Computational Materiality for Sustainable Architectures and Comprehensive Skins

WIND, VENTILATION AND OTHER PASSIVE DEVICES

Wind & Passive Ventilation

<u>Thermal comfort</u>= f (TEMPERATURE, WIND, HUMIDITY, METABOLIC RATE, DRESSING RATE)

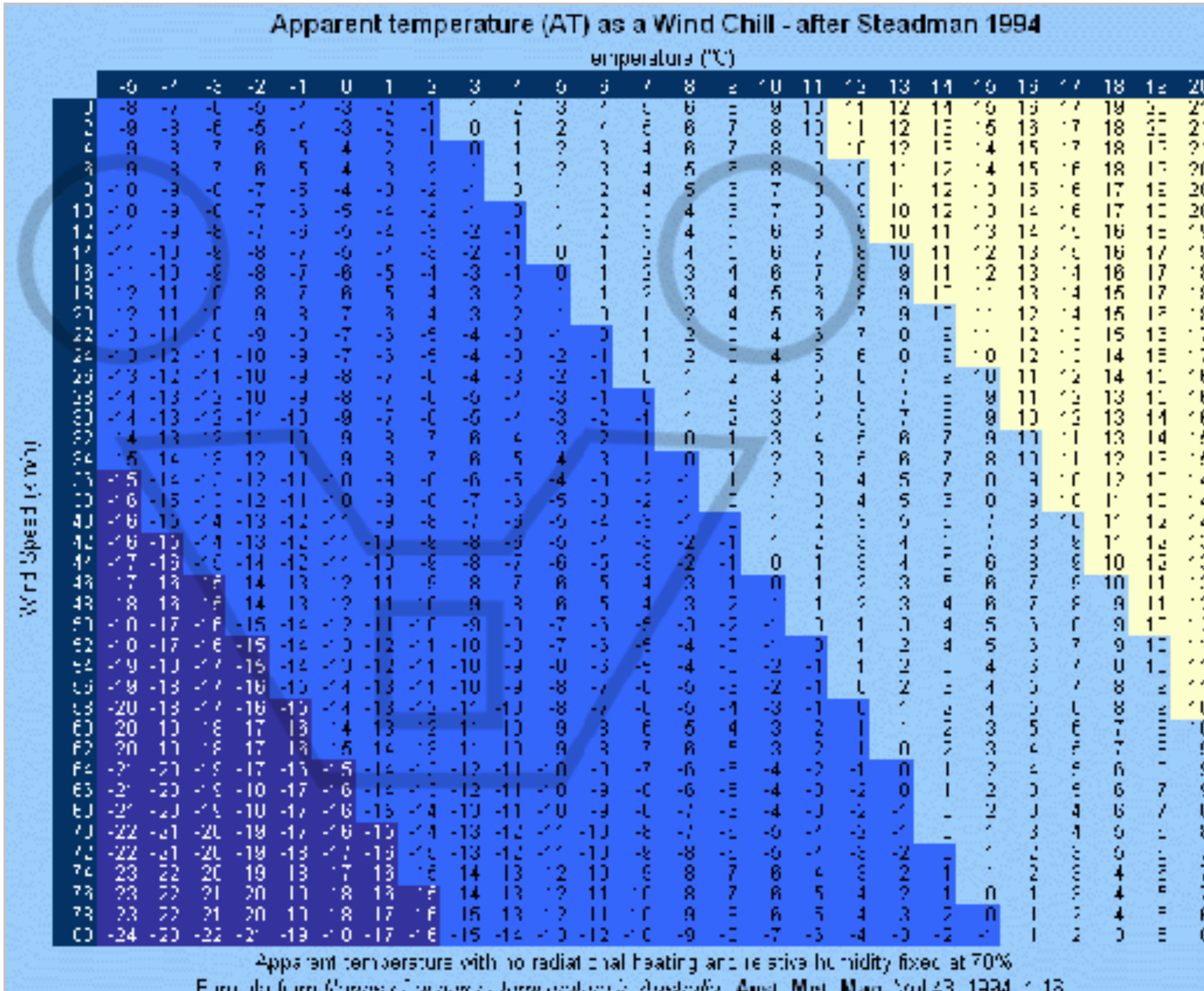
EFFECT OF WIND ON TEMPERATURE (Apparent Temperature)

	Wind Speed (mph)					
Temp (°C)	**10**	**20**	**30**	**40**	**50**	**60**
20	17	15	14	13	12	11
15	12	9	7	6	5	4
10	7	3	1	0	-2	-3
5	2	-3	-5	-7	-9	-10
0	-4	-9	-11	-14	-16	-17
-5	-9	-15	-18	-21	-23	-24
-10	-15	-21	-25	-28	-30	-32
-15	-21	-27	-32	-35	-37	-39
-20	-27	-33	-38	-42	-45	-47
		Significant	Severe	Extreme		

Wind chill equivalent temperatures from Steadman

Wind & Passive Ventilation

<u>Thermal comfort</u>= f (TEMPERATURE, WIND, HUMIDITY, METABOLIC RATE, DRESSING RATE)



Wind & Passive Ventilation

<u>Thermal comfort</u>= f (TEMPERATURE, WIND, HUMIDITY, METABOLIC RATE, DRESSING RATE)

WIND CHILL- Siple e Passel del 1945 reviewed in 2001

Wind Speed (km/hr)	Air Temperature (Celsius)																
	0	-1	-2	-3	-4	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50	-55	-60
6	-2	-3	-4	-5	-7	-8	-14	-19	-25	-31	-37	-42	-48	-54	-60	-65	-71
8	-3	-4	-5	-6	-7	-9	-14	-20	-26	-32	-38	-44	-50	-56	-61	-67	-73
10	-3	-5	-6	-7	-8	-9	-15	-21	-27	-33	-39	-45	-51	-57	-63	-69	-75
15	-4	-6	-7	-8	-9	-11	-17	-23	-29	-35	-41	-48	-54	-60	-66	-72	-78
20	-5	-7	-8	-9	-10	-12	-18	-24	-30	-37	-43	-49	-56	-62	-68	-75	-81
25	-6	-7	-8	-10	-11	-12	-19	-25	-32	-38	-44	-51	-57	-64	-70	-77	-83
30	-6	-8	-9	-10	-12	-13	-20	-26	-33	-39	-46	-52	-59	-65	-72	-78	-85
35	-7	-8	-10	-11	-12	-14	-20	-27	-33	-40	-47	-53	-60	-66	-73	-80	-86
40	-7	-9	-10	-11	-13	-14	-21	-27	-34	-41	-48	-54	-61	-68	-74	-81	-88
45	-8	-9	-10	-12	-13	-15	-21	-28	-35	-42	-48	-55	-62	-69	-75	-82	-89
50	-8	-10	-11	-12	-14	-15	-22	-29	-35	-42	-49	-56	-63	-69	-76	-83	-90
55	-8	-10	-11	-13	-14	-15	-22	-29	-36	-43	-50	-57	-63	-70	-77	-84	-91
60	-9	-10	-12	-13	-14	-16	-23	-30	-36	-43	-50	-57	-64	-71	-78	-85	-92
65	-9	-10	-12	-13	-15	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
70	-9	-11	-12	-14	-15	-16	-23	-30	-37	-44	-51	-58	-65	-72	-80	-87	-94
75	-10	-11	-12	-14	-15	-17	-24	-31	-38	-45	-52	-59	-66	-73	-80	-87	-94
80	-10	-11	-13	-14	-15	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
85	-10	-11	-13	-14	-16	-17	-24	-31	-39	-46	-53	-60	-67	-74	-81	-89	-96
90	-10	-12	-13	-15	-16	-17	-25	-32	-39	-46	-53	-61	-68	-75	-82	-89	-96
95	-10	-12	-13	-15	-16	-18	-25	-32	-39	-47	-54	-61	-68	-75	-83	-90	-97
100	-11	-12	-14	-15	-16	-18	-25	-32	-40	-47	-54	-61	-69	-76	-83	-90	-98
105	-11	-12	-14	-15	-17	-18	-25	-33	-40	-47	-55	-62	-69	-76	-84	-91	-98
110	-11	-12	-14	-15	-17	-18	-26	-33	-40	-48	-55	-62	-70	-77	-84	-91	-99

0 to -10 Low | -10 to -25 Moderate | -25 to - 45 Cold | -45 to -59 Extreme | -60 Plus very Extreme

Computational Materiality for Sustainable Architectures and Comprehensive Skins

WIND, AND PASSIVE VENTILATION

For cooling, better thermal distribution and indoor air quality

- To heat/cool through thermal convection
- to refresh through the sweating acceleration
- to clean exhausted indoor air
- to prevent condensation, moisture, and germs

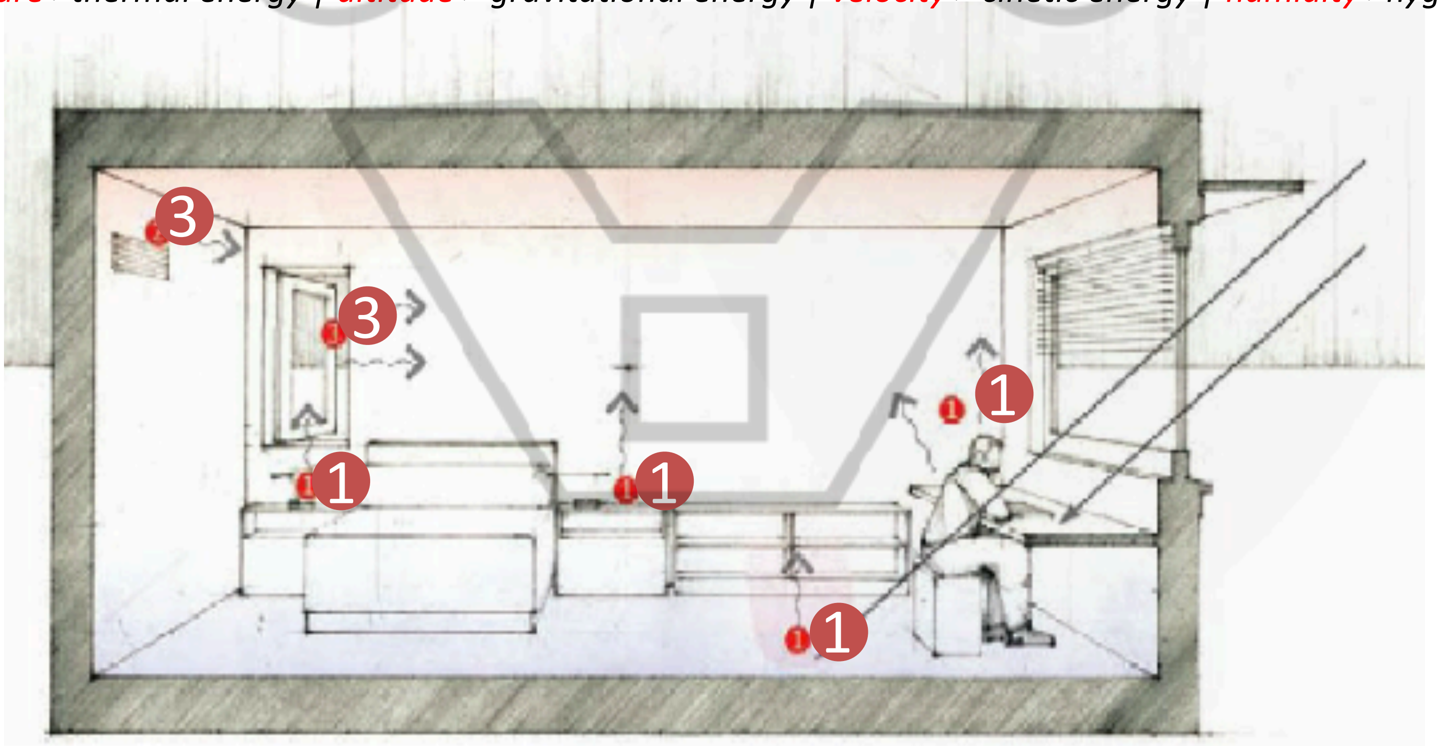
MOVIMENTO PASSIVO DELL'ARIA NEGLI EDIFICI: TIPI DI MOVIMENTI

1 **Densità *f*** *(temperatura, altitudine)* movimento verticale alto/basso (moti convettivi)

2 **Cinetica *f*** (*velocità del vento*) spinta direzionale

3 **Δ Pressione *f*** *(umidità, altitudine)* spostamento verso bassa pressione

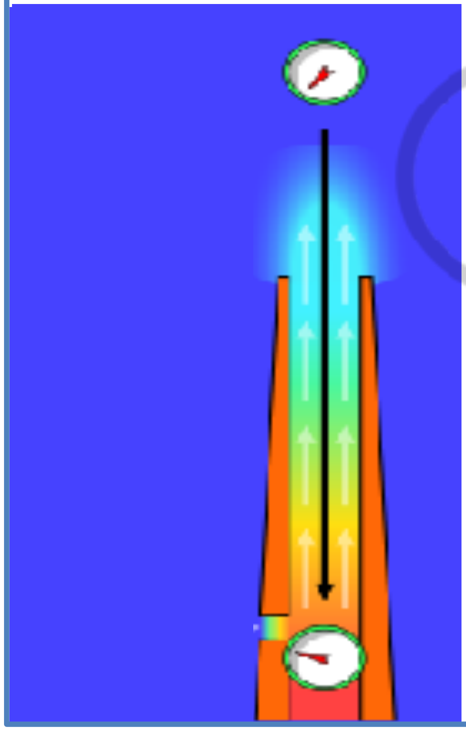
f *[temperature >thermal energy | altitude > gravitational energy | velocity > cinetic energy | humidity >hygrometry]*



1 MOVIMENTI DELL'ARIA PER DENSITA': LE CARATTERISTICHE DELL'ARIA

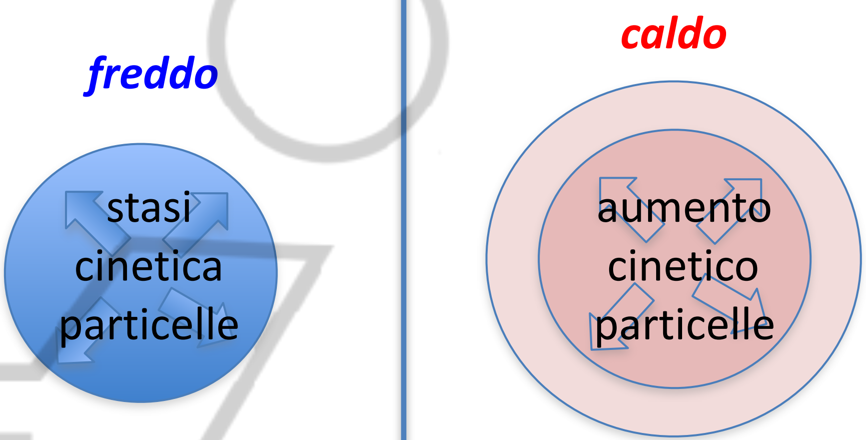
stack (or chimney) effect

Buoyancy Effect



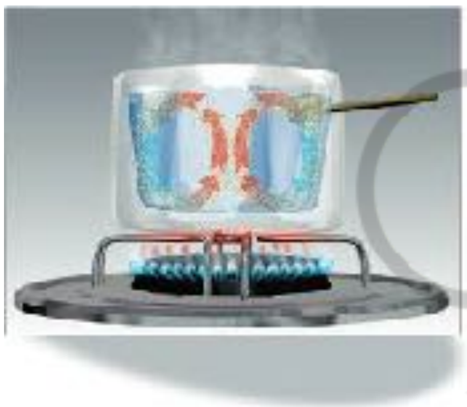
Il surriscaldamento dell'aria comporta la dilatazione del gas e conseguentemente riduzione del peso dell'aria che ne induce il movimento verso l'alto. Viceversa il suo raffreddamento provoca il fenomeno inverso

NB. Anche l'aumento di vapore acqueo comporta una diminuzione di peso in quanto la sua densità è minore degli altri gas che compongono l'aria

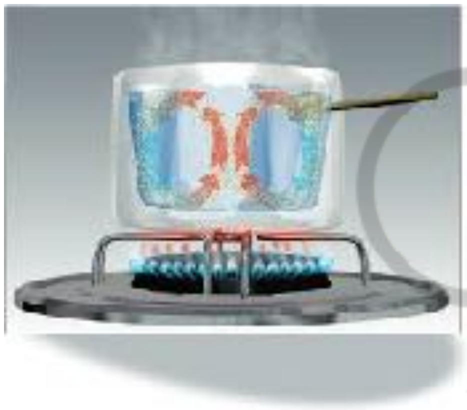


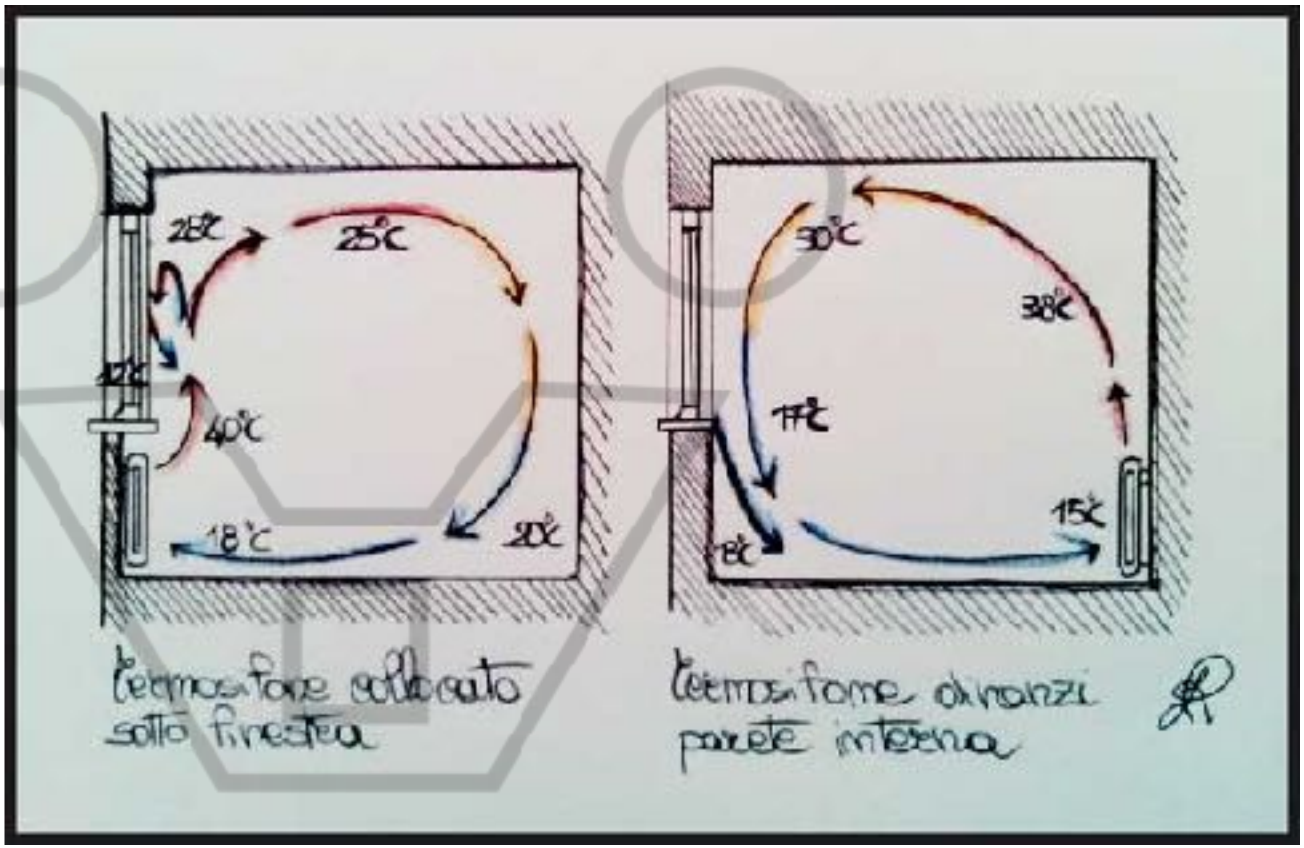
	freddo	caldo
TEMPERATURA:	*bassa*	*alta*
DENSITA':	*alta*	*bassa*
PRESSIONE CINETICA:	*bassa*	*alta*

1 MOVIMENTI DELL'ARIA PER **DENSITA'**: I MOTI CONVETTIVI INTERNI



1 MOVIMENTI DELL’ARIA PER **DENSITA’**: **I MOTI CONVETTIVI INTERNI**

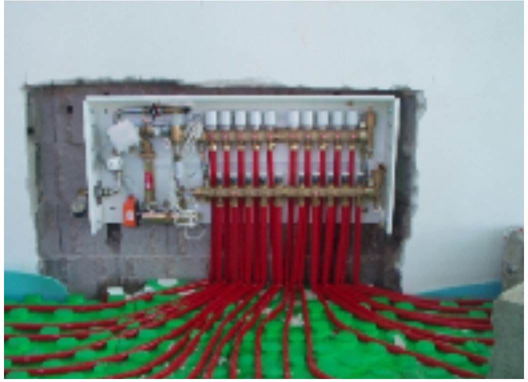


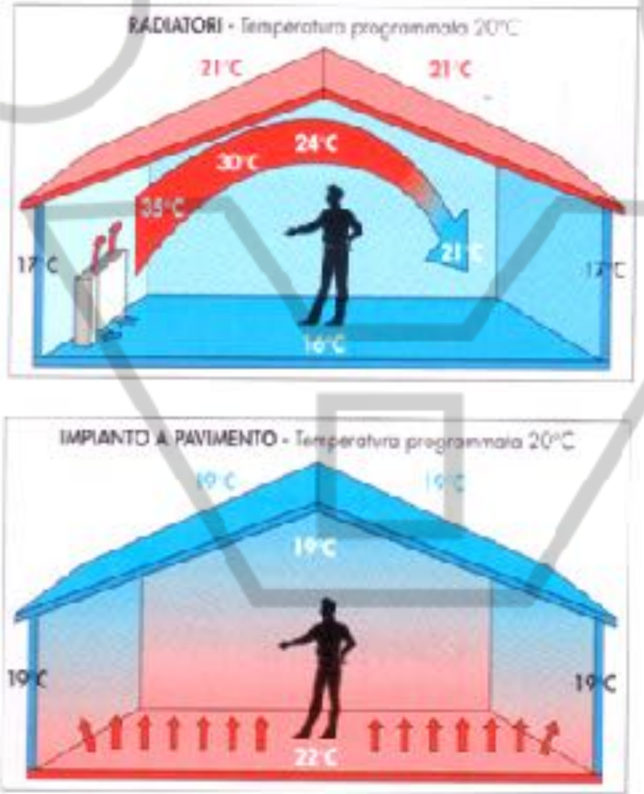


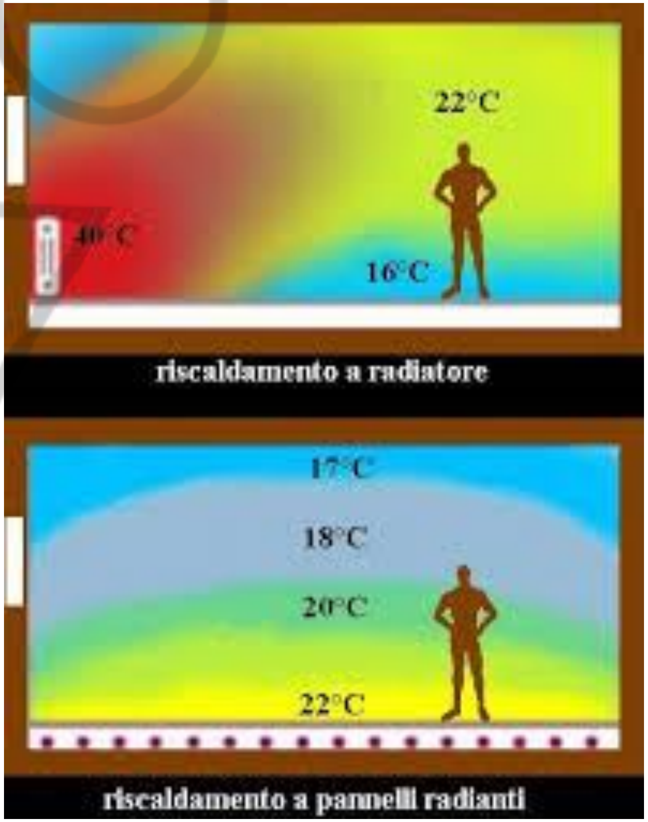
1 MOVIMENTI DELL'ARIA PER DENSITA': I MOTI CONVETTIVI INTERNI

il sistema a pavimenti radianti garantisce una più omogenea distribuzione delle temperature interne

HEATING







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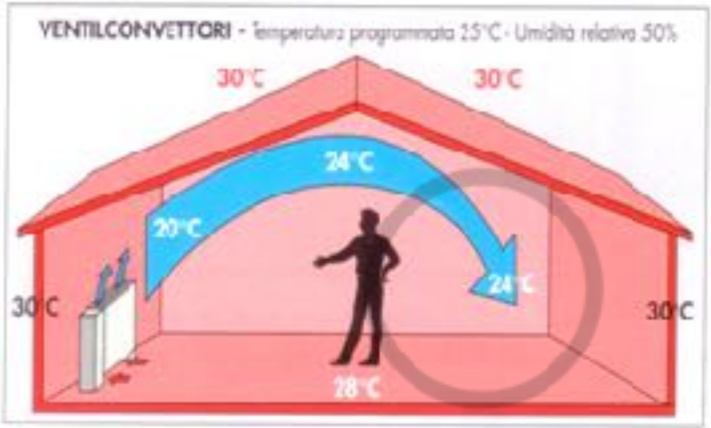
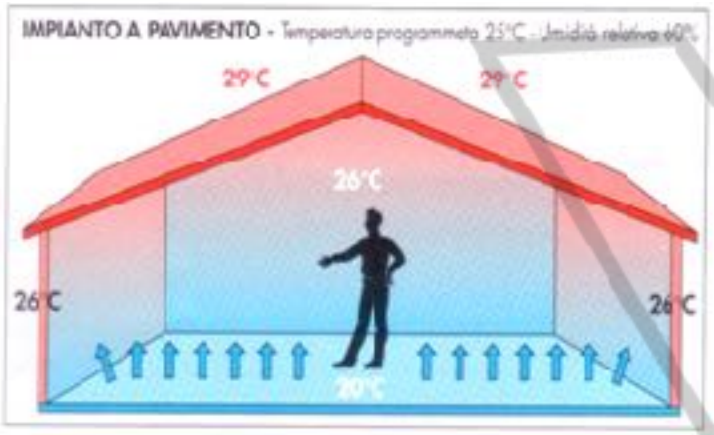
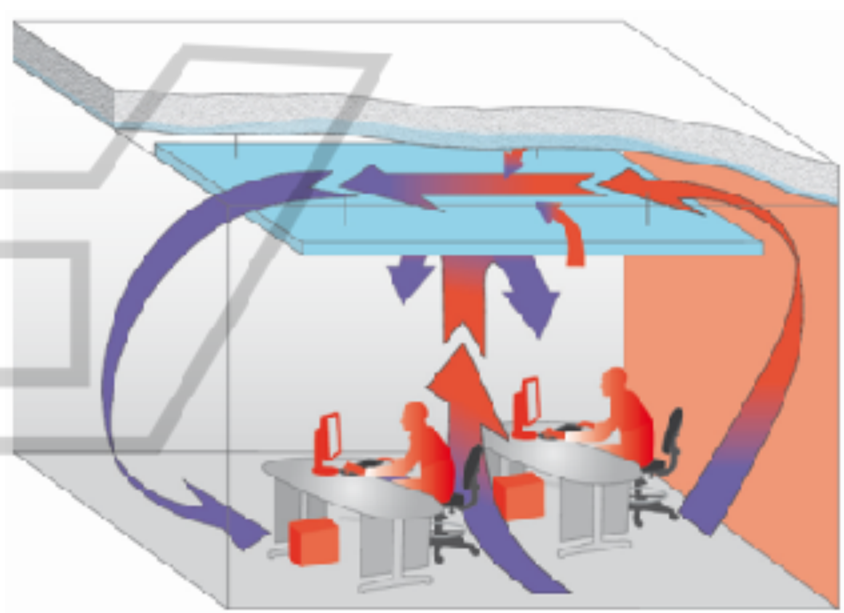


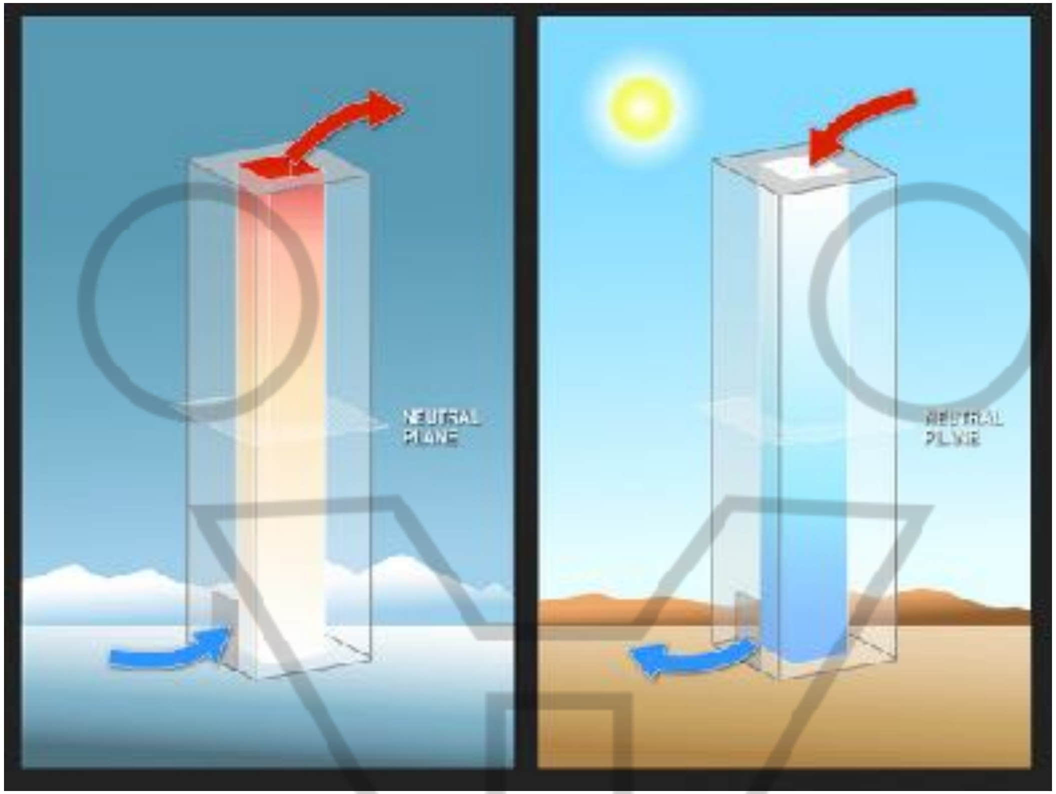


COOLING



Sistema raffreddamento a piastra radiante

1 MOVIMENTI DELL'ARIA PER **DENSITA'**: **EFFETTI CAMINO**



winter time

– Air within a building acts like a bubble of hot air in a sea of cold air
– Rises to the top
– Draws outdoor air in from cracks/ gaps/openings in the bottom
– Indoor air flows out through openings in the top

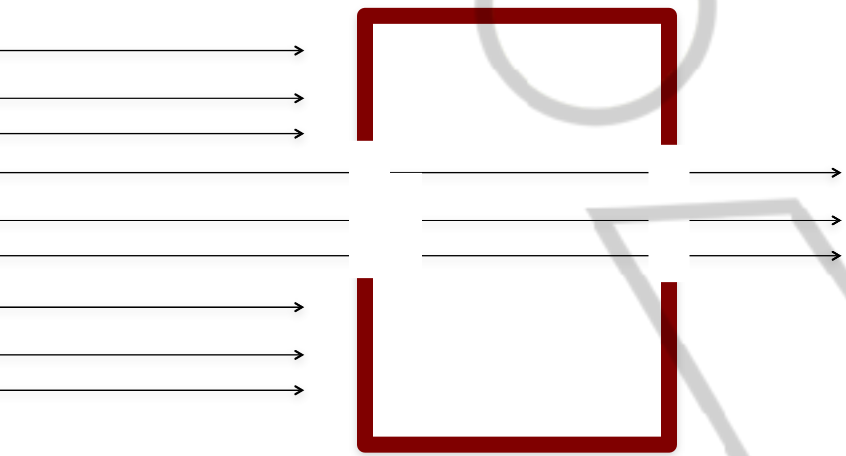
summer time

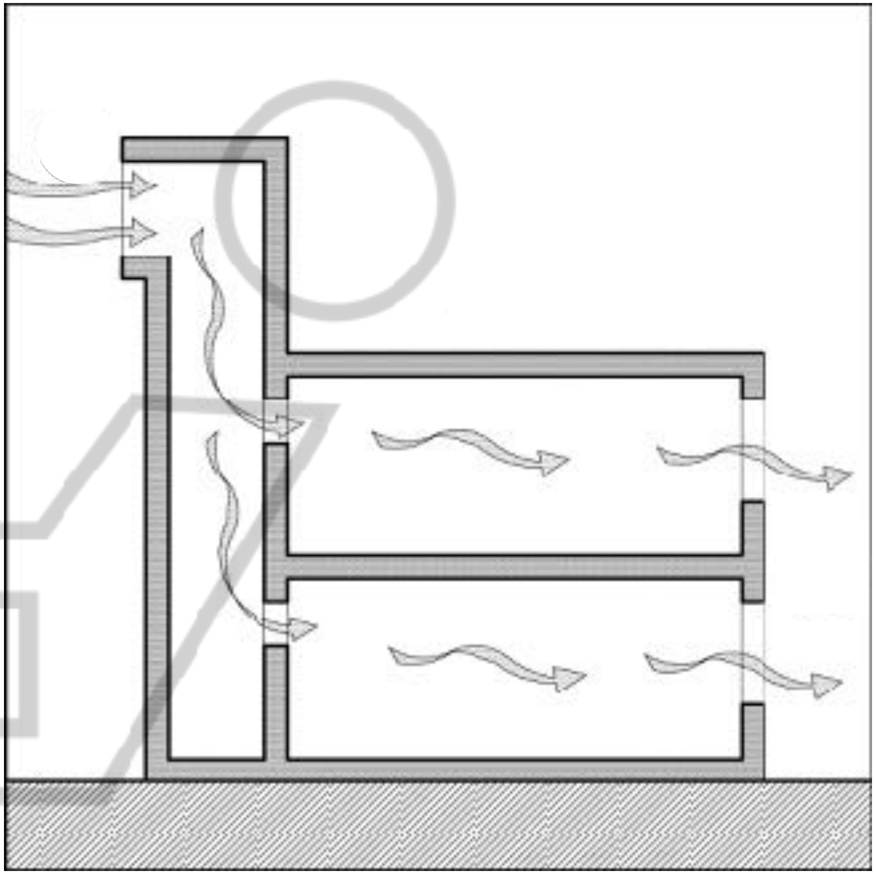
– Air within a building acts like a bubble of cold air in a sea of hot air – Falls to the bottom
– Drives indoor air out through cracks/gaps/ openings in bottom – Outdoor air is drawn in through openings in the top

- Temperature differences usually lower in the summer time so the amount of flow is smaller

2 MOVIMENTI DELL'ARIA PER CINETICA: LA SPINTA DEI VENTI

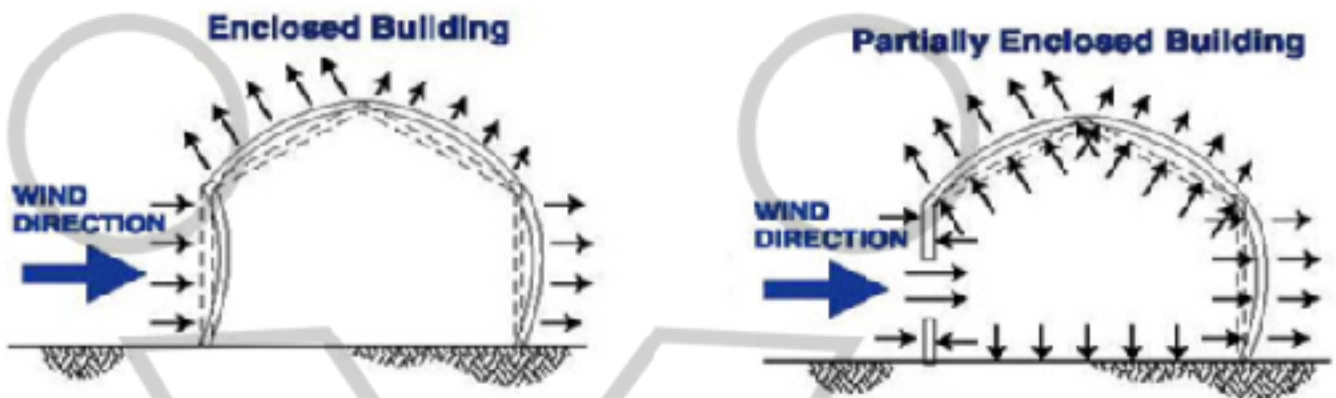
Cinetica *f* (velocità del vento) spinta direzionale



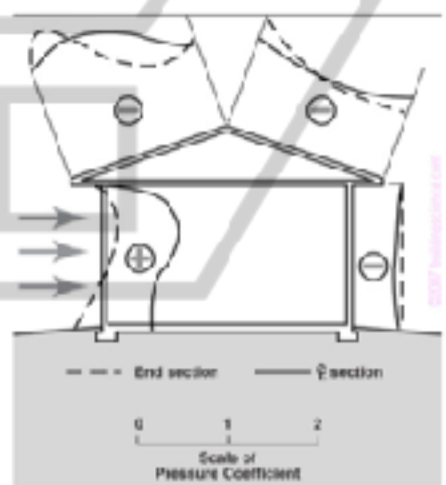


2 MOVIMENTI DELL'ARIA PER CINETICA: LA SPINTA DEI VENTI

Wind pressure coefficients (C_p) vary around buildings



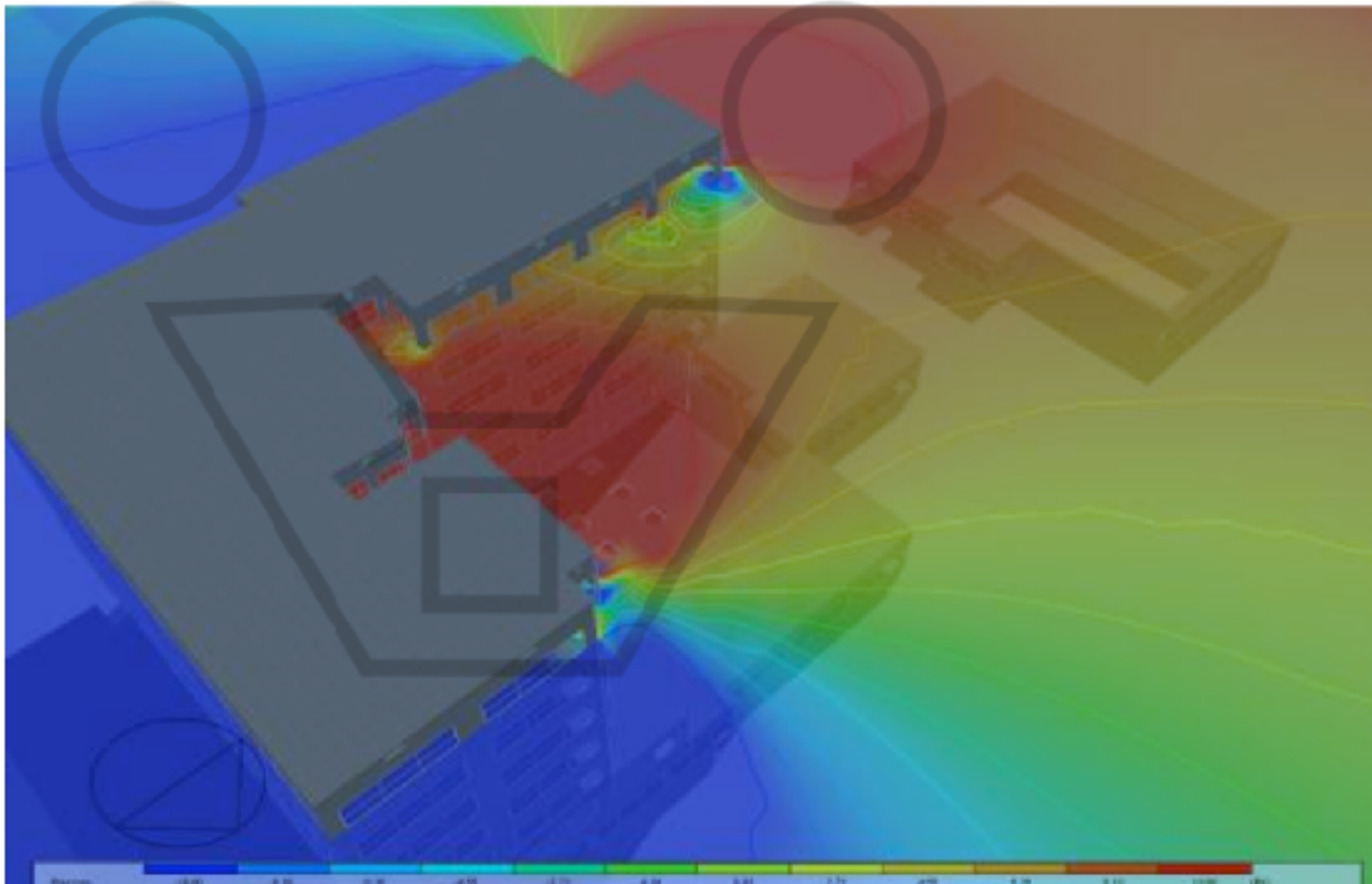
http://seblog.strongtie.com/wp-content/uploads/2013/02/Wind-Pressure-Figure.jpg



https://buildingscience.com/documents/digests/bsd-109-pressures-in-buildings

2 MOVIMENTI DELL'ARIA PER CINETICA: **LA SPINTA DEI VENTI**

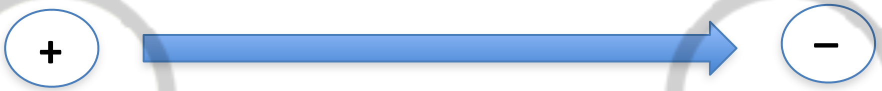
Wind pressure coefficients (C_p) vary around buildings

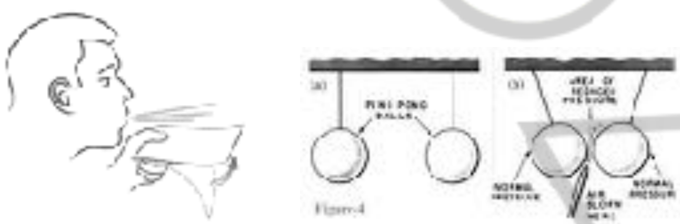


3 MOVIMENTI DELL'ARIA PER PRESSIONE: CAUSE/EFFETTI DEI DIFFERENZIALI DI PRESSIONE

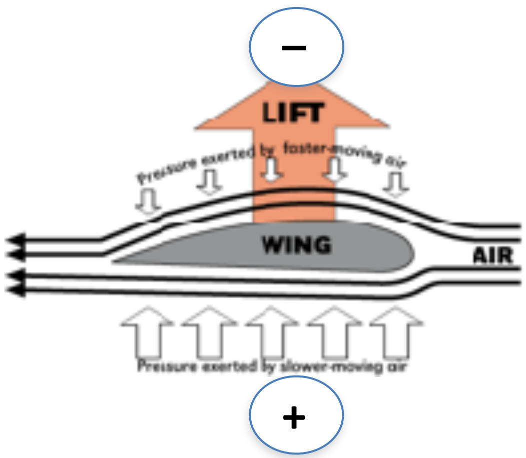
Δ Pressione ***f*** *(velocità, altitudine) spostamenti verso la bassa pressione*

FROM HIGHER PRESSURE **TO LOWER PRESSURE**

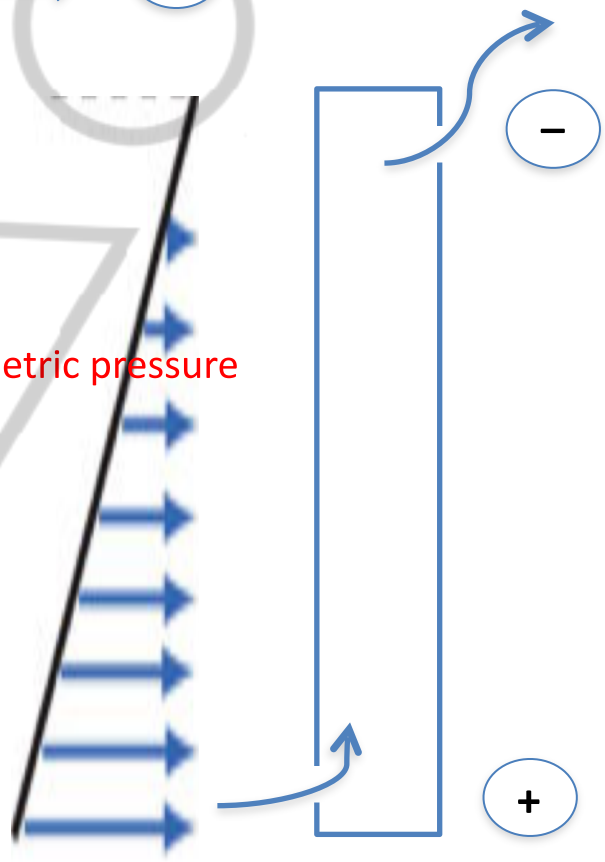




Bernoulli principle= higher speed lower pressure

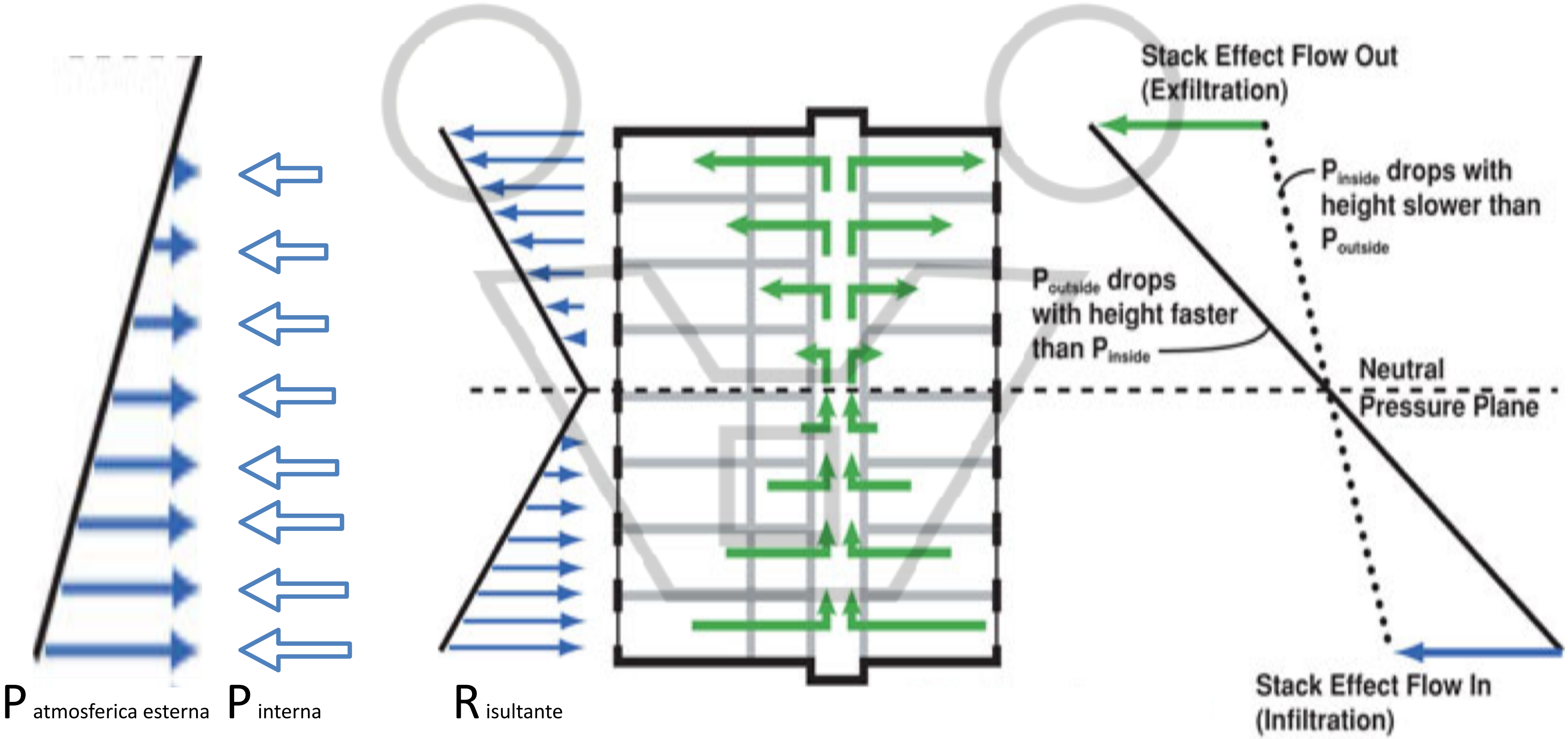


Barometric pressure



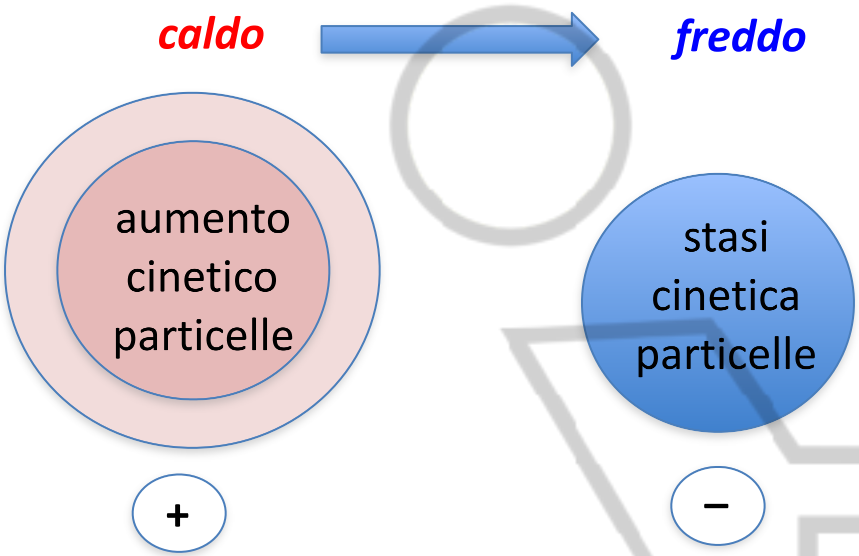
3 MOVIMENTI DELL'ARIA PER **PRESSIONE**: **DINAMICHE NEGLI EDIFICI**

- The stack effect is magnified in taller buildings

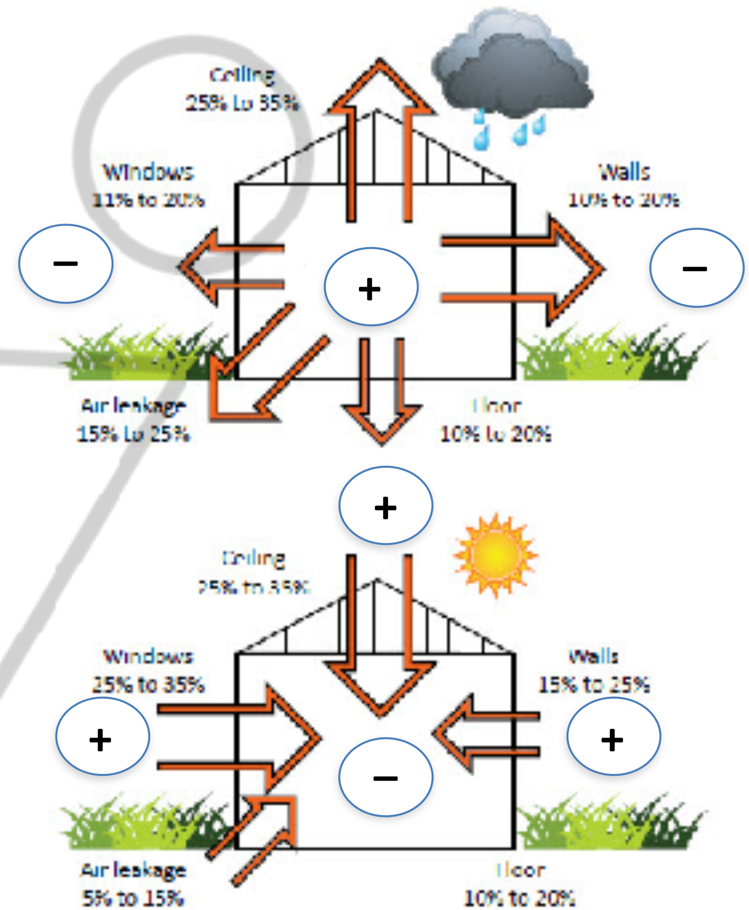


❸ MOVIMENTI DELL’ARIA PER **PRESSIONE**: **DINAMICHE NEGLI EDIFICI**

MOVIMENTO ARIA

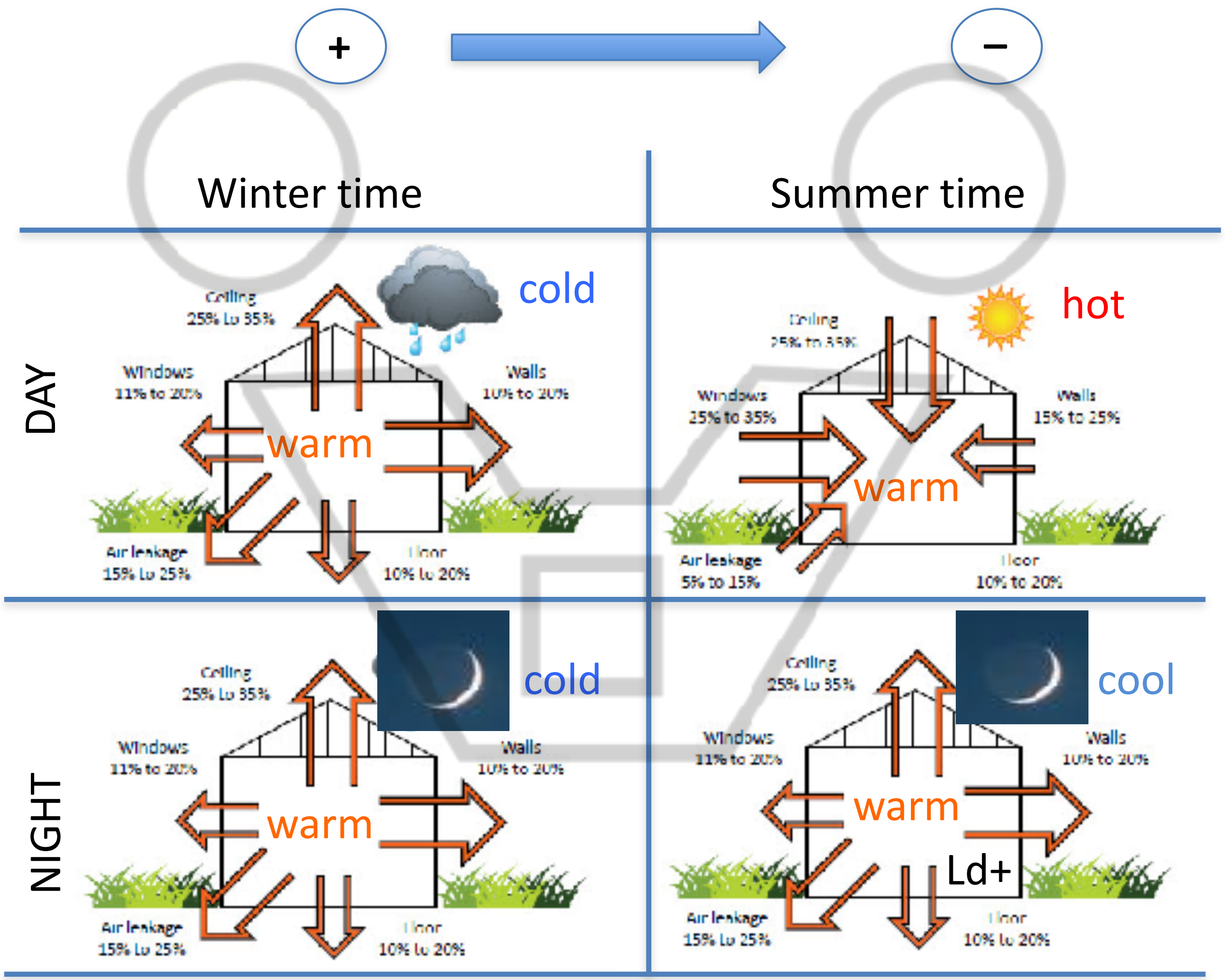


alta PRESSIONE CINETICA *bassa*

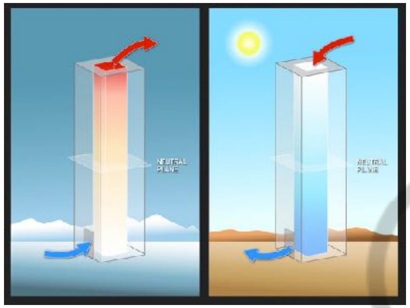


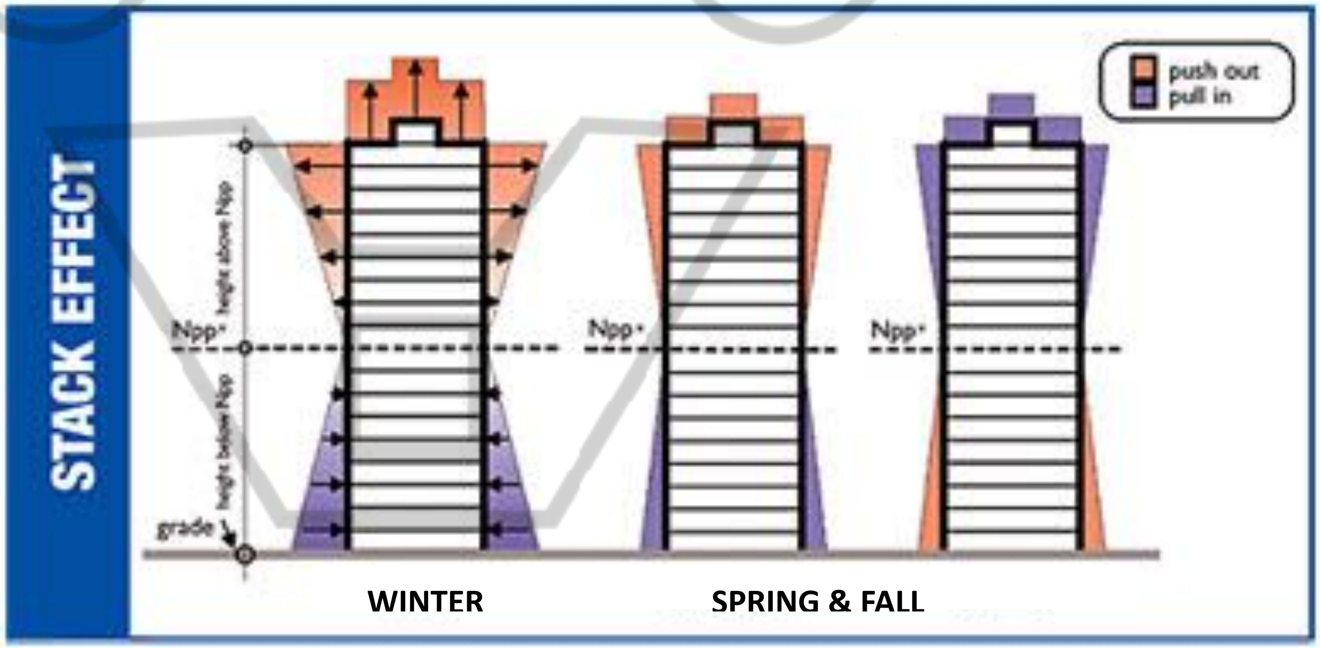
3 MOVIMENTI DELL'ARIA PER **PRESSIONE**: **DINAMICHE NEGLI EDIFICI**

FROM HIGHER PRESSURE **TO LOWER PRESSURE**



3 MOVIMENTI DELL'ARIA PER PRESSIONE: **DINAMICHE NEGLI EDIFICI**

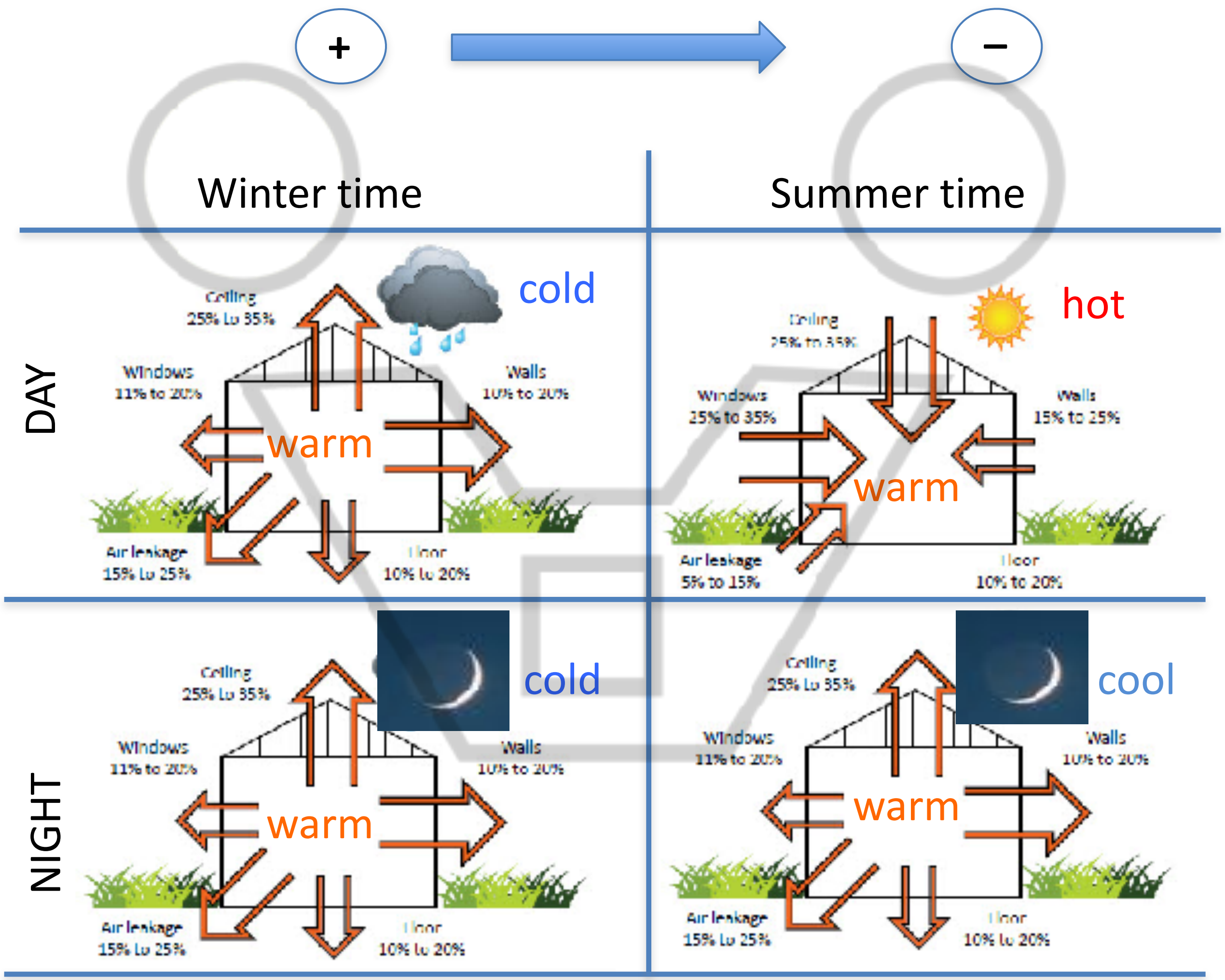




*Npp = Neutral pressure plane

3 MOVIMENTI DELL'ARIA PER **PRESSIONE**: **DINAMICHE NEGLI EDIFICI**

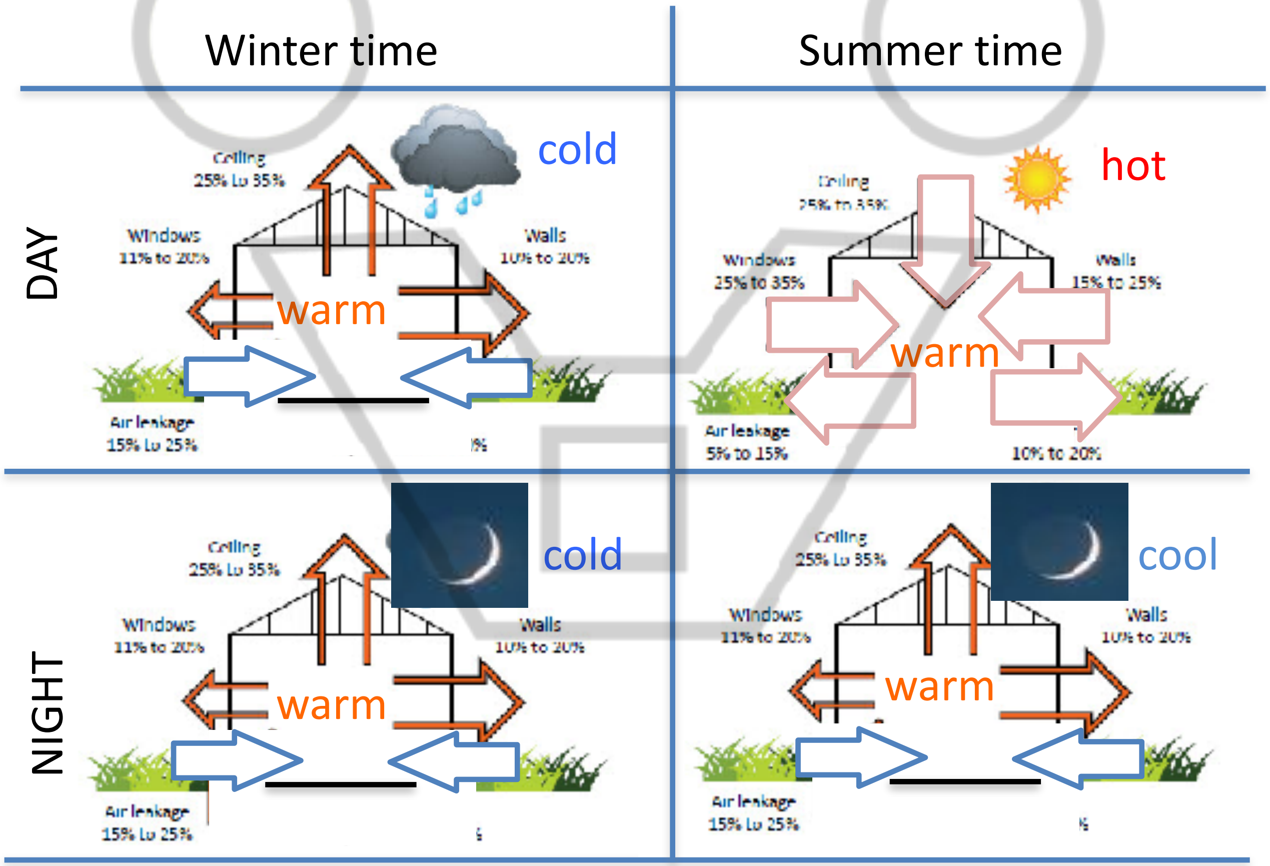
FROM HIGHER PRESSURE **TO LOWER PRESSURE**



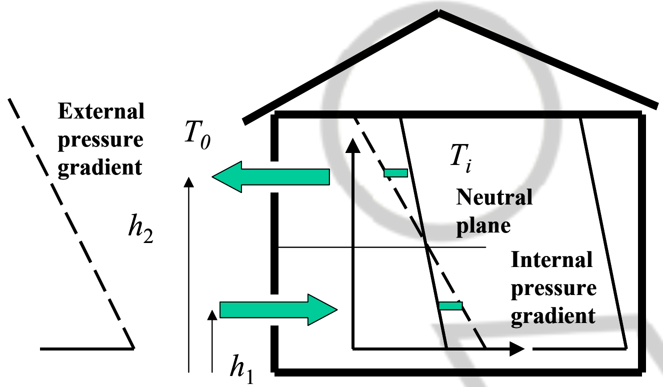
3 MOVIMENTI DELL'ARIA PER **PRESSIONE**: **DINAMICHE NEGLI EDIFICI**

FROM HIGHER PRESSURE **TO LOWER PRESSURE**

+ → −

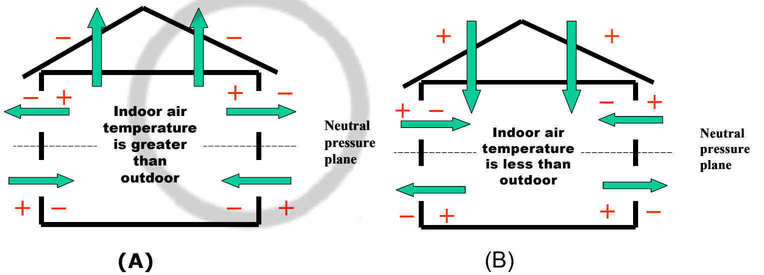


Concept of the neutral level



26

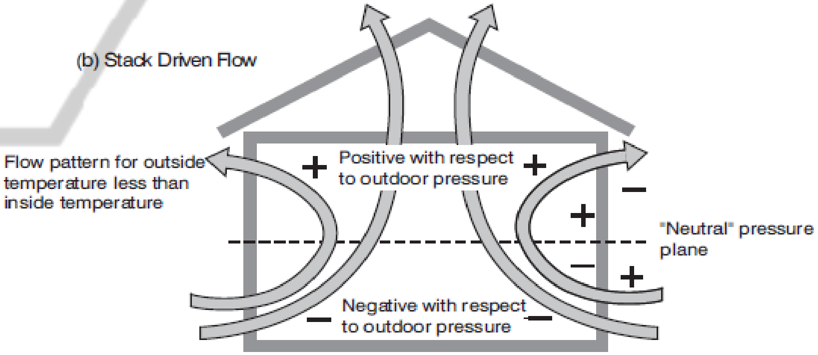
Stack driving flows in a building



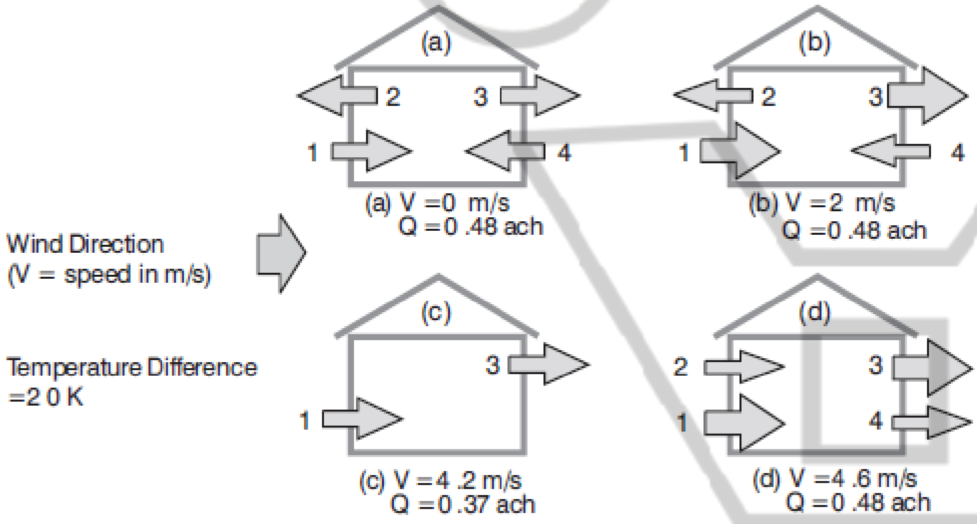
Indoor air warmer than outdoor

Indoor air cooler than outdoor

32



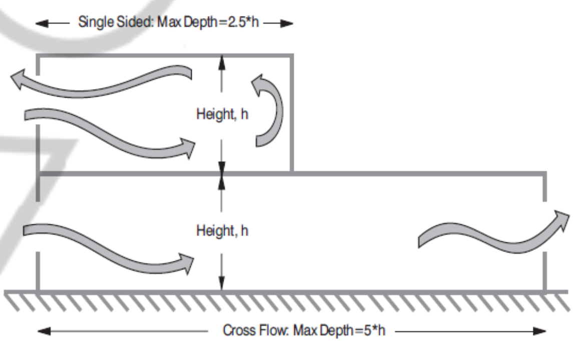
Influence of wind and temperature (stack effect) on ventilation and air flow pattern



Influence of wind and temperature (stack effect) on ventilation rate and air flow pattern

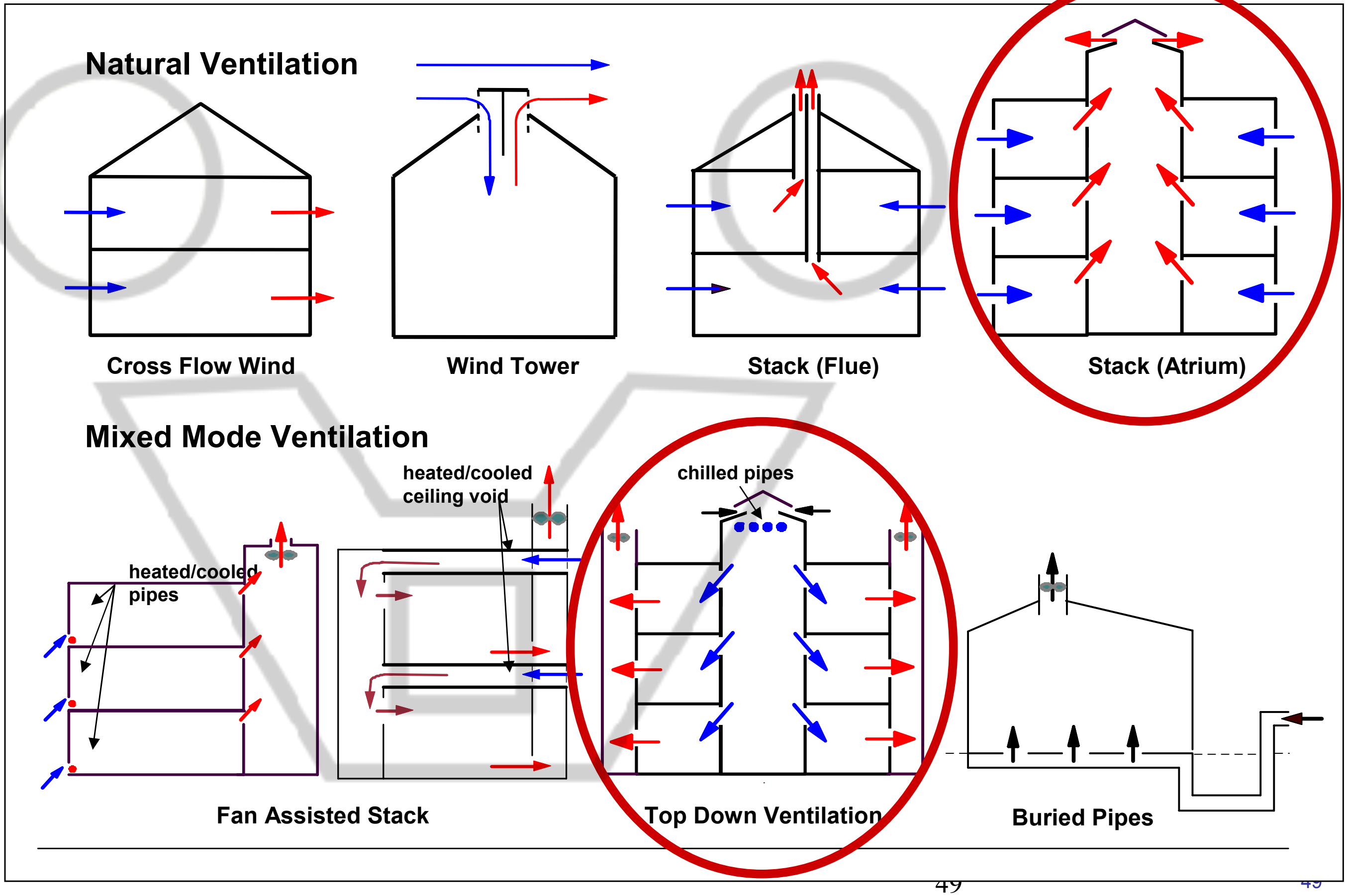
Cross flow ventilation

(source: AIVC, 2009)



Wind & Passive Ventilation

Natural and Mixed Mode Ventilation Mechanisms



Courtesy of Martin Liddament via Yuguo Li

3 MOVIMENTI DELL'ARIA PER **PRESSIONE**: **CAUSE COMBINATE**

"Driving forces" of ventilation and infiltration: ΔP

$$\Delta P = \Delta P_{wind} + \Delta P_{stack} + \Delta P_{mech}$$

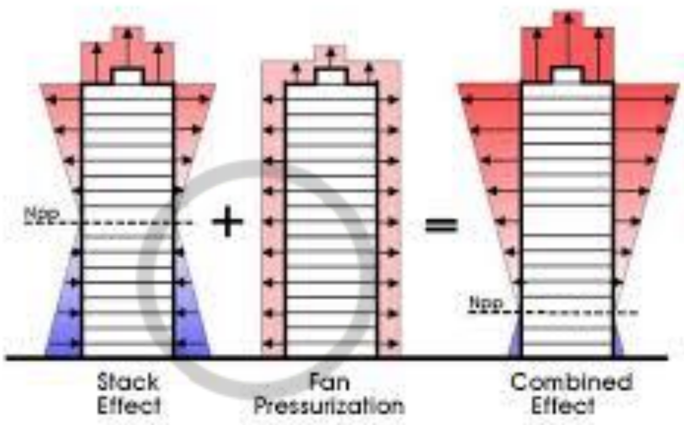
1. Three primary mechanisms generate pressure differences:

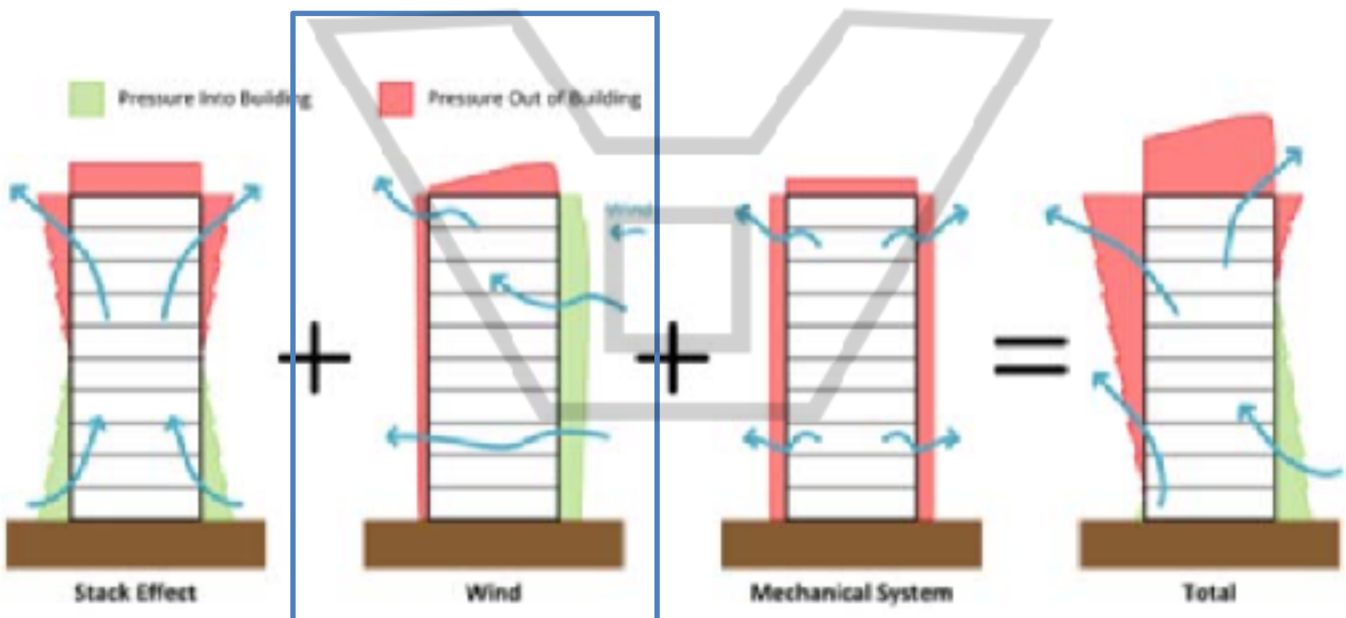
– **Wind**
- Caused by wind impinging on a building, creating a distribution of pressures on the exterior surface
- Depends on wind direction, wind speed, air density, surface orientation, and surrounding conditions

– **Stack effect (natural buoyancy)**
- Caused by the weight of a column of air located inside/outside a building
- Depends on air density and height above a neutral reference level – Density is a function of temperature (so this is temperature driven)

– **Mechanical air handling equipment (fans)**
- Fans are used to supply, recirculate, exhaust, and otherwise balance pressures and flows in buildings

❸ MOVIMENTI DELL'ARIA PER **PRESSIONE**: **CAUSE COMBINATE**

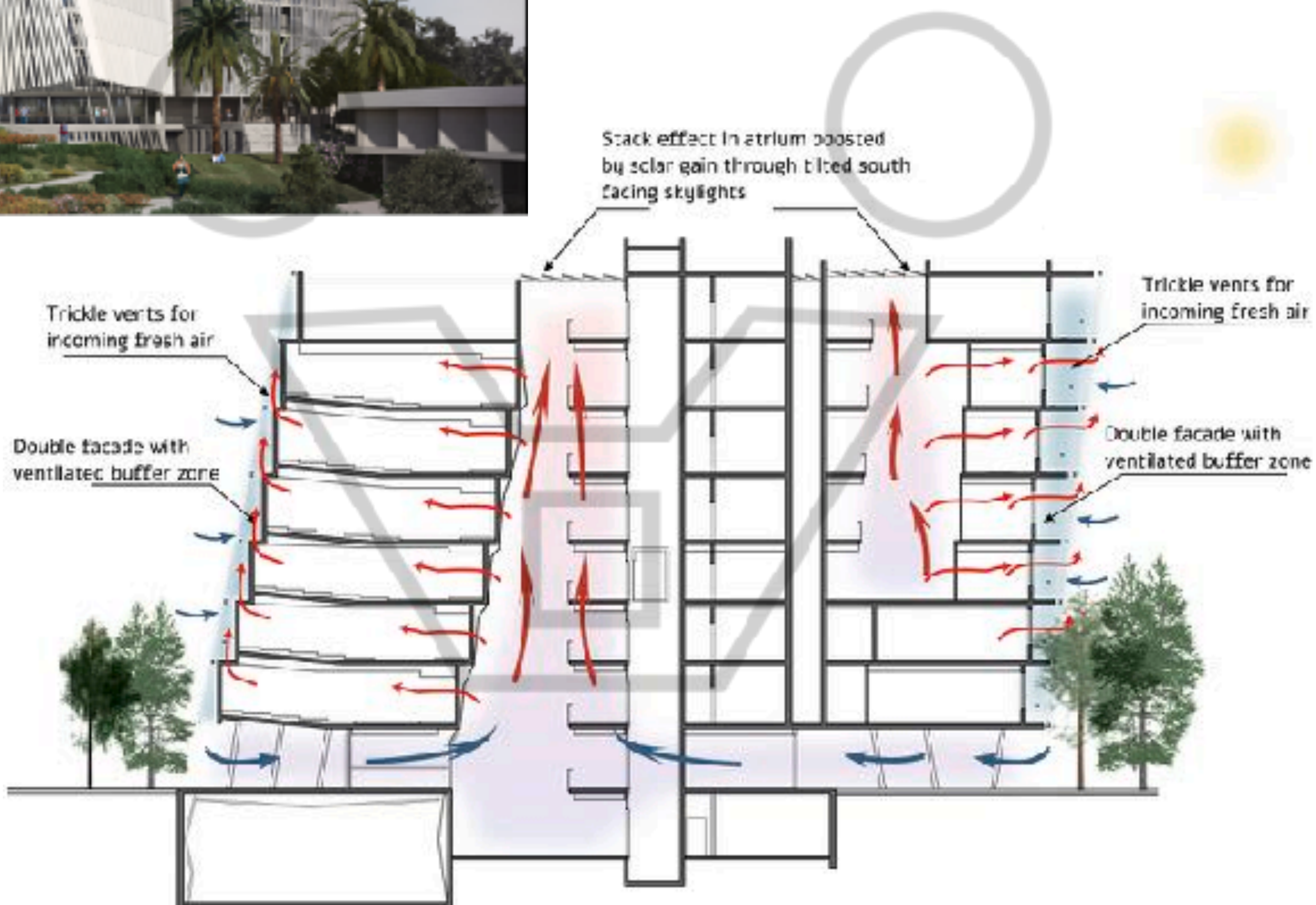




Wind & Passive Ventilation

https://www.archdaily.com

o2a Studio has unveiled their proposal for the Lorry I. Lokey School of Management at Tel Aviv University.



Climatic Diagram

Wind & Passive Ventilation

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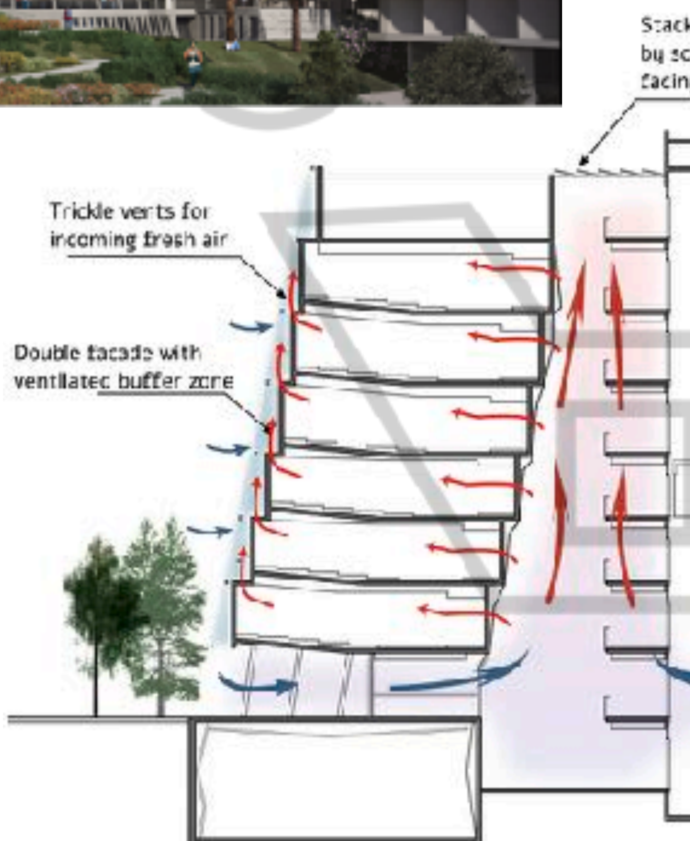
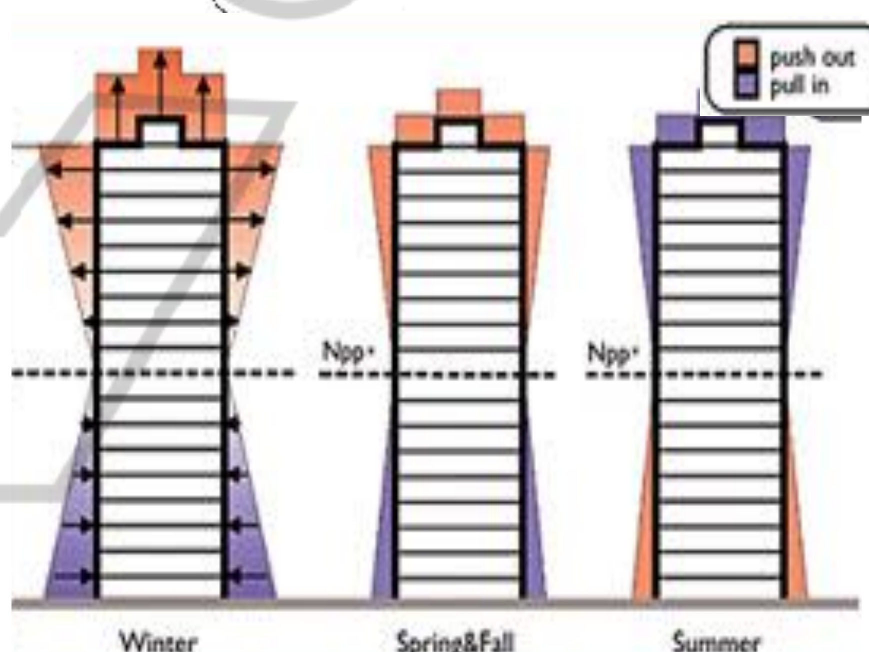


Climatic Diagram



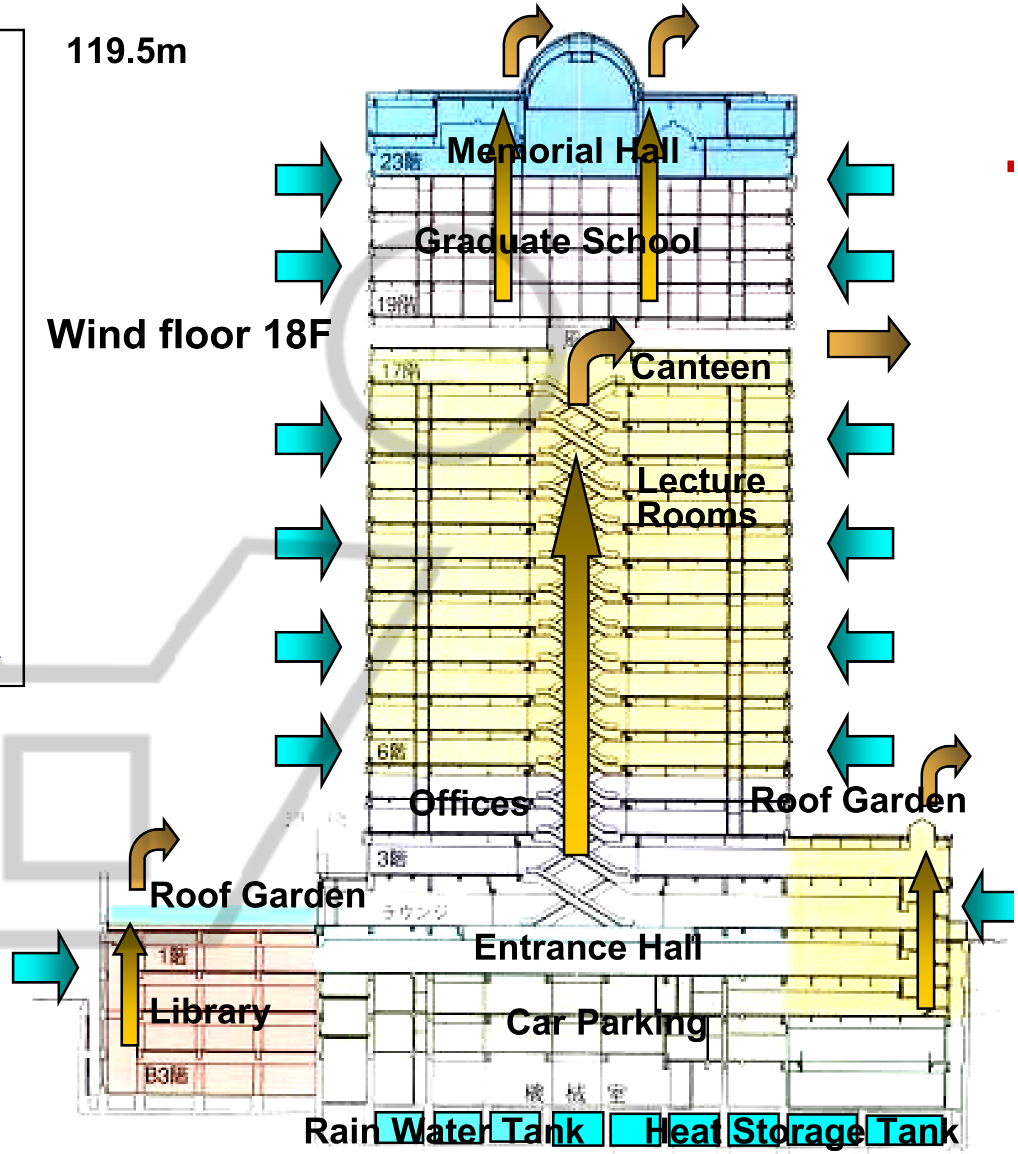
Wind & Passive Ventilation

Meiji University Liberty Tower, Tokyo, Japan
(source: Professor Toshihara Ikaga, Keio University)

Wind Floor for Hybrid Ventilation

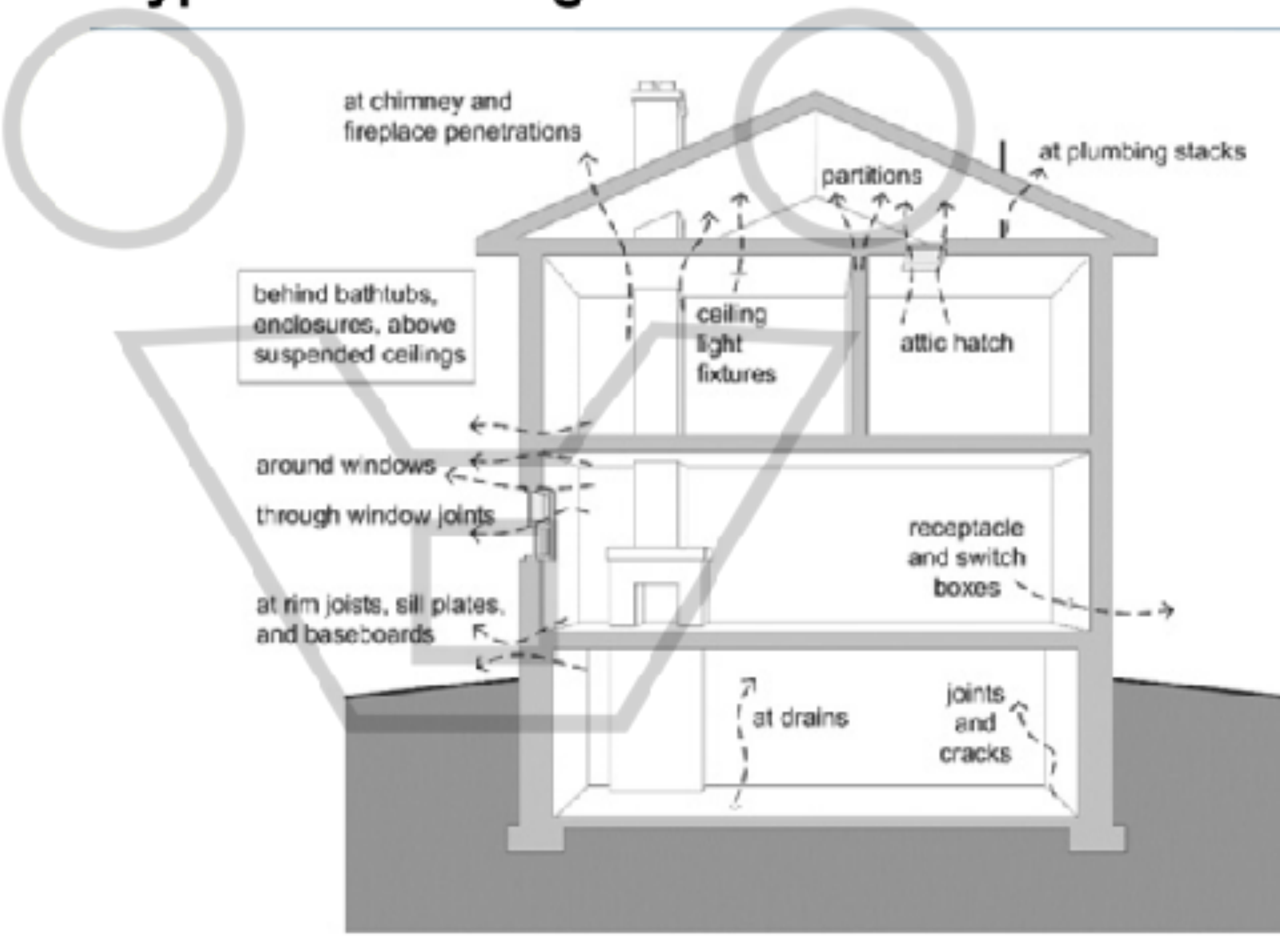
Gross Floor Area: 59000 m²
completed in 1998

34



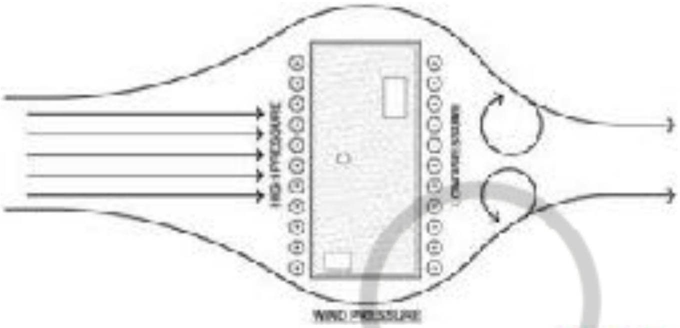
❸ MOVIMENTI DELL'ARIA PER **PRESSIONE**: **EFFETTI SULLE INFILTRAZIONI POSITIVE/NEGATIVE**

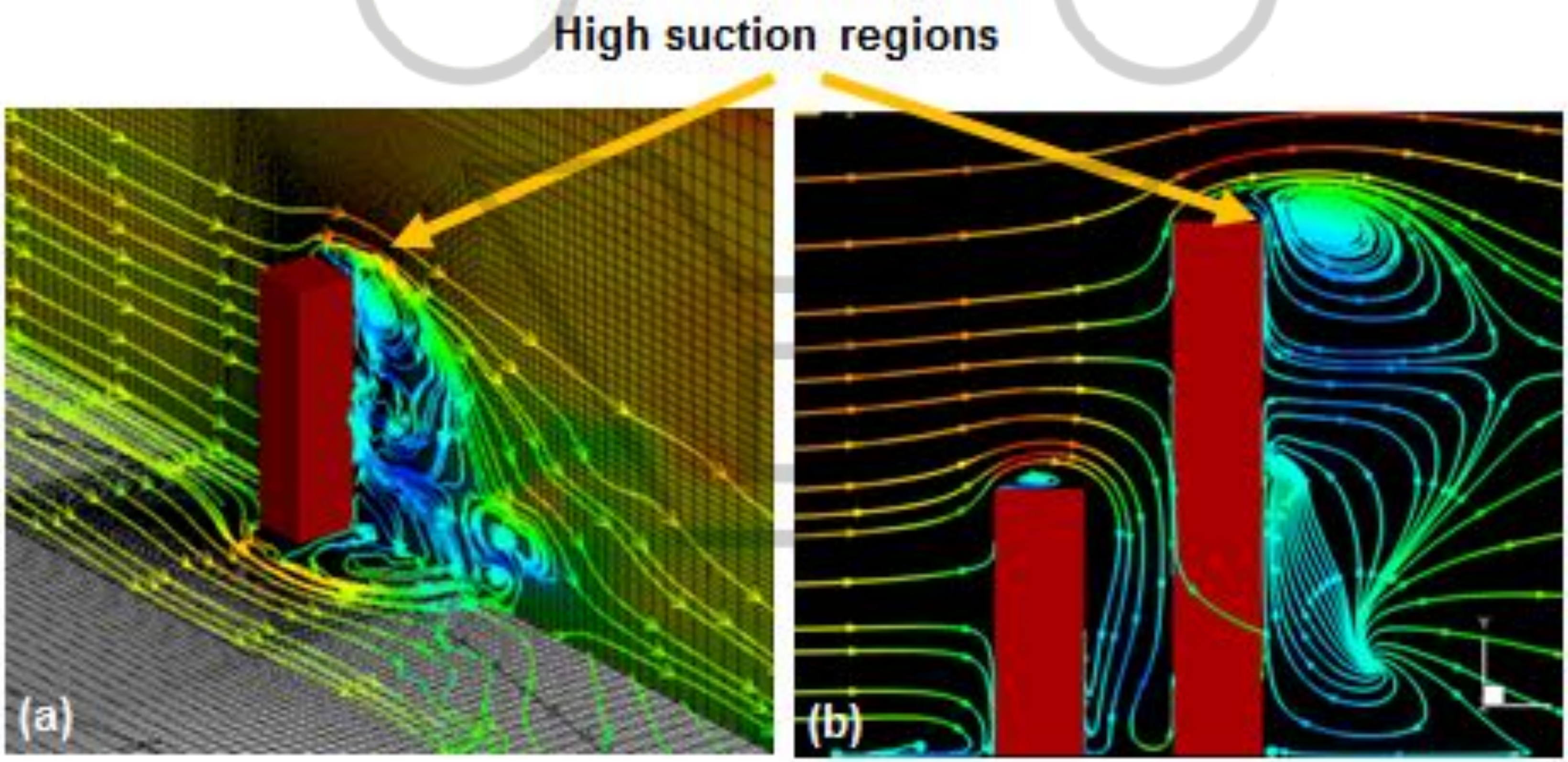
Typical air leakage sites in residential buildings



http://buildingscience.com.678elmp02.blackmesh.com/sites/default/files/migrate/jpg/Figure_07_Typical_air_leaka.jpg

WINDS & AIRFLOW MODELING

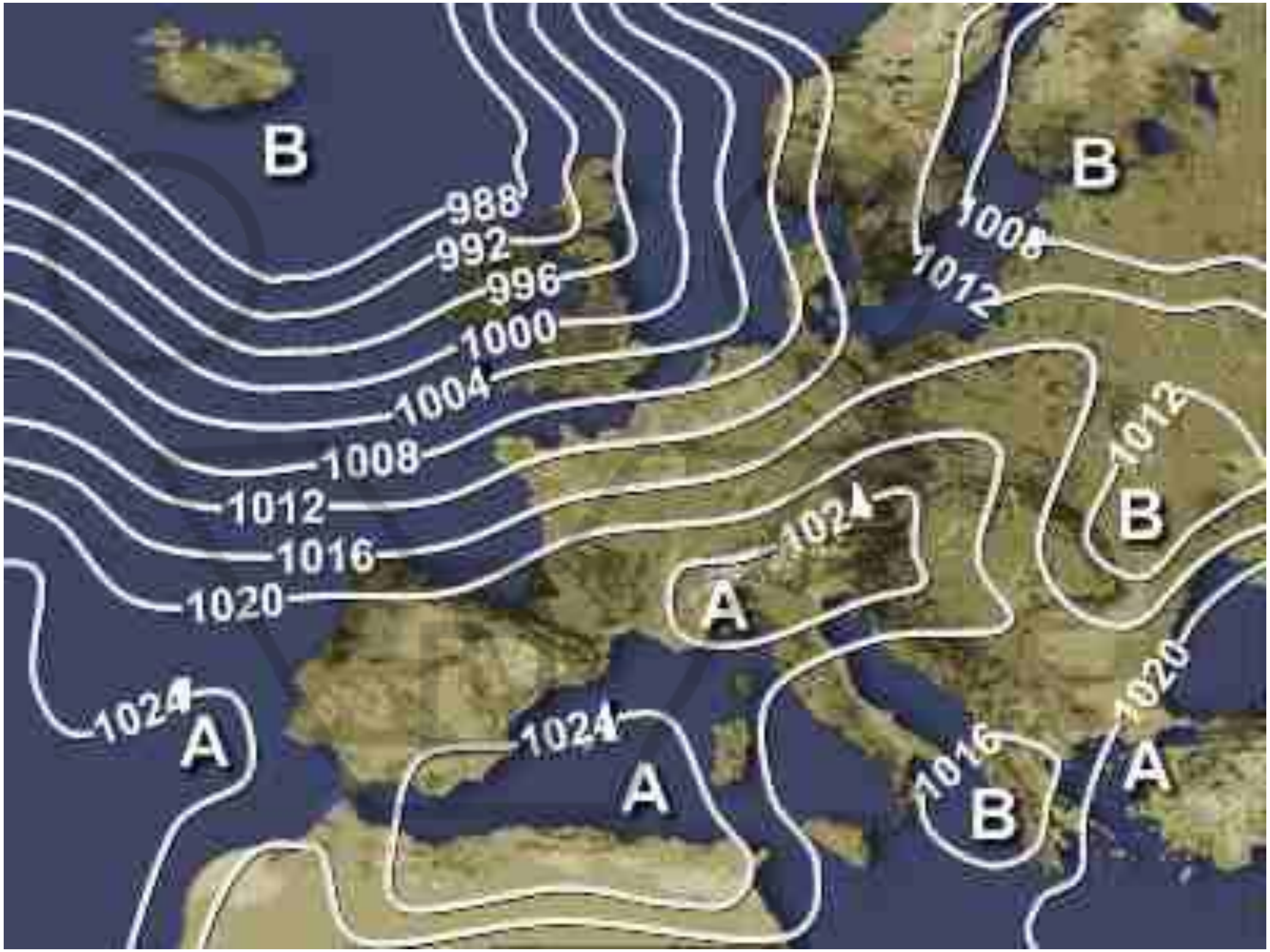




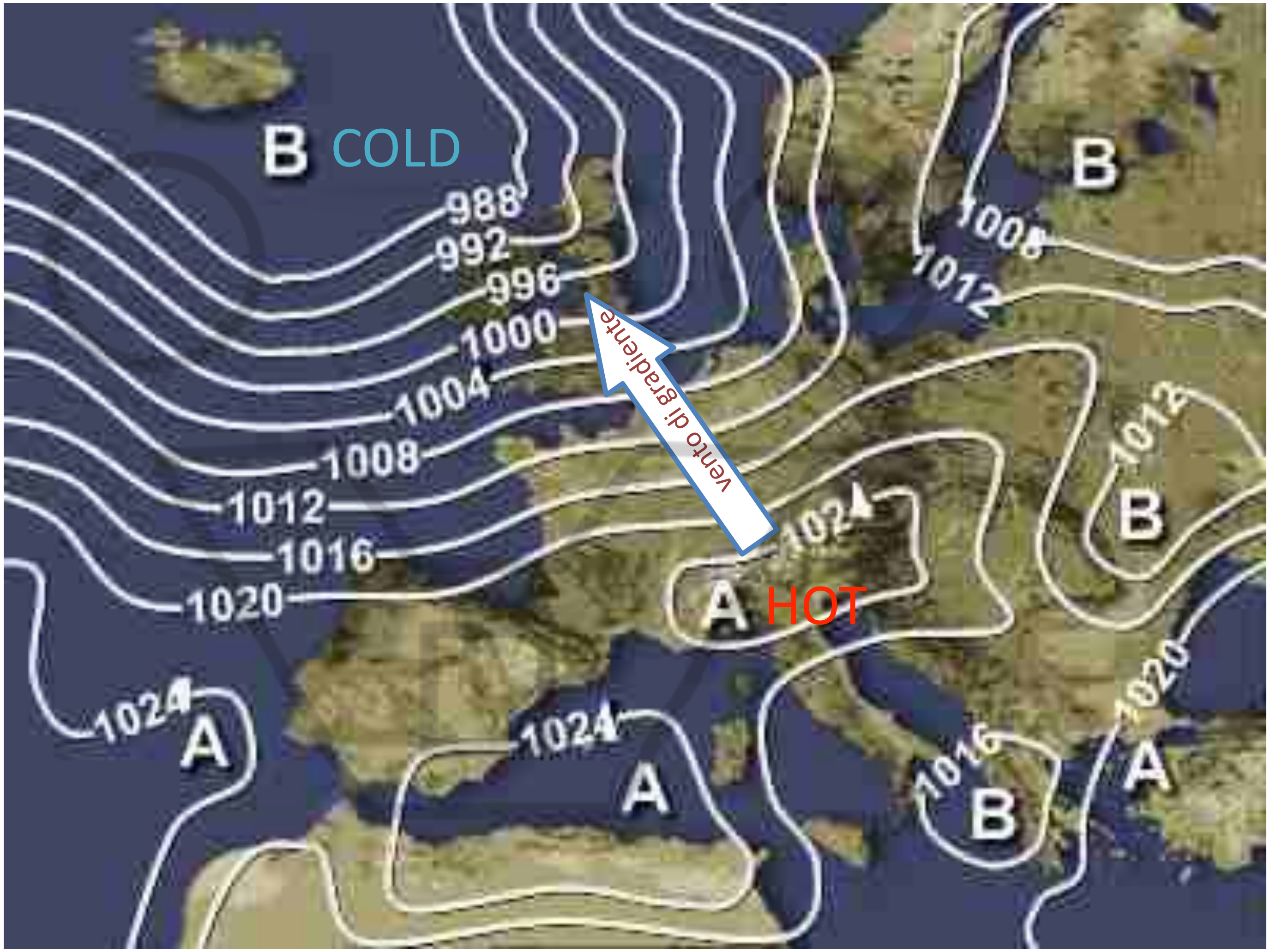
WINDS & AIRFLOW MODELING

ORIGINI E DINAMICHE DI VENTI E BREZZE

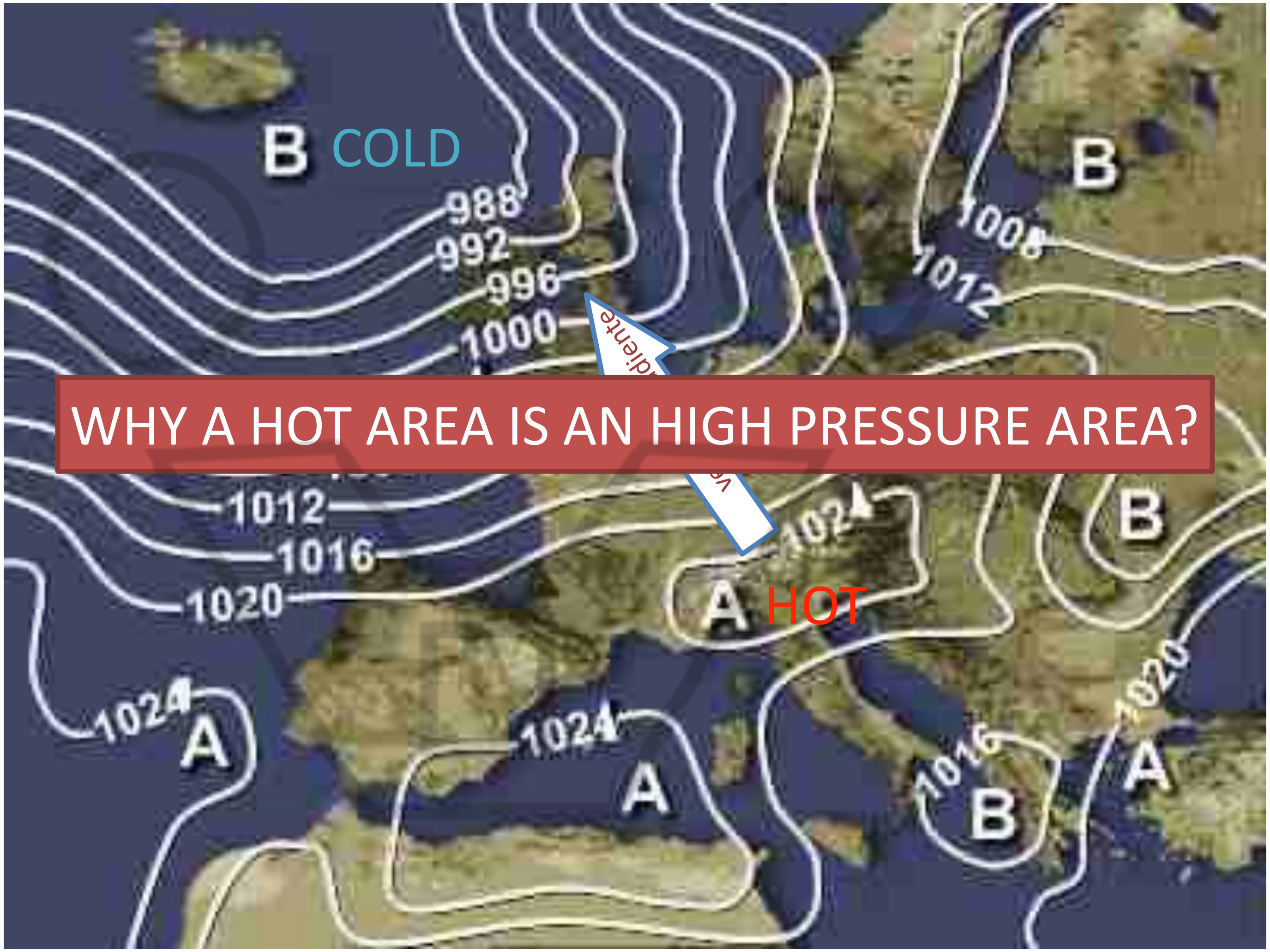
WINDS & AIRFLOW MODELING



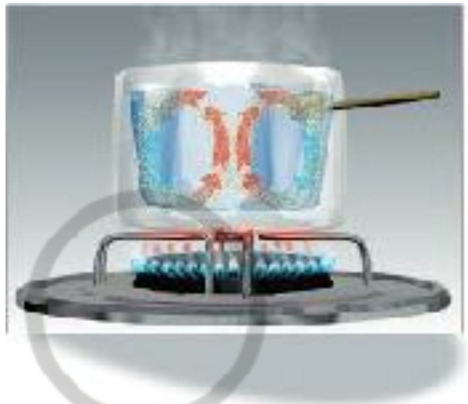
WINDS & AIRFLOW MODELING



WINDS & AIRFLOW MODELING

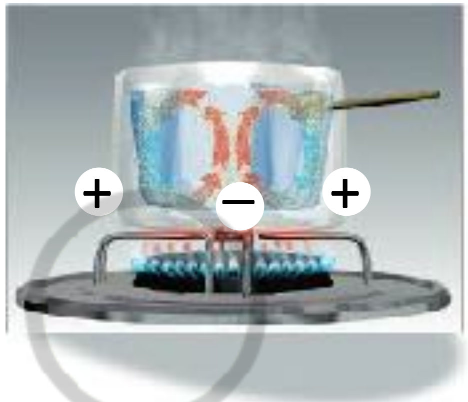


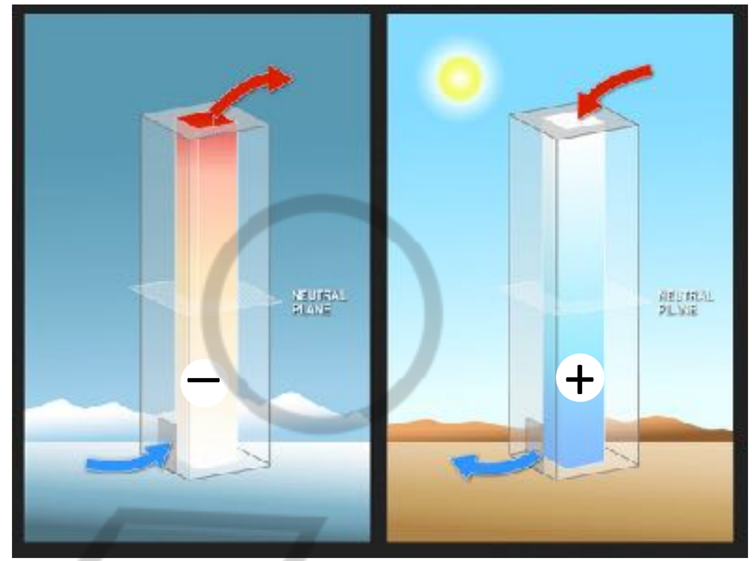
WINDS



Wind & Passive Ventilation

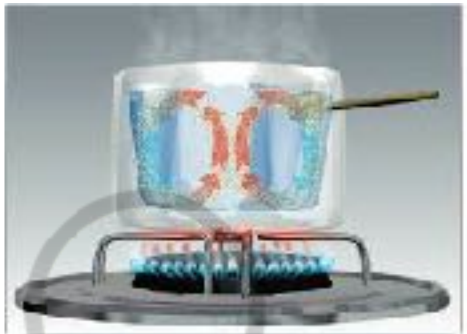
WINDS

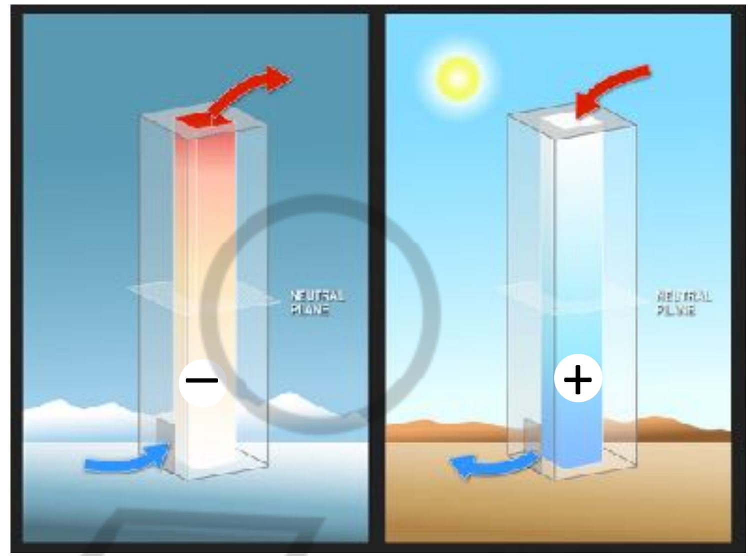


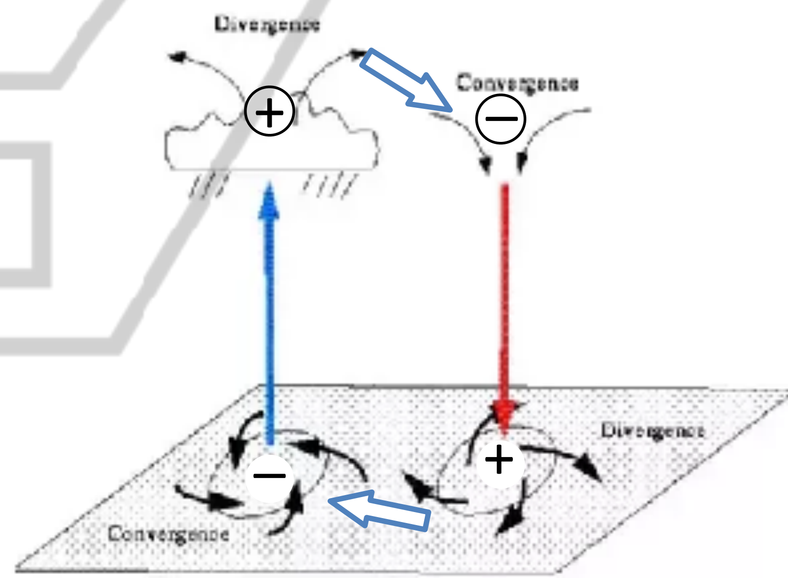


Wind & Passive Ventilation

WINDS







Circolazione ciclonica Circolazione anticiclonica

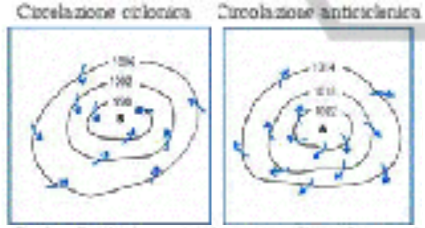
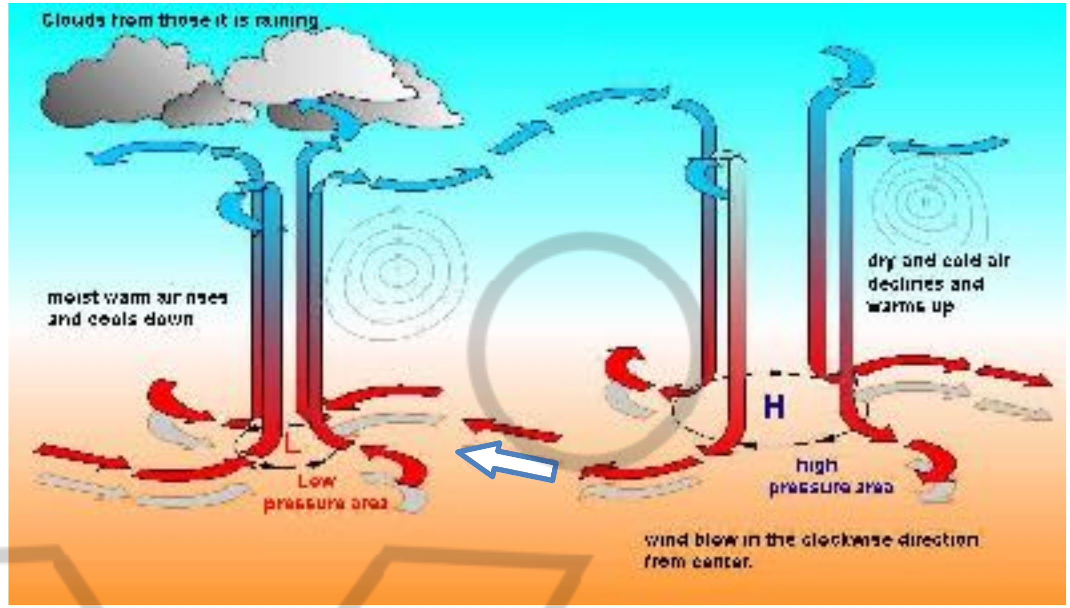
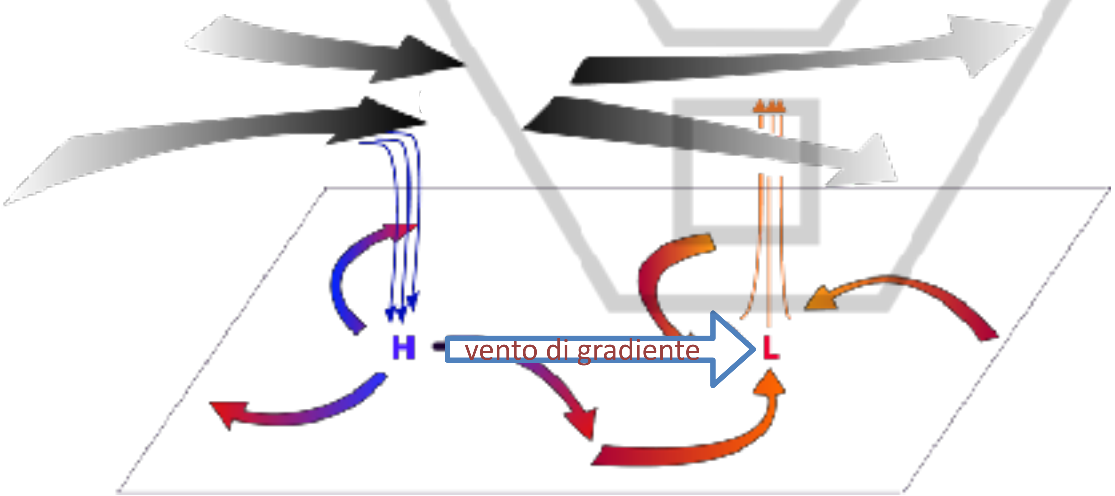


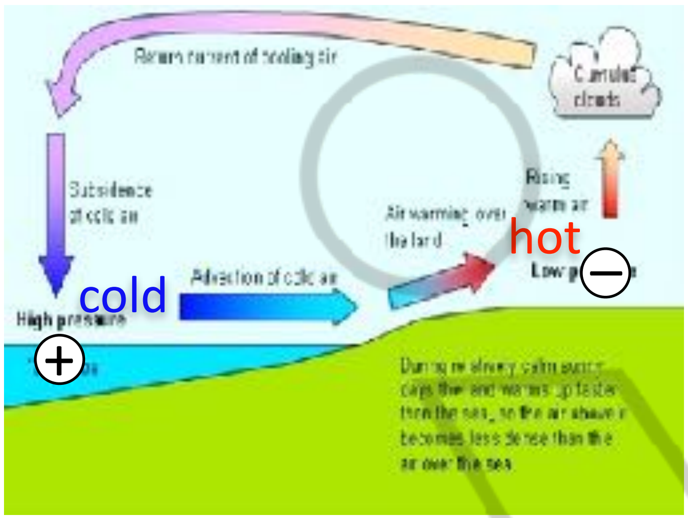
Grafico 2 - Andamento dei venti nell'emisfero nord

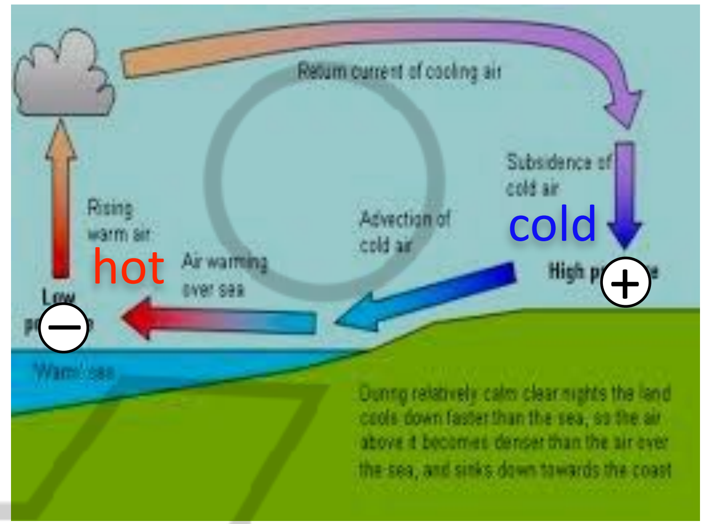
WINDS

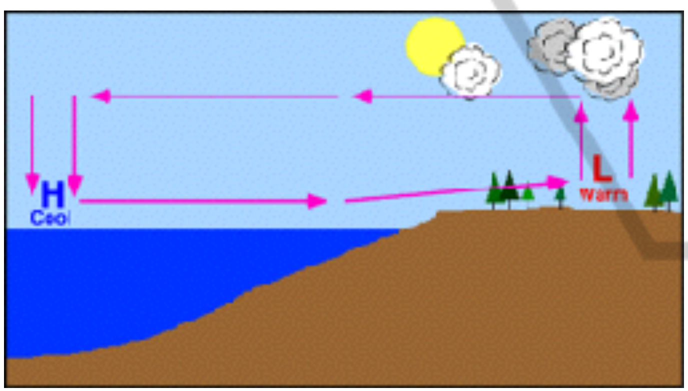

Clouds from those it is raining
moist warm air rises and cools down
dry and cold air declines and warms up
L
Low pressure area
H
high pressure area
wind blow in the clockwise direction from center.

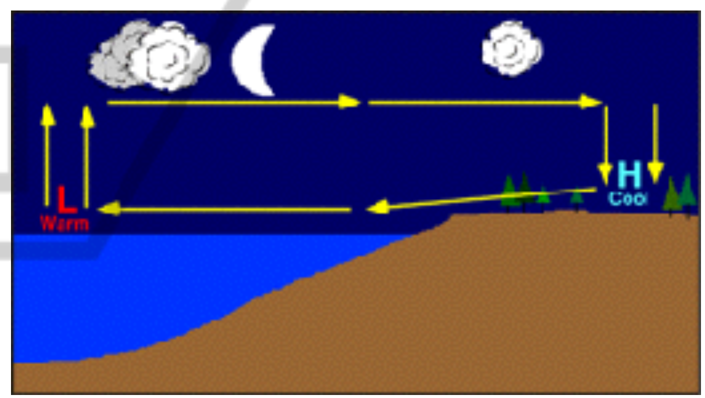

H
vento di gradiente
L

SEA & LAND BREEZES

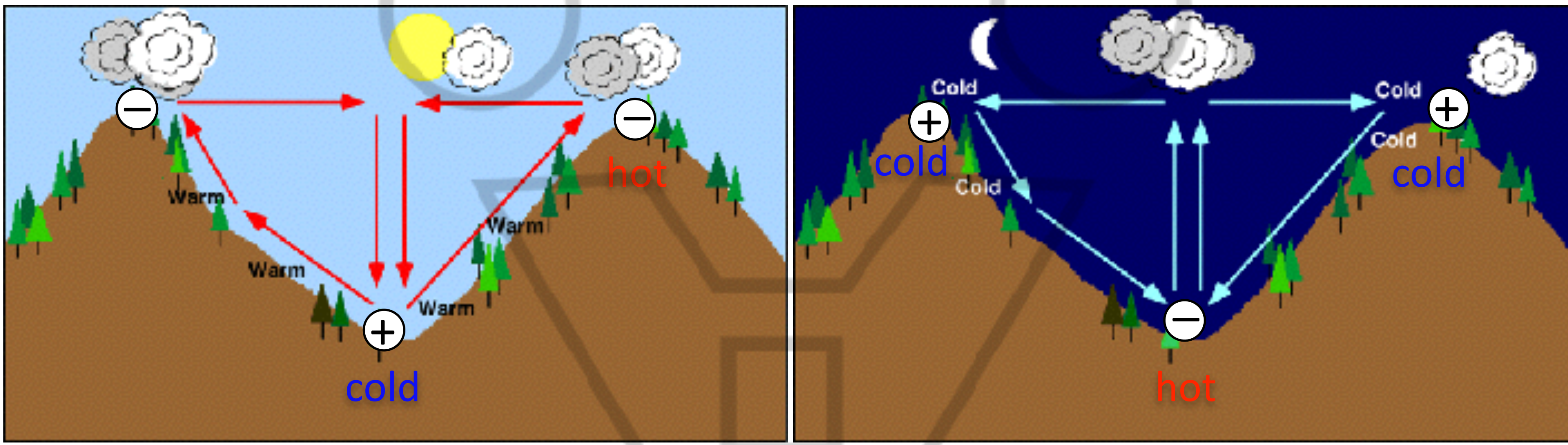




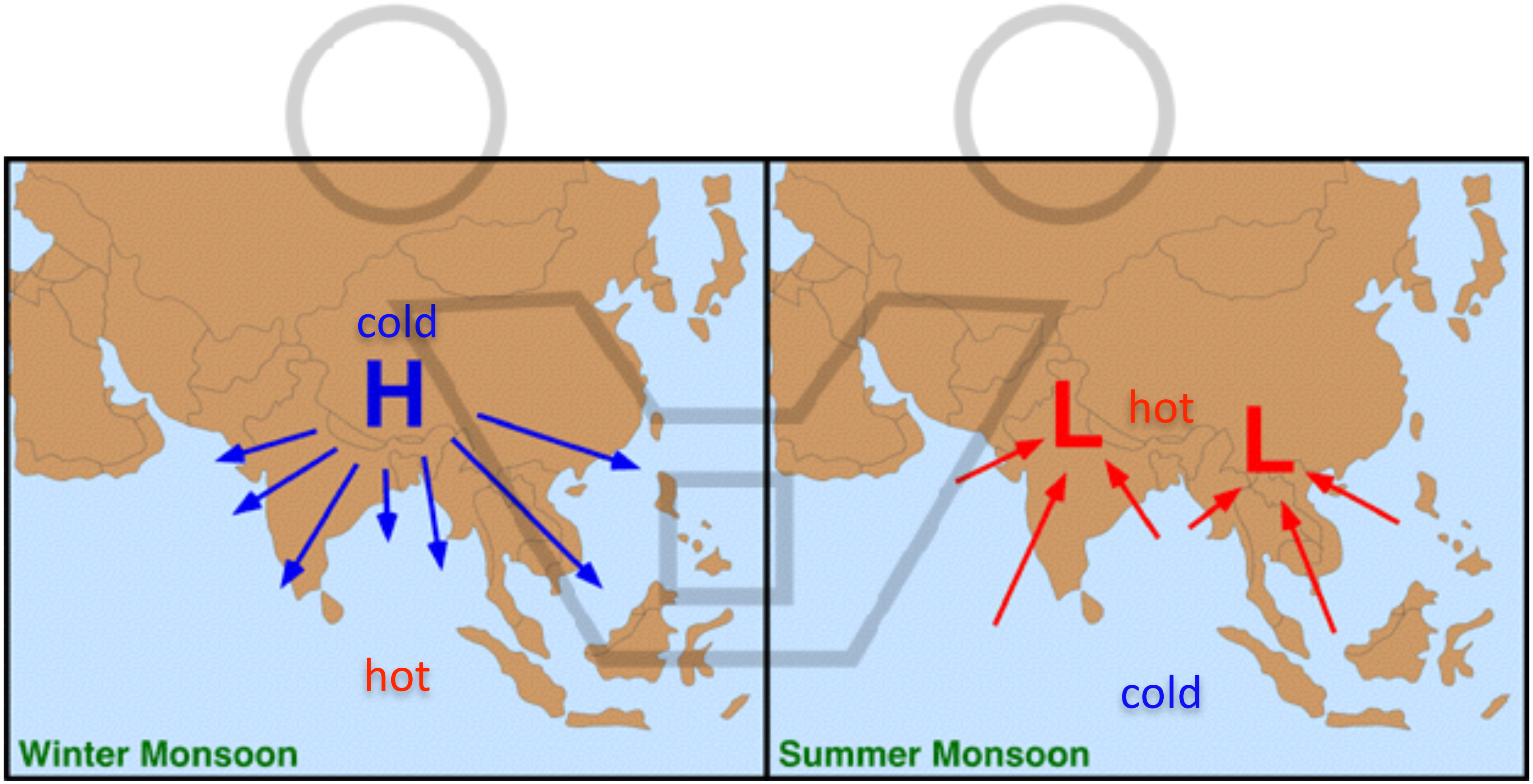




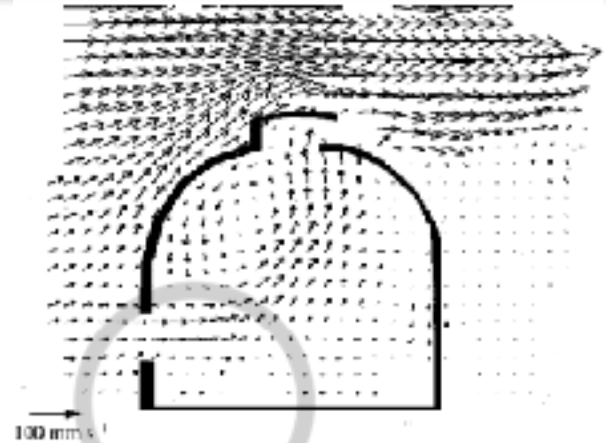
MOUNTAIN & VALLEY BREEZES



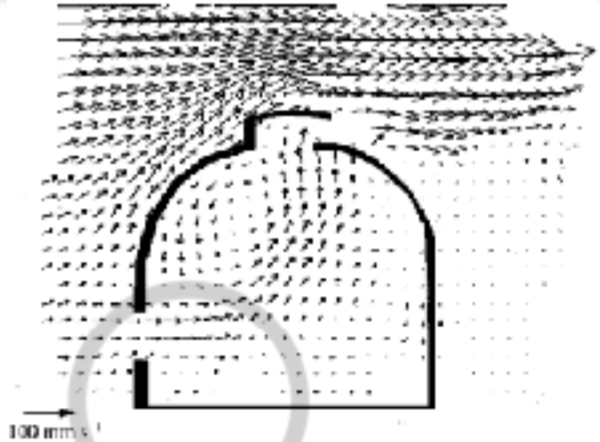
SEASONAL WINDS



AIRFLOW MODELING



AIRFLOW MODELING



Understanding the air flow and distribution patterns for buildings.
The building form and shape can affect how air flows through the building and across neighboring developments into the building.
This is an important consideration for natural ventilation and can significantly reduce costs of air-conditioning provisions.
There are Computational Fluid Dynamics (CFD) tools available that can help simulate the air-flow patterns within built-spaces as well as for whole building estates

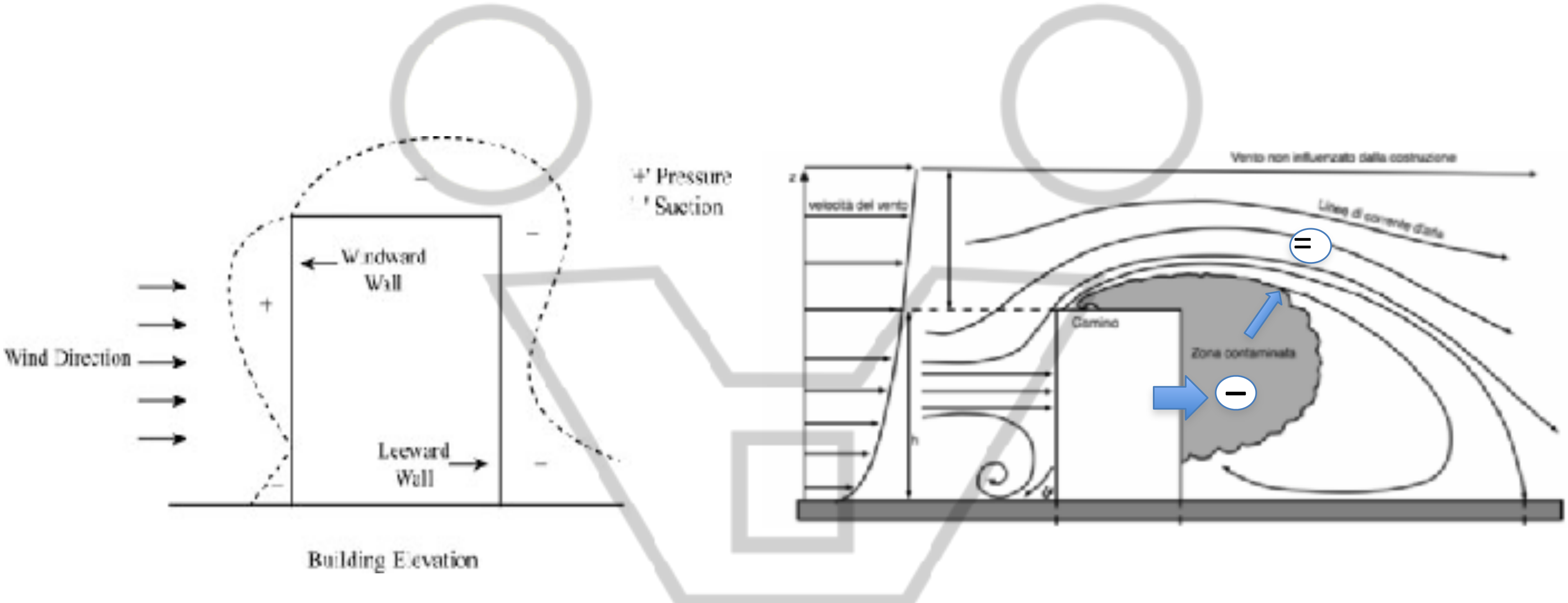
Basic software tool:
Flow Design http://www.autodesk.com/education/free-software/flow-design (student version available)

Other popular software tools:
Fluent by Ansys: http://www.ansys.com/. (student version available)
FloVent from Mentor Graphics: http://www.mentor.com/.
Comsol Multiphysics modeling software: https://www.comsol.com/.

References

AIA (The American Institute of Architects) (2012) An Architect's guide to integrating energy modeling in the design process
ERI@N (Energy Research Institute @ NTU) (2013) Nanyang Technological University (NTU), Singapore
NREL (2009) A handbook for planning and conducting charrettes for high-performance projects, National Renewable Energy Laboratory (NREL), Sept 2009

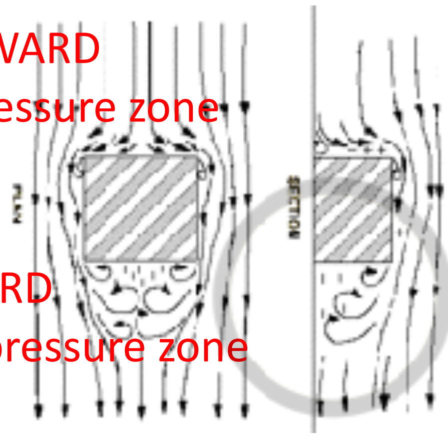
RICONOSCERE I DIFFERENZIALI DI PRESSIONE INDOTTI DAL VENTO SUGLI EDIFICI



METODI INTUITIVI

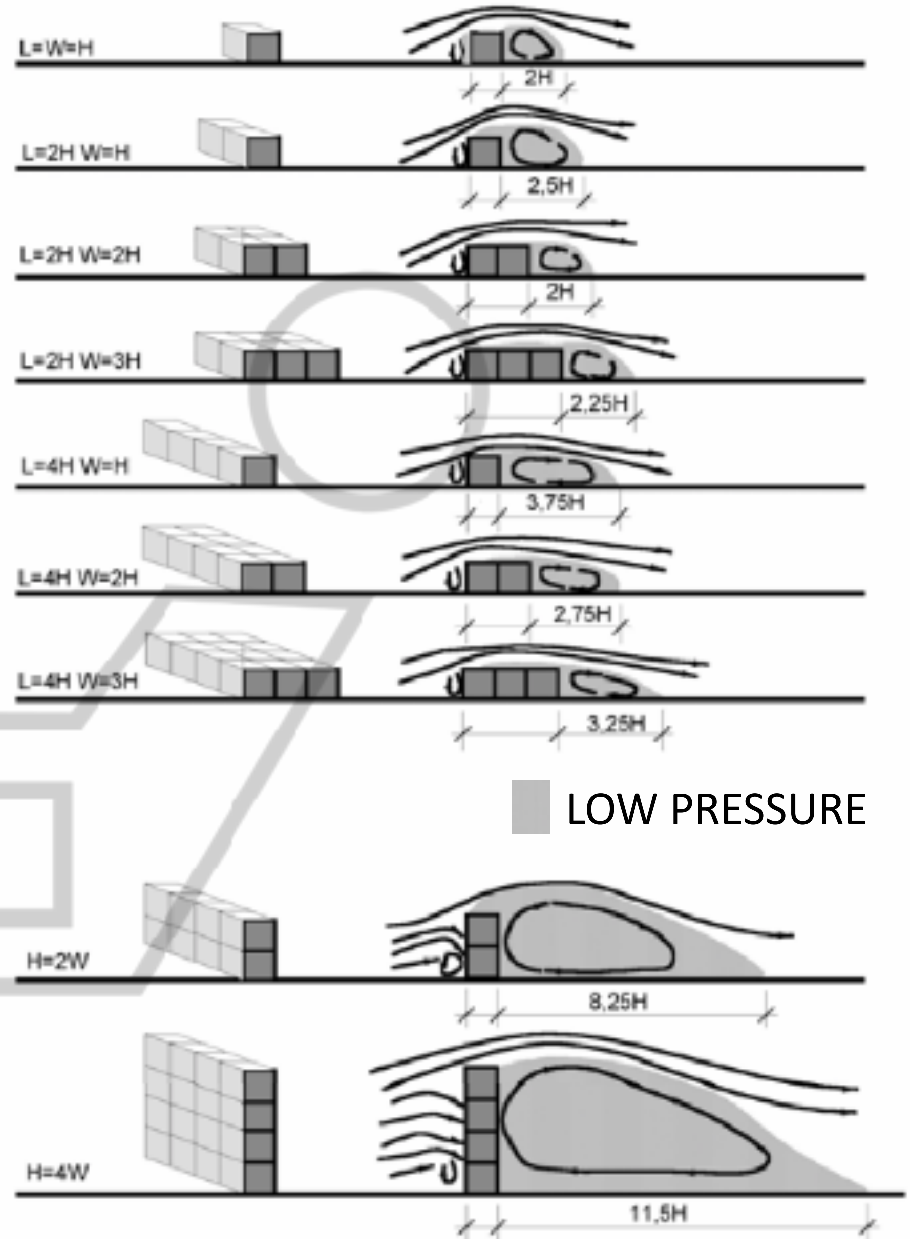
WINDWARD
overpressure zone

LEEWARD
underpressure zone

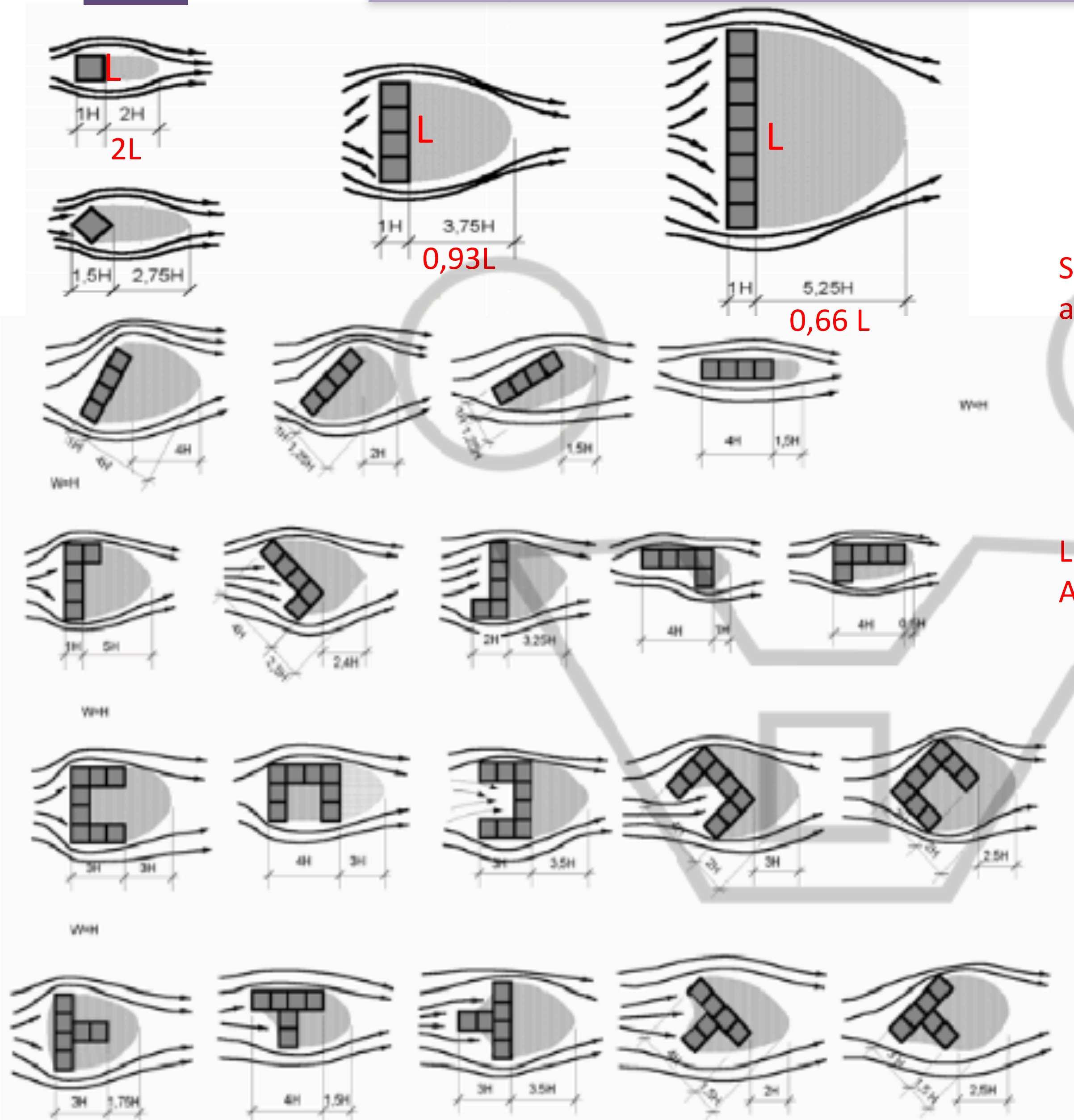


Skinny buildings create
deeper low pressure area

Taller buildings create
(proportionally) deeper
low pressure area



Wind & Passive Ventilation



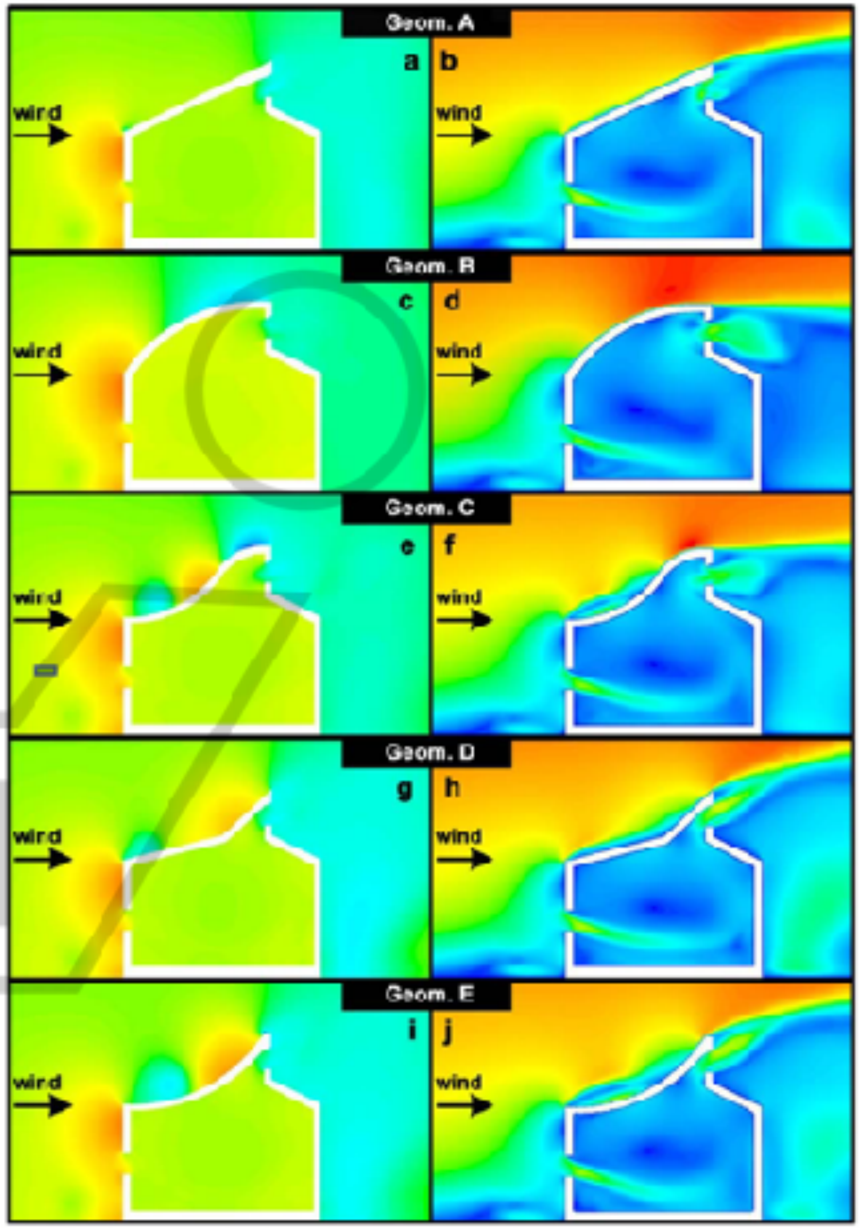
LOW PRESSURE

Shorter building creates (proprotionally) a deeper low pressure area

Longest building create
A deeper low pressure area

AIRFLOW MODELING

METODI COMPUTAZIONALI
come procedere



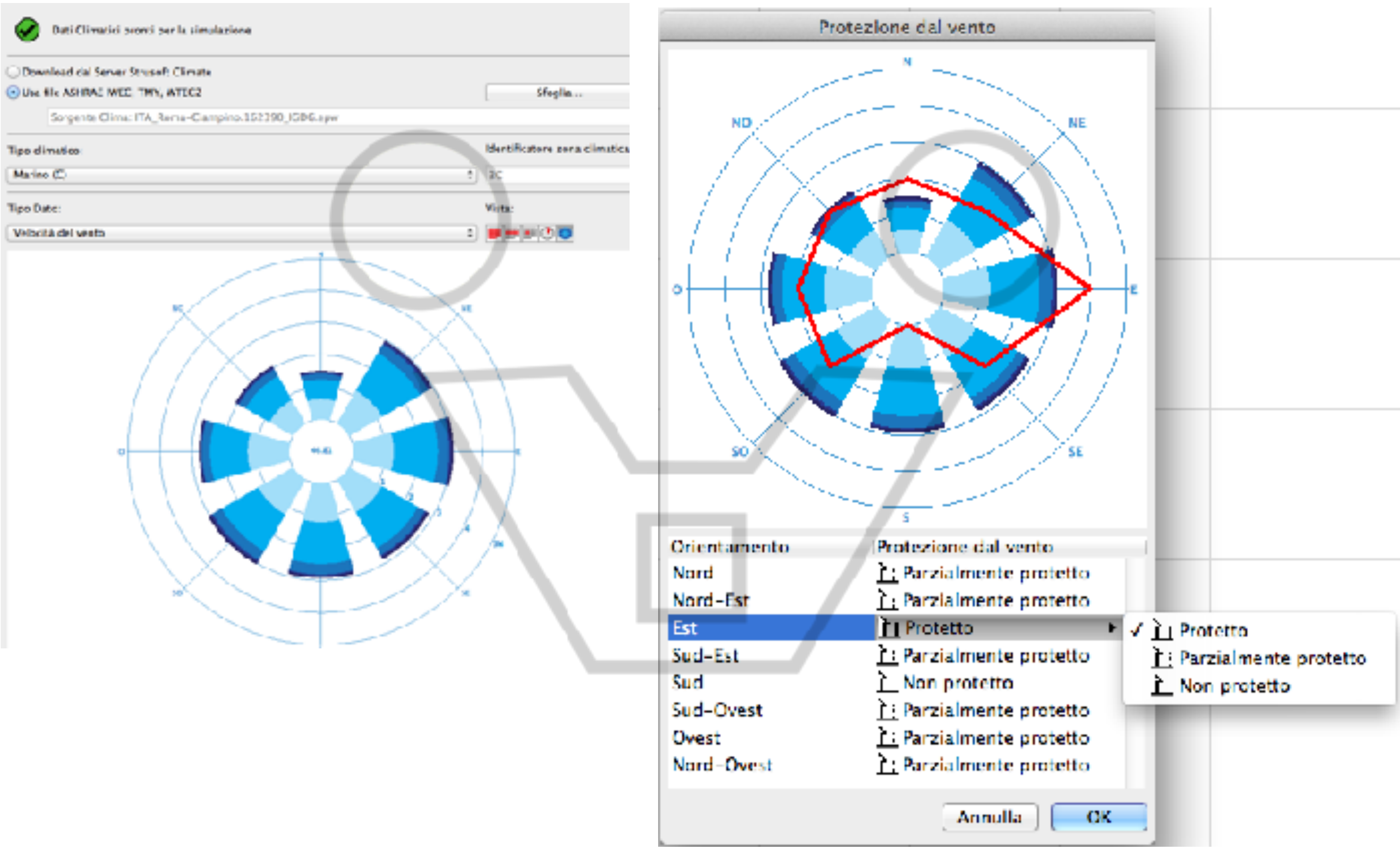
FORME COPERTURE / EFFETTI SULLE PRESSIONI

Fig. 12. Contour plot of the pressure coefficient C_P (a,c,e,g,i) and the dimensionless velocity magnitude ($|V|/U_{ref}$) (b,d,f,h,j) in the vertical center plane for the five roof geometry cases.

METODI COMPUTAZIONALI

1- determine the coldest and the hottest seasonal period and hours

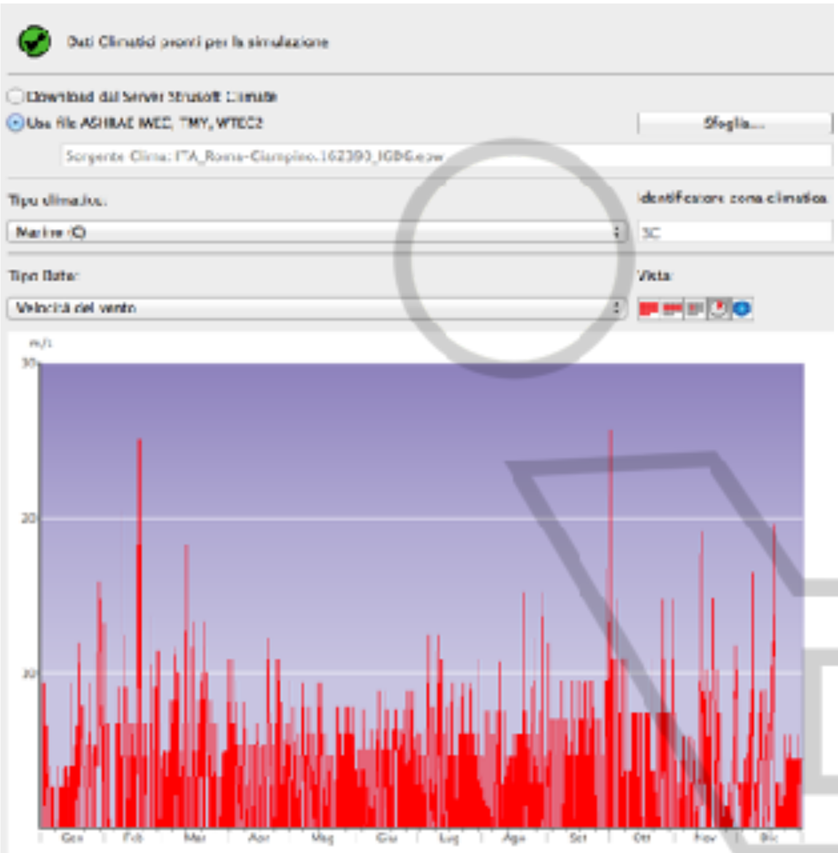
2- for that periods find the most frequent wind directions

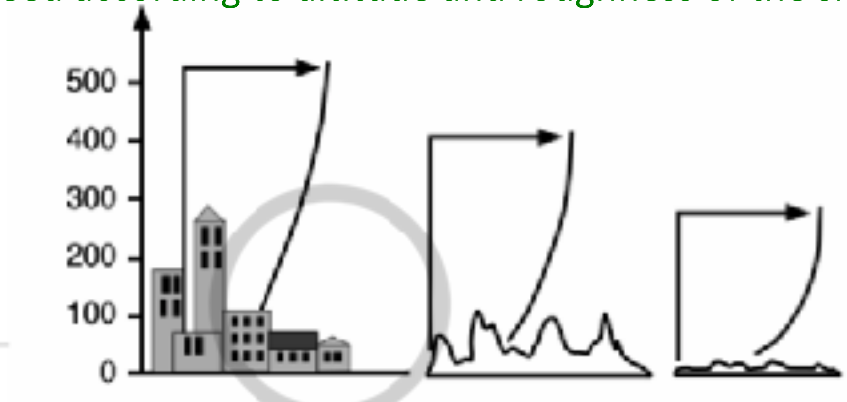


METODI COMPUTAZIONALI

3- define wind speed for the hottest and coldest periods

4- reduce the speed according to altitude and roughness of the site





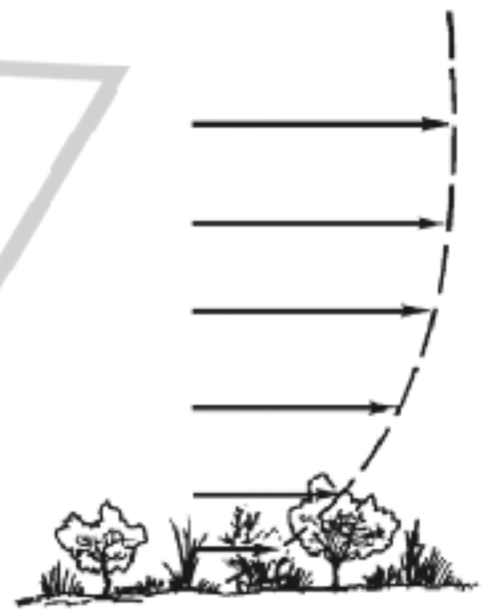
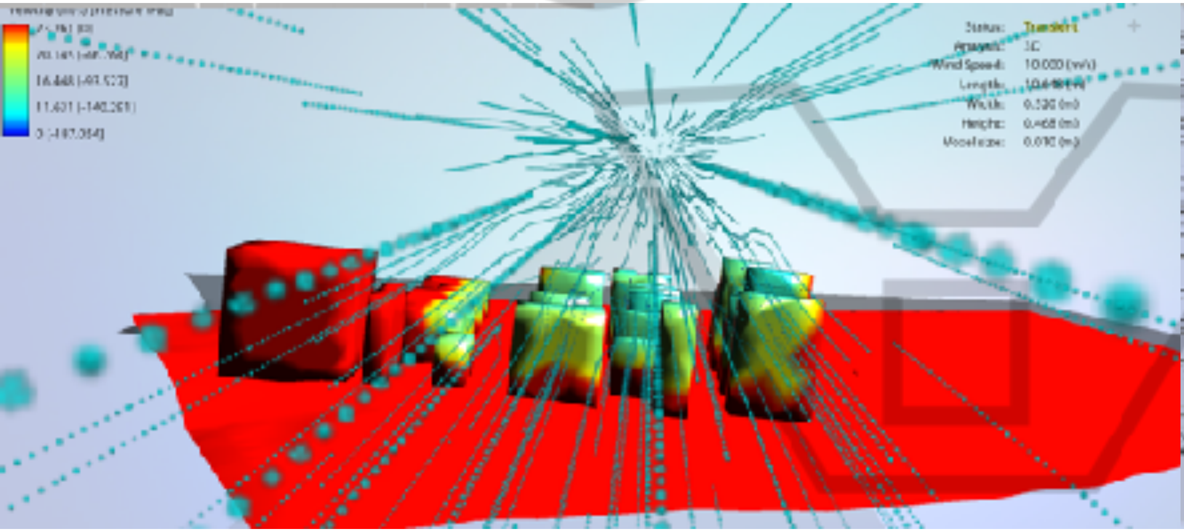


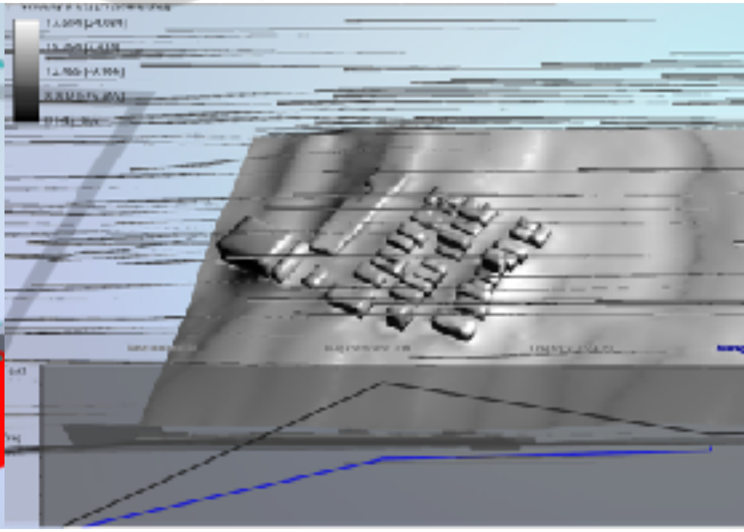
Figure 1—General wind velocity profile near surface (from Rothermel 1983).

METODI COMPUTAZIONALI

5- Orient the model according to the wind direction

FLOW DESIGN



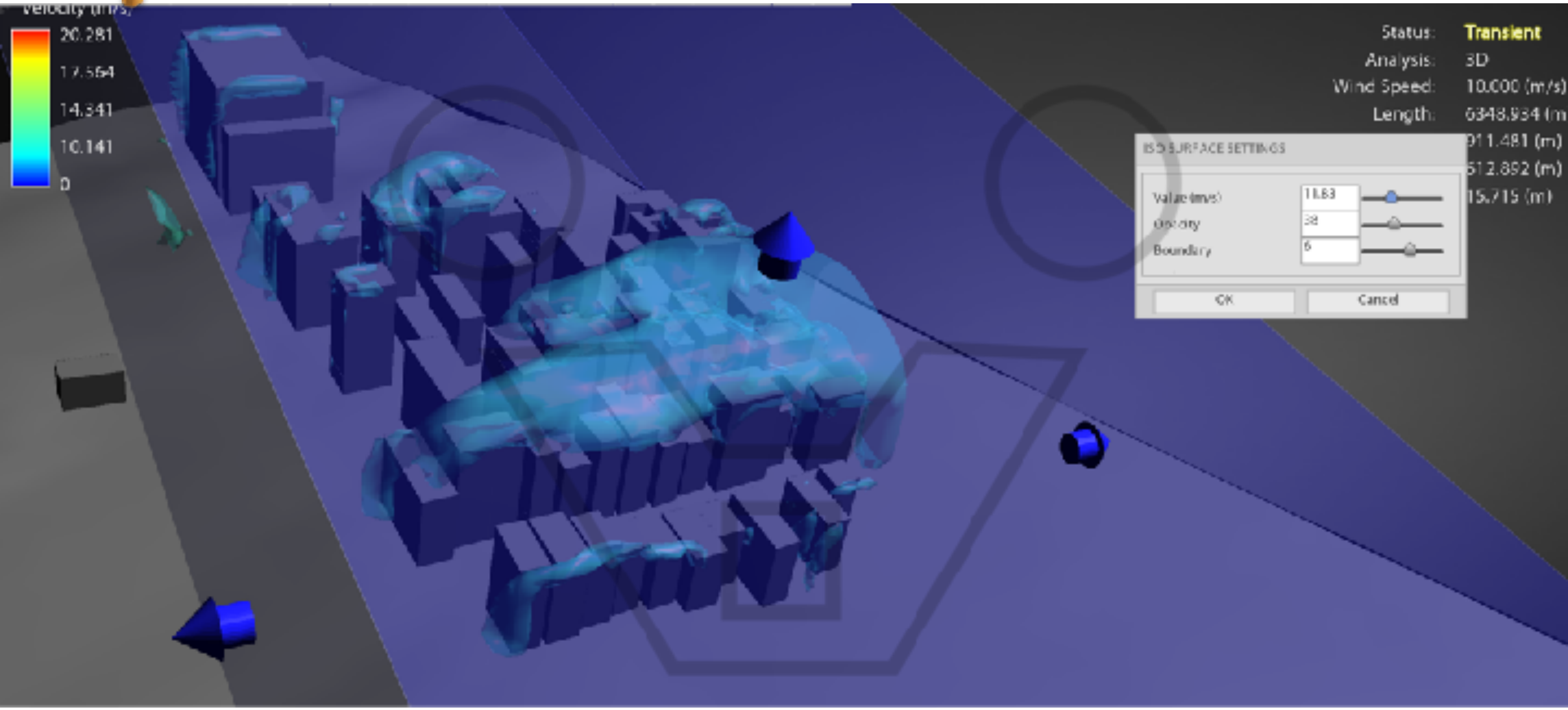


Wind & Passive Ventilation

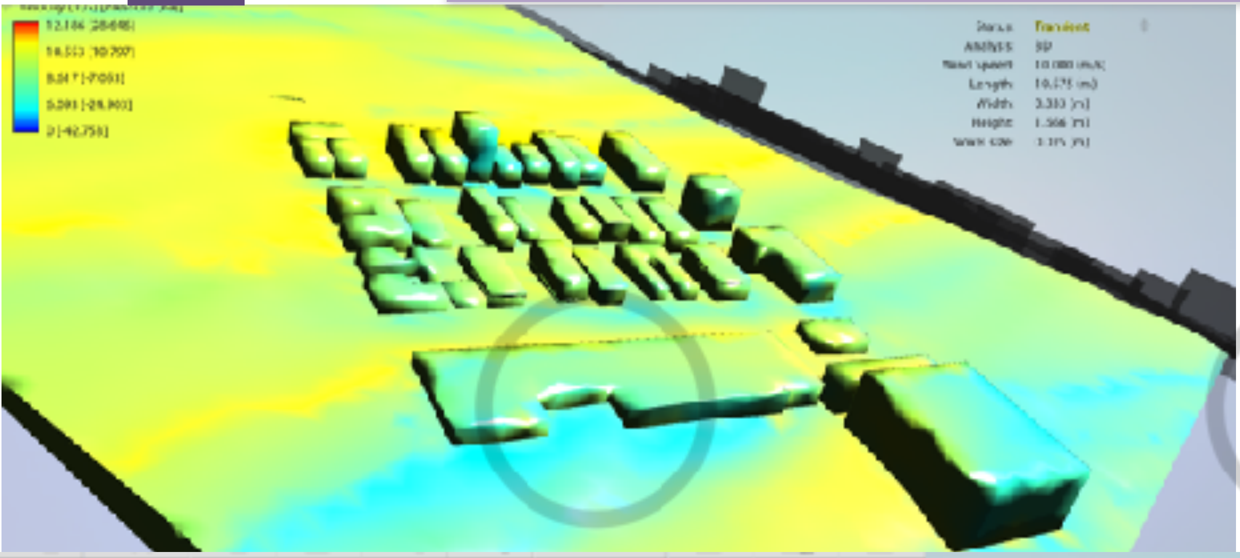
METODI COMPUTAZIONALI

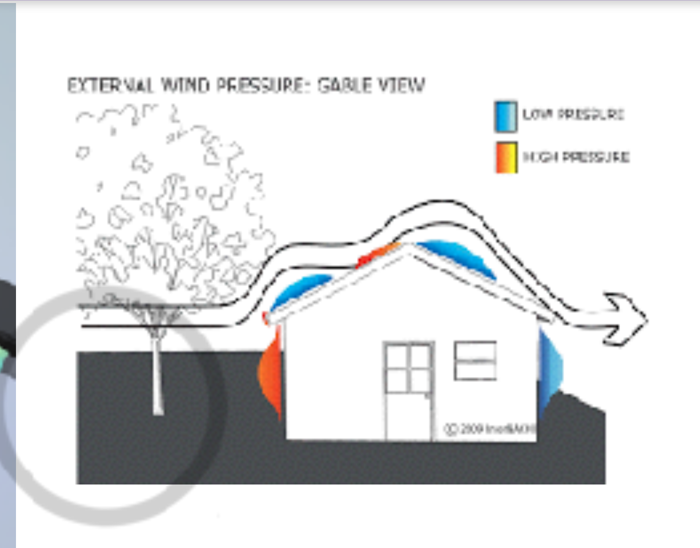
FLOW DESIGN

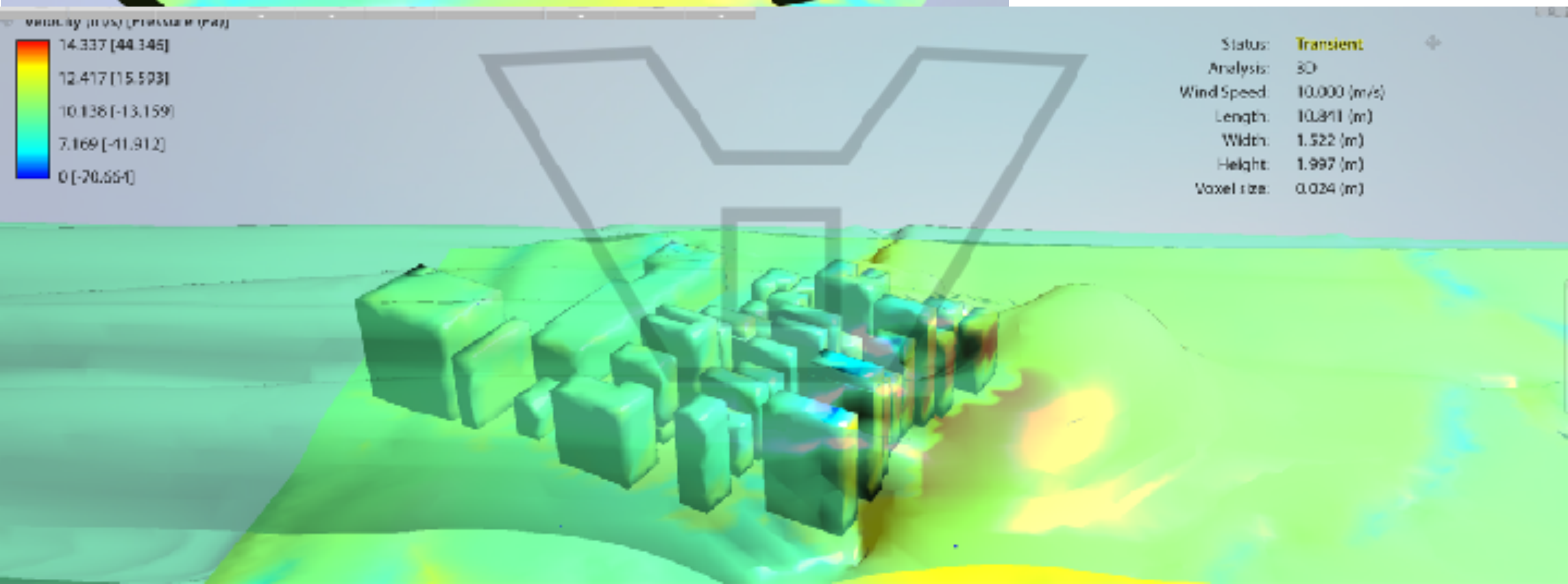
6- Set the wind velocity & analyze results (low, high pressure zones)
NOTE: in order to get a better visualization, wind speed MUST be proportionally increased



Wind & Passive Ventilation



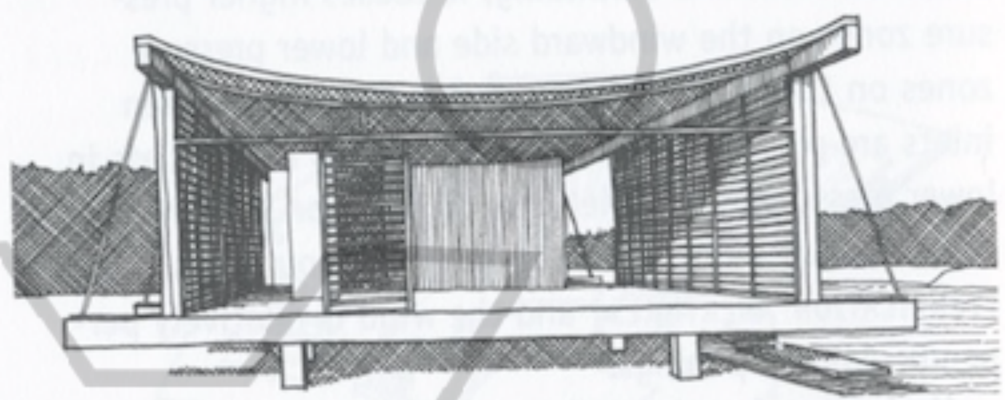




Wind & Passive Ventilation

7- Design buildings according the wind pressure zones and cinetic forces

- Effect on ventilation related to the building rooms dimension

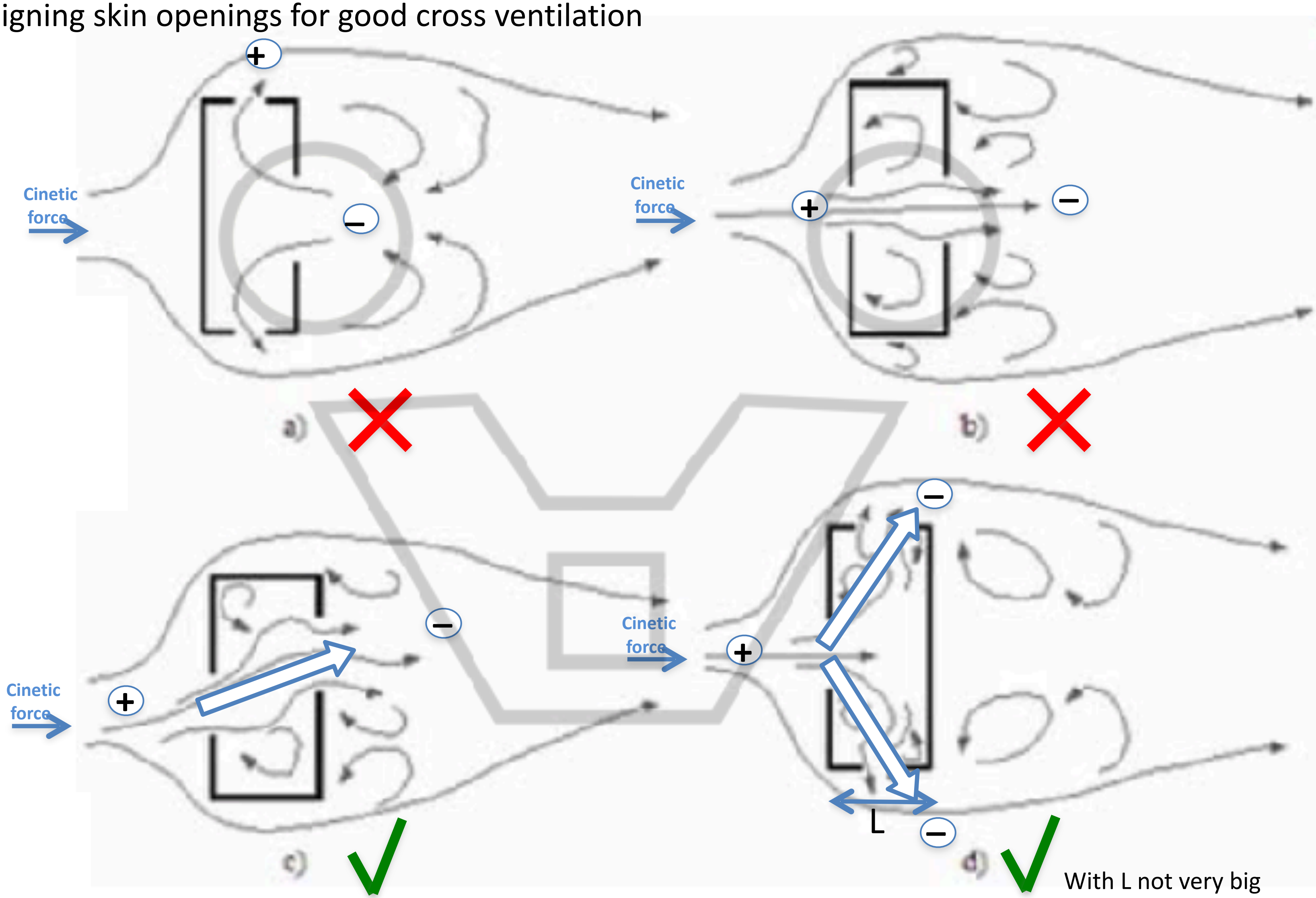


Cacoon House, Sarasota, Florida, Paul Rudolph

The maximum ventilating area may be achieved, as in Paul Rudolph's **Cacoon House** in Sarasota, Florida, by treating almost the entire house as a single room and opening its opposite walls completely with operable louvers (Fry and Drew, 1956, p. 75).

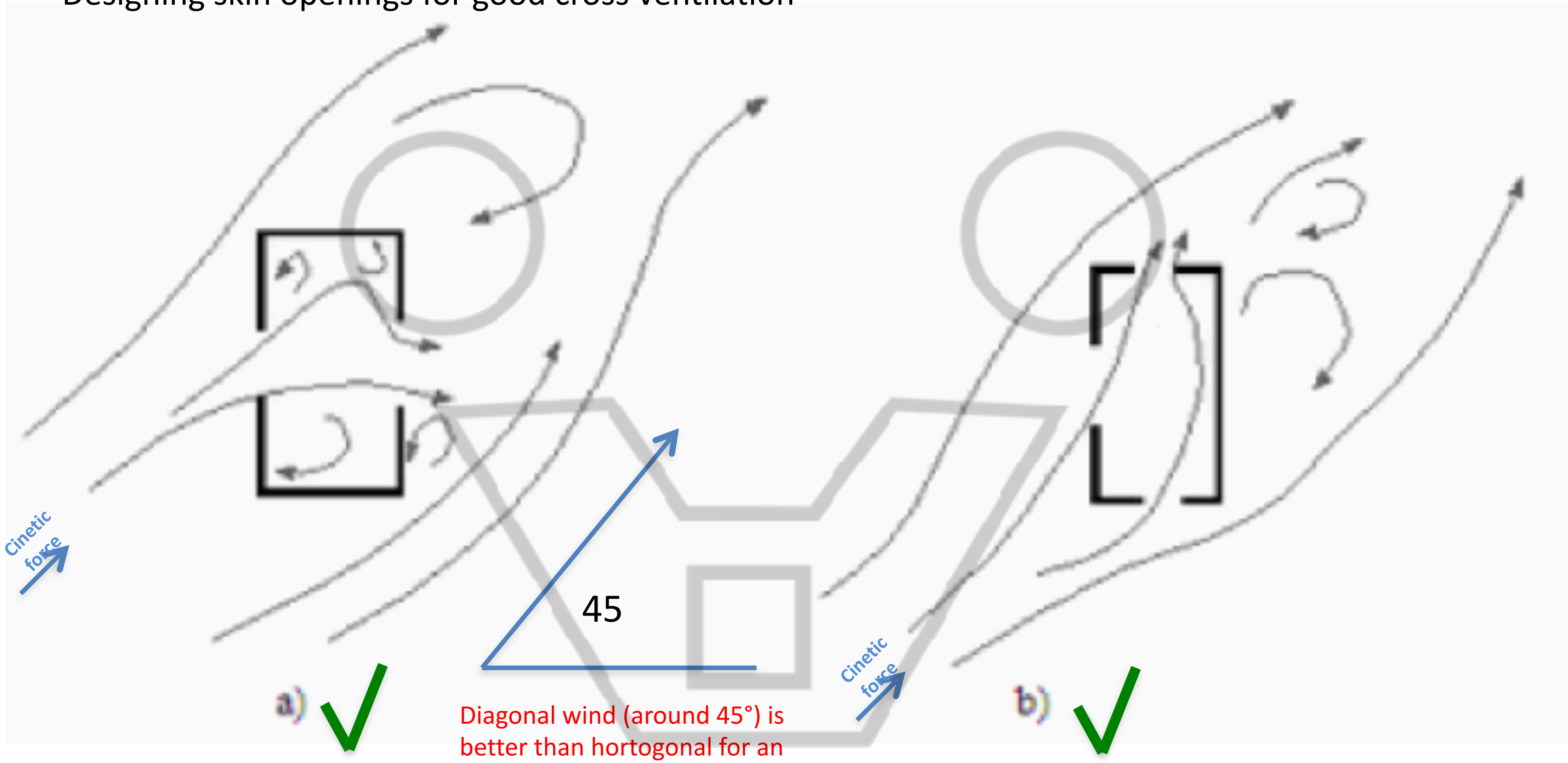
7- Design buildings according the wind pressure zones and cinetic forces

- Designing skin openings for good cross ventilation



7- Design buildings according the wind pressure zones and cinetic forces

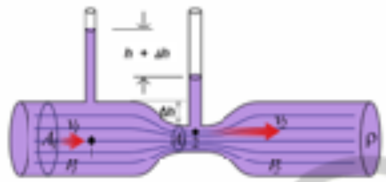
- Designing skin openings for good cross ventilation



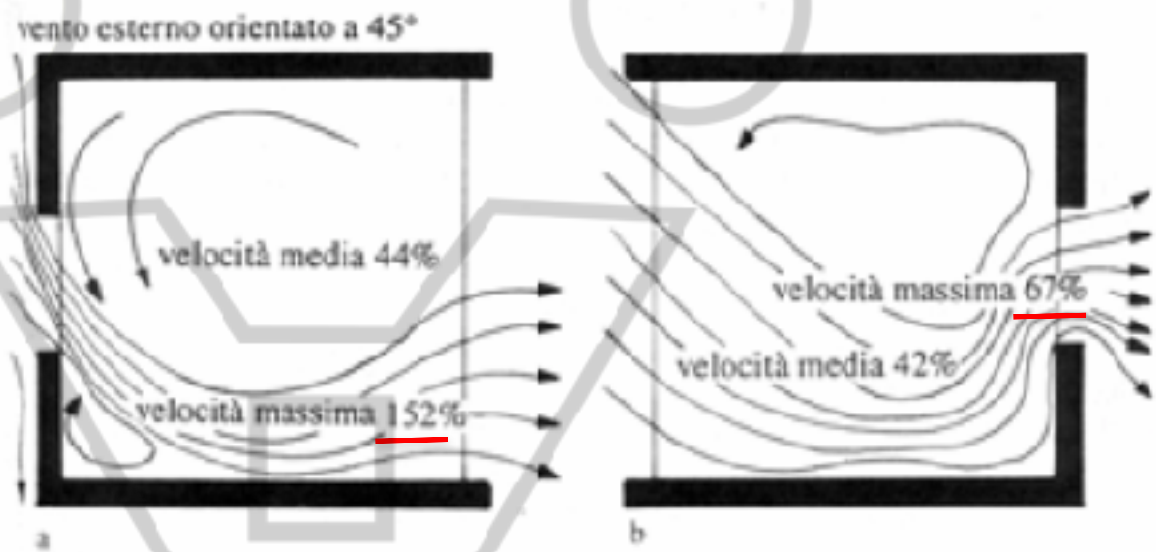
Diagonal wind (around 45°) is better than hortogonal for an homogenous distribution of ventilation inside the building

7- Design buildings according the wind pressure zones and cinetic forces

- Designing skin openings for good cross ventilation



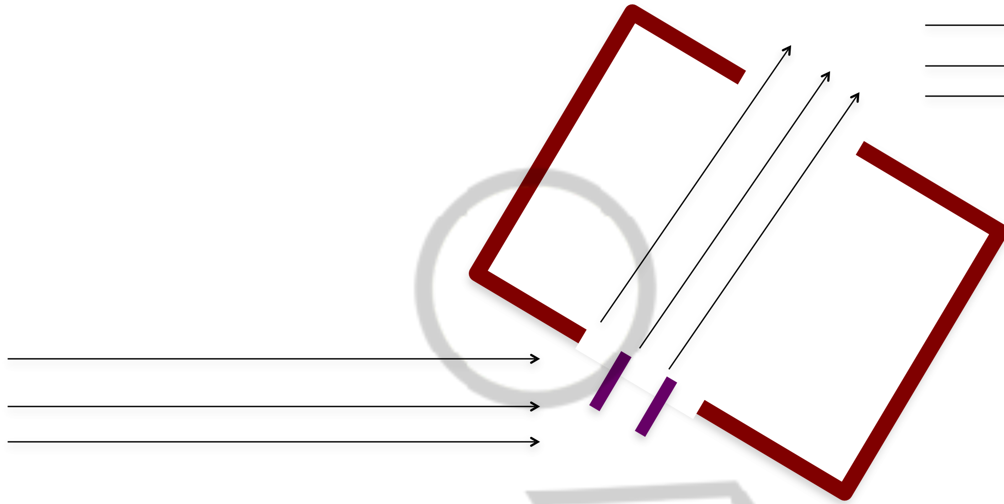
VENTURI EFFECT : Higher speed (lower pressure) if the entrance is smaller than the ex

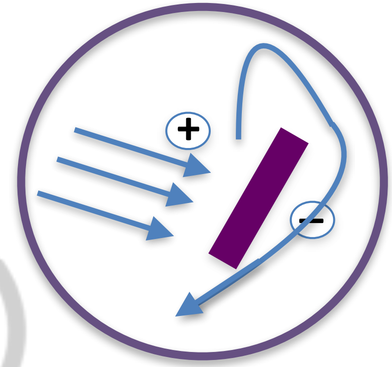


Pairing a large outlet with a small inlet increases incoming wind speed.

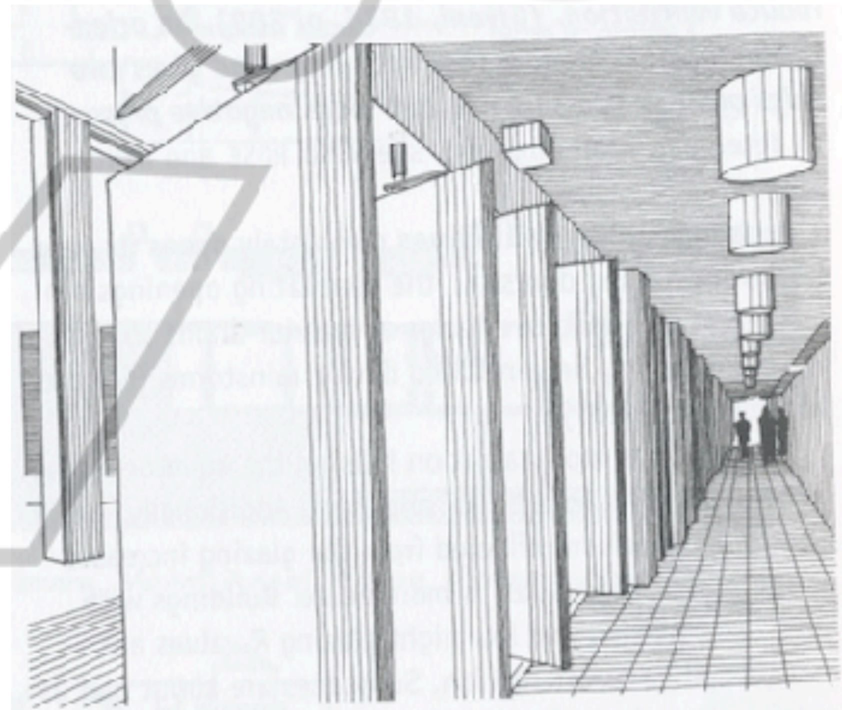
7- Design buildings according the wind pressure zones and cinetic forces

- Designing fins for good cross ventilation





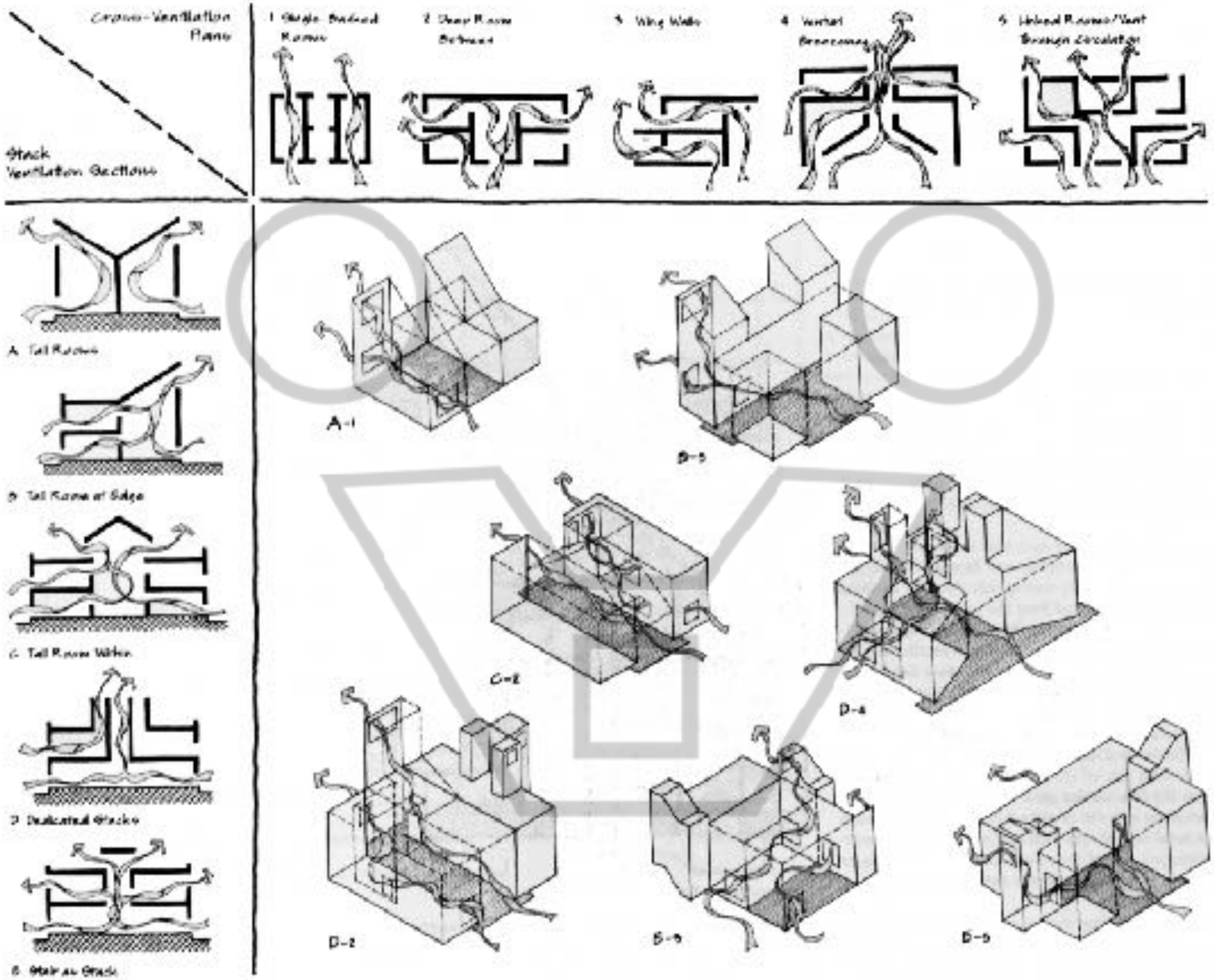
When openings cannot be oriented to the prevailing breeze and if rooms have windows in only one wall, landscaping or wing walls can alter the positive and negative pressure zones around the building and induce wind flow through windows parallel to the prevailing wind directions (R. H. Reed, 1953, p. 56; Robinette, 1977, p. 29). If located correctly, vertical fin projections create a positive pressure at one window and a negative pressure at another. Outward opening casement windows can create a similar effect. The effect of wing walls is limited to windows on the windward side of a building and has no effect on leeward openings.



Interior View of Alierons, Academy of the Antilles and Guiana, Christiane Hauvette & Jérôme Nouel

Air movement: VERTICAL VENTILATION

Working with natural ventilation **Air movement: Cross ventilation + Stack effect room diagrams**



Room Organization Strategies That Facilitate Both Cross and Stack-Ventilation

Computational Materiality for Sustainable Architectures and Comprehensive Skins

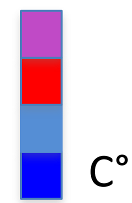
WORKING WITH NATURAL VENTILATION DEVICES

WORKING WITH NATURAL VENTILATION DEVICES

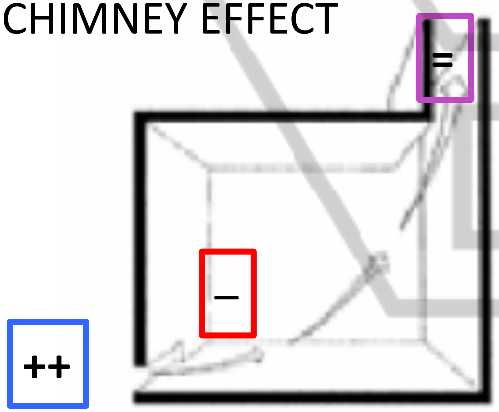
	FROM HIGHER WEIGHT	TO LOWER WEIGHT
	+	–
DENSITY	Higher	Lower
TEMPERATURE	Lower	Higher
ALTITUDE	Lower	Higher
VELOCITY	Lower	Higher

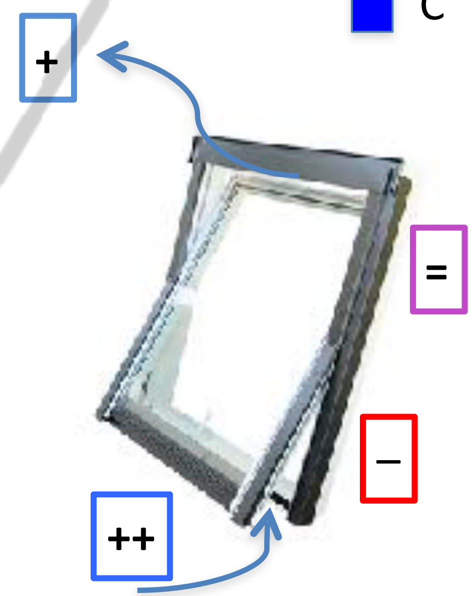
= Lower weight

++ Higher weight



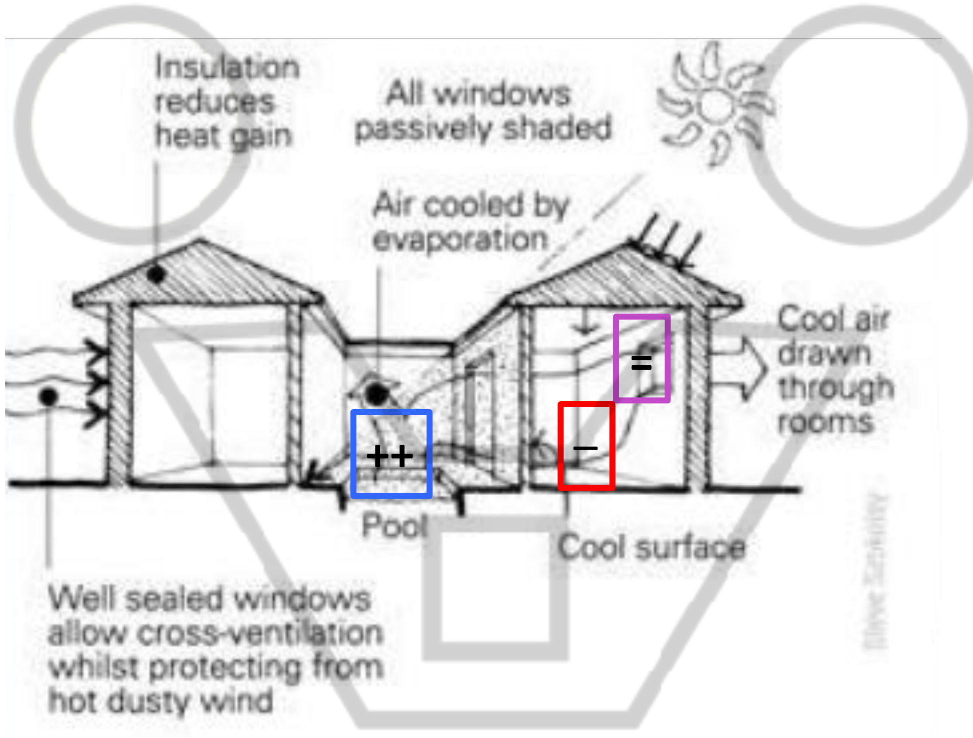
STACK EFFECT or CHIMNEY EFFECT





WORKING WITH NATURAL VENTILATION DEVICES

FROM HIGHER WEIGHT + → **TO LOWER WEIGHT** −

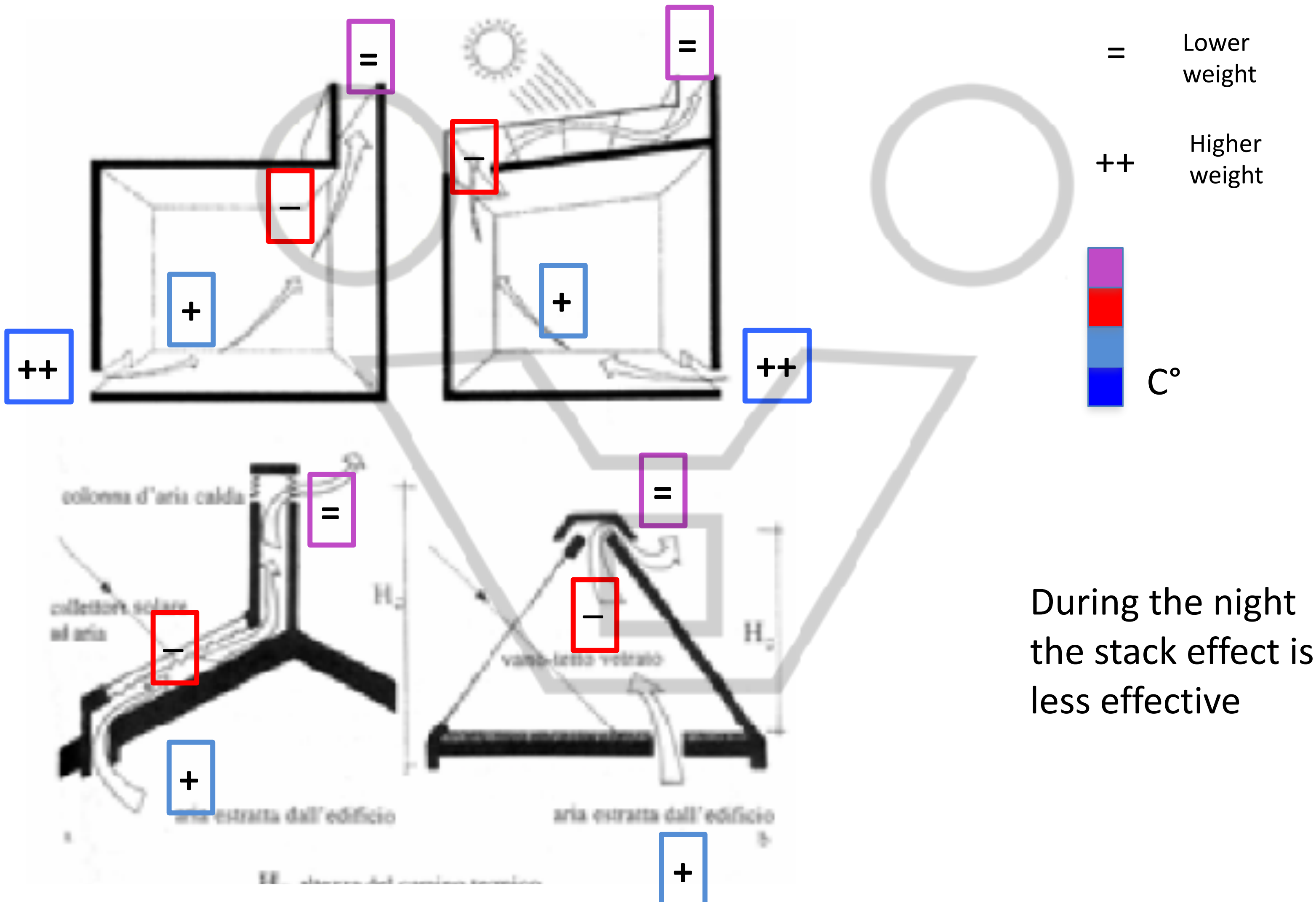


= Lower weight

++ Higher weight

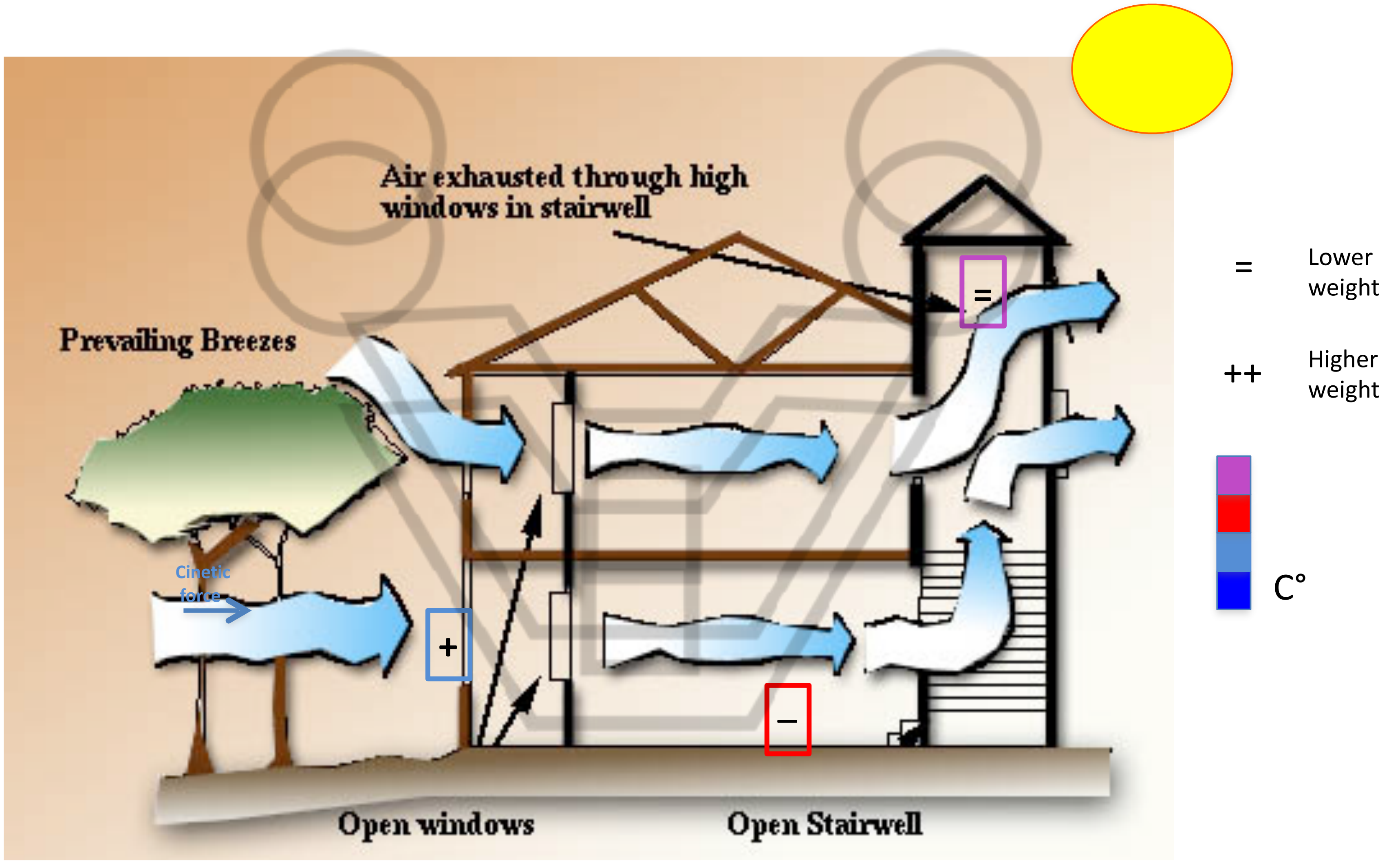
C°

WORKING WITH NATURAL VENTILATION DEVICES



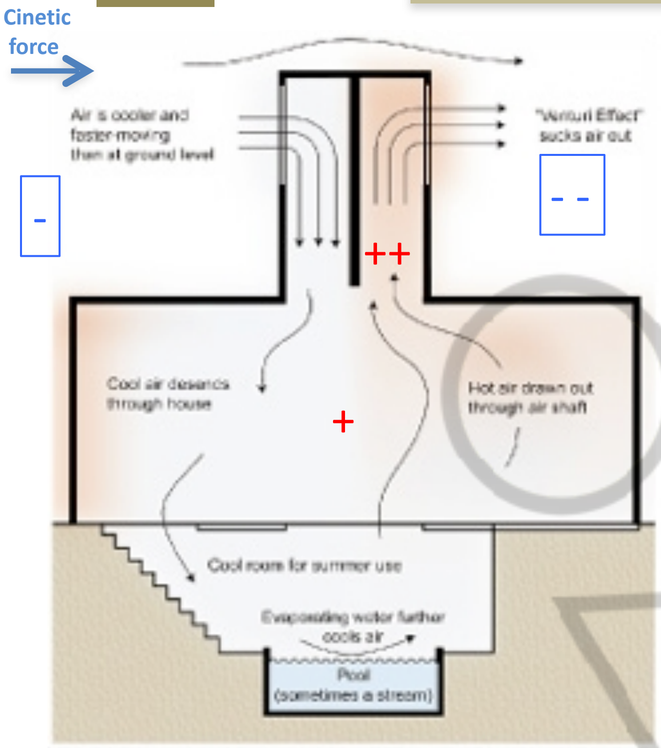
During the night the stack effect is less effective

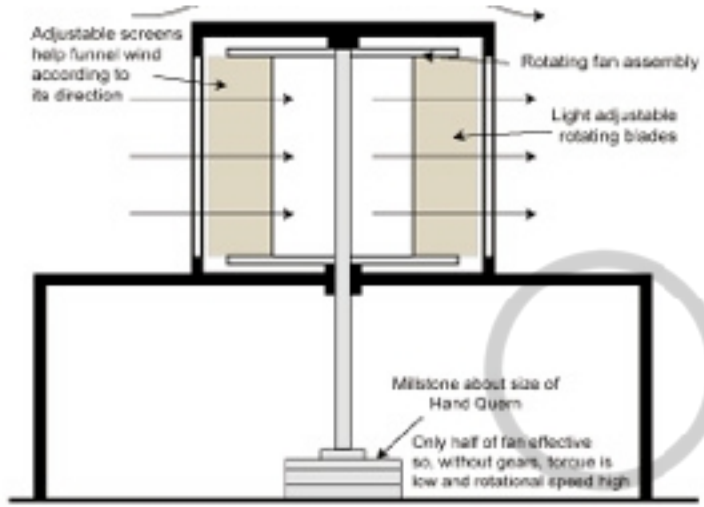
WORKING WITH NATURAL VENTILATION DEVICES

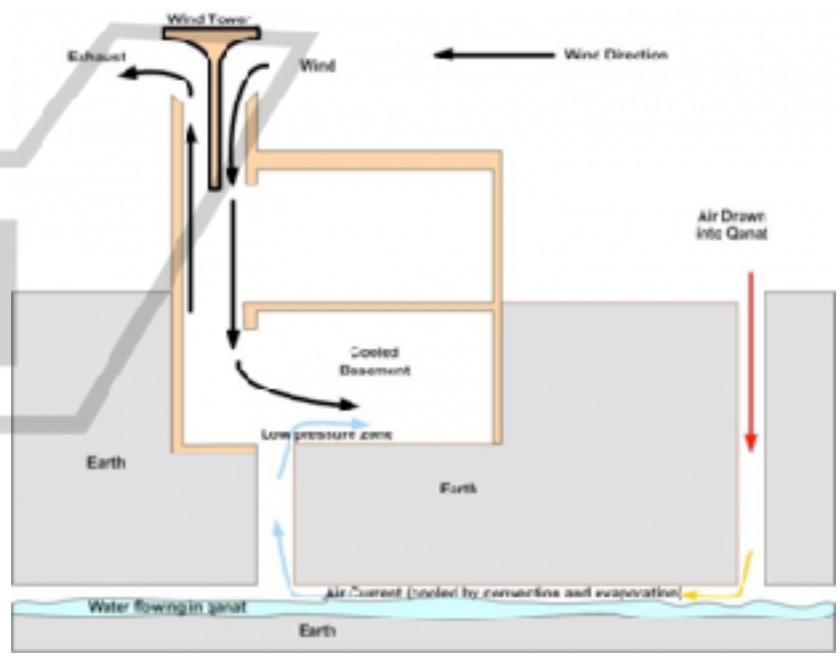


WORKING WITH NATURAL VENTILATION DEVICES Wind Towers

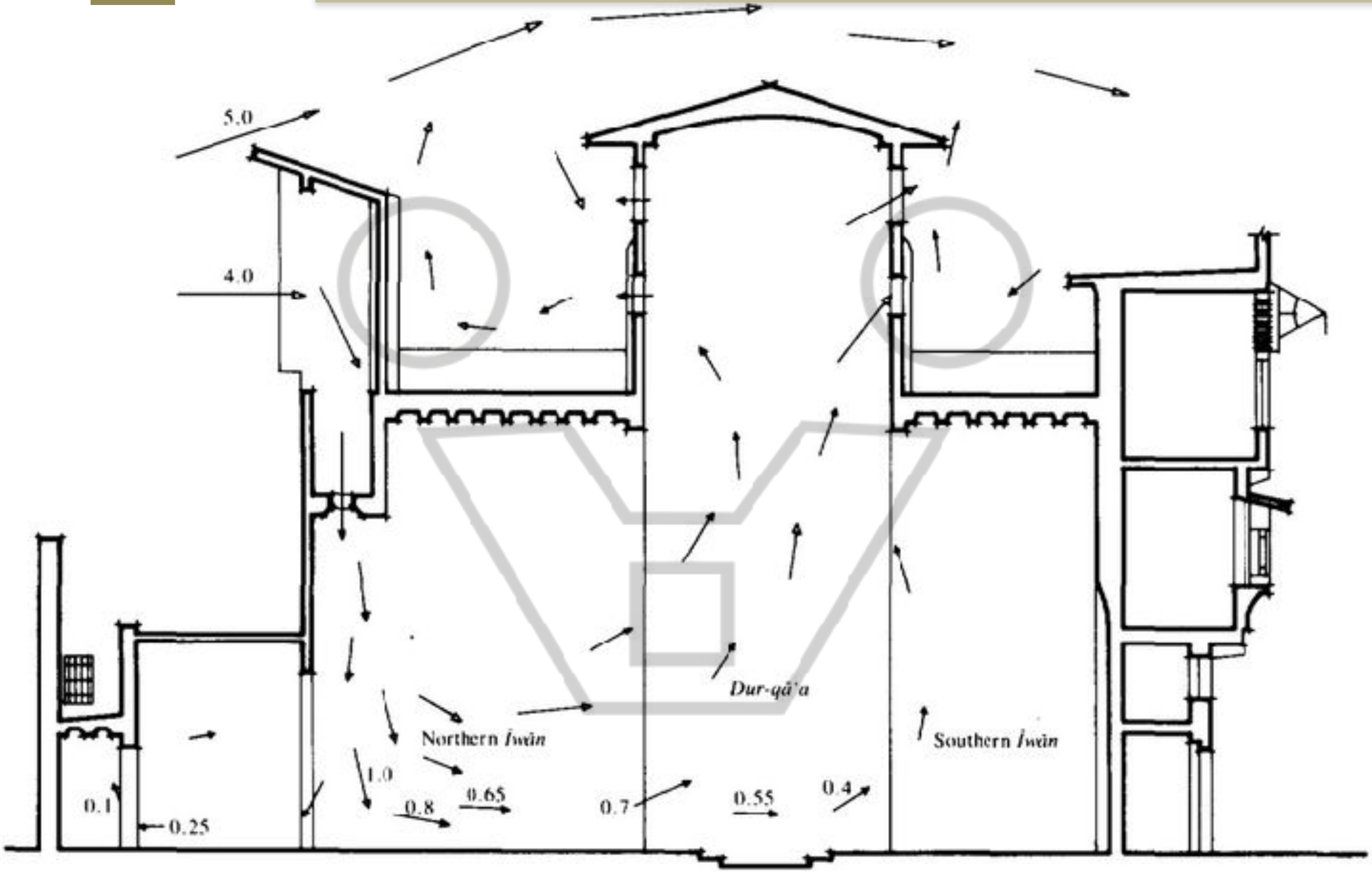
WORKING WITH NATURAL VENTILATION DEVICES Wind Towers







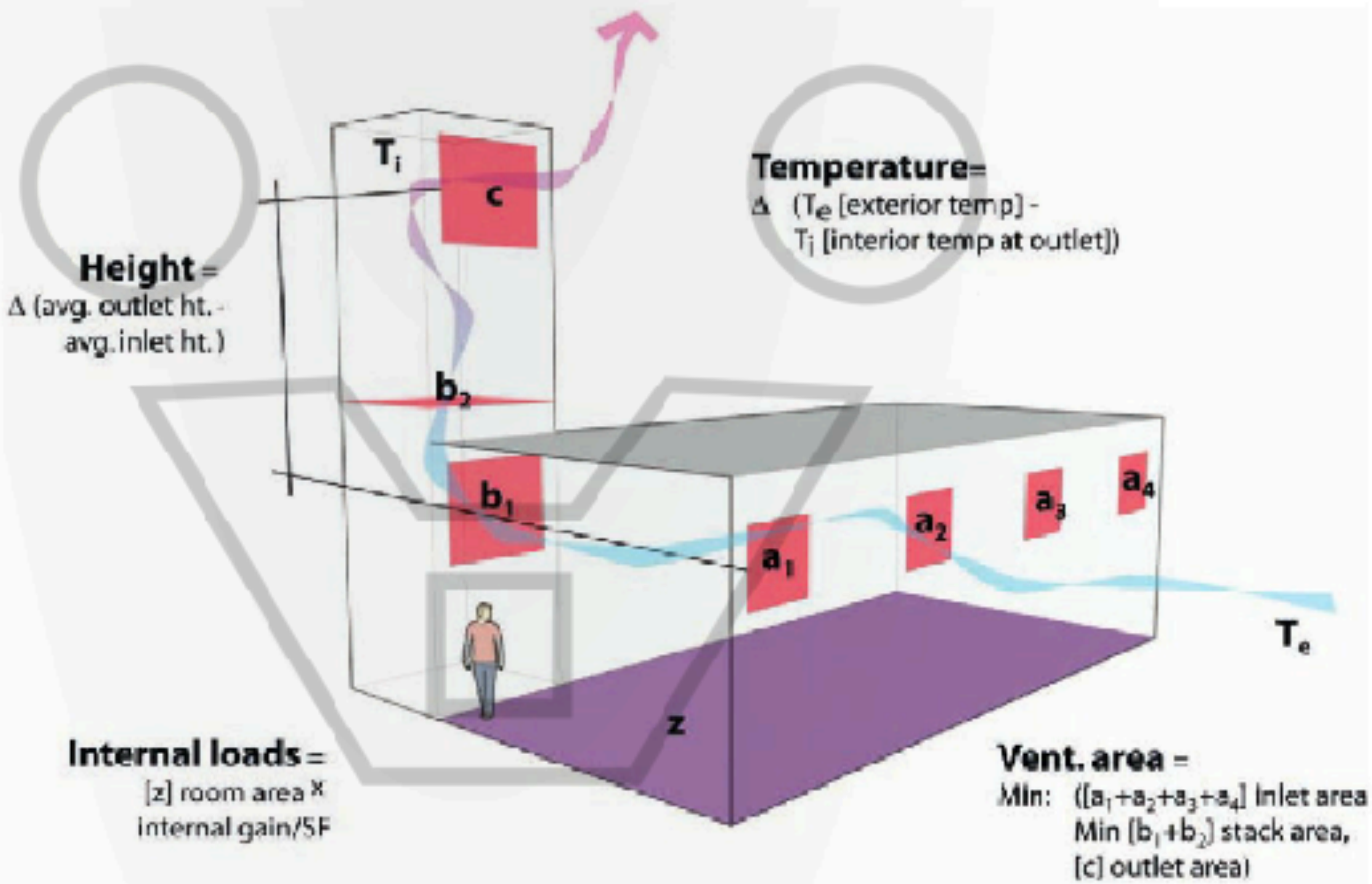
WORKING WITH NATURAL VENTILATION DEVICES **Wind Towers**



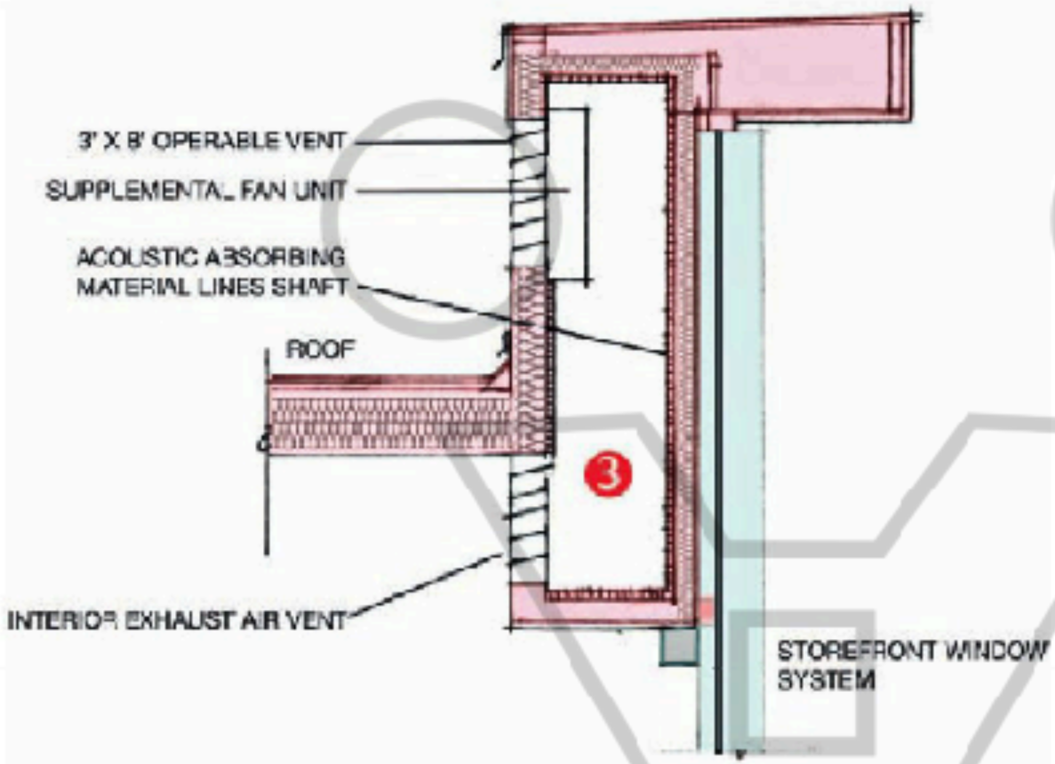
WORKING WITH NATURAL VENTILATION DEVICES Wind Towers

9.12

Stack diagram showing the important inputs into a natural ventilation model.



WORKING WITH NATURAL VENTILATION DEVICES **Exhaust Air Vent**

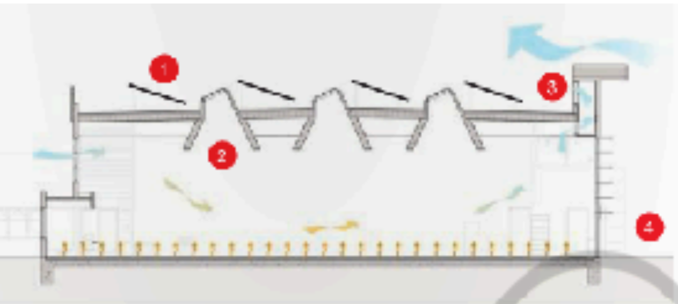


Natural Ventilation Exhaust Vent

9.5

Natural ventilation exhaust vent.

WORKING WITH NATURAL VENTILATION DEVICES Chimney



Mode 1

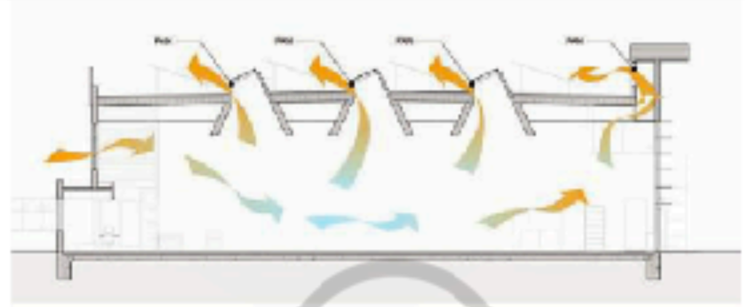
Heating Season.
Minimum outside air admitted.

Mode 2

Swing Season.
Outside air quantity varies to provide cooling and fresh air. Wind chimney only.

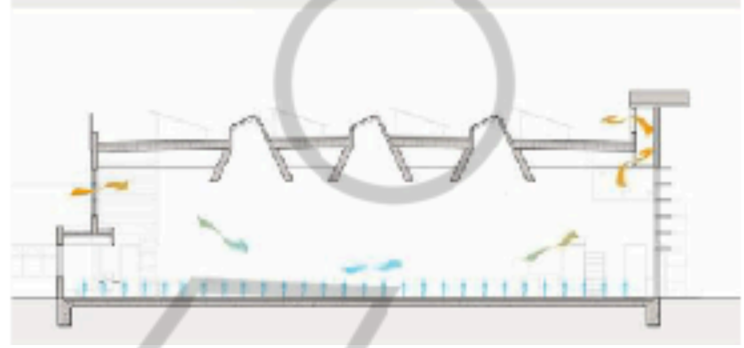
Mode 3

Early Cooling Season.
Cooling via wind chimney and venting skylights.



Mode 4

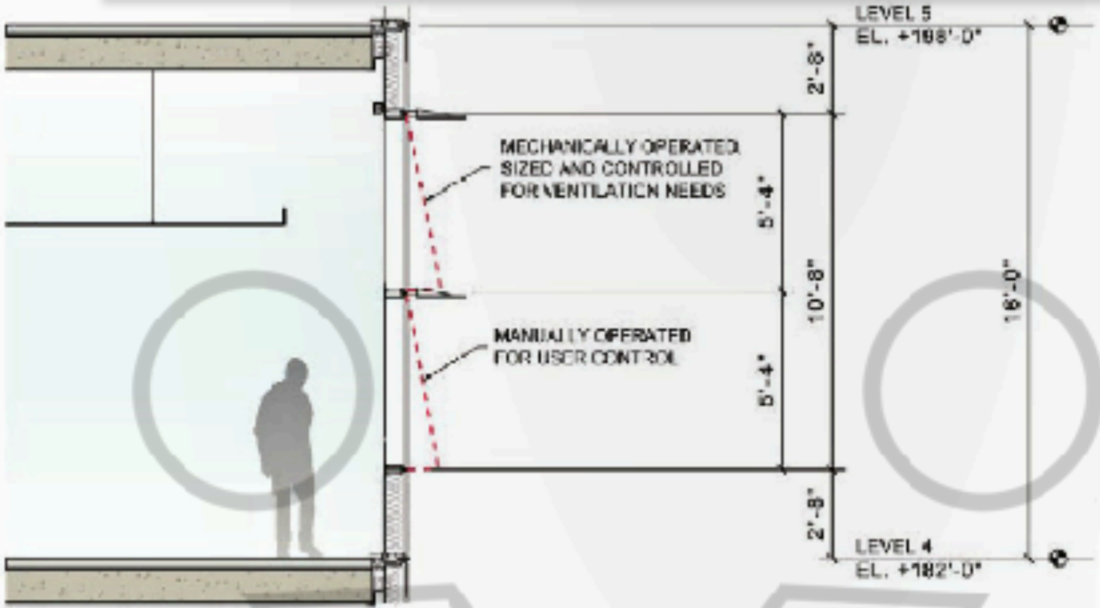
Cooling Season.
Skylight roof fans maximize outdoor air for cooling. Nighttime purging as necessary.



Mode 5

Peak Cooling.
Minimum fresh air. Cooling provided by radiant slab.

WORKING WITH NATURAL VENTILATION DEVICES Chimney



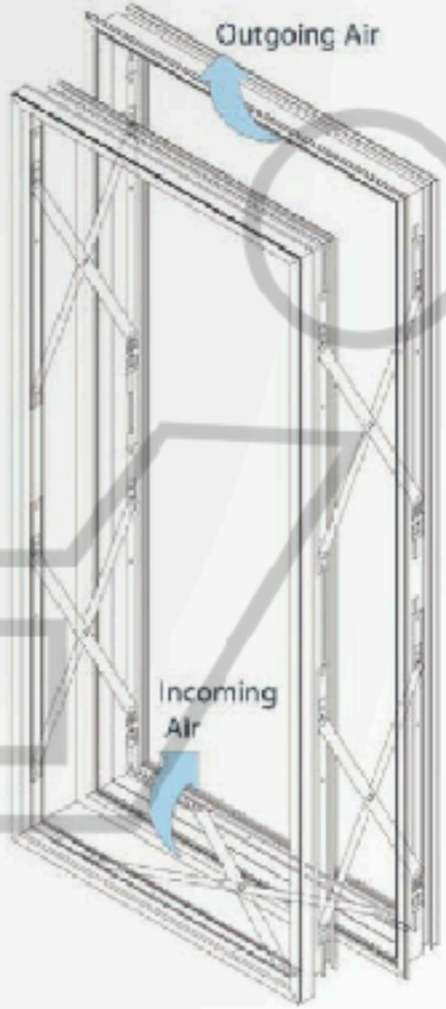
9.13

Section through window showing window uses and sizes.

9.14

Natural ventilation diagram showing airflow into the offices and up through each floor's stacks.

WORKING WITH NATURAL VENTILATION DEVICES Windows



9.16

Photograph of the type of operable windows used at the Bullitt Center. Window diagram shows equal opening size around window's perimeter to reduce wear and provide even, controlled airflow.

Source: Photo and diagram courtesy Schuco.

Computational Materiality for Sustainable Architectures and Comprehensive Skins

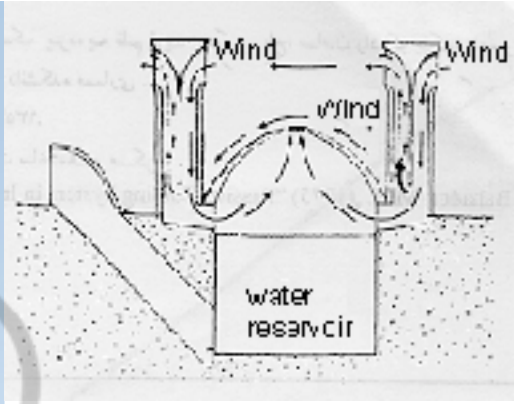
WORKING WITH NATURAL VENTILATION DEVICES

Computational Materiality for Sustainable Architectures and Comprehensive Skins

WORKING WITH WATER EVAPORATION IN HOT DRY CLIMATE

Working with water evaporation in hot dry climate

Working with water evaporation in hot dry climate



Yakhchal
(from Parsi Ice pit)

Latent heat is the energy absorbed by or released from a substance during a phase change from a gas to a liquid or to a solid or vice versa. If a substance is changing from a solid to a liquid, for example, the substance needs to absorb energy from the surrounding environment in order to spread out the molecules into a larger, more fluid volume. If the substance is changing from something with lower density, like a gas, to a phase with higher density like a liquid, the substance gives off energy as the molecules come closer together and lose energy from motion and vibration.

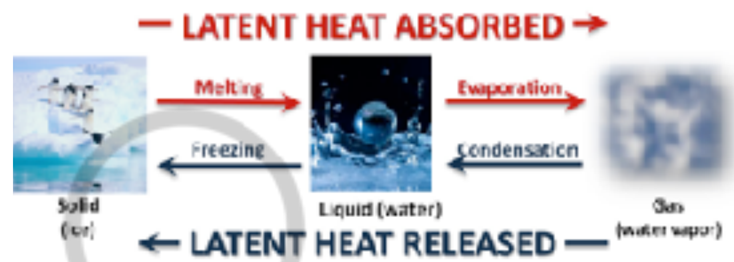
Sensible heat **is the energy required to change the temperature of a substance with no phase change**. The temperature change can come from the absorption of sunlight by the soil or the air itself. Or it can come from contact with the warmer air caused by release of latent heat (by direct conduction). Energy moves through the atmosphere using both latent and sensible heat acting on the atmosphere to drive the movement of air molecules which create wind and vertical motions.

Working with water evaporation in hot dry climate

How much energy in water state transformation

0,09 W/h
0,079 kcal

Sostanza	Calore latente di fusione (J/g)	Temperatura di fusione (°C)
Acqua	333,5	0
Azoto	25,7	-210
Alcol etilico	108	-114
Ammoniaca	339	75
Mercurio	11	39
Zolfo	54	115



0,63 W/gh
0,54 Kcal/g

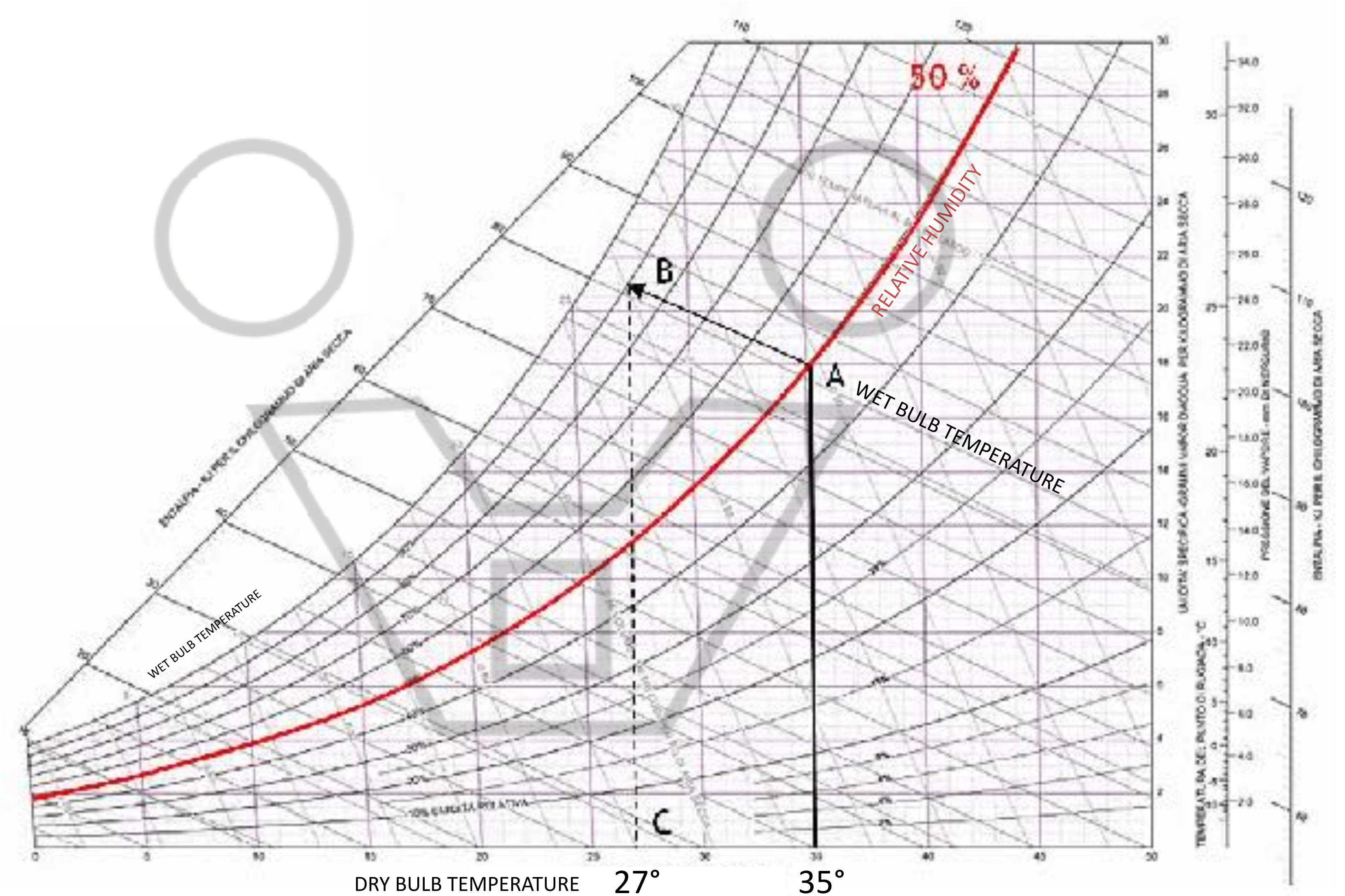
→ 1 litro = 630 W/h → 1 litro = 45 W

Tempo medio 15-20'

Sostanza	Calore latente di ebollizione (J/g)	Temperatura di ebollizione (°C)
Acqua	2272	100
Azoto	200	196
Alcol etilico	855	78,3
Ammoniaca	1369	33
Mercurio	294	357
Zolfo	1406	445

Working with water evaporation in hot dry climate

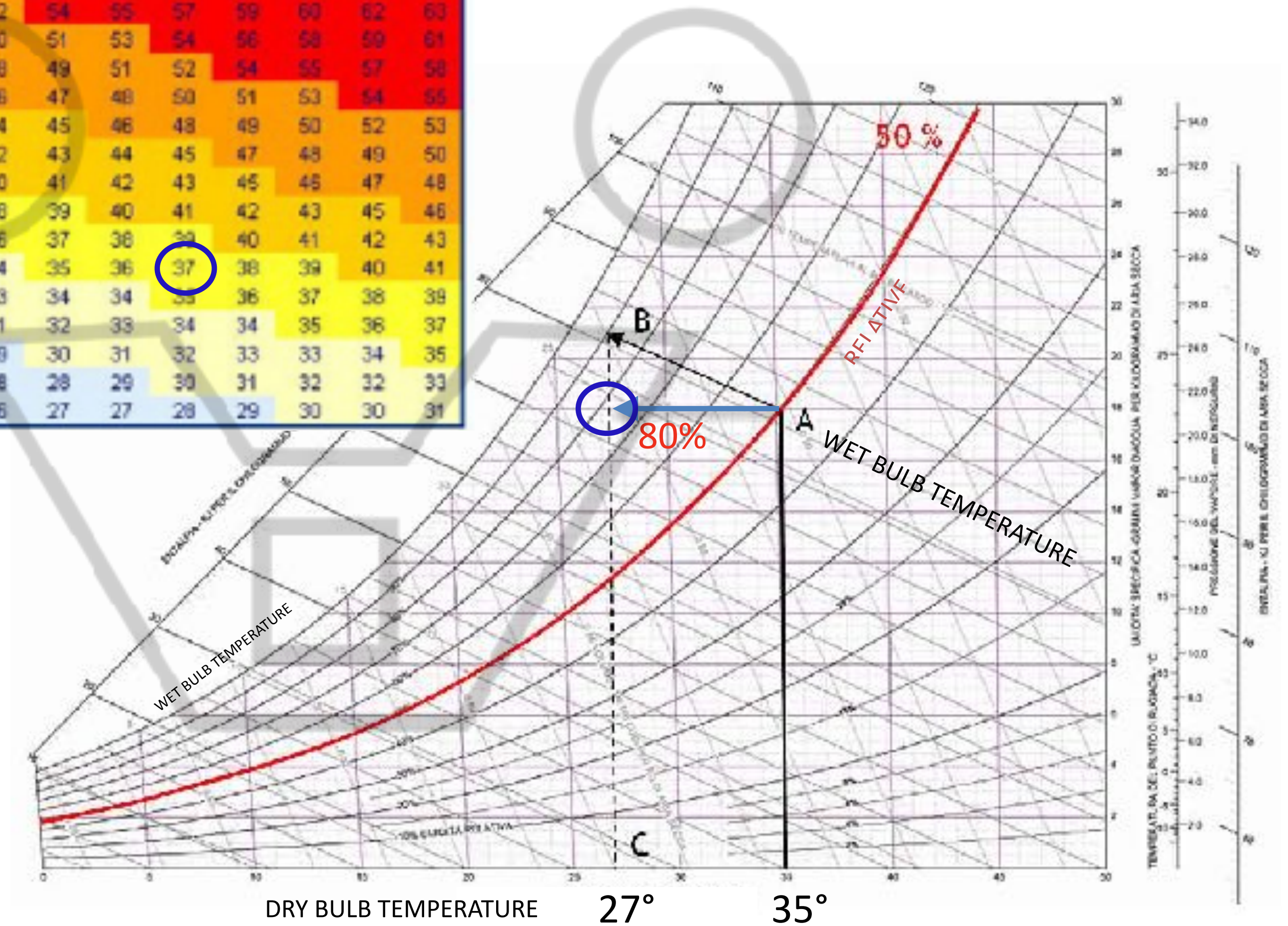
How much is the benefit from evaporative cooling



Working with water evaporation in hot dry climate

How much is the benefit from evaporative cooling

	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
42°	48	50	52	55	57	59	62	64	66	68	71	73	75	77	80	82
41°	46	48	51	53	55	57	59	61	64	66	68	70	72	74	76	79
40°	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75
39°	43	45	47	49	51	53	55	57	59	61	63	65	66	68	70	72
38°	42	44	45	47	49	51	53	55	56	58	60	62	64	66	67	69
37°	40	42	44	45	47	49	51	52	54	56	58	59	61	63	65	66
36°	39	40	42	44	45	47	49	50	52	54	55	57	59	60	62	63
35°	37	39	40	42	44	45	47	48	50	51	53	54	56	58	59	61
34°	36	37	39	40	42	43	45	46	48	49	51	52	54	55	57	58
33°	34	36	37	39	40	41	43	44	46	47	48	50	51	53	54	55
32°	33	34	36	37	38	40	41	42	44	45	46	48	49	50	52	53
31°	32	33	34	35	37	38	39	40	42	43	44	45	47	48	49	50
30°	30	32	33	34	35	36	37	39	40	41	42	43	45	46	47	48
29°	29	30	31	32	33	35	36	37	38	39	40	41	42	43	45	46
28°	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
27°	27	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
26°	26	26	27	28	29	30	31	32	33	34	34	35	36	37	38	39
25°	25	25	26	27	27	28	29	30	31	32	33	34	34	35	36	37
24°	24	24	24	25	26	27	28	28	29	30	31	32	33	33	34	35
23°	23	23	23	24	25	25	26	27	28	28	29	30	31	32	32	33
22°	22	22	22	22	23	24	25	25	26	27	27	28	29	30	30	31

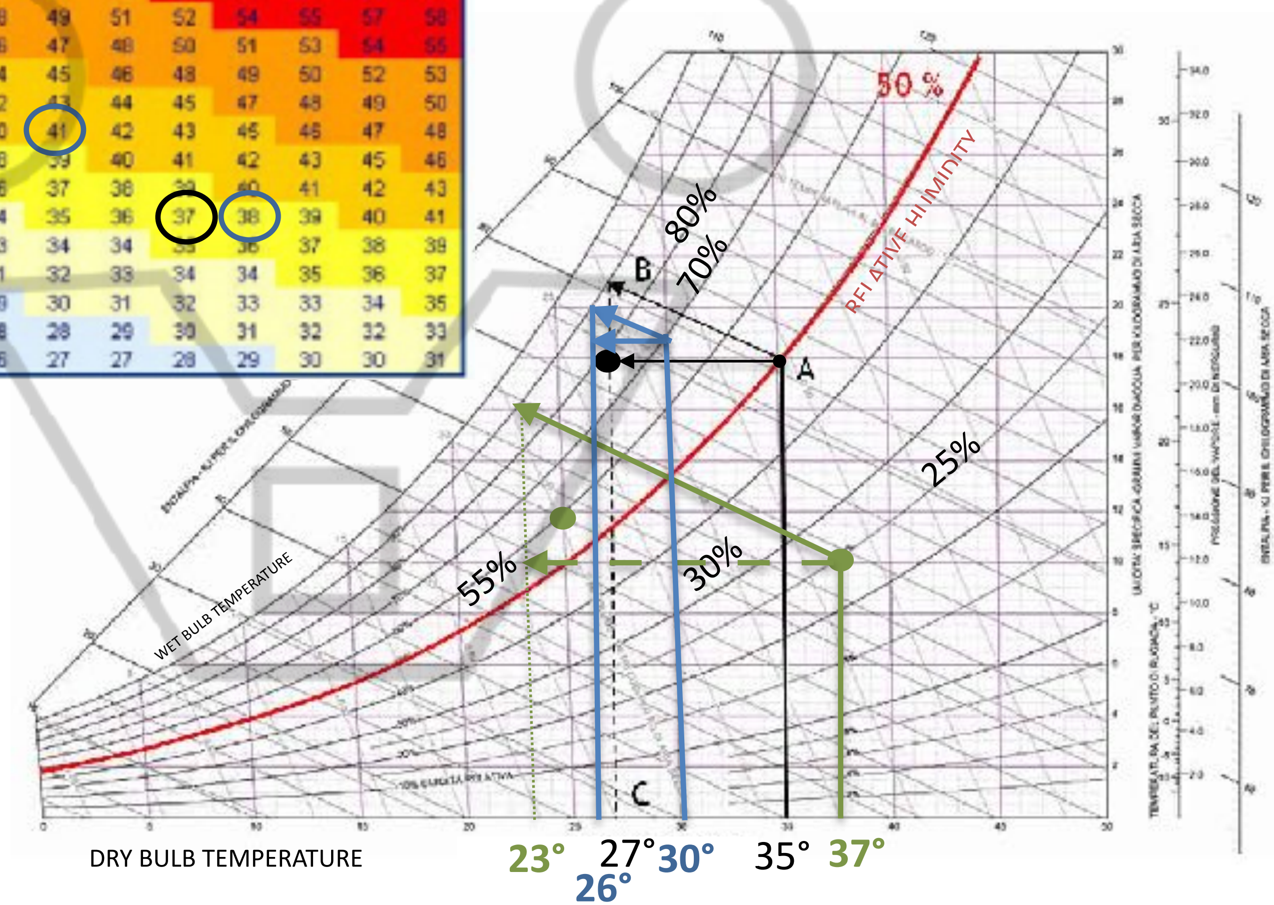


Working with water evaporation in hot dry climate

How much is the benefit from evaporative cooling

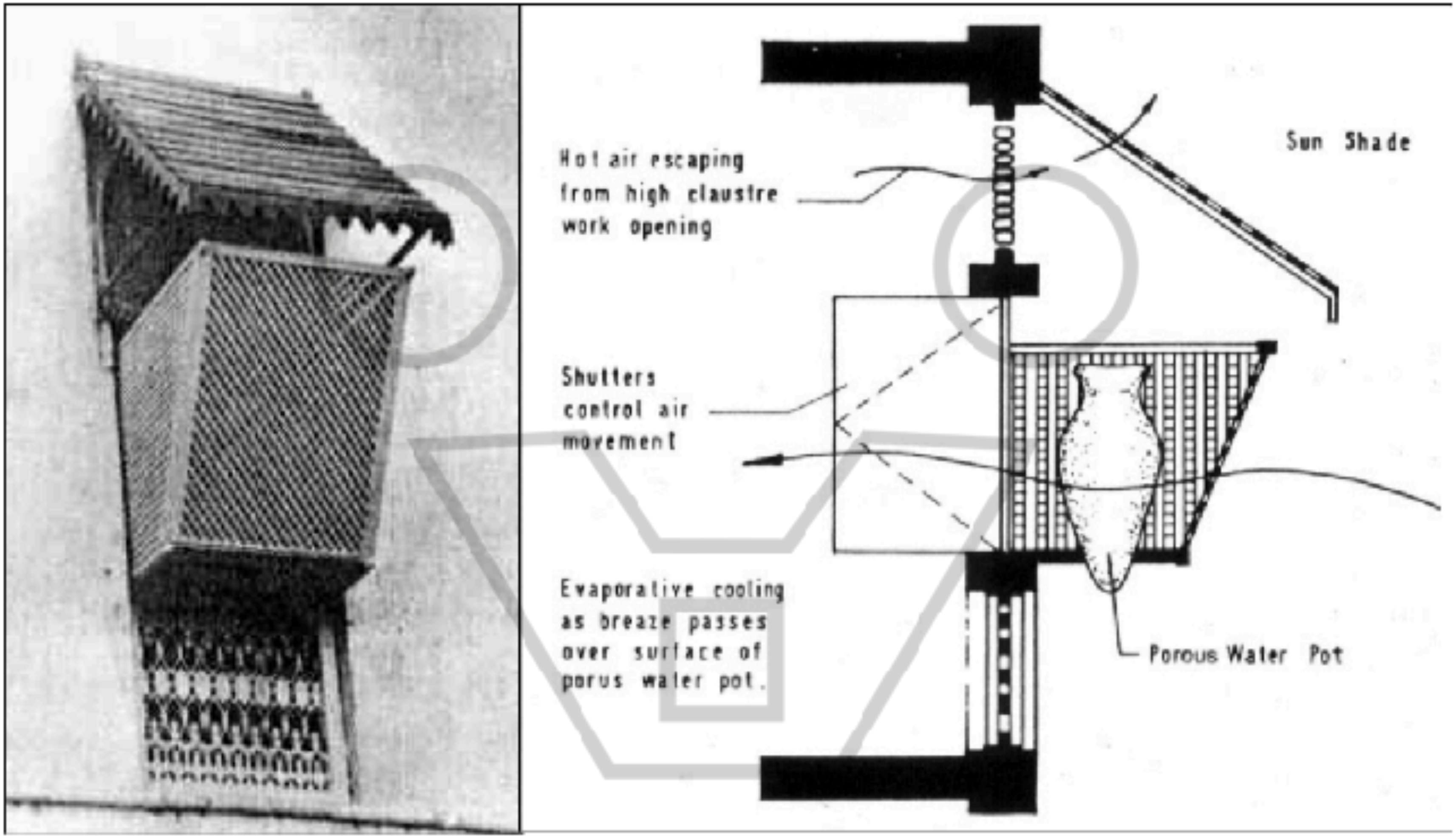
	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
42°	48	50	52	55	57	59	62	64	66	68	71	73	75	77	80	82
41°	46	48	51	53	55	57	59	61	64	66	68	70	72	74	76	79
40°	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75
39°	43	45	47	49	51	53	55	57	59	61	63	65	66	68	70	72
38°	42	44	45	47	49	51	53	55	56	58	60	62	64	66	67	69
37°	40	42	44	45	47	49	51	52	54	56	58	59	61	63	65	66
36°	39	40	42	44	45	47	49	50	52	54	55	57	59	60	62	63
35°	37	39	40	42	44	45	47	48	50	51	53	54	56	58	59	61
34°	36	37	39	40	42	43	45	46	48	49	51	52	54	55	57	58
33°	34	36	37	39	40	41	43	44	46	47	48	50	51	53	54	55
32°	33	34	36	37	38	40	41	42	44	45	46	48	49	50	52	53
31°	32	33	34	35	37	38	39	40	42	43	44	45	47	48	49	50
30°	30	32	33	34	35	36	37	39	40	41	42	43	45	46	47	48
29°	29	30	31	32	33	35	36	37	38	39	40	41	42	43	45	46
28°	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
27°	27	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
26°	26	26	27	28	29	30	31	32	33	34	34	35	36	37	38	39
25°	25	25	26	27	27	28	29	30	31	32	33	34	34	35	36	37
24°	24	24	24	25	26	27	28	28	29	30	31	32	33	33	34	35
23°	23	23	23	24	25	25	26	27	28	28	29	30	31	32	32	33
22°	22	22	22	22	23	24	25	25	26	27	27	28	29	30	30	31

	PRE Humid. Tbs (HR)= Tap	POST Humid Tbs*(HR*)=Tap*	Tbs-Tap*
●	35° (50%)= 45° =>	27°(80%) =37° =>	Δ +2°
●	37° (25%)= 40° =>	25°(55%) =26° =>	Δ -11°
●	30° (70%)= 41° =>	26°(85%) =38° =>	Δ +8°

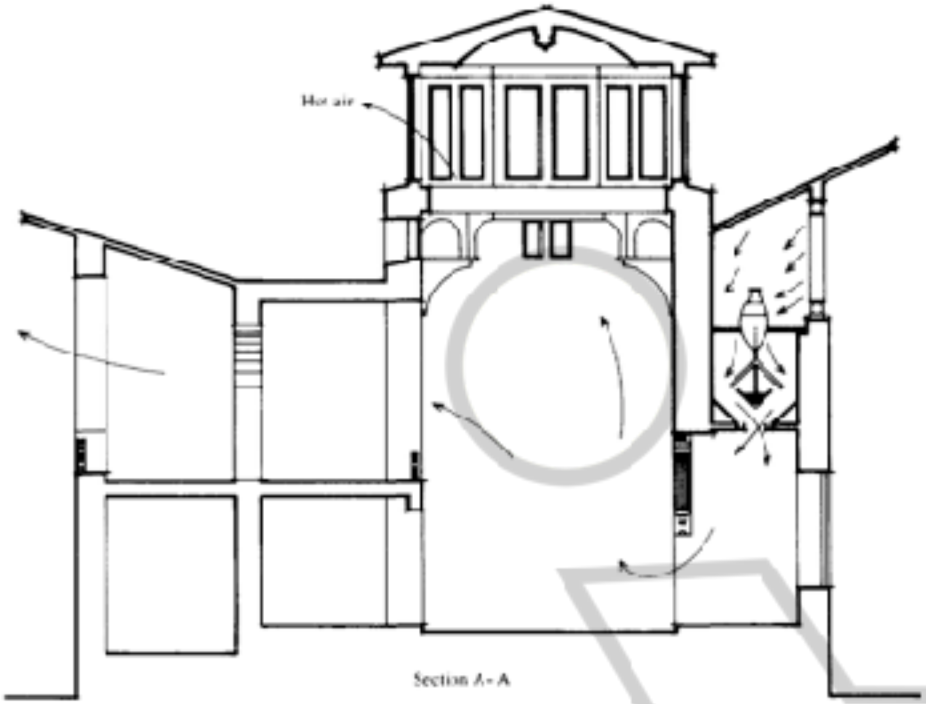


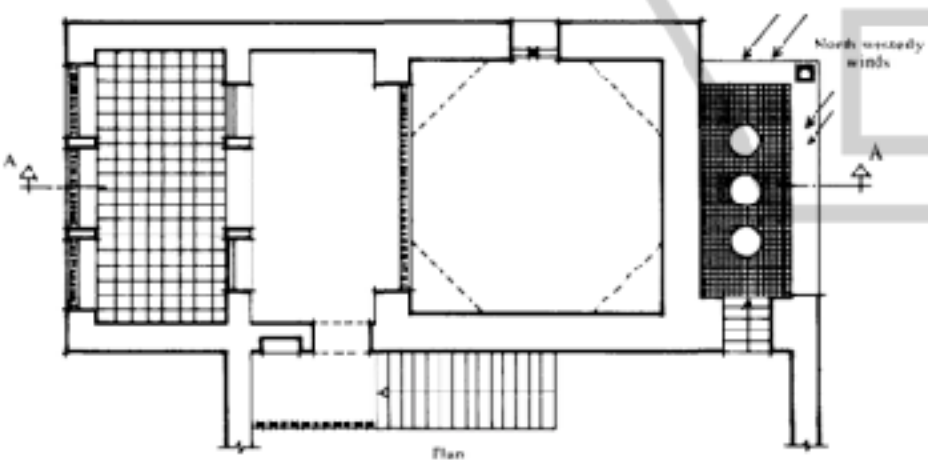
Working with water evaporation in hot dry climate

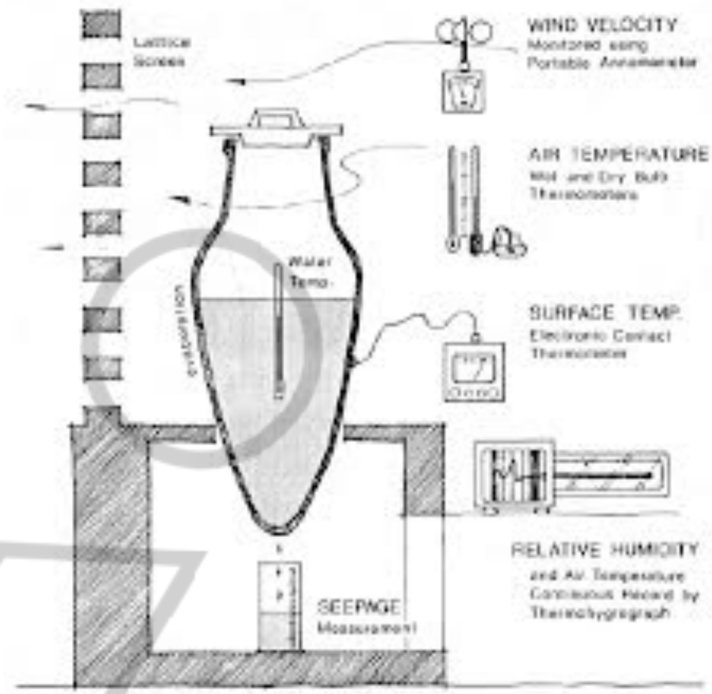
Figure : Muscatese Evaporative cooling window system (Rosa Schiano 2007)



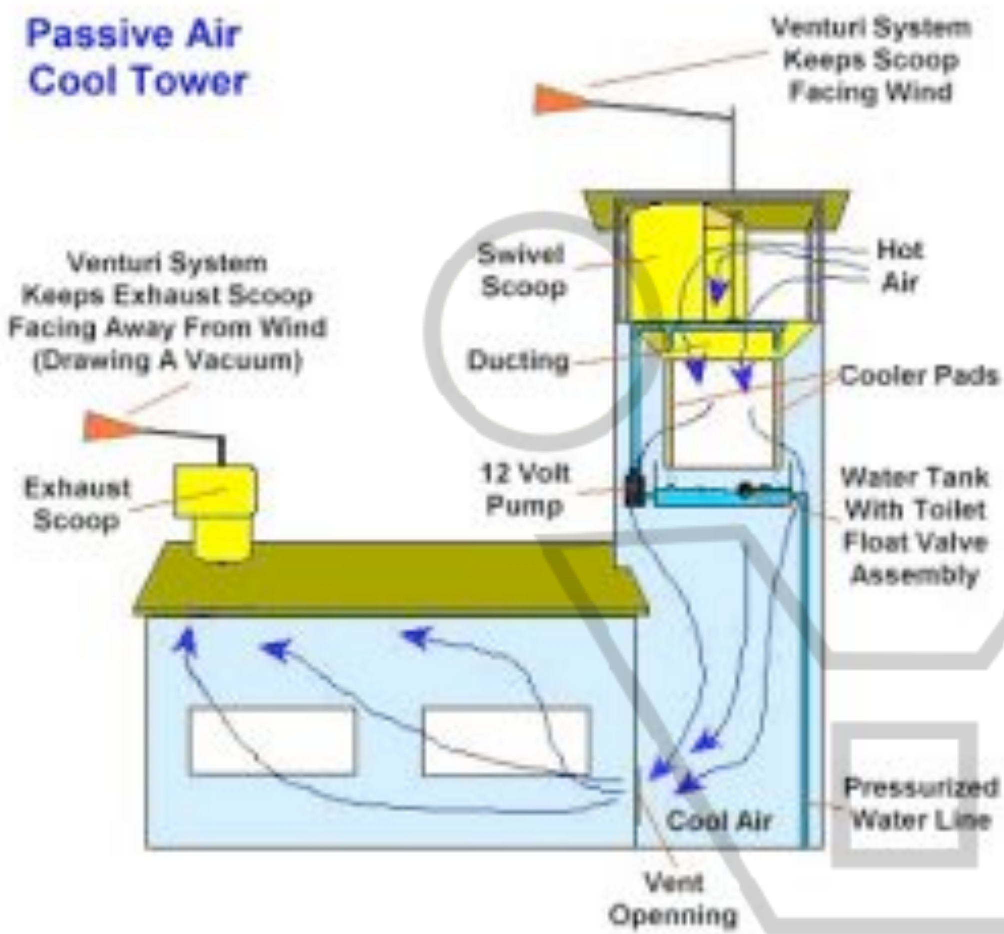
Working with water evaporation in hot dry climate

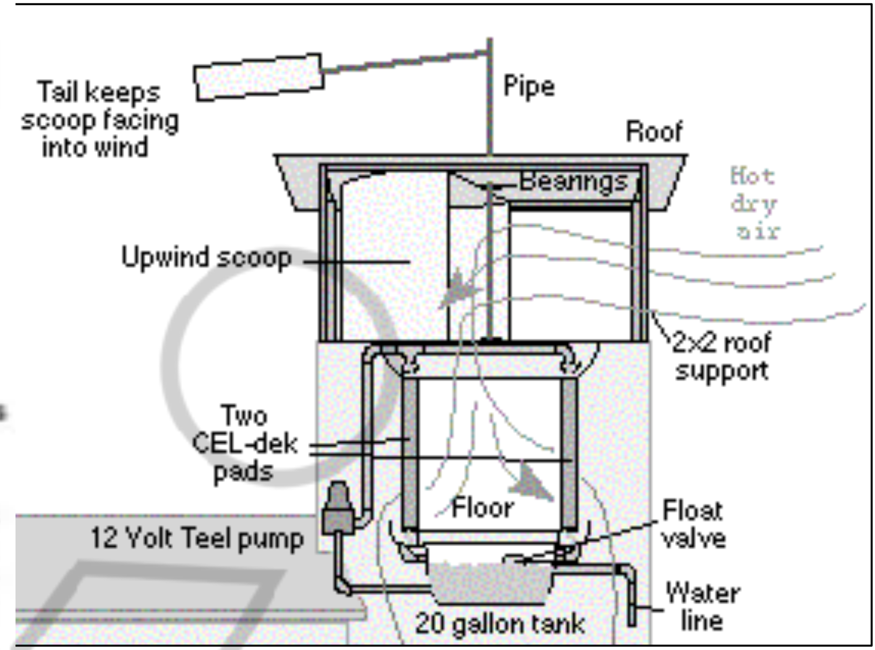




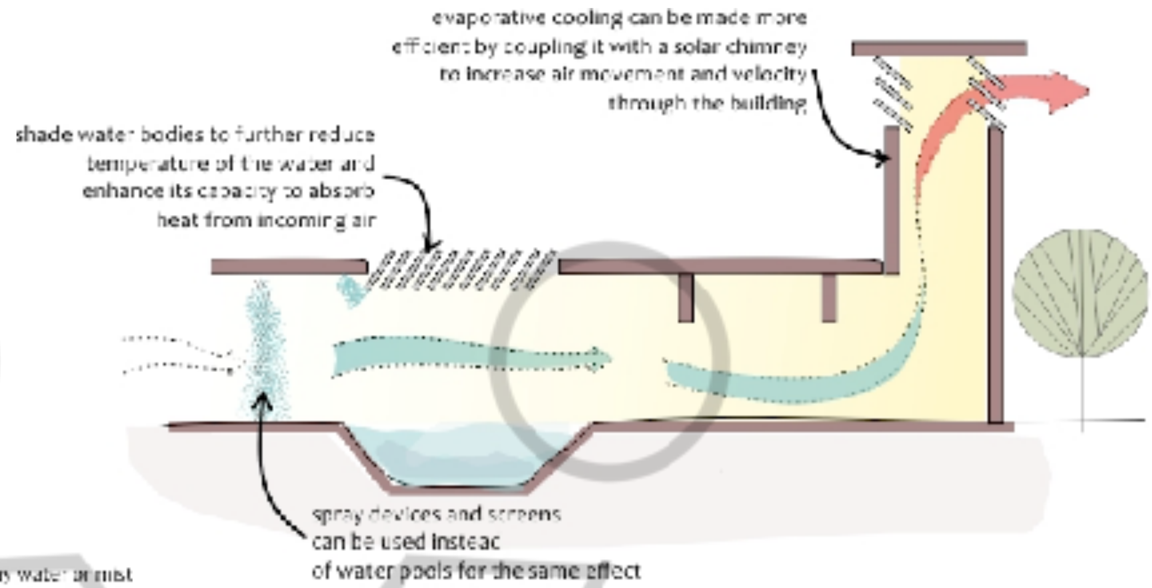


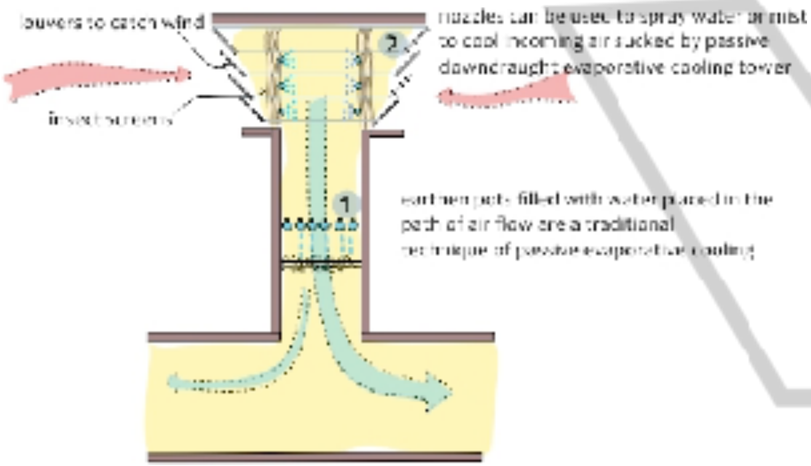
Working with water evaporation in hot dry climate

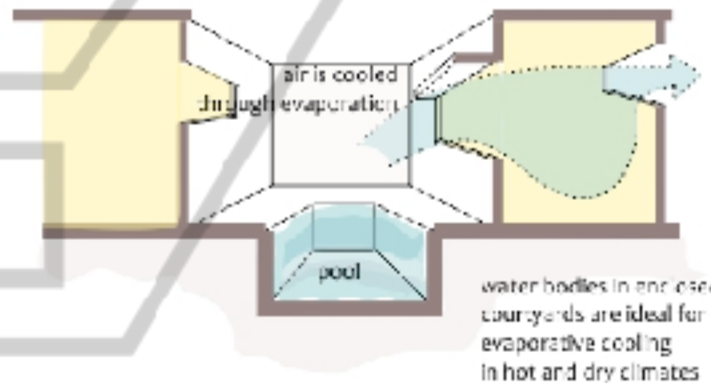




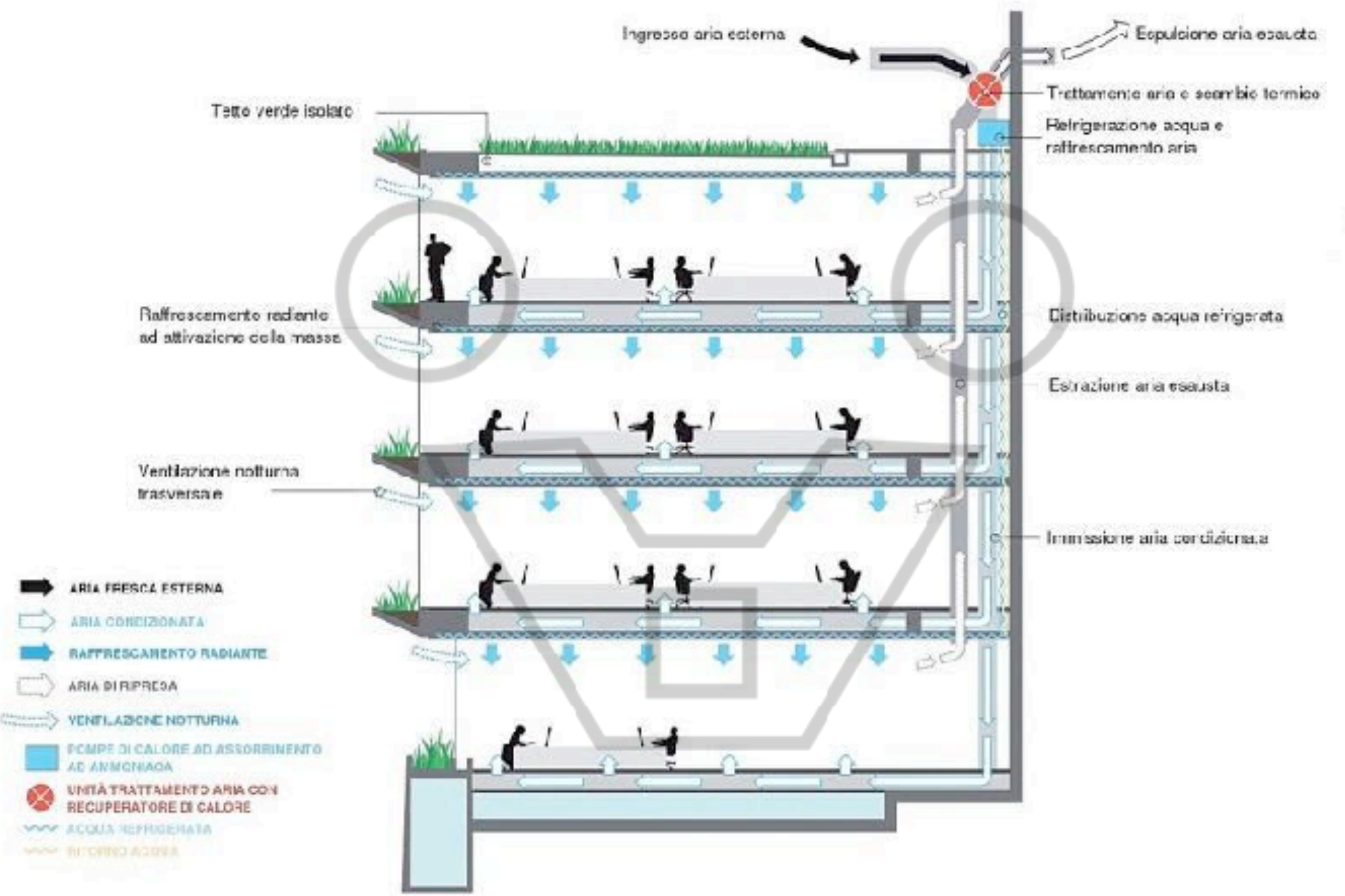
Working with water evaporation in hot dry climate







Working with water evaporation in hot dry climate



WORKING WITH MASS LATENCY & THERMAL LAG

Working with Mass Latency or Thermal Lag

What is THERMAL LAG?

Thermal Lag describes a body's thermal mass with respect to time. A body with high thermal mass (high heat capacity and low conductivity) will have a large thermal lag.

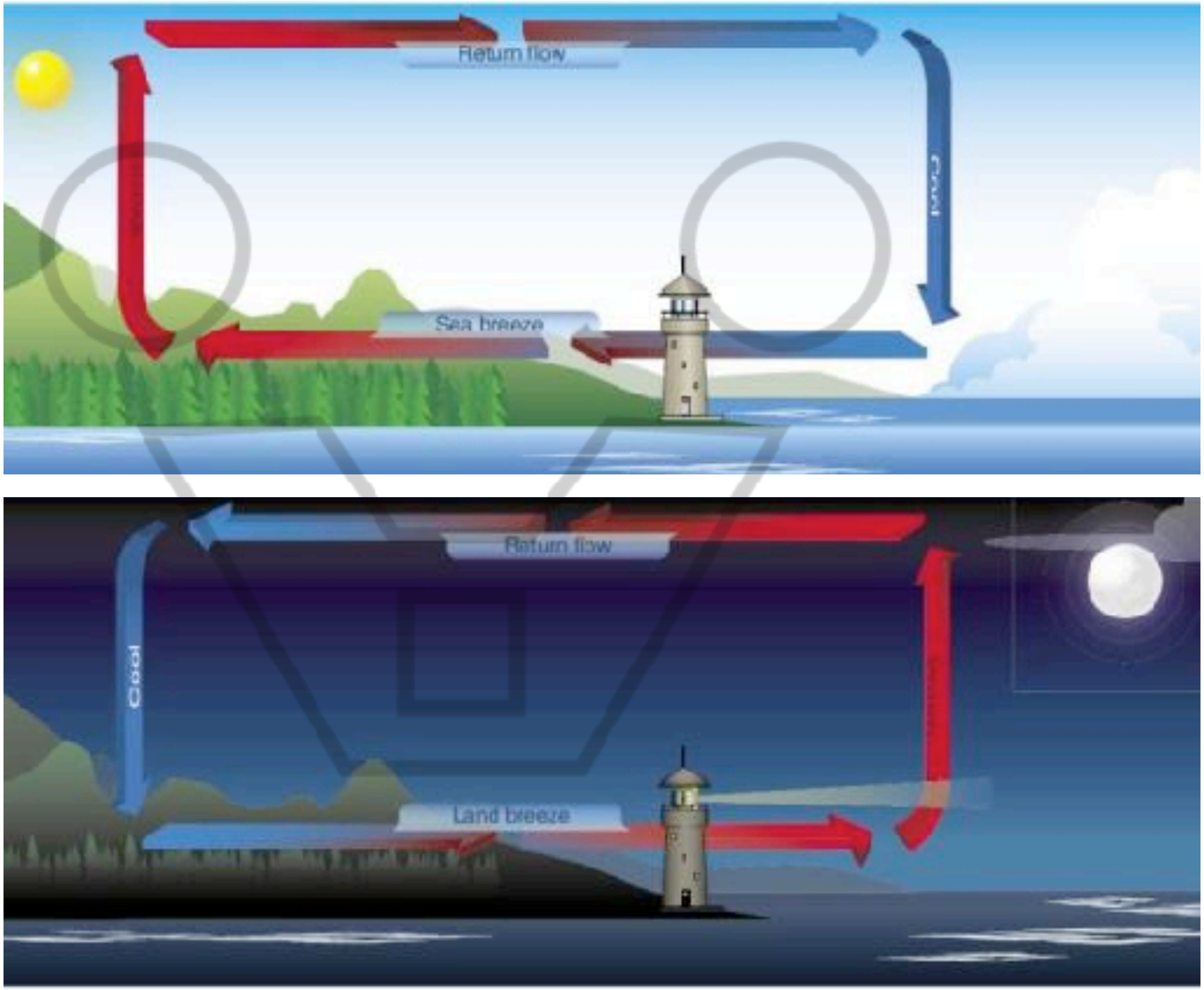
Thermal diffusivity is the thermal conductivity divided by density and specific heat capacity at constant pressure

thermal mass is a property of the mass of a building which enables it to store heat, providing "inertia" against temperature fluctuations. It is sometimes known as the *thermal flywheel effect.*

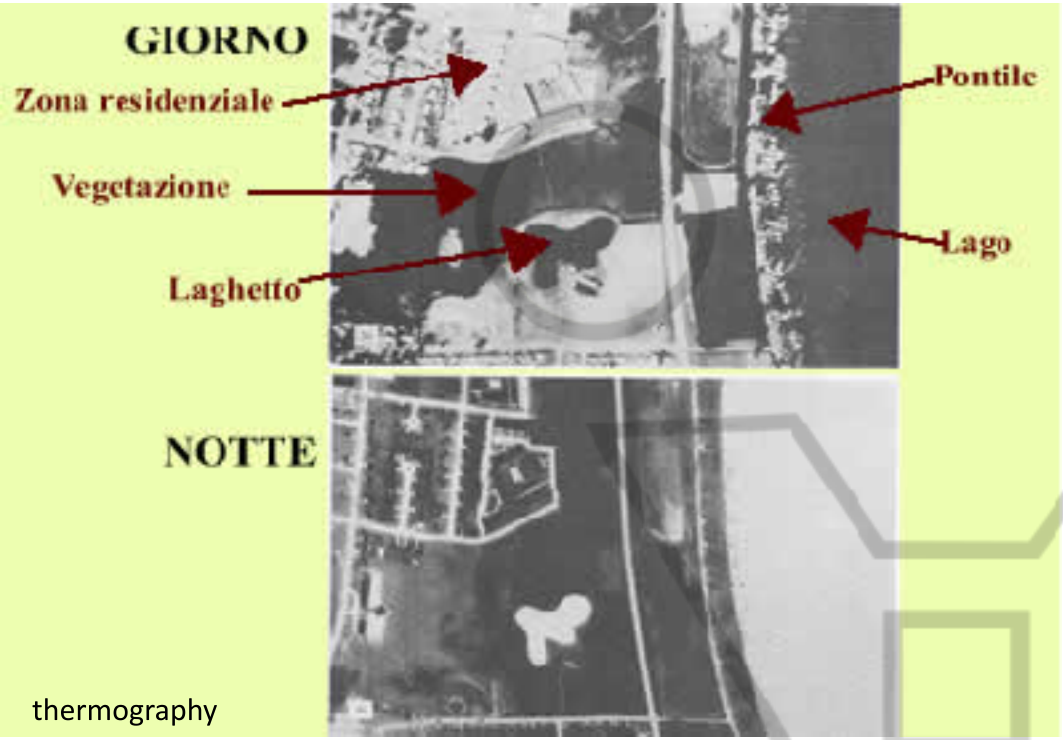
This is distinct from a material's insulative value, which reduces a building's thermal conductivity, allowing it to be heated or cooled relatively separate from the outside,

Working with Mass Latency or Thermal Lag

A thermal flywheel effect from Nature: Marine breezes



Benefit of Thermal Mass



thermography

Thermal mass affects the temperature within a building by stabilizing internal temperatures in three ways:

- *stabilizing internal temperatures* by providing heat source and heat sink surfaces for radiative, conductive and convective heat exchange processes;
- *providing a time-lag* in the equalization of external and internal temperatures;
- *providing a temperature reduction* across an external wall (the decrement factor).

Working with Mass Latency or Thermal Lag

Internal temperature stabilization

Thermal mass influences comfort by radiant exchanges with the skin. In fact radiant exchange with mass surfaces is singularly the most efficient way of maintaining comfort compared with an other technique as the body is more that twice as sensitive to radiant losses and gains than all other pathways combined (conduction, convection, respiration, evaporation) and more than four times as sensitive than any other single pathway.

Thermal comfort exists when a body's heat loss equals its heat gain or *vice versa*.
The body exchanges:

- ·62% of this heat via radiation,
- ·15% by evaporation,
- ·10% by convection,
- ·10% by respiration and
- ·3% by conduction.

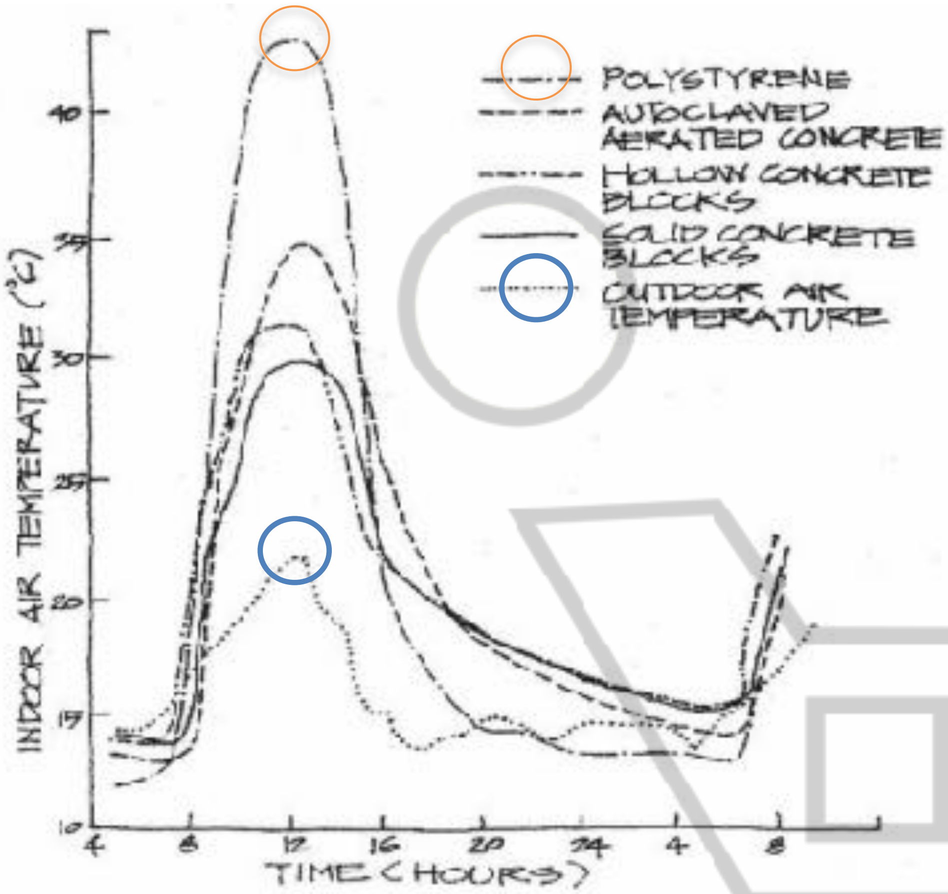
http://www2.ecospecifier.org/

Relatively small changes in mean radiant temperature have a far greater effect than similar changes in air temperatures (Ballinger 1992). This gives rise to the importance of recognizing the overall Environmental Temperature [T(env)], *as opposed to just the dry bulb temperature.*

T(env) = 2/3 Mean radiant surface temperature + 1/3 Air temperature

Working with Mass Latency or Thermal Lag

Internal temperature stabilization

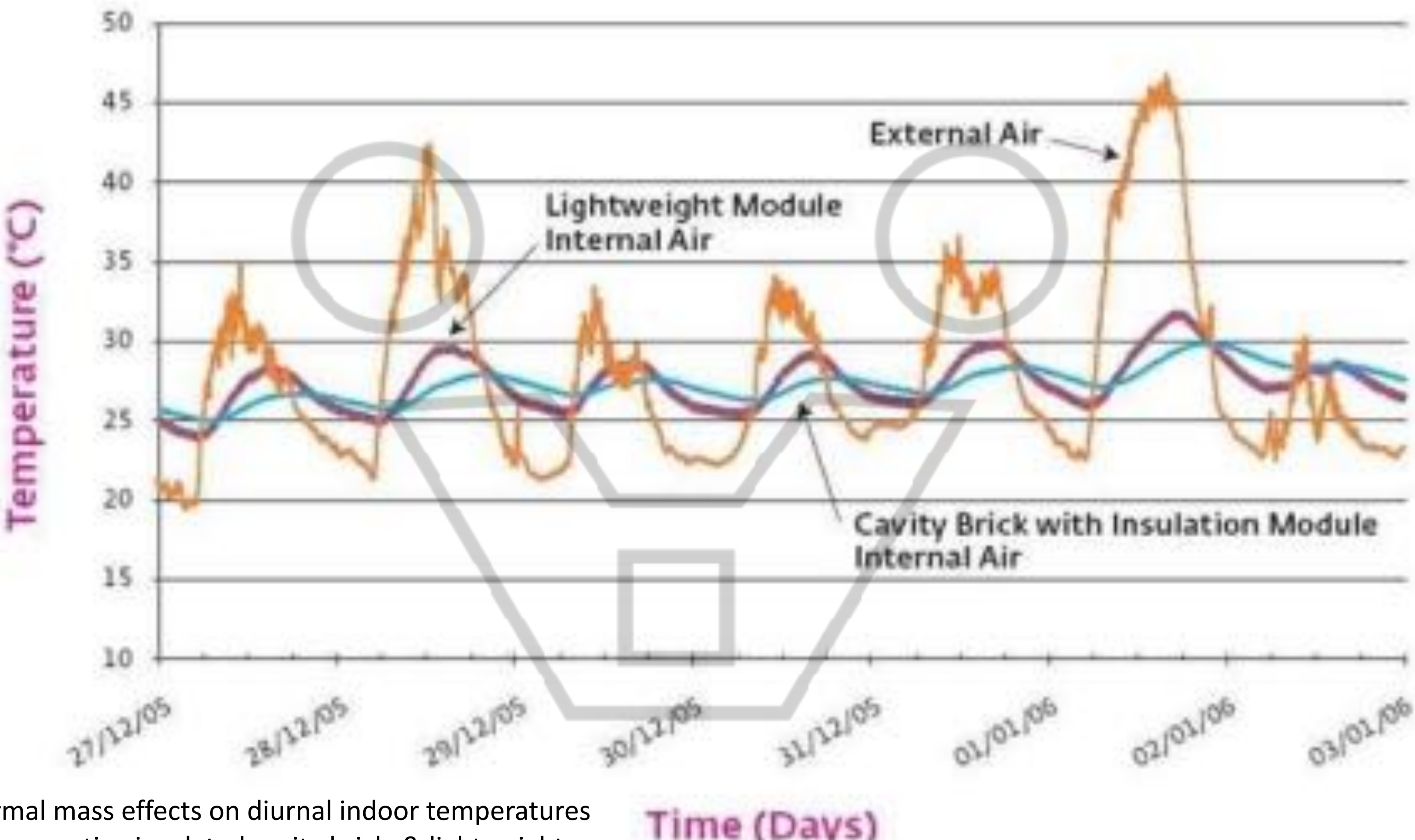


Thermal mass effects on diurnal indoor temperatures of various materials.

When heat enters a space directly by penetration of sunlight, lighting, equipment losses or heating, the temperature rise will be in inverse relationship to the accessible volume of thermal mass. Therefore, the indoor temperature will rise almost immediately if there is little thermal mass in the room.

Working with Mass Latency or Thermal Lag

Internal temperatures stabilization using different structural materials



Thermal mass effects on diurnal indoor temperatures of comparative insulated cavity brick & lightweight structures (Think Brick Australia 2006)

Working with Mass Latency or Thermal Lag

Heat capacity by materials

Specific heat is the amount of heat needed to raise the temperature of one kilogram of mass by 1 kelvin.

Material	Density (Kg/m3)	Specific heat (kJ/kg.K)	Volumetric heat capacity Thermal mass (kJ/m3.K)
Water	1000	4.186	4186
Concrete	2240	0.920	2060
AAC	500	1.100	550
Brick	1700	0.920	1360
Stone (Sandstone)	2000	0.900	1800
FC Sheet (compressed)	1700	0.900	1530
Earth Wall (Adobe)	1550	0.837	1300
Rammed Earth	2000	0.837	1673
Compressed Earth Blocks	2080	0.837	1740

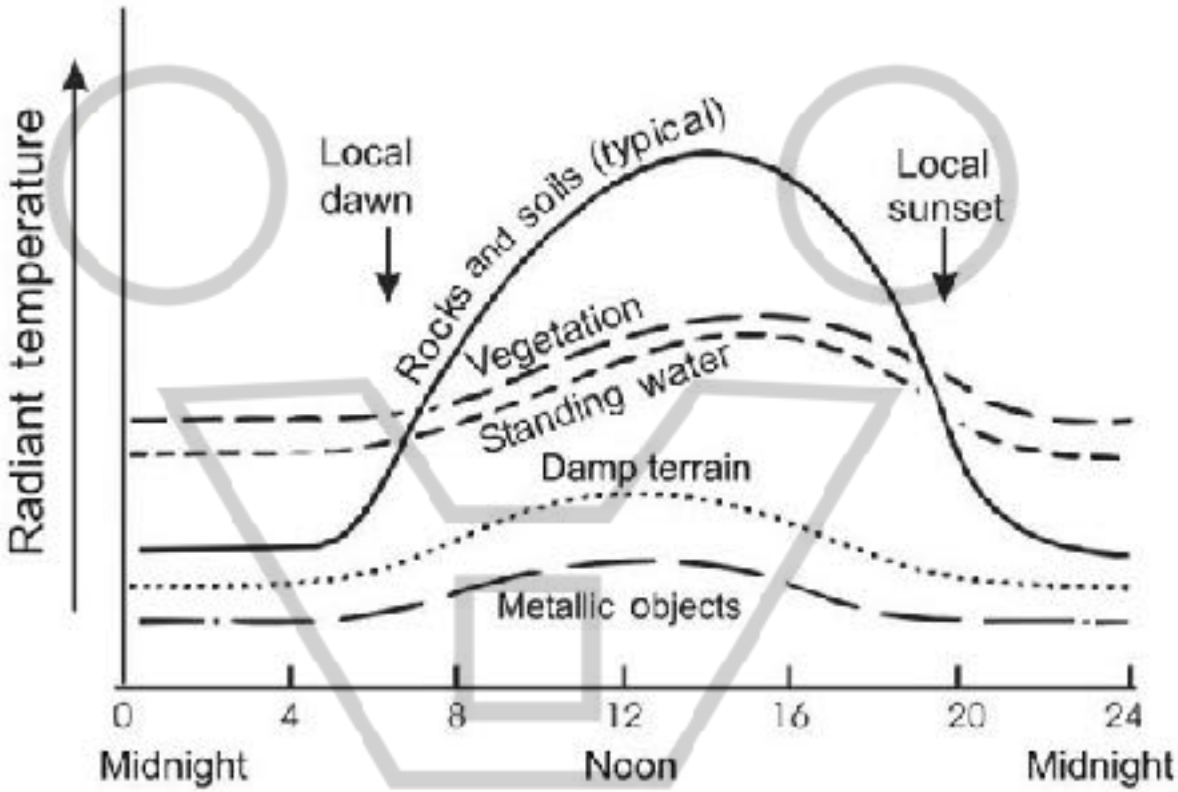
Table 1. Density, specific heat and thermal mass of a range of materials

Note: Figures are based on a number of sources and include estimations and interpolations.

http://www2.ecospecifier.org/knowledge_base/technical_guides/thermal_mass_building_comfort_energy_efficiency

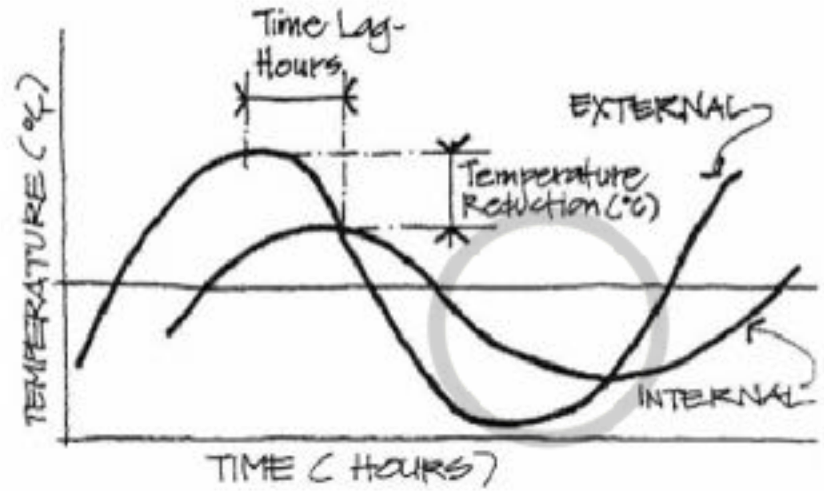
Working with Mass Latency or Thermal Lag

Radiant energy stored during the 24 hours

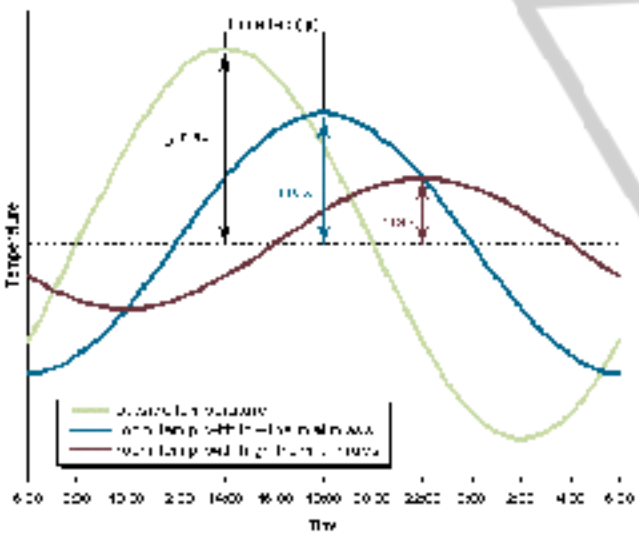


Working with Mass Latency or Thermal Lag

Time lag + temperature reduction



The effect of using heat generated during the day to warm at night in winter and vice versa in summer is known as the 'thermal flywheel' effect. The effectiveness of the flywheel depends on the time lag introduced to a building by an external wall or other boundary element. As can be seen from Figure 3, time 'lag' is the time delay between external maximum or minimum temperatures and internal maximum or minimum temperatures respectively



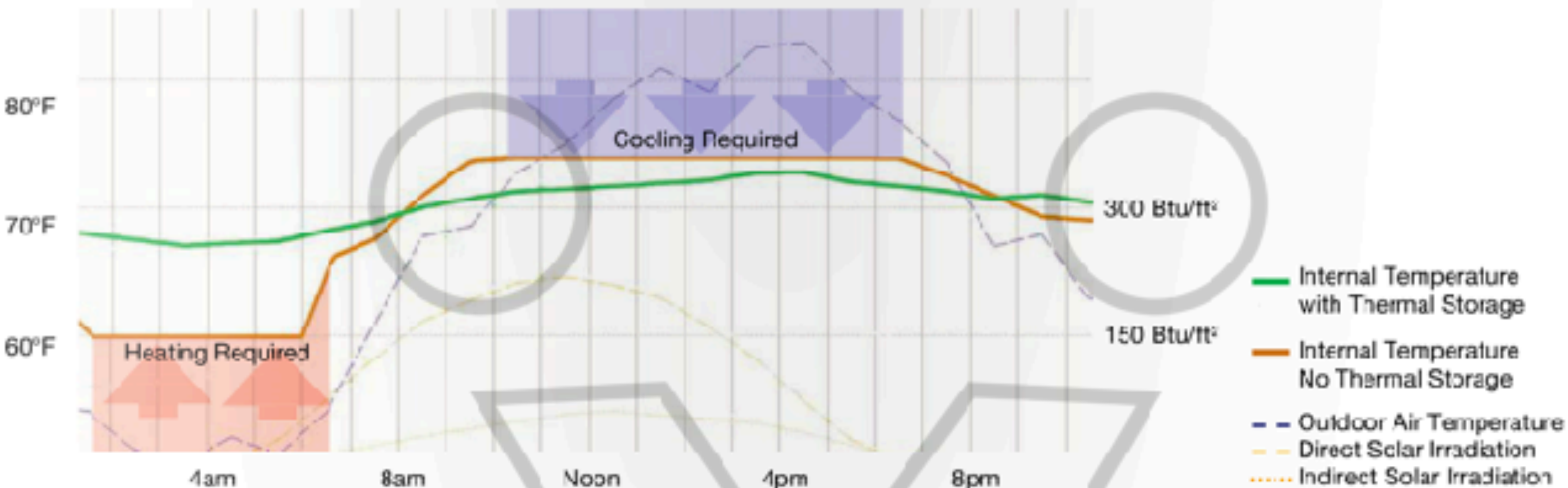
Material (thickness in mm)	Time lag (hours)
Insulated Brick Veneer	5.0
Concrete (250)	6.9
Double Brick (260)	7.0
AAC (200)	7.0
Adobe (250)	9.2
Rammed Earth (250)	10.3
Compressed Earth Blocks (250)	10.5
Sandy Loam (1000)	30 days

Table 4: Time lag figures for various materials
(Baggs, SA, JC, DB., 1991) and (Think Brick Australia, 2006).

Working with Mass Latency or Thermal Lag

Effect of Thermal mass storage

COOLING vs HEATING: Thermal storage strategy



7.11

Diagram showing air temperatures over a 24-hour period for an office with and without thermal storage.

Source: Modified output from an Autodesk Ecotect building model. Courtesy of Callison.

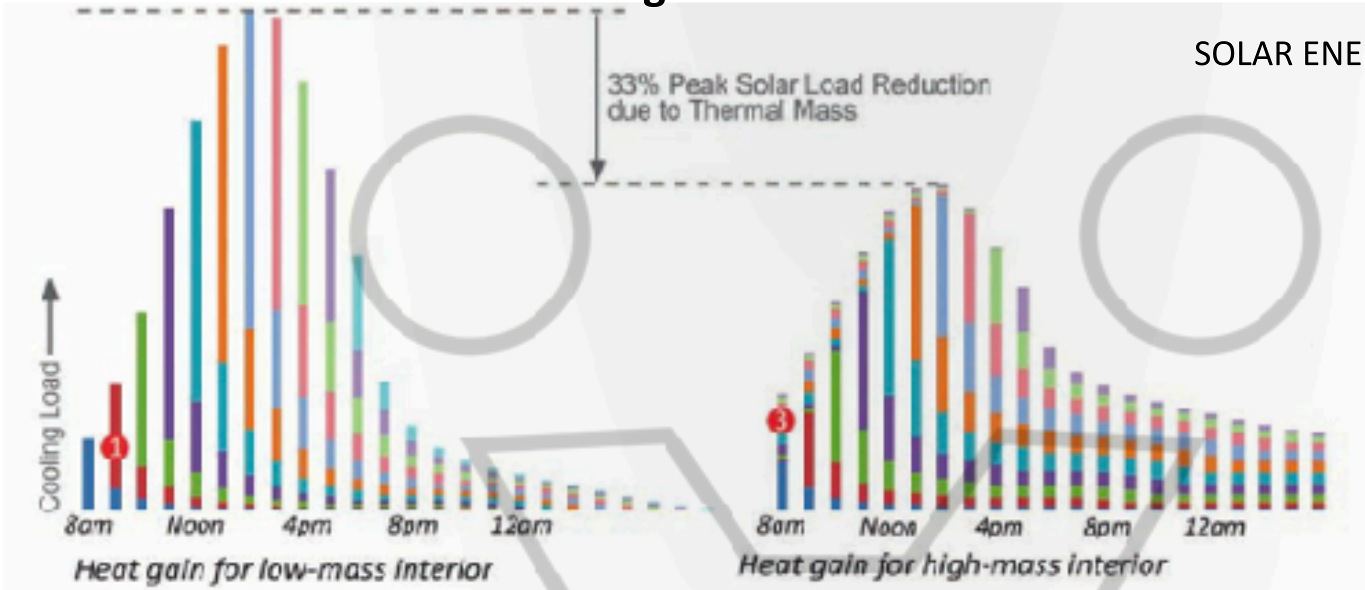
THERMAL STORAGE

Although thermal storage can be an important part of maintaining comfort with minimal energy inputs, over the past 200 years construction in much of the First World has tended towards lightweight, insulated buildings. Lightweight buildings are typically less able to use solar energy, since they cannot delay or

Working with Mass Latency or Thermal Lag

Effect of Thermal mass storage

SOLAR ENERGY TIME DELAY



Percentage of Solar Gain released during each hour after being transmited through glazing

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
High Thermal Mass Example	27%	13%	7%	5%	4%	4%	3%	3%	3%	3%	3%	3%	2%	2%	2%	2%	2%	2%	2%	2%	1%	1%	2%	1%	1%
2 Low Thermal Mass Example	55%	17%	9%	5%	3%	2%	2%	1%	1%	1%	1%	1%	1%	1%	-	-	-	-	-	-	-	-	-	-	-

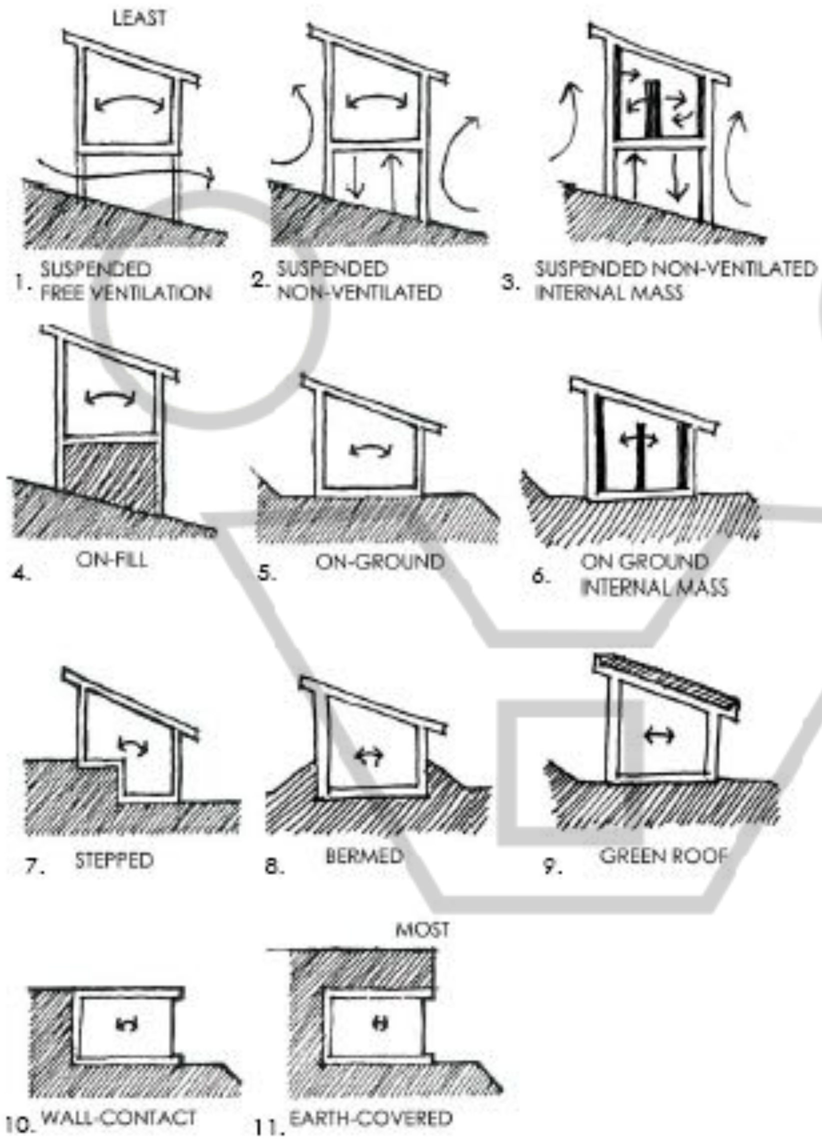
7.12

Solar irradiation values on a south-facing window in Toronto with a .50 glazing to wall ratio were imported onto a spreadsheet to calculate thermal mass effects on peak solar loading using the Radiant Time Series (RTS) method. Each hour's transmitted solar energy becomes a cooling load to the zone over the next 24 hours according to the percentages below for a low-mass and high-mass interior, which are color-coded to show the cumulative effects. At 9am, the solar irradiation that enters is colored red (1), and can be tracked over the next several hours until it becomes nearly negligible. For the low-mass option (2), 55% of the solar energy becomes a cooling load within the same hour it reaches the zone, and 27% is delayed until the second hour, with 9% becoming a cooling load in the third, etc. Each hour has been assigned a color to track it through the day, with the high-mass system including a small remaining solar load from the previous day (3) over the first several hours. The Radiant Time Series method (ASHRAE, 2013) is used to estimating peak cooling loads and contains an accurate but simplified version of estimating the time-delay of solar gain in low-, medium-, and high-mass constructions. The low-mass construction contains carpet, while the high-mass construction exposes concrete floors. The time-delay of other elements, such as exterior walls and solar energy absorbed by the glazing, was not considered. Solar irradiation values calculated in Autodesk Ecotect.

Source: Courtesy of Callison.

Working with Mass Latency or Thermal Lag

Locating mass in a building



HIGH IMPACT on
CLIMATE DOMINATED BUILDING

- skinny buildings
- single houses,
- medium density residential,
- low-rise commercial buildings
- small scale educational and industrial buildings.

MEDIUM INTERNAL on
LOAD DOMINATED BUILDING

- medium and high-rise commercial and educational structures,

(Baverstock (1994) has shown that mass used in this way can provide 27% of the overall building cooling benefits and 38% of the overall building heating benefits.)

Working with Mass Latency or Thermal Lag

Locating mass in a building and operations in buildings with thermal mass

- **External walls require minimum levels of added insulation for wall types under 200kg/m2**

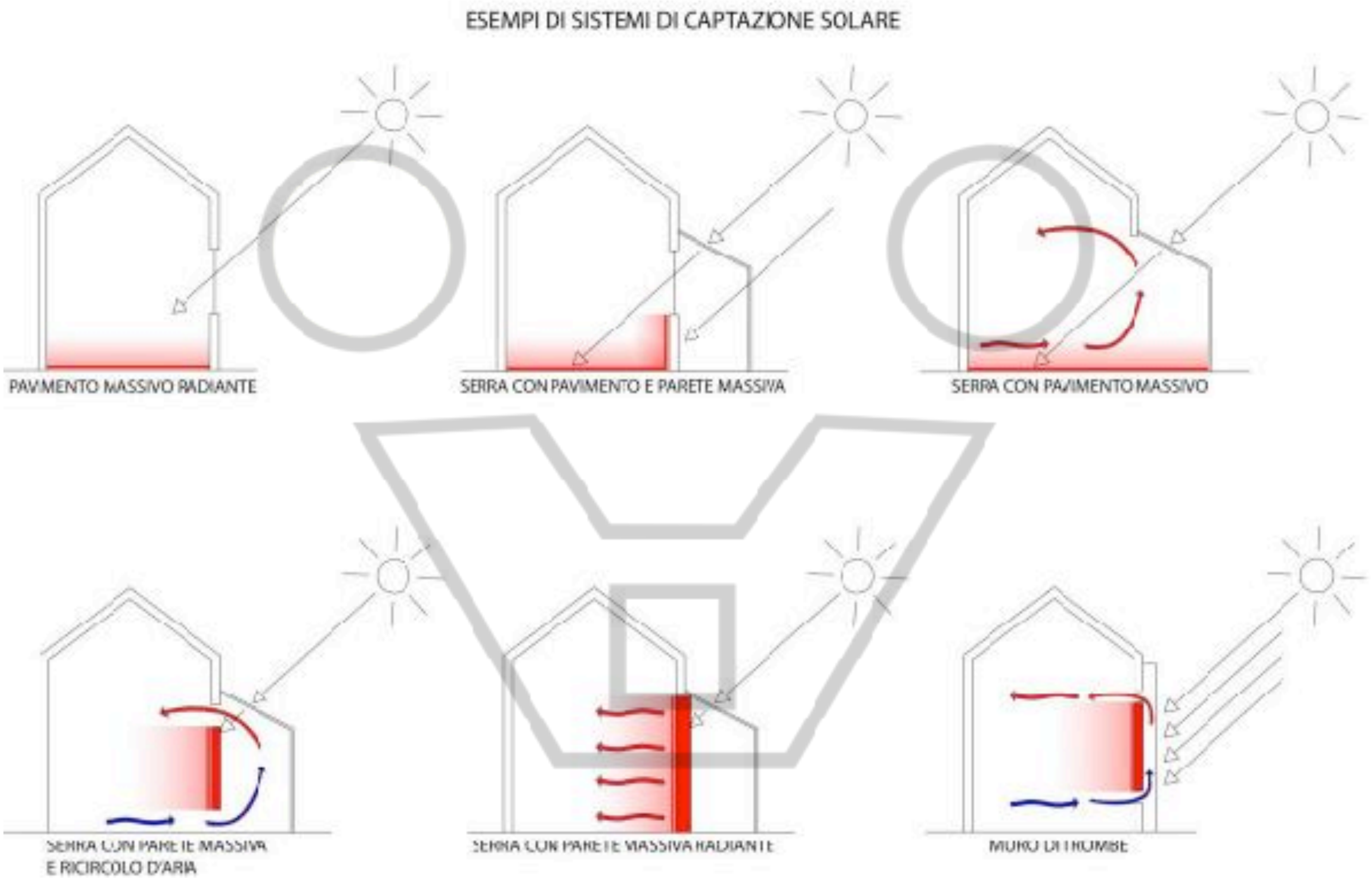
In the case of if adequate solar heat various kinds of earth walls such as adobe, rammed earth and compressed earth blocks, with their time lags of 10-11+ hours, is recommended left unsealed or finished with a 'breathable' paint.

	Summer		Winter	
Device	day	night	day	night
Windows, doors	closed	open	closed	closed
Blinds (external)	closed	open	open	closed
Curtains (internal)	closed	open	open	closed

Table 2: User control of shading and ventilation devices

Working with Mass Latency or Thermal Lag

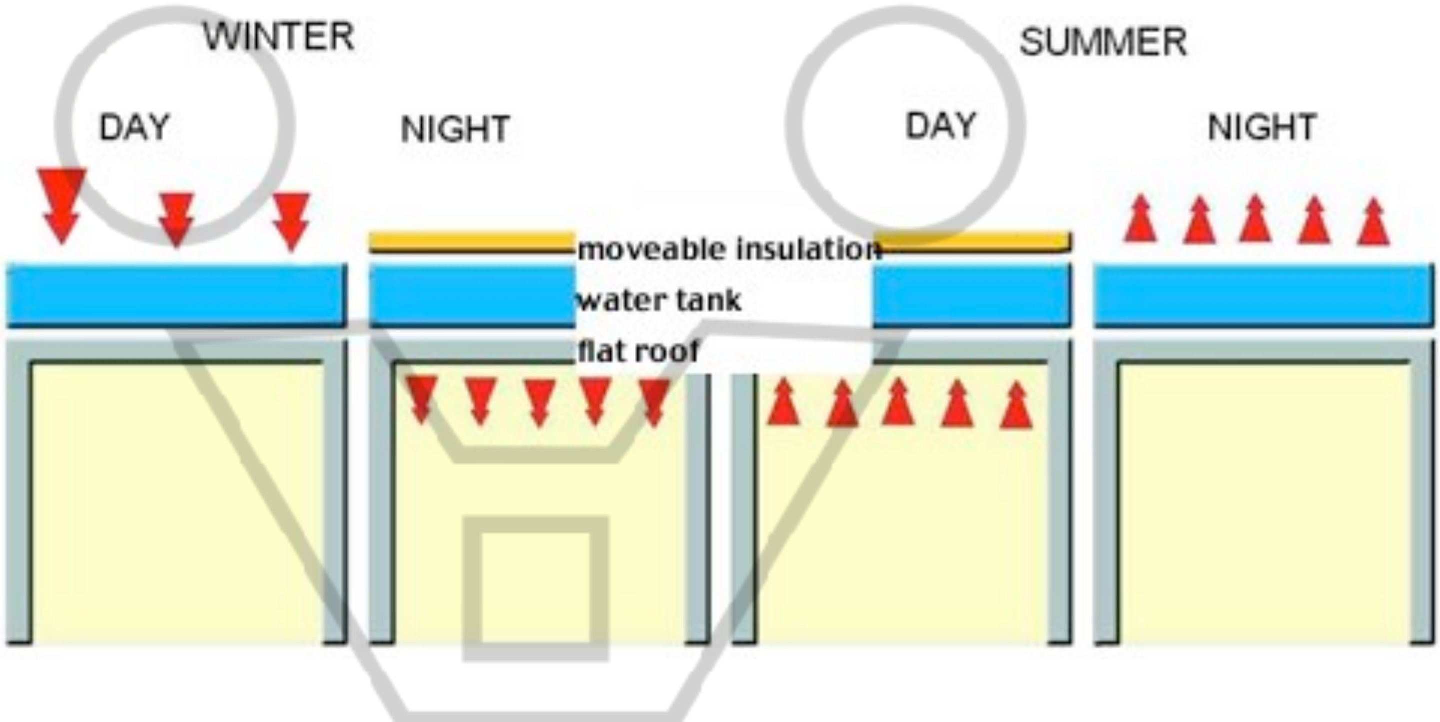
Locating mass in a building



Working with Mass Latency or Thermal Lag

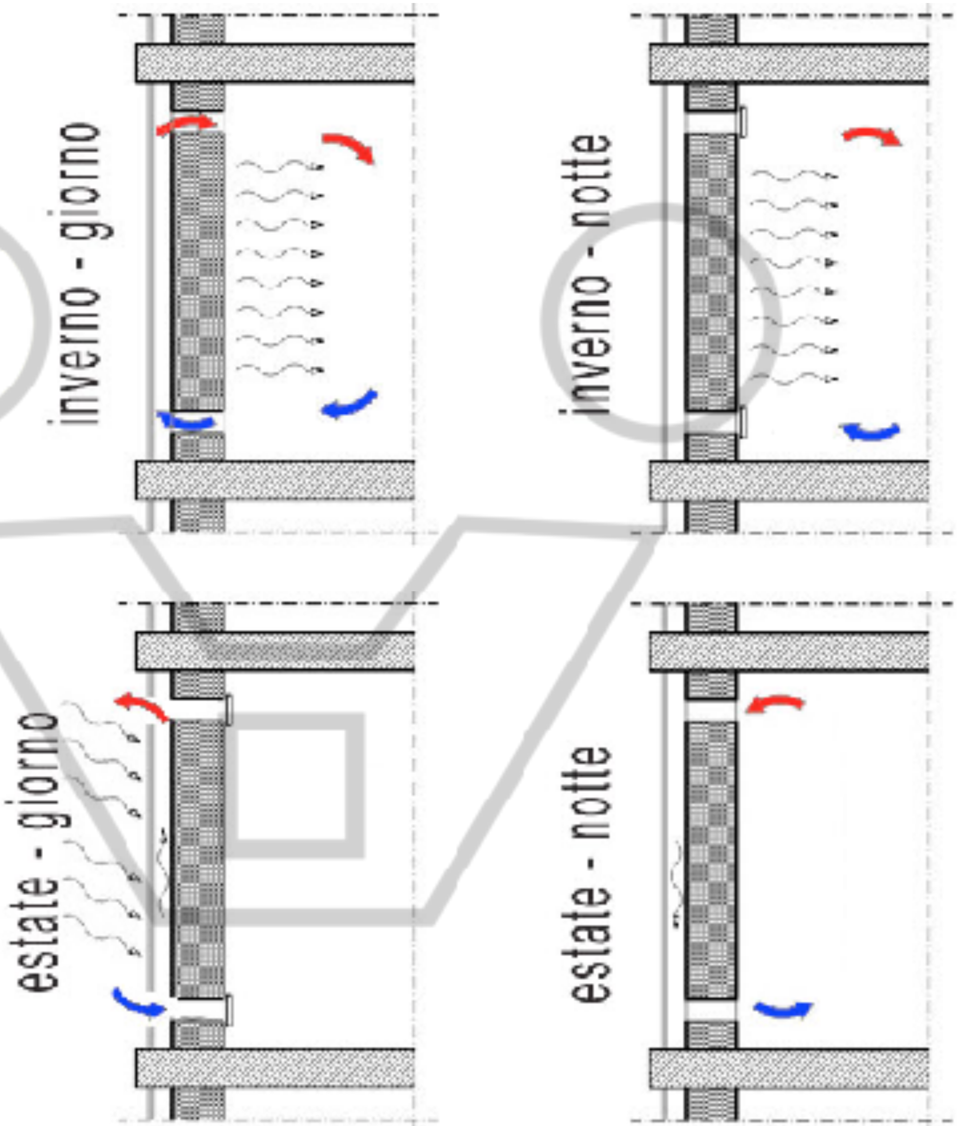
Locating mass in a building

THERMAL STORAGE FOR HOT ARID CLIMATE



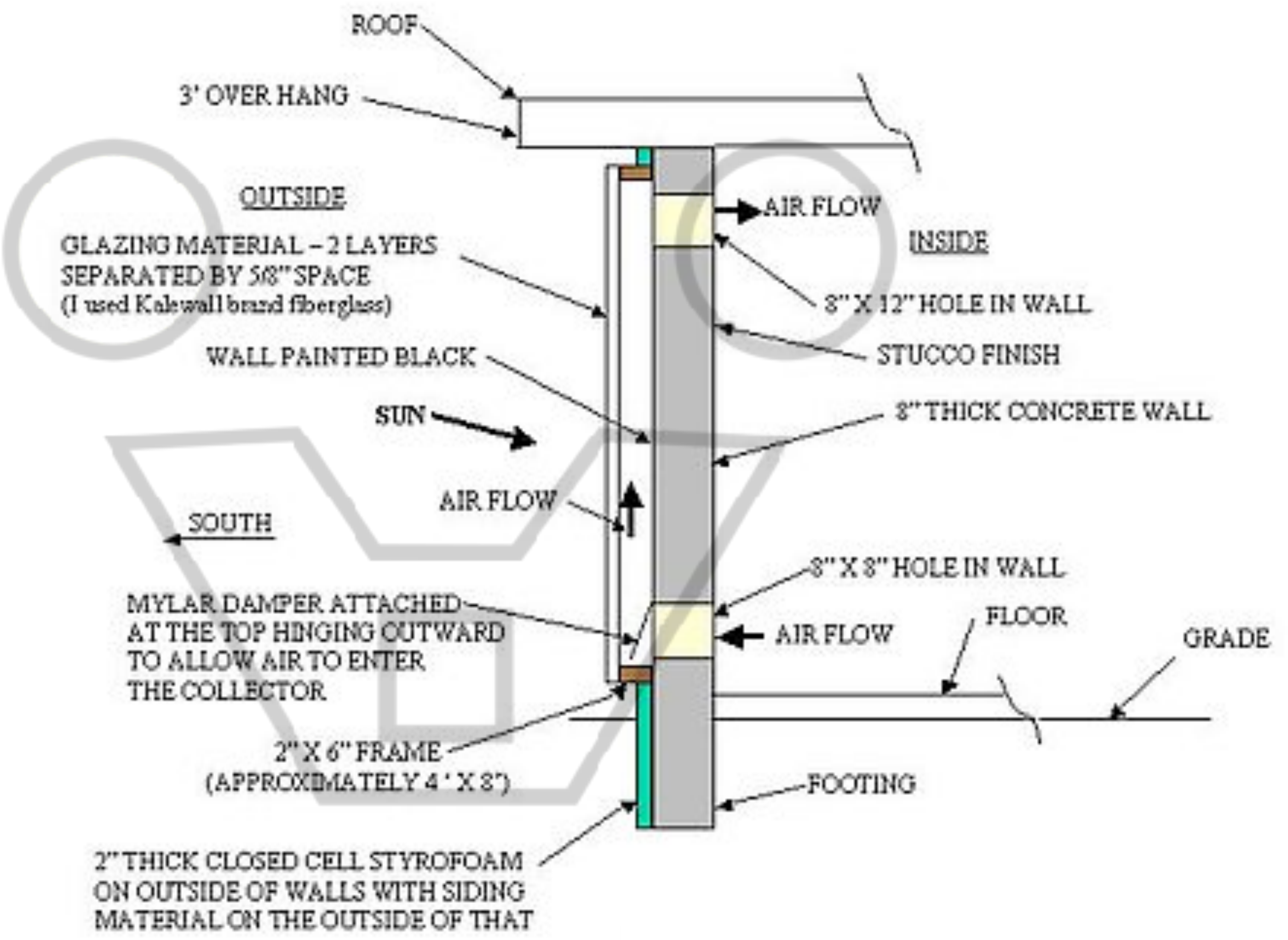
Working with Mass Latency or Thermal Lag

Trombe wall



Working with Mass Latency or Thermal Lag

Modified Trombe wall



Working with Mass Latency or Thermal Lag

Modified Trombe wall