESS

3. Waste


SUSTAINABLE
Low ecological impact
NATURAL
Local, renewable, less transformation
RECYCLING
Recycle waste & reuse materials
SOBRIETY
Reduce material use

2. BUILDING LOCATION

1. Climate
2. Built environment

2.1. Establishing the climate

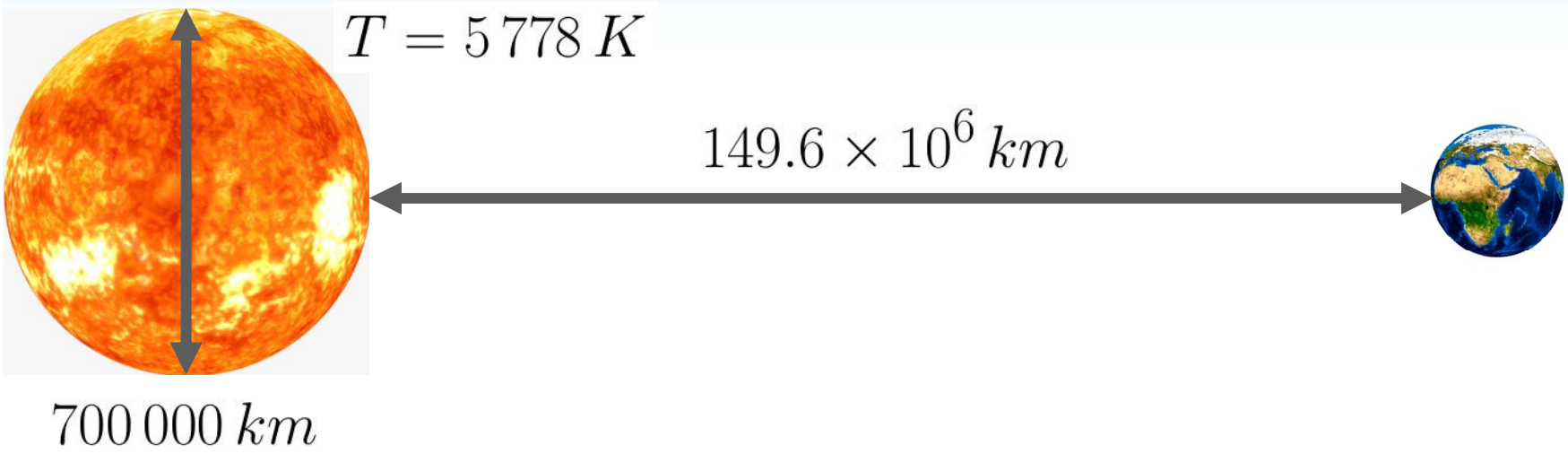
© Turbosquid

Montezuma Castle – Arizona (US)
© Working on Wanderlust

Okinawa Institute for Science & Technology
© Kosodate

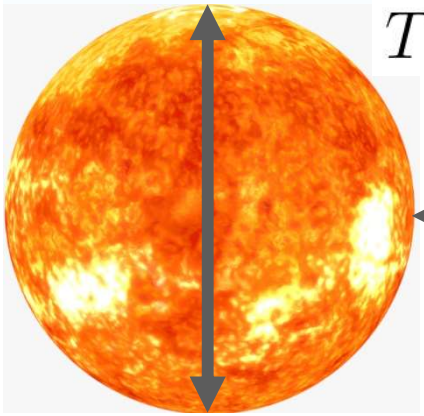
Manhattan
© Max Touhey

2.1.a. Solar irradiation



Total Solar Irradiation @ Earth's surface:

2.1.a. Solar irradiation



$T = 5\,778\,K$

$149.6 \times 10^6\,km$

$700\,000\,km$

Total Solar Irradiation @ Earth's surface:

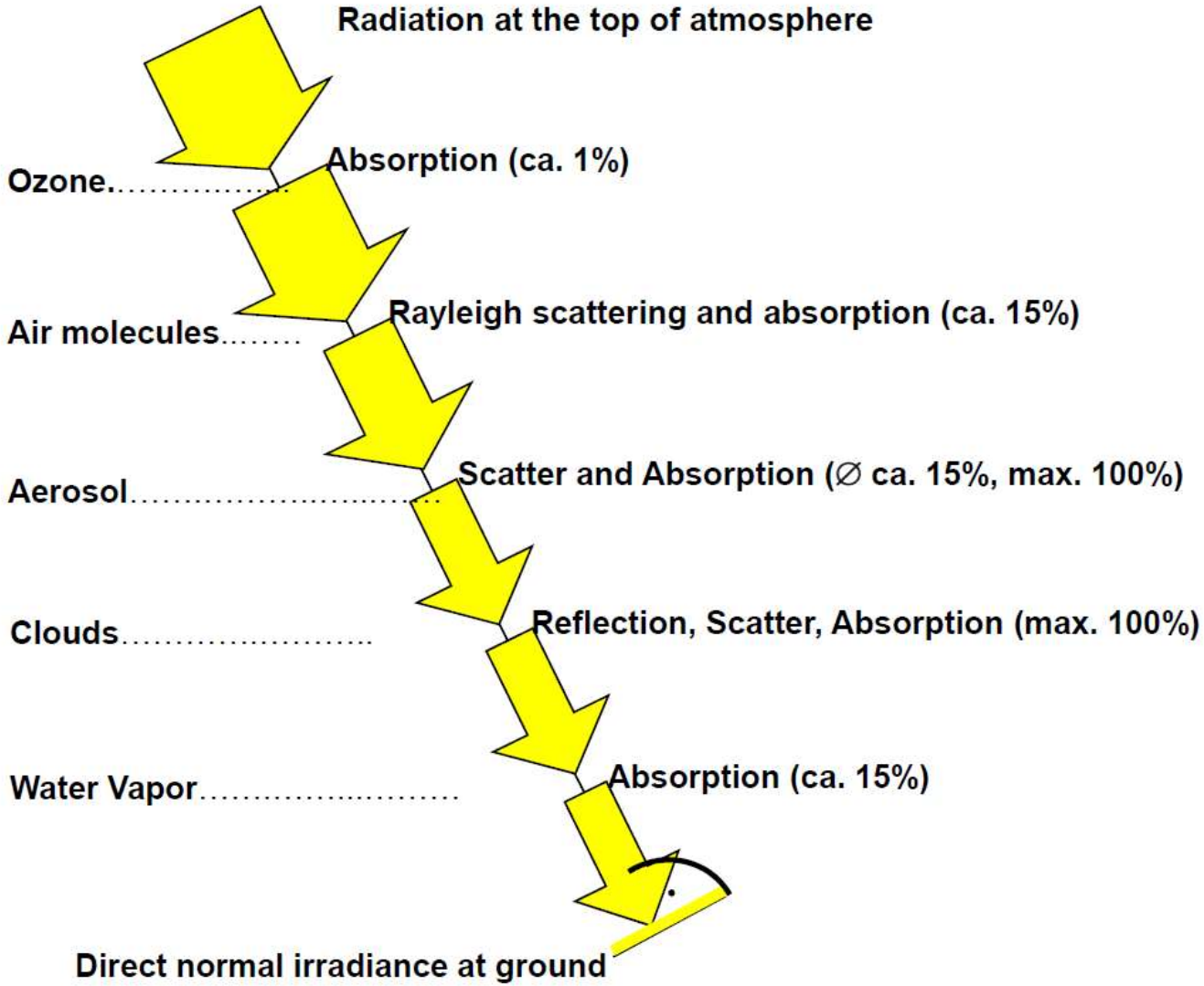
- *Stefan-Boltzman equation for black body radiation (per m² of emiting surface):*

$$P = \sigma T^4 \qquad \sigma = 5.67^{-8}\,W.m^{-2}.K^{-4}$$

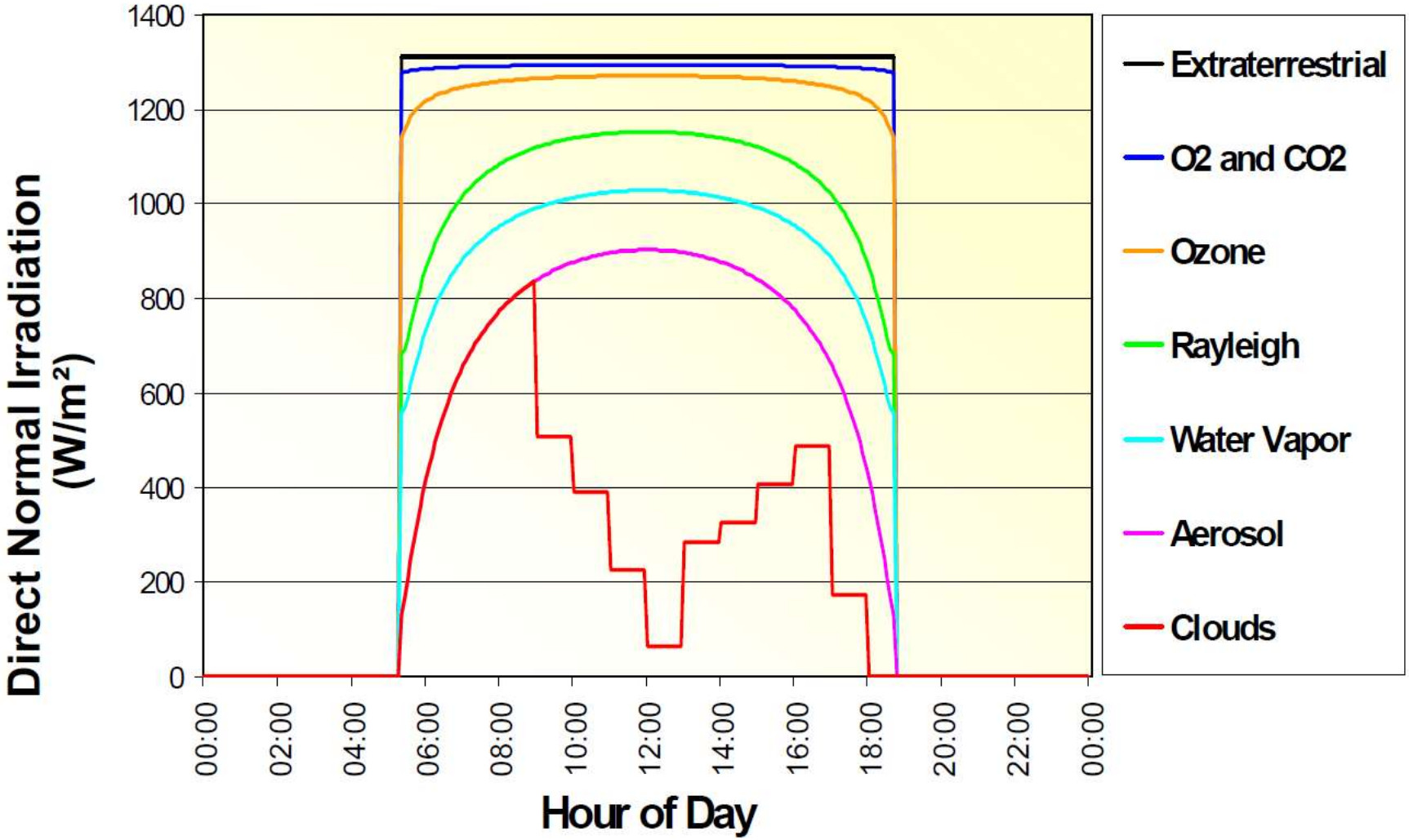
- *Solar constant:*

$$TSI = \frac{5.68 \times 10^{-8} * 5\,778^4\, 4\pi(7 \times 10^8)^2}{4\pi(1.496 \times 10^{11})^2} = 1366\,W/m^2$$

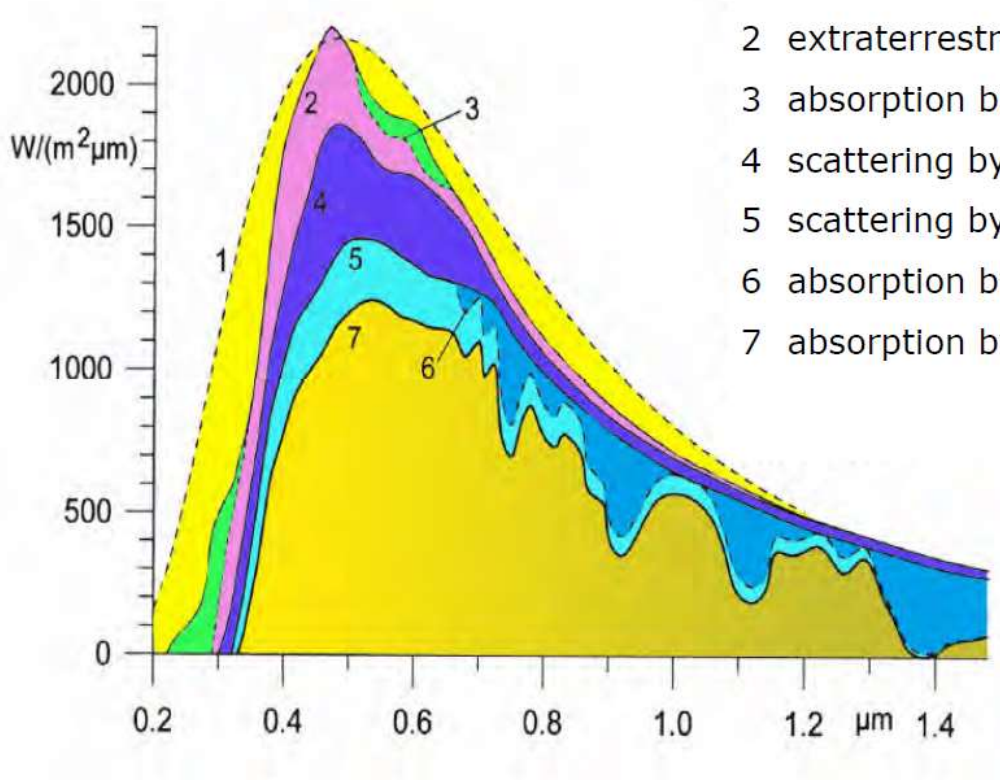
2.1.a. Solar irradiation



2.1.a. Solar irradiation



2.1.a. Solar irradiation

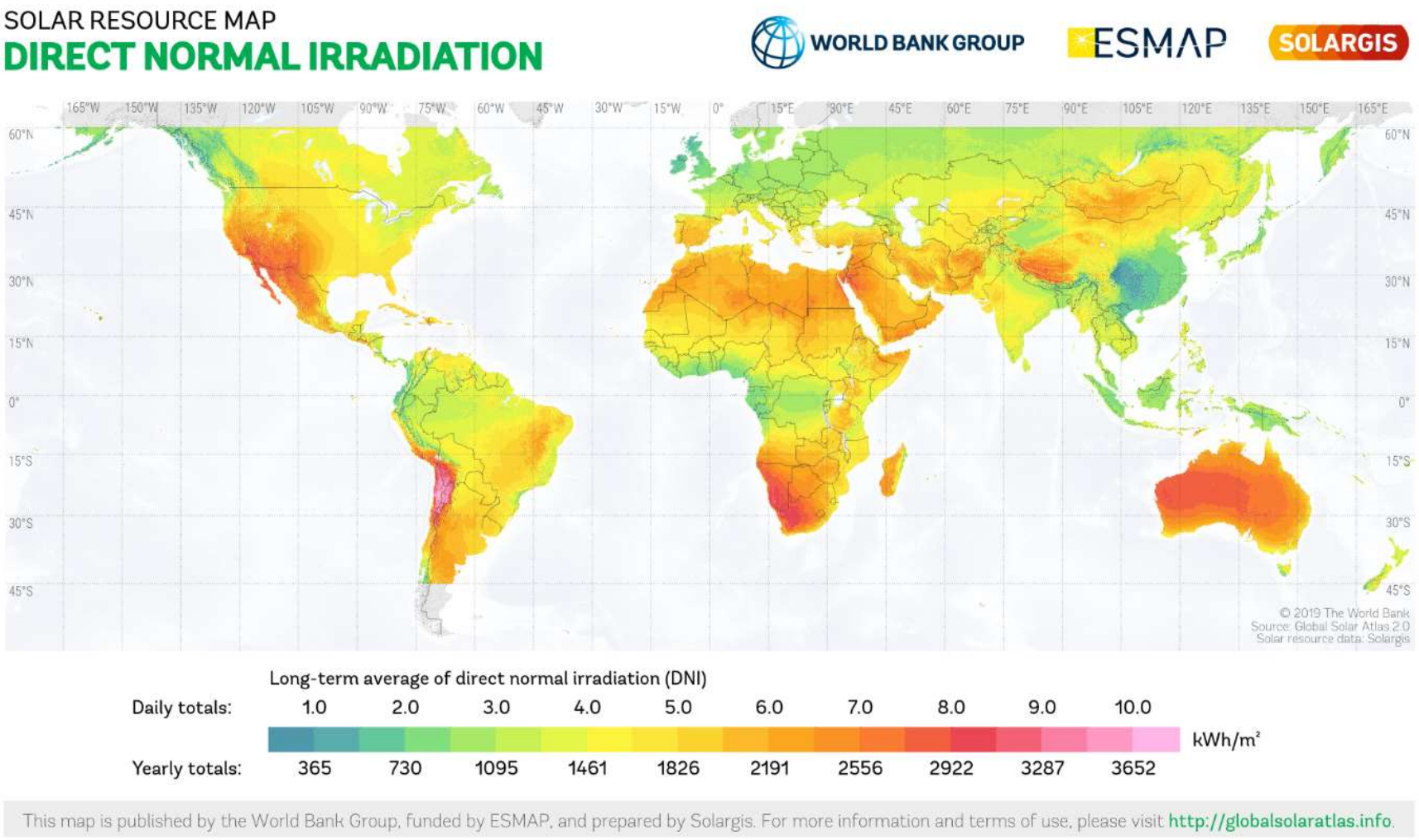


1 Planck curve T=5780 K at mean sun-earth distance
2 extraterrestrial solar spectrum
3 absorption by 0_3
4 scattering by 0_2 und N_2
5 scattering by aerosols
6 absorption by H_2O vapor
7 absorption by aerosols

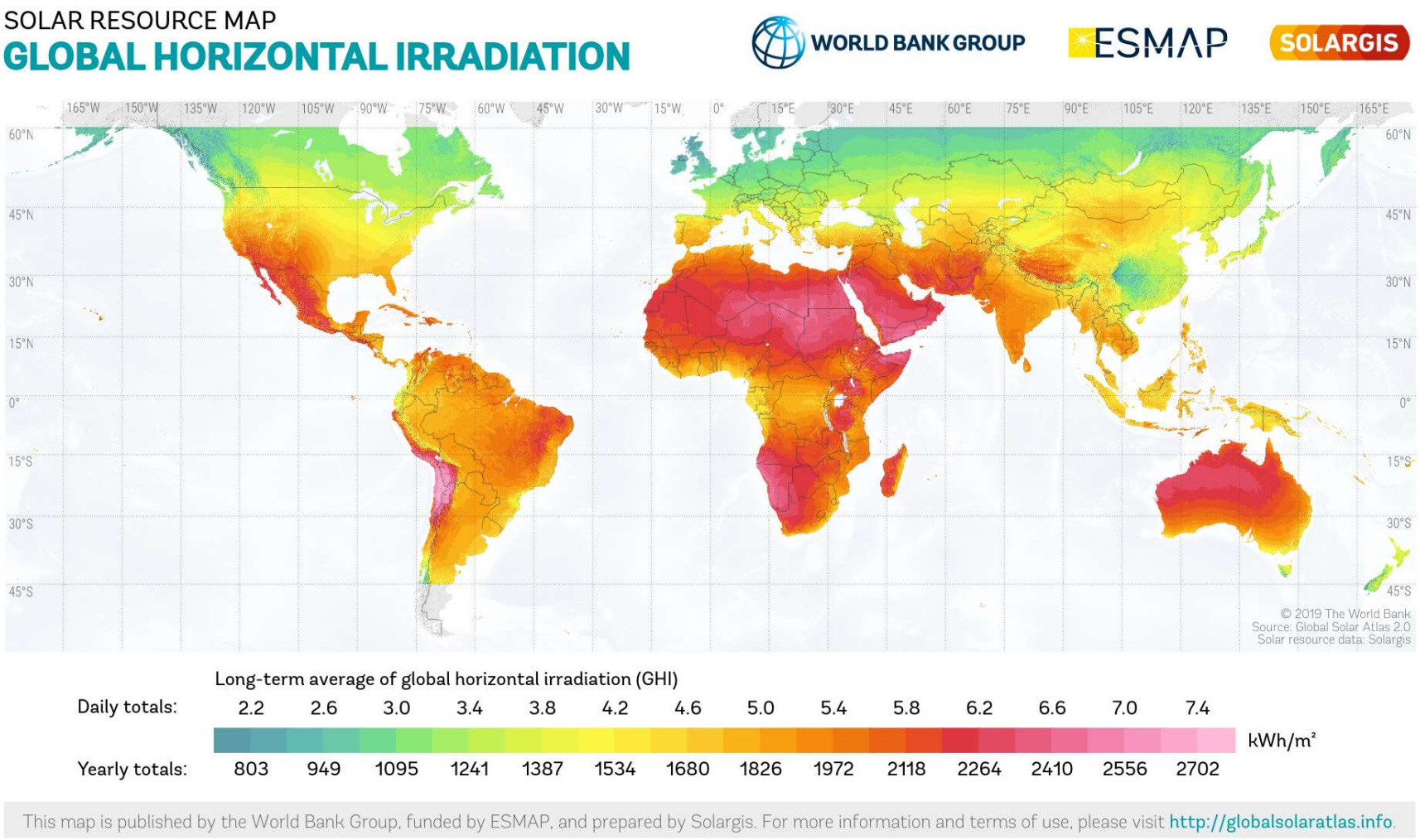
UV radiation:	0.01 - 0.39 µm, ~ 7 %
Visible Spectrum:	0.39 – 0.75 µm, ~ 46 %
Near infrared:	0.75 – 2.5 µm, ~ 47 %

www.volker-quaschning.de/articles/fundamentals1/index.php

2.1.a. Solar irradiation

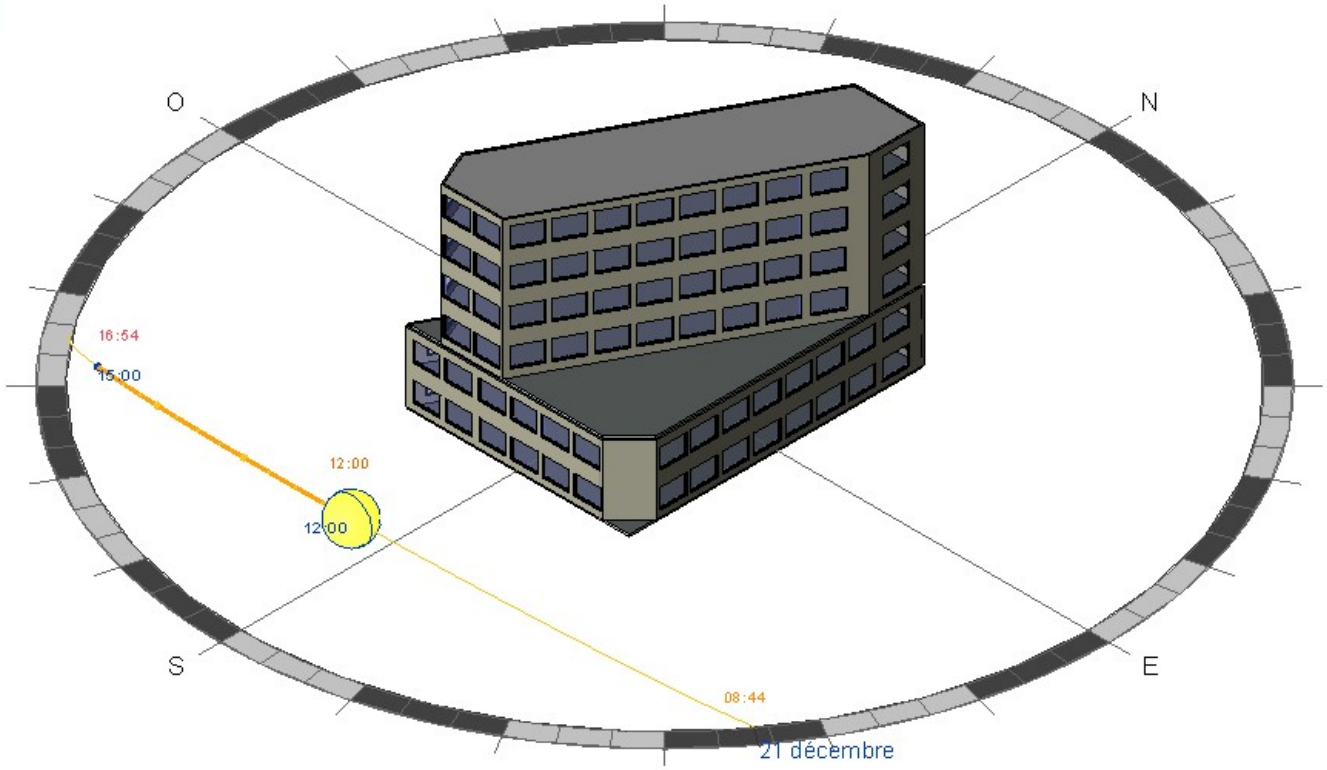


2.1.a. Solar irradiation



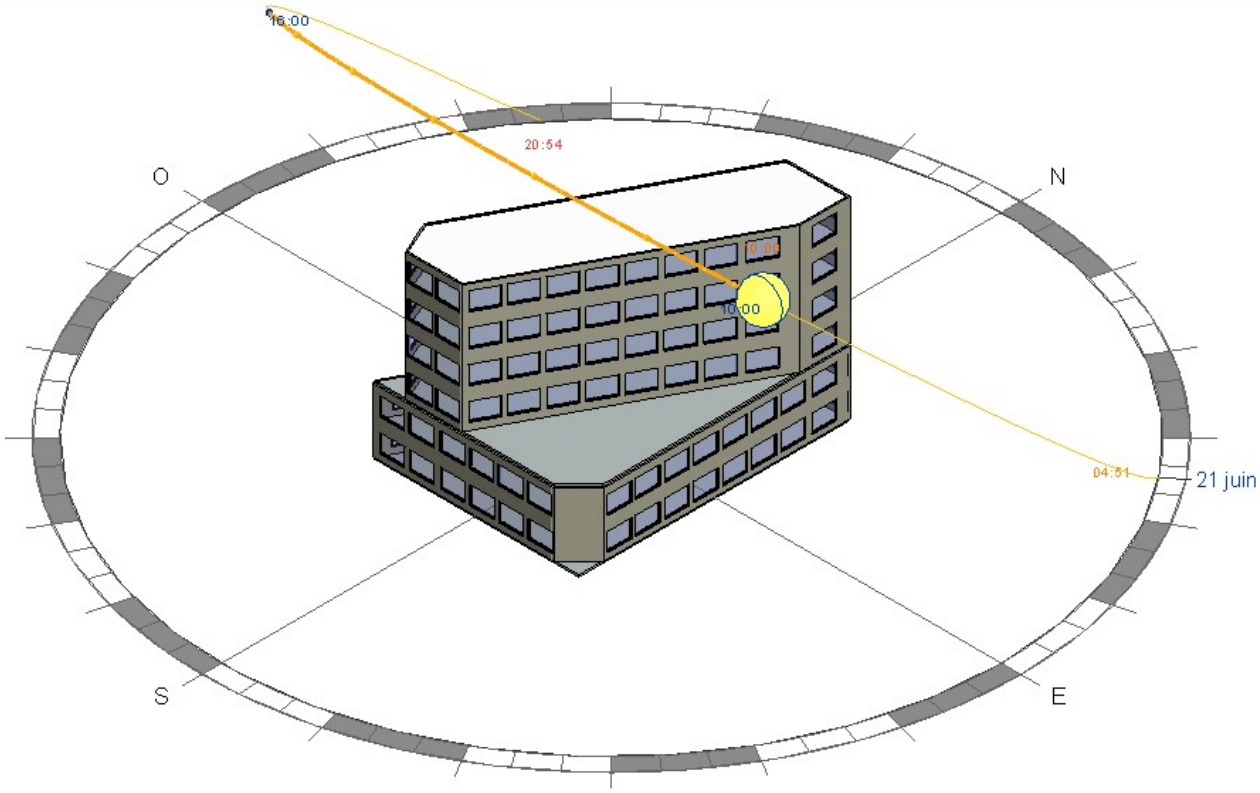
2.1.a. Solar irradiation

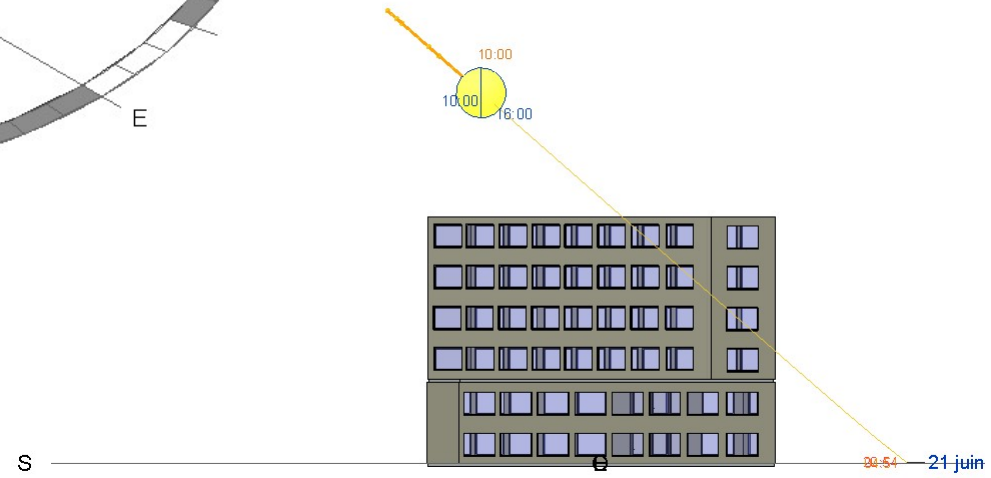
Heliodon
Hbar
Winter Solstice



2.1.a. Solar irradiation

Heliodon
Hbar
Summer Solstice



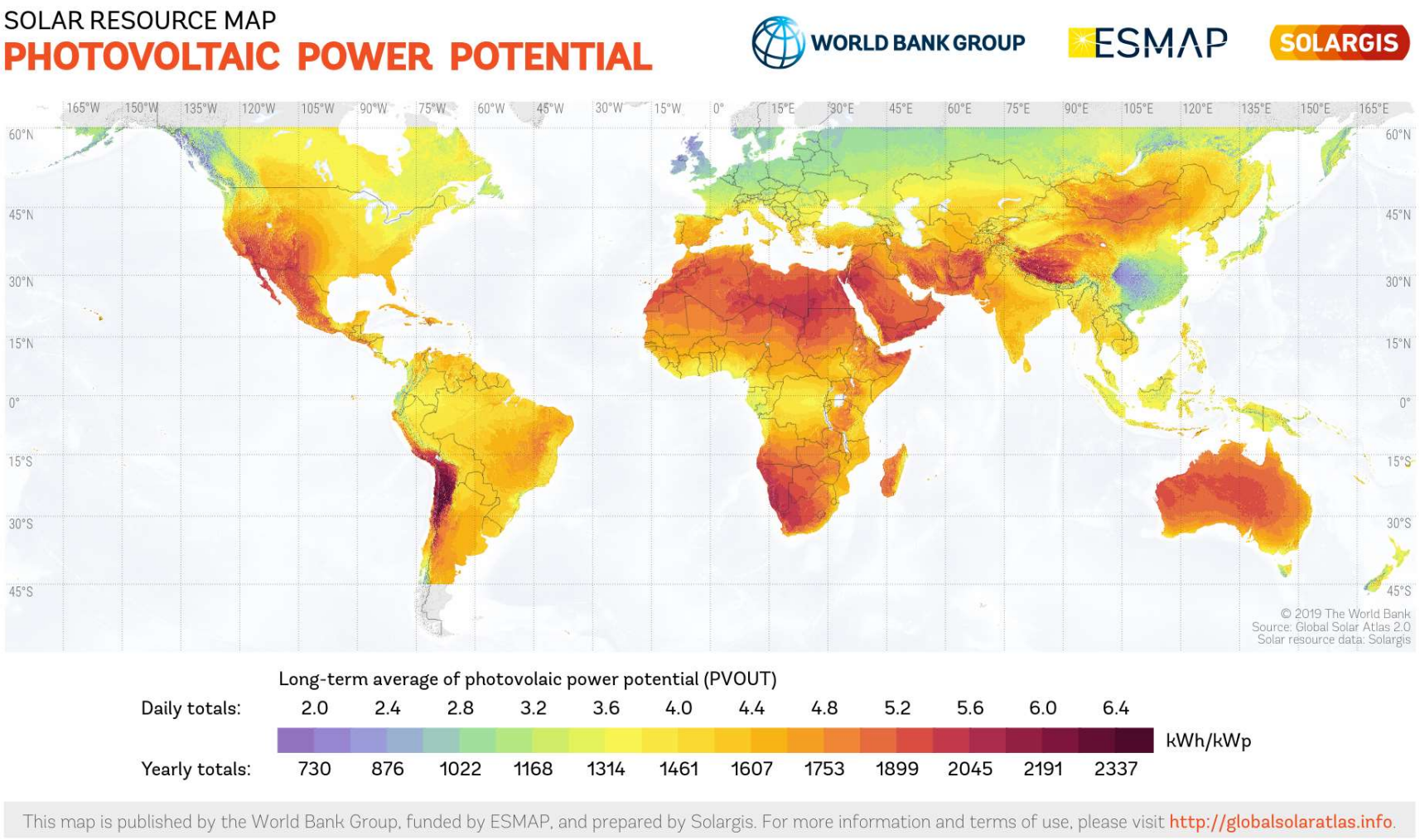


2.1.a. Solar irradiation

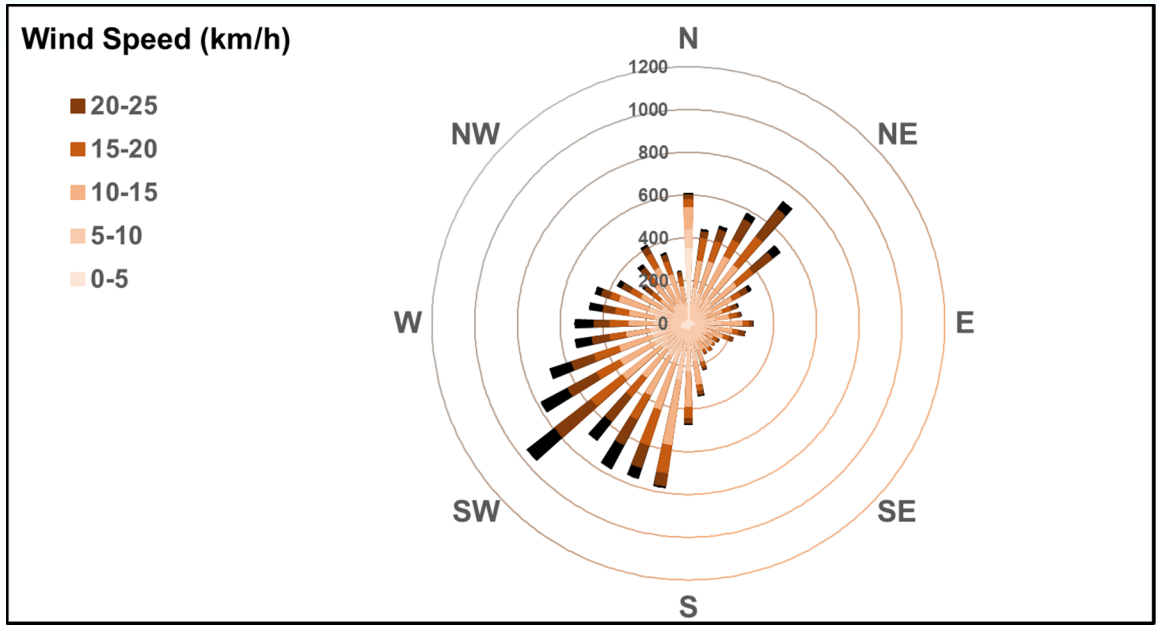
Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1	0	0	0	0	0	0	0	0	0	0	0	0
1 - 2	0	0	0	0	0	0	0	0	0	0	0	0
2 - 3	0	0	0	0	0	0	0	0	0	0	0	0
3 - 4	0	0	0	0	0	0	0	0	0	0	0	0
4 - 5	0	0	0	0	17	59	25	1	0	0	0	0
5 - 6	0	0	0	47	157	183	157	87	7	0	0	0
6 - 7	0	0	31	203	255	261	248	230	168	26	0	0
7 - 8	0	45	192	298	321	322	318	309	290	177	58	0
8 - 9	92	186	265	350	349	369	354	363	342	241	156	94
9 - 10	155	225	295	366	361	388	375	382	357	262	189	162
10 - 11	187	249	309	369	368	381	373	382	362	288	210	192
11 - 12	204	270	341	372	367	381	372	385	366	313	216	214
12 - 13	205	273	352	368	364	373	368	381	357	286	209	200
13 - 14	192	241	313	347	324	357	343	353	332	257	190	169
14 - 15	165	217	282	315	311	345	332	329	302	230	166	131
15 - 16	76	180	255	286	285	316	317	315	281	187	72	41
16 - 17	0	54	195	243	250	283	279	275	222	32	0	0
17 - 18	0	0	31	146	201	243	235	202	42	0	0	0
18 - 19	0	0	0	8	80	158	138	34	0	0	0	0
19 - 20	0	0	0	0	0	18	8	0	0	0	0	0
20 - 21	0	0	0	0	0	0	0	0	0	0	0	0
21 - 22	0	0	0	0	0	0	0	0	0	0	0	0
22 - 23	0	0	0	0	0	0	0	0	0	0	0	0
23 - 24	0	0	0	0	0	0	0	0	0	0	0	0

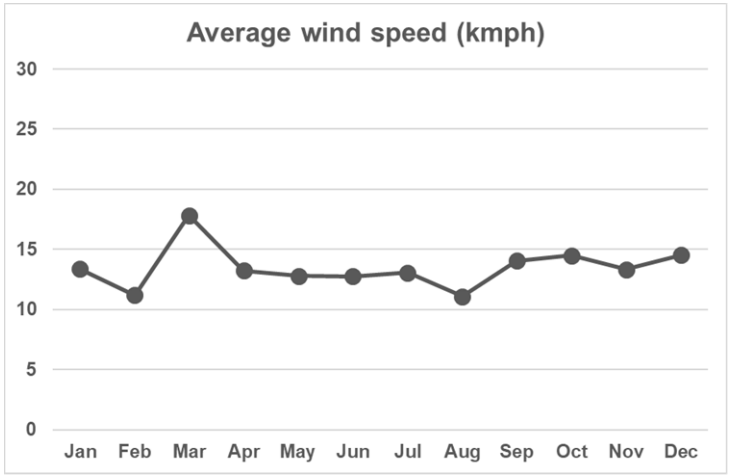
Direct Normal Irradiance (DNI) in Paris

2.1.a. Solar irradiation



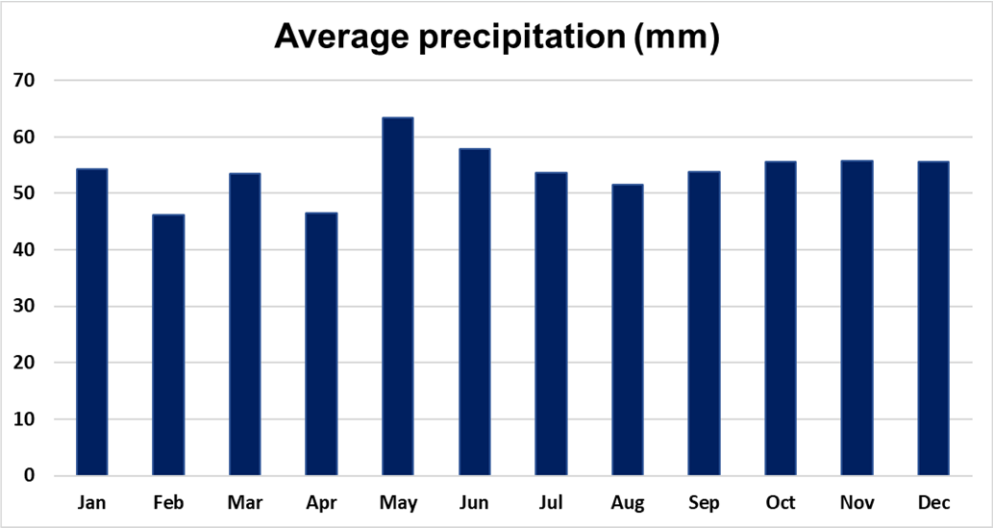
2.1.b. Wind



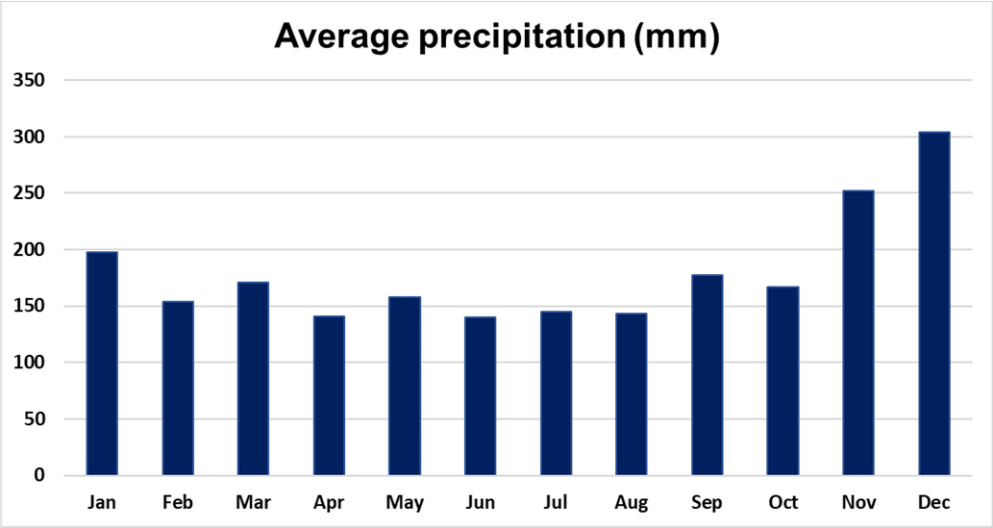


Wind speed & direction in Paris

2.1.c. Precipitation

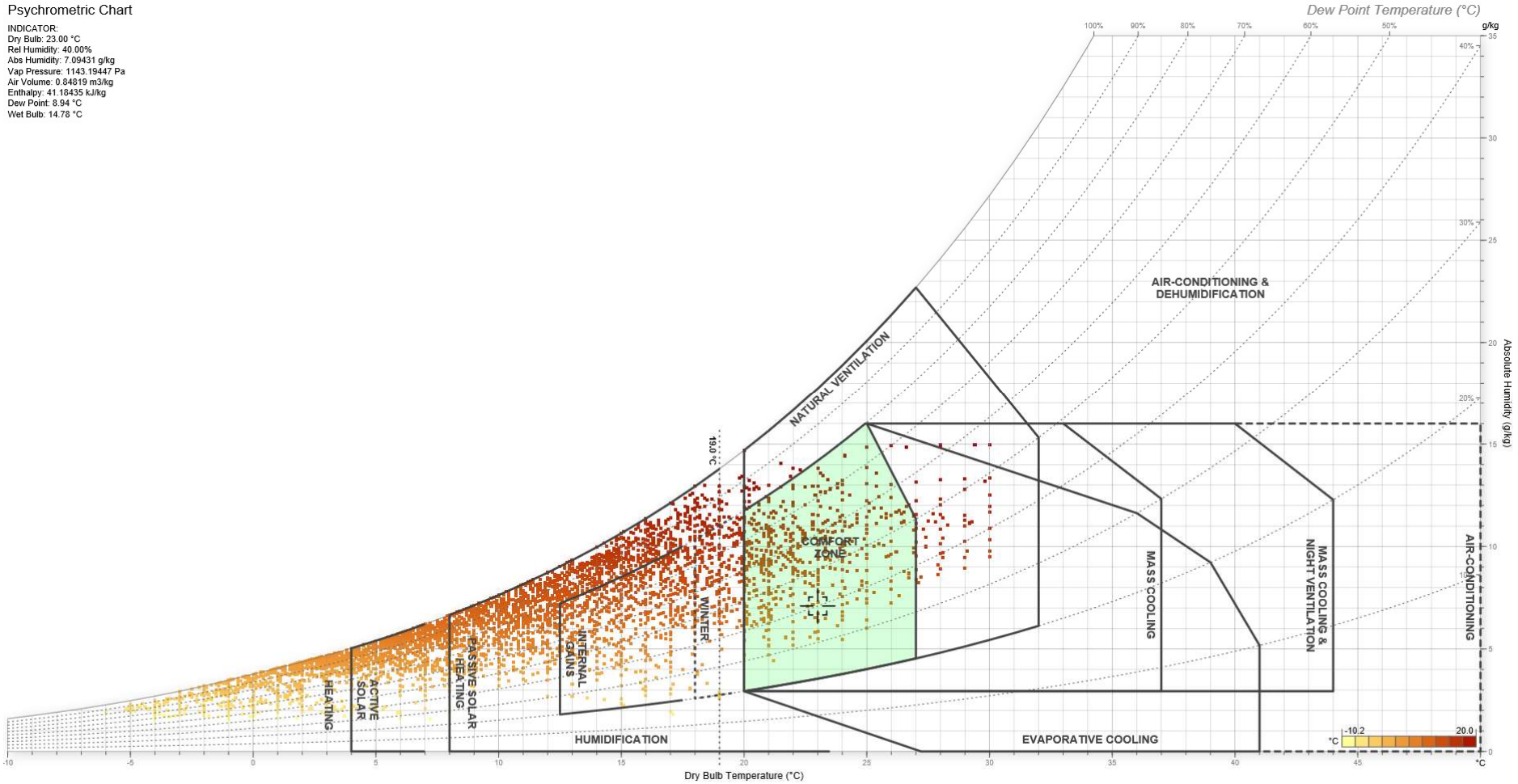


Precipitation in Paris



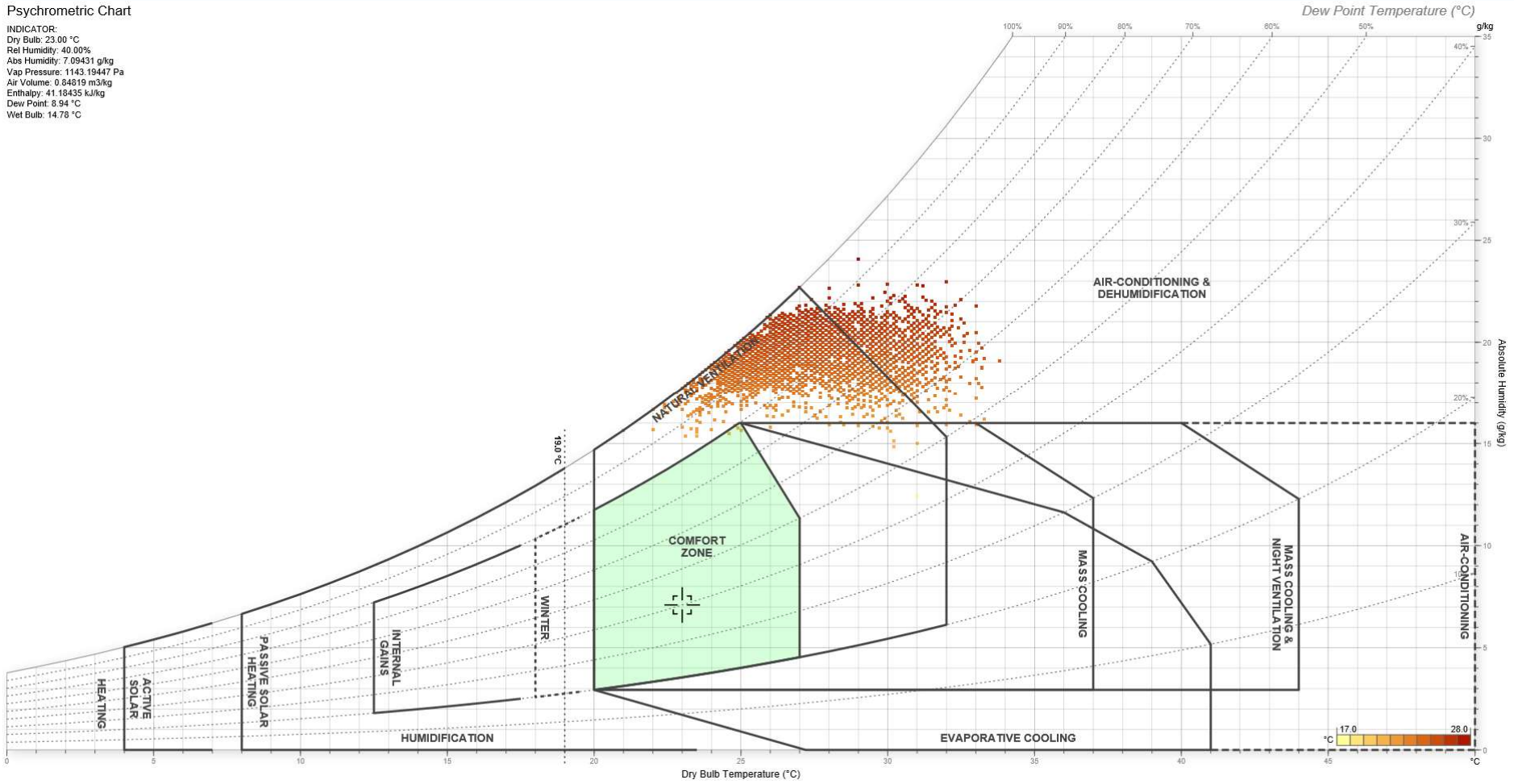
Precipitation in Singapore

2.1.d. Psychromatic chart



Paris

2.1.d. Psychromatic chart



Singapore

2.2. Building environment

US suburbs
© Jason Hawkes

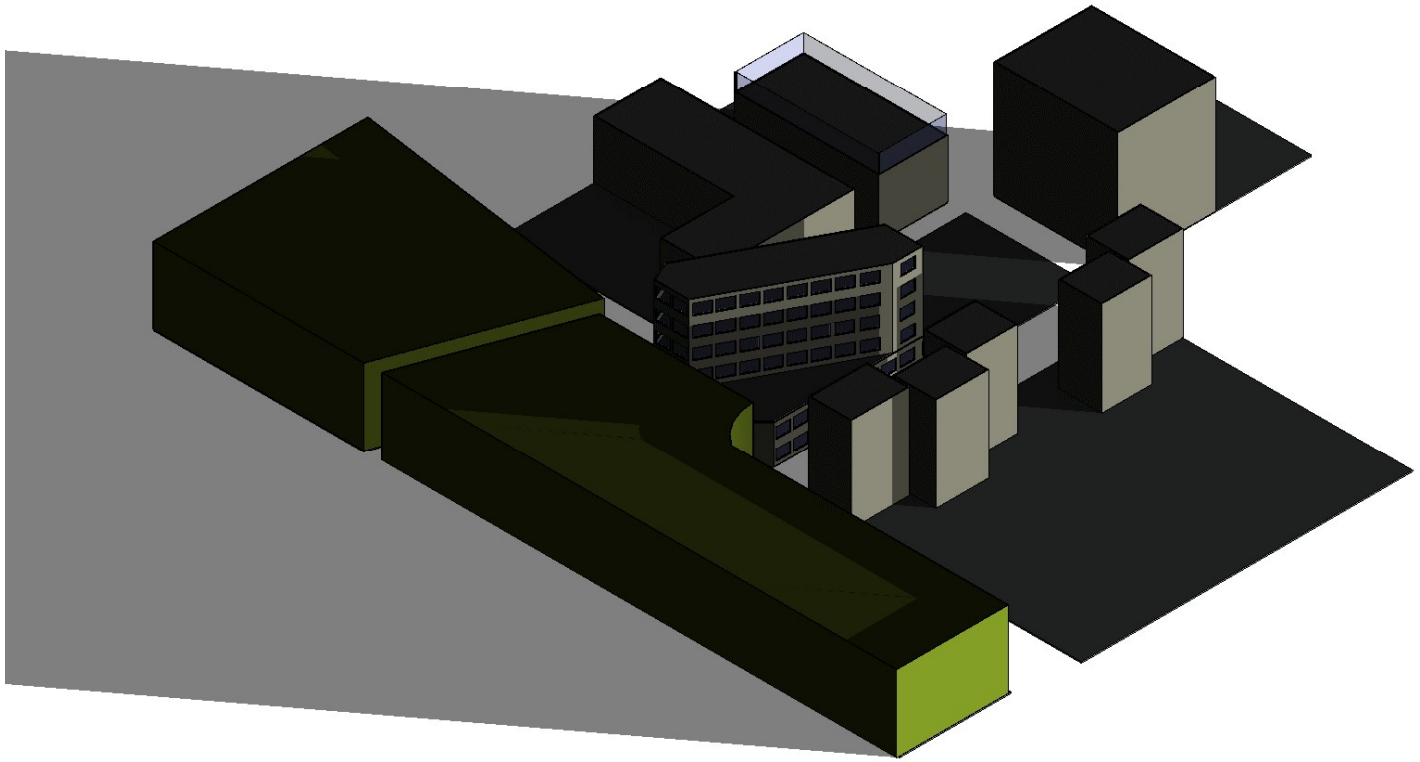
Beijing
© South China Morning Post

Wengen (Switzerland)
© Kosodate

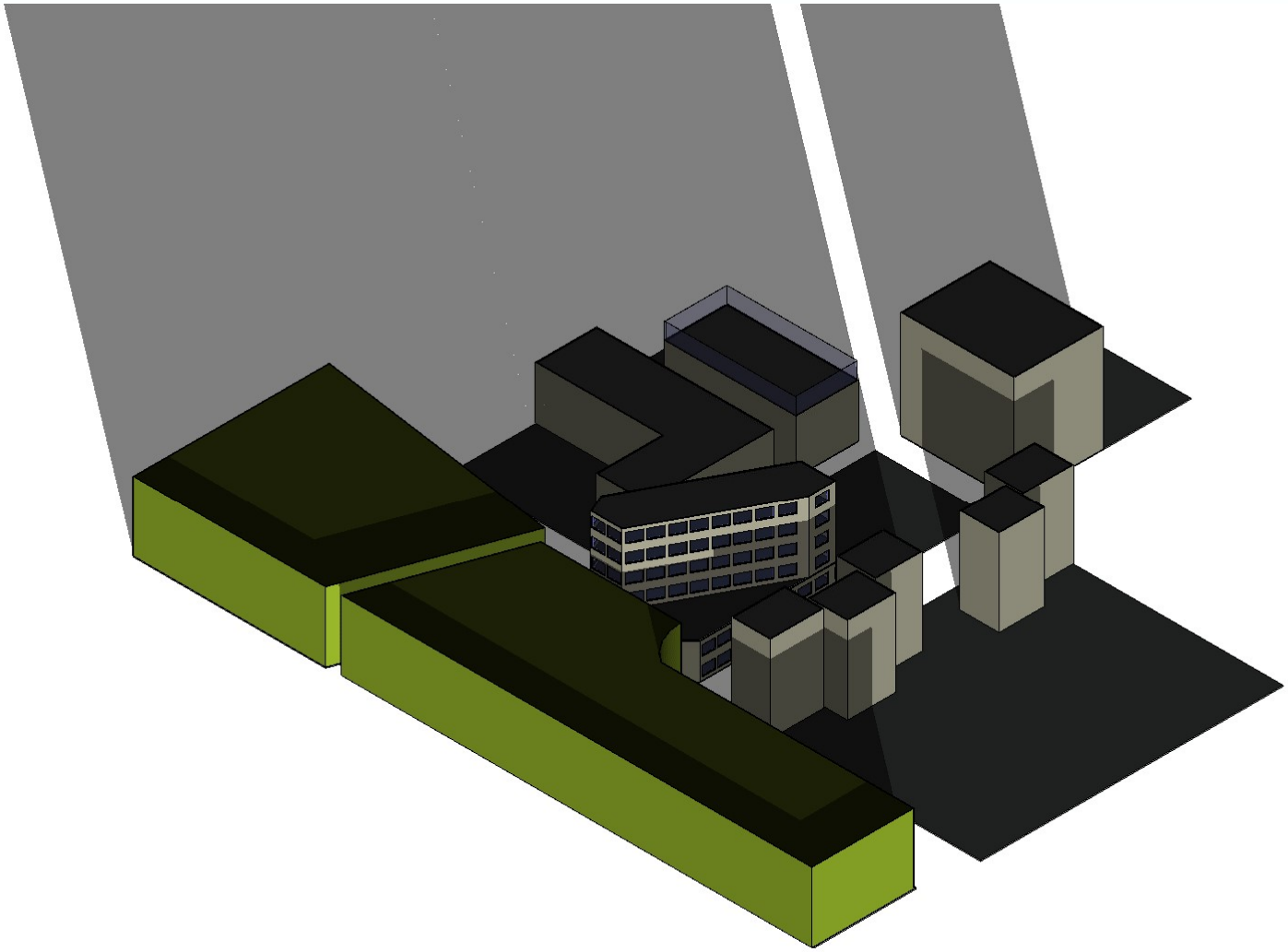
Hong Kong
© Andy Yeung

2.2.a. Shadow

Summer solstice
5 am – 9 pm

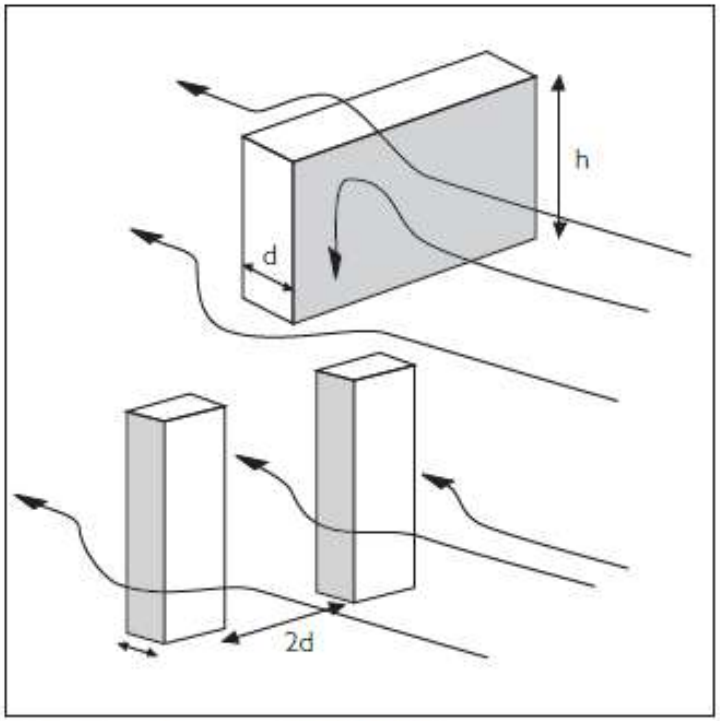


2.2.a. Shadow

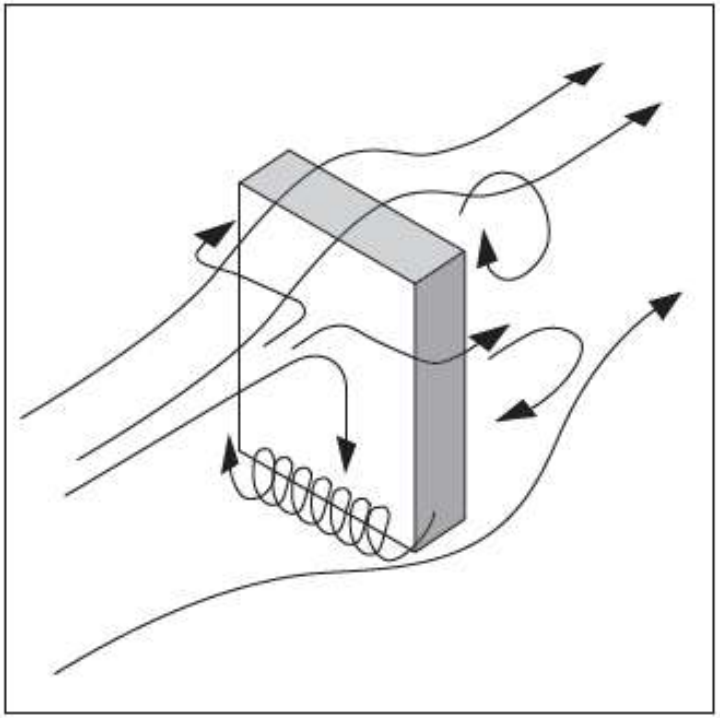


Winter solstice
9 am – 5 pm

2.2.b. Wind funnel

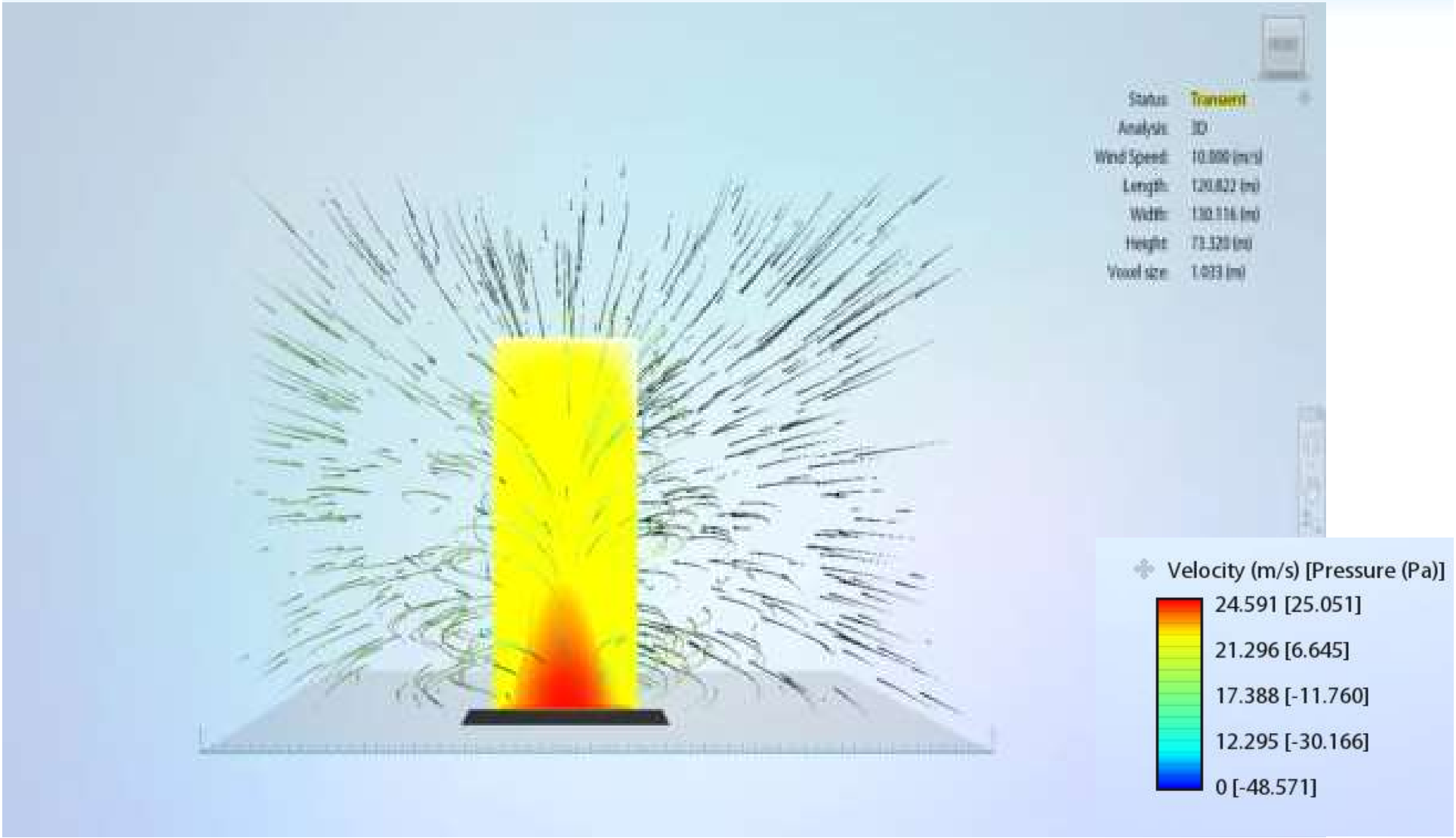


Turbulence around tall buildings

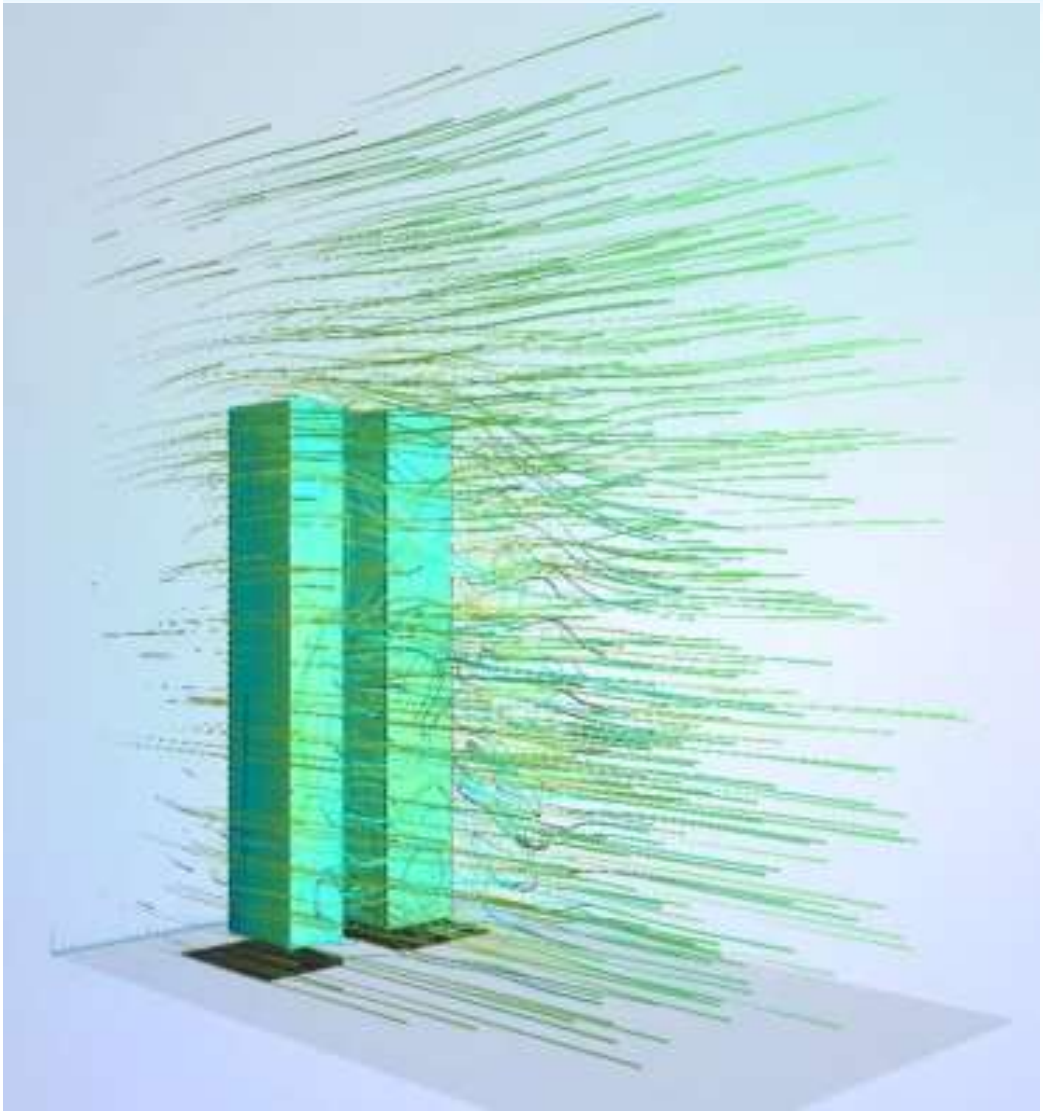


Turbulence and buildings

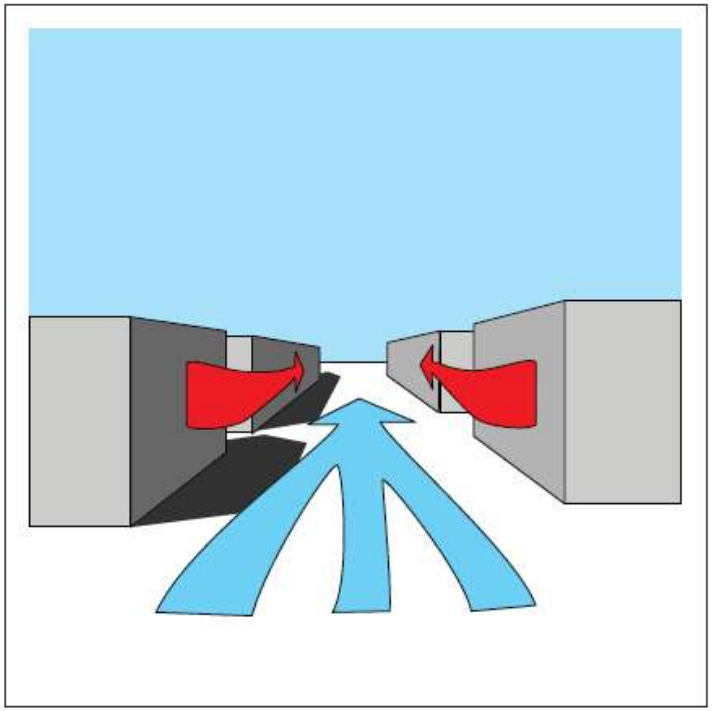
2.1.b. Wind


Status: Transient
Analysis: 3D
Wind Speed: 10.000 (m/s)
Length: 120.822 (m)
Width: 130.116 (m)
Height: 73.320 (m)
Voxel size: 1.933 (m)
Velocity (m/s) [Pressure (Pa)]
24.591 [25.051]
21.296 [6.645]
17.388 [-11.760]
12.295 [-30.166]
0 [-48.571]

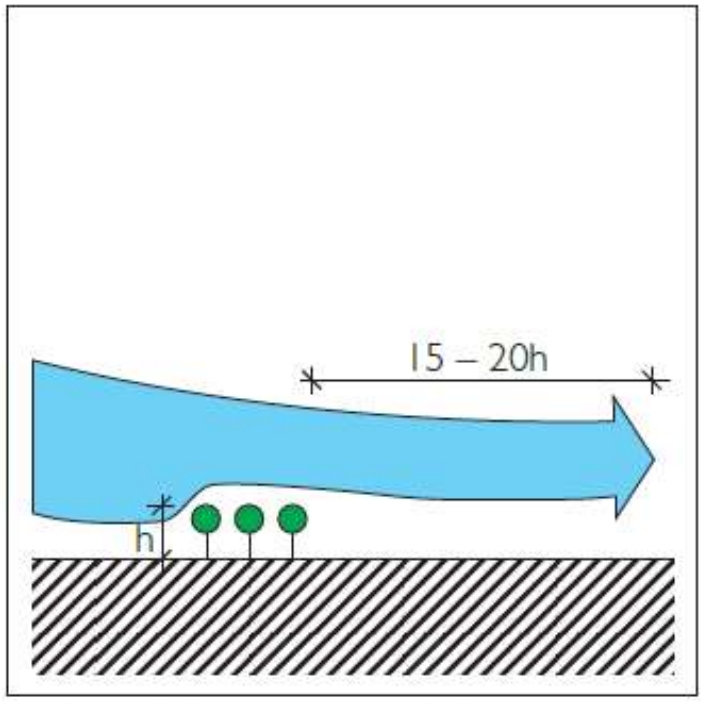
2.1.b. Wind


Velocity (m/s) [Pressure (Pa)]
24.591 [25.051]
21.296 [6.645]
17.388 [-11.760]
12.295 [-30.166]
0 [-48.571]

2.2.b. Wind in height

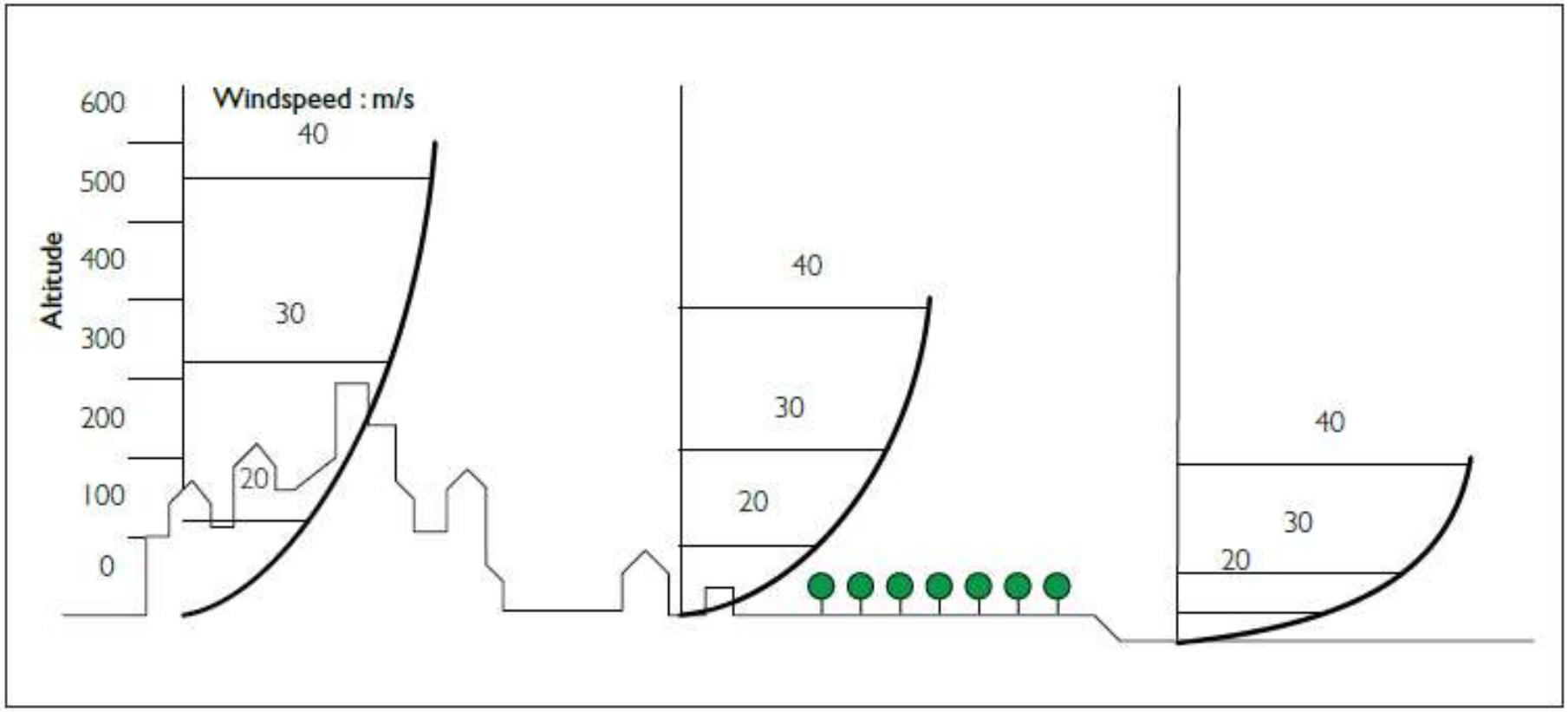


Prevailing wind funneled through a city street



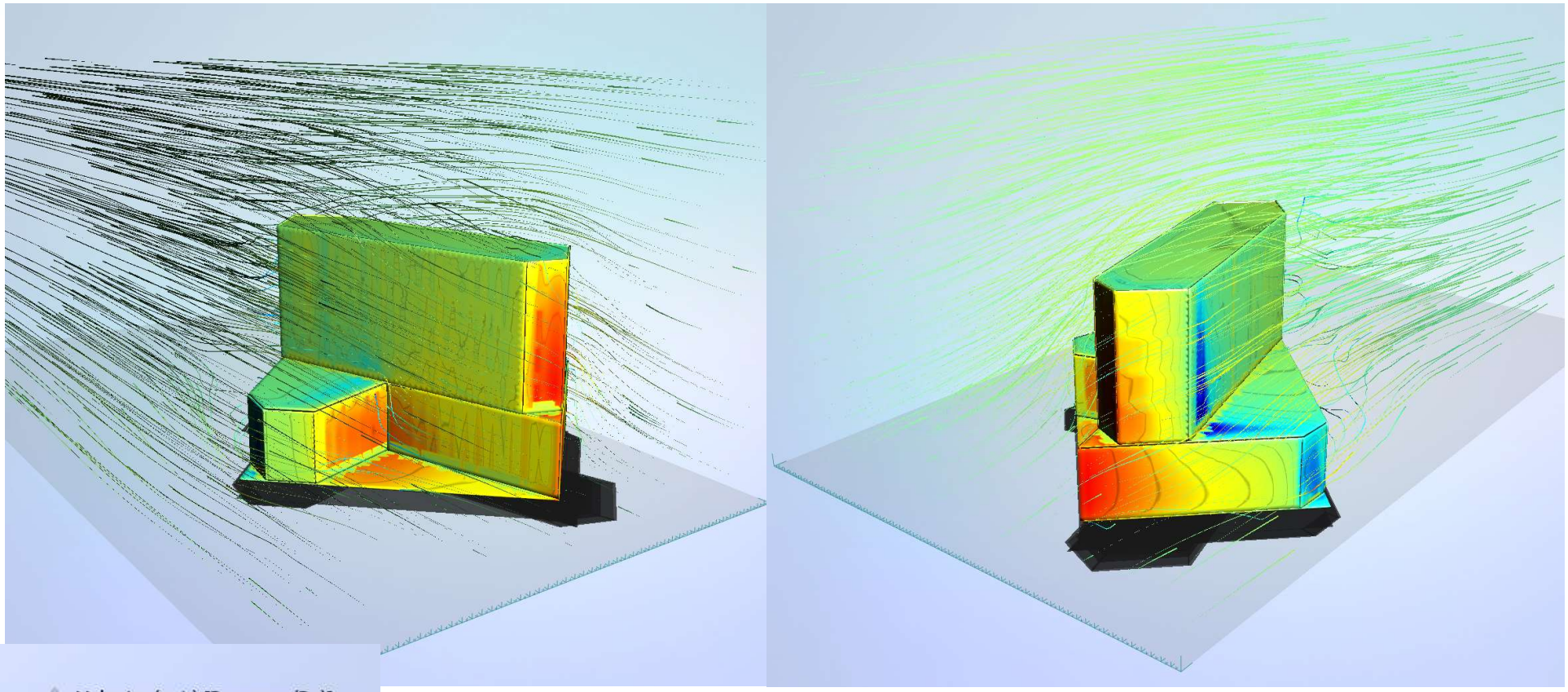
Natural shelter belts: extent of sheltered zone

2.2.b. Wind in height



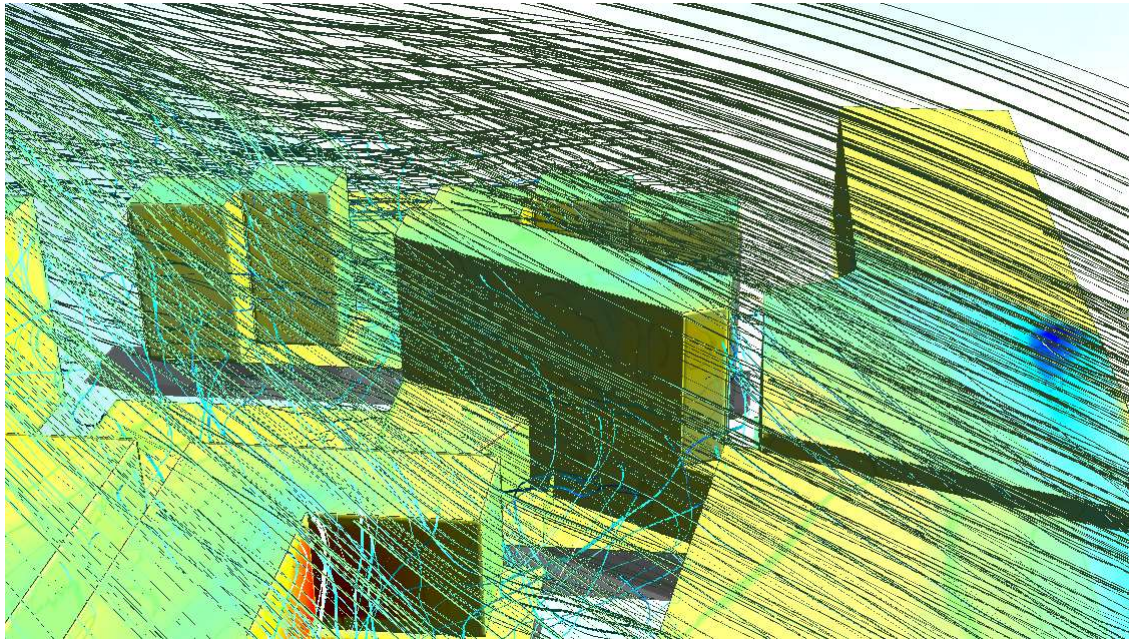
Wind speed at a given height is lower in towns than over open land

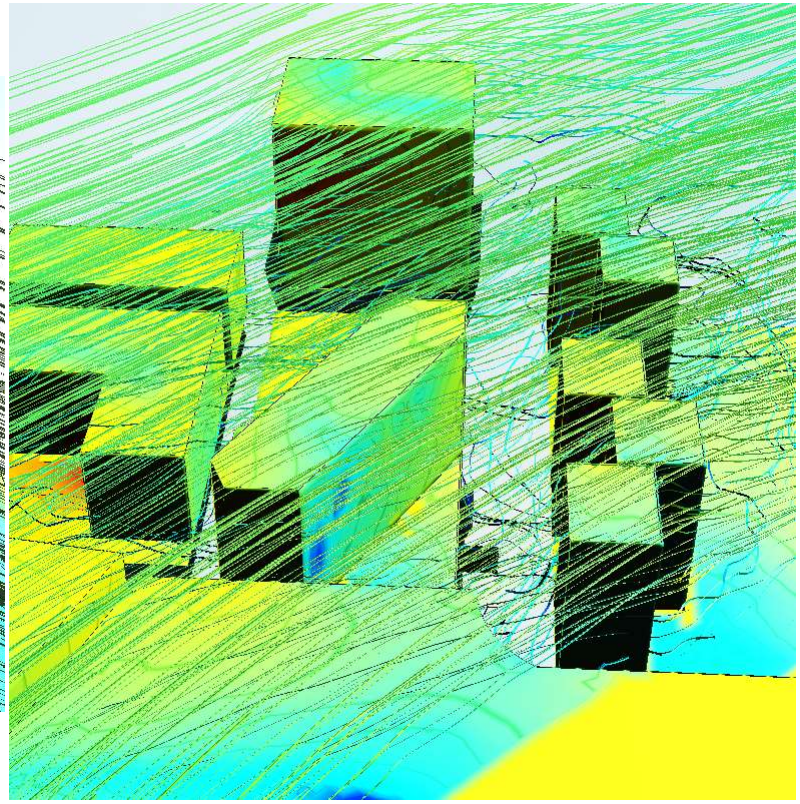
2.2.c. Wind breakers



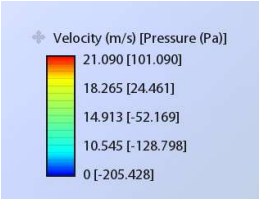
South-West wind
10 m/s

2.2.c. Wind breakers





South-West wind
10 m/s



3. BUILDING CONCEPTION

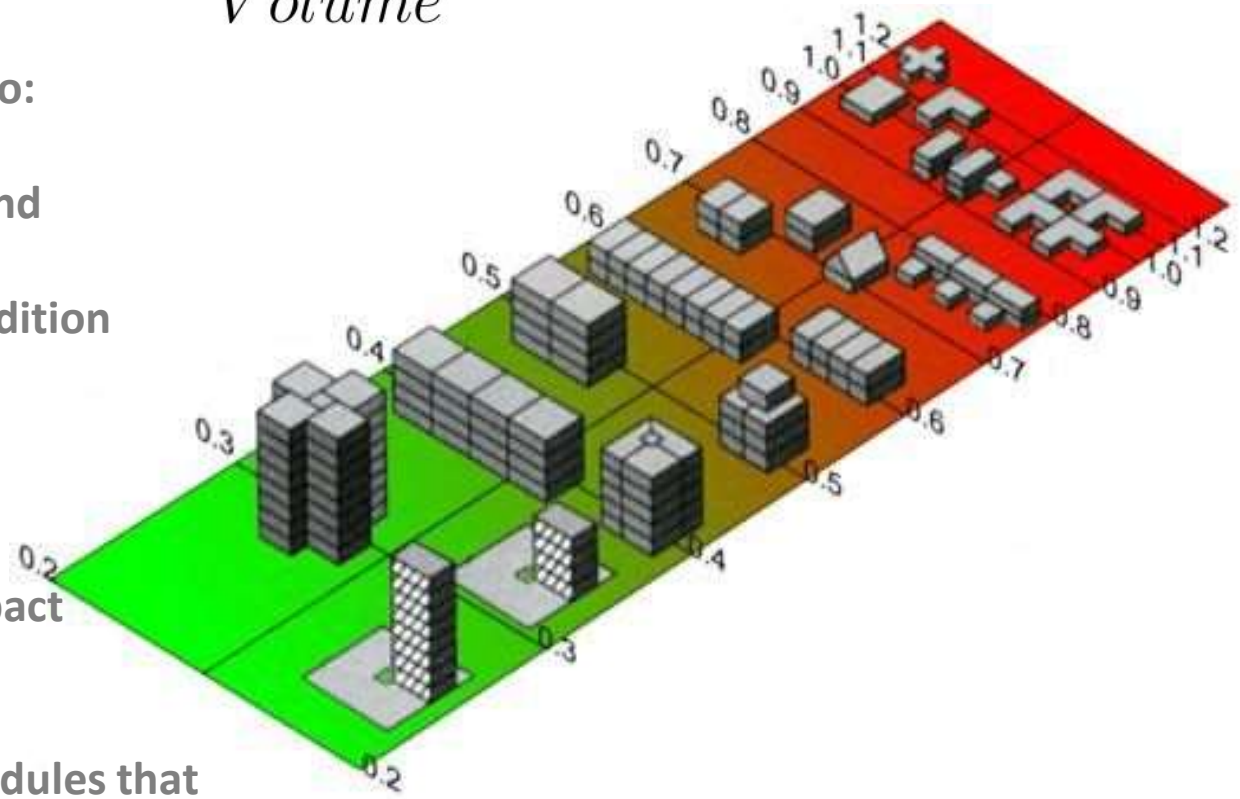
1. Organization of the façade
2. Organization of the rooms
3. Solar inputs
4. Lighting
5. Water

3.1. Organization of the façade

$$CompactnessRatio = \frac{Surface\ of\ the\ facade.}{Volume}$$

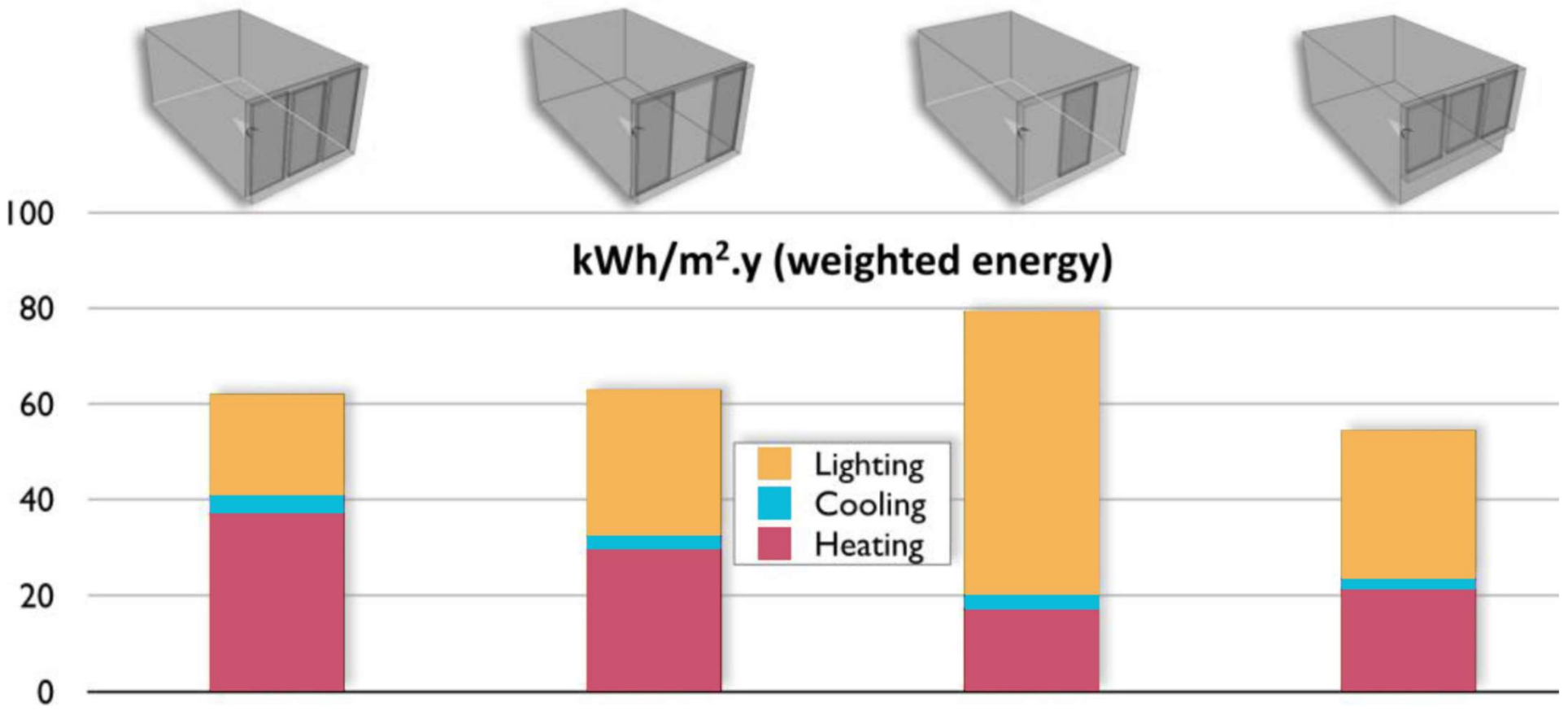
The larger the compactness ratio:

- **The higher the energy demand**
- **The higher the energy deperdition through wind**
- **The higher the lighting**
- **The larger the ecological impact (imperviousness of soils)**
- **The larger the area of PV modules that can be installed**



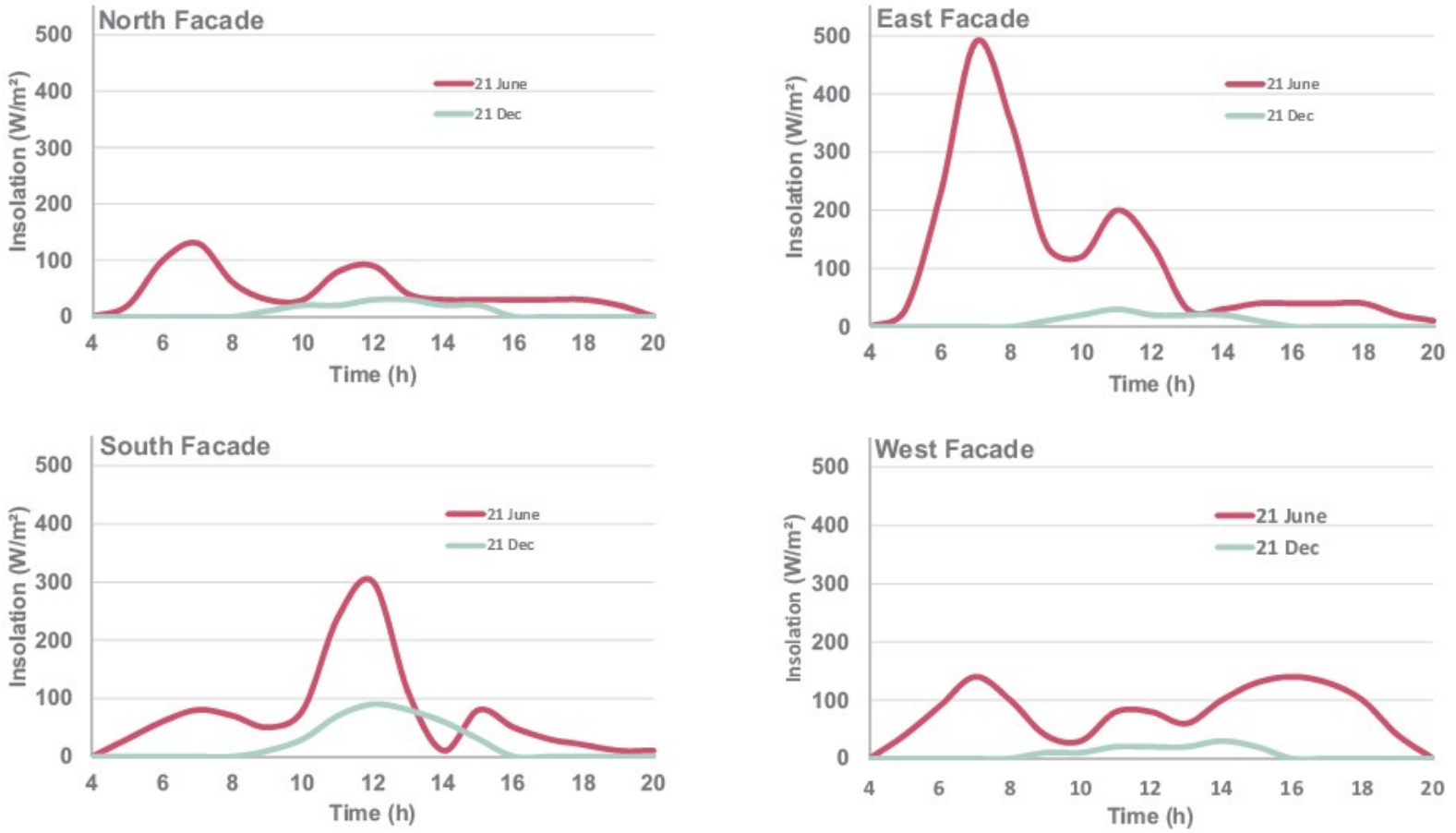
Buildings with different Compactness Ratio
© Cherki

3.1. Organization of the façade



Energy consumption for different opening types

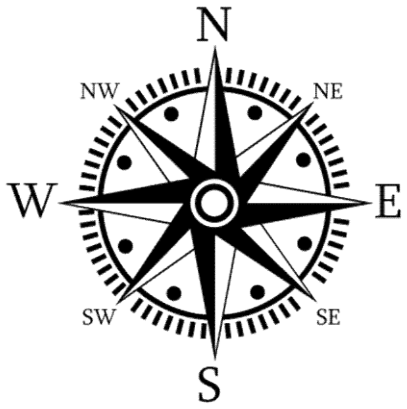
3.1. Organization of the façade



Sunlighting of the facades at the winter and summer solstices under average conditions in Paris

3.2. Organization of the rooms

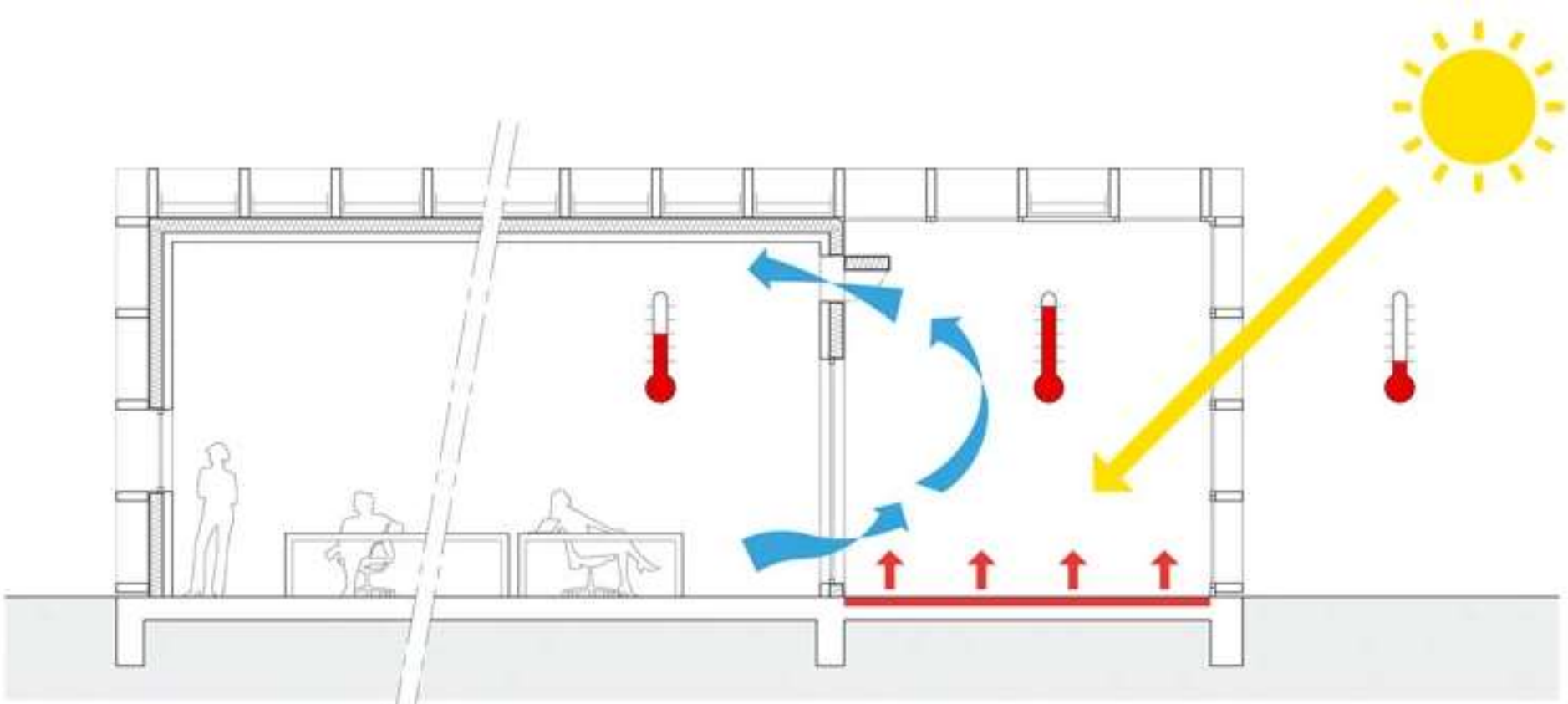
Spaces requiring less or discontinuous heating
Buffer zones



Spaces with high heating demands
Unheated conservatories or sunspaces

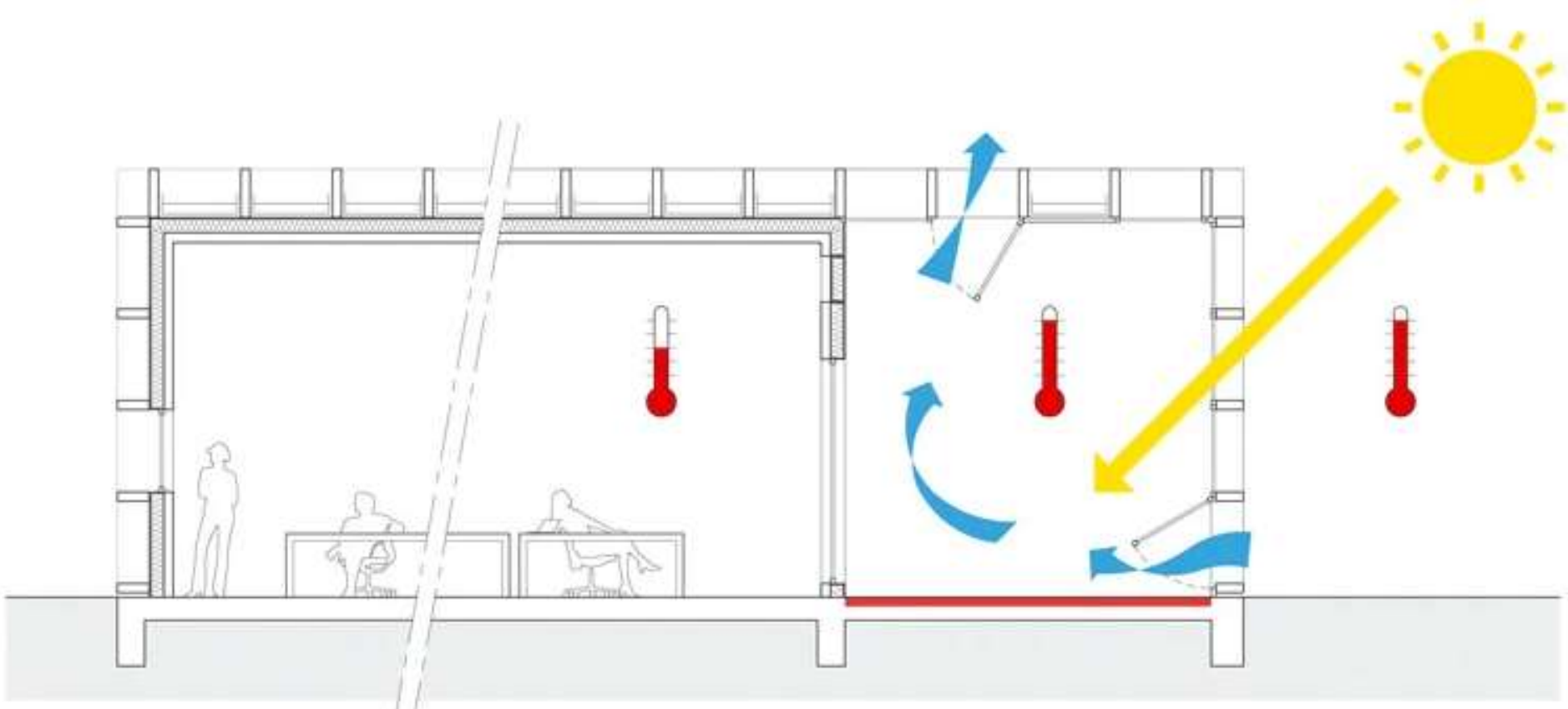
- Reduction of surface exposed to prevailing winds
- Control of ventilation & infiltration
- Location of entrance doors away from corners and from prevailing winds
- Use atria and courtyards to act as buffer space and introduce daylight

3.2. Organization of the rooms



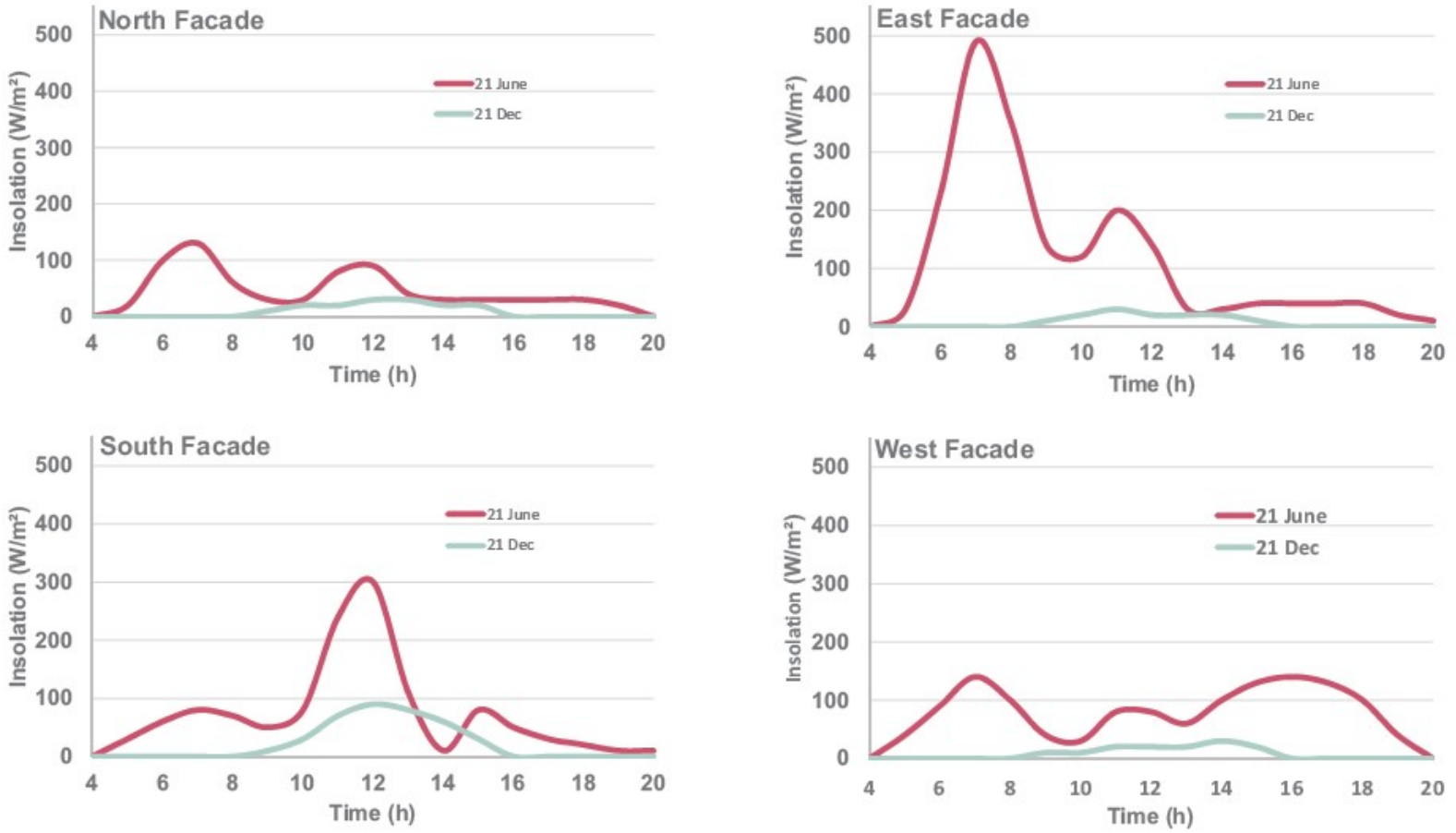
SUNROOM IN WINTER

3.2. Organization of the rooms



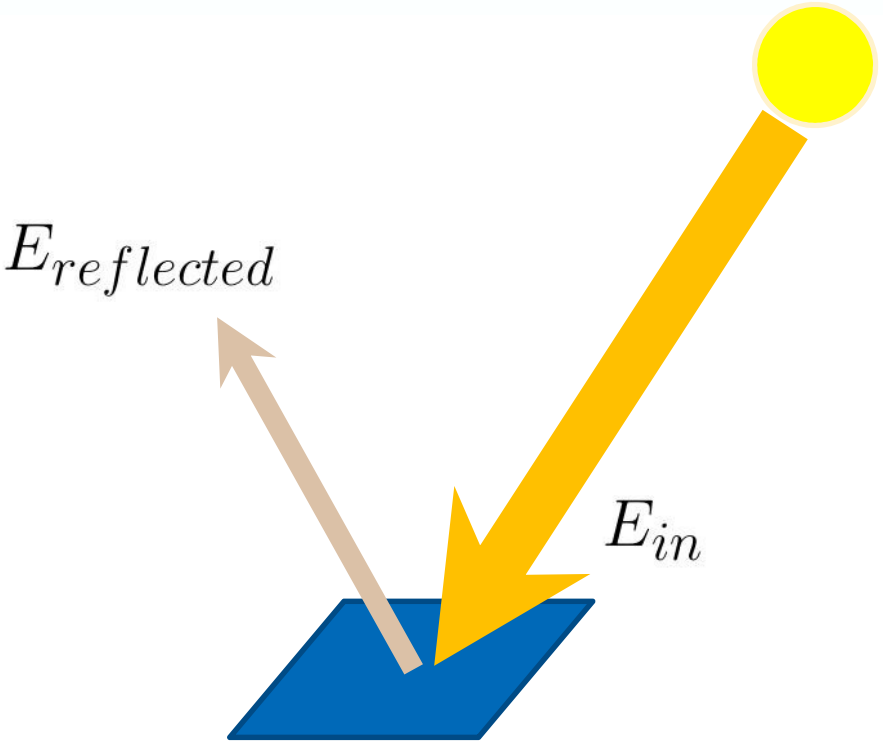
SUNROOM IN SUMMER

3.3. Solar inputs

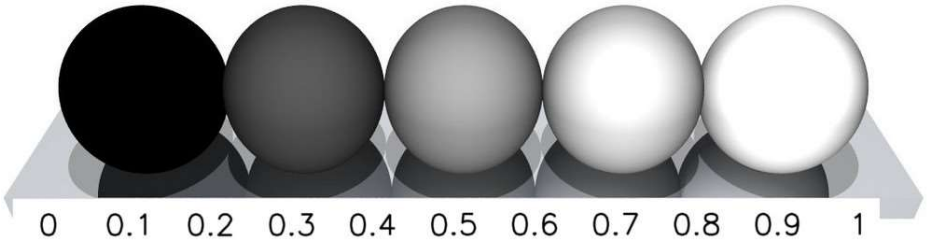


Sunlighting of the facades at the winter and summer solstices under average conditions in Paris

3.3. Solar inputs



$$albedo = \frac{E_{reflected}}{E_{in}}$$

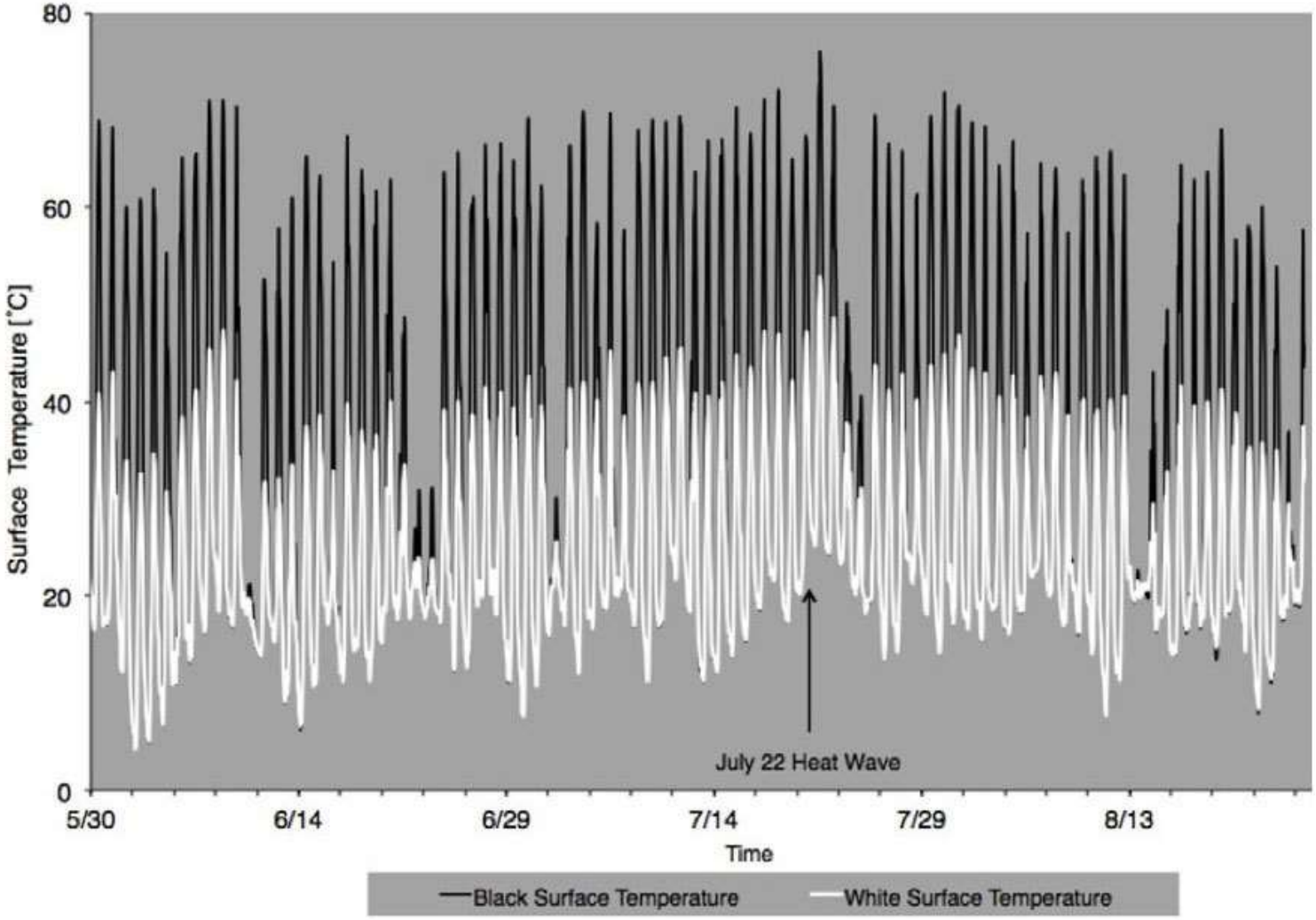


3.3. Solar inputs

© NASA

New York « Cool Roofs » Initiative
© Huffington Post

3.3. Solar inputs



© Gaffin et al.

3.3. Solar inputs

New York « Cool Roofs » Initiative
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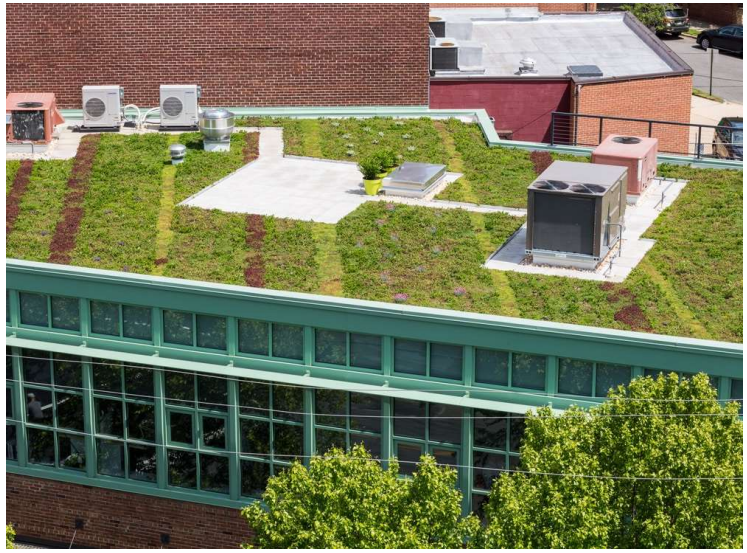
OR



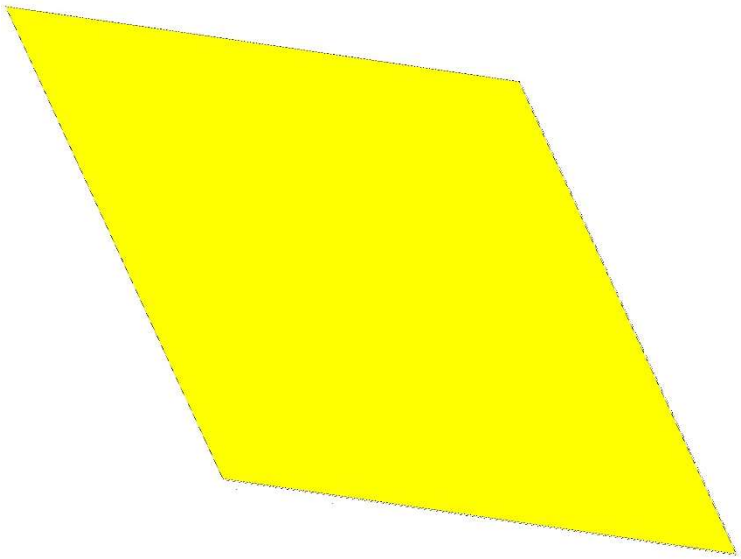
© Buildings

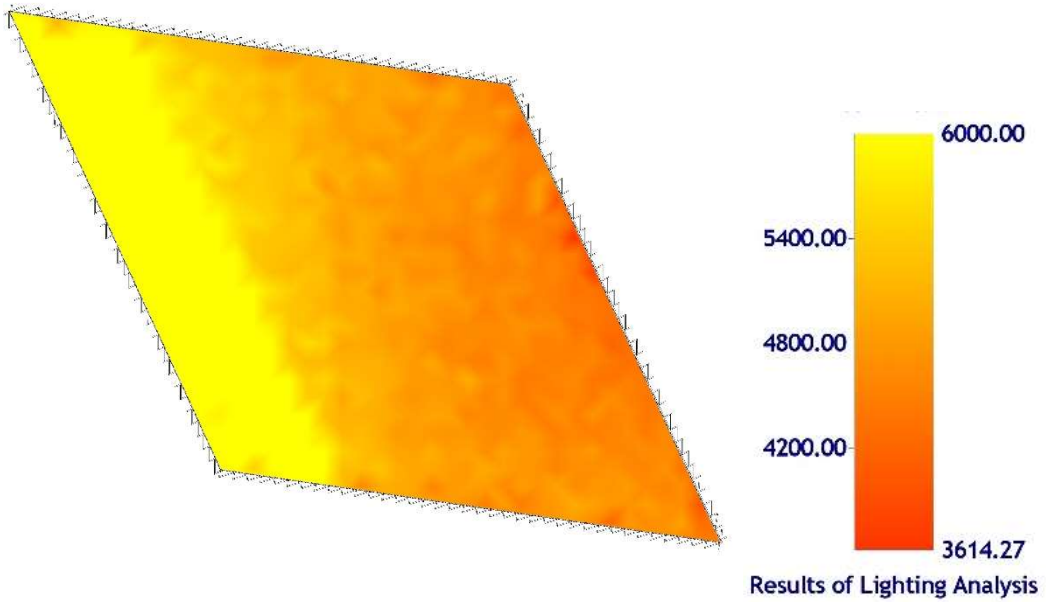
- **Higher albedo**
- **Less heat absorption**

- **Increases building insulation**
- **Contributes to evapotranspiration**
- **Filters PM + pollutants**

3.4.a. Lighting simulation

Summer solstice
2 pm





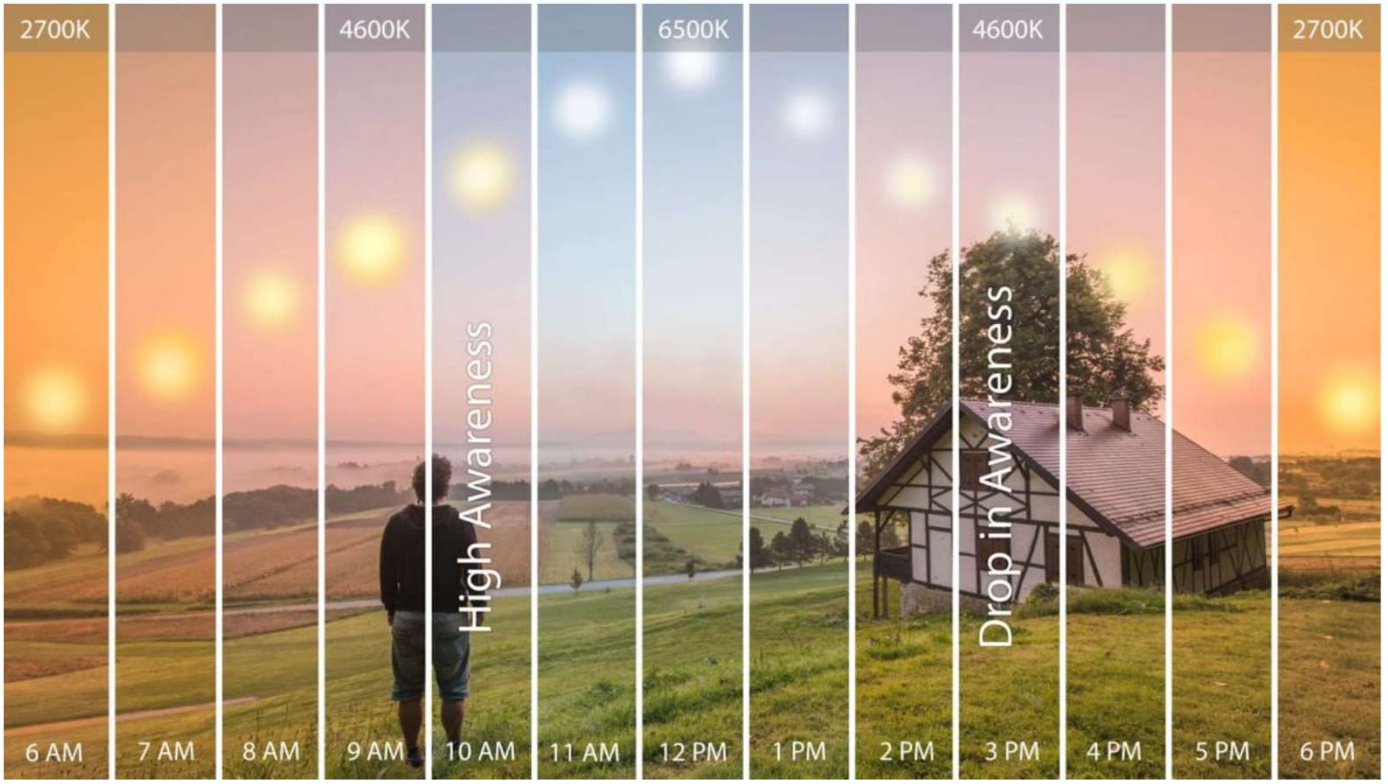
PLANE SURFACE

TEXTURED SURFACE

Natural lighting for a plain or textured facade

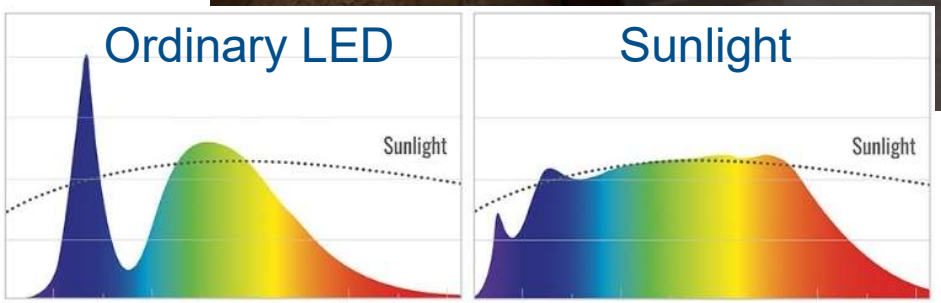
3.4.b. Circadian lighting

Circadian lighting
© The Lighting Practice



3.4.b. Circadian lighting

© Coelux



© Sunlight

3.4.c. Transporting light

Openings

© Daily Mail

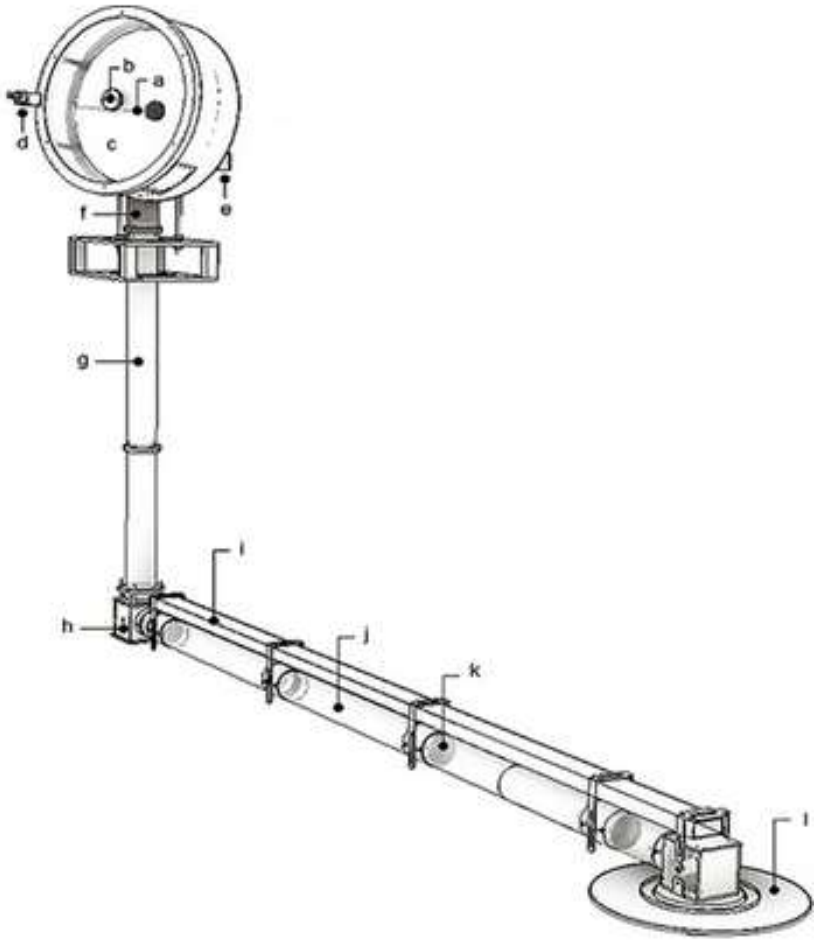
© Solatube

3.4.c. Transporting light

Optical fiber

© Parans

3.4.c. Transporting light



a. Parabolic mirror(1st)

b. Parabolic mirror(2nd)

c. Cover glass

d. Solar tracking sensor

e. Operator

f. Concentrator post

g. Al pipe

h. Bendor

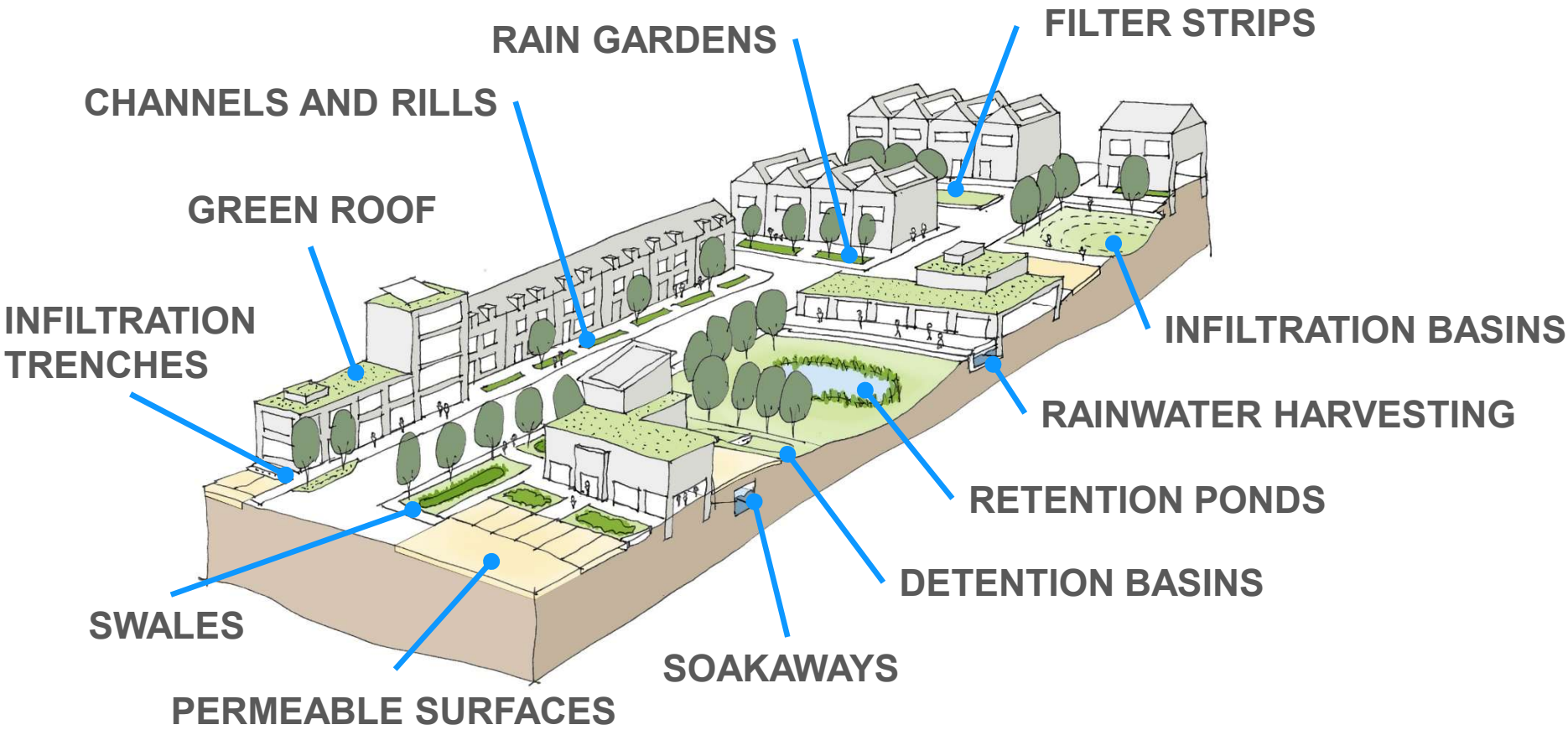
i. Guide rail

j. Acrylic pipe

k. Relay lense

l. Diffuser

3.5.a. Water collection



Source: European Natural Water Retention Measures Platform (NWRM)

3.5.a. Water collection

	Mechanisms of Water Retention					Biophysical impacts resulting from water retention										Ecosystem Services										Policy objectives											Score
	Slowing and Storing Runoff		Reducing Runoff			Reducing Pollution		Soil Conservation		Creating Habitat			Climate Alteration			Provisioning		Regulatory and maintenance						Cultural		Water Framework Directive						Flood management	Biodiversity strategy				
	Store runoff	Slow runoff	Increase evapotranspiration	Increase infiltration and/or groundwater recharge	Increase soil water retention	Reduce Pollutant Source	Intercept pollution pathways	Reduce erosion and/or sediment delivery	Improve soils	Create Aquatic habitat	Create Riparian habitat	Create Terrestrial habitat	Increase Precipitation	Reduce Peak temperature	Absorb and/or retain CO2	Water storage	Natural Biomass Production	Biodiversity Prevention	Climate Change Adaptation and Mitigation	Groundwater/Aquifer Recharge	Flood Risk Reduction	Erosion/Sediment Control	Filtration of Pollutants	Recreational Opportunities	Aesthetic/Cultural Value	Improving status of physico-chemical quality elements	Improving status of hydromorphology quality elements	Improving chemical status & priority substances	improved quantitative status	Prevent surface water status deterioration	Prevent Groundwater status deterioration	Take Adequate and coordinated measures to reduce flood risks	Better protection for ecosystems and more use of Green infrastructure	more sustainable agriculture and forestry	Prevention of biodiversity loss	
Green Roof	2	2	3			1	1					1		1	1		1	1	2		2		1	1	2	1		1		1		2	2		1	30
Rainwater harvesting	1	1														3			2		1						1		1			1				1
Permeable paving	2	2		2		1	1									1			1	2	2	1	1			1		1	1	1		3	1			24
Swales	2	3	2	2	1	1	2	2			1	2		1	1	1	1	2	2	2	2	1	2		2	1		1	1	2	1	3	2	1	2	45
Channels and rills	1	2	2	1			2	1		1		1		1	1		1	1	1		1	1	1		2							2	1		1	25
Filter strips		1		1	1		3	3				2		1	1		1	2	1	1	1	2	3		2	1		1		2		2	2	1	2	37
Soakaways	2			3	1	1	1									1			1	3	3		1			1		1	2	1	1	3	1			27
Infiltration trenches	2	1		3	1		2	2								1			1	3	3	1	2		1	1		1	2	1	1	3	1	1		34
Rain gardens	2	2	3	3	1	1	2	2				3		2	1	1	1	2	2	2	3	1	2	2	2	1		1	2	2	1	3	3		2	55
Detention basins	3	3	2	1	1		2	2				2		1	1	2	1	2	2	1	3	2	2	2	2	1		1		2		3	3	1	2	50
Retention ponds	3	3	2			1	3	3		3	2	1	1	1		2	2	3	2		3	2	3	2	3	1		1		2		3	3	1	3	59
Infiltration basins	3	3	1	3	1		3	2				2		1	1	2	1	2	2	3	3	1	3	2	2	1		1	2	2	1	3	3	1	2	57

Source: European Natural Water Retention Measures Platform (NWRM)

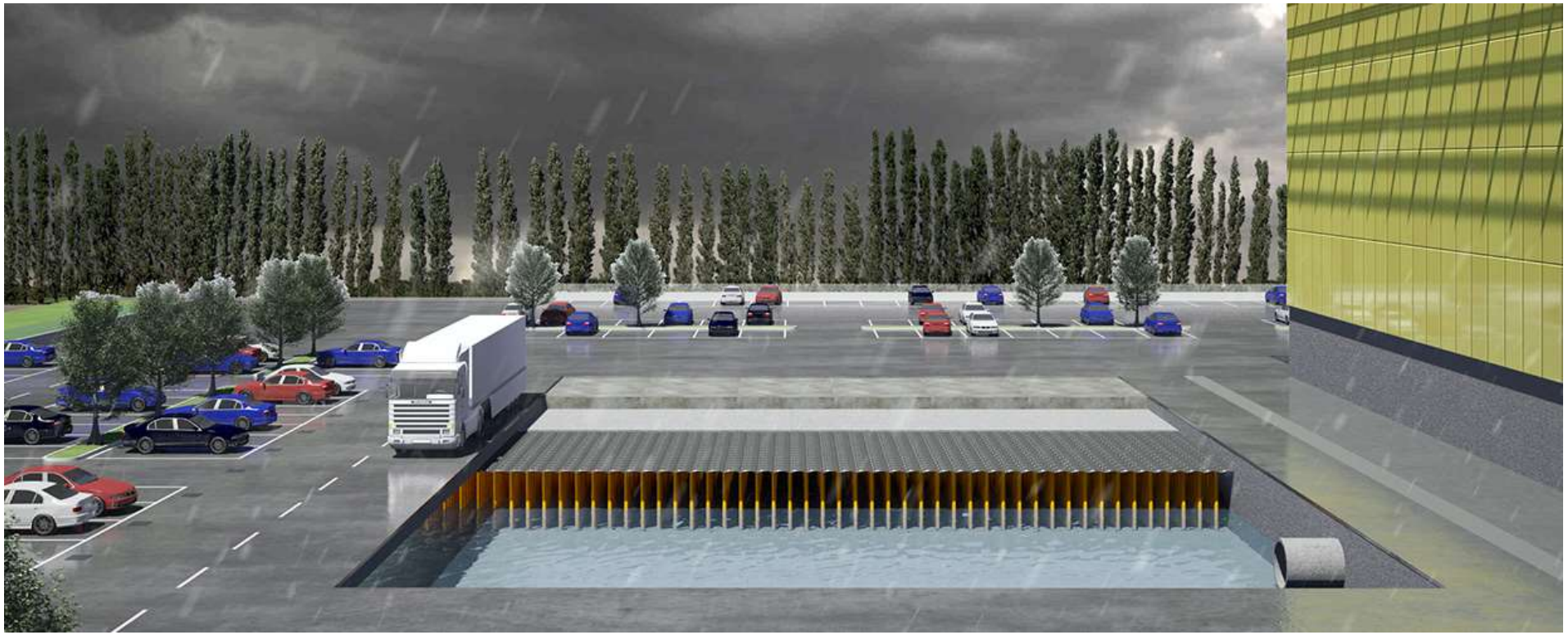
3.5.a. Water collection

Green roof

Source: European Natural Water Retention Measures Platform (NWRM)

3.5.a. Water collection

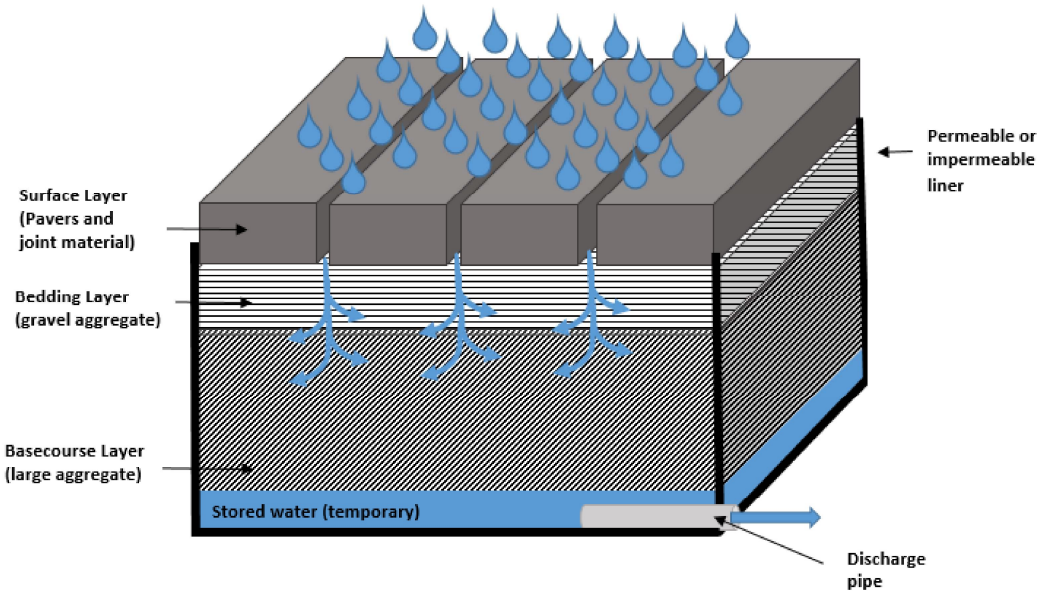
Rainwater harvesting



© Geoplast

3.5.a. Water collection

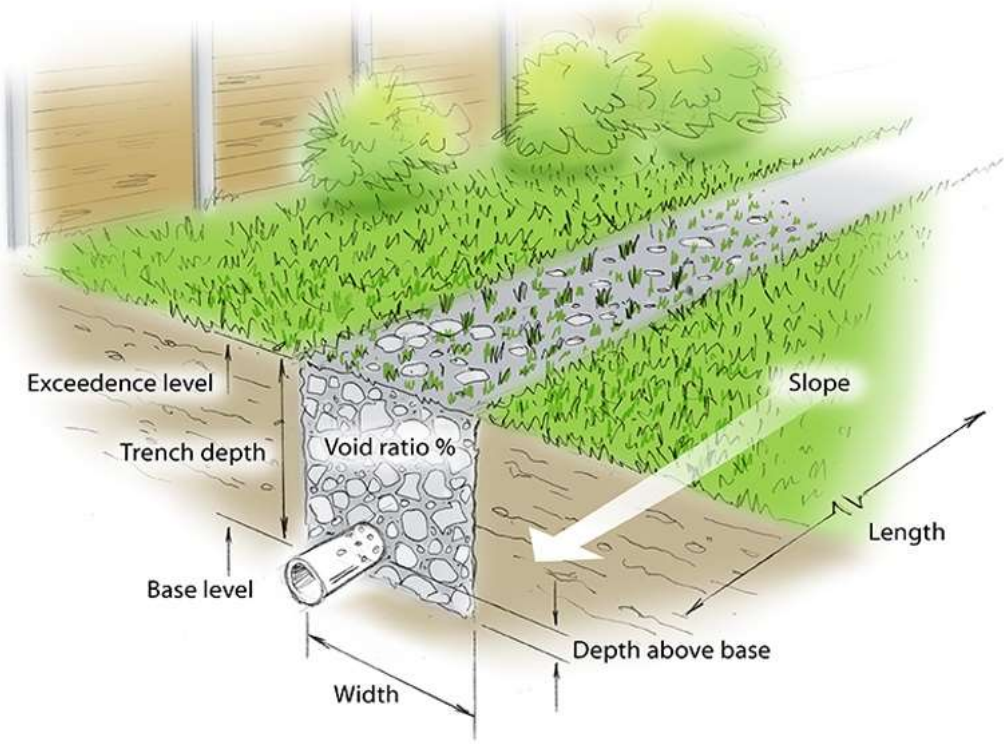
Permeable pavement



Source: European Natural Water Retention Measures Platform (NWRM)

3.5.a. Water collection

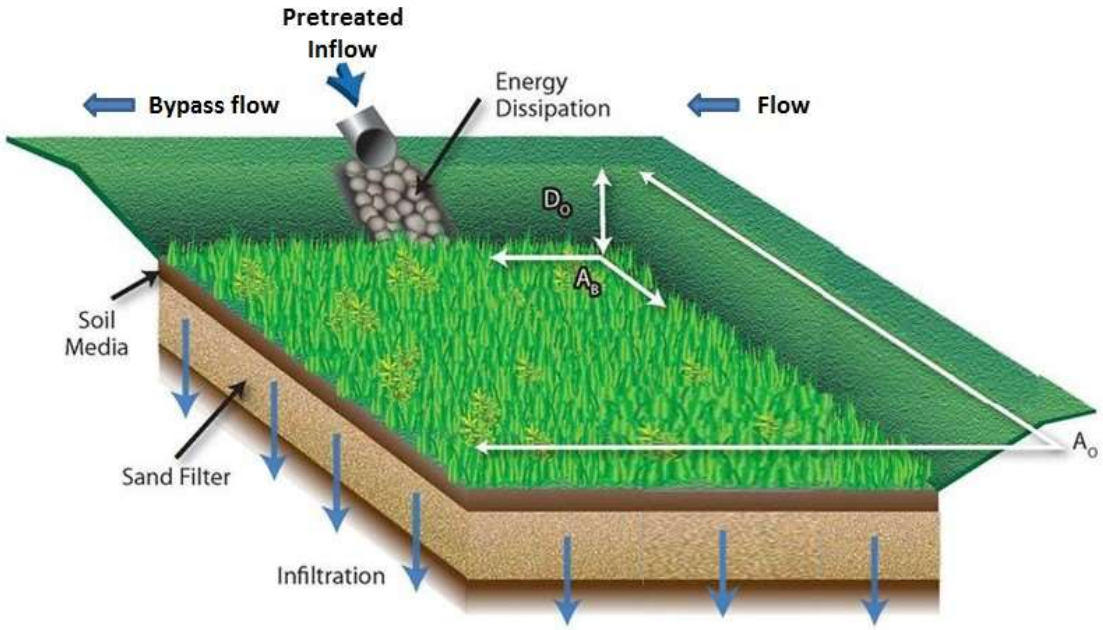
Infiltration trenches



Source: European Natural Water Retention Measures Platform (NWRM)

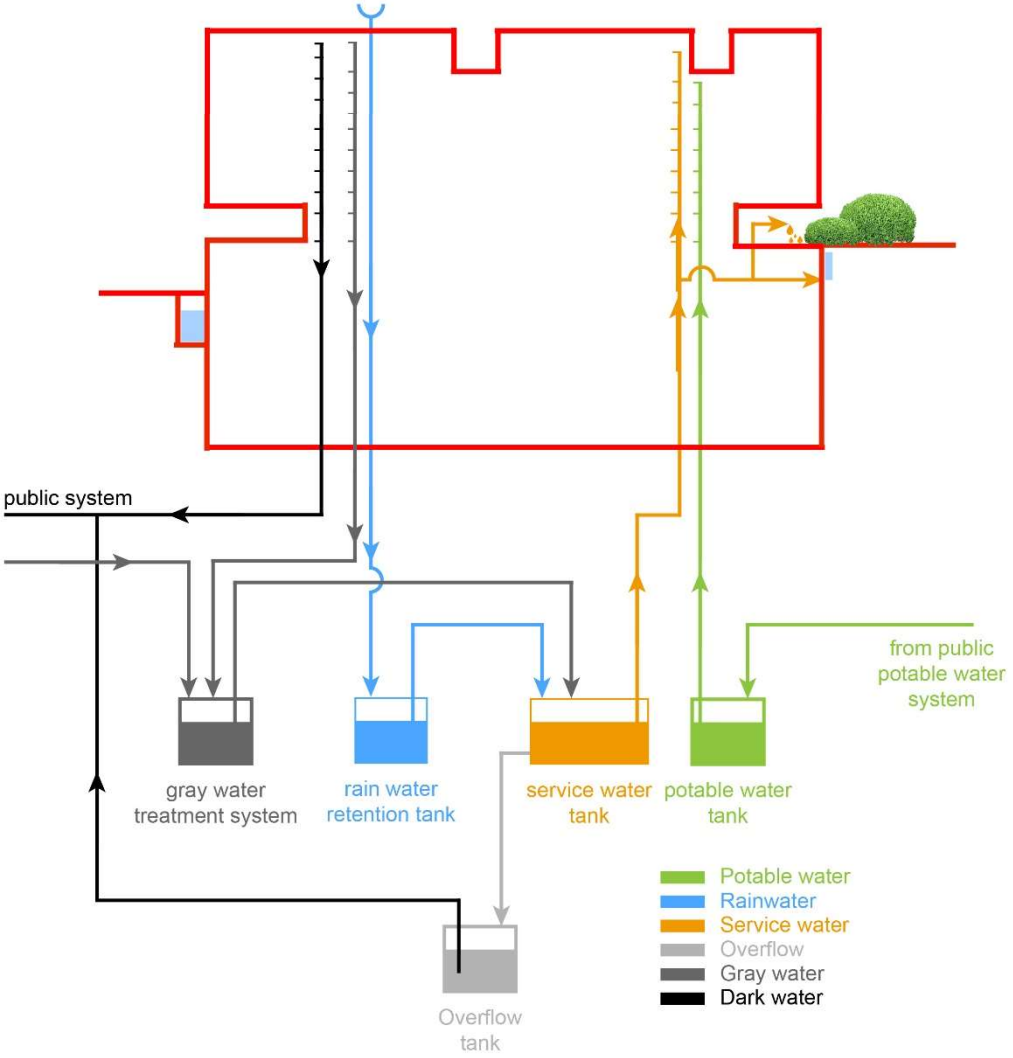
3.5.a. Water collection

Infiltration basins

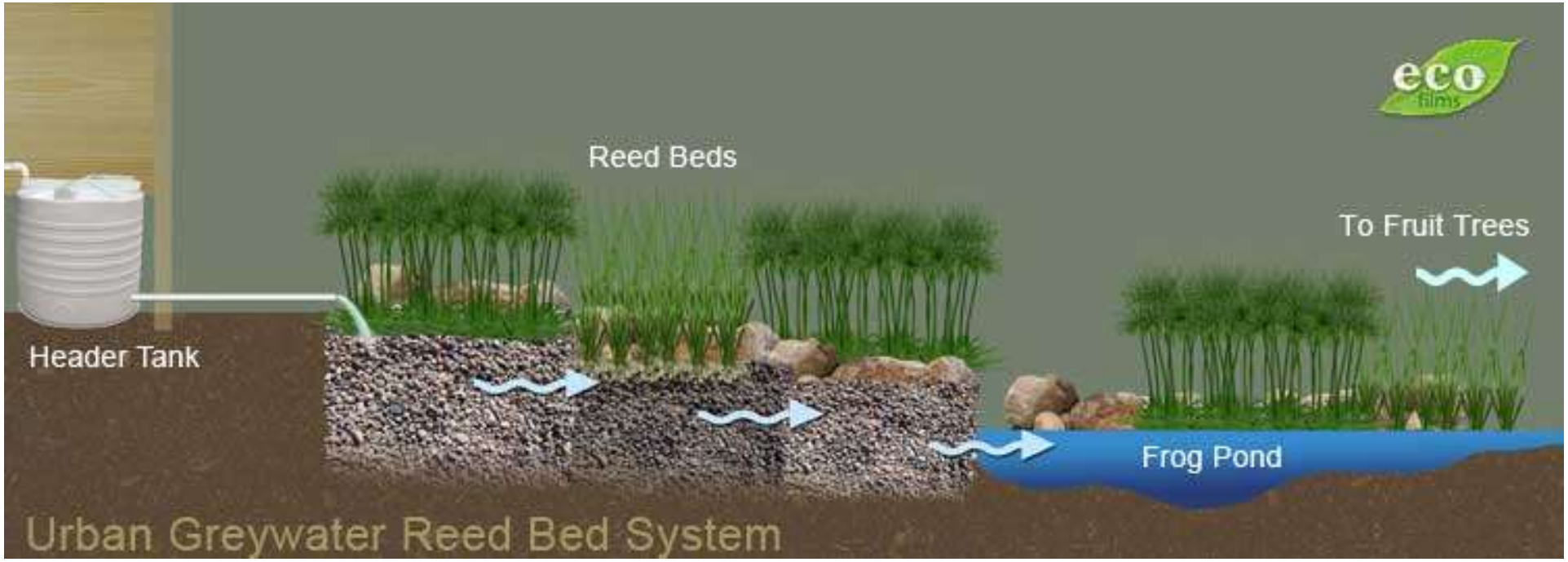


Source: European Natural Water Retention Measures Platform (NWRM)

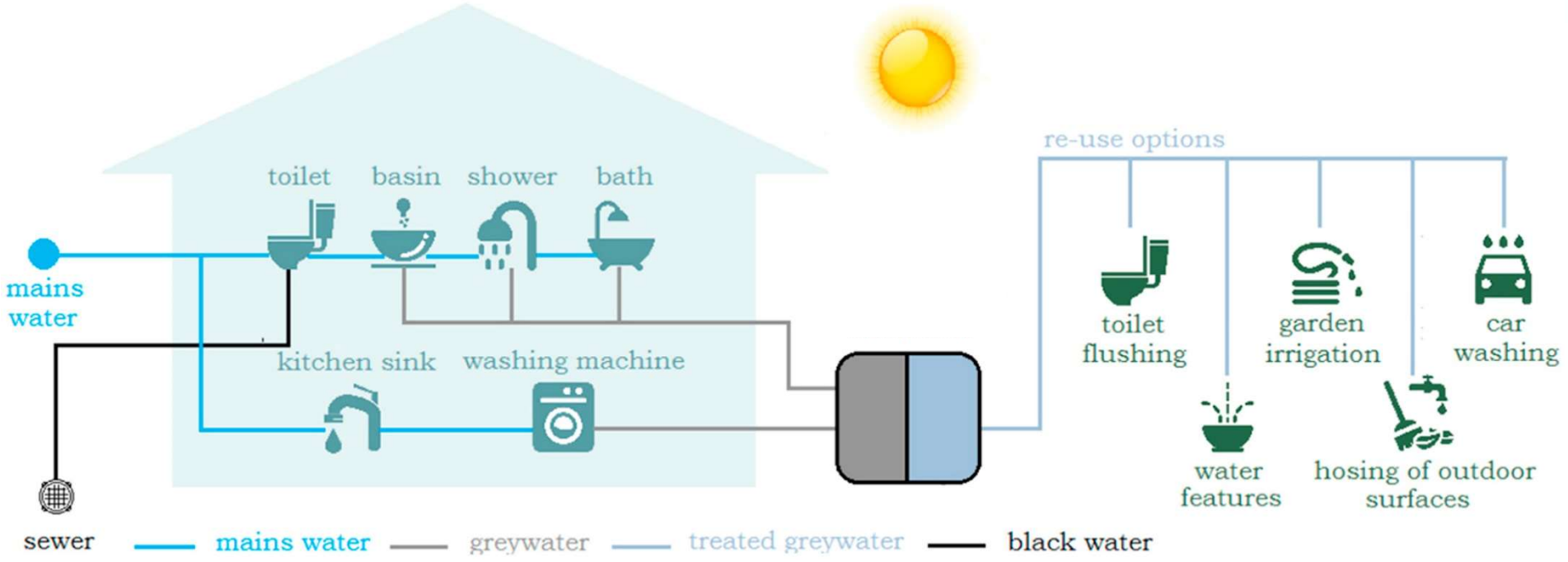
3.5.b. Water recycling



3.5.c. Water purification



3.5.c. Water purification



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Class activity

- Work in groups of 2 or 3
- Choose a location
- Establish its climate using the Methodology described in http://lptms.u-psud.fr/wiki-cours/index.php/Physics_of_sustainable_development
- If you were to build a house or a building on this location, what are the parameters you would keep in mind during the project design?