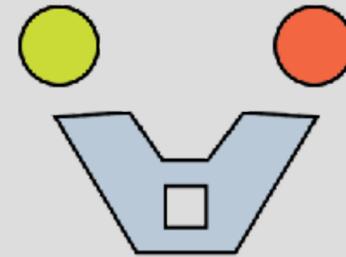




UNIVERSITÀ  
DEGLI STUDI  
FIRENZE

Scuola di  
Architettura



MULTIMEDIA | ARCHITECTURE | INTERACTION

# PASSIVE DESIGN STRATEGIES AND DEVICES

## Part 1.

Insolation/Insulation, Thermal Lag, Natural Ventilation & Double Skin Envelopes

prof. arch. Giuseppe Ridolfi PhD

e n v i r o n m e n t

↓ ↑

# THERMODYNAMIC SYSTEMS

OPEN



energy and matter exchange

CLOSED

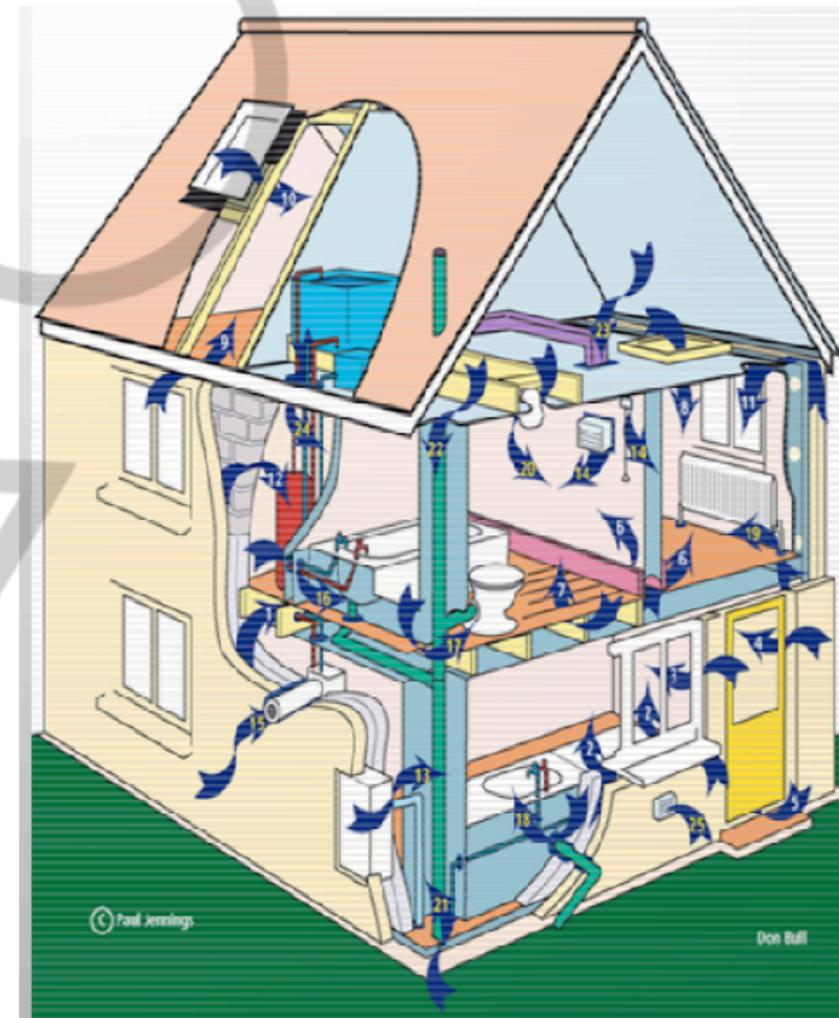
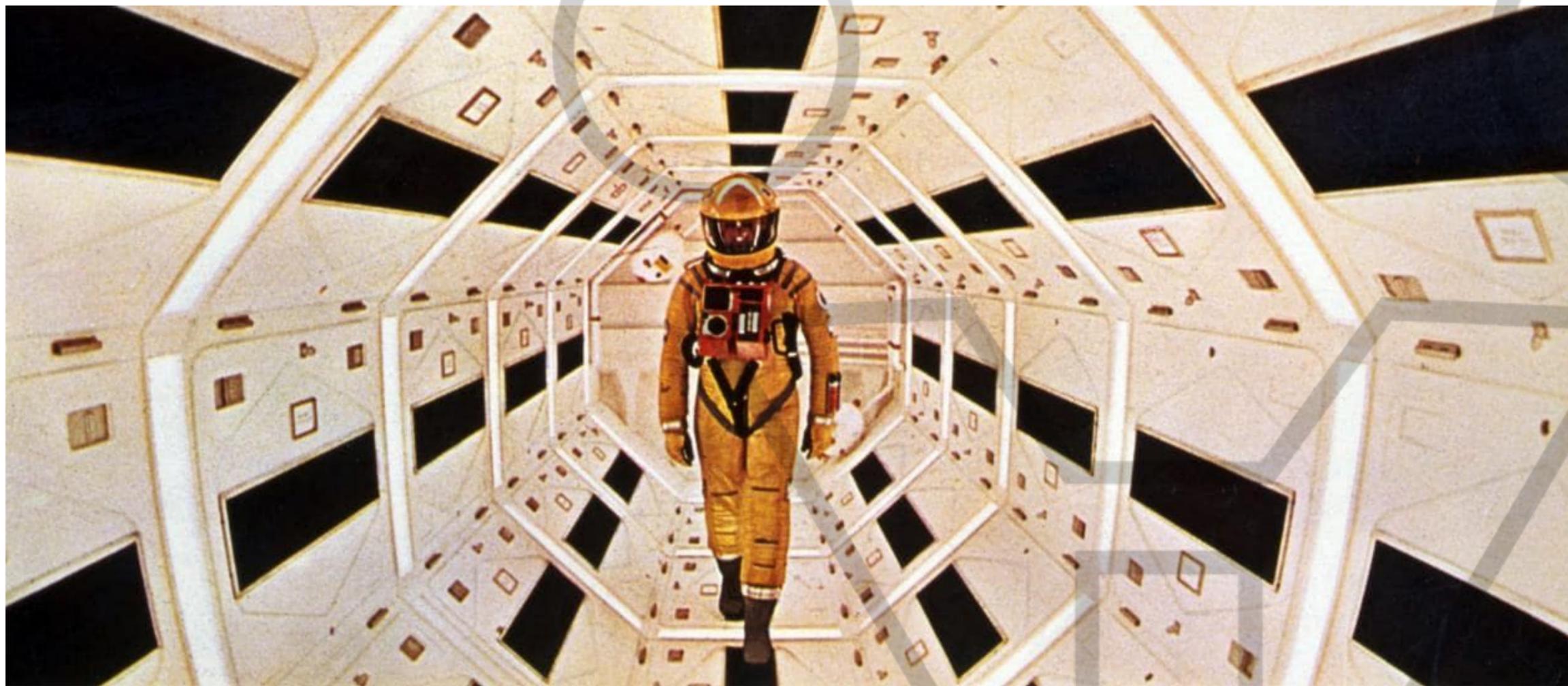


energy exchange

ISOLATED



no exchange

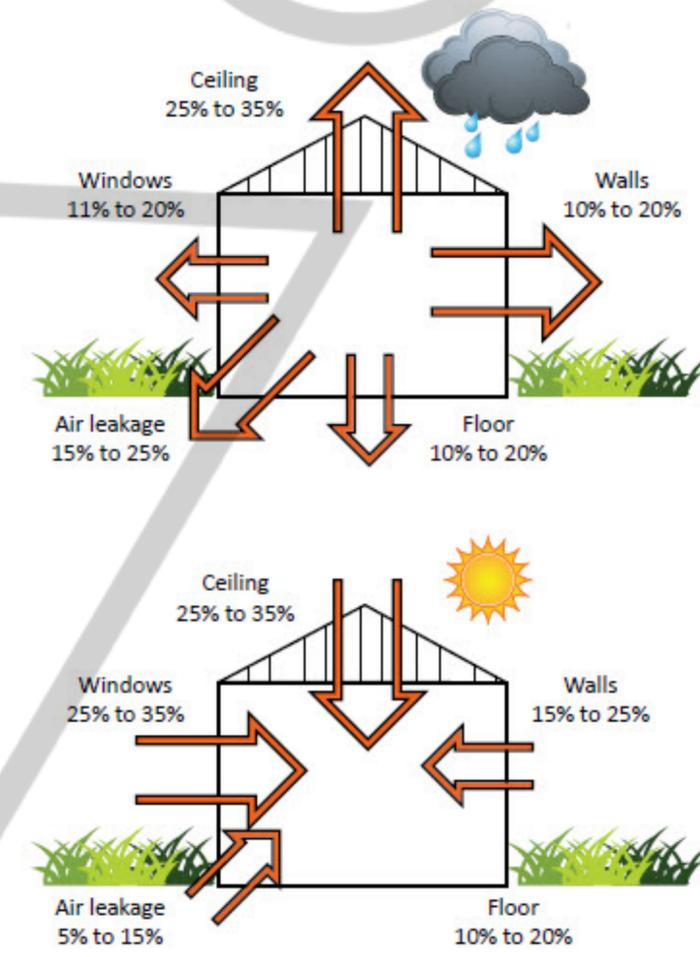
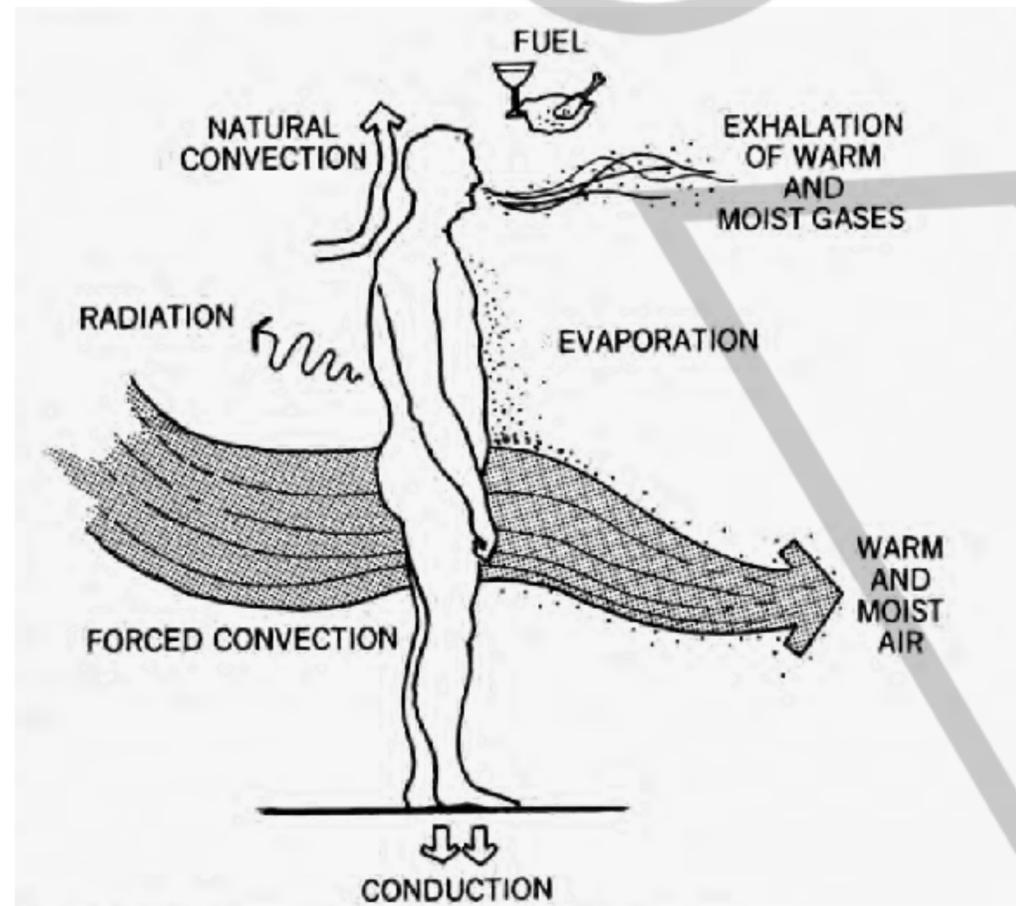


# Energy mediator devices

Human skin

&

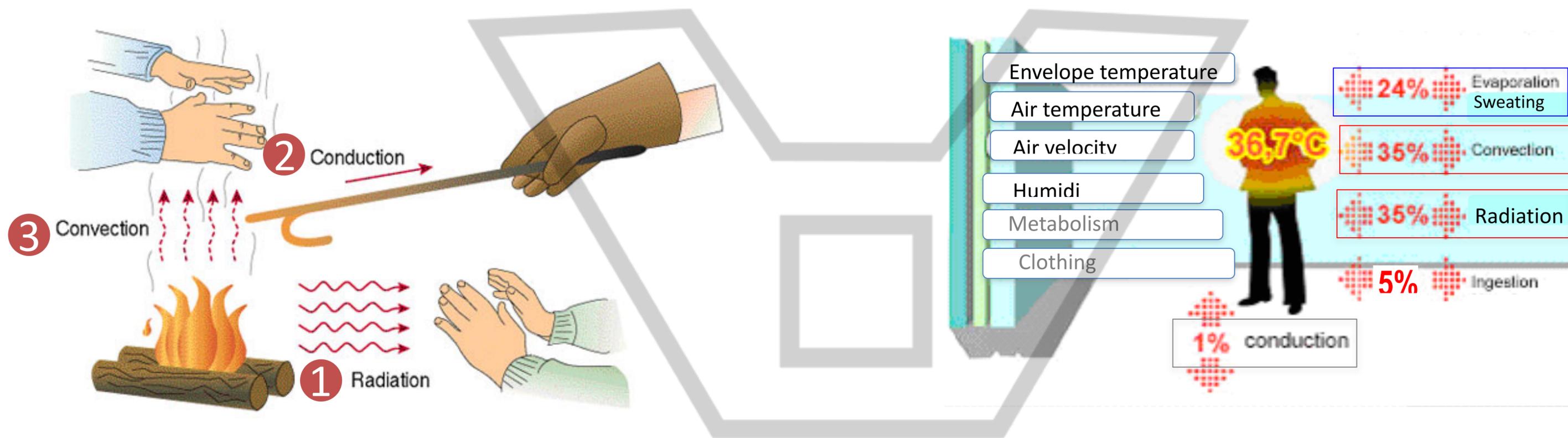
Building skin



# RECOGNIZING ENERGY FORMS

## FORMS of ENERGY EXCHANGE

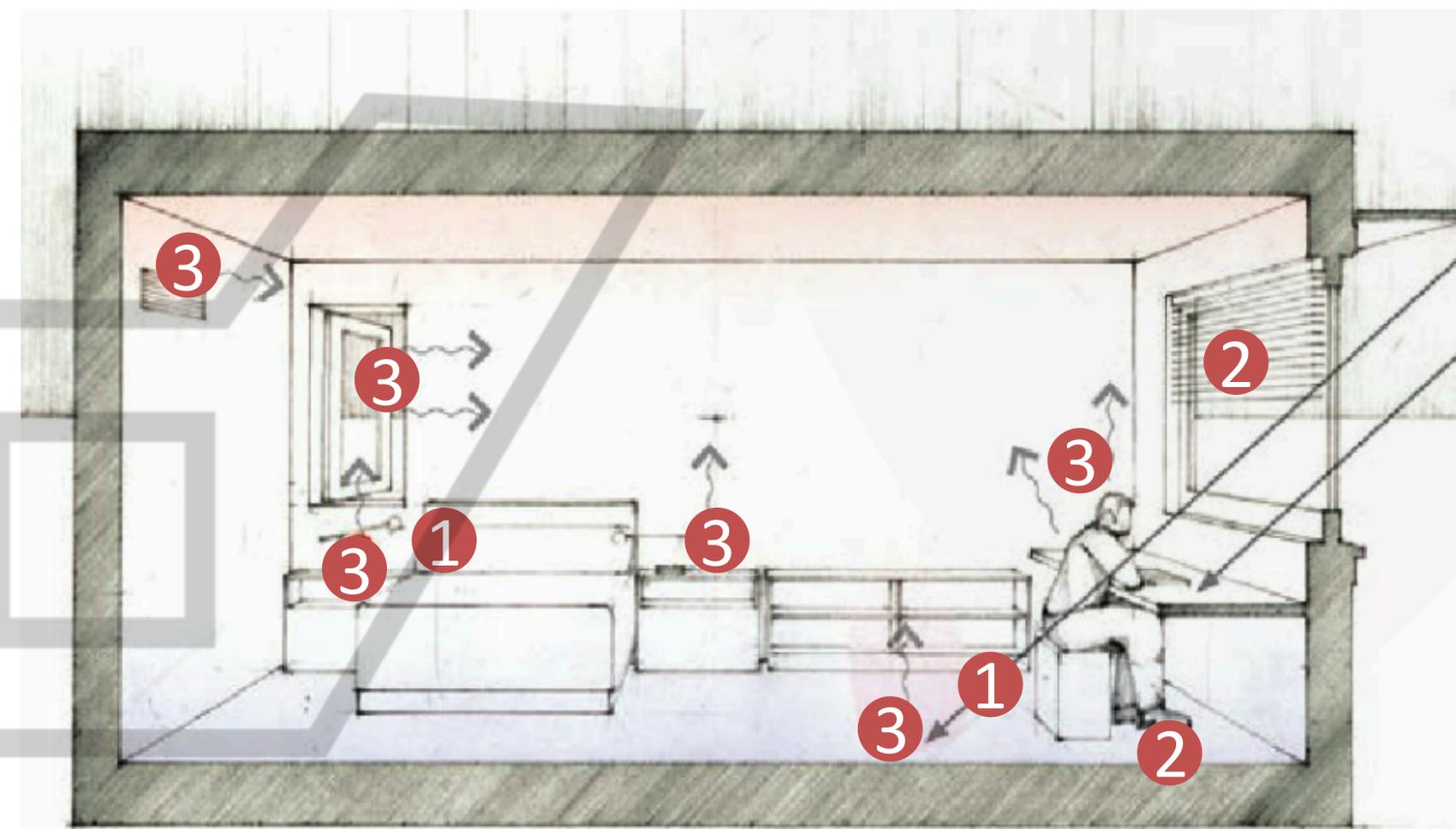
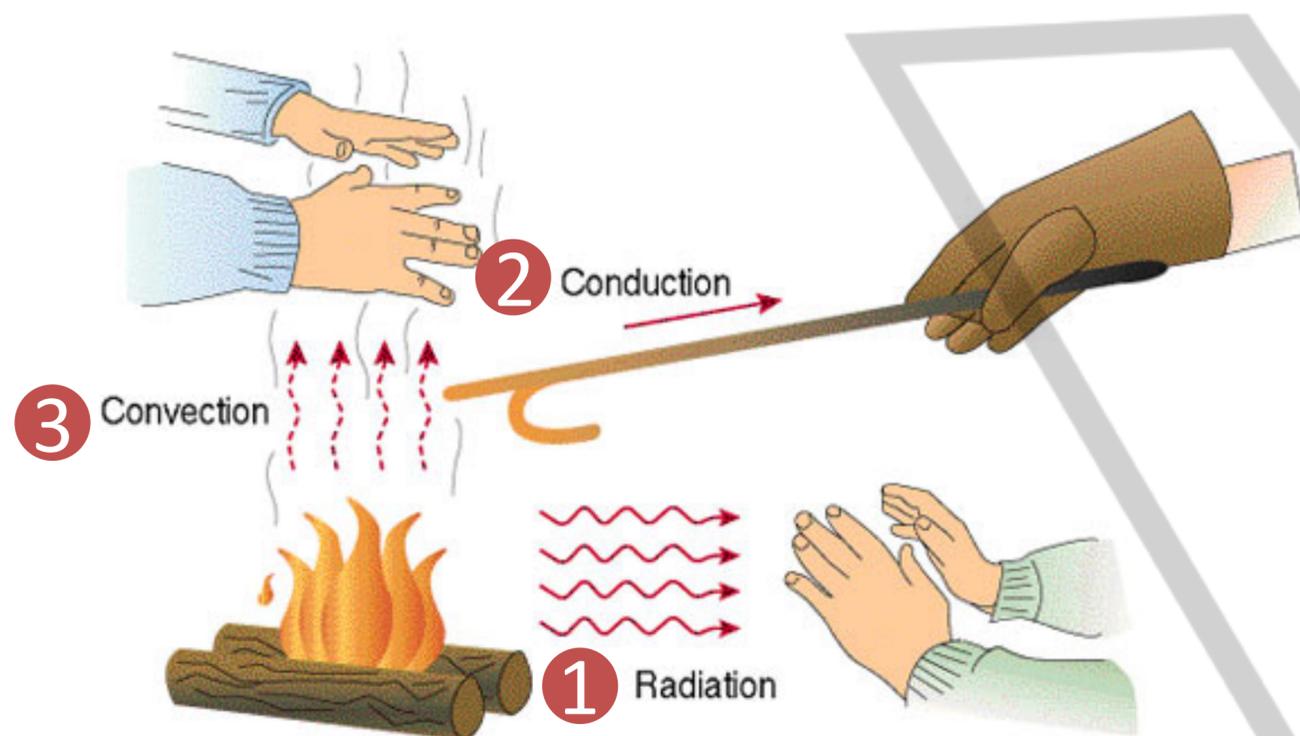
## HUMAN BODY ENERGY EXCHANGE WITH THE ENVIRONMENT



# RECOGNIZING ENERGY FORMS

FORMS of ENERGY EXCHANGE

INDOOR SPACE EXCHANGE WITH THE ENVIRONMENT



## IMPORTANCE OF RADIATION IN THERMAL COMFORT

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.

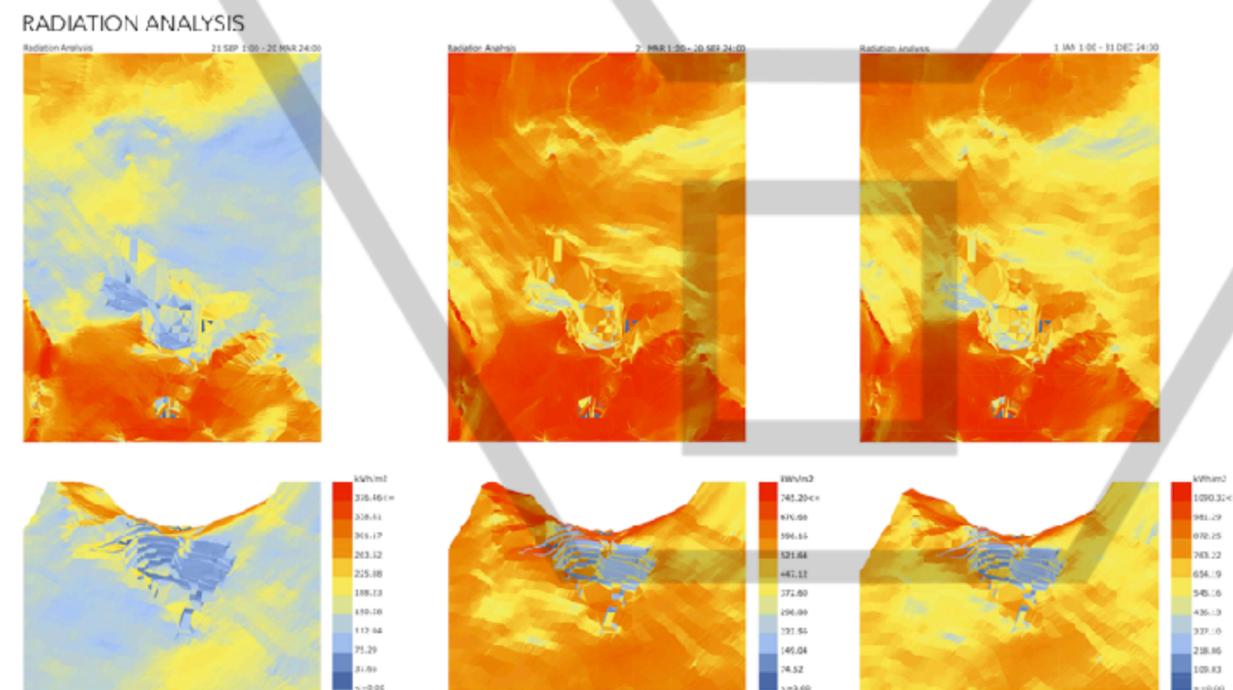
<http://www2.ecospecifier.org/>

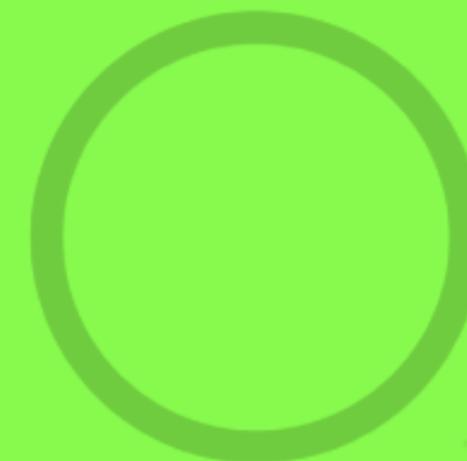
*Relatively small changes in mean radiant temperature have a far greater effect than similar changes in air temperatures (Ballinger 1992). This gives rise to the importance of recognizing the overall Environmental Temperature [T(env)], as opposed to just the dry bulb temperature.*

$$T(env) = \frac{2}{3} \text{ Mean radiant surface temperature} + \frac{1}{3} \text{ Air temperature}$$

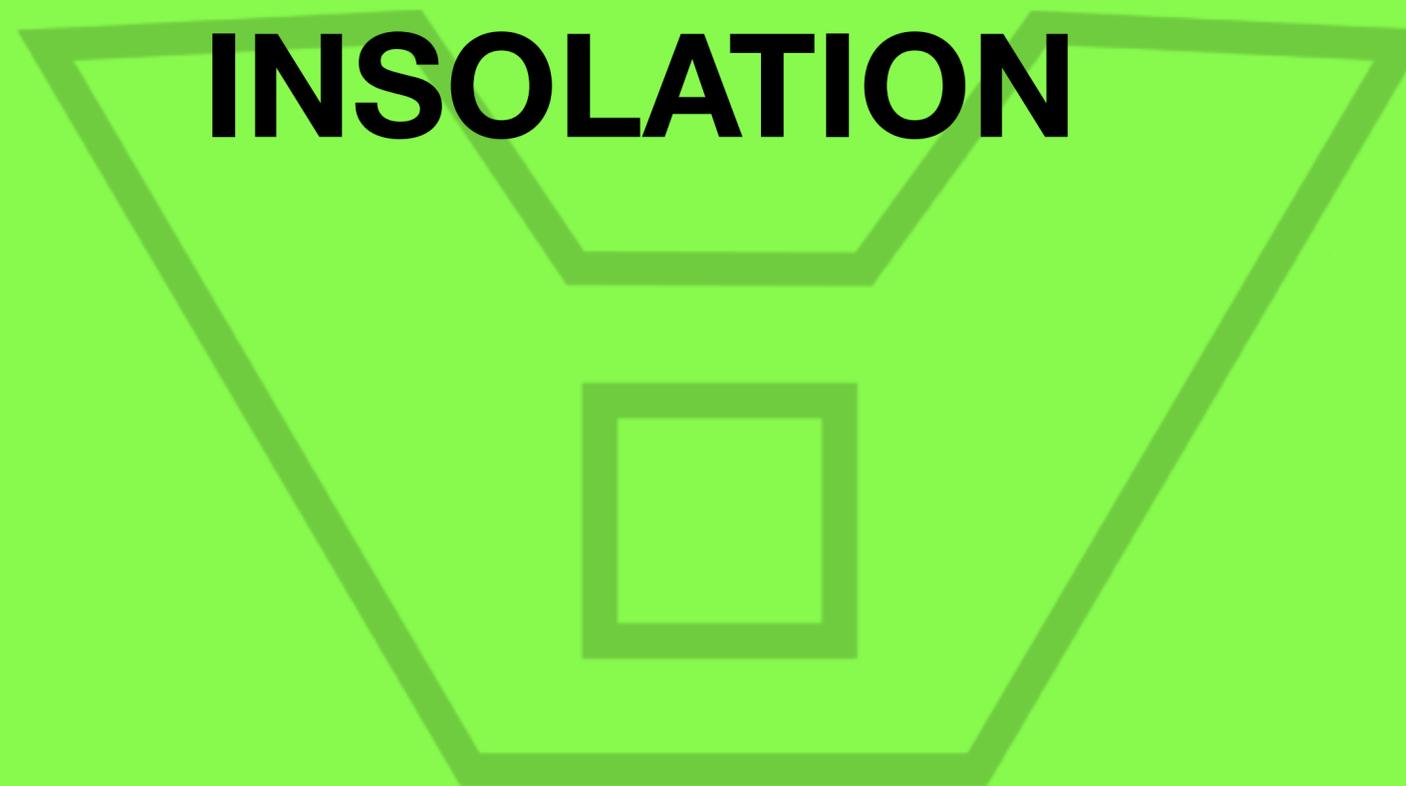
# DEFINING PASSIVE DESIGN STRATEGIES

# INSOLATION / INSULATION

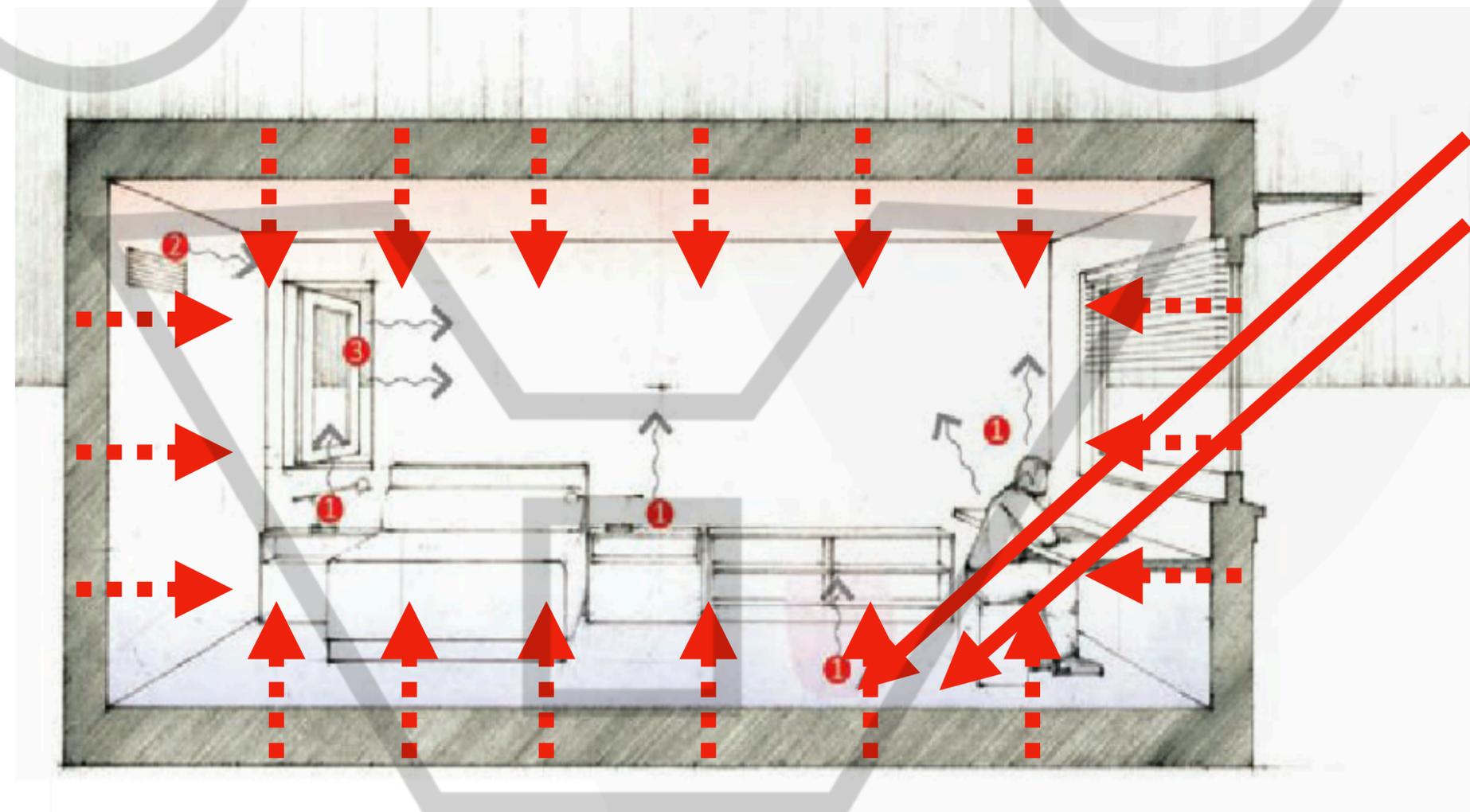




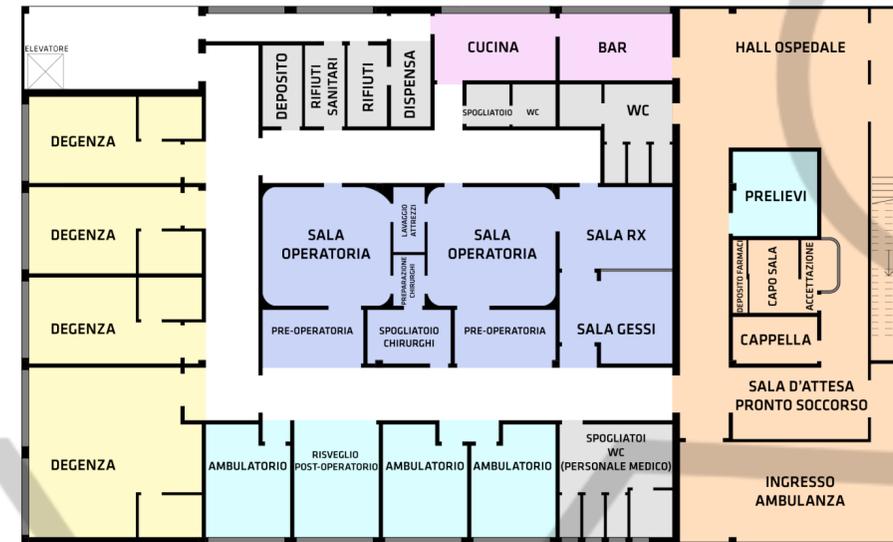
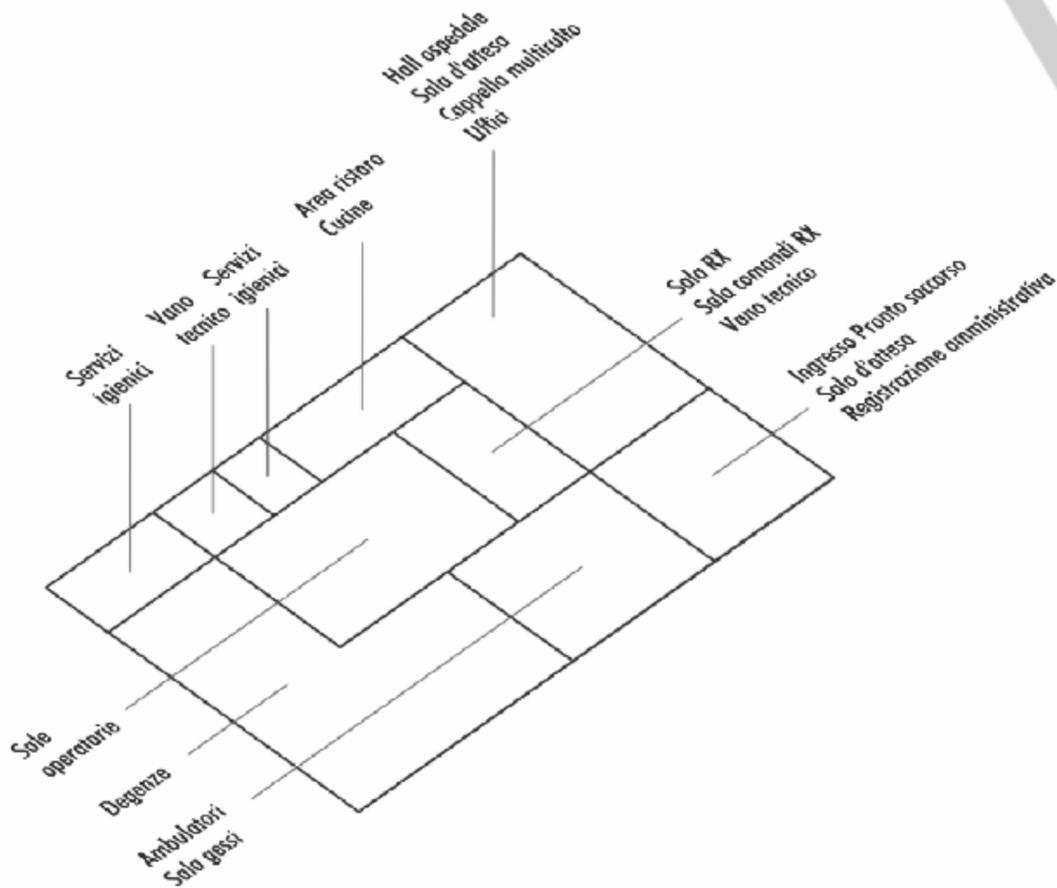
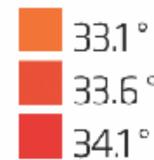
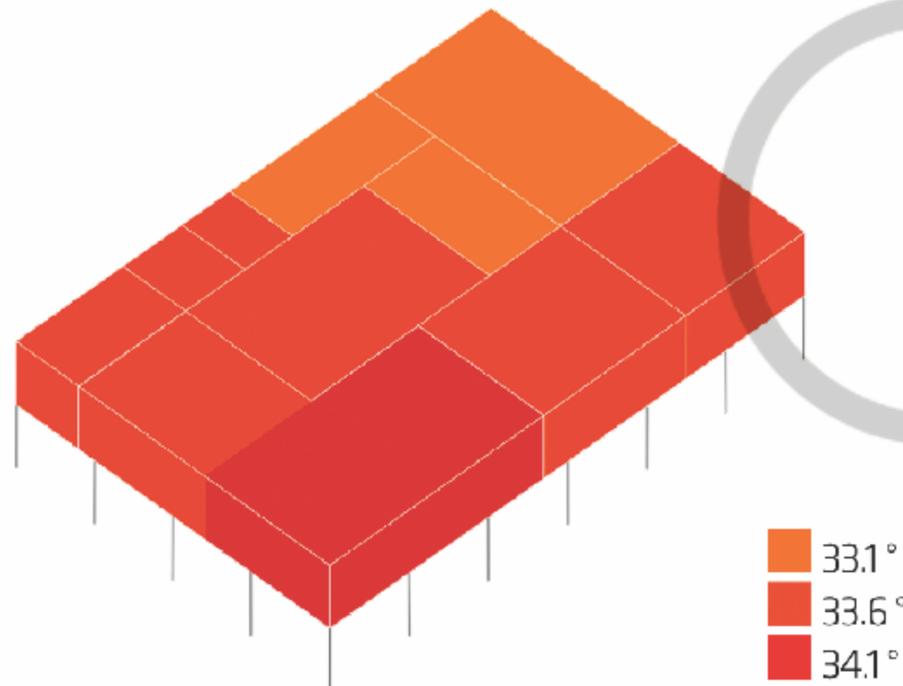
# INSOLATION



# INSOLATION or SUN HARVESTING

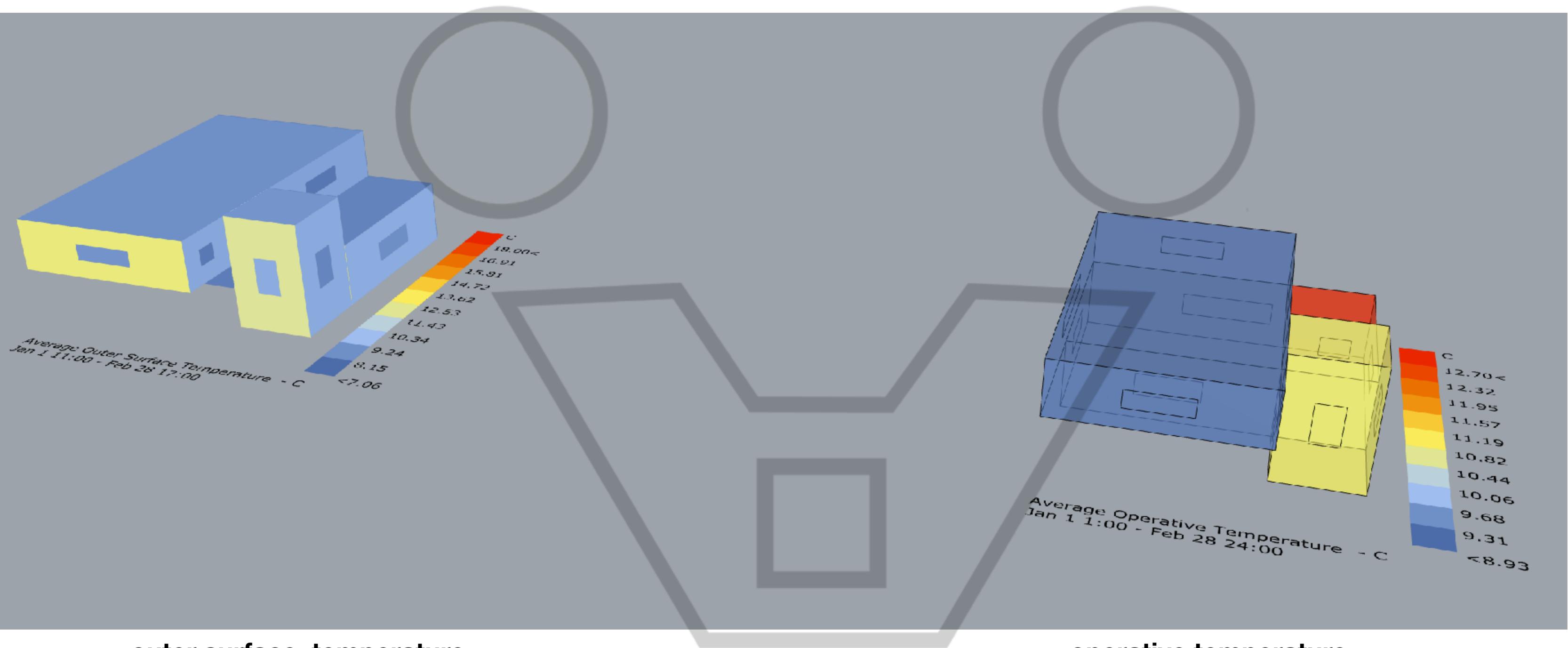


# FUNCTIONAL LAY OUT ACCORDING TO THERMAL BLOCKS VOCATION



- Blocco hall/ingressi
- Blocco sanitario
- Blocco ambulatori
- Blocco cucina/bar
- Blocco degenze
- Blocco servizi

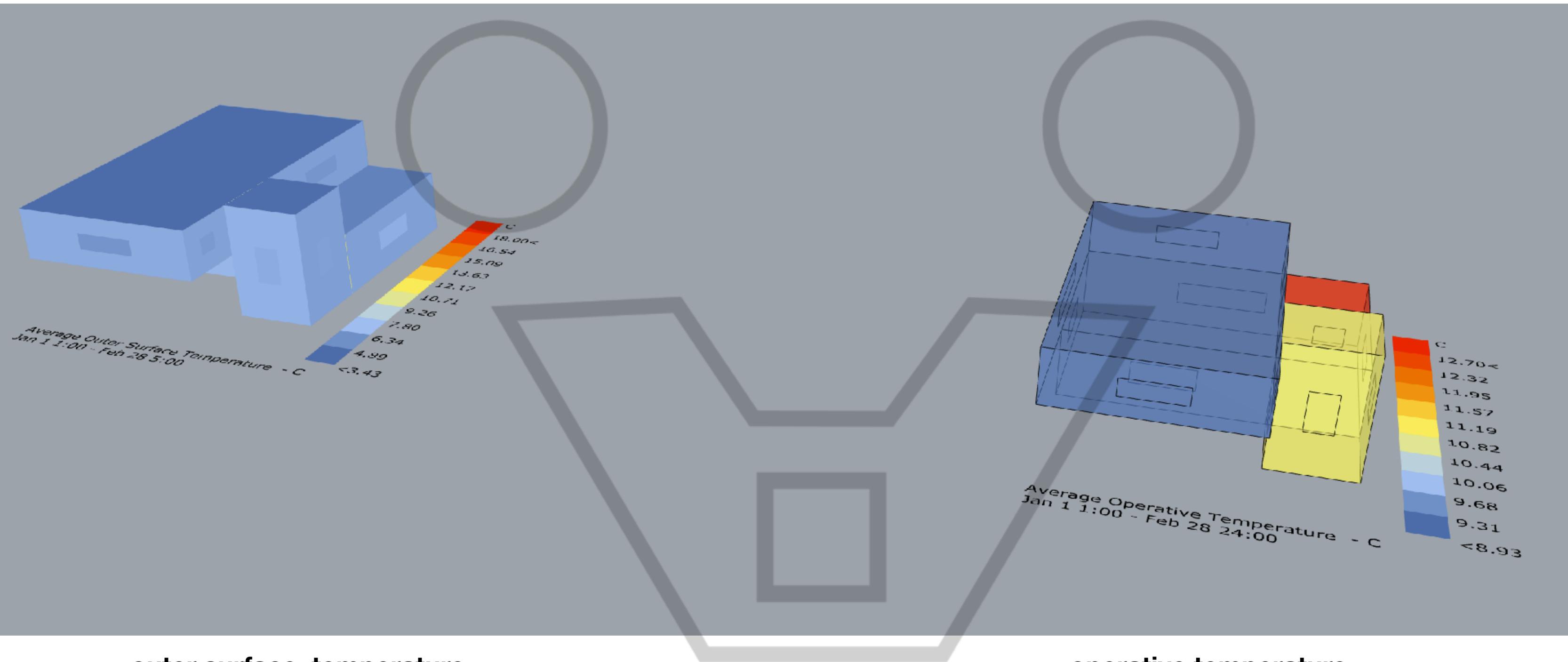
	m <sup>2</sup>	°C	%	m/s	met	clo
Hall   Sale d'attesa	50 m <sup>2</sup>	30 °C	78 %	4.1	1.2	0.6
Cappella multiculto	10 m <sup>2</sup>	30 °C	78 %	4.1	1.0	0.6
Ambulatori	15 m <sup>2</sup>	28.5 °C	60 %	0.45	1.0	0.6
Sala gessi	20 m <sup>2</sup>	28.5 °C	60 %	0.45	1.0	0.6
Sala RX	20 m <sup>2</sup>	27 °C	45 %	0.5	1.0	0.7
Sale operatorie	36 m <sup>2</sup>	27 °C	45 %	0.5	1.4	0.7
Sala preoperatoria	15 m <sup>2</sup>	27 °C	45 %	0.5	1.4	0.7
Sala postoperatoria   Degenze	25 m <sup>2</sup>	30 °C	70 %	0.45	0.8	0.5
Cucina	20 m <sup>2</sup>	29.5 °C	50 %	1.5	1.8	0.6
Bar	20 m <sup>2</sup>	30 °C	60 %	1.5	1.0	0.6



outer surface temperature

operative temperature

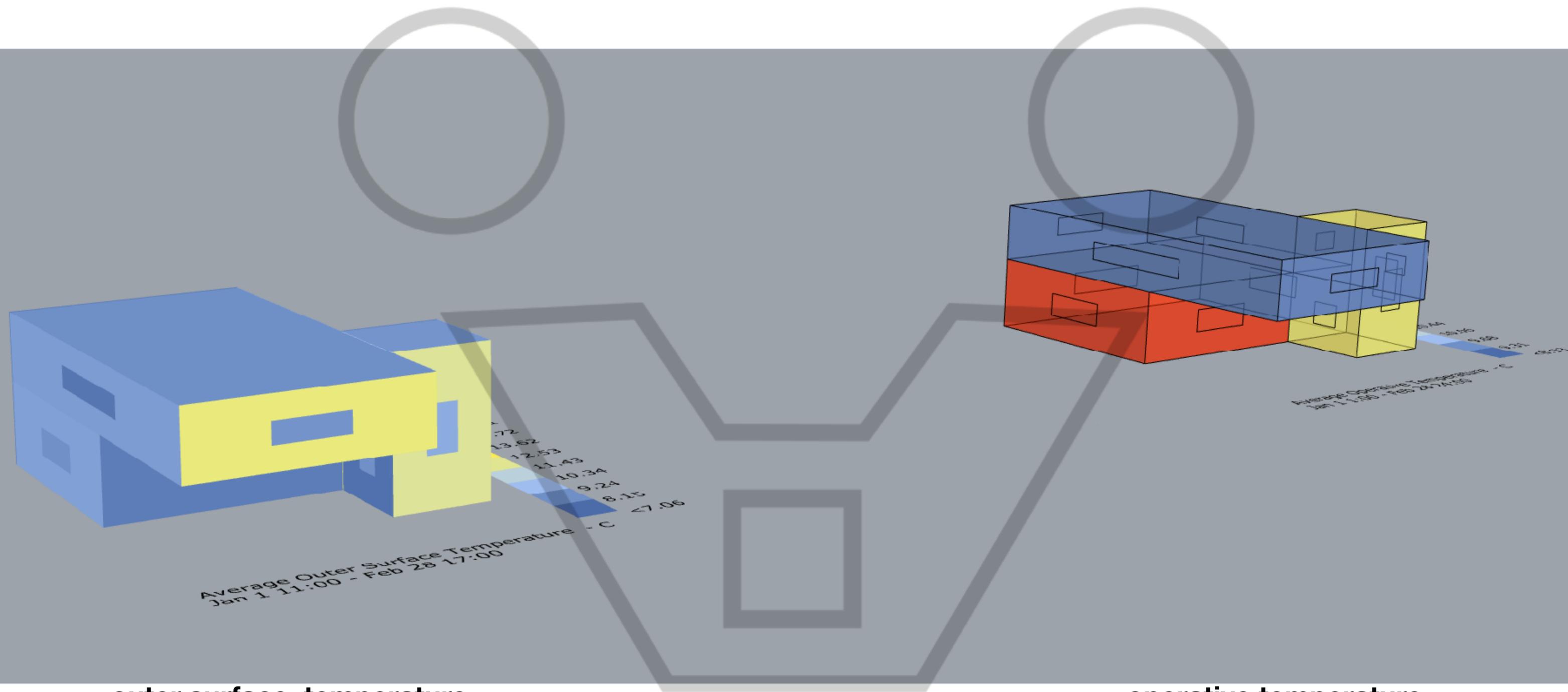
ALL DAY IN COLD PERIOD



outer surface temperature

operative temperature

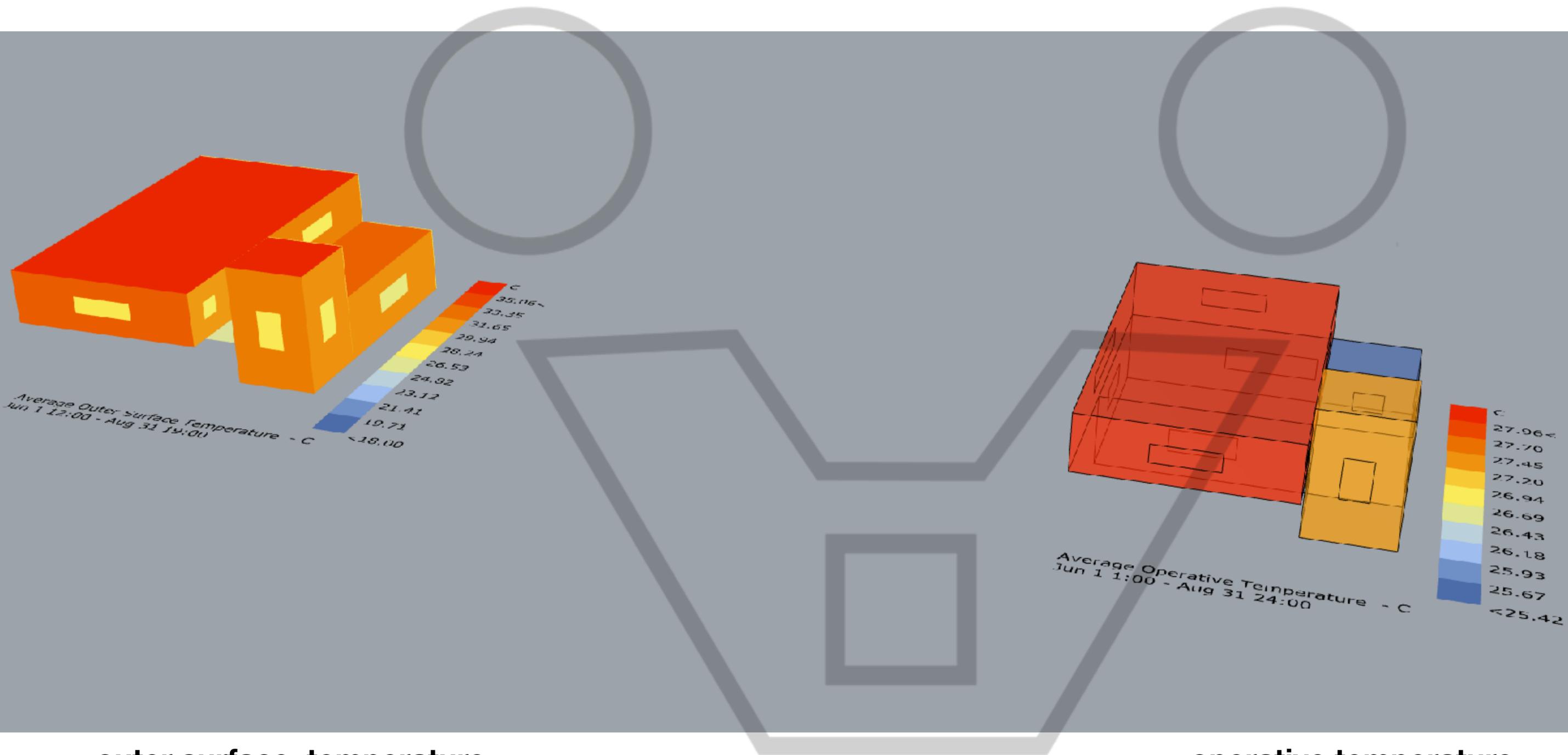
COLD HOURS IN COLD PERIOD



outer surface temperature

operative temperature

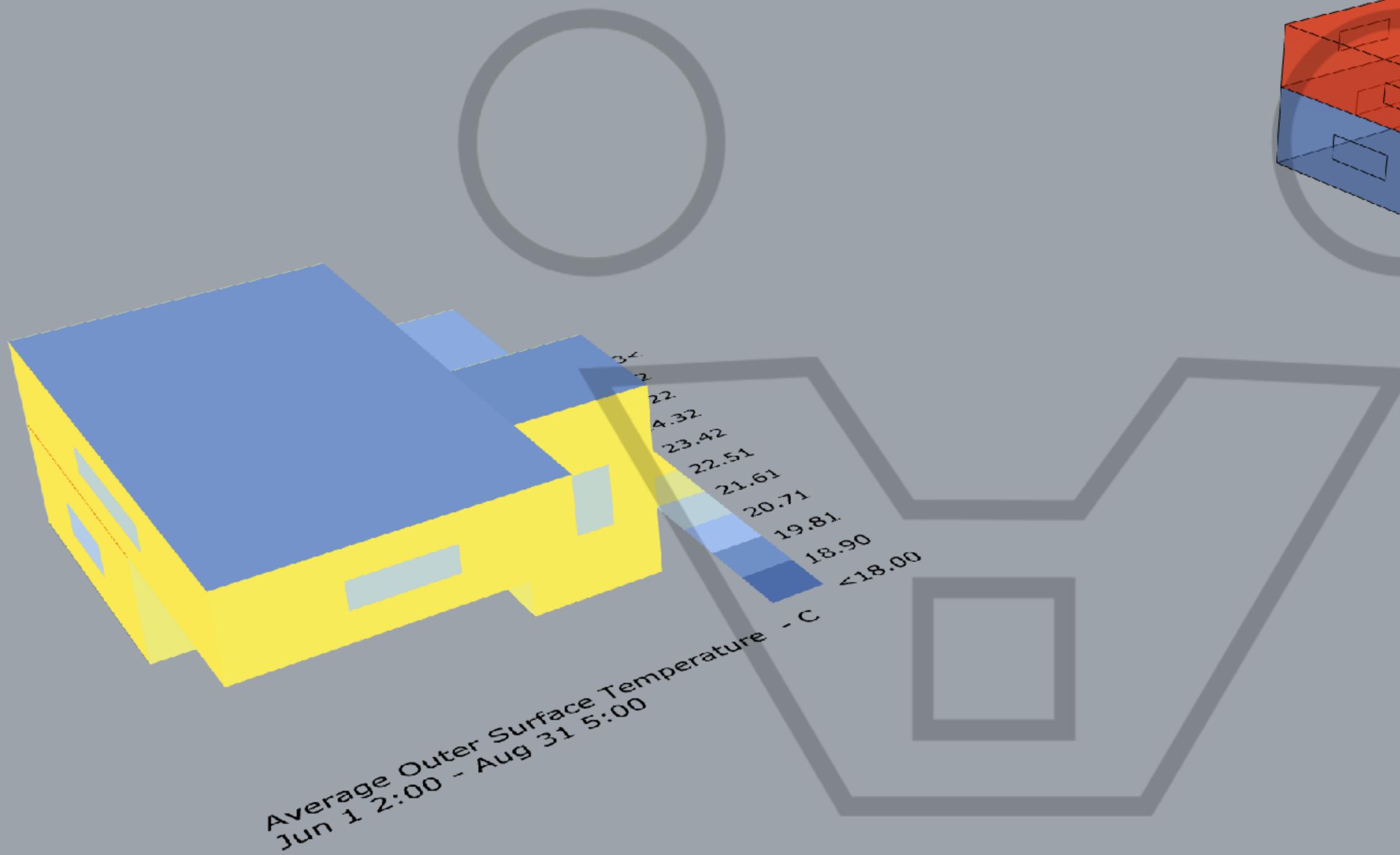
**WARM HOURS IN COLD SEASON**



outer surface temperature

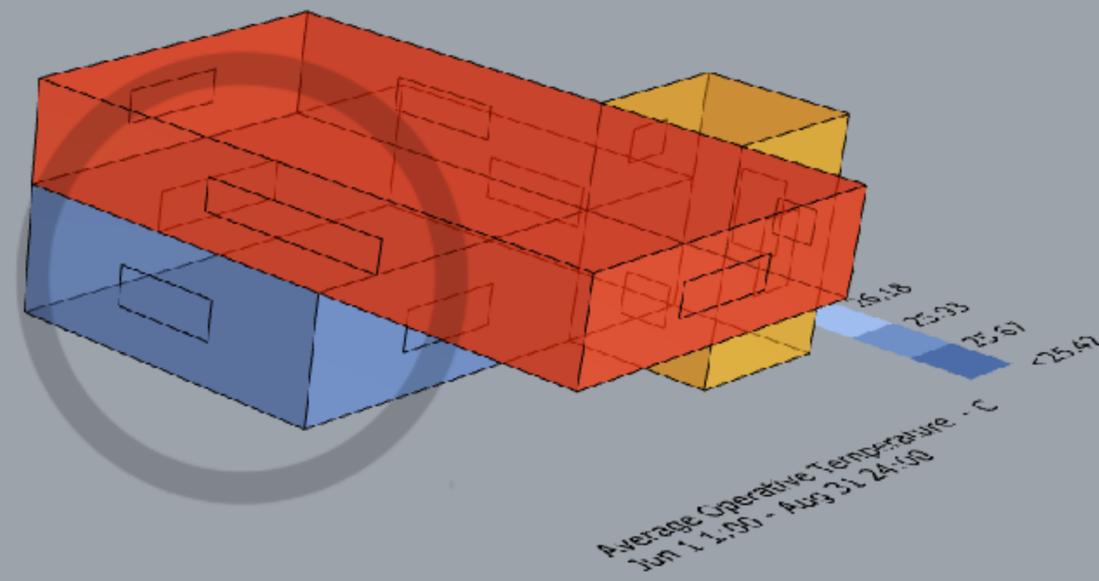
operative temperature

HOT HOURS



outer surface temperature

HOT HOURS at NIGHT



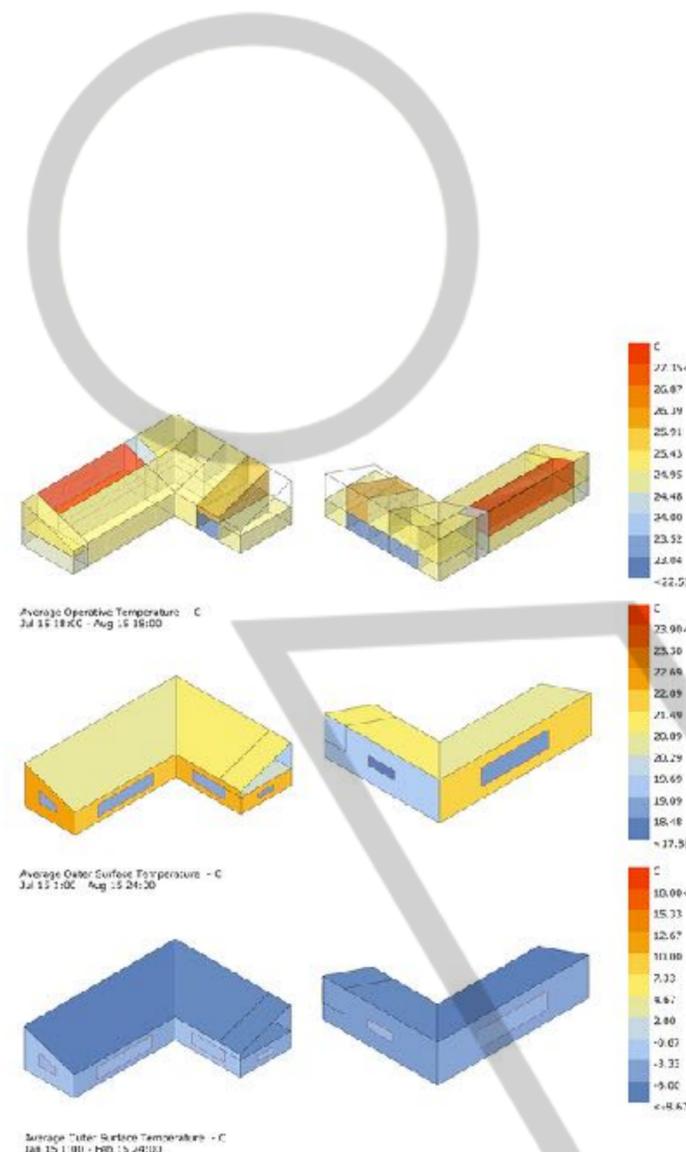
operative temperature

Considerando l'analisi della temperatura operativa studiata precedentemente si osserva come, nel periodo estivo e nell'ora più calda, gli ambienti orientati a ovest raggiungono una temperatura di discomfort, circa 27.5 °C; necessitano quindi di un riparo dal calore estivo.

L'analisi termica delle superfici delle facciate permette una scelta più consapevole delle varie stratigrafie. Lo studio è stato condotto nei periodi più critici - più caldo e più freddo- per comprendere il comportamento termico dell'involucro.

Nello specifico nel periodo più caldo (15 luglio-15 agosto) la copertura e la facciata ovest raggiungono 20.5-21.5 °C, le facciate sud ed est sono le più calde, 22-23°C. A nord, facciata non esposta al sole e più fredda, la temperatura superficiale è di 19°C.

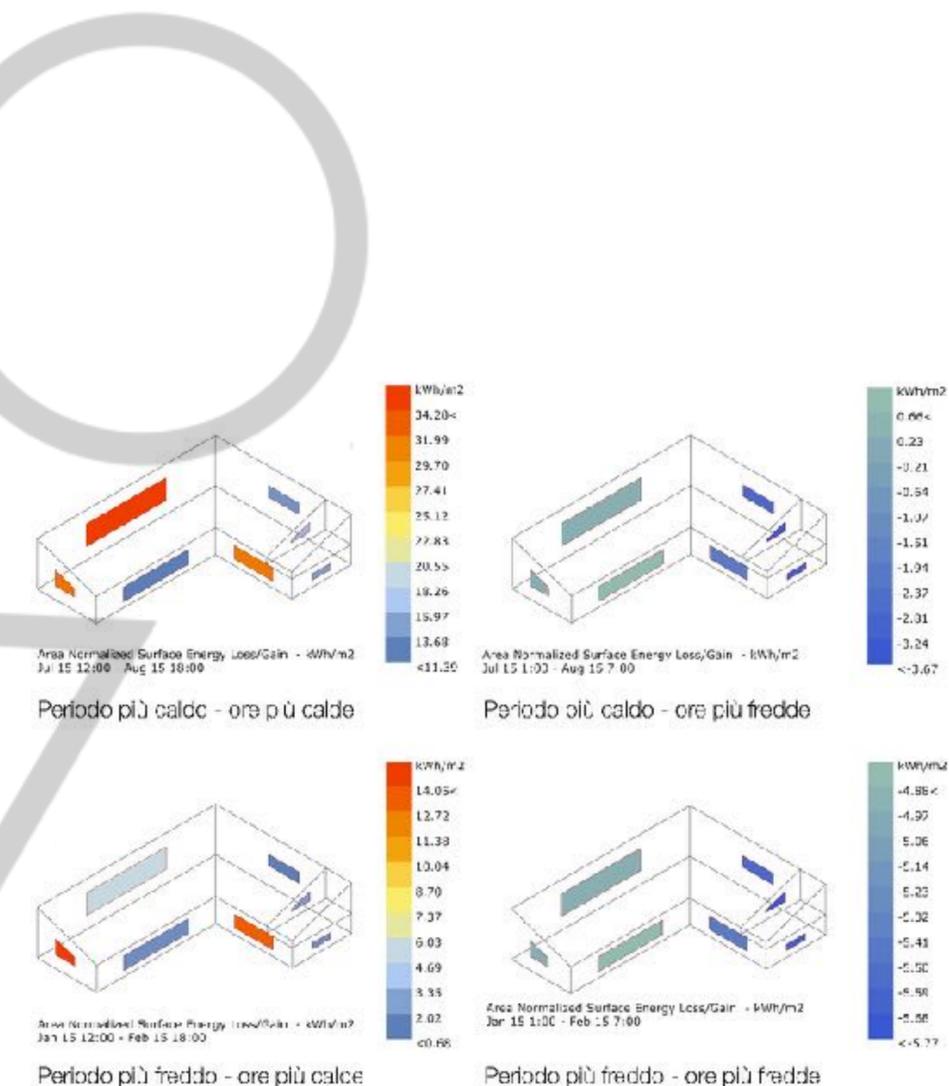
Durante l'inverno le temperature superficiali oscillano tra i +3°C e i -8°C. La copertura registra la minor temperatura (-7°C), le facciate sud ed est raggiungono tra i -3 e 1 °C. Ad ovest e nord circa -5°C.



In base al rapporto aeroilluminante da soddisfare e alla funzione di ogni vano, le finestre sono state dimensionate tenendo conto anche dell'orientamento delle varie facciate. In particolare le aperture sono state limitate a nord -per evitare dispersione termiche- e posizionate in maggior numero a sud ed est, per garantire illuminazione e guadagno termico.

L'analisi del guadagno e dispersione termica delle finestre è stata condotta nuovamente nel periodo più caldo e più freddo, prendendo in considerazione separatamente le ore più calde (12.00-18.00) e più fredde (1.00-7.00).

L'analisi evidenzia che a nord si ha la più alta dispersione e il minor guadagno solare. I valori della dispersione a sud, est e ovest sono invece simili, con l'unica eccezione di un guadagno di calore maggiore nelle ore più calde d'estate per quanto riguarda le finestre disposte a sud ed ovest.



**ABACO DEGLI INVOLUCRI**

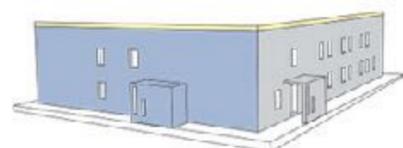
	ESIGENZE	REQUISITI	STRATEGIE	CONFRONTO	ALTERNATIVA MIGLIORE	ULTERIORI RIVESTIMENTI
<p><b>FACCIATA NORD</b></p>	<ul style="list-style-type: none"> <li>- Massima protezione dalle basse temperature in inverno</li> </ul>	<ul style="list-style-type: none"> <li>- Accumulo termico</li> </ul>	<ul style="list-style-type: none"> <li>- Forte isolamento termico</li> <li>- Aperture limitate</li> <li>- Finestre con elevate prestazioni termiche</li> </ul>	<p><b>ISOLAMENTO A CAPPOTTO</b></p> <p><b>PUNTI DI FORZA</b> Costo minore</p> <p><b>DEBOLEZZE</b> Minor isolamento</p>	<p><b>FACCIATA VENTILATA</b></p> <p>Maggior isolamento Vantaggi estetici Costo maggiore</p> <p>La soluzione della facciata ventilata è l'oriposta in copertura, con il tetto ventilato</p>	<p><b>FACCIATA VERDE</b></p> <p>La facciata verde ad avest protegge dall'irraggiamento diretto estivo. Utilizzando piante caduche che si seccano d'inverno, le prestazioni termiche dell'involucro non si modificano.</p>
<p><b>FACCIATA OVEST</b></p>	<ul style="list-style-type: none"> <li>- Benessere termico sia d'inverno che d'estate, durante la quale l'irraggiamento potrebbe risultare eccessivo.</li> </ul>	<ul style="list-style-type: none"> <li>- Garantire la massima captazione solare d'inverno per beneficiare del calore</li> <li>- Garantire la minore dissipazione di calore</li> <li>- Schermare d'estate a causa dell'eccessivo soleggiamento che causa surriscaldamento</li> </ul>	<ul style="list-style-type: none"> <li>- Forte isolamento termico</li> <li>- Schermature scorrevoli per le finestre</li> <li>- Involucro che permetta le medesime qualità isolanti delle altre facciate d'inverno, ma maggiore protezione dai raggi solari estivi</li> </ul>	<p><b>TRIPLO VETRO</b></p> <p><b>PUNTI DI FORZA</b> Elevato isolamento</p> <p><b>DEBOLEZZE</b> Più pesante Costo maggiore</p>	<p><b>DOPPIO VETRO BASSO EMISSIVO</b></p> <p>Il vetro basso emissivo, ottenuto con trattamento sulla superficie del vetro, ha una prestazione termica molto simile al vetro triplo.</p> <p>Elevato isolamento Più leggero Costo minore</p>	<p><b>SCHERMATURE CHIUSE</b></p> <p>Cukrowicz Nachbar - Hiesau for a carpenter Hittsau</p> <p>Maggior isolamento rispetto alle schermature semichiusa. Esse scorrono all'interno dell'intercapedine d'aria della facciata ventilata.</p>
<p><b>FACCIATA SUD</b></p>	<ul style="list-style-type: none"> <li>- Benessere termico</li> </ul>	<ul style="list-style-type: none"> <li>- Garantire la massima captazione solare d'inverno per l'accumulo termico</li> <li>- Soddisfamento del rapporto aerilluminante</li> <li>- Schermature per l'eccessivo soleggiamento d'estate</li> </ul>	<ul style="list-style-type: none"> <li>- Aperture limitate</li> <li>- Forte isolamento termico</li> <li>- Schermature scorrevoli per le finestre</li> <li>- Dispositivi orientabili per le vetrate</li> </ul>	<p><b>DISPOSITIVI MOBILI VERTICALI</b></p> <p><b>PUNTI DI FORZA</b> Elevato isolamento</p> <p><b>DEBOLEZZE</b> Più pesante Costo maggiore</p>	<p><b>DOPPIO VETRO BASSO EMISSIVO</b></p> <p>Elevato isolamento Più leggero Costo minore</p>	<p><b>SCHERMATURE CHIUSE</b></p> <p>Cukrowicz Nachbar - Hiesau for a carpenter Hittsau</p> <p>Maggior isolamento rispetto alle schermature semichiusa. Esse scorrono all'interno dell'intercapedine d'aria della facciata ventilata.</p>
<p><b>FACCIATA EST</b></p>	<ul style="list-style-type: none"> <li>- Benessere termico</li> <li>- Soddisfamento del rapporto aerilluminante per ambienti grandi e fruibili lungo tutto l'arco della giornata.</li> </ul>	<ul style="list-style-type: none"> <li>- Garantire la massima captazione solare per beneficiare della luce e del calore.</li> </ul>	<ul style="list-style-type: none"> <li>- Grandi vetrate con vetri termici</li> <li>- Facciata ventilata</li> <li>- Schermature scorrevoli</li> </ul>	<p><b>DISPOSITIVI MOBILI VERTICALI</b></p> <p><b>PUNTI DI FORZA</b> Elevato isolamento</p> <p><b>DEBOLEZZE</b> Più pesante Costo maggiore</p>	<p><b>DOPPIO VETRO BASSO EMISSIVO</b></p> <p>Elevato isolamento Più leggero Costo minore</p>	<p><b>SCHERMATURE CHIUSE</b></p> <p>Cukrowicz Nachbar - Hiesau for a carpenter Hittsau</p> <p>Maggior isolamento rispetto alle schermature semichiusa. Esse scorrono all'interno dell'intercapedine d'aria della facciata ventilata.</p>
<p><b>COPERTURA</b></p>	<ul style="list-style-type: none"> <li>- Deflusso delle acque meteoriche</li> <li>- Benessere termico</li> <li>- Protezione dall'abbagliamento</li> </ul>	<ul style="list-style-type: none"> <li>- Garantire la minore dissipazione di calore</li> <li>- Evitare il deposito di acqua e neve</li> <li>- Limitazione dei raggi diretti del sole</li> </ul>	<ul style="list-style-type: none"> <li>- Falda inclinata</li> <li>- Aperture nella parte più alta per consentire la ventilazione (camino del vento)</li> <li>- Dispositivi orientabili per i lucernari</li> <li>- Ulteriore protezione dei dispositivi per evitare il deposito di neve su di essi</li> </ul>	<p><b>DISPOSITIVI MOBILI VERTICALI</b></p> <p><b>PUNTI DI FORZA</b> Elevato isolamento</p> <p><b>DEBOLEZZE</b> Più pesante Costo maggiore</p>	<p><b>DOPPIO VETRO BASSO EMISSIVO</b></p> <p>Elevato isolamento Più leggero Costo minore</p>	<p><b>SCHERMATURE CHIUSE</b></p> <p>Cukrowicz Nachbar - Hiesau for a carpenter Hittsau</p> <p>Maggior isolamento rispetto alle schermature semichiusa. Esse scorrono all'interno dell'intercapedine d'aria della facciata ventilata.</p>
				<p><b>DISPOSITIVI MOBILI ORIZZONTALI</b></p> <p>La posizione ottimale dei brise soleil è all'esterno delle vetrate, poiché schermano preventivamente i raggi, evitando il surriscaldamento d'estate. Essi costituiscono anche un'ulteriore protezione dal freddo se chiusi.</p> <p><b>PUNTI DI FORZA</b></p> <p><b>DEBOLEZZE</b> Possibile abbagliamento perché non intercettano i raggi solari</p>	<p><b>DISPOSITIVI MOBILI ORIZZONTALI</b></p> <p>Schermano i raggi solari Evitano l'abbagliamento</p>	<p><b>ULTERIORE "PELLE" DI VETRO</b></p> <p>Coupedvie Architects - Linkside Residence, London</p> <p>Poiché Tavasio si trova in un luogo soggetto ad abbondanti nevicate, per evitare il deposito di neve sui dispositivi oscuranti, sarà utilizzata a protezione un'ulteriore vetrata.</p>

# ABACO DEGLI INVOLUCRI

## ESIGENZE

- Massima protezione dalle basse temperature in inverno

### FACCIATA NORD



### FACCIATA OVEST

- Benessere termico sia d'inverno che d'estate, durante la quale l'irraggiamento potrebbe risultare eccessivo.



### FACCIATA SUD

- Benessere termico

## REQUISITI

- Accumulo termico

- Garantire la massima captazione solare d'inverno per beneficiare del calore  
- Garantire la minore dissipazione di calore  
- Schermare d'estate a causa dell'eccessivo soleggiamento che causa surriscaldamento

- Garantire la massima captazione solare d'inverno per l'accumulo termico  
- Soddisfacimento del rapporto aerilluminante  
- Schermature per l'eccessivo soleggiamento d'estate

## STRATEGIE

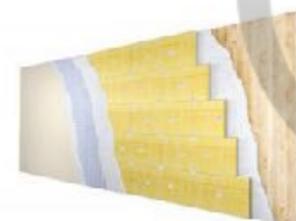
- Forte isolamento termico  
- Aperture limitate  
- Finestre con elevate prestazioni termiche

- Forte isolamento termico  
- Schermature scorrevoli per le finestre  
- Involucro che permetta le medesime qualità isolanti delle altre facciate d'inverno, ma maggiore protezione dai raggi solari estivi

- Aperture limitate  
- Forte isolamento termico  
- Schermature scorrevoli per le finestre  
- Dispositivi orientabili per le vetrate

## CONFRONTO

### ISOLAMENTO A CAPPOTTO

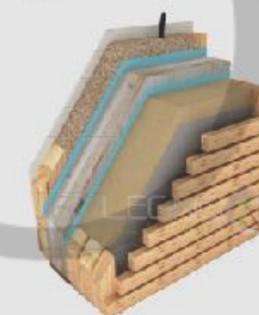


**PUNTI DI FORZA** Costo minore

**DEBOLLEZZE** Minor isolamento

### ALTERNATIVA MIGLIORE

#### FACCIATA VENTILATA

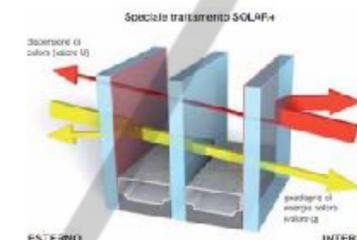


Maggior isolamento  
Valenza estetica

Costo maggiore

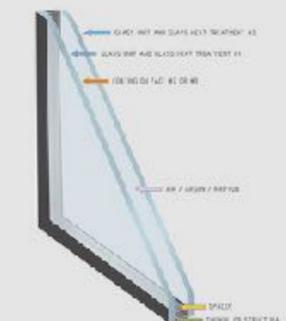
La soluzione della facciata ventilata è riproposta in copertura, con il tetto ventilato

### TRIPLO VETRO



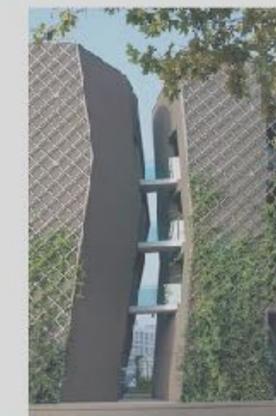
#### DOPPIO VETRO BASSO EMISSIVO

Il vetro basso emissivo, ottenuto con trattamento sulla superficie del vetro, ha una prestazione termica molto simile al vetro triplo.



### ULTERIORI RIVESTIMENTI

#### FACCIATA VERDE

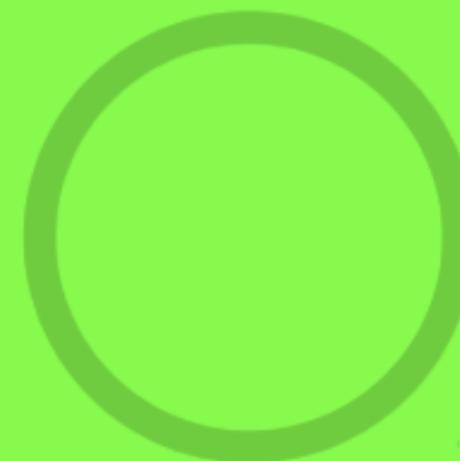


La facciata verde ad ovest protegge dall'irraggiamento diretto estivo. Utilizzando piante caduche che si seccano d'inverno, le prestazioni termiche dell'involucro non si modificano.

#### SCHERMATURE CHIUSE



Cukrowicz Nachbar - House for a carpenter, Hittsau

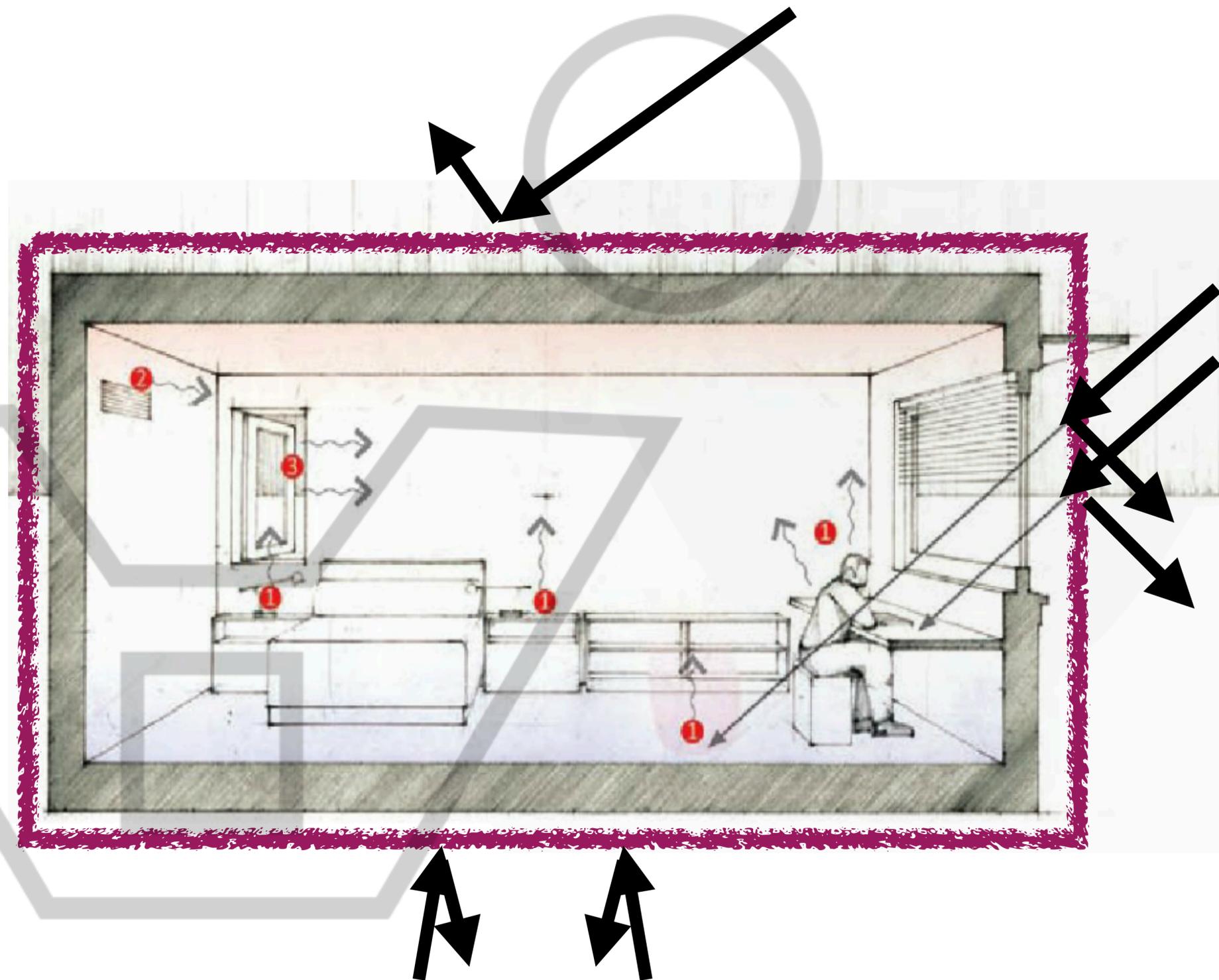


# INSULATION

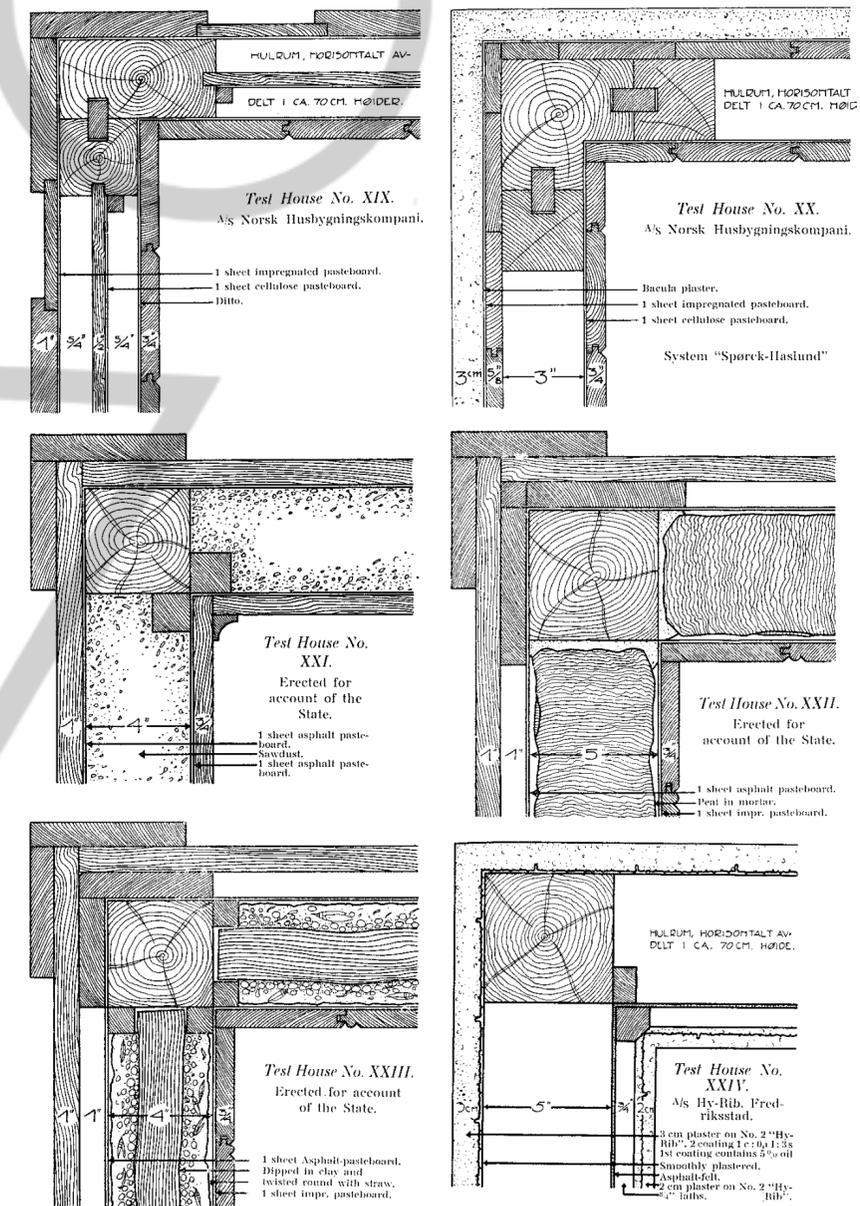


# INSULATION

... which reduces a building's **thermal conductivity**, allowing it to be heated or cooled relatively separate from the outside.



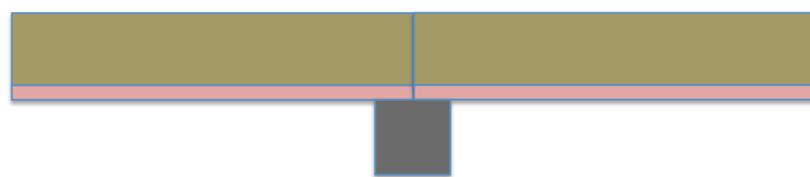
# from monolayer to multilayer envelopes



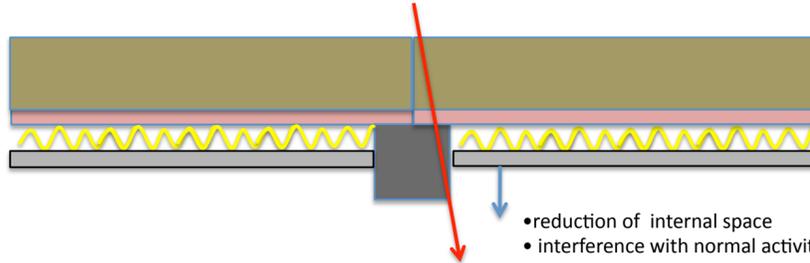
# WALL TYPES

## types and positions of layers

Current situation

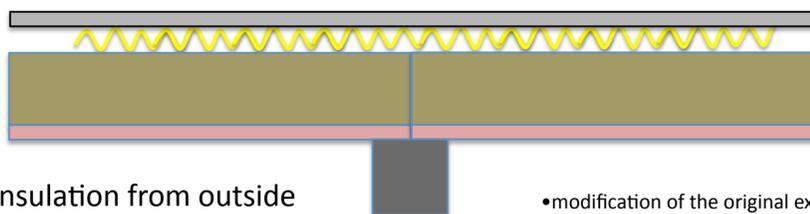


Insulation from inside



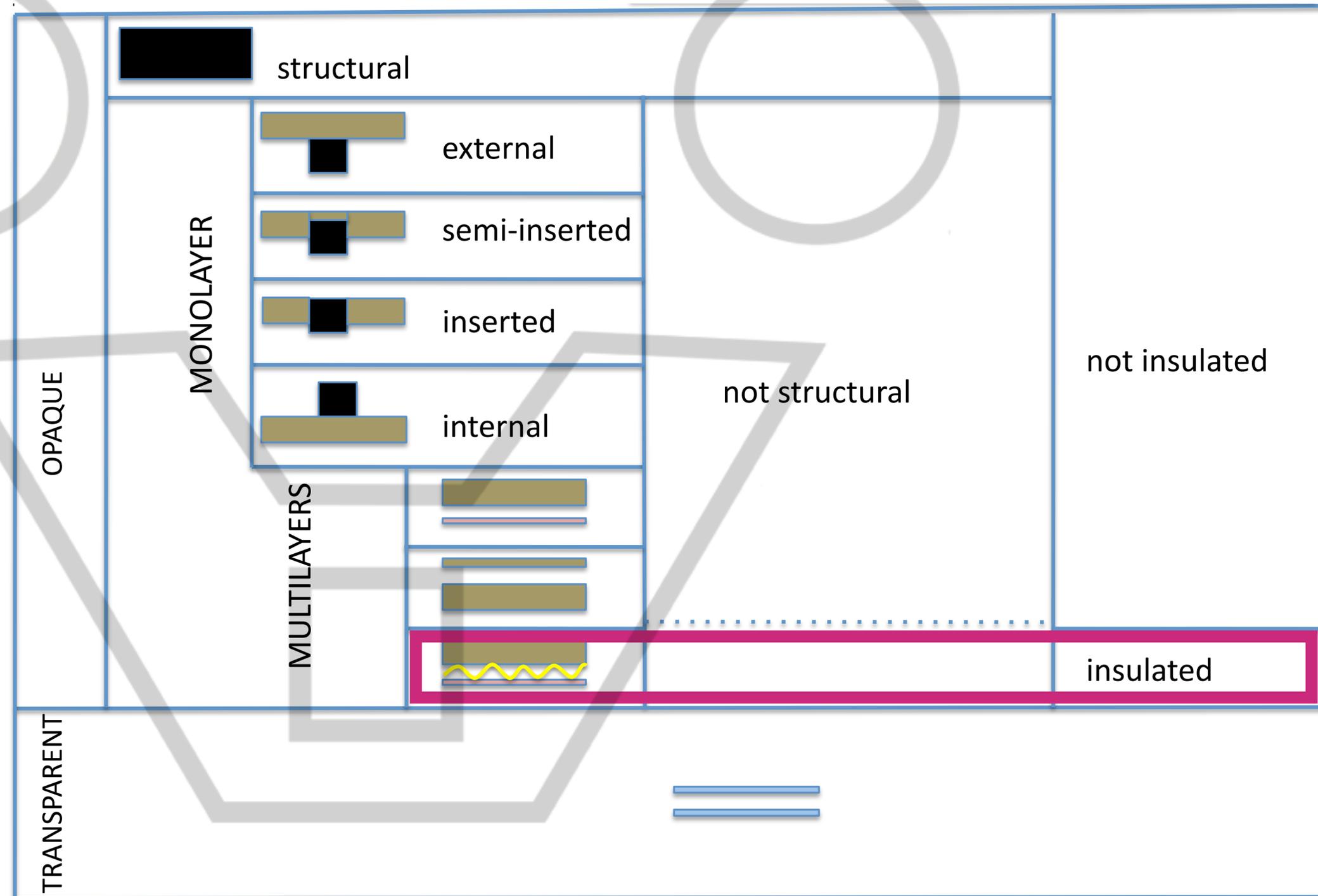
- reduction of internal space
- interference with normal activities
- thermal bridge

EXTERNAL INSULATION



Insulation from outside

- modification of the original external aspect



... SCREENED / NOT SCREENED; HEAVY/LIGHT; ADAPTIVE/NOT ADAPTIVE; MONOCOQUE/...

# ROOF TYPES

## types and positions of layers

### vapor barrier

CLASS I (impermeable) <0.1 per

### vapor retarder

CLASS II (semi impermeable) 0.1 -1 perms

CLASSIII (semi permeable) 1-10 perms

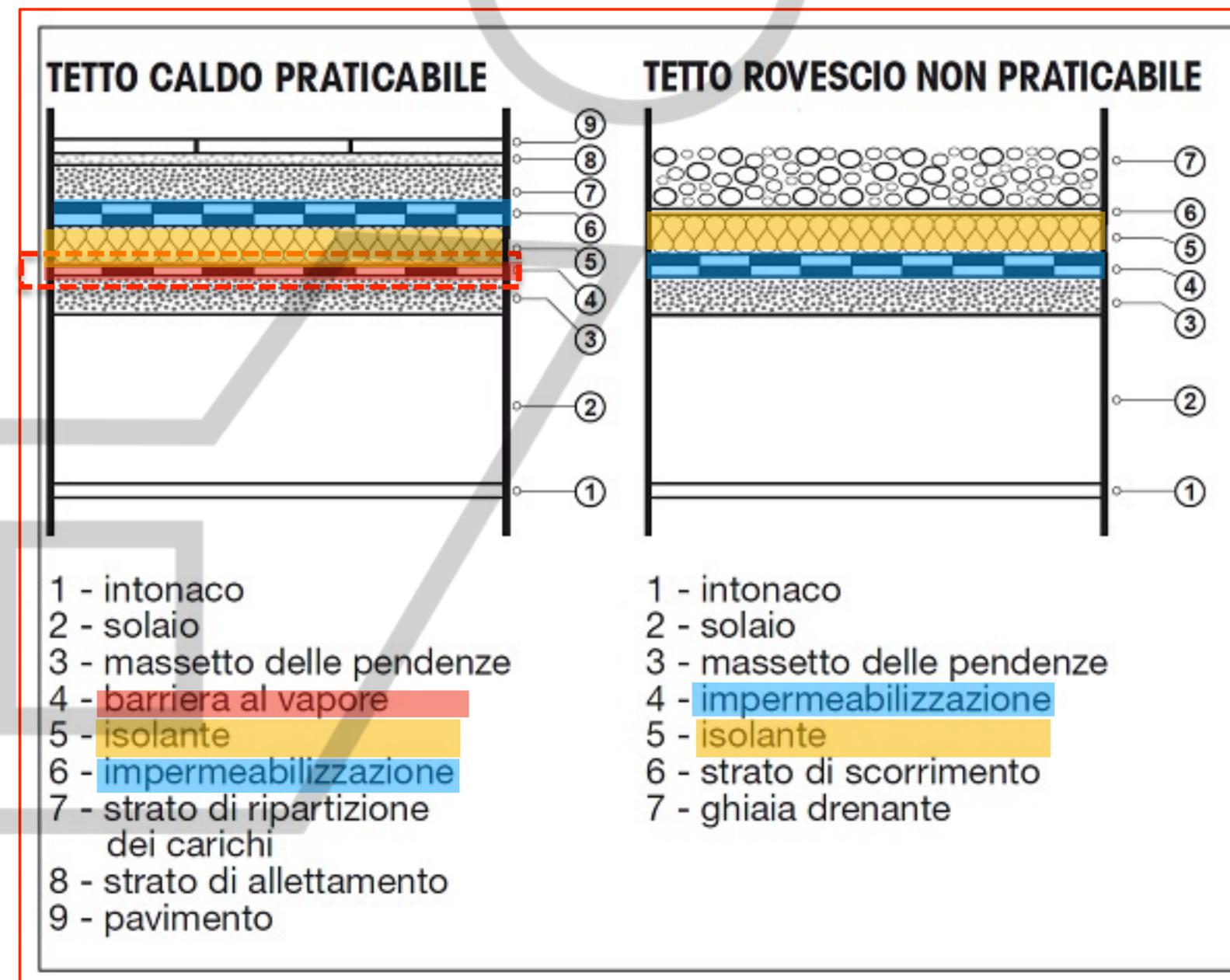
From WIKIPEDIA:

A **vapor barrier\*** (or **vapour barrier**) is any material used for damp proofing, typically a plastic or foil sheet, that resists diffusion of moisture through wall, ceiling and floor assemblies of buildings and of packaging.

Technically, many of these materials are only **vapor retarders** as they have varying degrees of permeability.

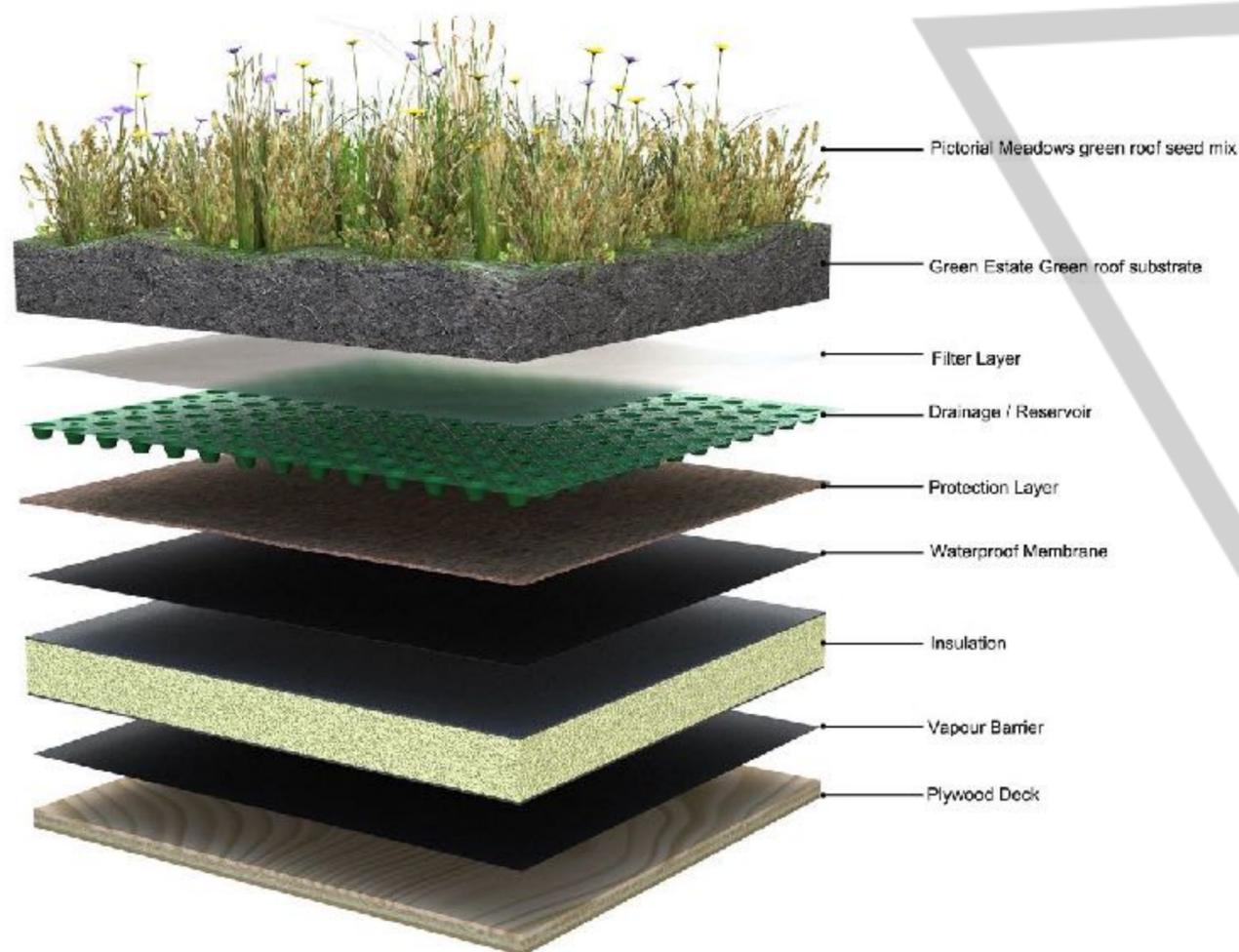
## WARM ROOF

## COLD ROOF



# GREEN TYPES

types and positions of layers



Extensive green roof layers  
(Sedum/drainage)

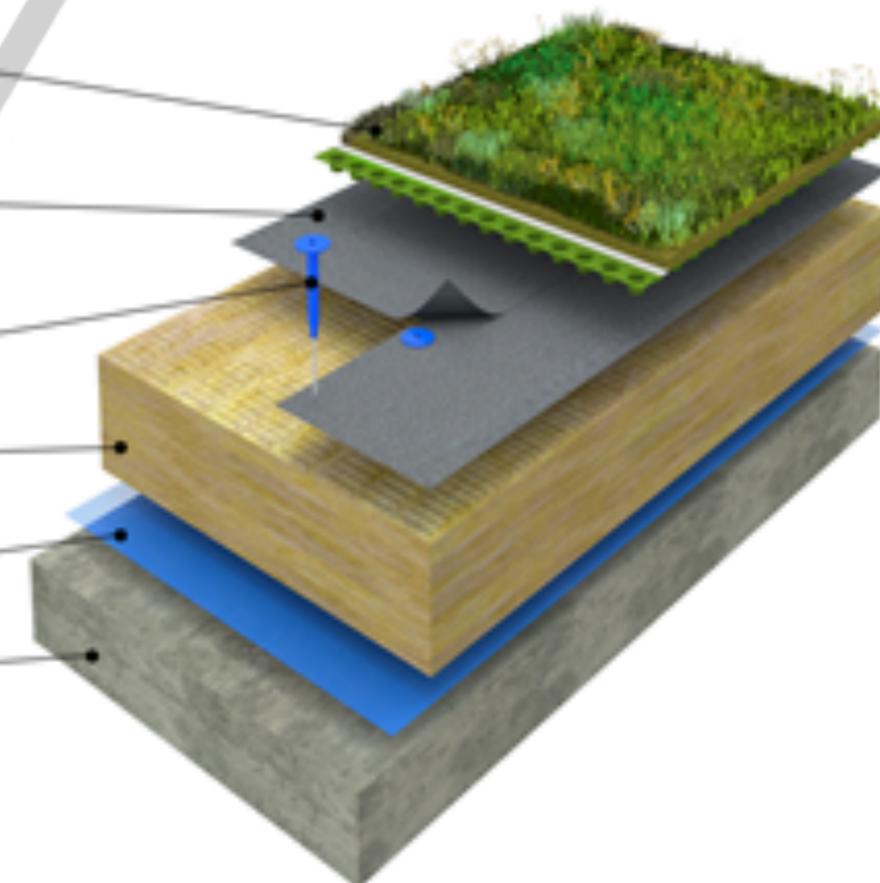
Protan SE Titanium +  
membrane

Fasteners

Insulation

Vapour control layer

Substrate



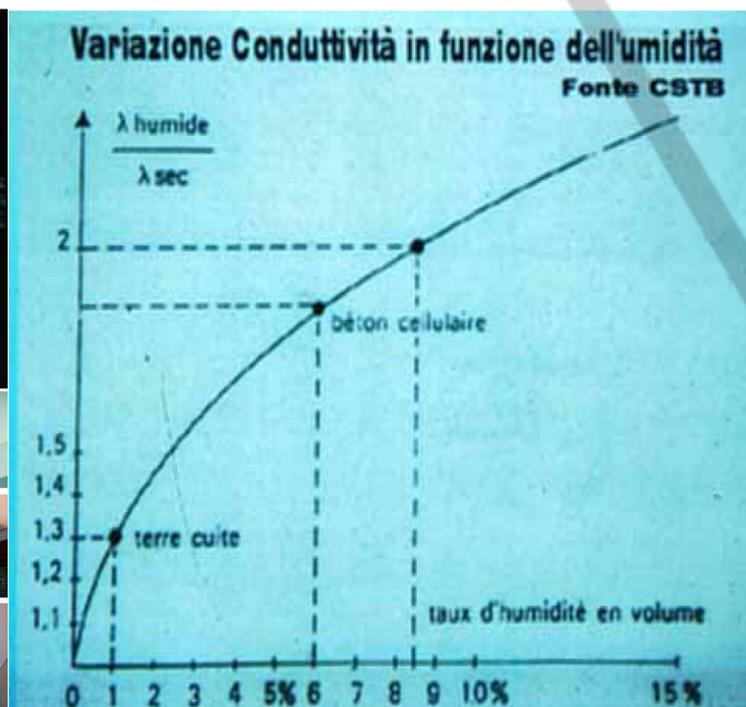
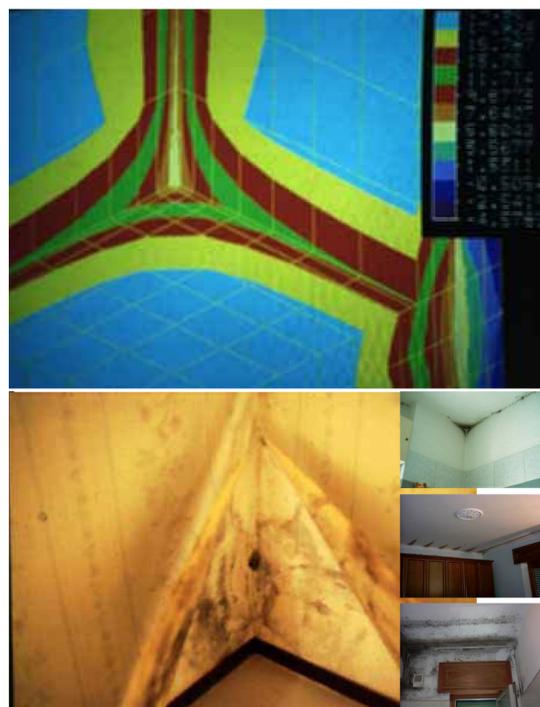
*lower is the thermal conductivity higher is the insulation*

CONDUCTIVITY  $f$  (DENSITY)  $\gg$  RESISTANCE =  $1 / \text{CONDUCTIVITY}$

# INSULATION MATERIALS

## THERMAL PROPERTIES & HUMIDITY EFFECTS

REDUCTION OF INSULATION PROPERTY DUE TO HUMIDITY



Material	Density (kg/m <sup>3</sup> )	Thermal Conductivity (W/mK)
<b>General Building Materials</b>		
Clay brickwork (outer leaf)	1,700	0.77
Clay brickwork (inner leaf)	1,700	0.56
Concrete block (heavyweight)	2,000	1.33
Concrete block (medium weight)	1,400	0.57
Concrete block (autoclaved aerated)	700	0.20
Concrete block (autoclaved aerated)	500	0.15
Concrete block (hollow)	1800	0.835
Cast concrete, high density	2,400	2.00
Cast concrete, medium density	1,800	1.15
Aerated concrete slab	500	0.16
Concrete screed	1,200	0.41
Reinforced concrete (1% steel)	2,300	2.30
Reinforced concrete (2% steel)	2,400	2.50
Wall ties, stainless steel	7,900	17.00
Wall ties, galvanised steel	7,800	50.00
Mortar (protected)	1,750	0.88
Mortar (exposed)	1,750	0.94
External rendering (cement sand)	1,800	1.00
Plaster (gypsum lightweight)	600	0.18
Plaster (gypsum)	1,200	0.43
Plasterboard	900	0.25
Natural slate	2,500	2.20
Concrete tiles	2,100	1.50
Clay tiles	2,000	1.00
Fibre cement slates	1,800	0.45
Ceramic/Porcelain tiles	2,300	1.30
Plastic tiles	1,000	0.20
Asphalt	2,100	0.70
Felt bitumen layers	1,100	0.23
Timber, softwood	500	0.13
Timber, hardwood	700	0.18
Wood wool slab	500	0.10
Wood-based panels (plywood, chipboard, etc.)	500	0.13

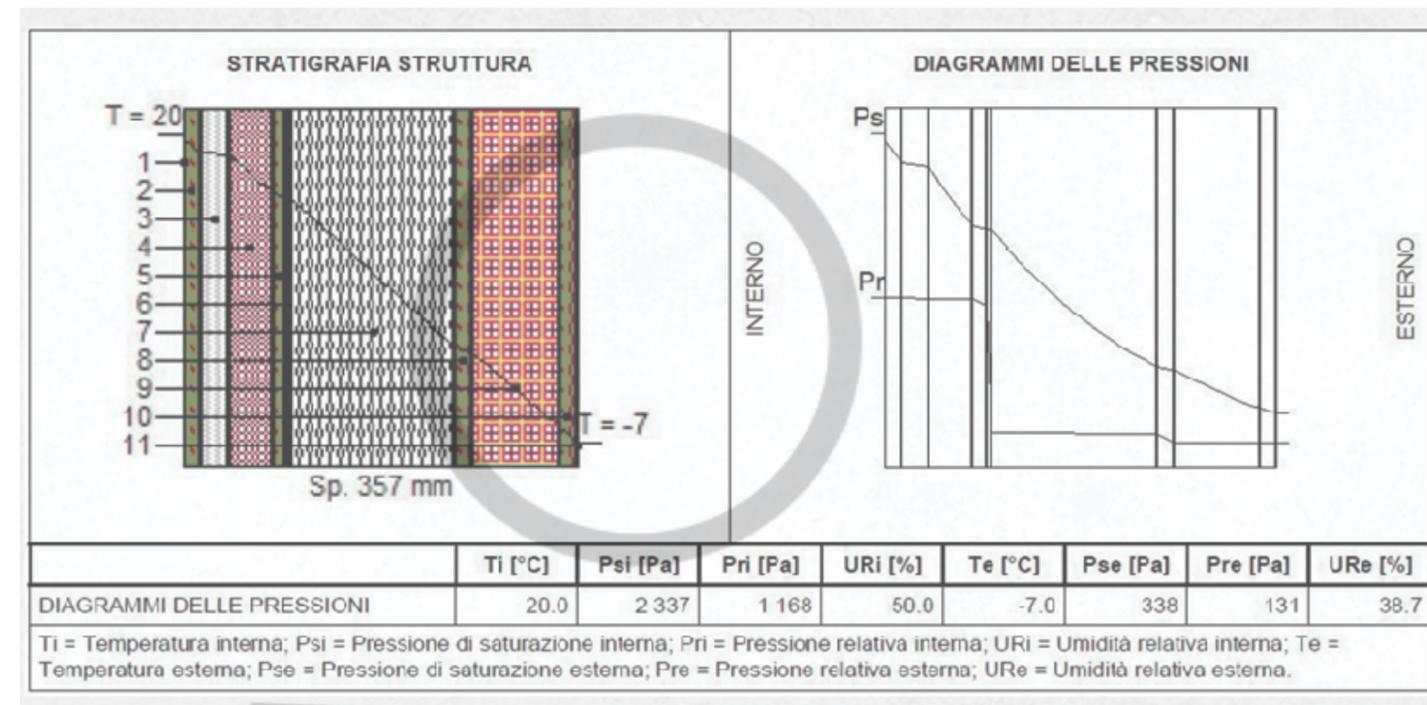
Note:  
The values in this table are indicative only. Certified values, should be used in preference, if available.

# INSULATION MATERIALS

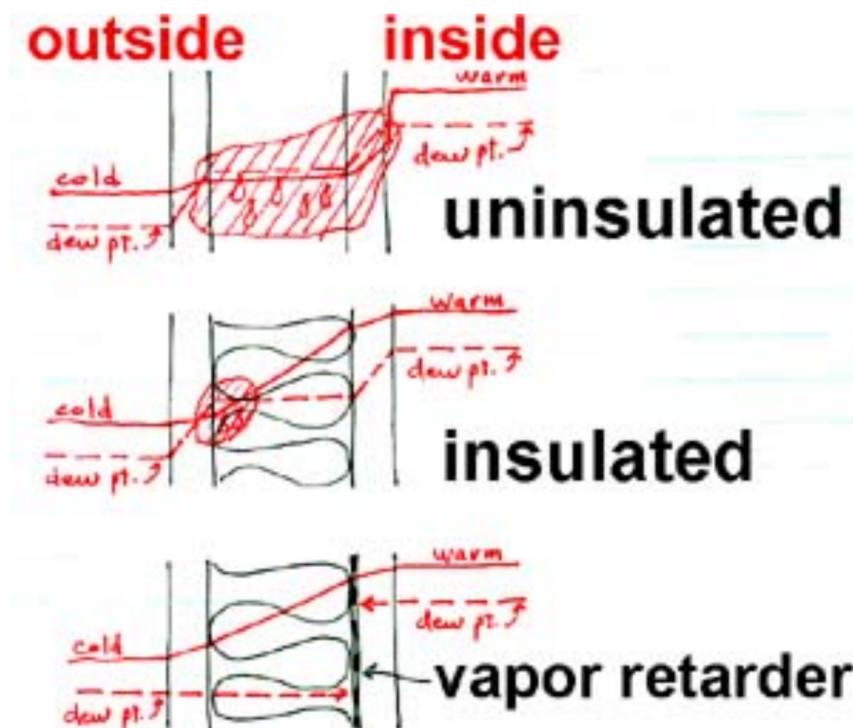
## THERMAL PROPERTIES & HUMIDITY EFFECTS

### DEW POINT

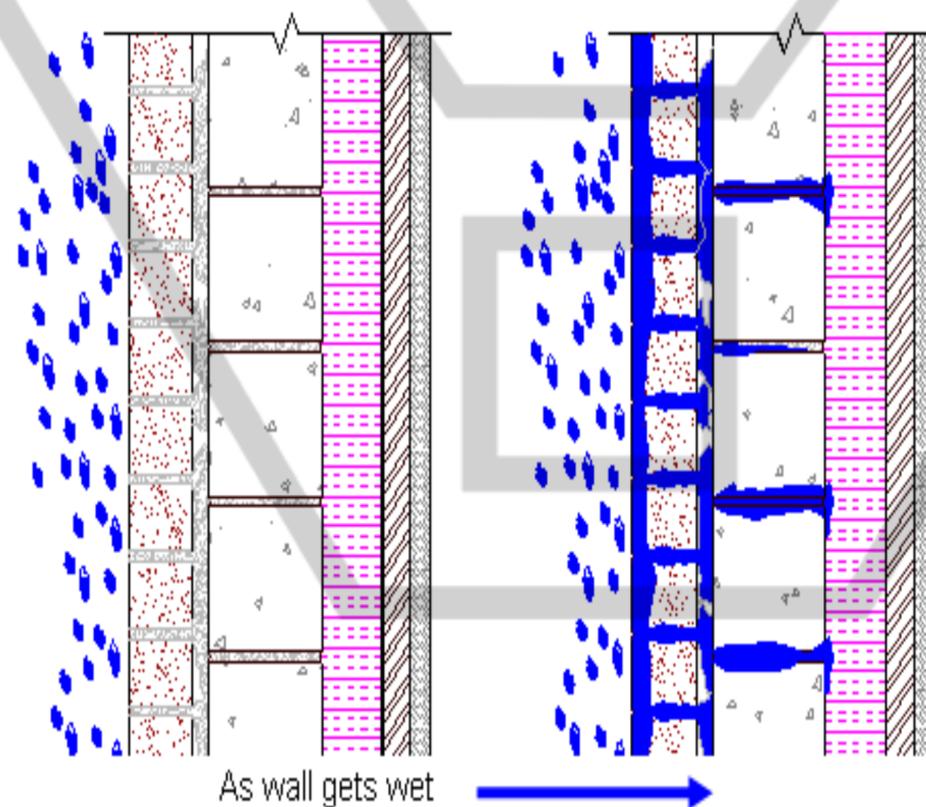
From WIKIPEDIA:  
The **dew point** is the [temperature](#) at which the [water vapor](#) in [air](#) at constant [barometric pressure](#) [condenses](#) into liquid water at the same rate at which it evaporates. At temperatures below the dew point, water will leave the air. The condensed water is called [dew](#) when it forms on a solid surface.



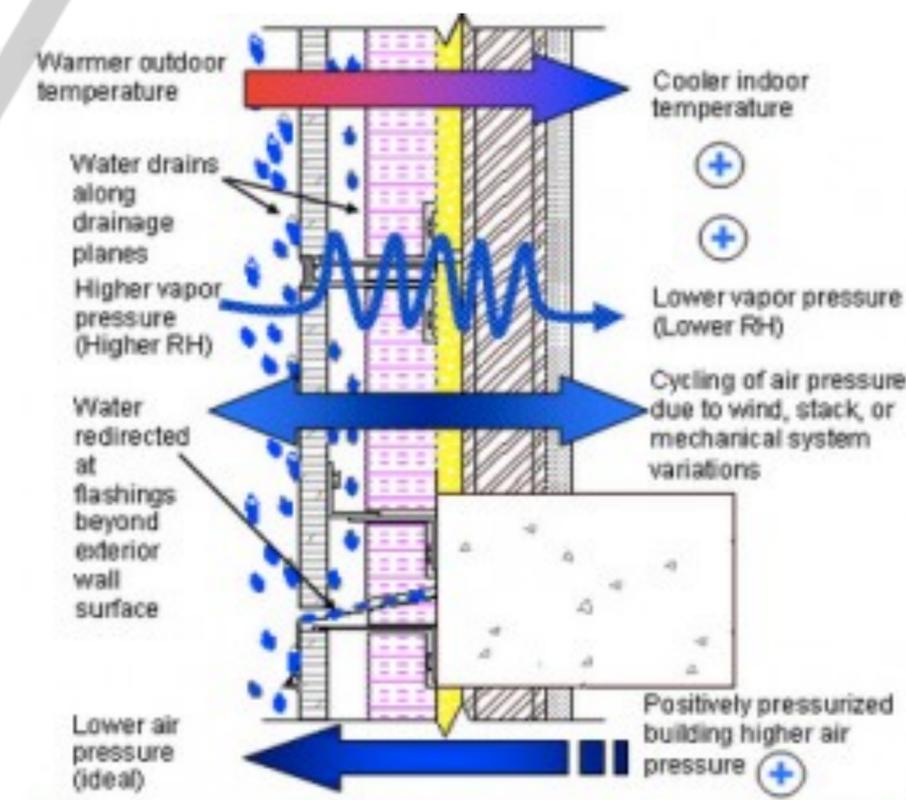
### TYPICAL WALL



### TYPICAL WALL



### VENTILATED WALL



# INSULATION MATERIALS

Morphology  
& application systems



PLASTER & FOAM



RIGID PANELS



MATTS



LOOSE MATERIALS

# INSULATION MATERIALS

## Nature of materials

### Conventional Insulation

EXPANDED PLASTICS (polystyrene, poliuretano (silicon-calcium- urea formaldehyde)

MINERAL FIBERS (fiber glass, mineral wool)

Conventional and include: fiberglass mineral wool, polystyrene, polyurethane foam, and multi-foils. These materials are widely used because not only are they inexpensive to buy and install, but there is an assumption from the building industry that their performance ability is higher than the natural alternatives. On the downside, almost all conventional insulation materials contain a wide range of chemical fire retardants, adhesives and other additives, and the embodied energy in the manufacturing process is very high.

### Natural Insulation

EXPANDED ROCKS

CLAY

CELLULAR CEMENTS (silicon-calcium)

NATURAL FIBERS (wool-cotton-cellulose and other wood derived)

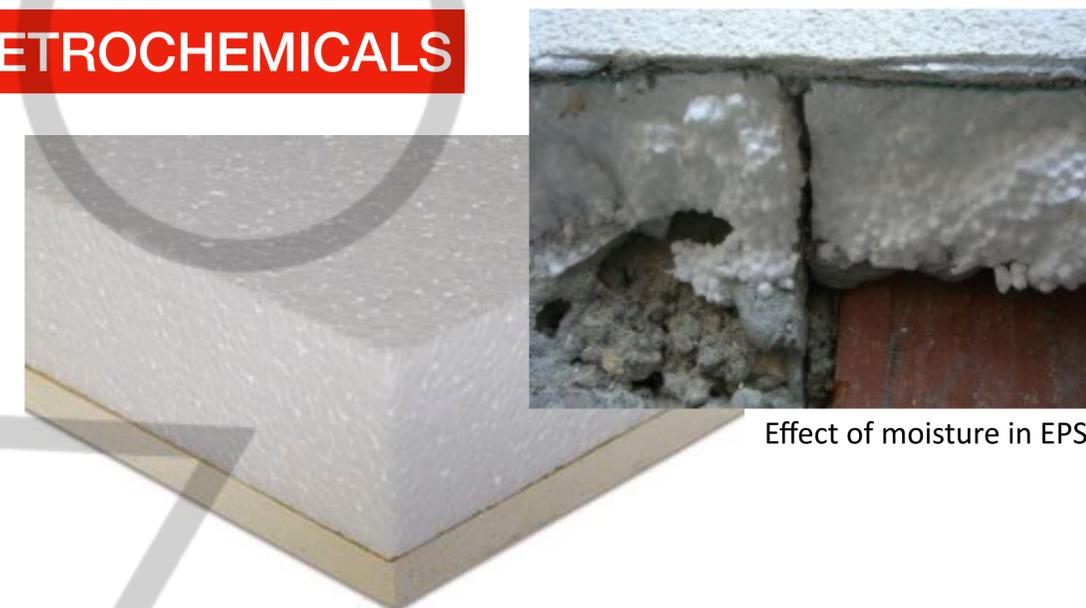
They are non-toxic, allergen-free and can be safely handled and installed. They also allow for a buildings to breathe by regulating humidity through their absorbent properties, and reducing problems of condensation. This keeps the indoor environment comfortable and protects any timber structures from rot.

Unfortunately, natural insulation materials are currently up to 3 times more expensive than conventional materials, which can be prohibitive to builders, architects and developers.

# INSULATION MATERIALS

Nature of materials

## INSULATIONS FROM PETROCHEMICALS



Effect of moisture in EPS

Polystyrene usually called polystyrol

**Polyurethane or Stiferite**  
*Over time, R-value decreases steadily. Is susceptible to moisture infiltration*

**Extruded Polystyrene (XPS)**  
*Over time, R-value decreases minimally*

**Sintered Expanded Polystyrene (EPS)**  
*Over time, R-value decreases. Is susceptible to moisture infiltration*

Not only is polystyrene in walk-ins made with recycled materials and is 100% recyclable but it is energy efficient and can save a great deal of money in energy costs and reduce carbon footprint over the life-cycle of the walk-in.

Extruded Polystyrene vs EPS has

- more density,
- around 5 times insulation properties
- higher mechanical resistance



**Pannelli Stiferite**  
• Applicazioni GT: Isolamento di coperture, pavimenti e pareti  
• Applicazioni Class G: Isolamento sotto manti bituminosi  
• Applicazioni Class SK: Isolamento di pareti a cappotto



**stiferite**  
l'isolante termico

STYROFOAM

# INSULATION MATERIALS

Nature of materials

INSULATIONS FROM MINERAL FIBERS AND EXPANDED ROCKS



# INSULATION MATERIALS

## Nature of materials

## INSULATIONS FROM NATURAL FIBERS & MATERIALS



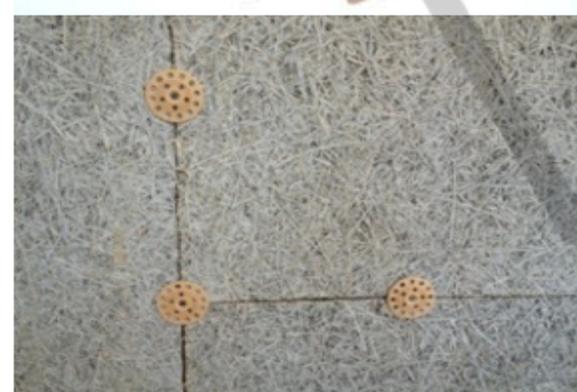
**CELLULOSE**

**Cellulose**  
A recycled product made from newsprint and other cellulose fibre. It is one of the most favoured materials of natural builders because it can be blown into cavity walls, floors and roofs or used as a loose fill. Also it is available in quilts, boards and batts. Like hemp and flax it contains borate as an additive. Products include: Warmcell and Ecocel.



**WOODFIBRE**

**Wood Fibre**  
Made from wood chips that have been compressed into boards or batts using water or natural resins as a binder. It has very low embodied energy and uses by-products from the forestry industry. Examples include: Pavatex, Thermowall and Homatherm



**FLAX**



**HEMP**



**STRAW**



**CORK**



**SHEEP WOOL**

The green alternative to synthetic insulation is natural insulation. There are many different types available, including:

### Flax and Hemp

Natural plant fibers that are available in bats and rolls, and typically contain borates that act as a fungicide, insecticide and fire retardant. Potato starch is added to flax as a binder. Both materials have low embodied energy and are often combined in the same product. Examples include Isonat and Flax 100.

### Flax and Hemp

It is obtained from the cork oak (*Quercus Suber L*) – a forest tree with the particular feature of allowing itself to be stripped of the outer casing which it then regenerates in 9 to 10 years. In one cubic inch in size, there are approximately 200 million of minute cells, each separated by an impermeable and remarkably strong, resinous membrane (more than 50% of the volume is air). This cellular structure makes cork light in weight, buoyant, resistant to the penetration of moisture, compressible, resilient, resistant to the effects of friction and an ideal thermal and sound insulation material. In addition, cork is much more chemically inert than most materials, and is therefore capable of withstanding deterioration through age. Cork does not support its own combustion and chars only slowly when subjected to a flame. Unlike some synthetic insulation materials, in burning it does not produce chlorides, cyanides or other toxic gases.

### Sheep's Wool

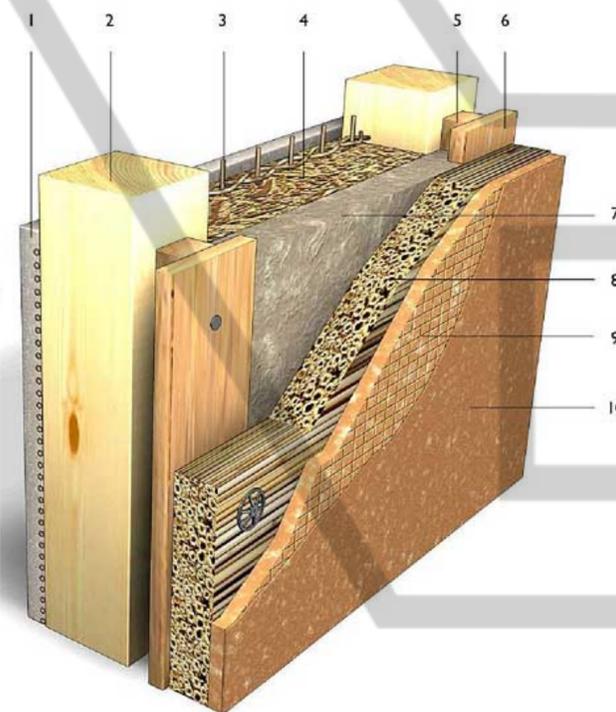
This material usually needs to be treated with chemicals to prevent mite infestation and reduce fire risk, although some natural builders use it untreated with success. It has very low embodied energy (unless it is imported) and performs exceptionally well as an insulation material. Thermafleece is the most common commercial brand available.



# INSULATION MATERIALS

Nature of materials

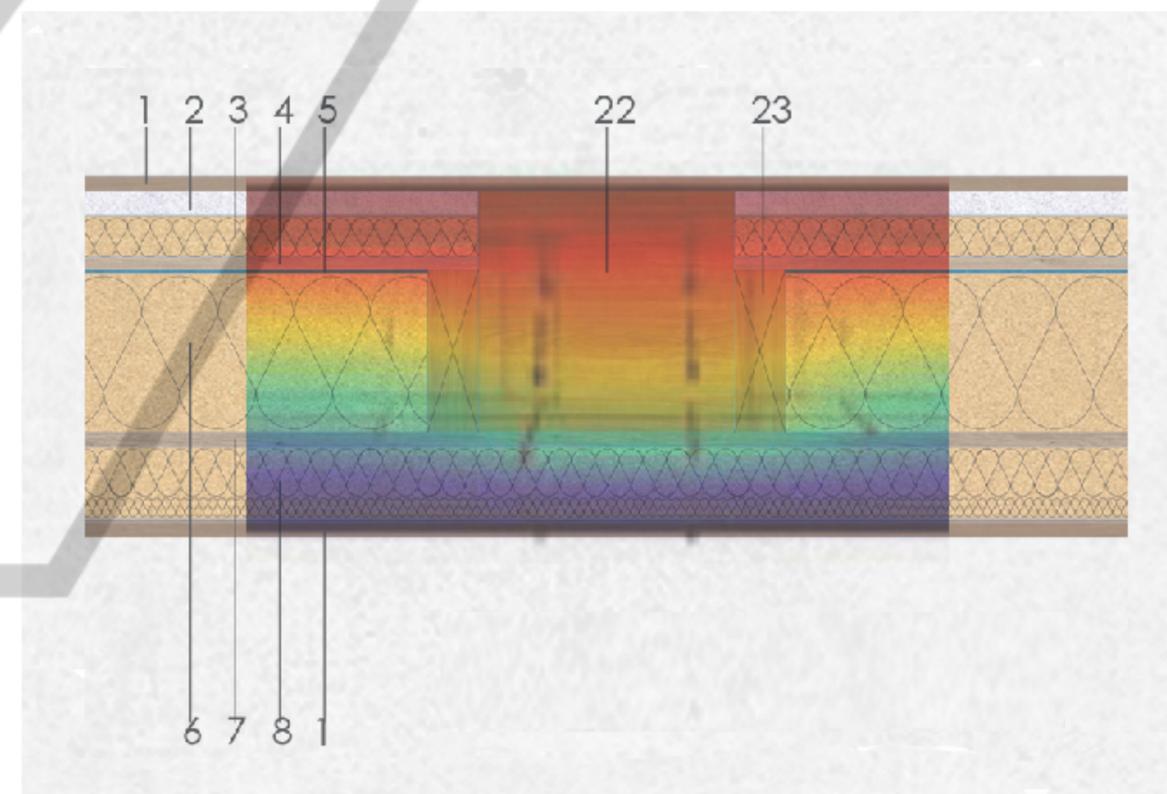
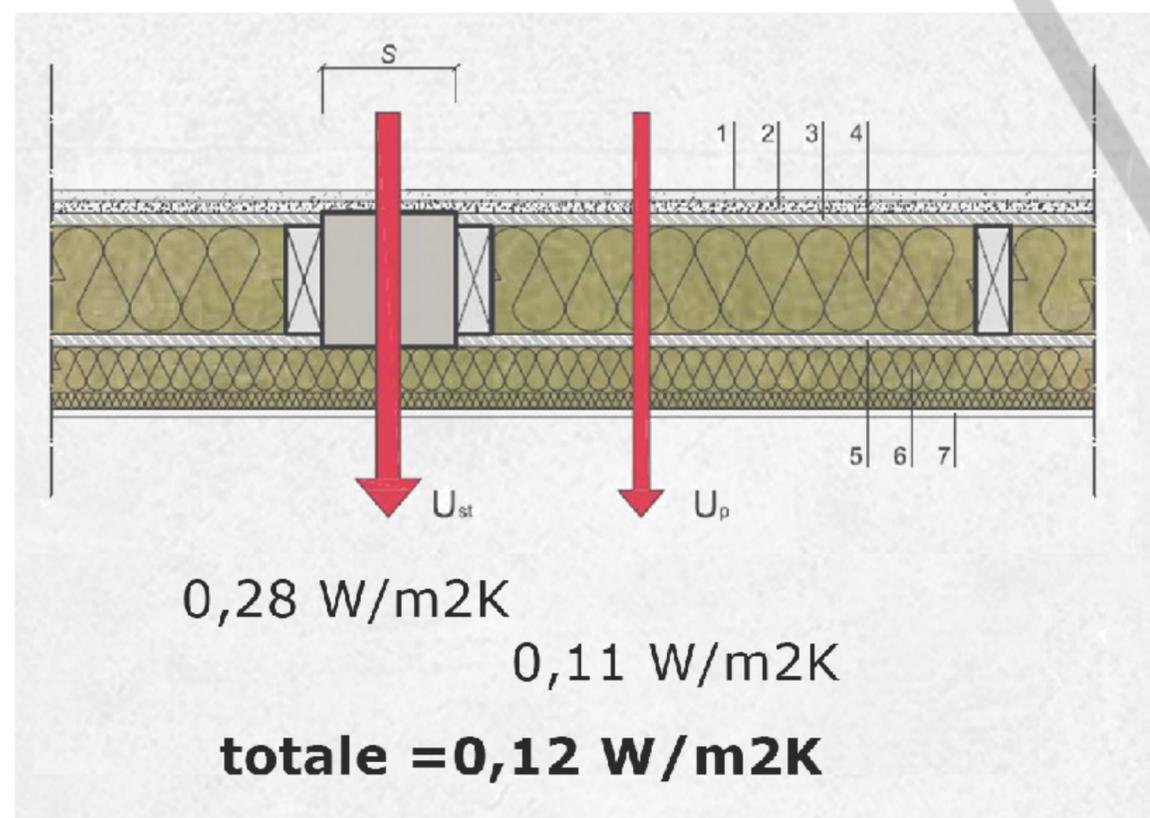
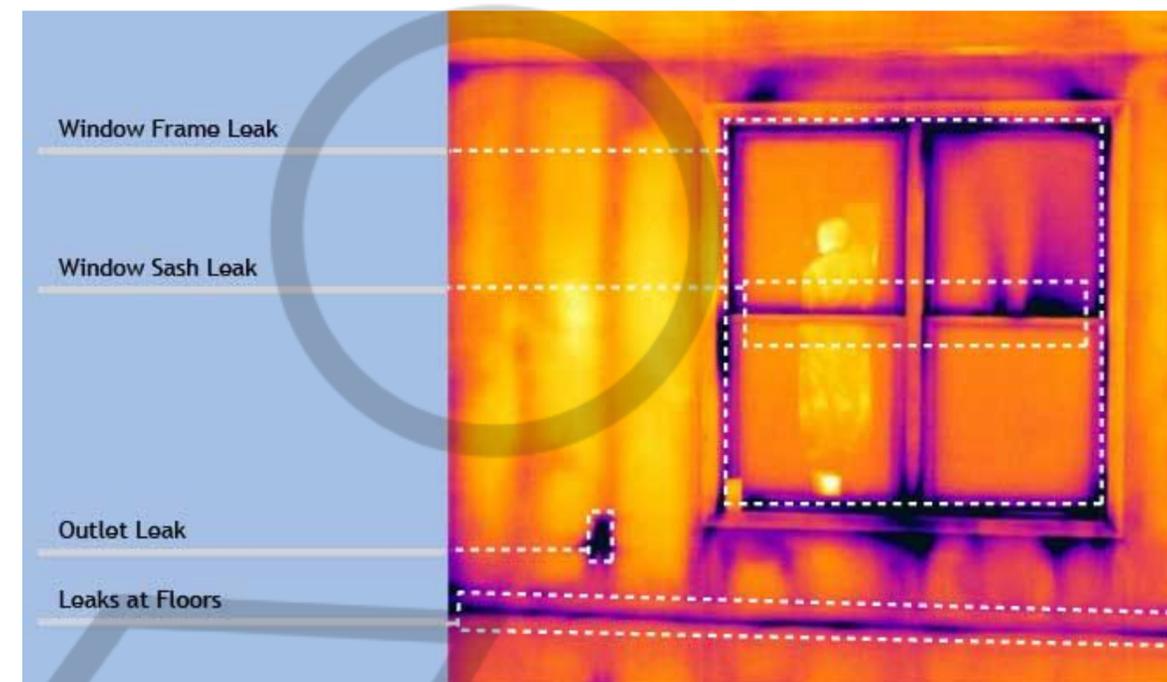
INSULATIONS FROM NATURAL FIBERS & MATERIALS



# INSULATION MATERIALS DETAILS

## THERMAL BRIDGE

From WIKIPEDIA:  
The **dew point** is the [temperature](#) at which the [water vapor](#) in [air](#) at constant [barometric pressure](#) [condenses](#) into liquid water at the same rate at which it evaporates. At temperatures below the dew point, water will leave the air. The condensed water is called [dew](#) when it forms on a solid surface.

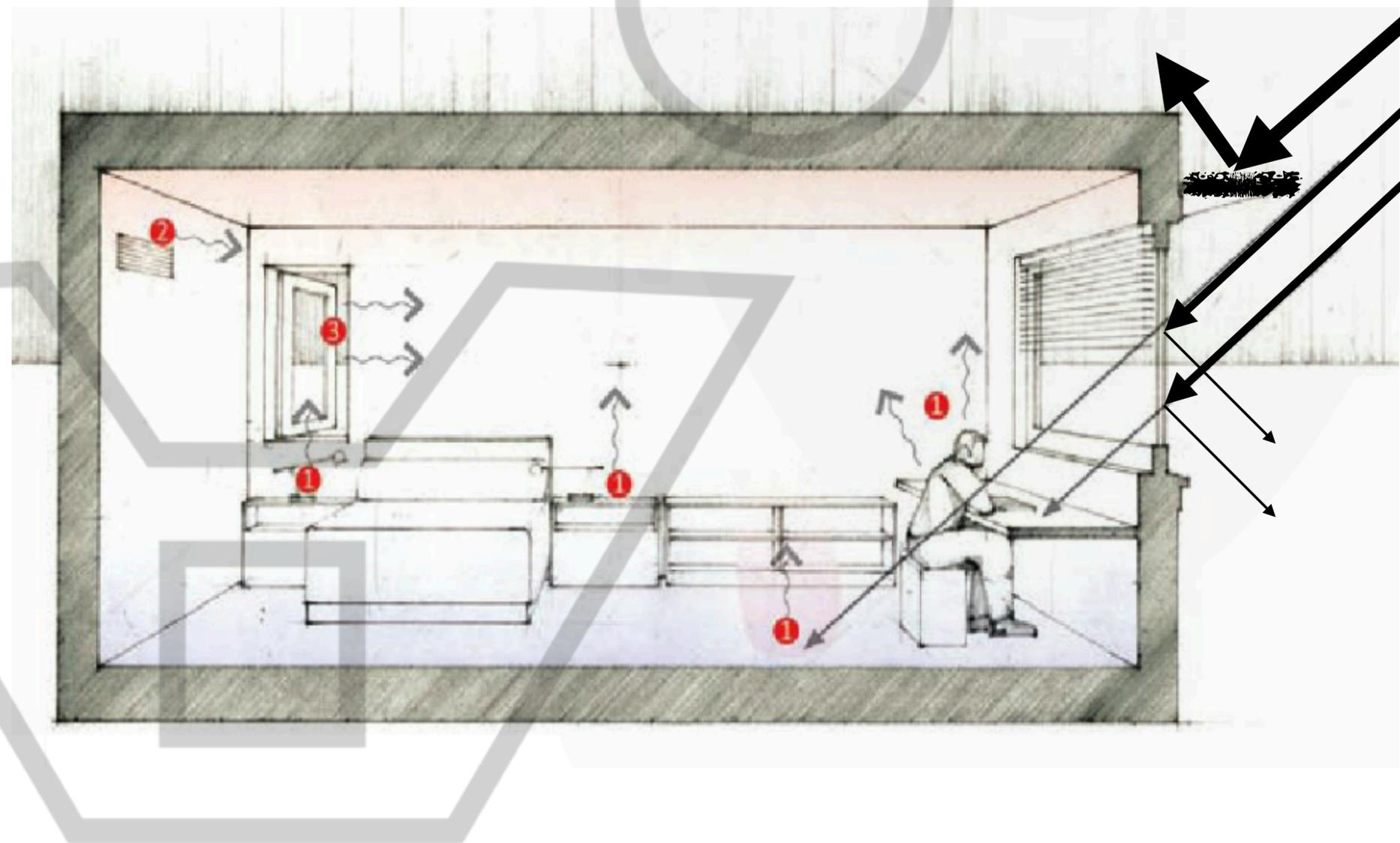


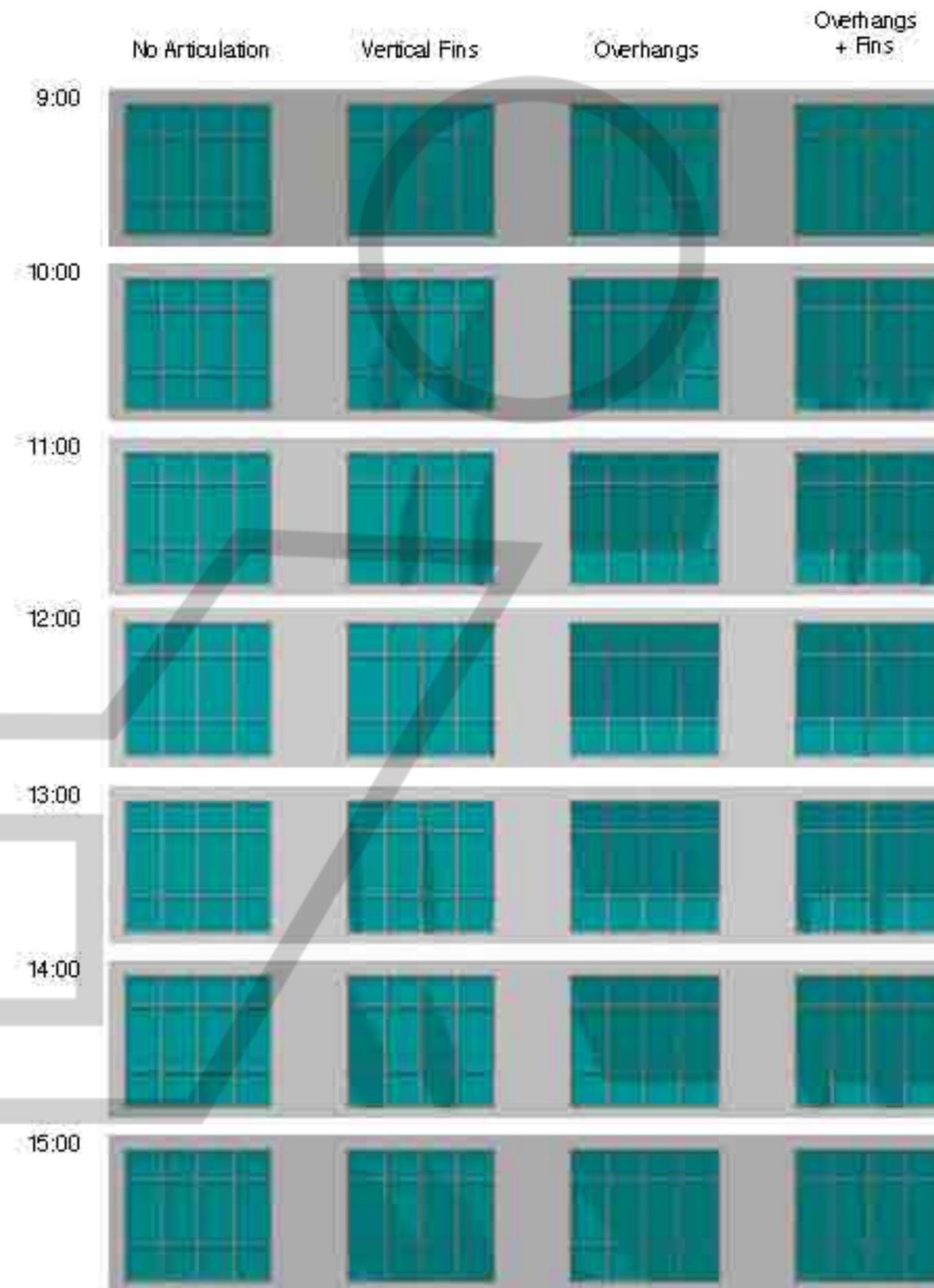
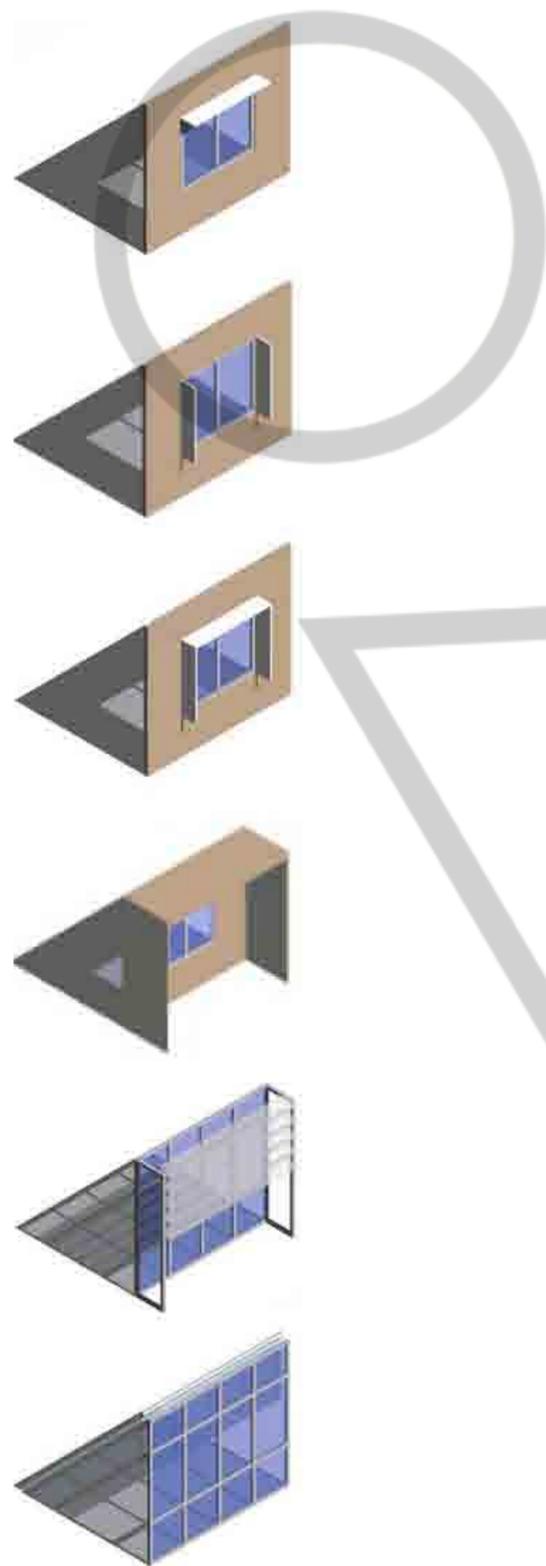
Environmental Design Course  
Prof. G. Ridolfi, PhD

# THE BUILDING ENVELOPE



# SHADING & REFLECTANCE







**SUN SHADING CHART**

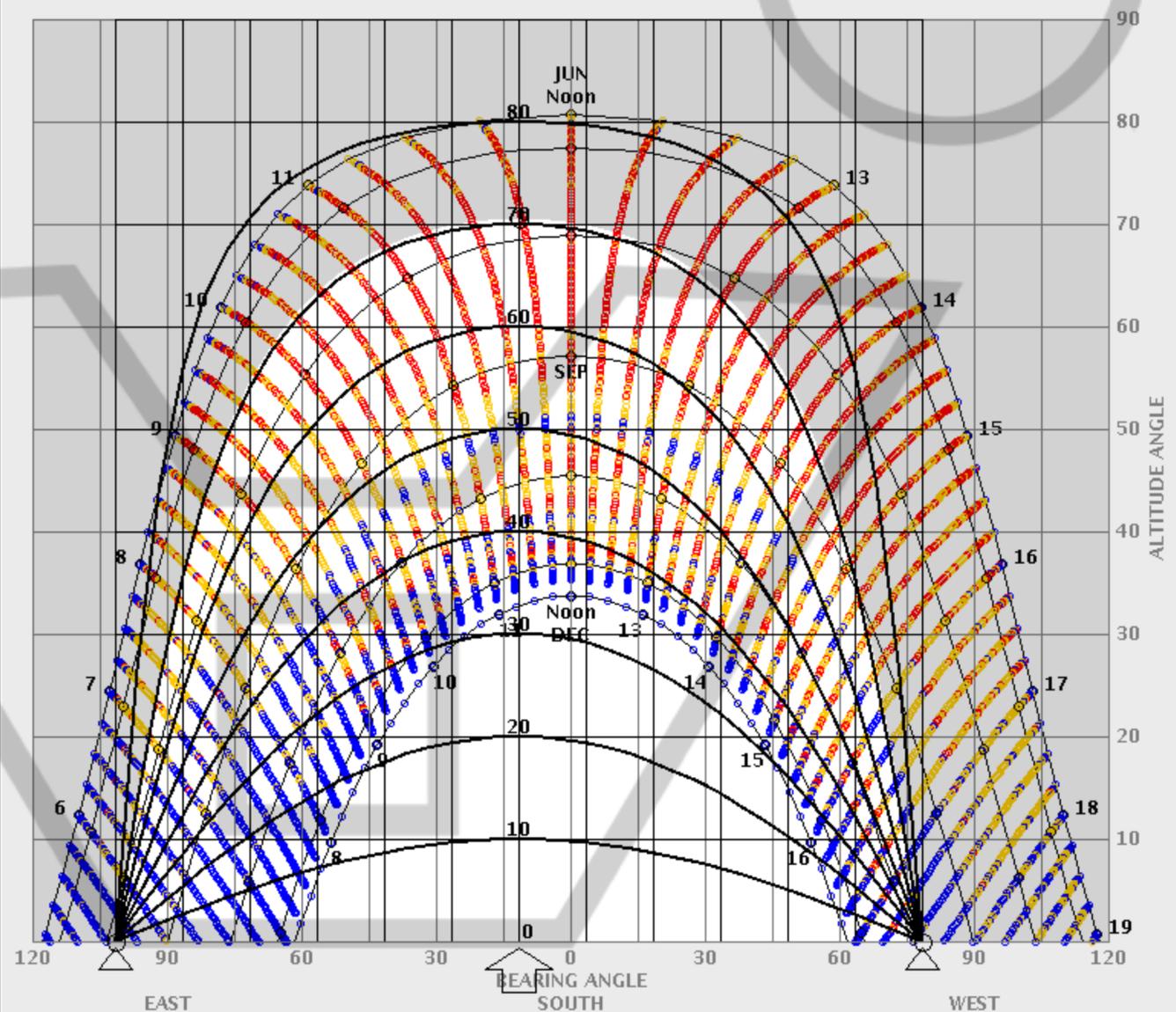
**LOCATION:** Climate Zone 7, CA, USA  
**Latitude/Longitude:** 32.7° North, 117.2° West, Time Zone from Greenwich -8  
**Data Source:** WYEC2-C-00007 722900 WMO Station Number, Elevation 4 m

**LEGEND**

- **WARM/HOT > 24°C**  
(SHADE NEEDED)  
288 Hours Exposed  
268 Hours Shaded
- **COMFORT > 20°C**  
(SHADE HELPS)  
435 Hours Exposed  
575 Hours Shaded
- **COOL/COLD < 20°C**  
(SUN NEEDED)  
627 Hours Exposed  
403 Hours Shaded

- PLOT MONTHS:**
- WINTER SPRING  
December 21 to June 21
  - SUMMER FALL  
June 21 to December 21

- Display Grid
  - Display Shading Calculator
  - Display Obstruction Elevation
- Input Obstructions





Le Corbu, Curutchet House, La Plata, 1949-55



Giuseppe Terragni, Asilo Sant'Elia, Como 1936-1937





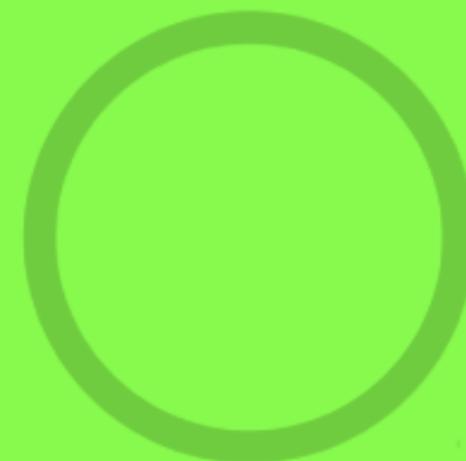
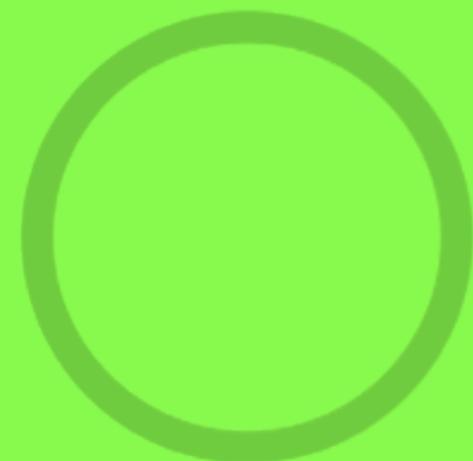
## The Brise Soleil Milam House Paul Rudolph









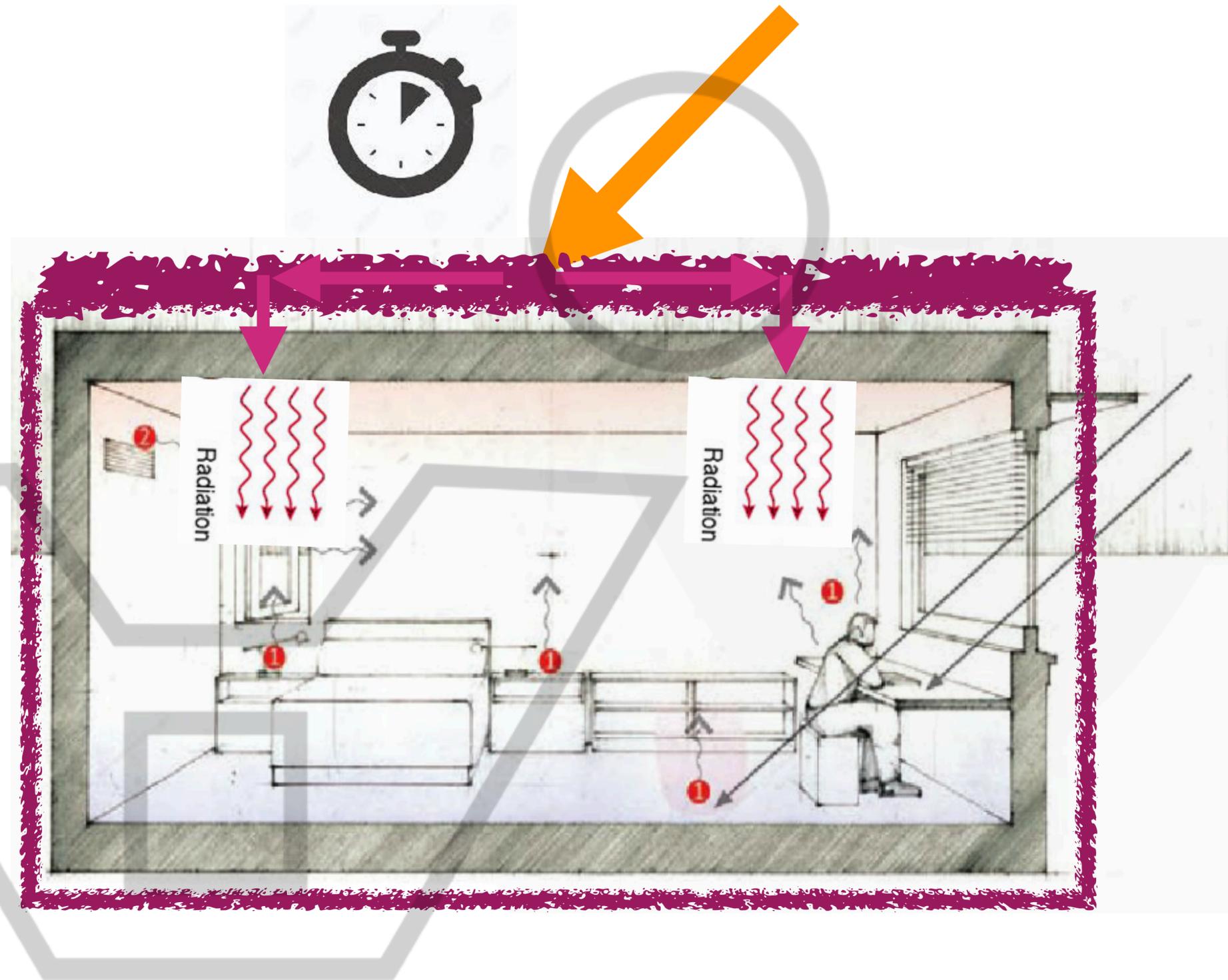


# THERMAL LAG



# THERMAL LAG

*working with inertia,  
thermal mass  
& mass latency*



# THERMAL LAG

*energy transmission  
by radiation*

## Internal temperature stabilization

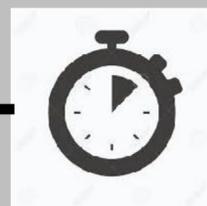
Thermal mass influences comfort by radiant exchanges with the skin. In fact **radiant exchange with mass surfaces is singularly the most efficient way of maintaining comfort**

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.

$$\text{Environmental Temperature } -T(\text{env}) = \frac{2}{3} \text{ Mean radiant surface temperature} + \frac{1}{3} \text{ Air temperature}$$

## INERTIA vs INSULATION

Inertia is distinctive alternative from insulation that allows to smooth temperature fluctuations known as the *thermal flywheel effect*.



### What is THERMAL LAG?

Thermal Lag is related to a body with **high thermal mass** (**high heat capacity** and **low conductivity**) that will have a capacity to store thermal energy for a certain amount of time

wikipedia

**Heat capacity** or **thermal capacity** is a physical property of matter, defined as the amount of heat to be supplied to a given mass of a material to produce a unit change in its temperature.<sup>[1]</sup> The SI unit of heat capacity is joule per kelvin (J/K).

**THERMAL MASS** is a property of the mass of a building which enables it to store heat, providing "inertia"

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

## Heat capacity by materials

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

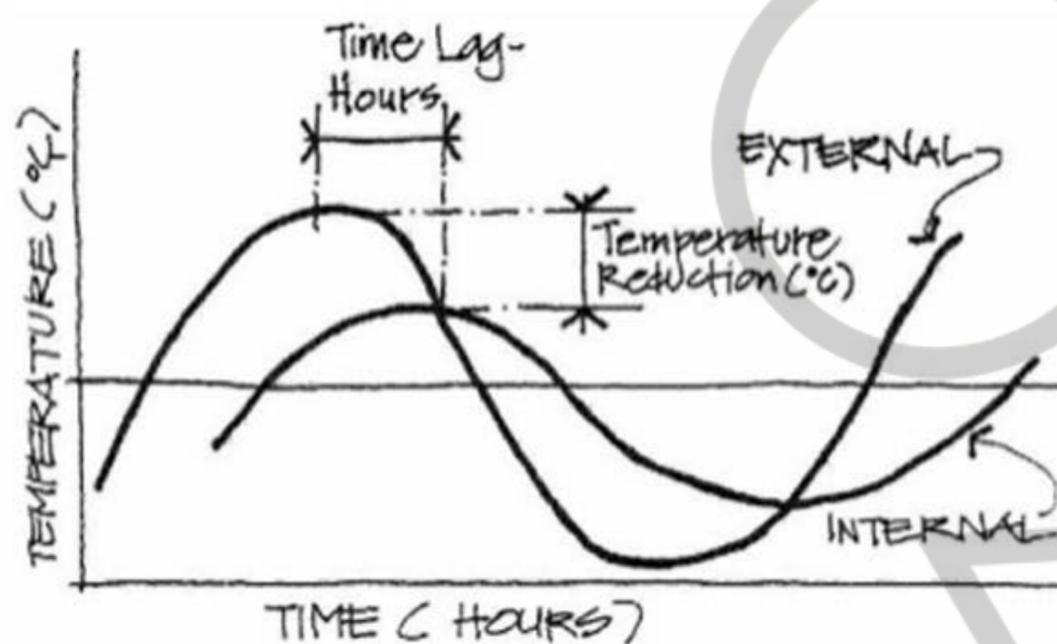
Material	Density (Kg/m <sup>3</sup> )	Specific heat (kJ/kg.K)	Volumetric heat capacity <b>THERMAL MASS (KJ/m<sup>3</sup>.K)</b>
Water	1000	4.186	4186 <b>highest</b>
Concrete	2240	0.920	2060
AAC Autoclaved Aerated Concrete	500	1.100	550 <b>lowest</b>
Brick	1700	0.920	1360
Stone (Sandstone)	2000	0.900	1800
FC Sheet (compressed) Fiber Cement	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**

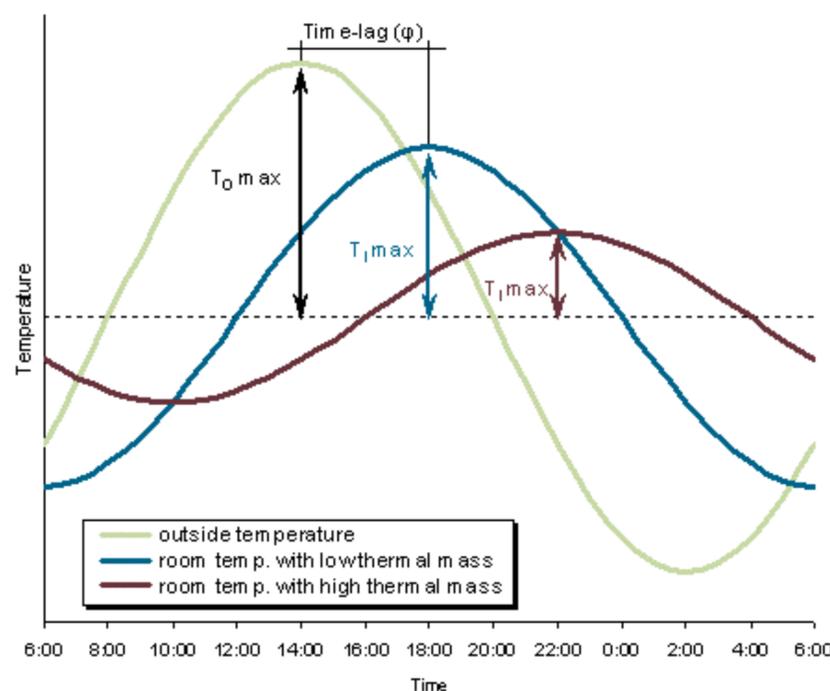
Note: Figures are based on a number of sources and include estimations and interpolations.

[http://www2.ecospecifier.org/knowledge\\_base/technical\\_guides/thermal\\_mass\\_building\\_comfort\\_energy\\_efficiency](http://www2.ecospecifier.org/knowledge_base/technical_guides/thermal_mass_building_comfort_energy_efficiency)

## 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

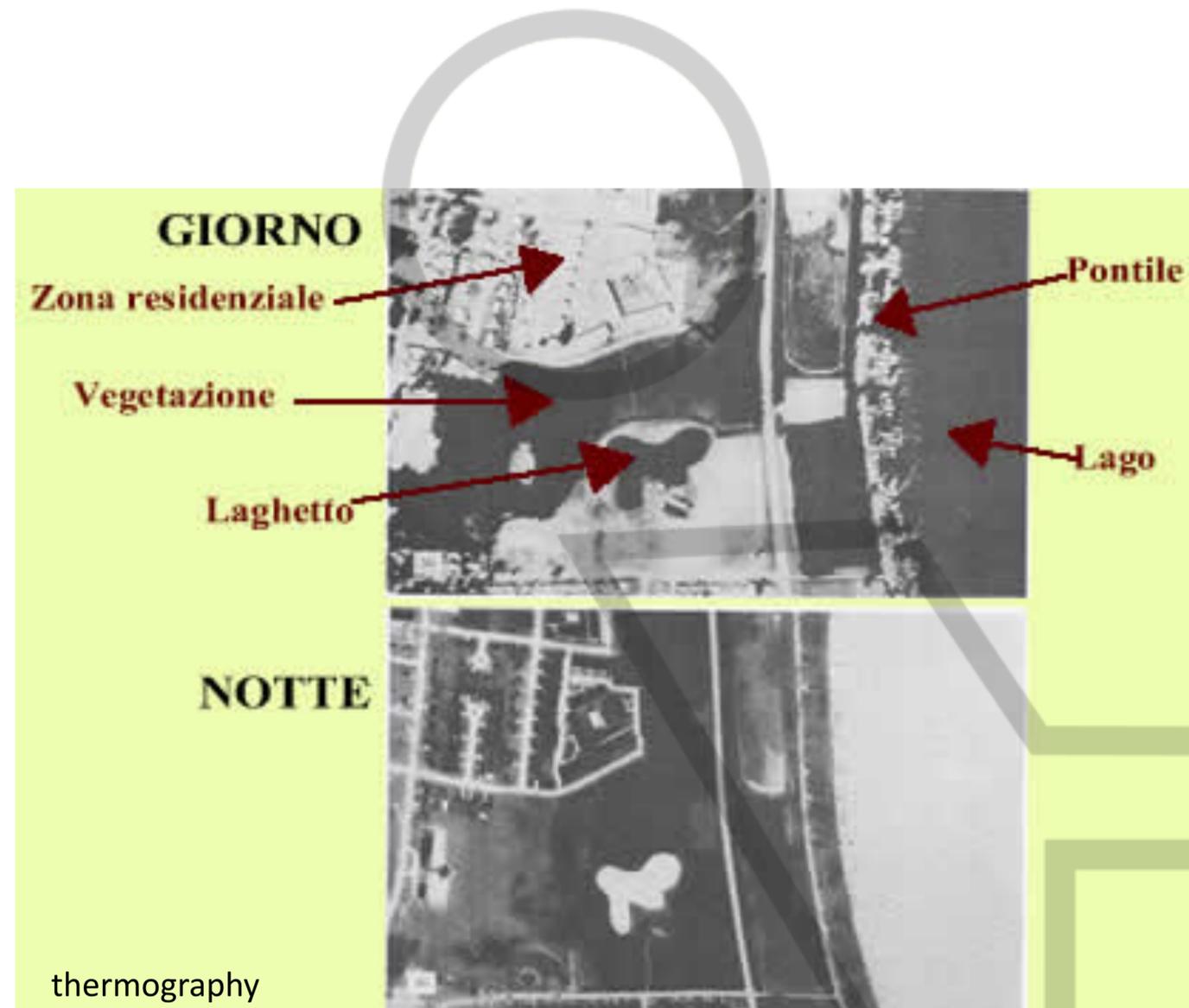


Material (thickness in mm)	Time lag (hours)
Insulated Brick Veneer	5.0
Concrete (250)	6.9
Double Brick (250)	7.0
AAC (200)	7.0
Adobe (250)	9.2
Rammed Earth (250)	10.3
Compressed Earth Blocks (250)	10.5
Sandy Loam (1000)	30 days

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

A **thermal flywheel effect** from Nature: Marine breezes

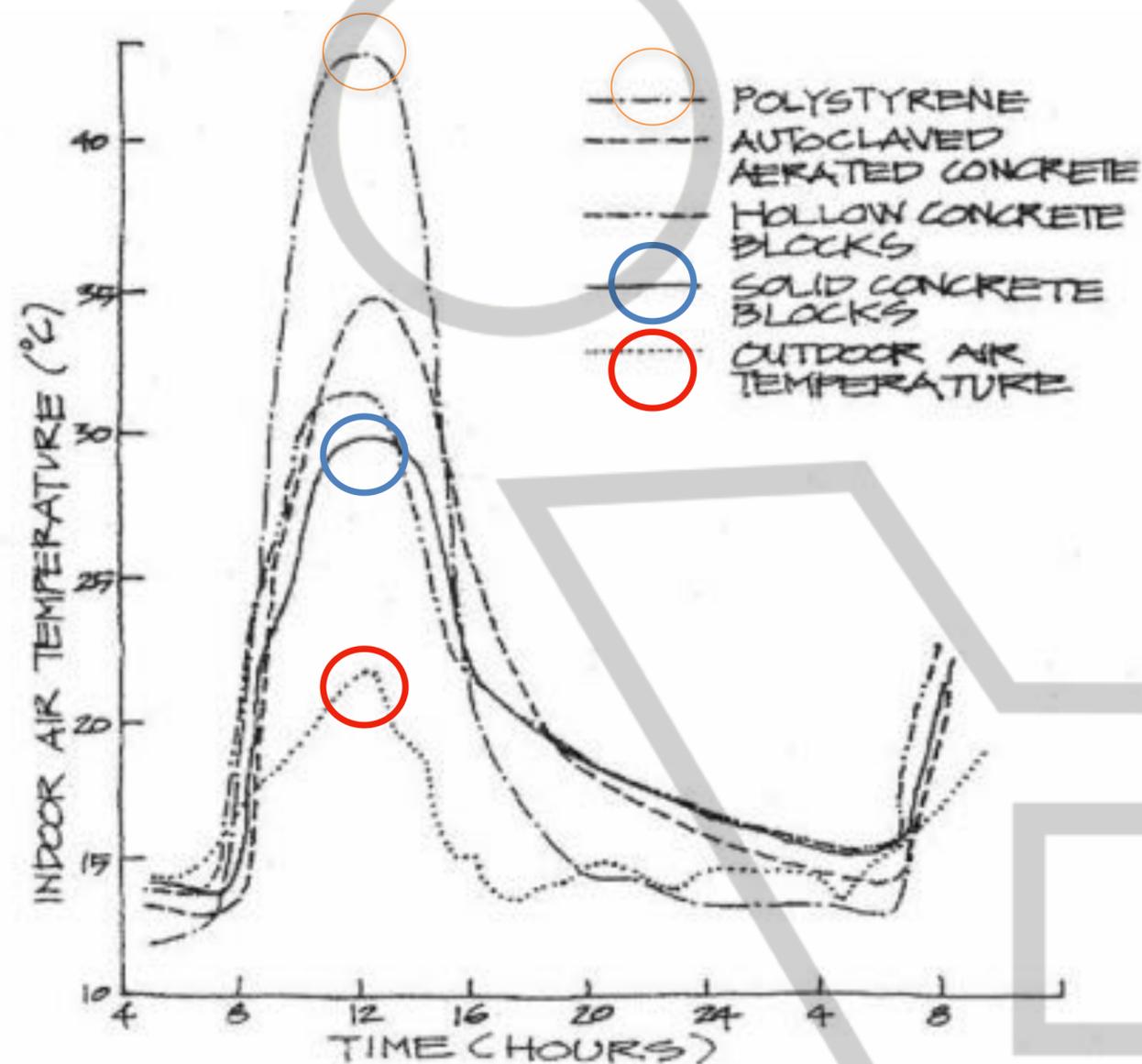




Thermal mass affects the temperature within a building by stabilizing internal temperatures in three ways:

- *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).

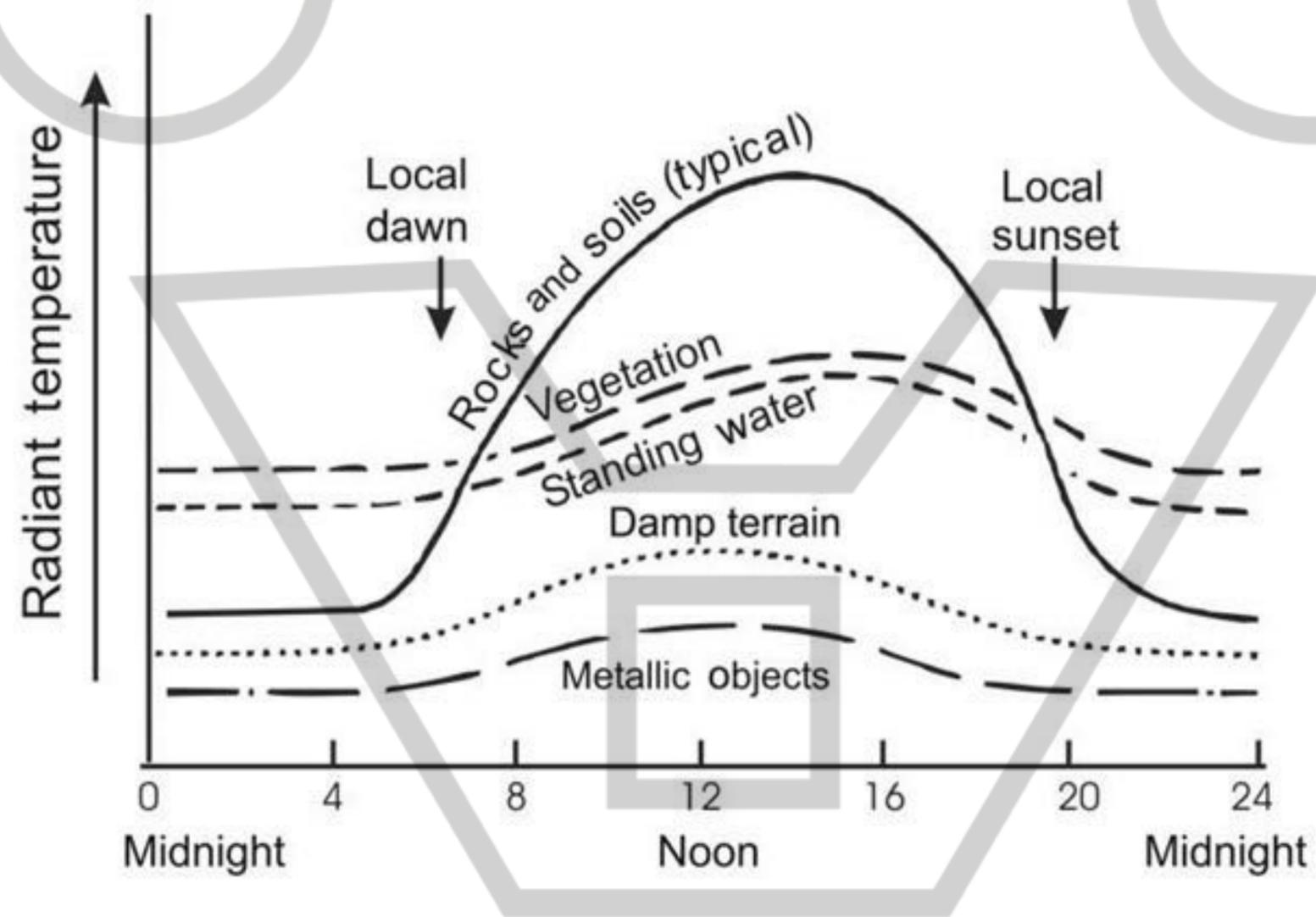
## Internal temperature stabilization



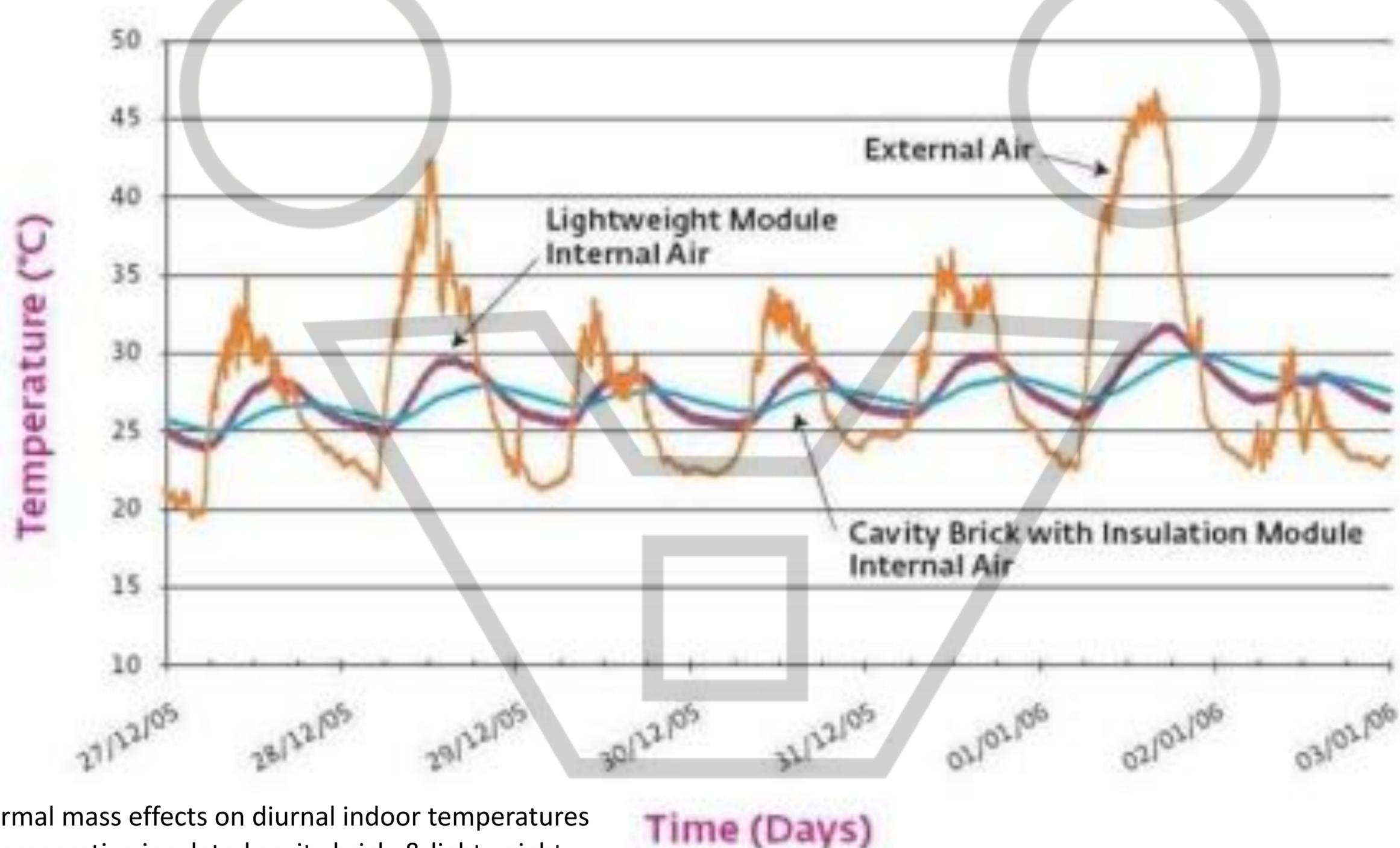
When heat enters a space directly by penetration of sunlight, lighting, equipment losses or heating, the temperature rise will be in inverse relationship to the accessible volume of thermal mass. Therefore, the indoor temperature will rise almost immediately if there is little thermal mass in the room.

Thermal mass effects on diurnal indoor temperatures of various materials.

## Radiant energy stored during the 24 hours



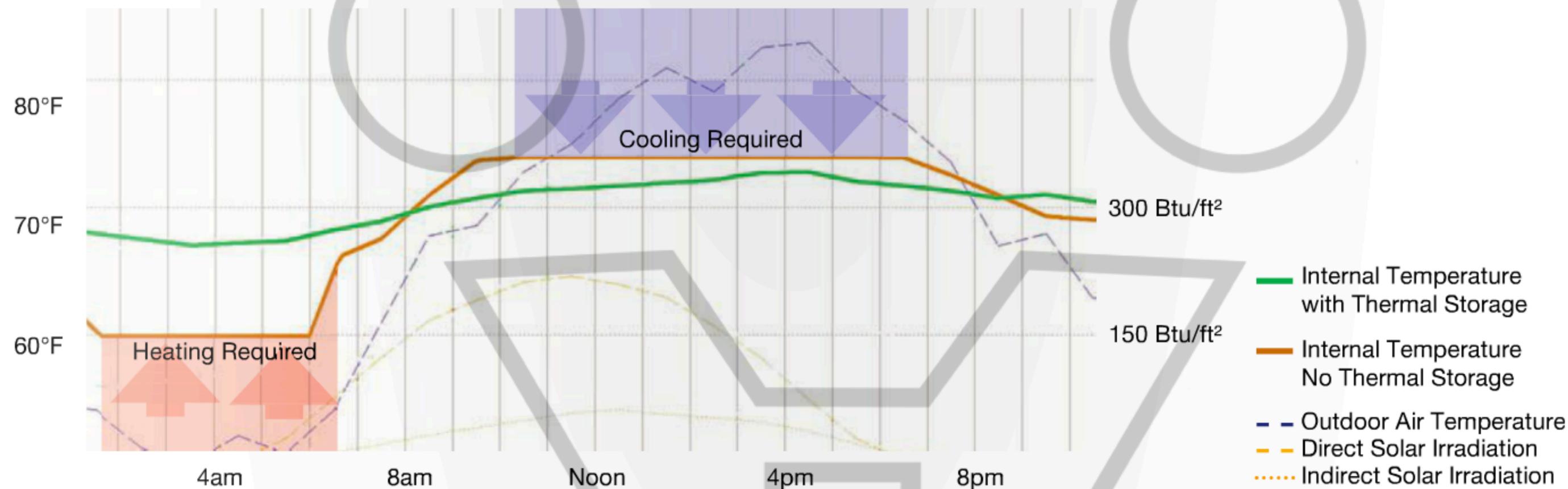
## Internal temperatures stabilization using different structural materials



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

## Effect of Thermal mass storage

### COOLING vs HEATING: Thermal storage strategy



#### 7.11

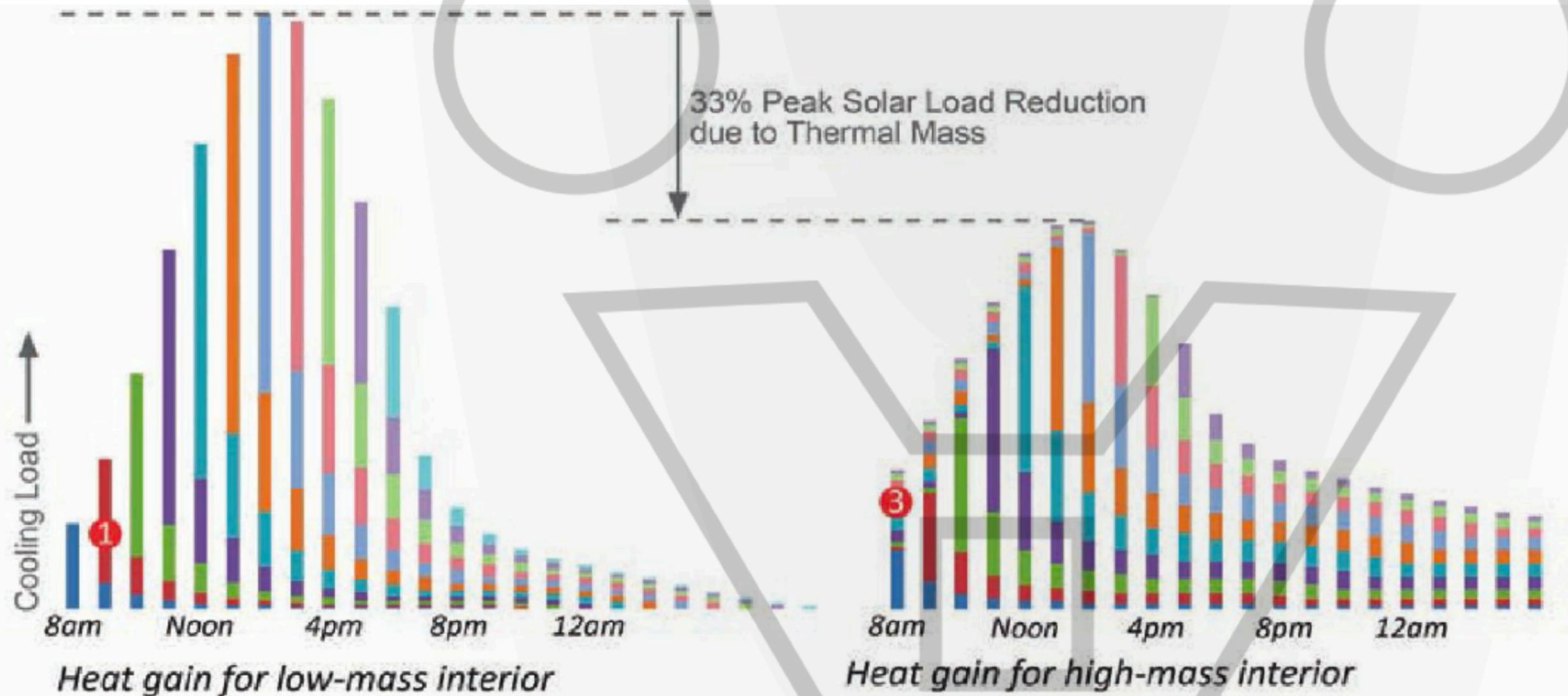
Diagram showing air temperatures over a 24-hour period for an office with and without thermal storage.

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

## Effect of Thermal mass storage

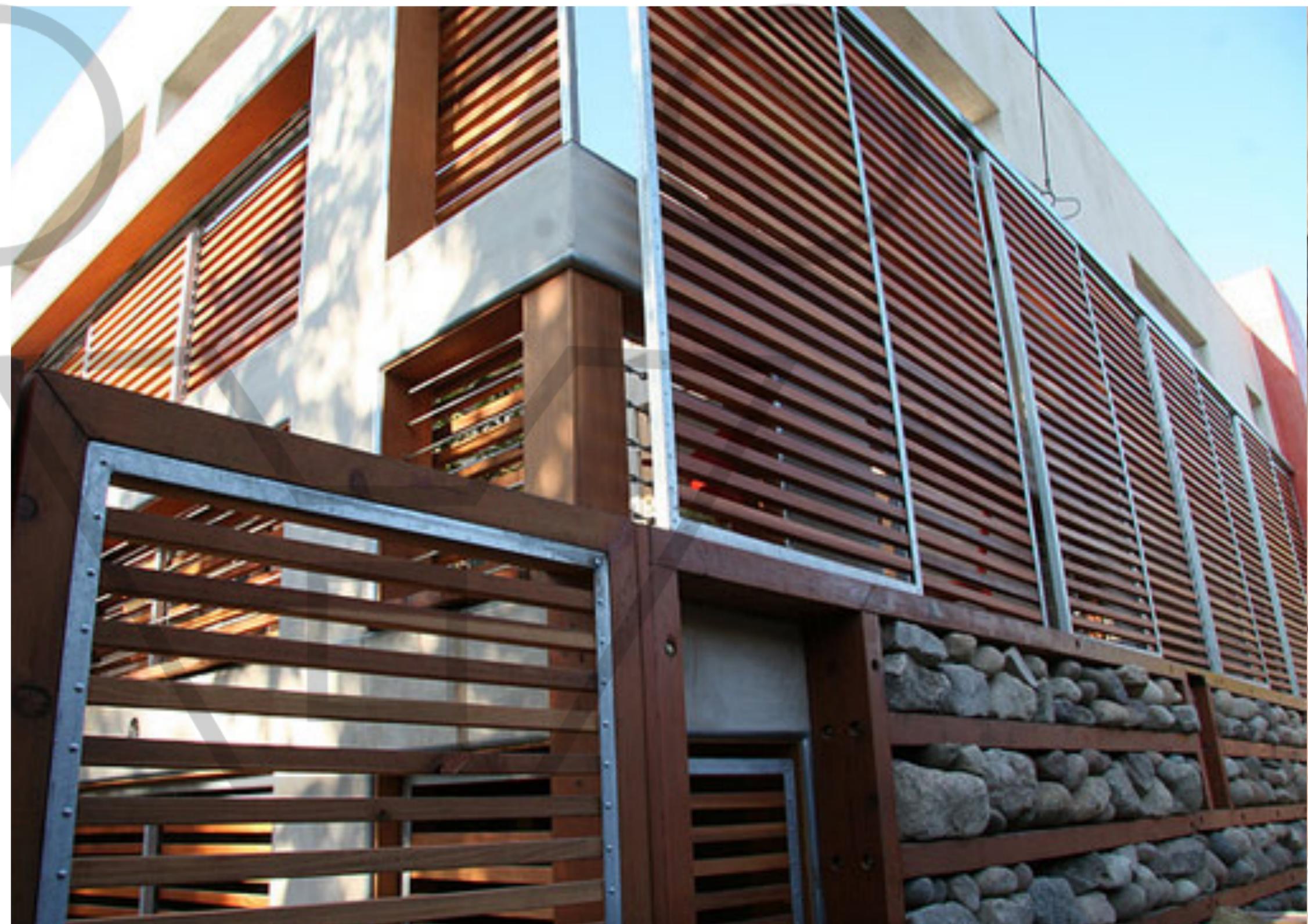
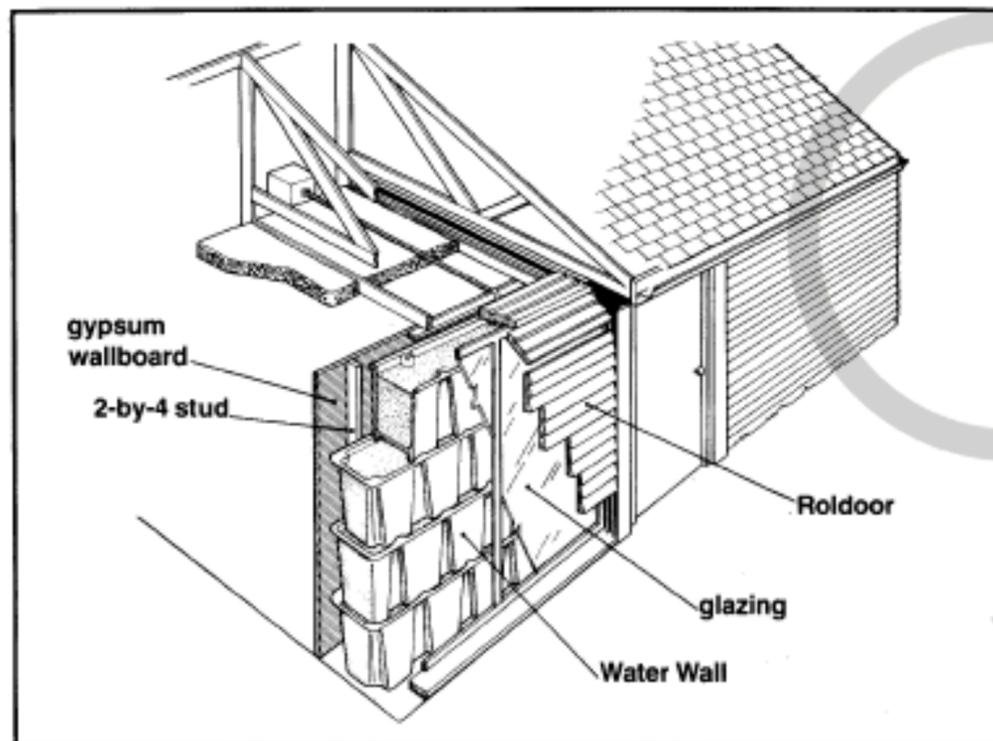


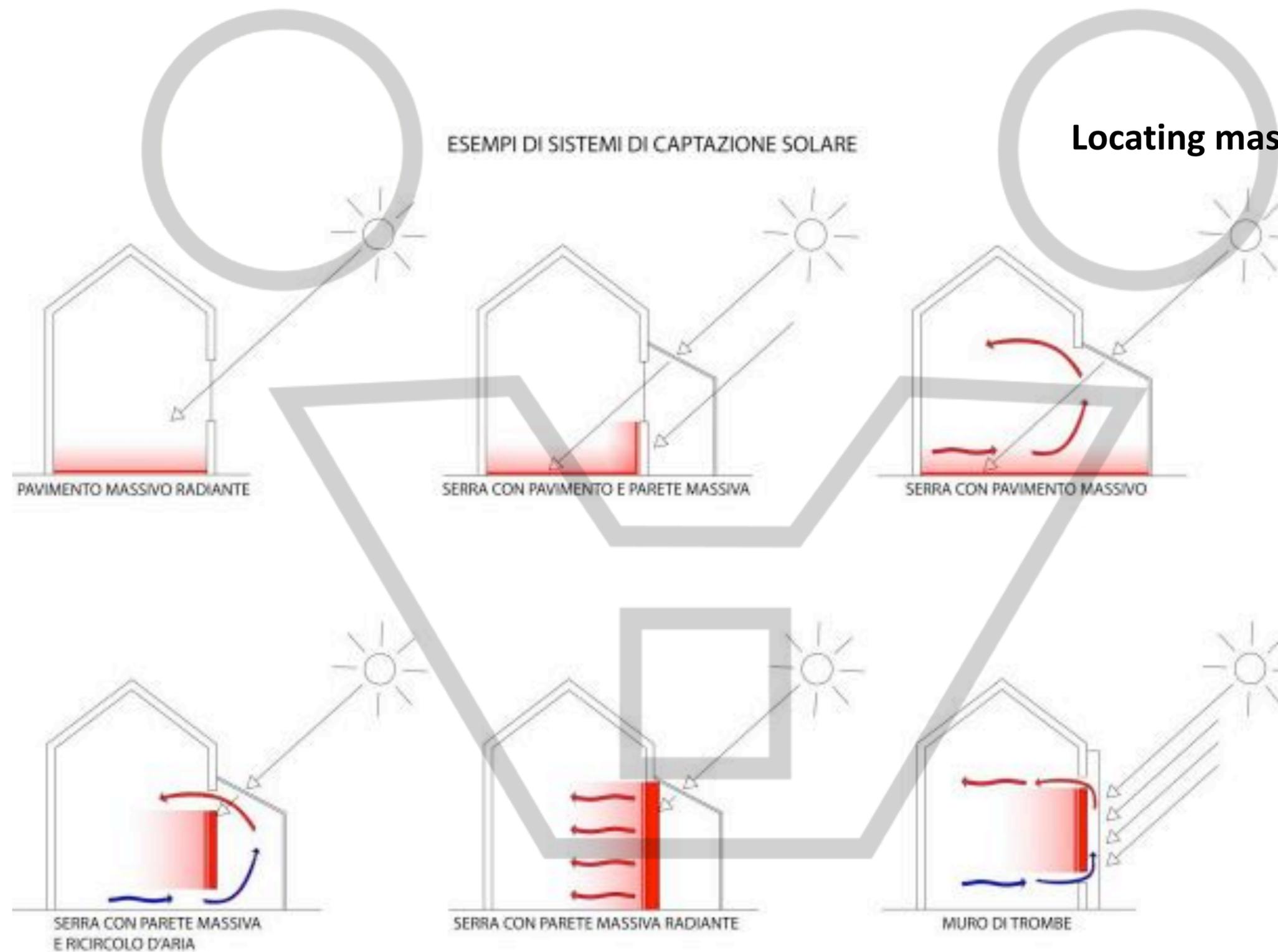
Percentage of Solar Gain released during each hour after being transmitted through glazing

	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%	2%	2%	2%	1%	1%
Low Thermal Mass Example	55%	17%	9%	5%	3%	2%	2%	1%	1%	1%	1%	1%	1%	-	-	-	-	-	-	-	-	-	-	-	-

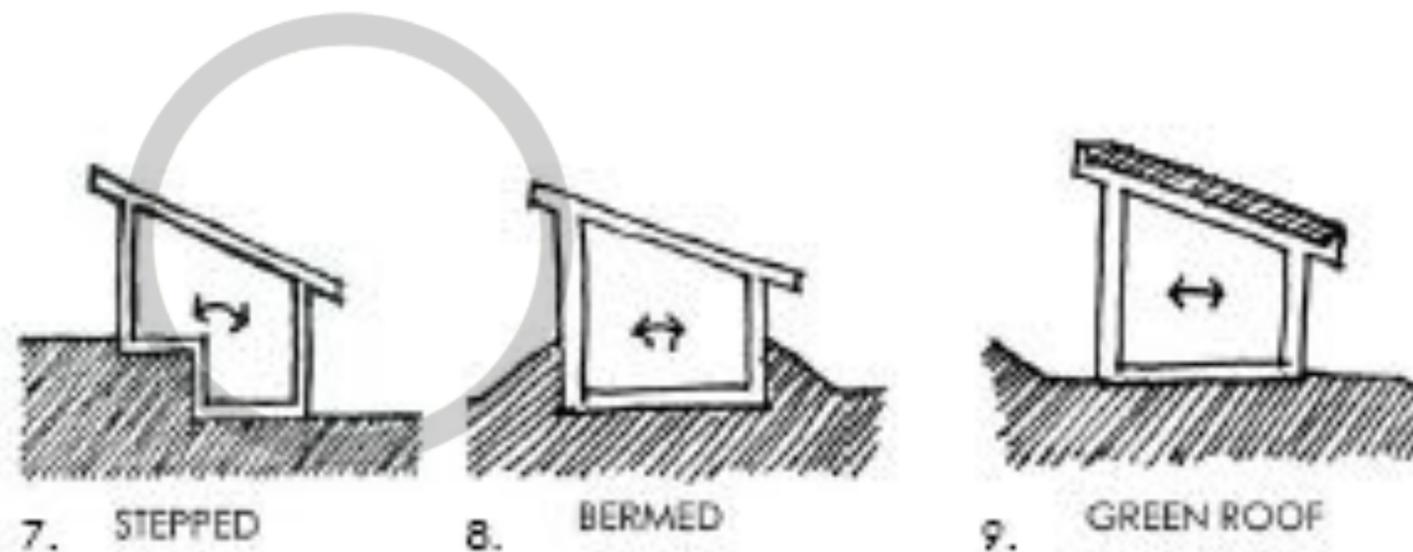
- **External walls require minimum levels of added insulation for wall types under 200kg/m<sup>2</sup>**

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.



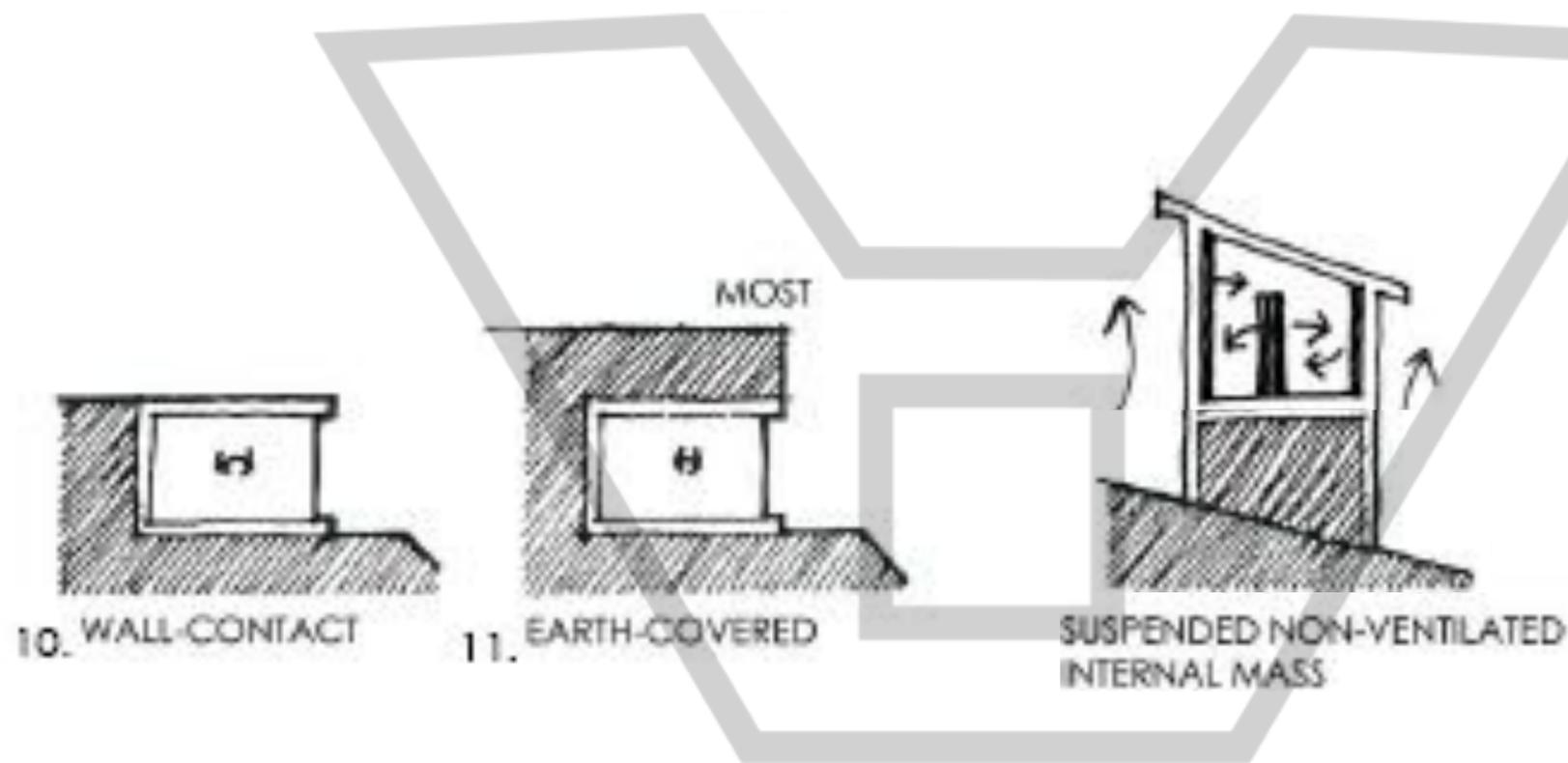


**Locating mass in a building**



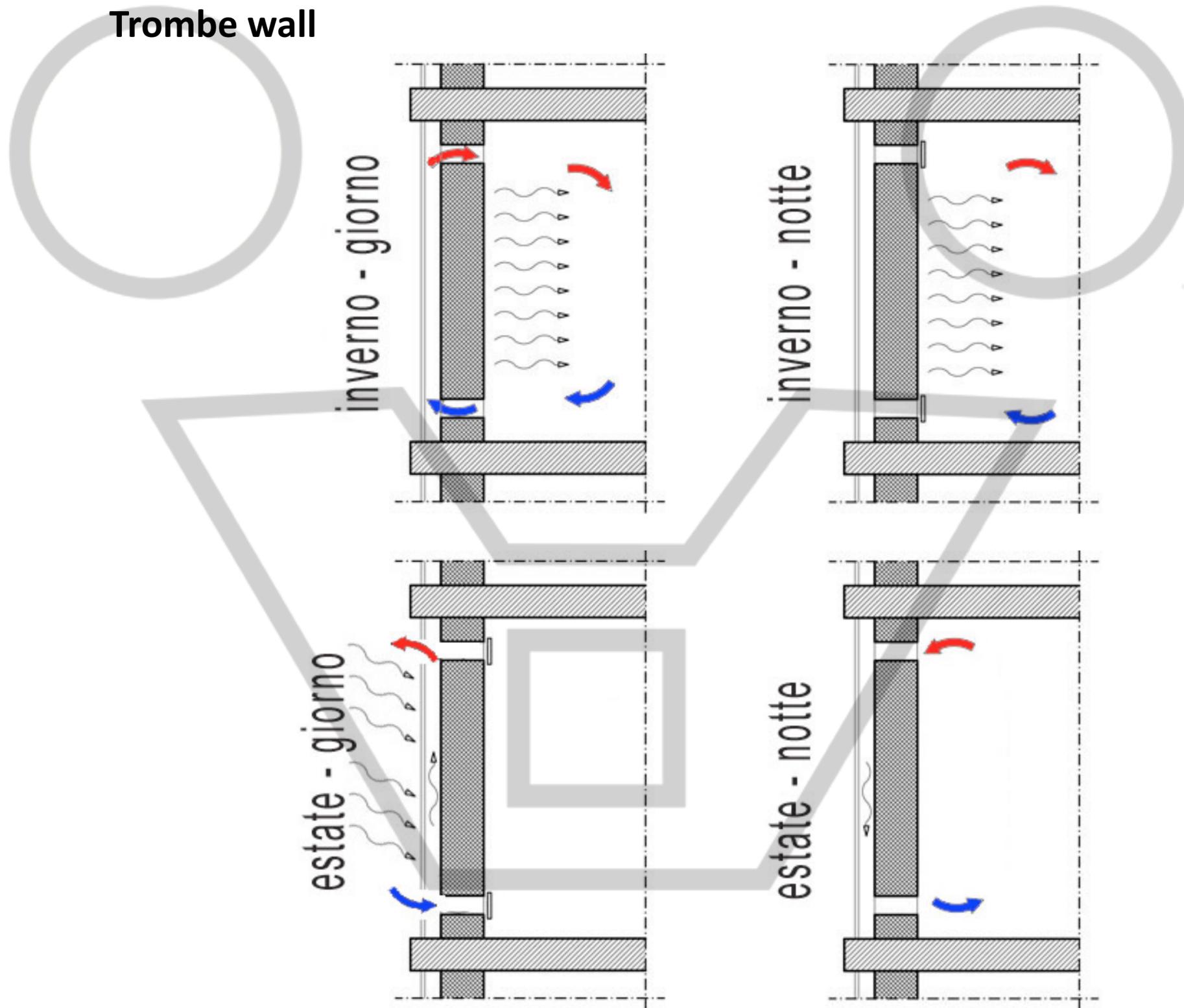
## Locating mass in a building

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.)

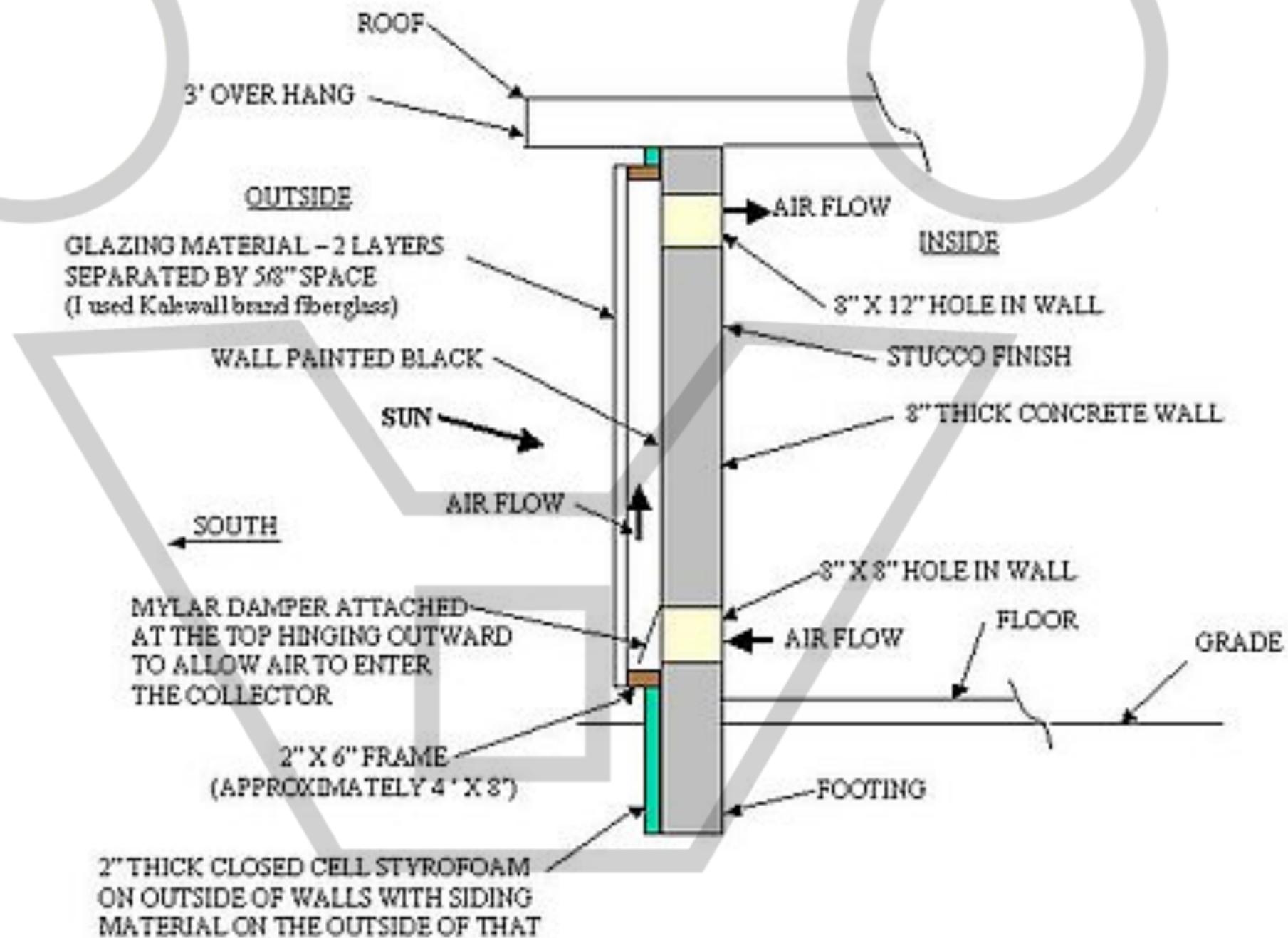


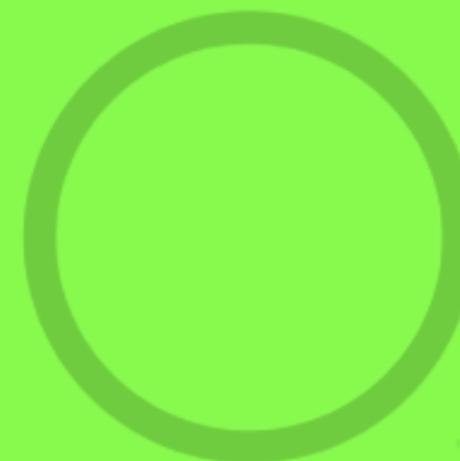
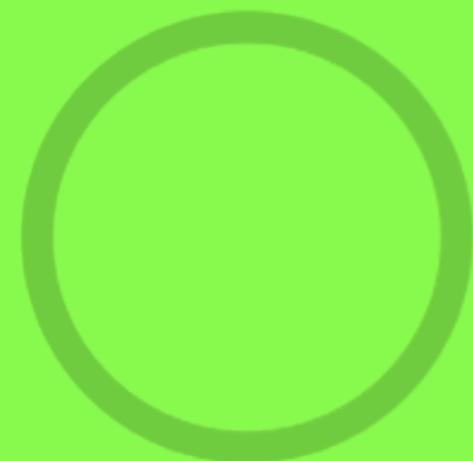


# Trombe wall

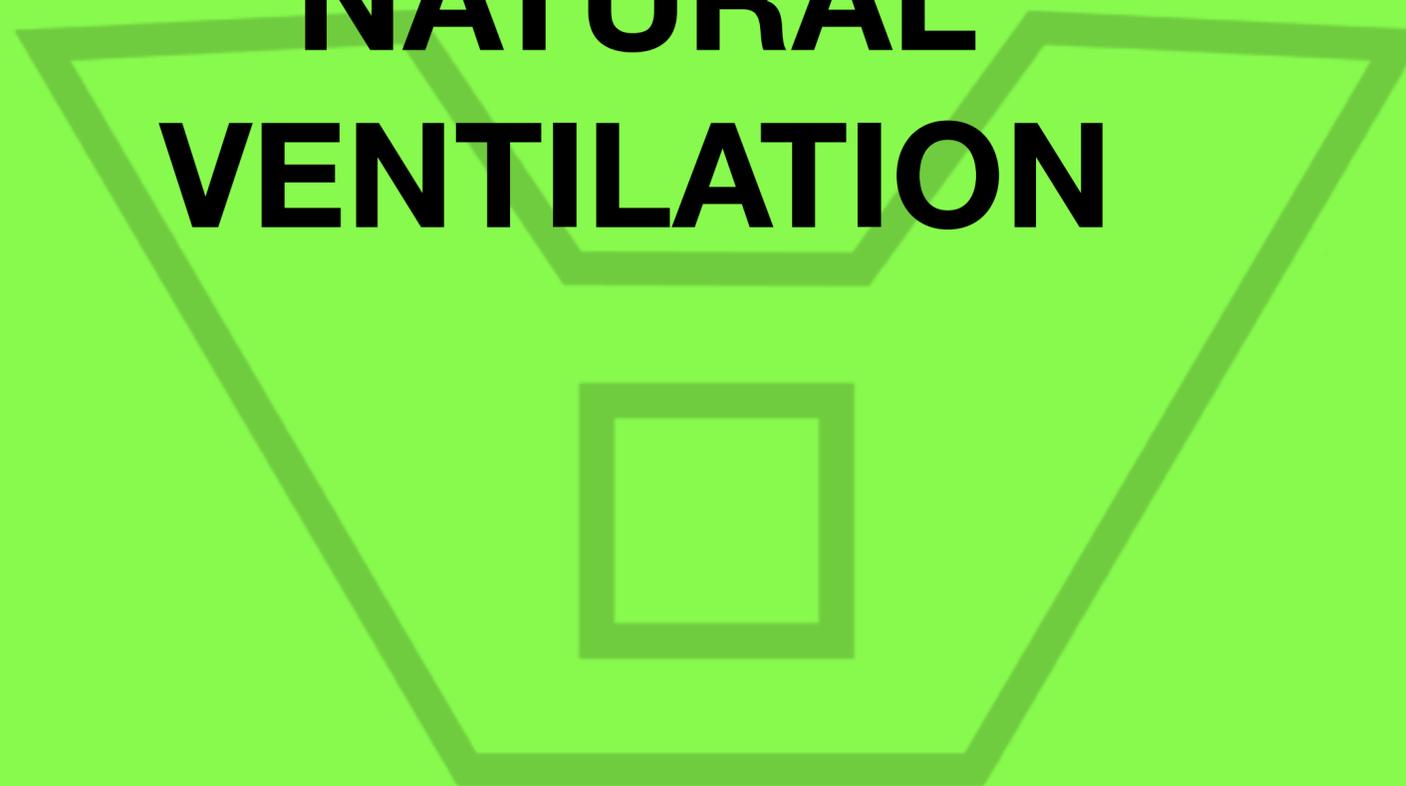


## Modified Trombe wall



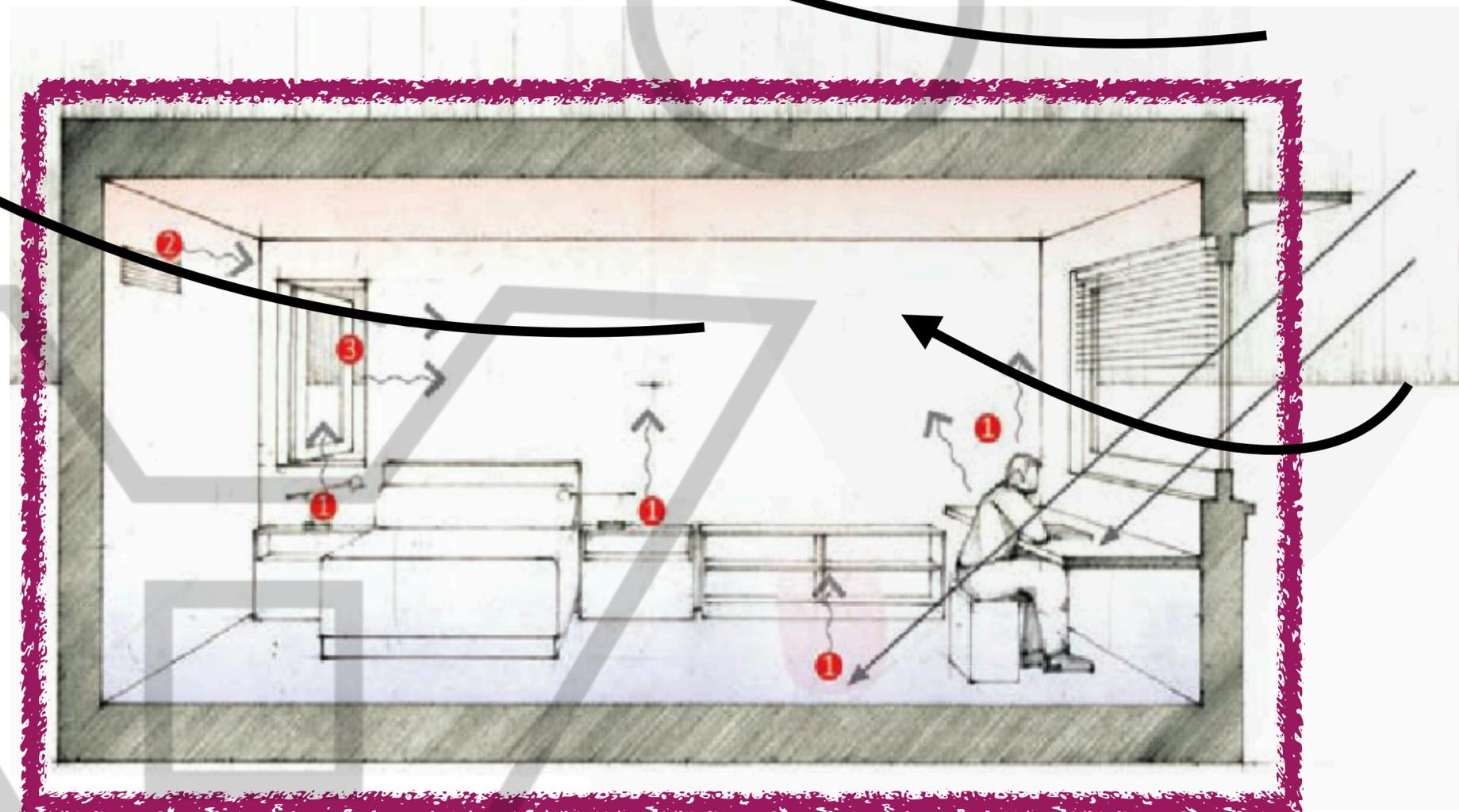


# NATURAL VENTILATION





# NATURAL VENTILATION

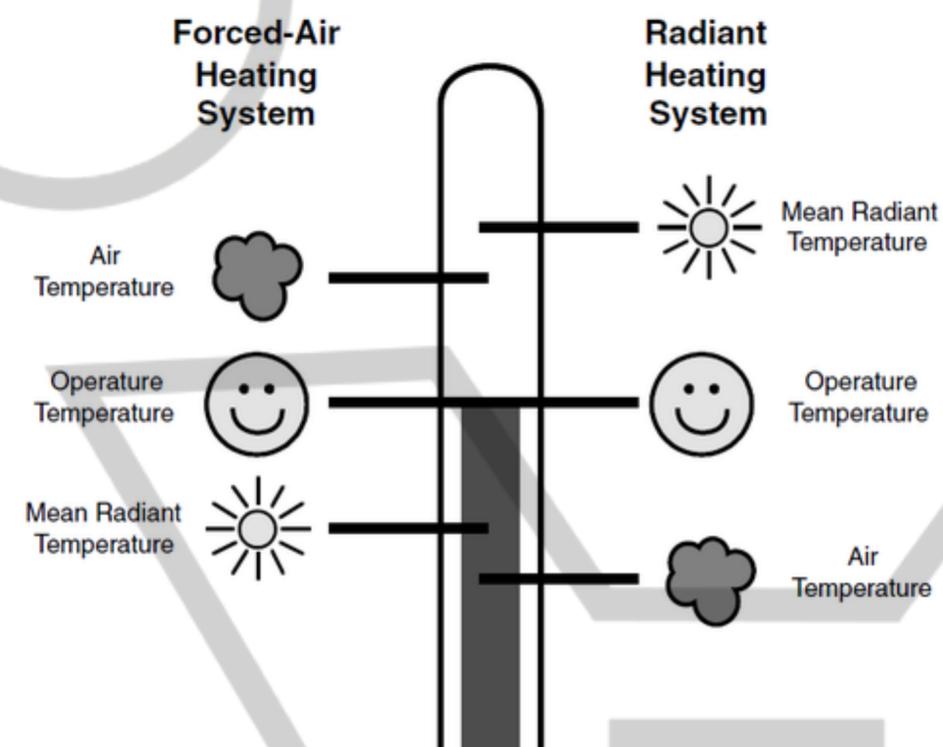


# WIND, AND PASSIVE VENTILATION

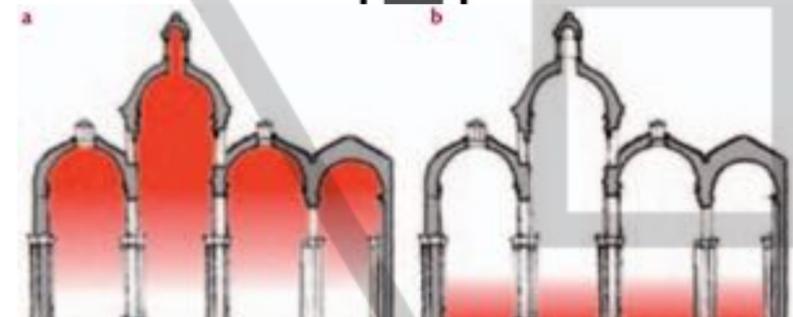
*For cooling, better thermal distribution and indoor air quality*

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

## RADIATION vs CONVECTION FOR INDOOR HEATING



Radiant heating systems compensate a lower air temperature with a higher radiant temperature, while air heating systems compensate a lower radiant temperature with a higher air temperature. The operative temperature -- a weighted average of both -- can be the same. Source: *Radiant Heating & Cooling Handbook*, Richard Watson, 2008.



Air heating (left) versus radiant heating (right) in a church building. Source: *Fabric-friendly heating*, Dario Camuffo.

Wind Speed (mph)		10	20	30	40	50	60
Temp (°C)	10	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 CHILL- Siple e Passel del 1945 reviewed in 2001

		Air Temperature (Celsius)																
		0	-1	-2	-3	-4	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50	-55	-60
Wind Speed (km/hr)	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	-59	-66	-73	-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	-69	-76	-84	-91	-99	

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

# COOLING EFFECT ON APPARENT TEMPERATURE

		Apparent temperature (AT) as a Wind Chill - after Steadman 1994																																						
		Temperature (°C)																																						
Wind Speed (km/h)	0	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20													
	2	-9	-8	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20										
	4	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20									
	6	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20									
	8	-10	-9	-8	-7	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20									
	10	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20								
	12	-11	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20								
	14	-11	-10	-9	-8	-7	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20								
	16	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20							
	18	-12	-11	-10	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20							
	20	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20						
	22	-13	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20						
	24	-13	-12	-11	-10	-9	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20						
	26	-13	-12	-11	-10	-9	-8	-7	-6	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20						
	28	-14	-13	-12	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20					
	30	-14	-13	-12	-11	-10	-9	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20					
	32	-14	-13	-12	-11	-10	-9	-8	-7	-6	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20					
	34	-15	-14	-13	-12	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20				
	36	-15	-14	-13	-12	-11	-10	-9	-8	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20				
	38	-16	-15	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20			
40	-16	-15	-14	-13	-12	-11	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20				
42	-16	-15	-14	-13	-12	-11	-10	-9	-8	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20				
44	-17	-16	-15	-14	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20			
46	-17	-16	-15	-14	-13	-12	-11	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20			
48	-18	-16	-15	-14	-13	-12	-11	-10	-9	-8	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20			
50	-18	-17	-16	-15	-14	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
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64	-21	-20	-19	-17	-16	-15	-14	-13	-12	-11	-10	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10</										

## TYPES & FACTORS OF AIR MOVEMENTS

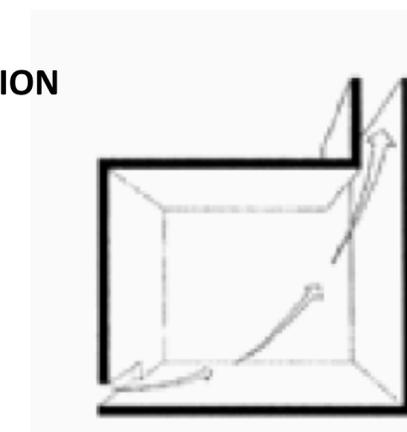
- 1 **Δ Pressure  $f$**  (*humidity, altitude, temperature*) from high pressure to low pressure
- 2 **Density  $f$**  (*temperature, altitude*) bottom up convective air movements
- 3 **Kinetic  $f$**  (*air velocity*) directional force

## TYPES OF INDOOR VENTILATION

CROSS VENTILATION



STACK VENTILATION  
upward draft



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

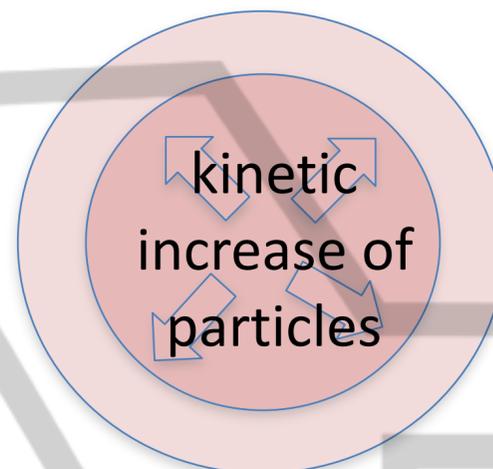
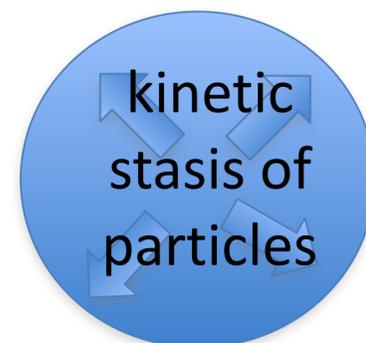
# 1 AIR MOVEMENTS BY DIFFERENT PRESSURE

## Horizontal movement

## Vertical movement

**LOW PRESSURE**

**HIGH PRESSURE**



**Barometric pressure**

TEMPERATURE: **low**  
DENSITY: **high**

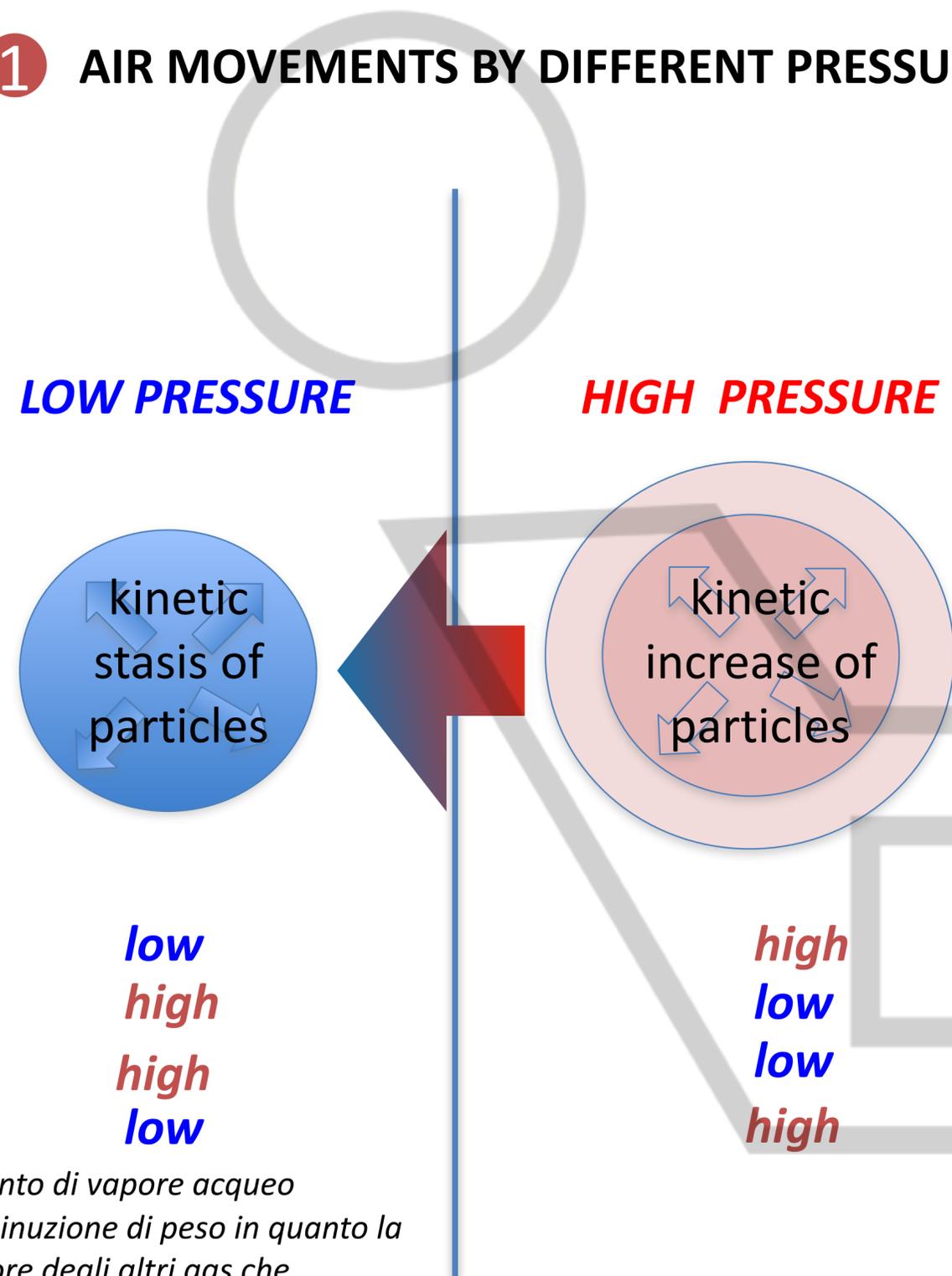
**high**  
**low**

-

+

$$f[\text{temperature} > \text{thermal energy} \mid \text{altitude} > \text{gravitational energy} \mid \text{velocity} > \text{cinetic energy} \mid \text{humidity} > \text{hygrometry}]$$

## 1 AIR MOVEMENTS BY DIFFERENT PRESSURE



TEMPERATURE: **low**  
 DENSITY: **high**  
 ALTITUDE: **high**  
 HUMIDITY: **low**

*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*

## 2 AIR MOVEMENTS BY DIFFERENT DENSITY

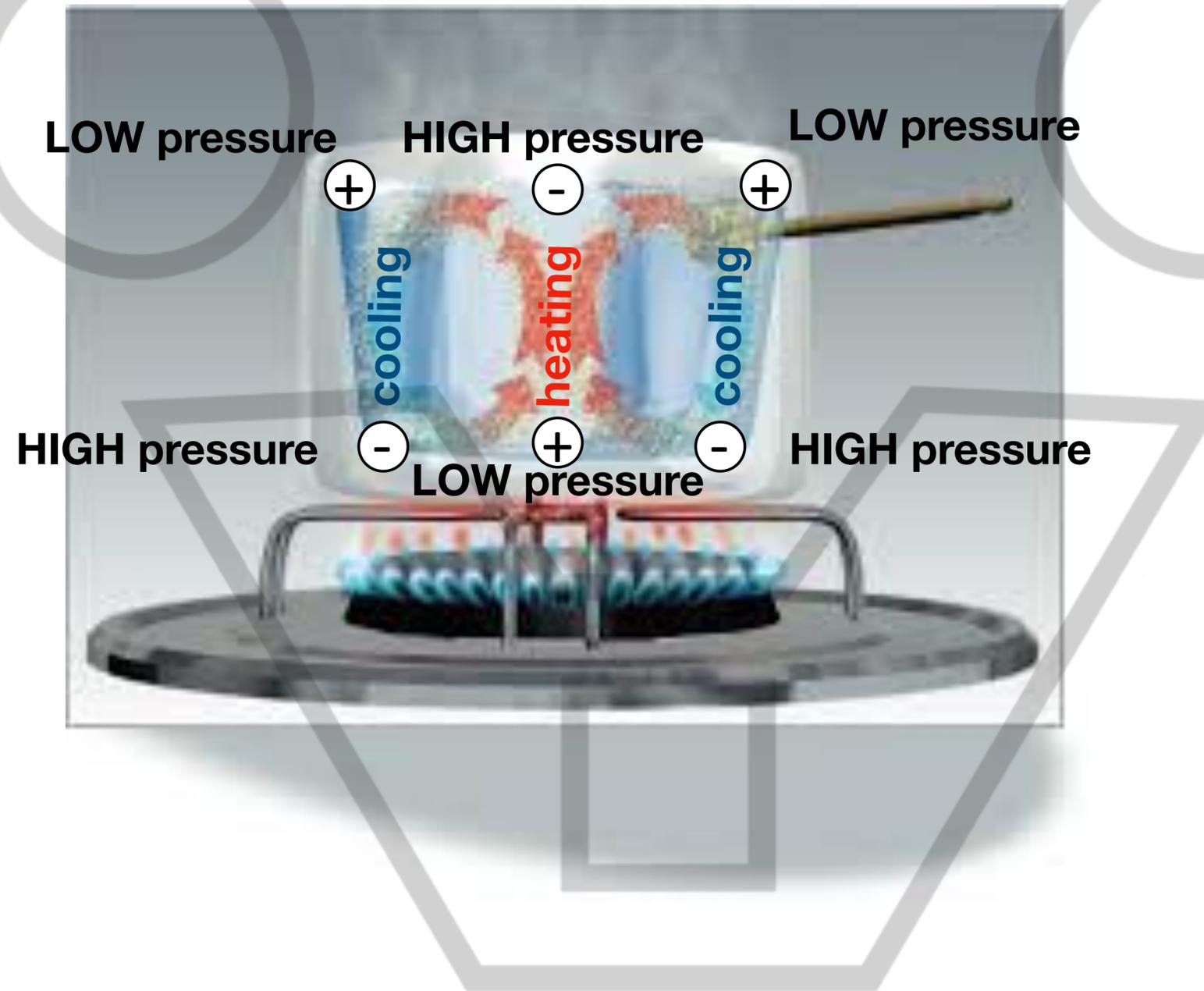
– Buoyancy Effect –  
 stack (or chimney) effect



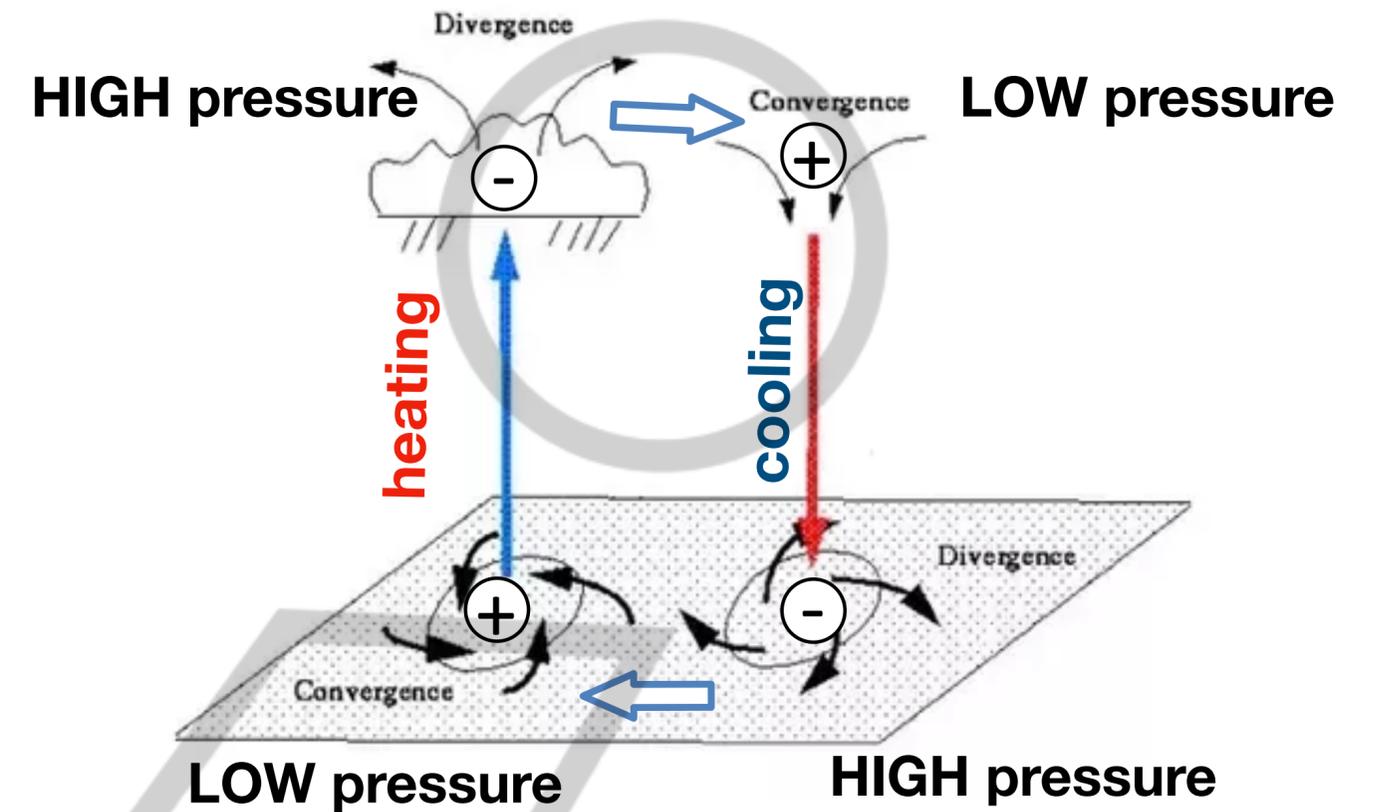
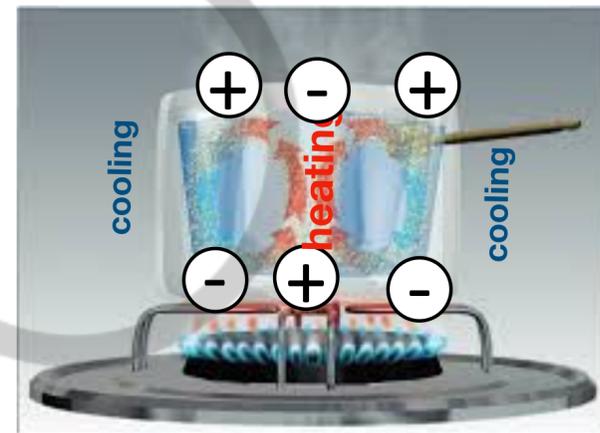
Il surriscaldamento dell'aria comporta la dilatazione del gas e conseguentemente riduzione del peso dell'aria che ne induce il movimento verso l'alto. Viceversa il suo raffreddamento provoca il fenomeno inverso

## 2 AIR MOVEMENTS BY DIFFERENT DENSITY

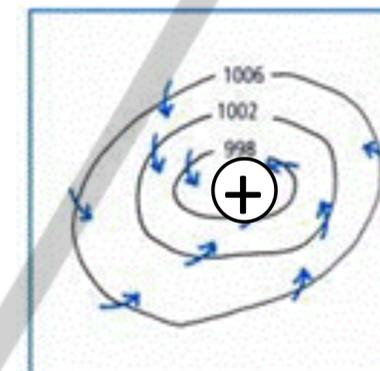
density  $\oplus$   $\ominus$



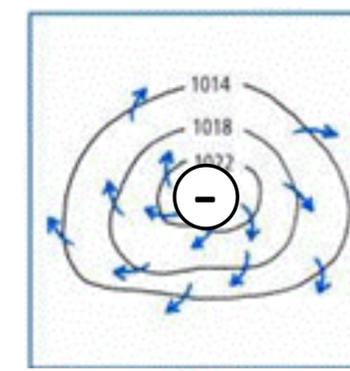
density (+) (-)



Circolazione ciclonica



Circolazione anticiclonica

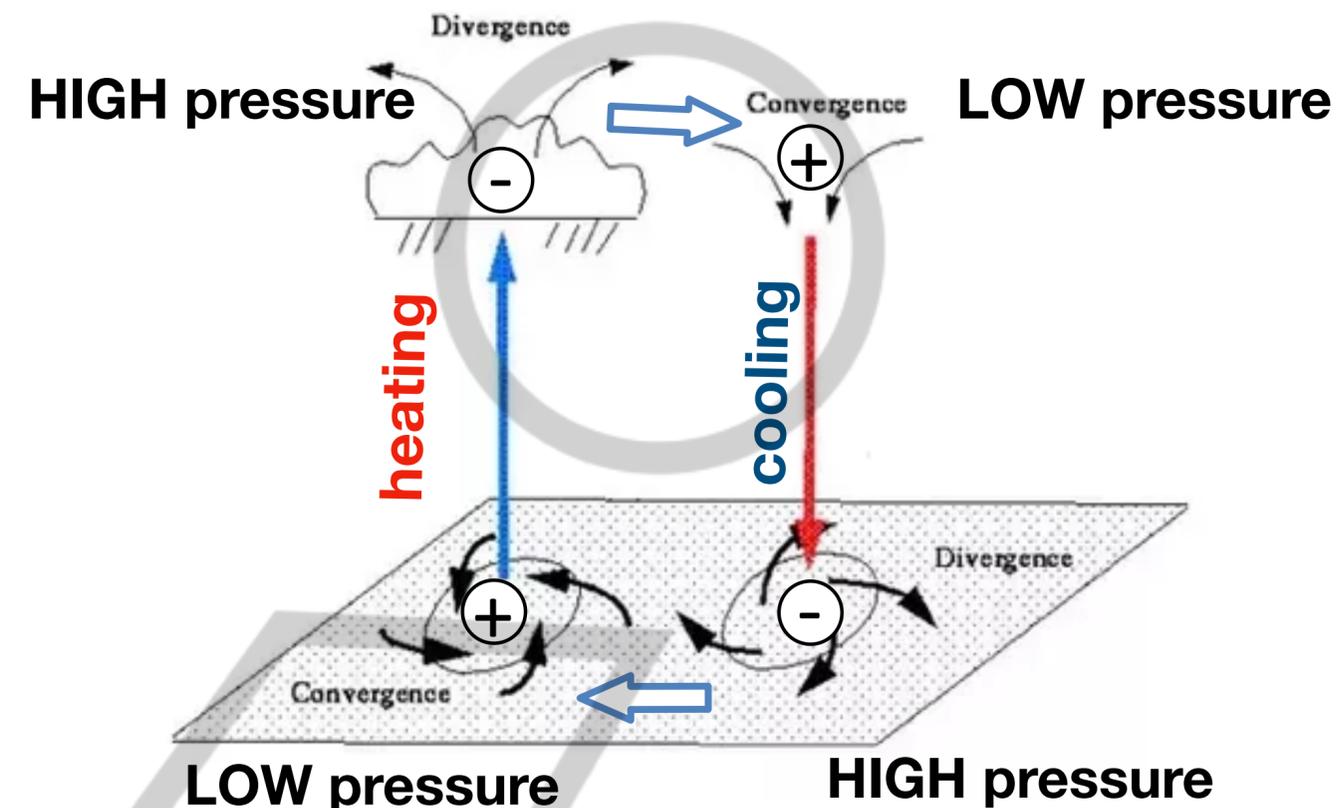
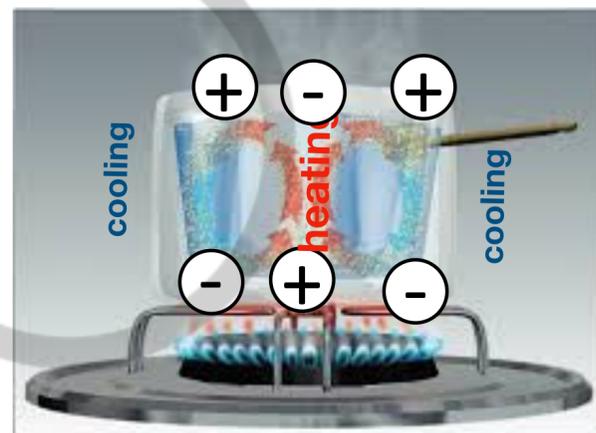


LOW pressure

HIGH pressure

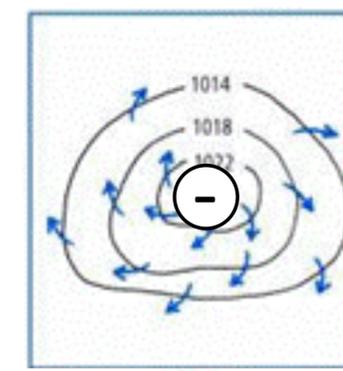
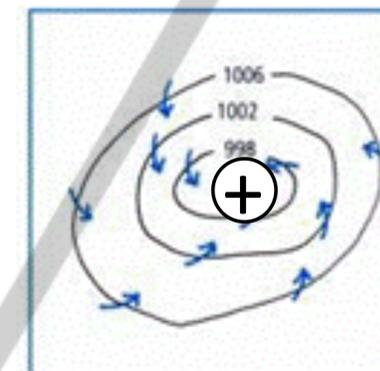
# AIR MOVEMENTS BY DIFFERENT DENSITY & PRESSURE

density (+) (-)



Circolazione ciclonica

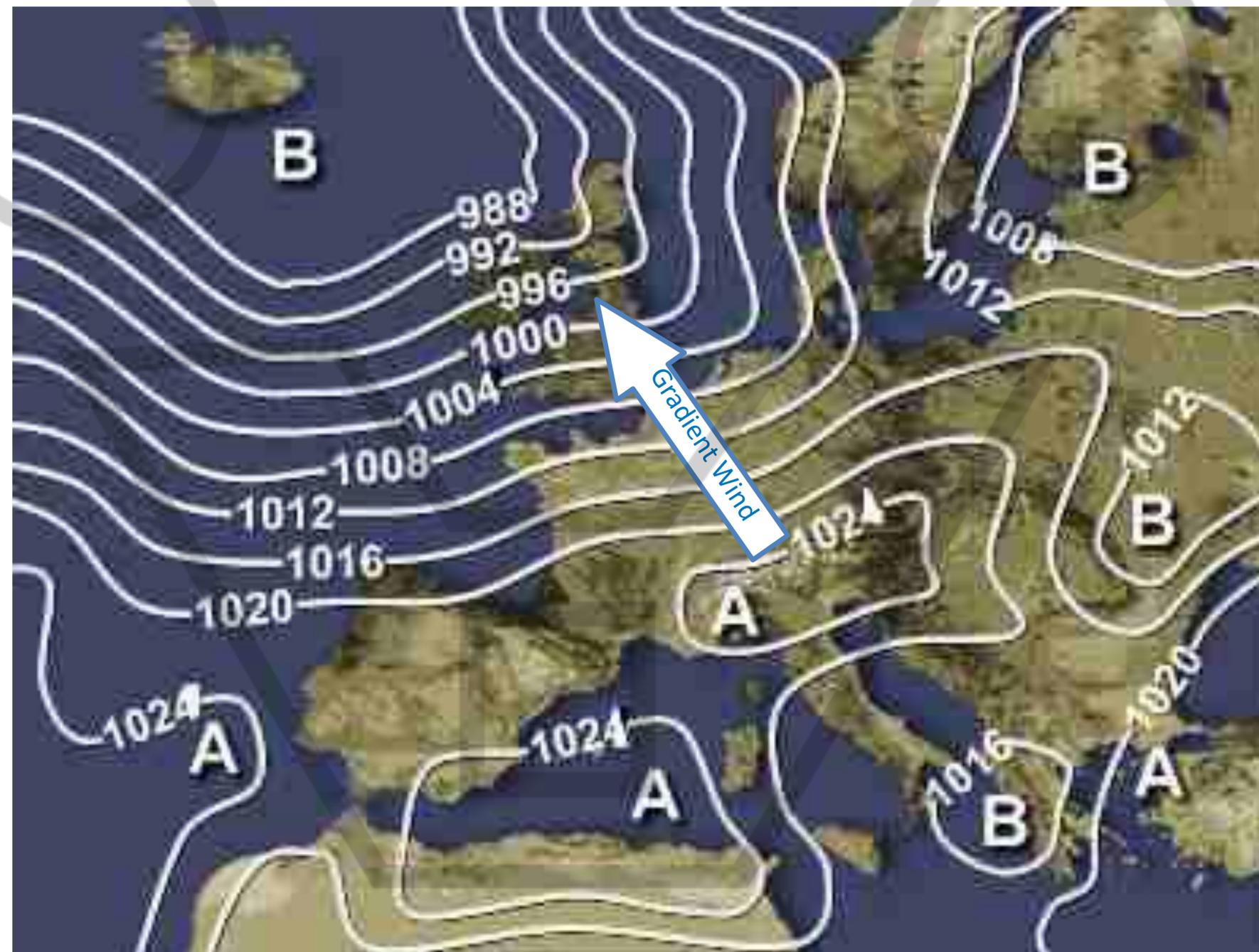
Circolazione anticiclonica



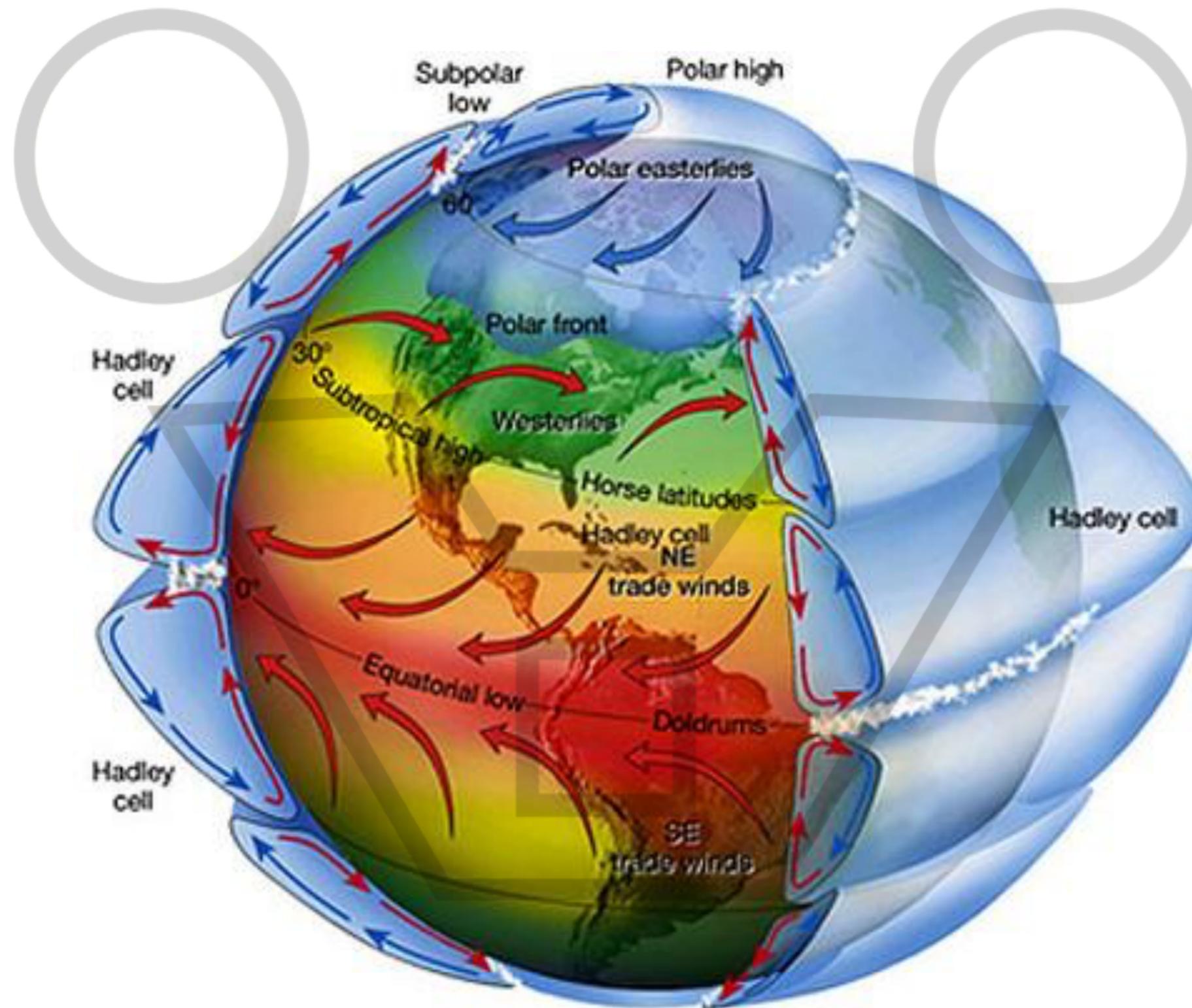
LOW pressure

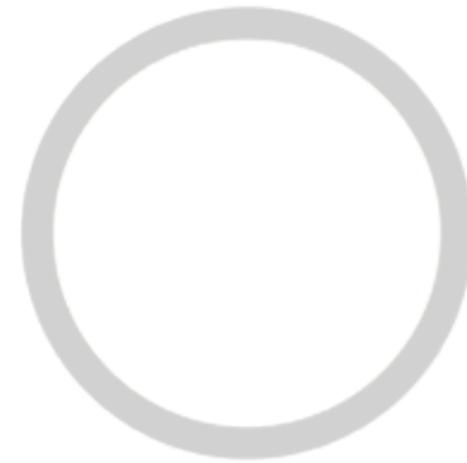
HIGH pressure

## AIR MOVEMENTS BY PRESSURE WINDS

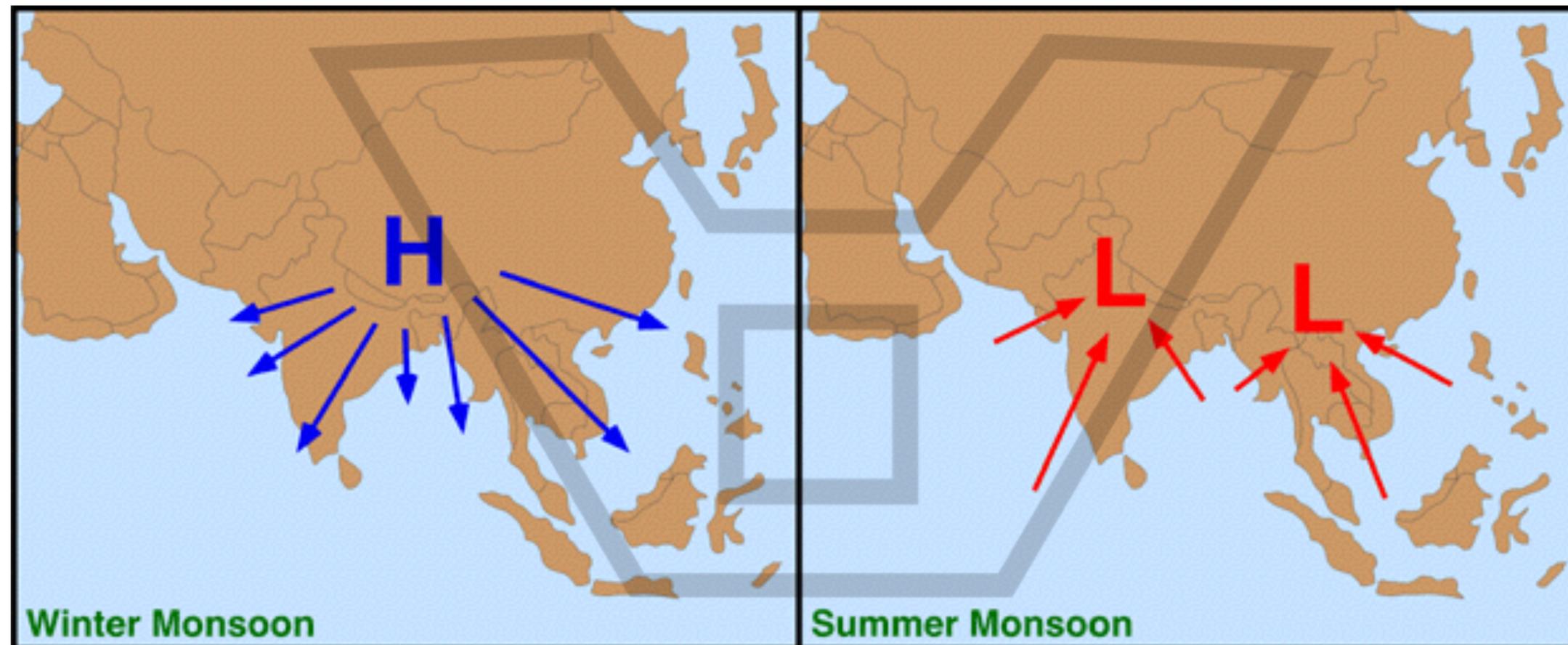


# GLOBAL WINDS



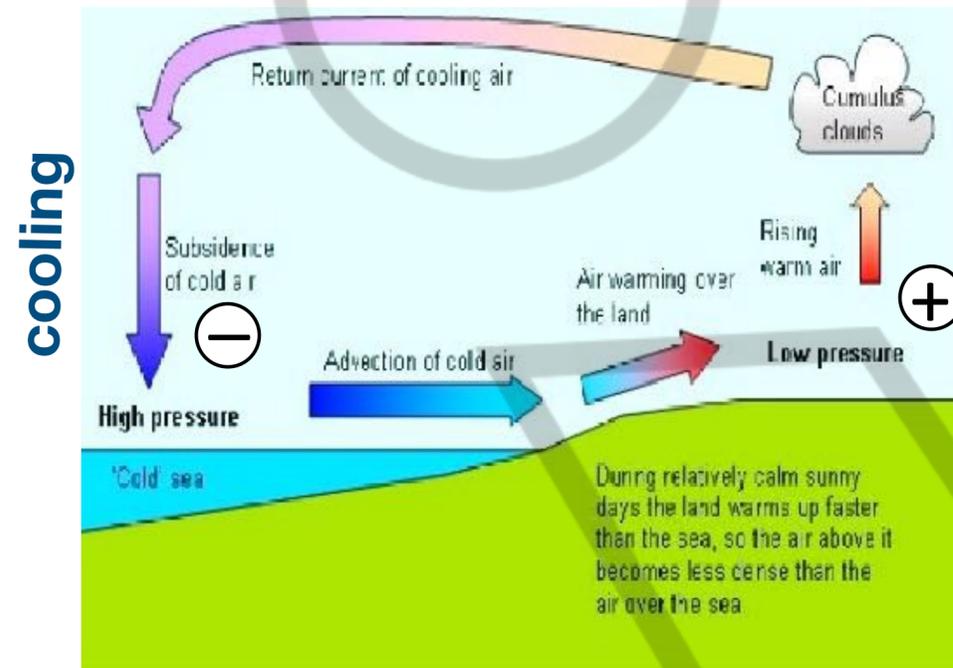


## SEASONAL WINDS

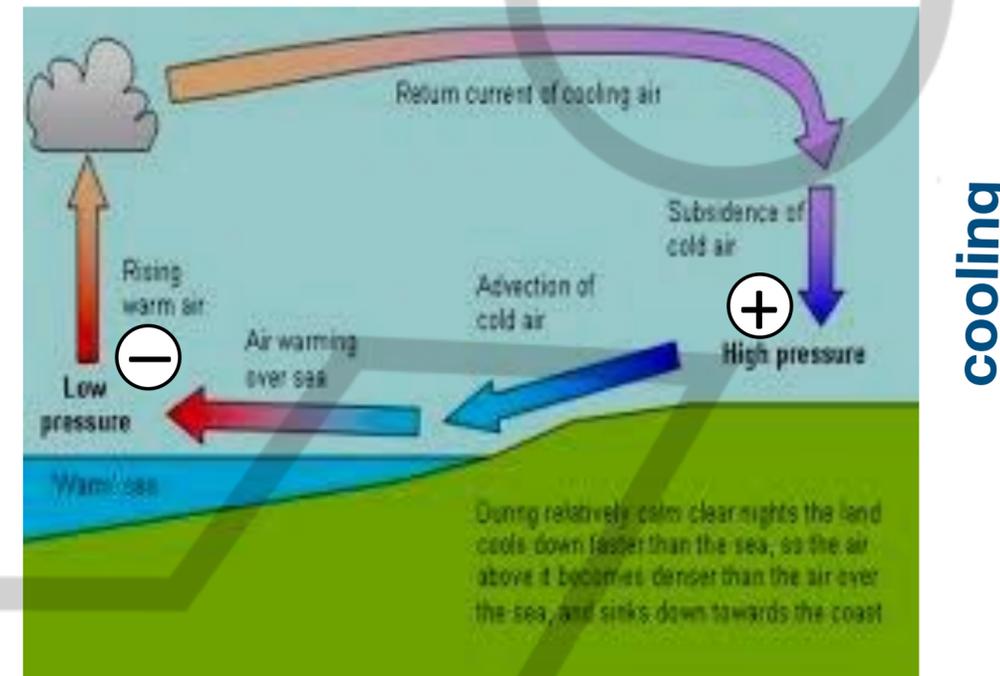


# SEA & LAND BREEZES

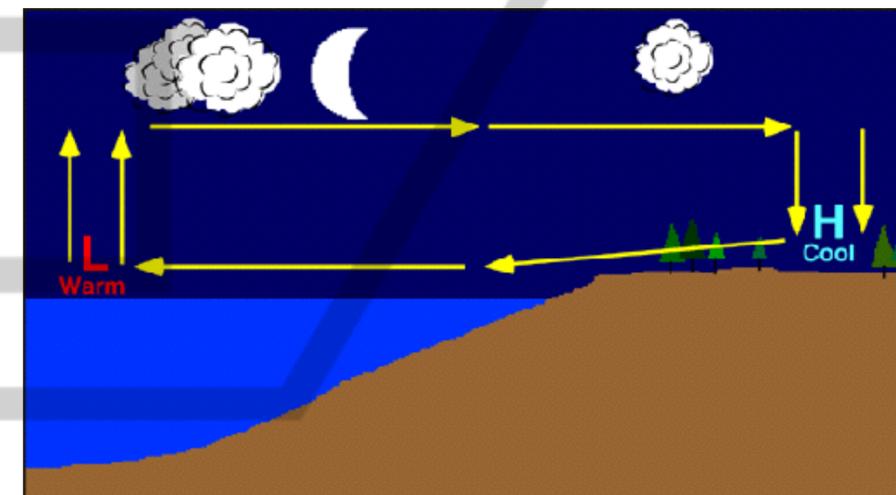
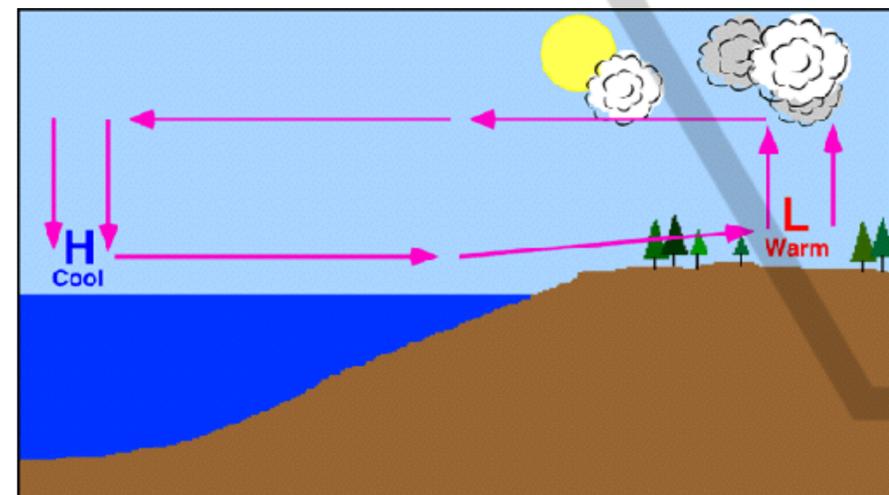
density (+) (-)



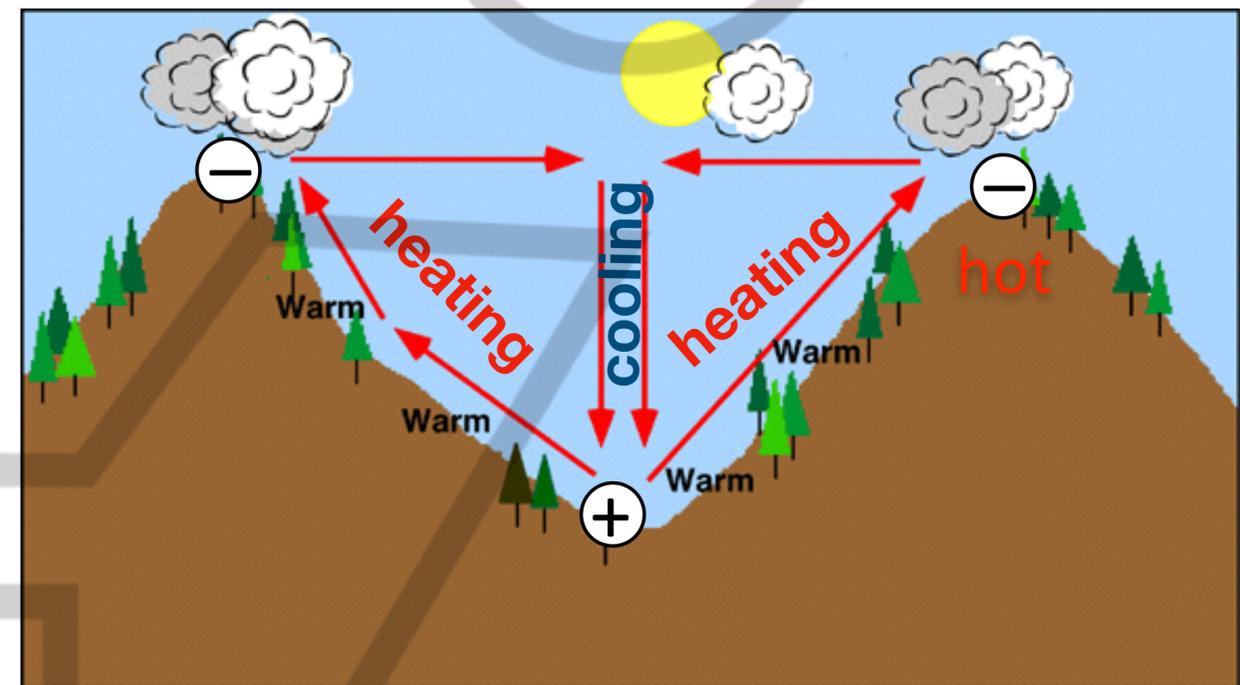
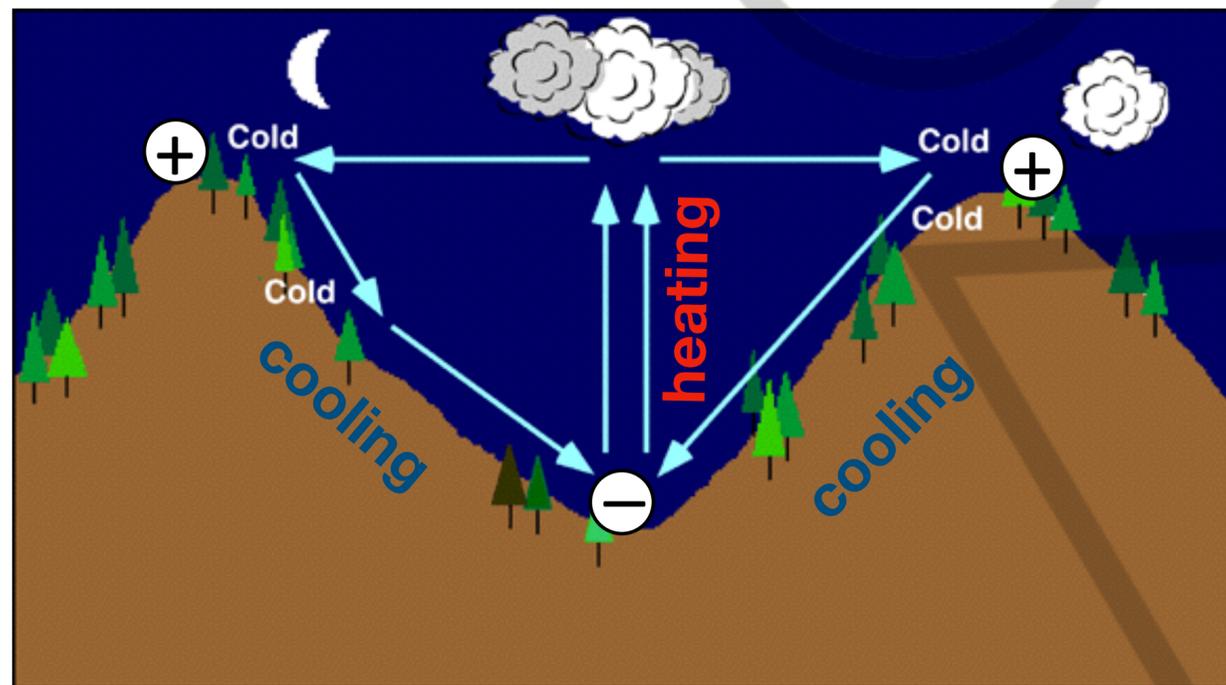
heating



cooling

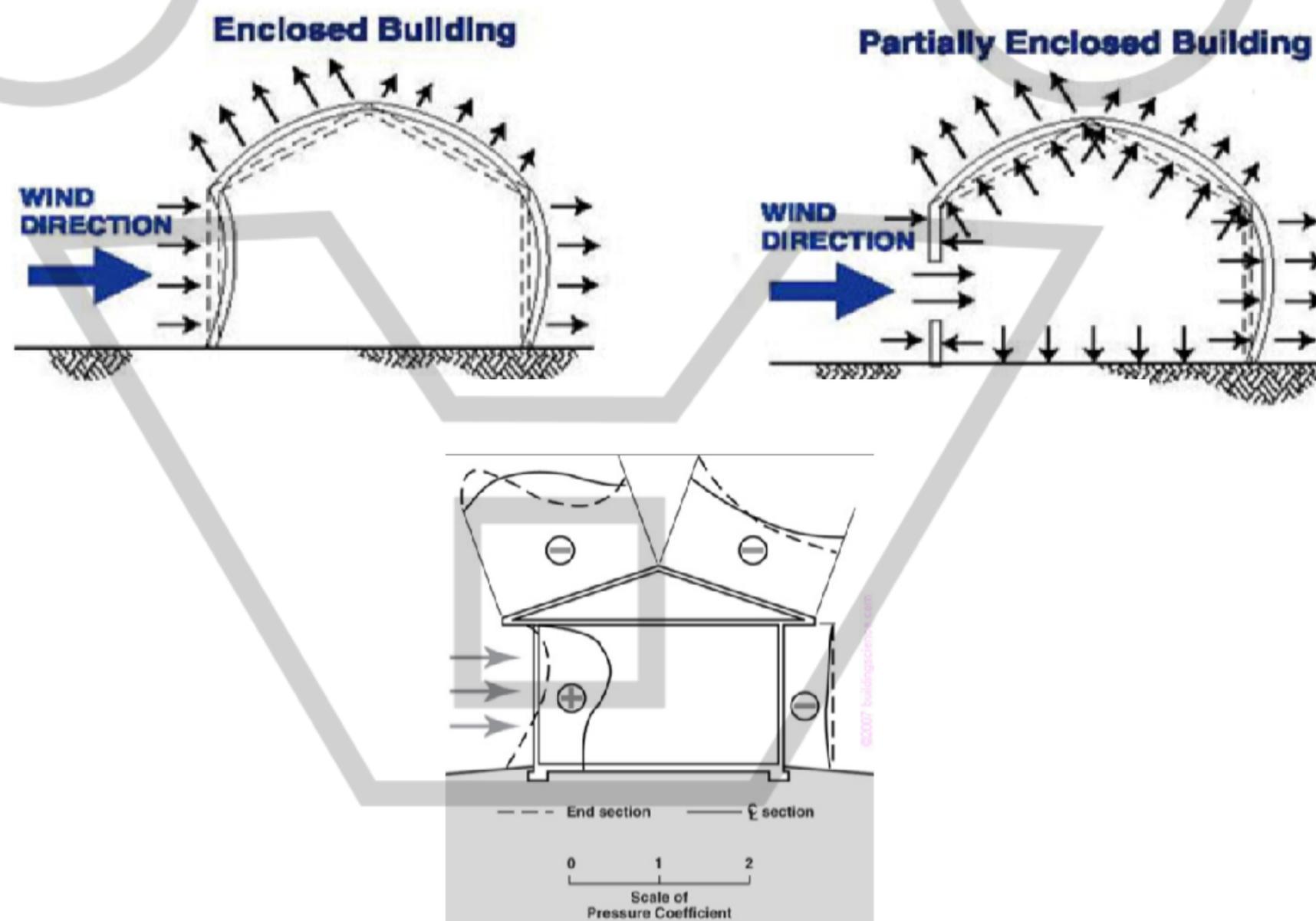


# MOUNTAIN & VALLEY BREEZES



**3** Kinetic  $f$  (air velocity) directional force

## Wind pressure coefficients ( $C_p$ ) vary around buildings



### 3 Kinetic $f$ (air velocity) directional force

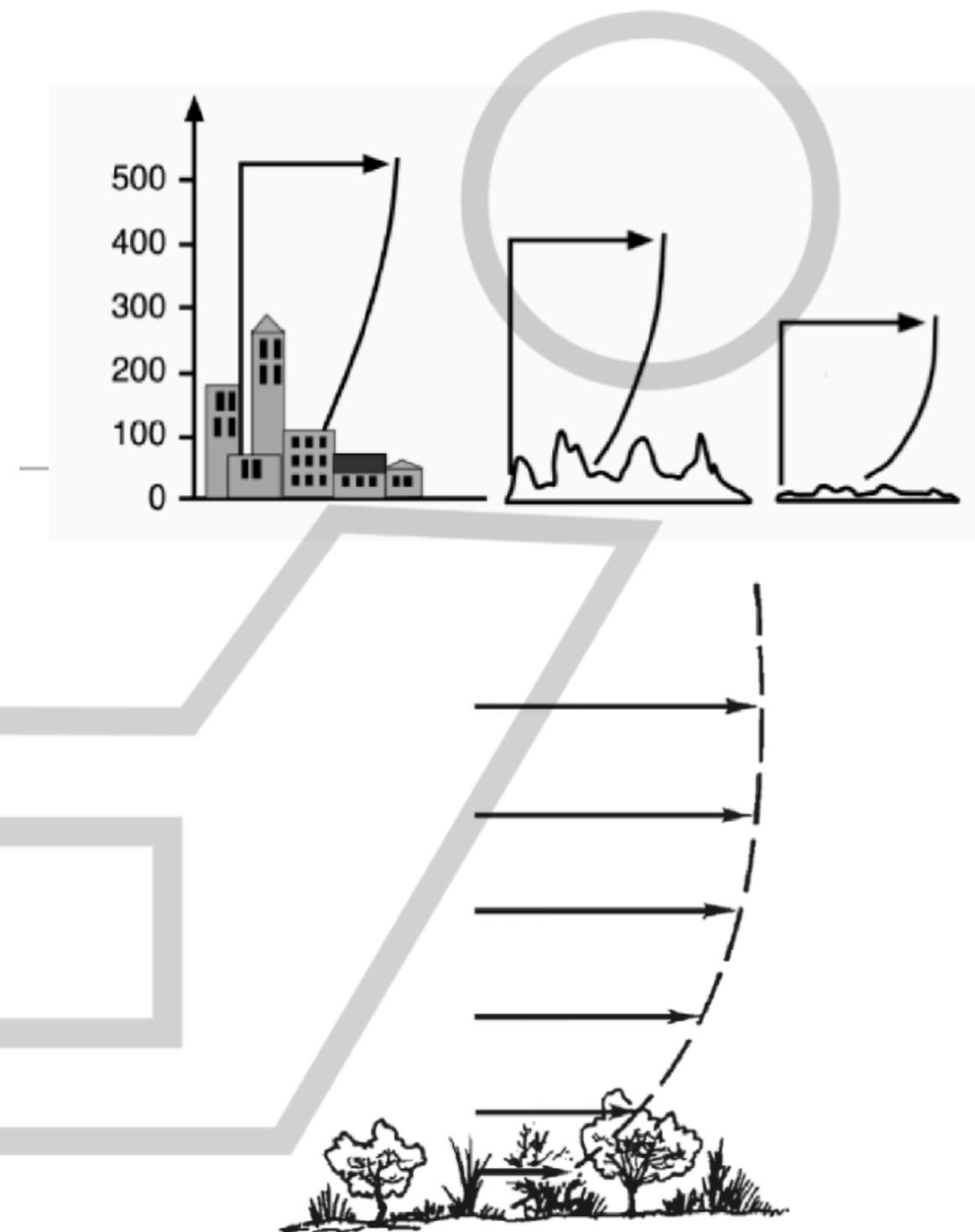
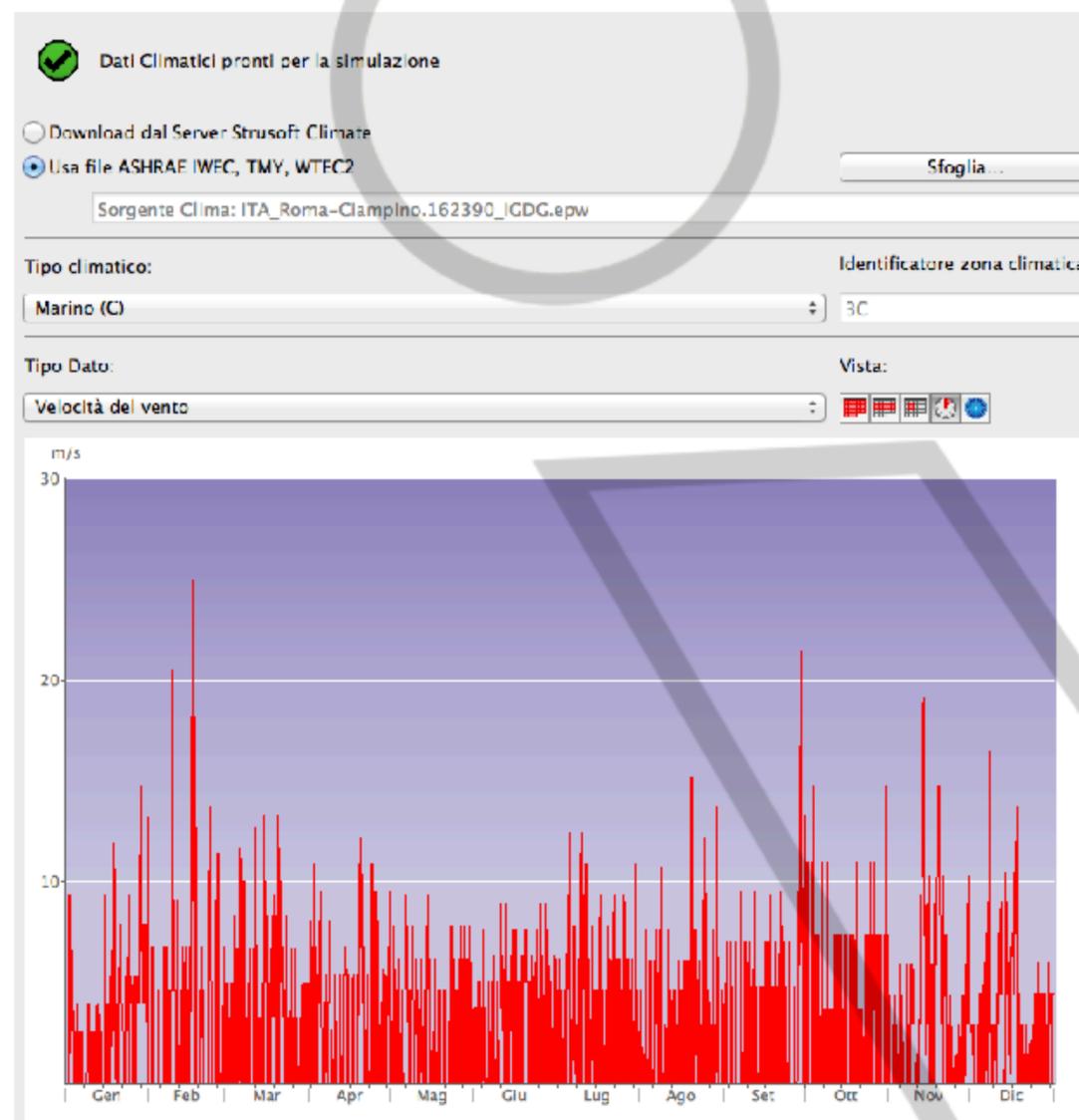
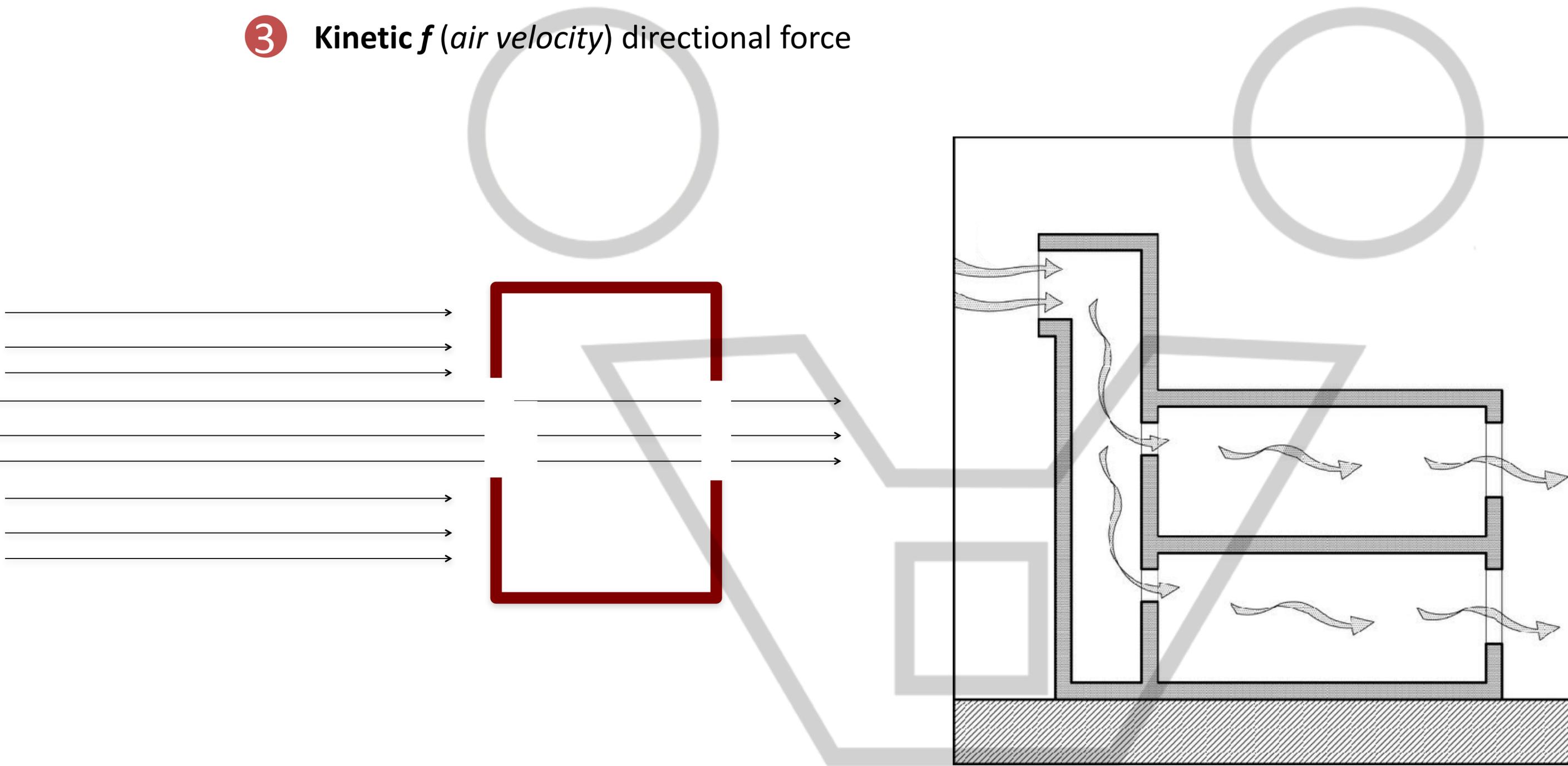


Figure 1—General wind velocity profile near surface (from Rothermel 1983).

### 3 Kinetic $f$ (air velocity) directional force



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

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

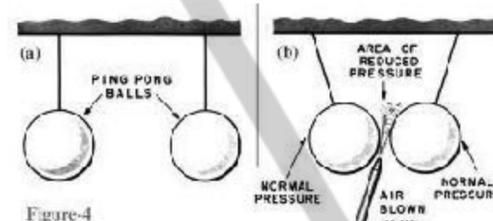
**FROM HIGHER PRESSURE**

**TO LOWER PRESSURE**

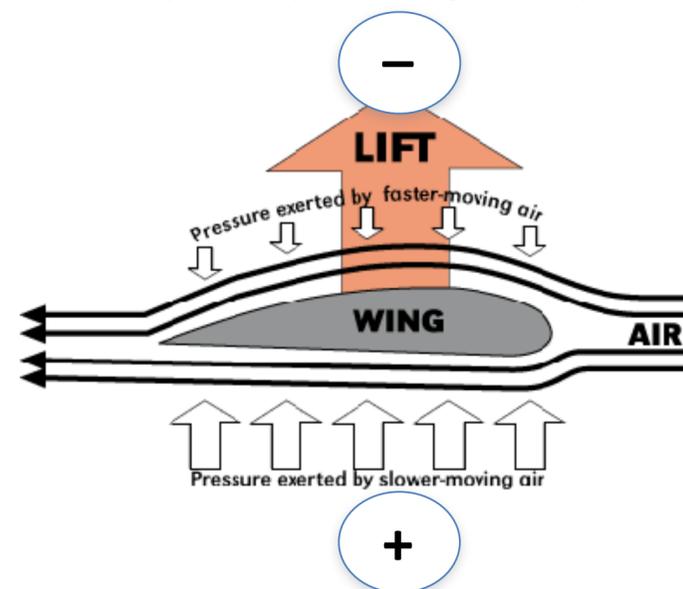
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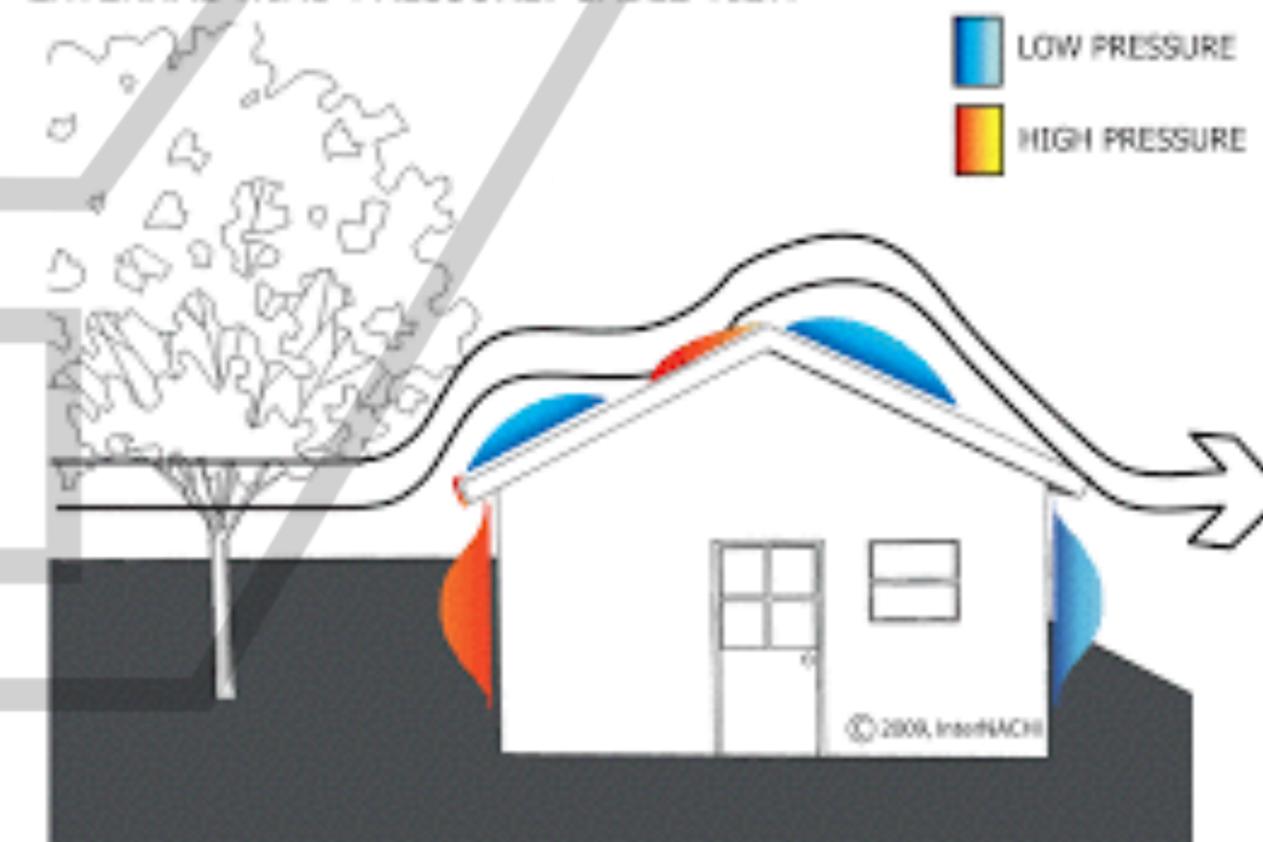
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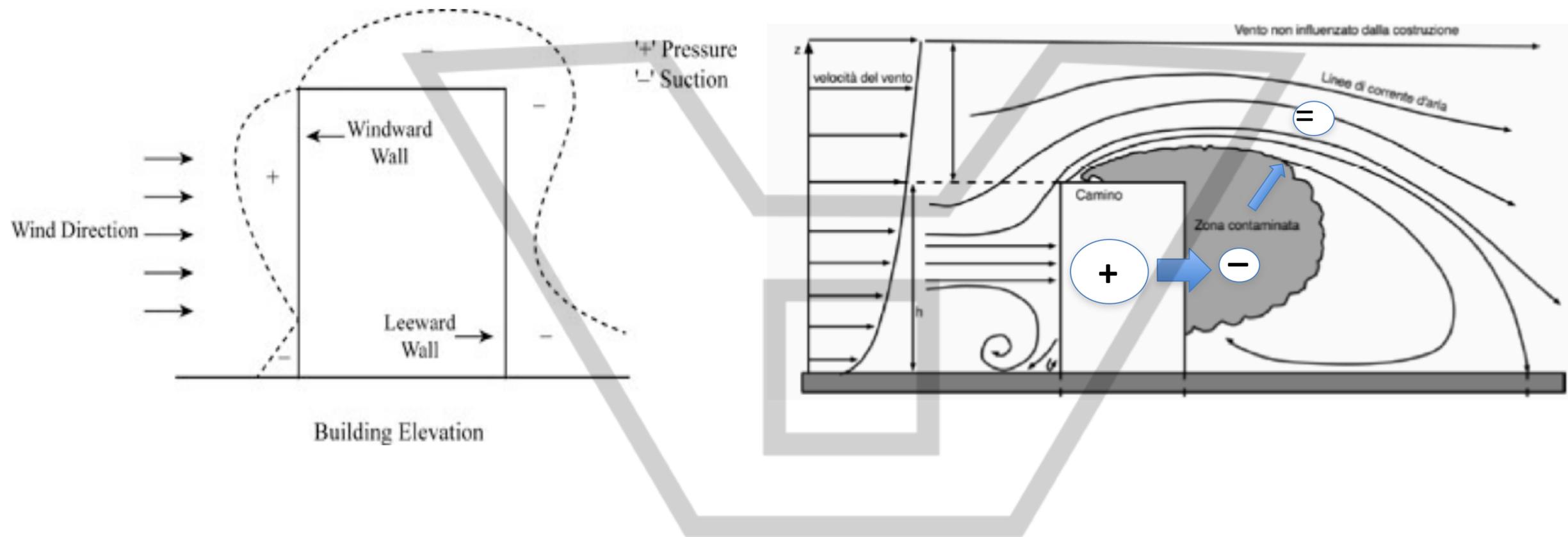
Bernoulli principle = higher speed lower pressure



EXTERNAL WIND PRESSURE: GABLE VIEW



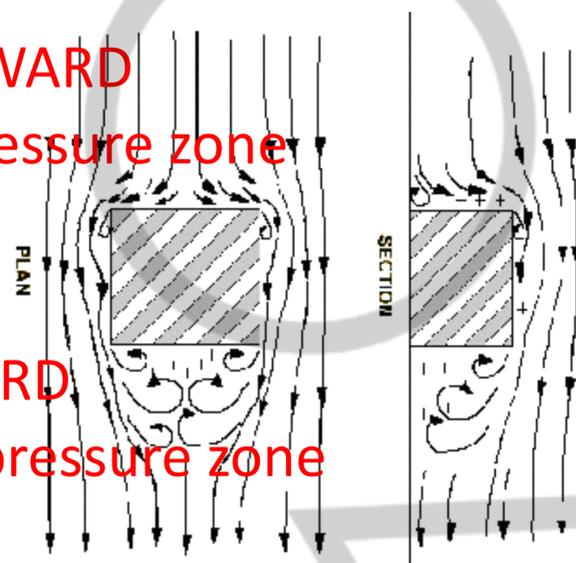
## RICONOSCERE I DIFFERENZIALI DI PRESSIONE INDOTTI DAL VENTO SUGLI EDIFICI



## INTUITIVE METHODS

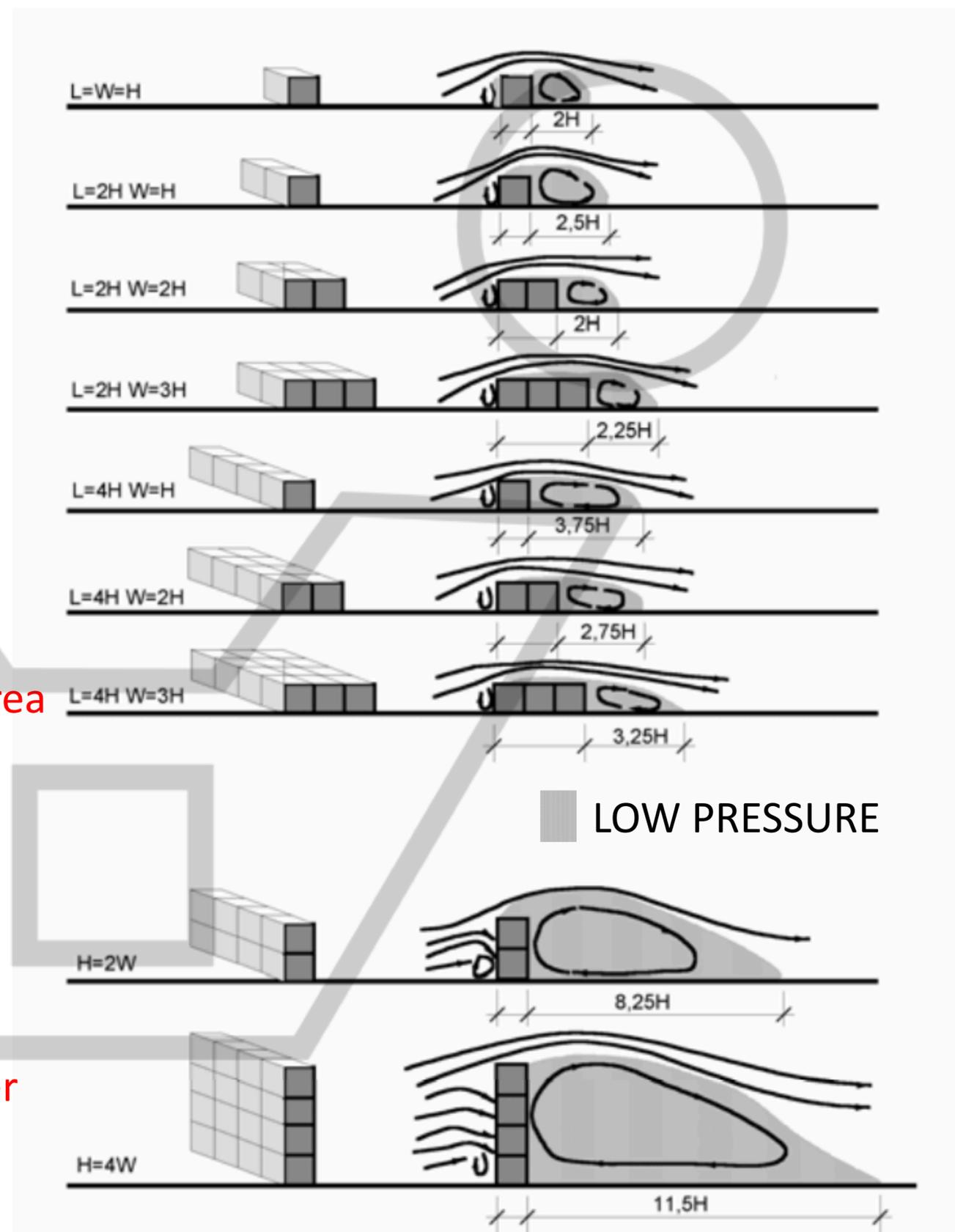
WINDWARD  
overpressure zone

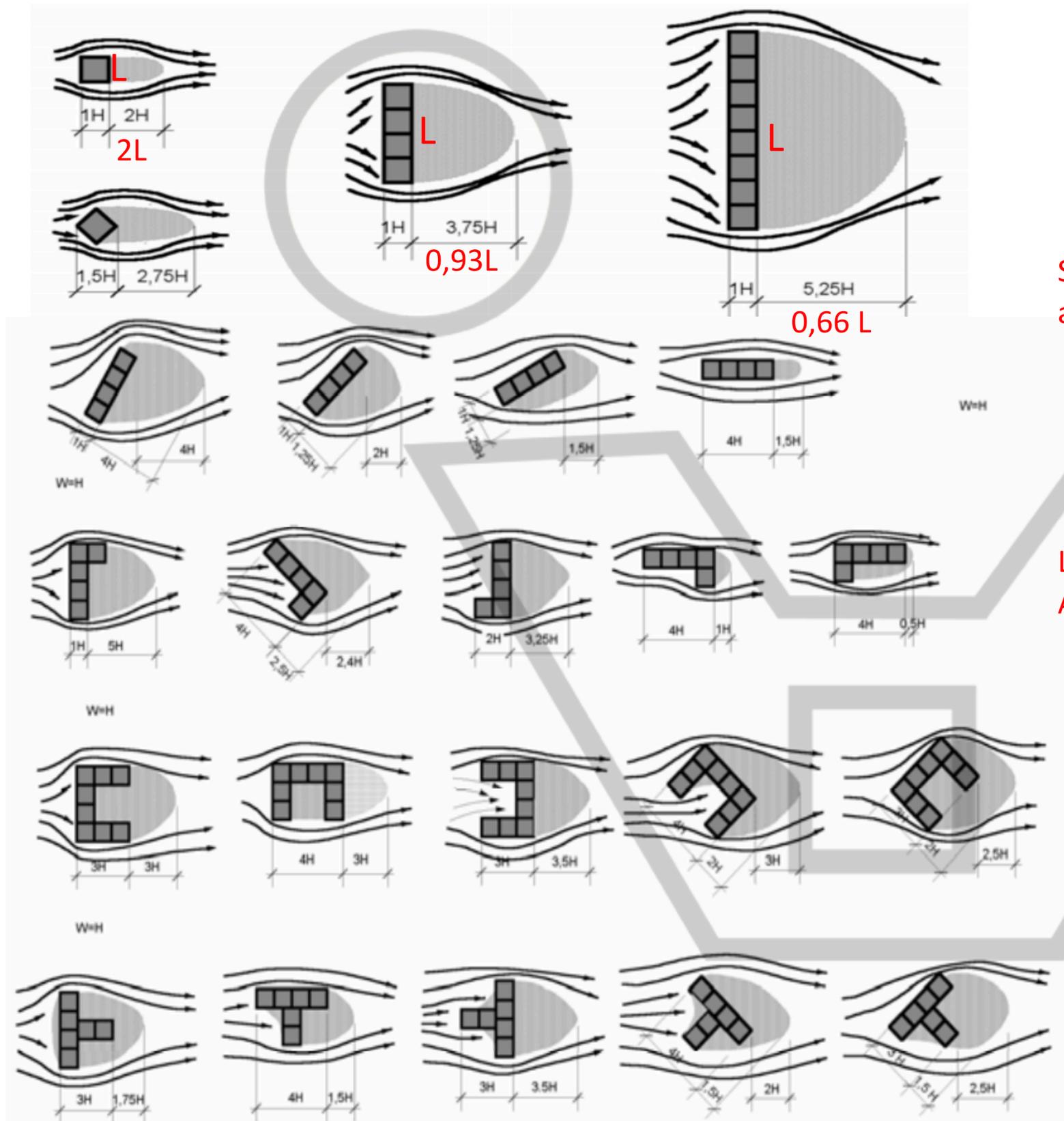
LEEWARD  
underpressure zone



Skinny buildings create  
deeper low pressure area

Taller buildings create  
(proportionally) deeper  
low pressure area





LOW PRESSURE

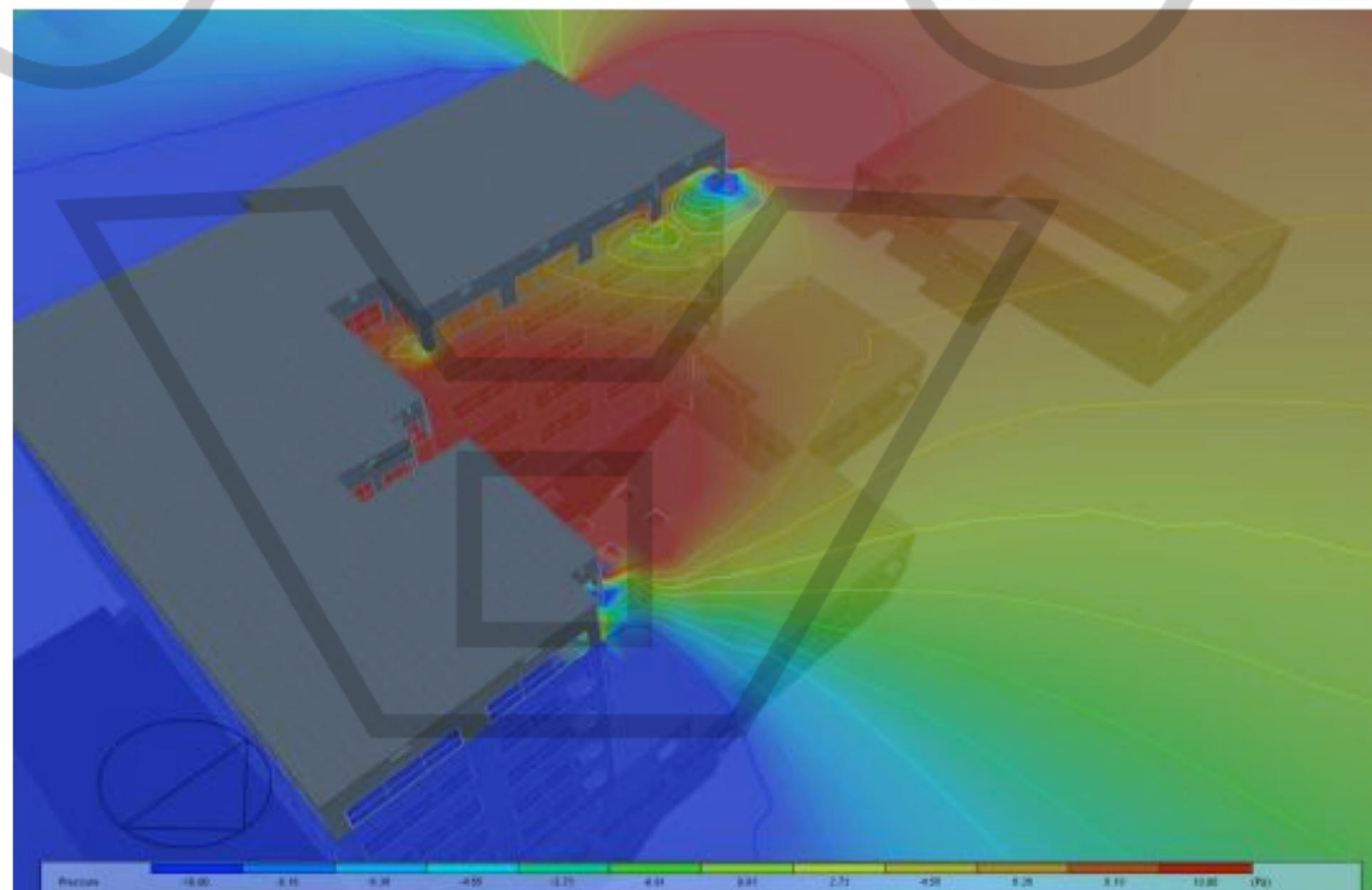
Shorter building creates (proportionally)  
a deeper low pressure area

Longest building create  
A deeper low pressure area

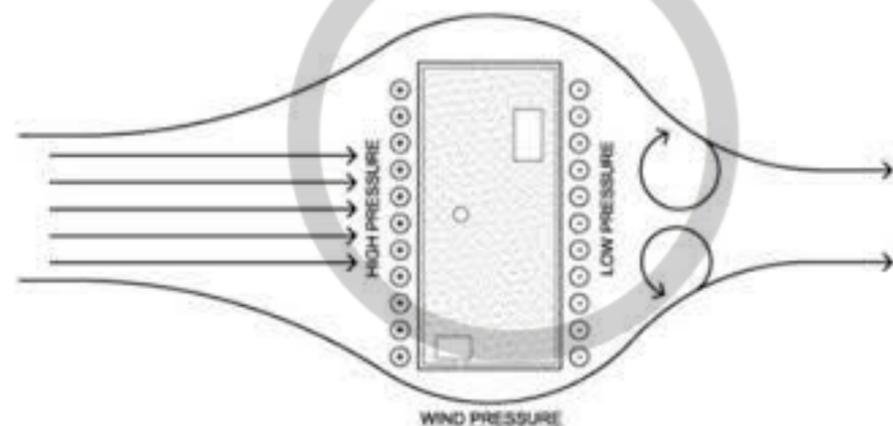
## COMPUTATIONAL METHODS

### WINDS & AIRFLOW MODELING

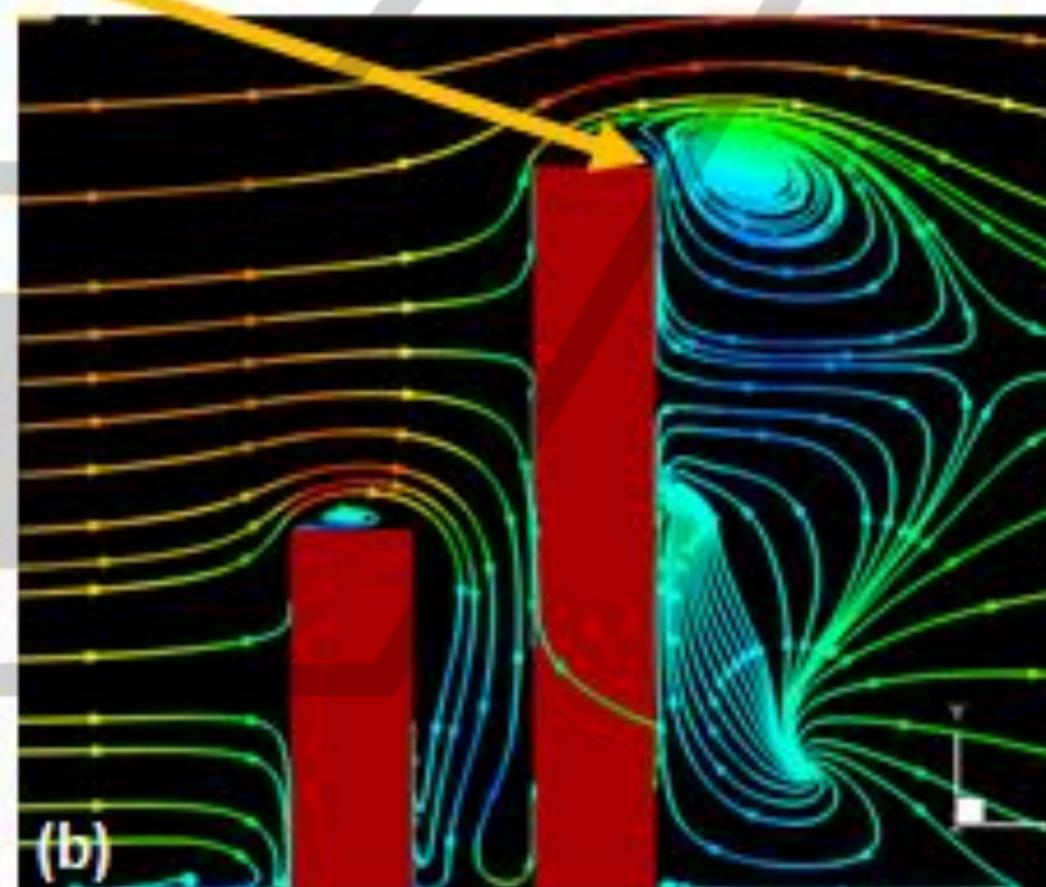
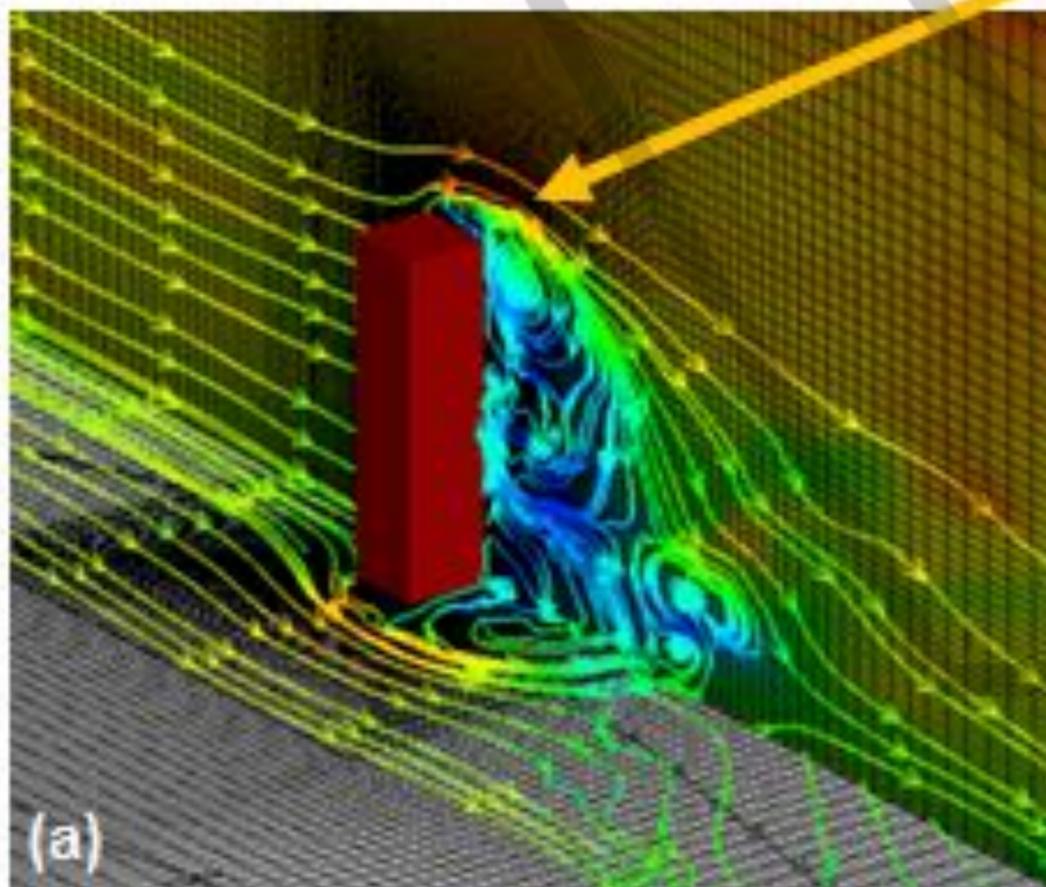
Wind pressure coefficients ( $C_p$ ) vary around buildings



# WINDS & AIRFLOW MODELING

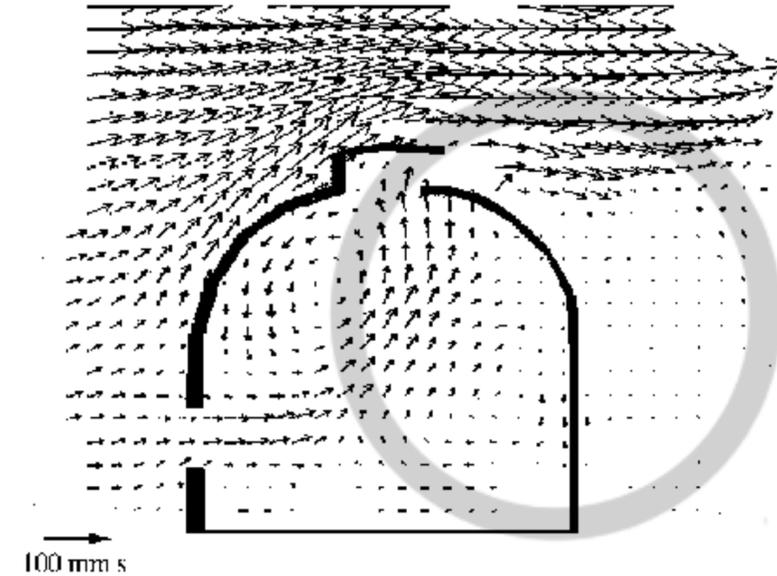


High suction regions



# AIRFLOW MODELING

## *Computational Fluid Dynamics (CFD)*



### ***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

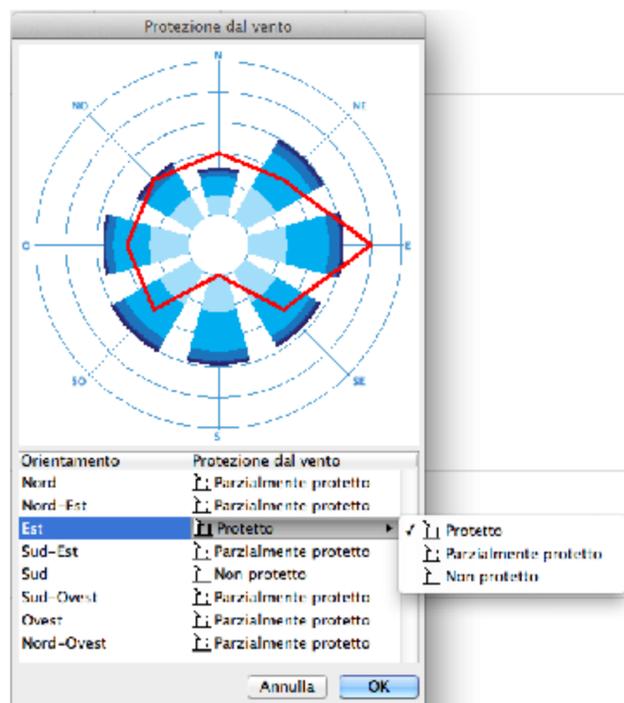
AIA (The American Institute of Architects) (2012) An Architect's guide to integrating energy modeling in the design process

ERI@N (Energy Research Institute @ NTU) (2013) Nanyang Technological University (NTU), Singapore

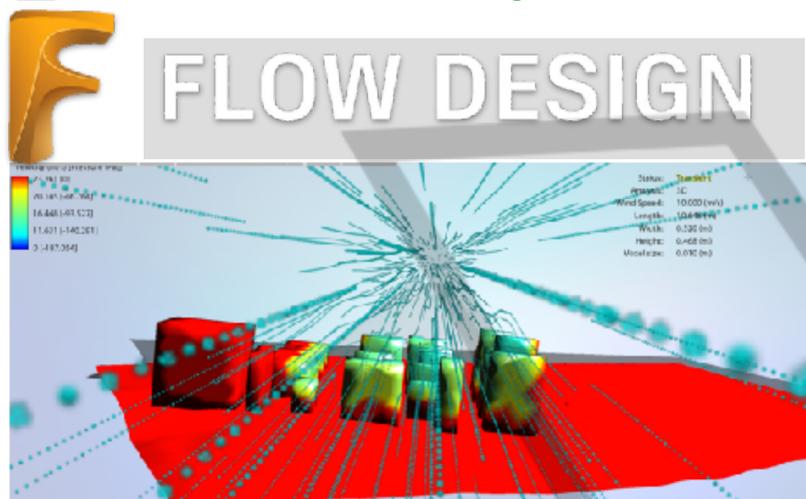
NREL (2009) A handbook for planning and conducting charrettes for high-performance projects, National Renewable Energy Laboratory (NREL), Sept 2009

# AIRFLOW MODELING. Procedures in Flow Design

- A** 1- determine the coldest and the hottest hours  
2- for these hours find the most frequent wind directions



- B** 3- import your model in Flow Design  
4. Rotate the model according to the wind direction previously found



- C** 5 Run the simulation in Flow design  
6 set the appropriate visualisation and analyse the results

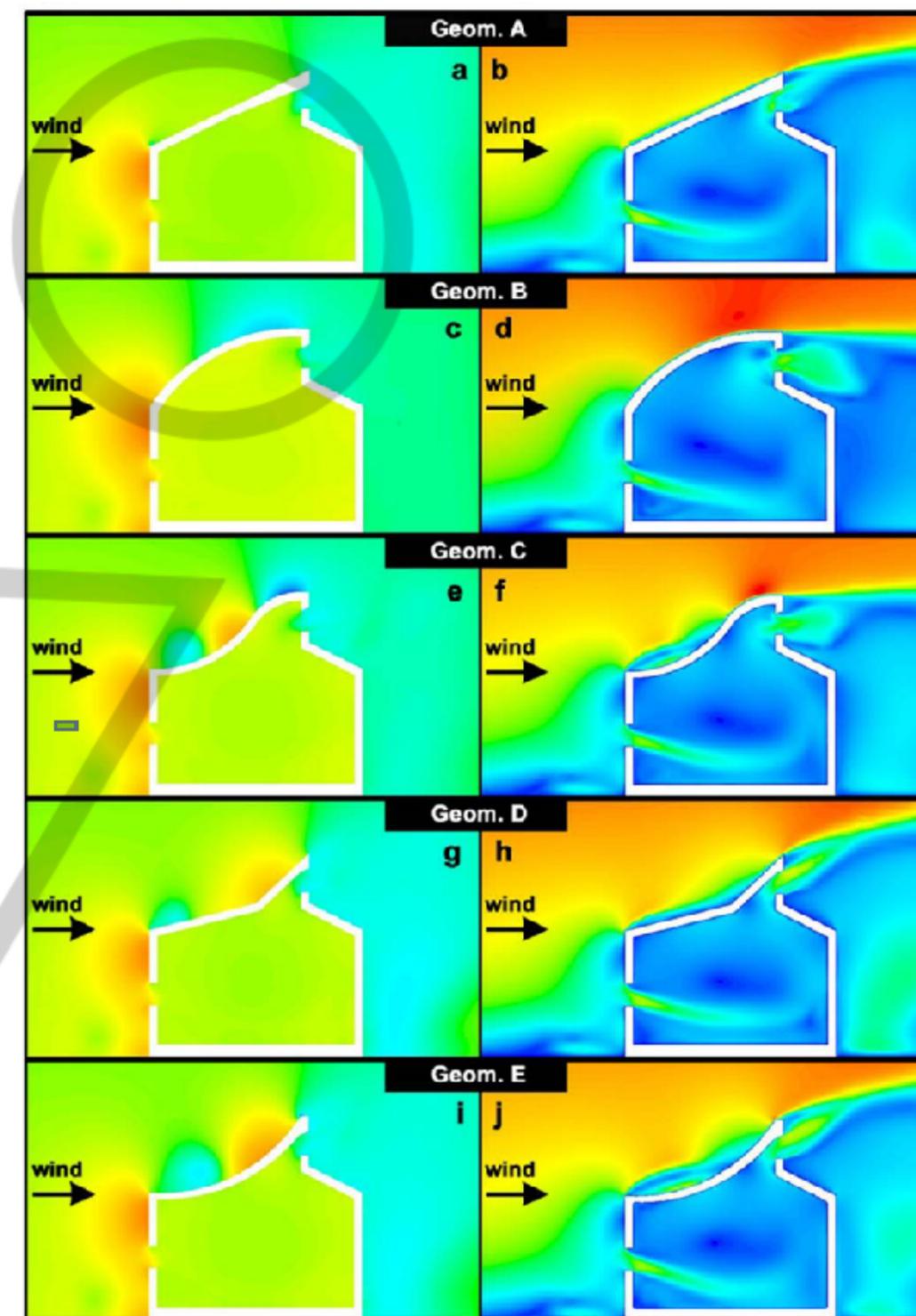
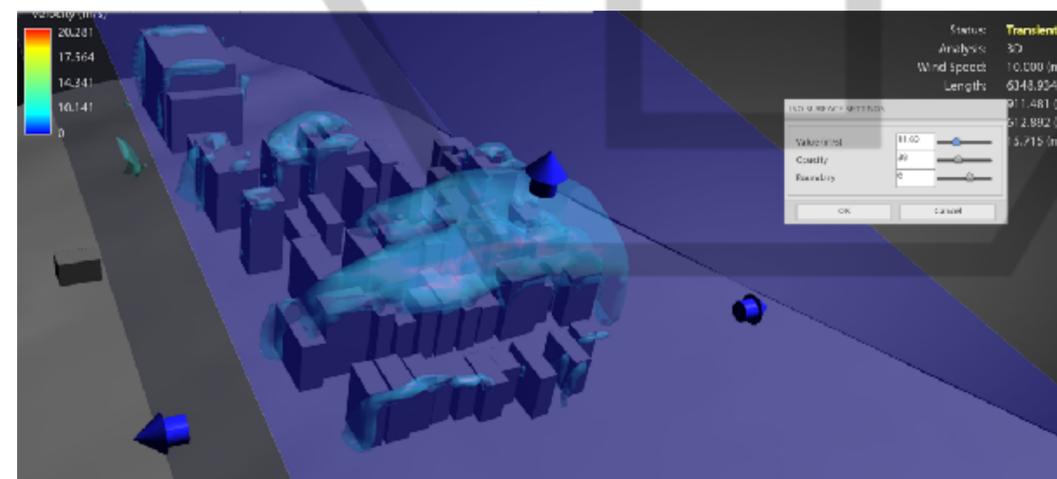
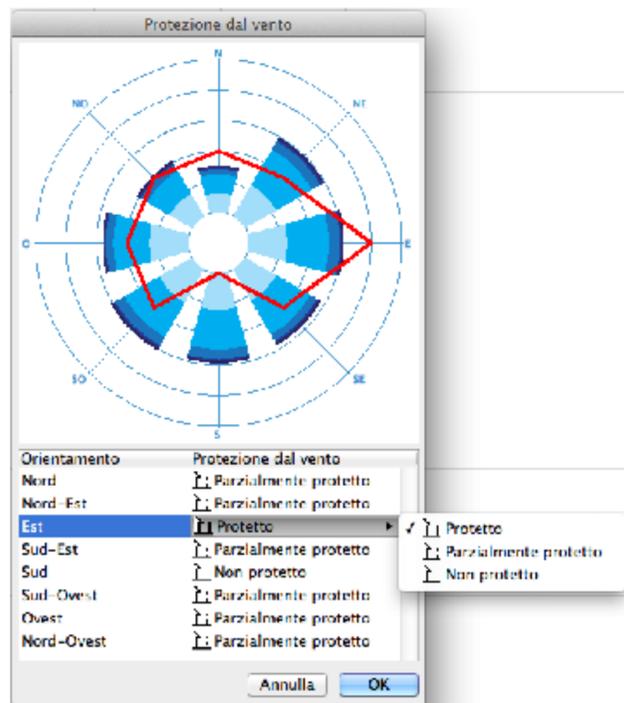


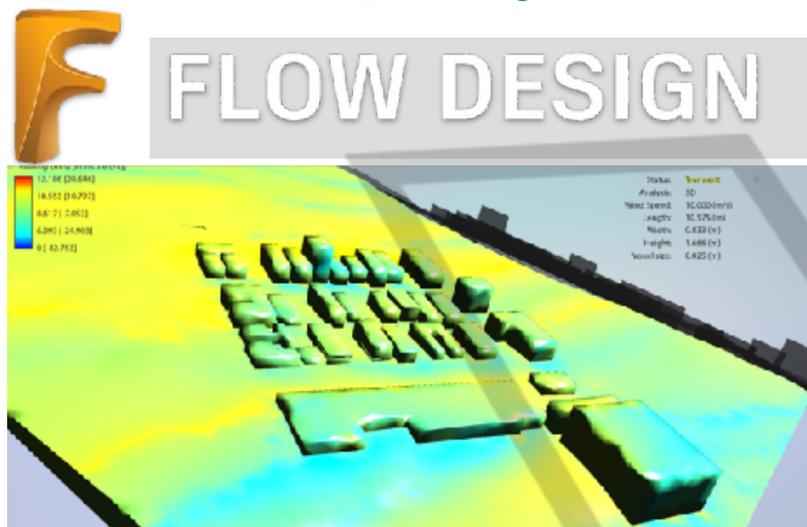
Fig. 12. Contour plot of the pressure coefficient  $C_p$  (a,c,e,g,i) and the dimensionless velocity magnitude  $(|V|/U_{ref})$  (b,d,f,h,j) in the vertical center plane for the five roof geometry cases.

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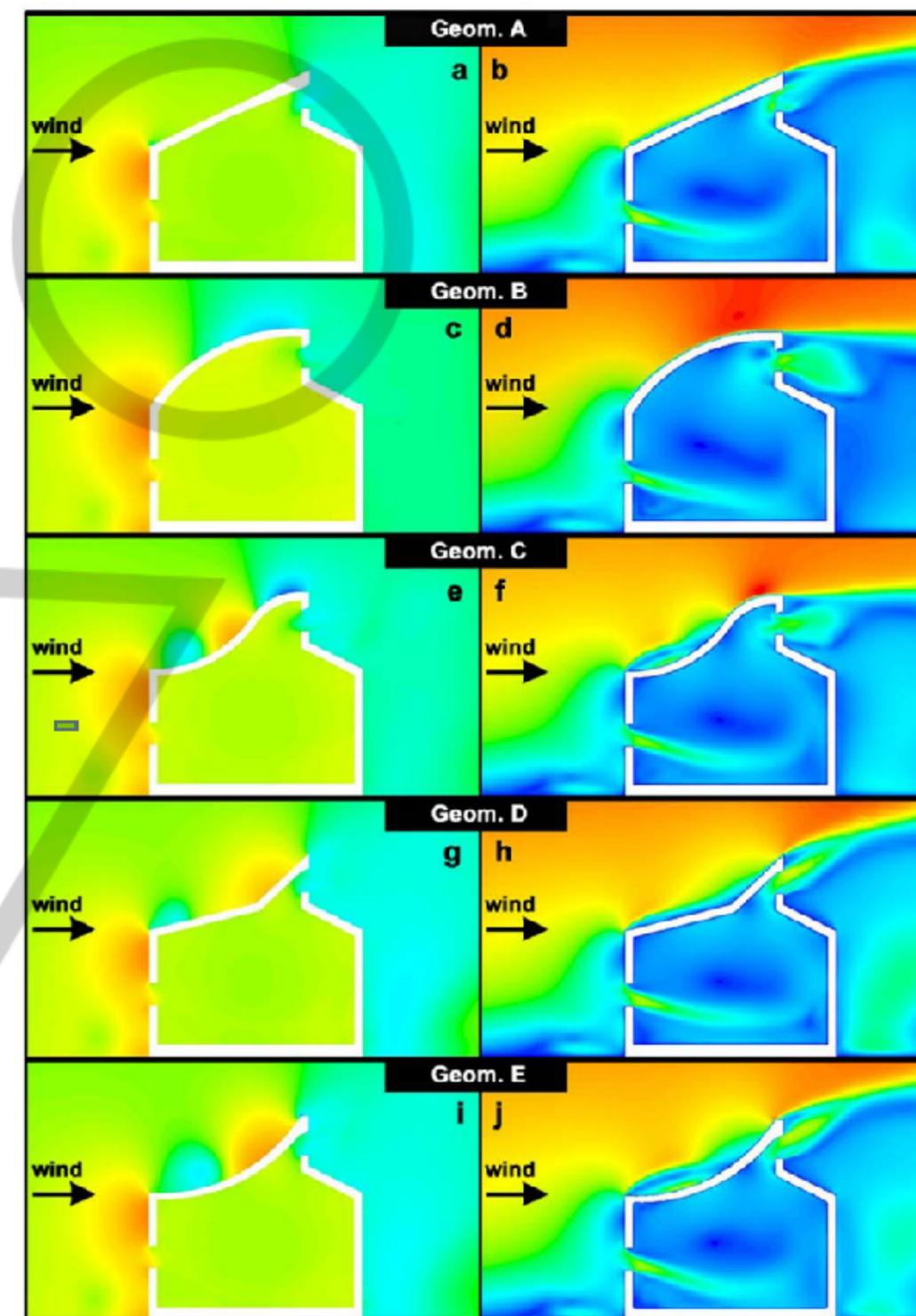
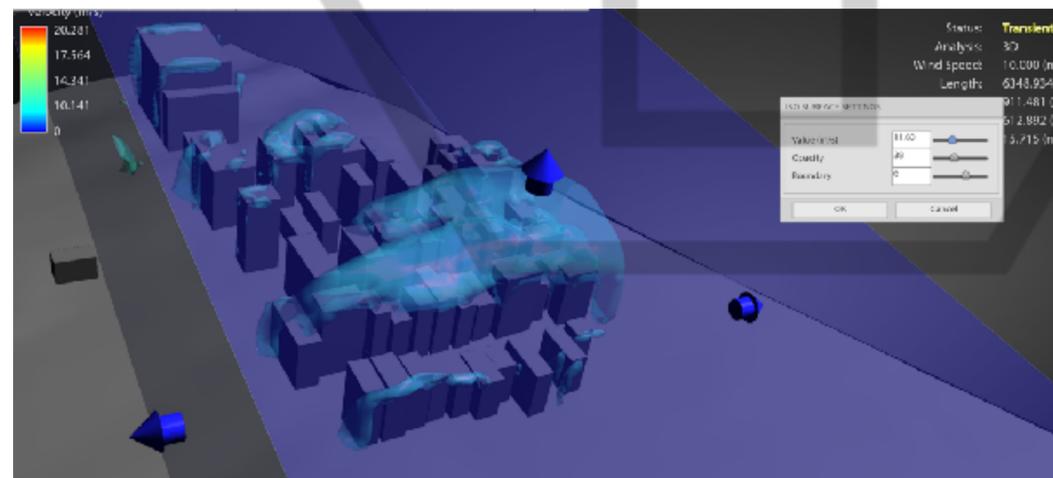
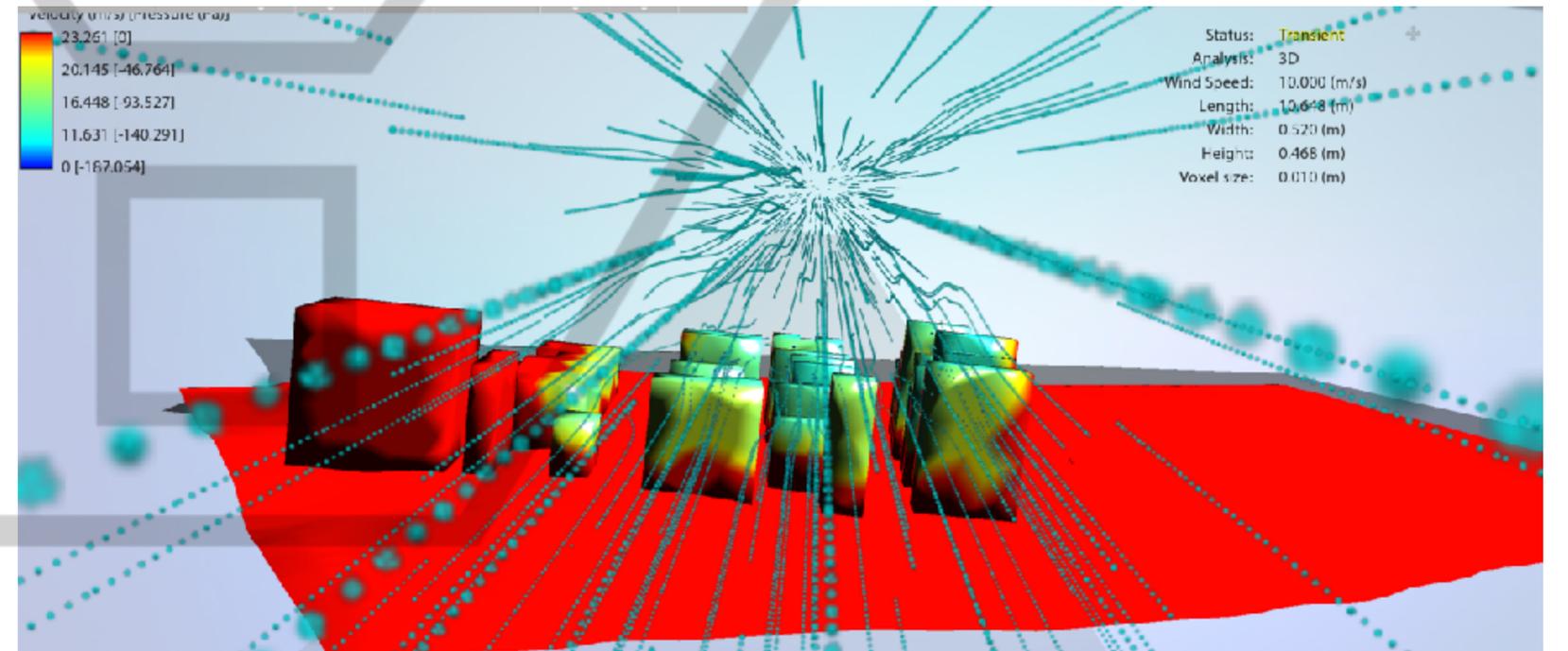
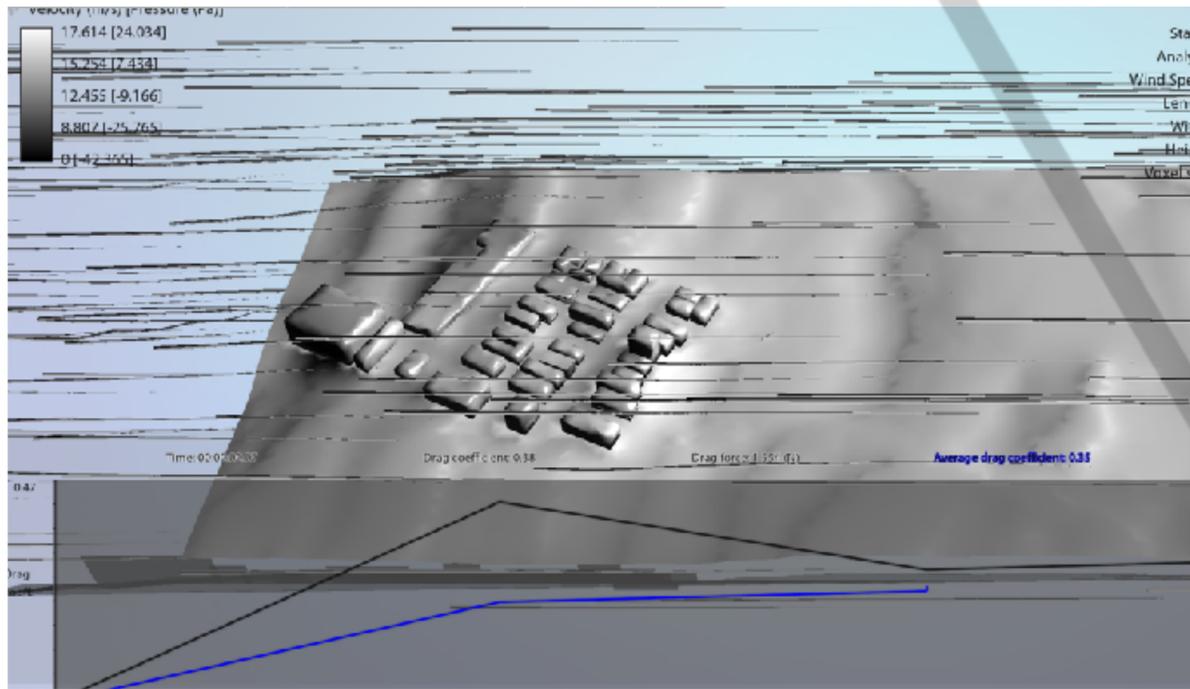
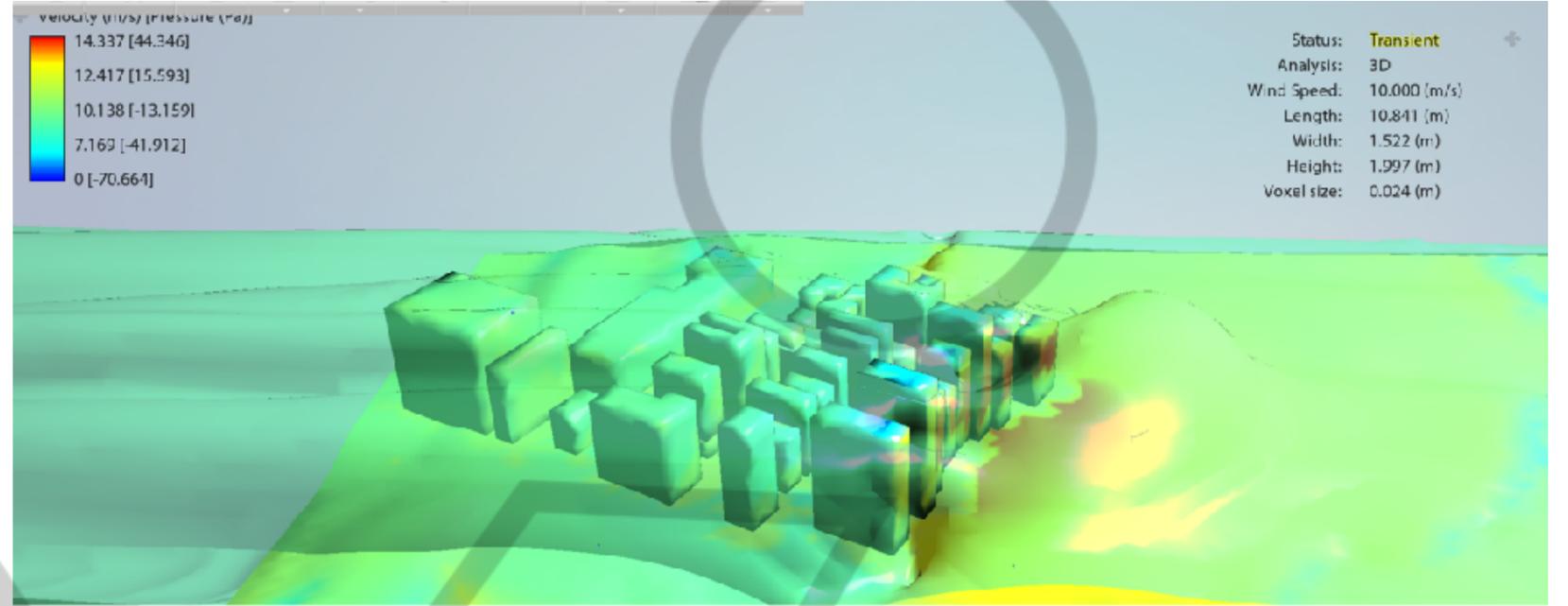
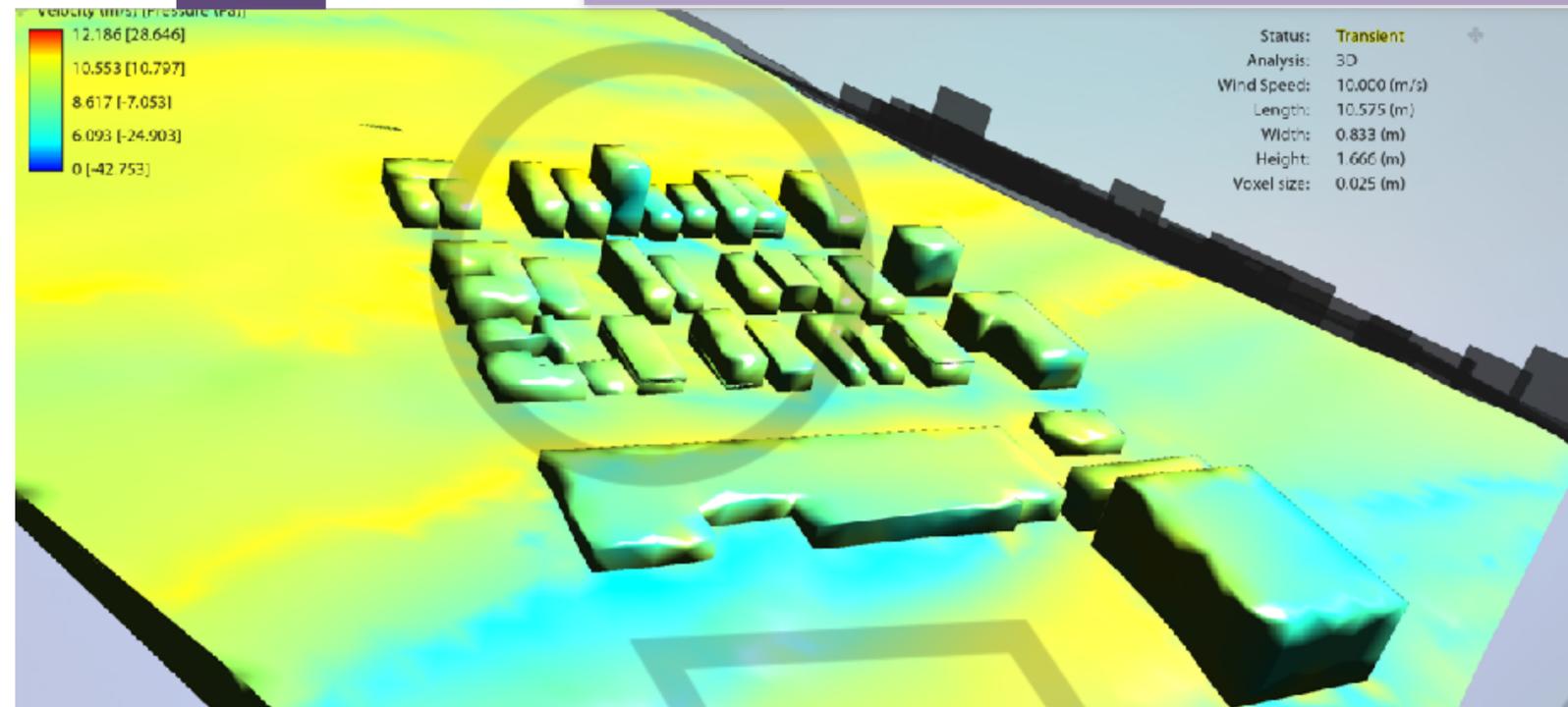


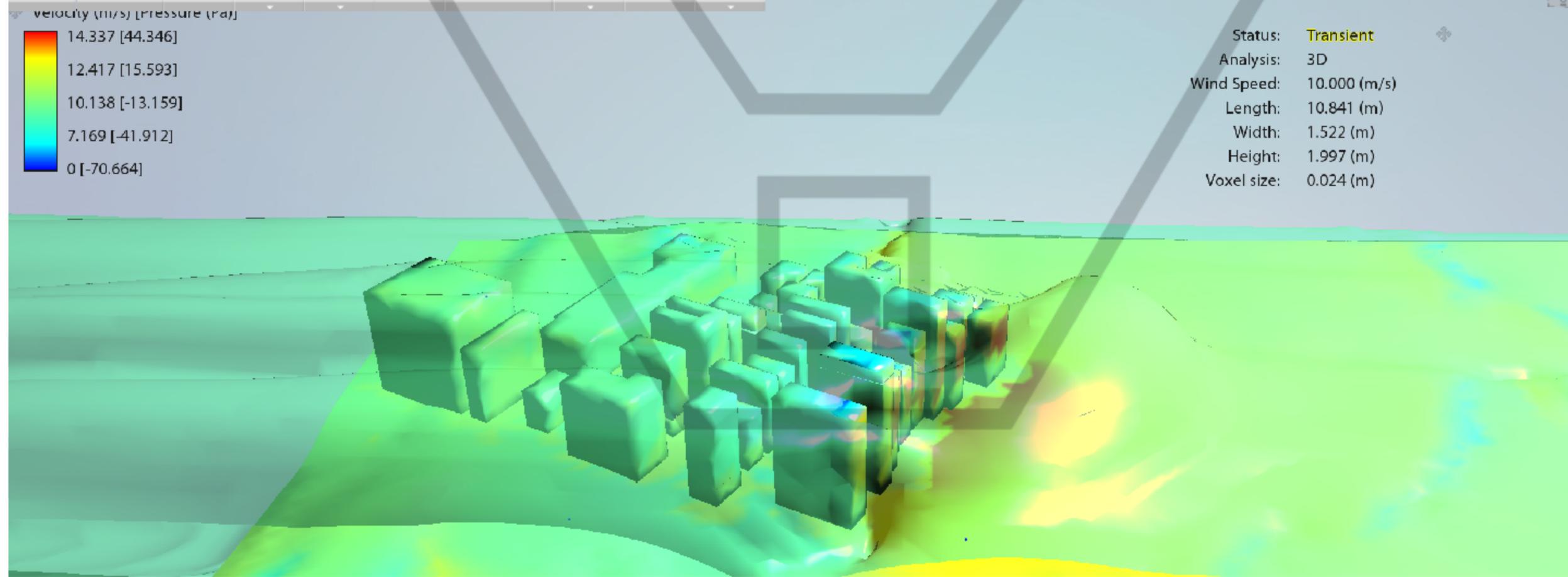
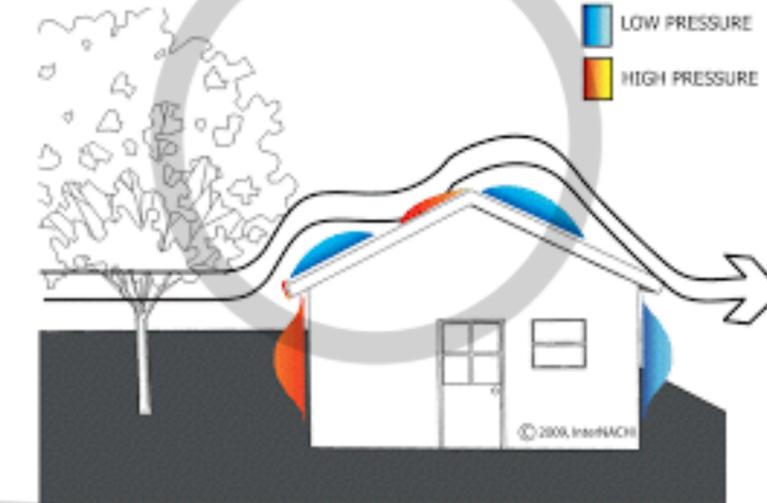
Fig. 12. Contour plot of the pressure coefficient  $C_p$  (a,c,e,g,i) and the dimensionless velocity magnitude  $(|V|/U_{ref})$  (b,d,f,h,j) in the vertical center plane for the five roof geometry cases.



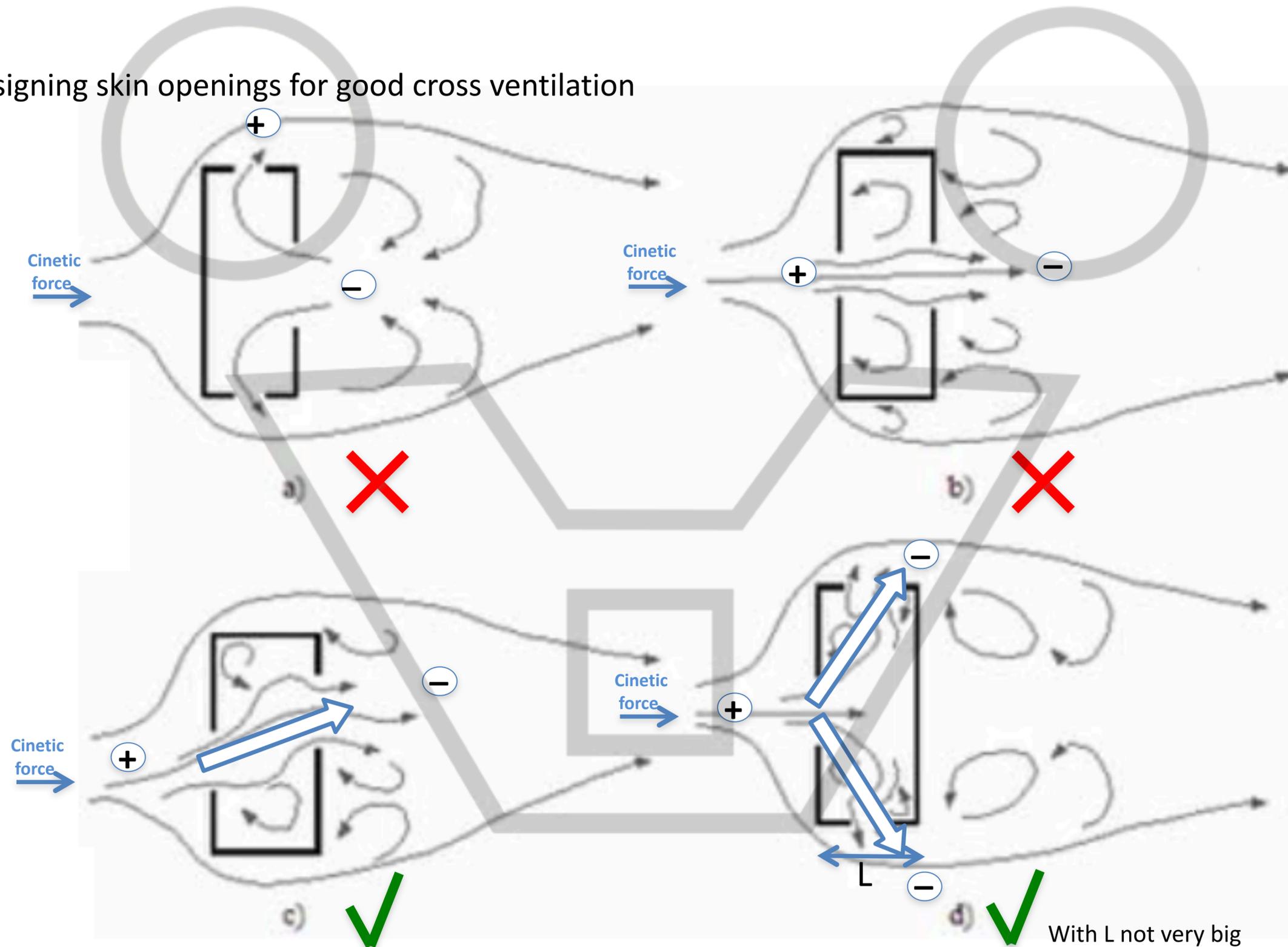
## Wind & Passive Ventilation



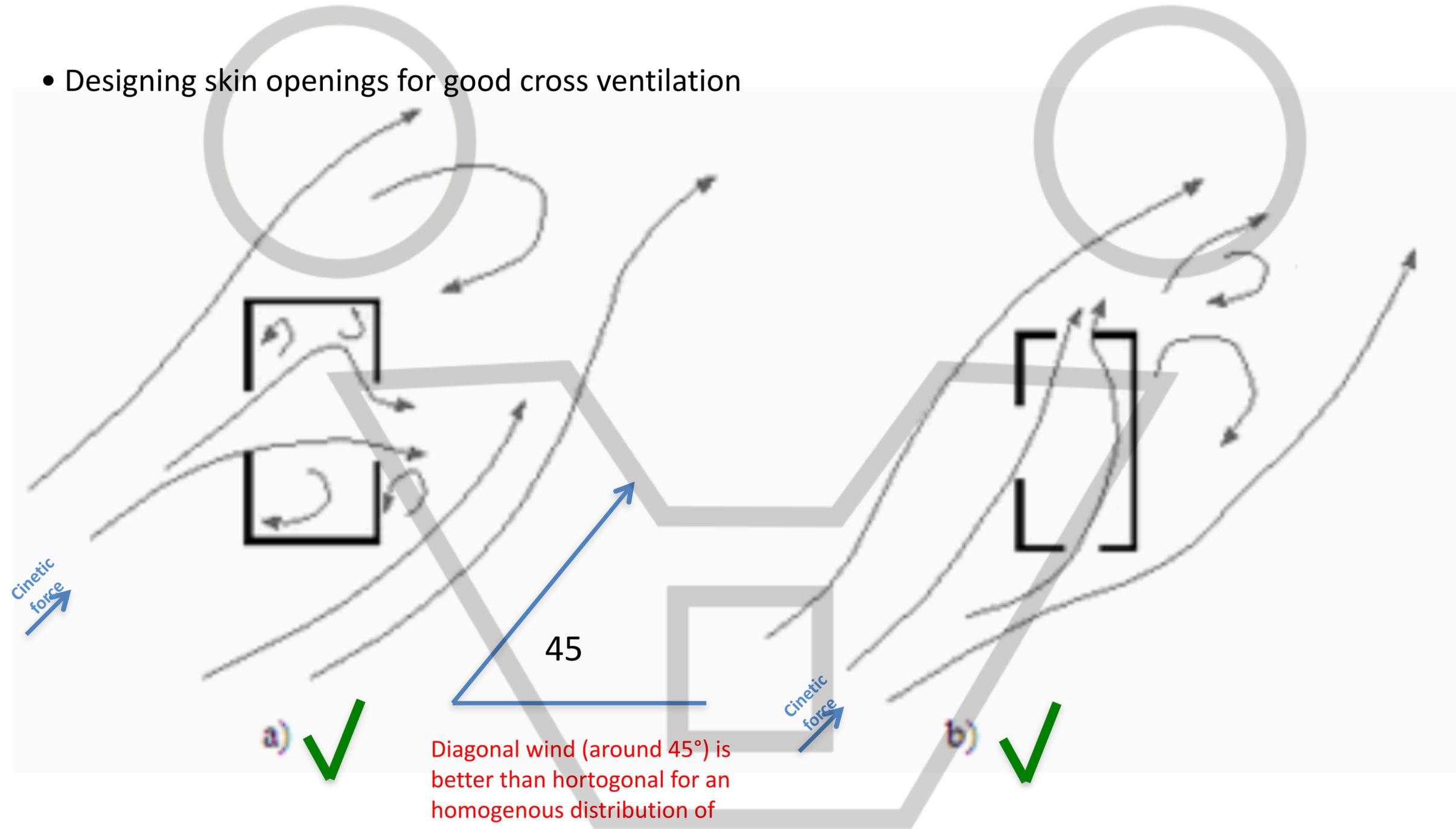
EXTERNAL WIND PRESSURE: GABLE VIEW



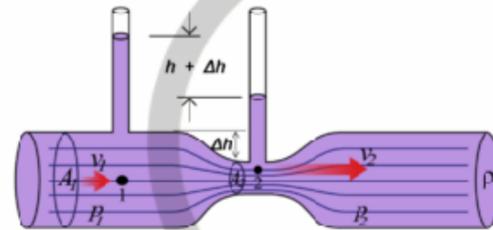
- Designing skin openings for good cross ventilation



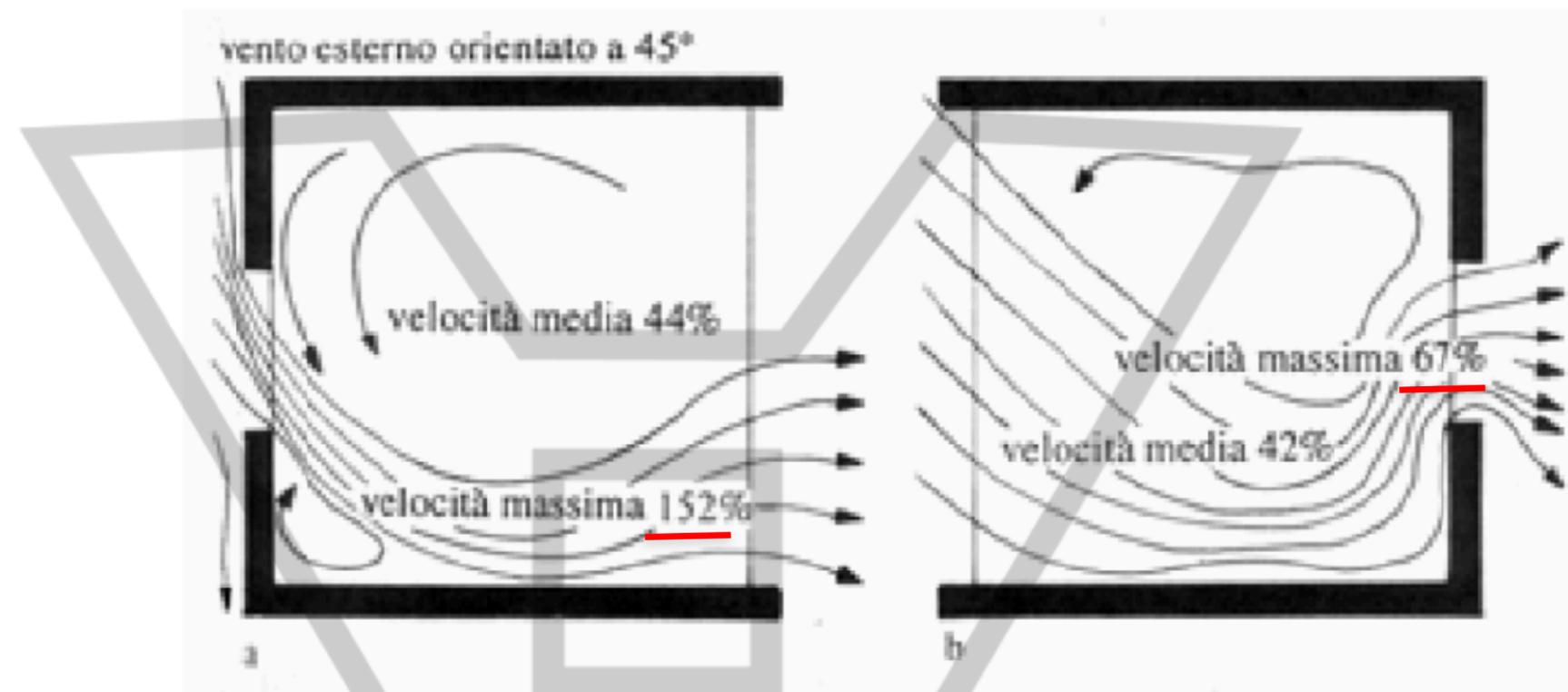
- Designing skin openings for good cross ventilation



- Designing skin openings for good cross ventilation

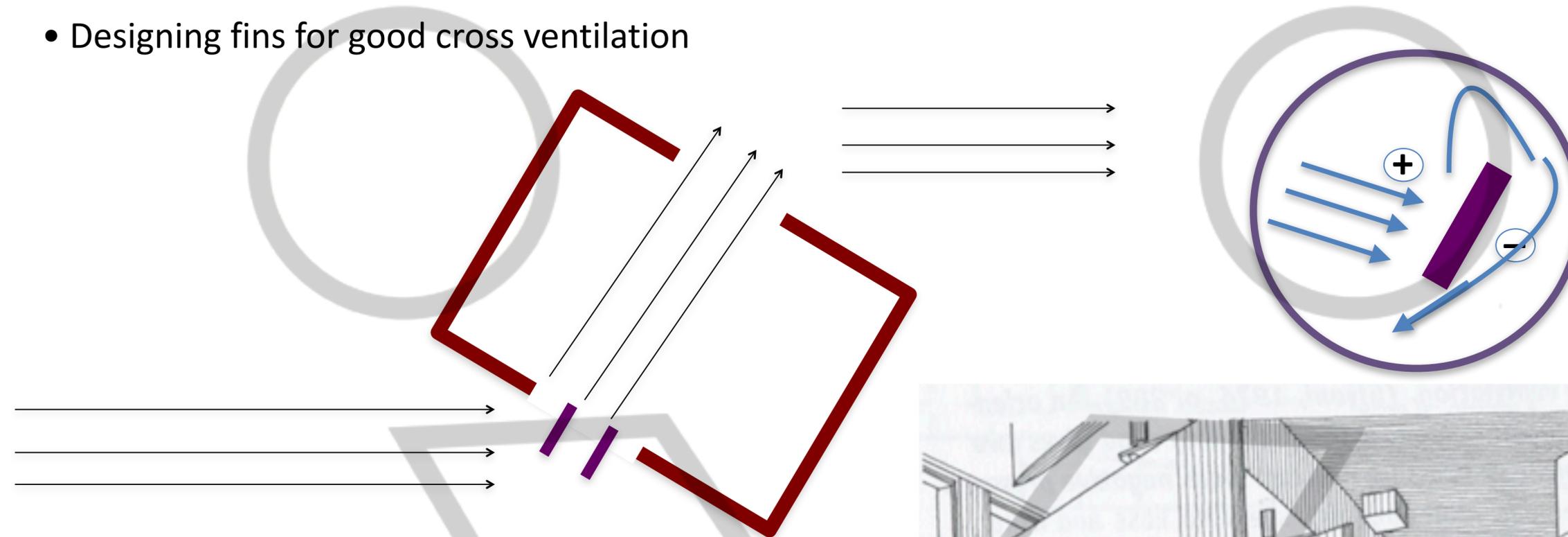


**VENTURI EFFECT** : Higher speed (lower pressure) if the entrance is smaller than the exit

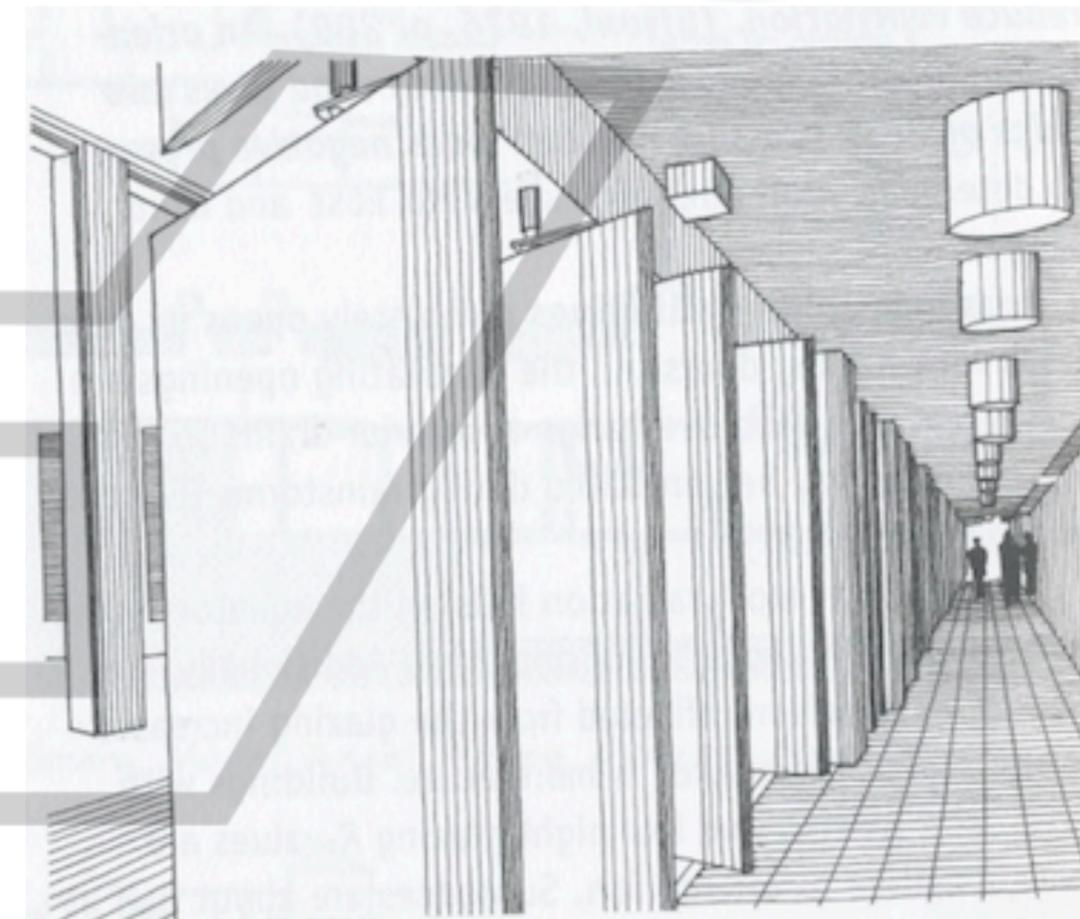


*Pairing a large outlet with a small inlet  
increases incoming wind speed.*

- Designing fins for good cross ventilation

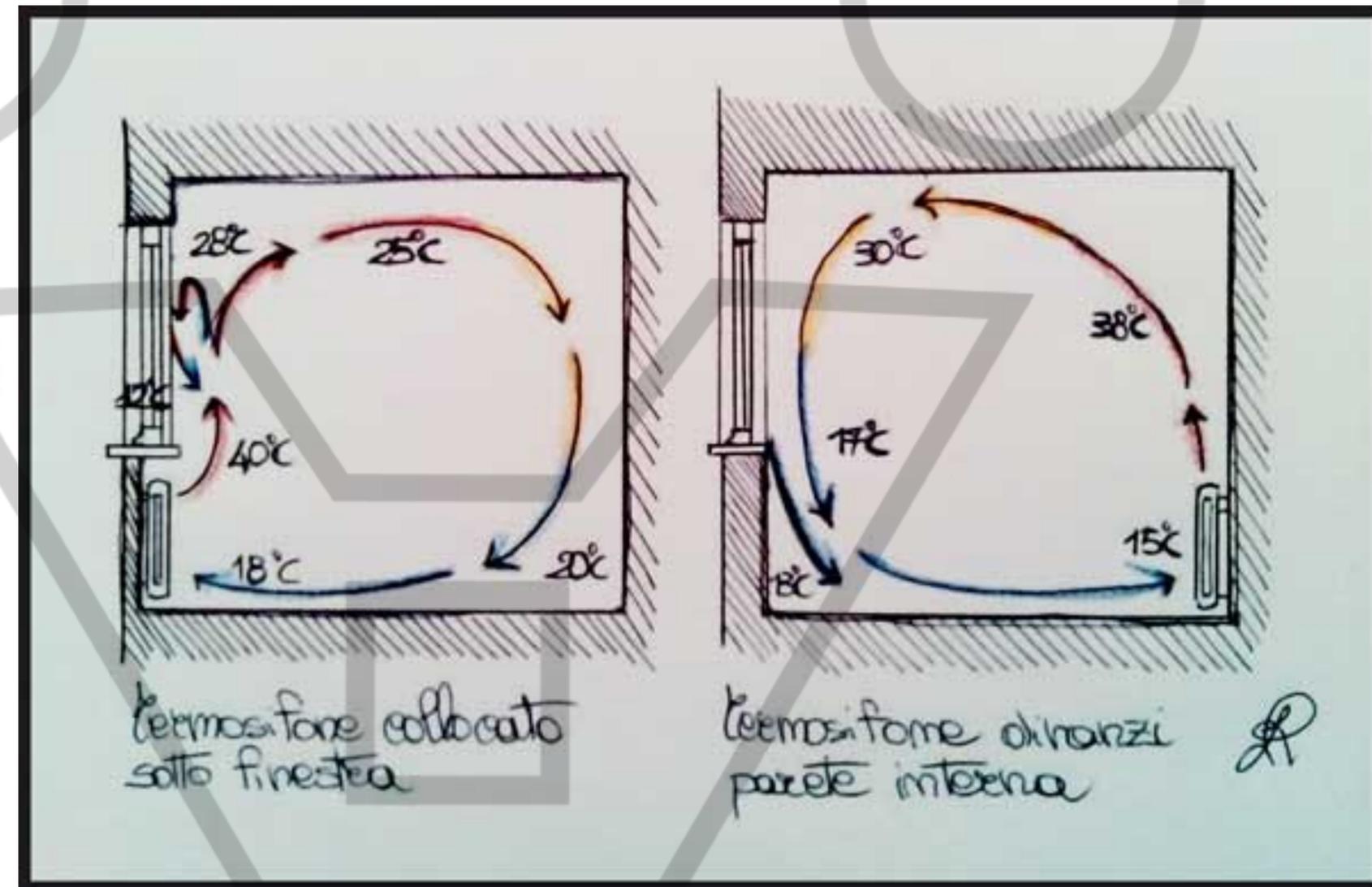
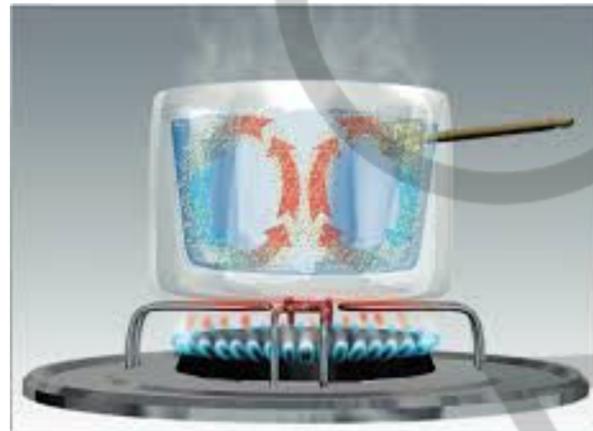


When openings cannot be oriented to the prevailing breeze and if rooms have windows in only one wall, landscaping or wing walls can alter the positive and negative pressure zones around the building and induce wind flow through windows parallel to the prevailing wind directions (R. H. Reed, 1953, p. 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.

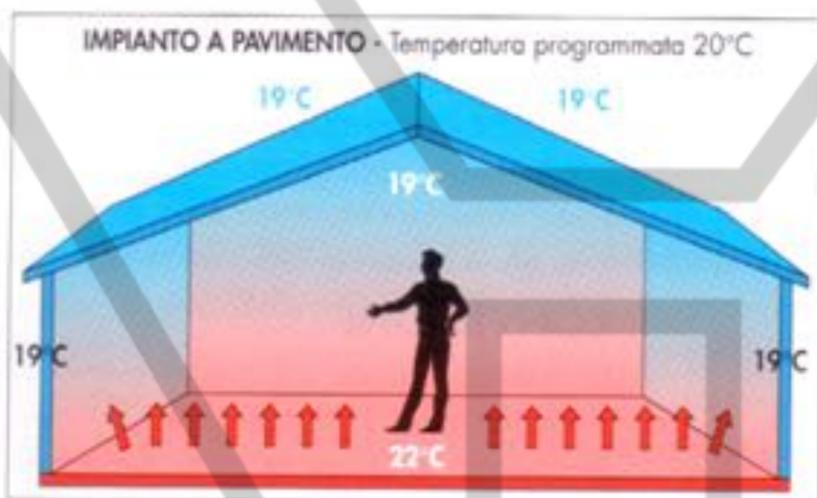
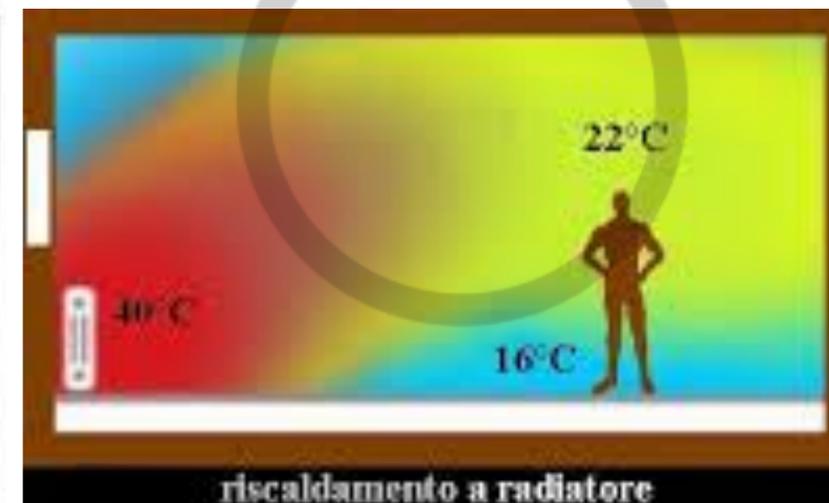
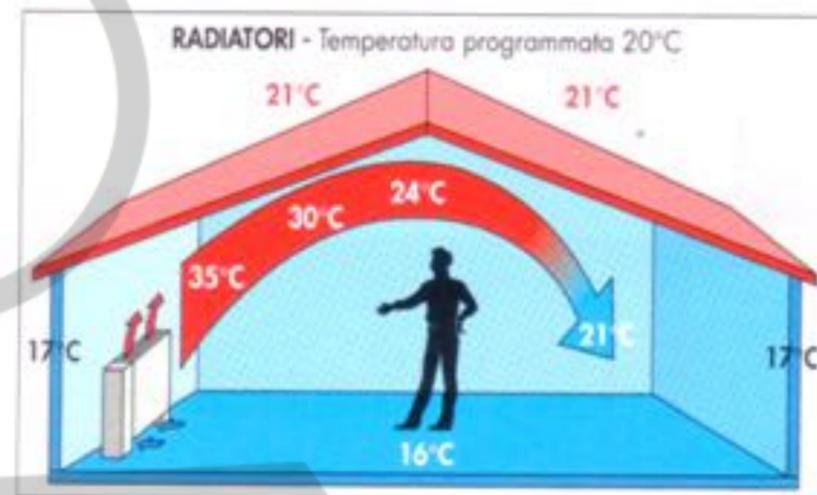
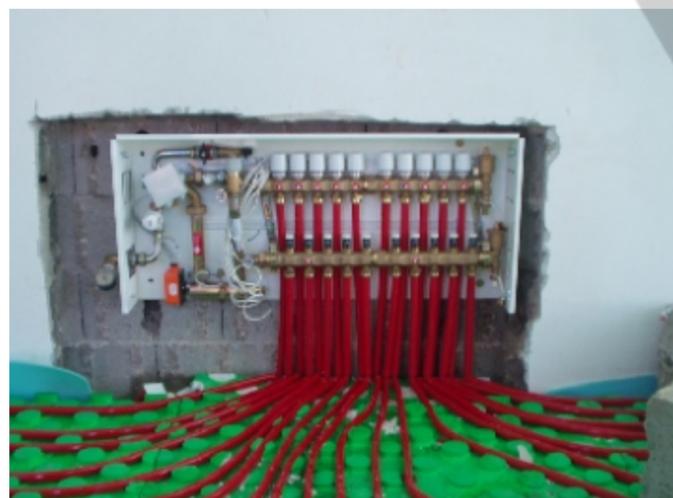


Interior View of Alierons, Academy of the Antilles and Guiana, Christiane Hauvette & Jérôme Nouel

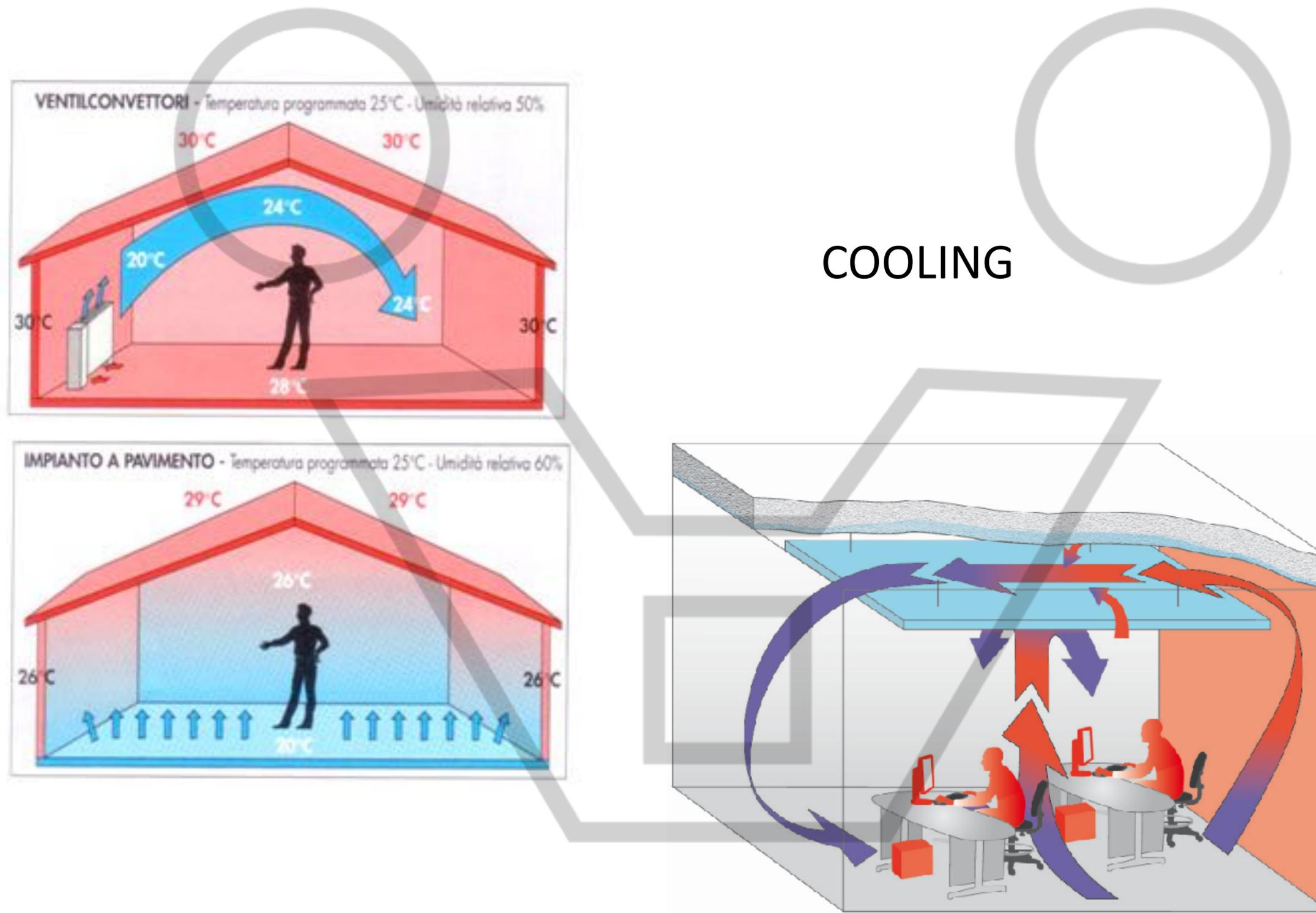
## 2 DENSITY & CONVECTIVE MOVEMENTS *f* (temperature, altitude) bottom up convective air movements



# HEATING



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



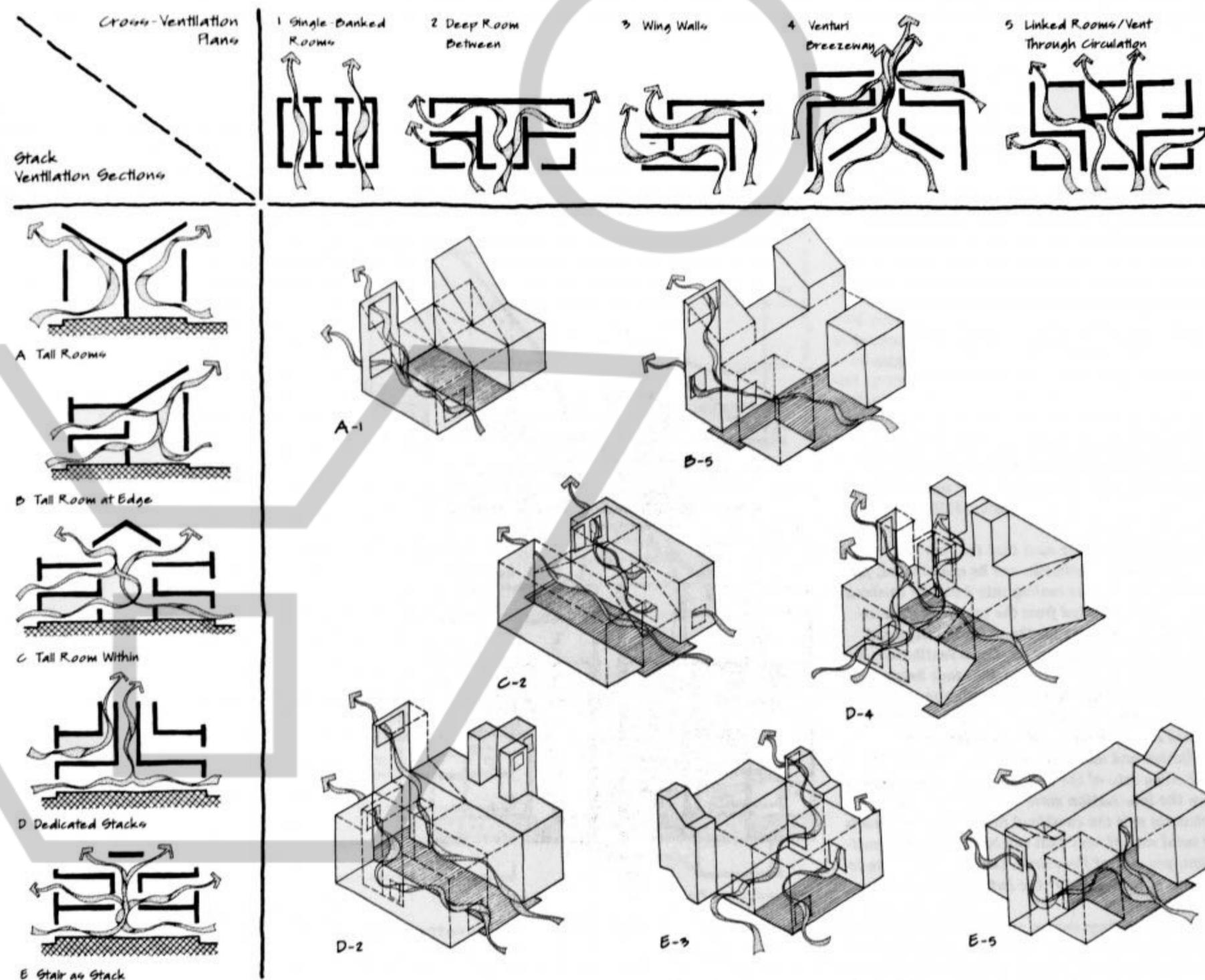
Sistema raffreddamento a piastra radiante

# Working with natural ventilation

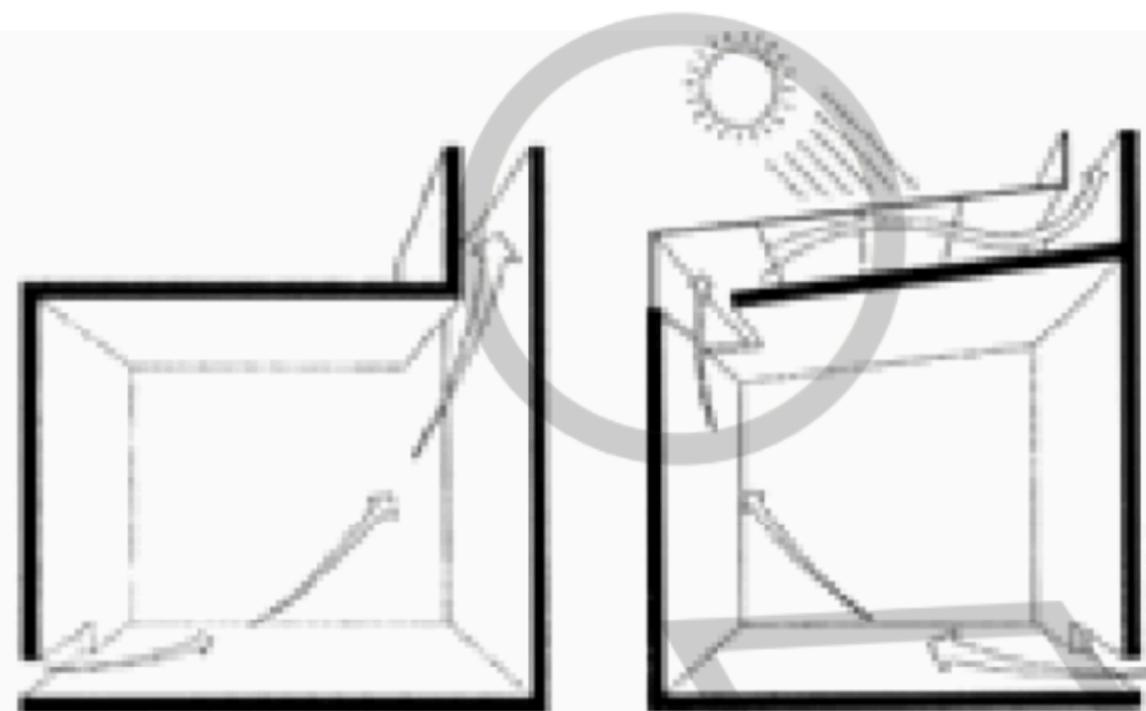
## Air movement: VERTICAL VENTILATION



**REMEMBER:**  
Kinetic force (wind direction and intensity )  
Difference of Pressure  
Difference of density

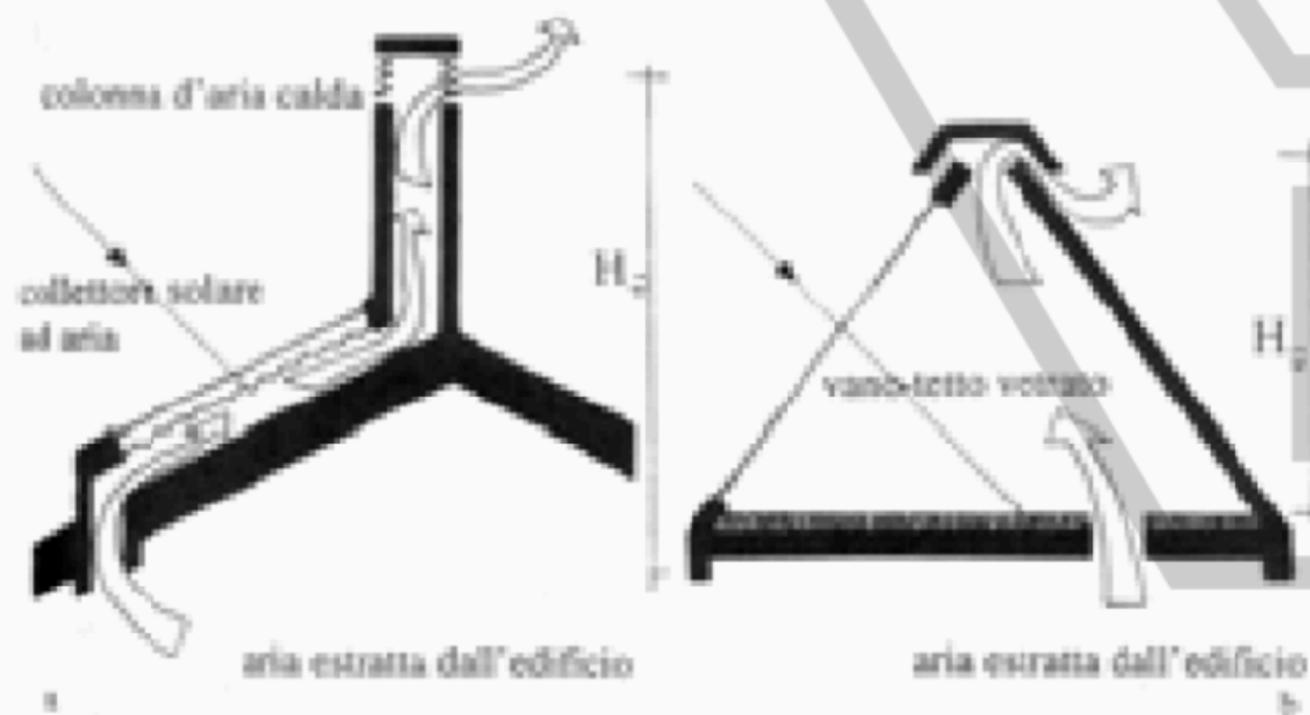


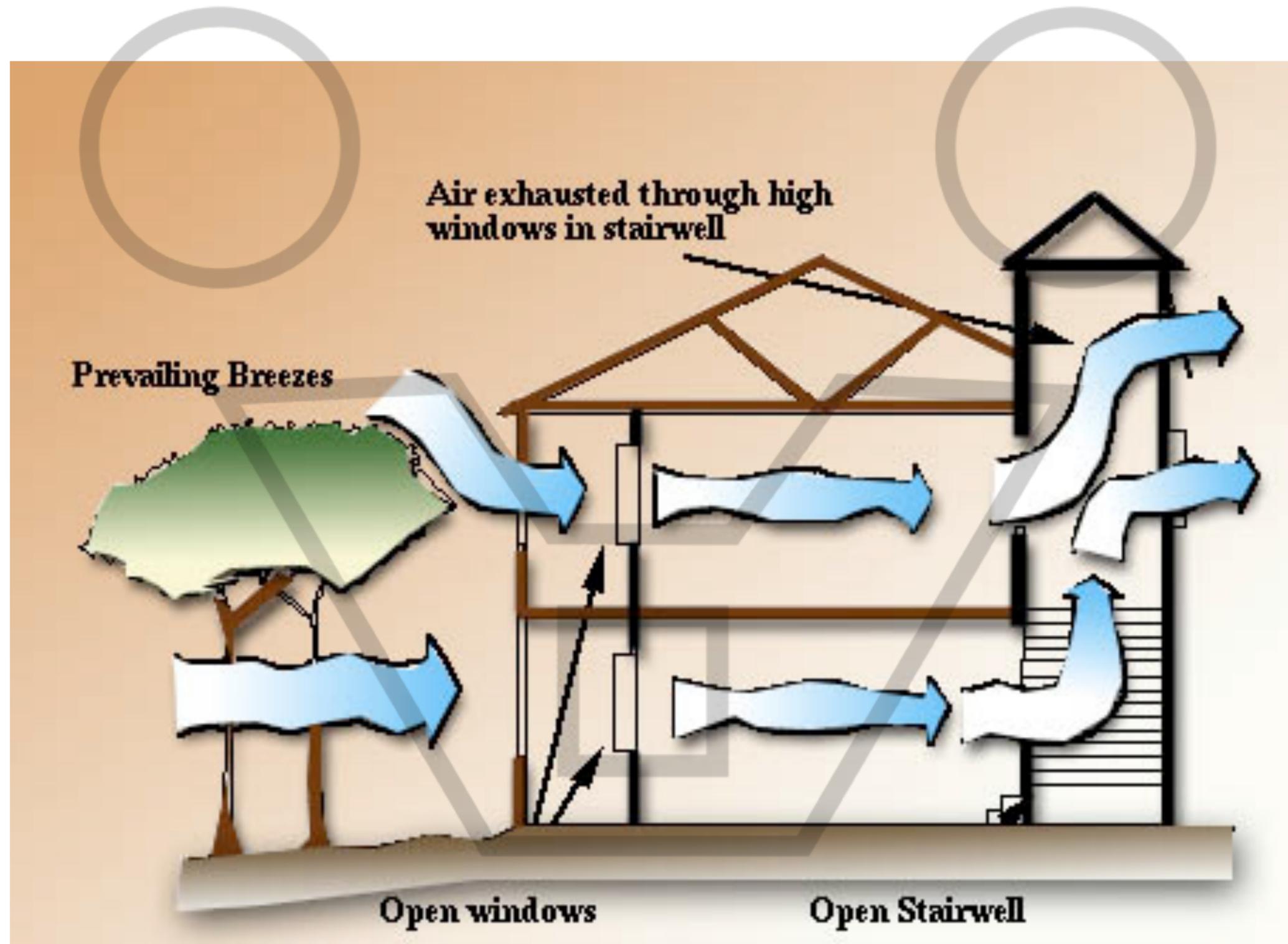
Cross ventilation + Stack effect room diagrams

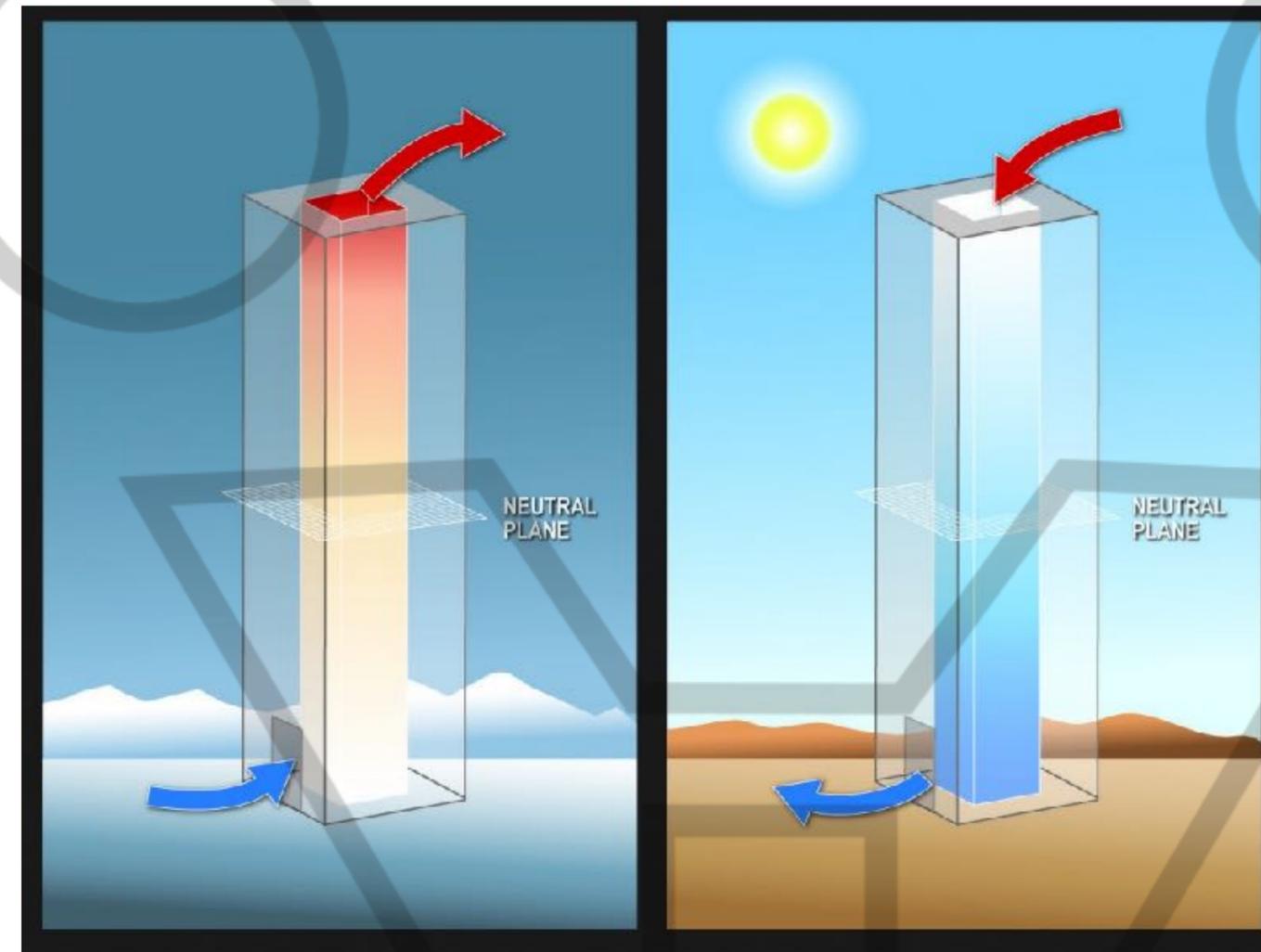


### HOW TO INCREASE STACK EFFECT:

- OVERHEAT THE ROOF, THE CHIMNEY,..
- INCREASE THE DISTANCE BETWEEN INLET AND OUTLET







**REMEMBER:**

**Kinetic force**

**Difference of Pressure**

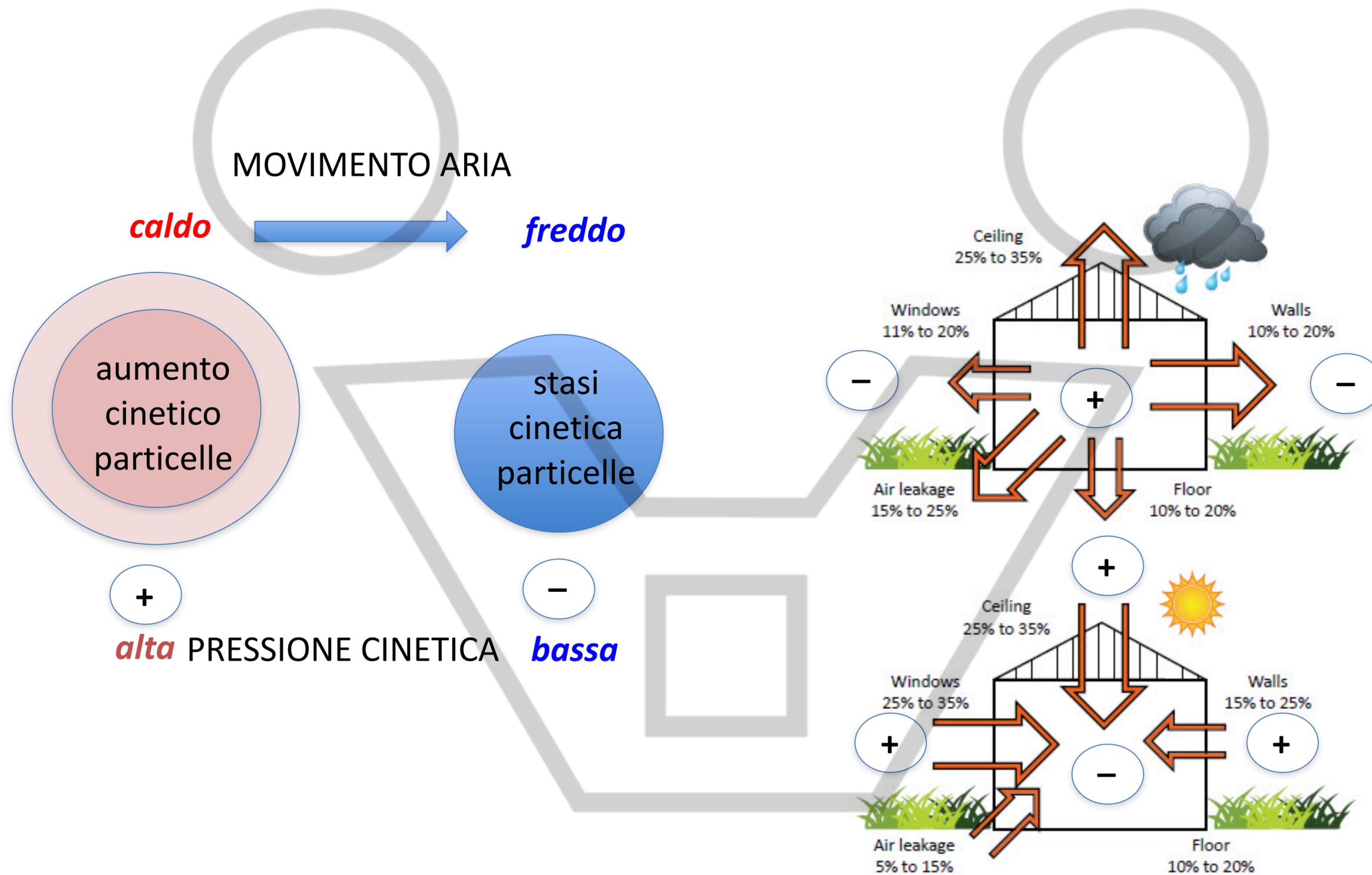
**Difference of density**

**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



FROM HIGHER PRESSURE

TO LOWER PRESSURE

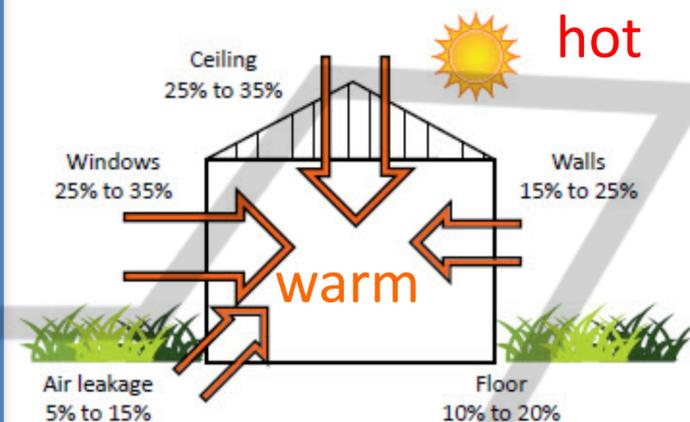
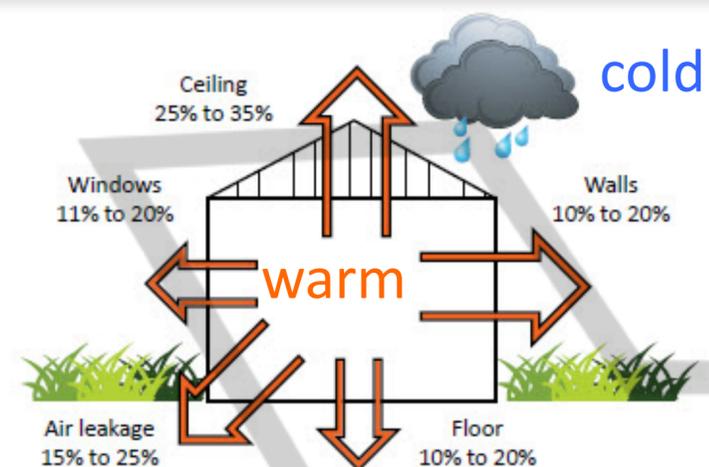
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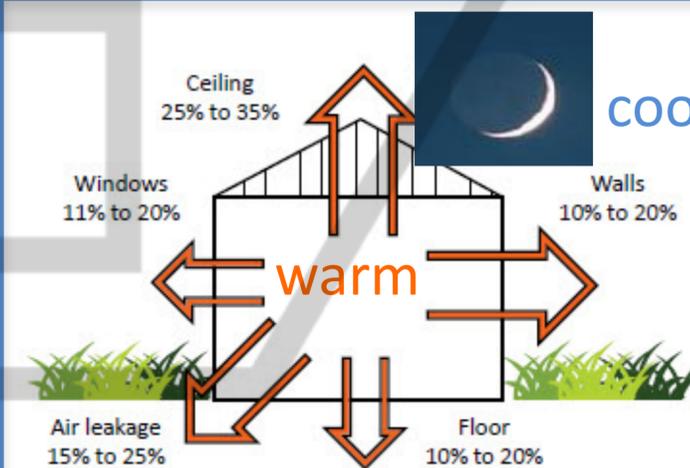
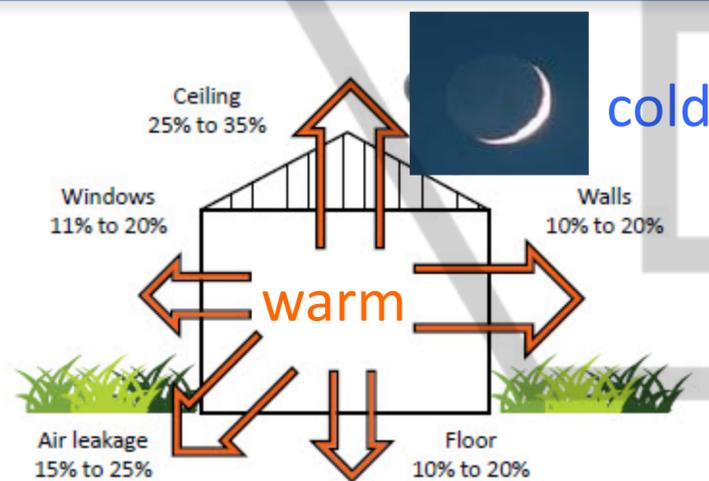
Winter time

Summer time

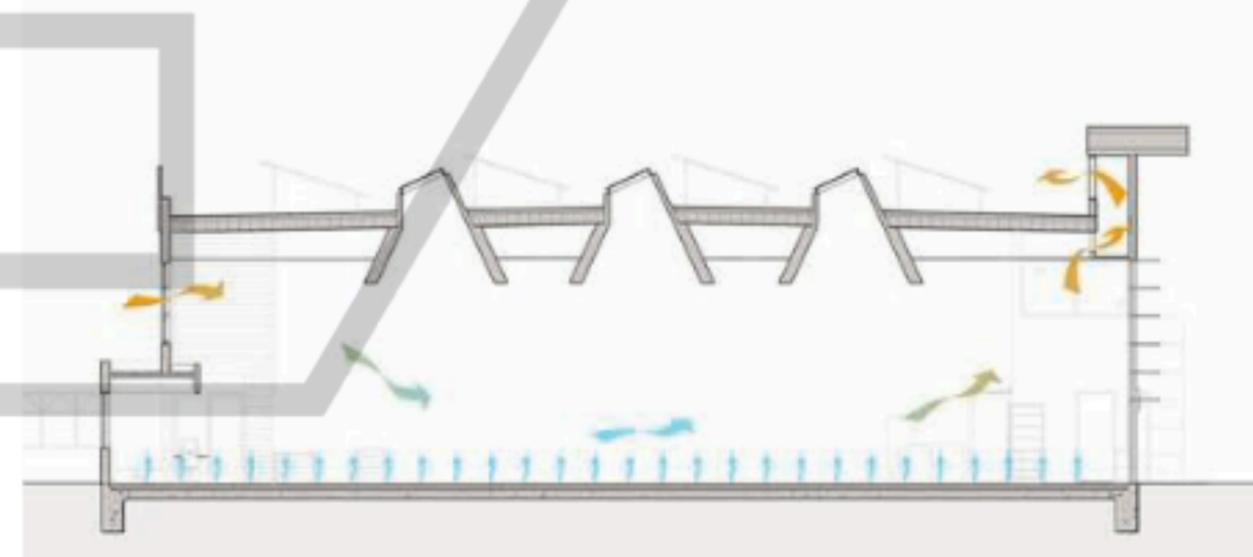
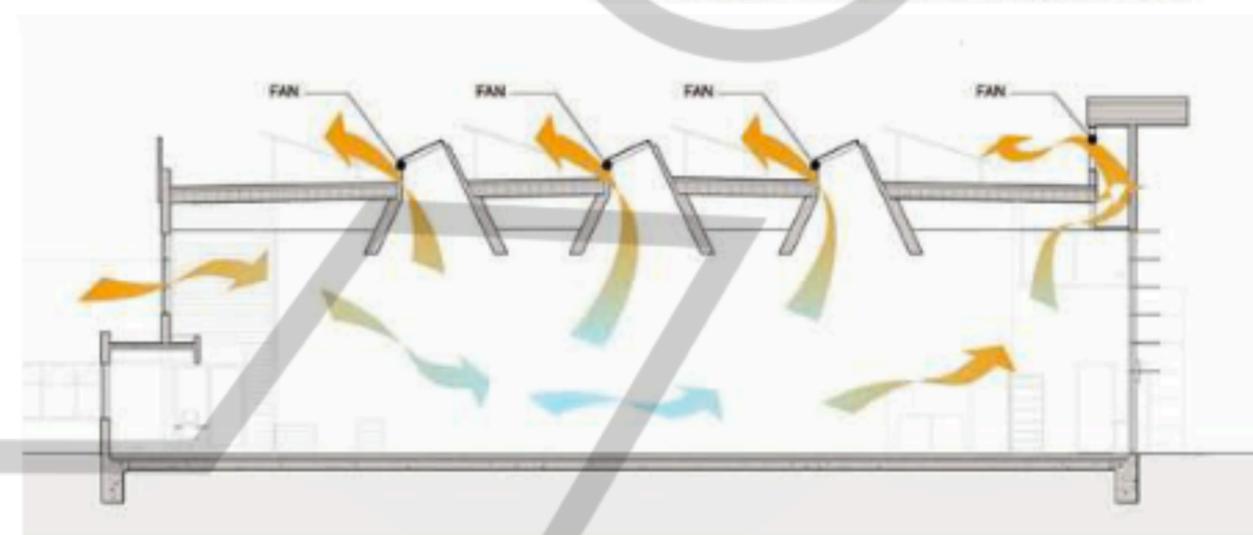
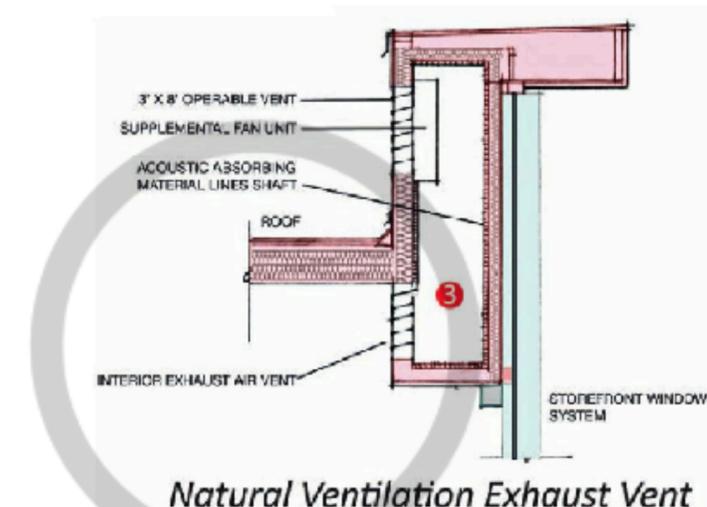
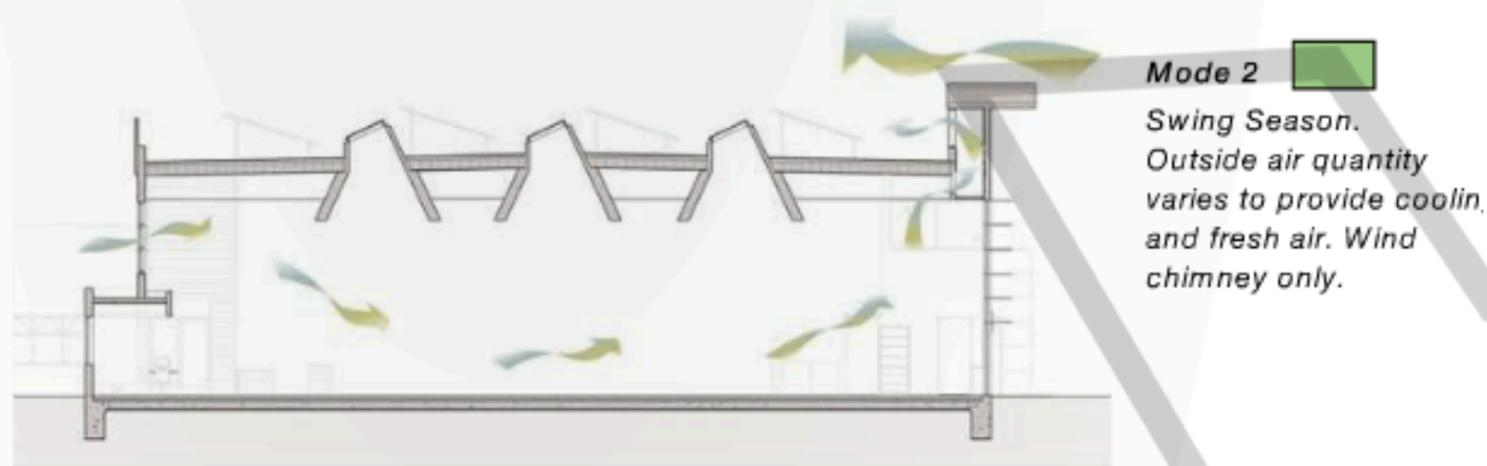
DAY



NIGHT



# Chimney



# EFFECT OF BAROMETRIC PRESSURE

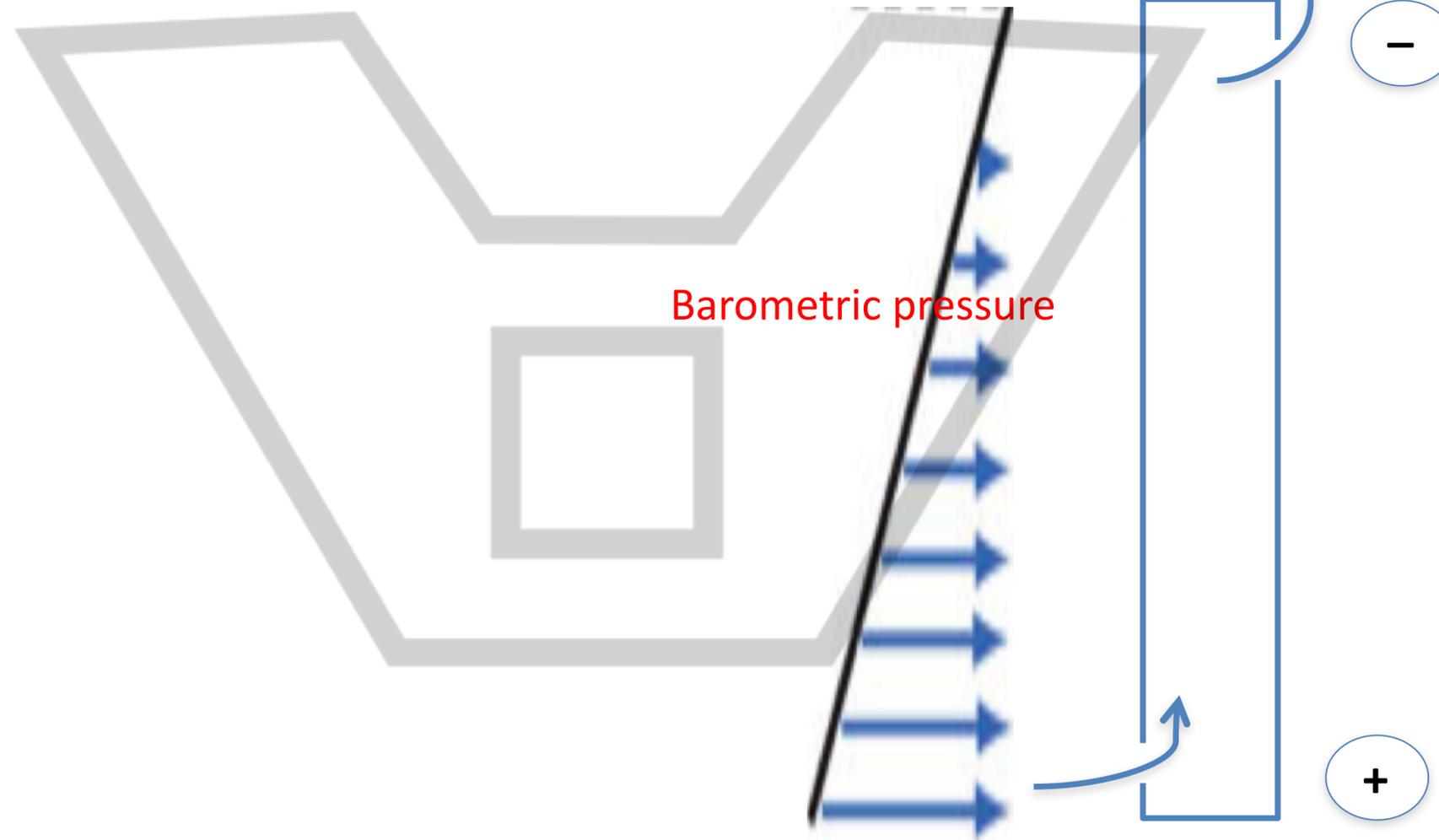
FROM HIGHER PRESSURE

TO LOWER PRESSURE

$f_{(high)}$

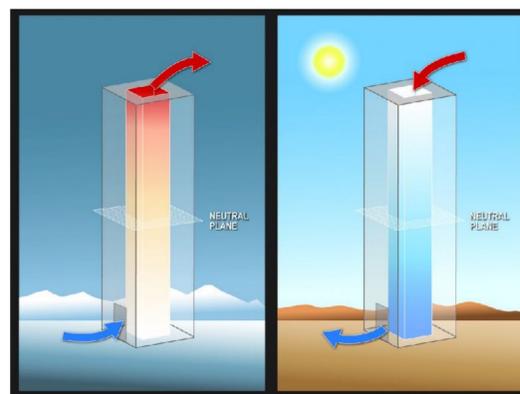
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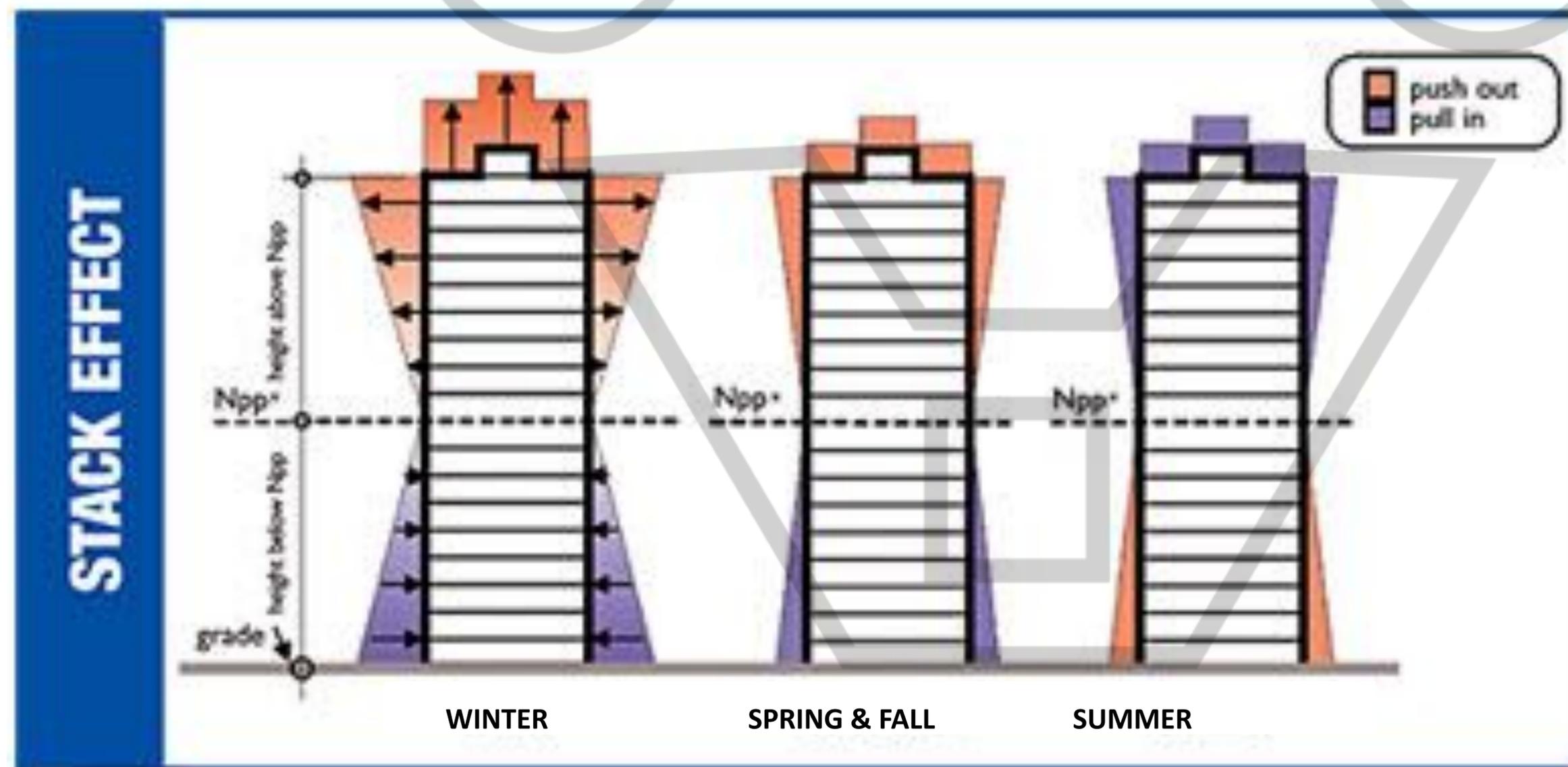
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## Combination of Barometric Pressure and Indoor Pressure

# The NEUTRAL PRESSURE PLANE (NPP)



\*Npp = Neutral pressure plane



### 9.16

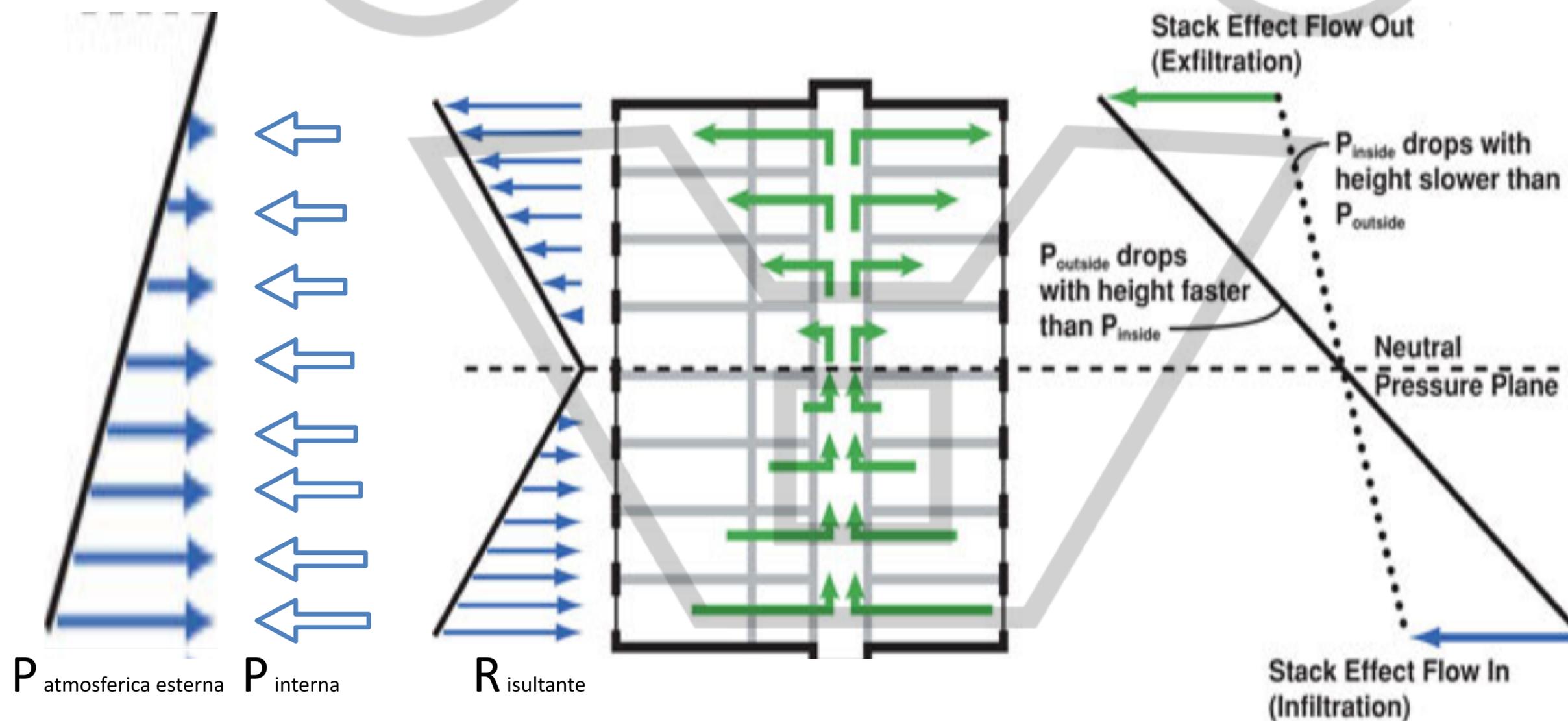
Photograph of the type of operable windows used at the Bullitt Center. Window diagram shows equal opening size around window's perimeter to reduce wear and provide even, controlled airflow.

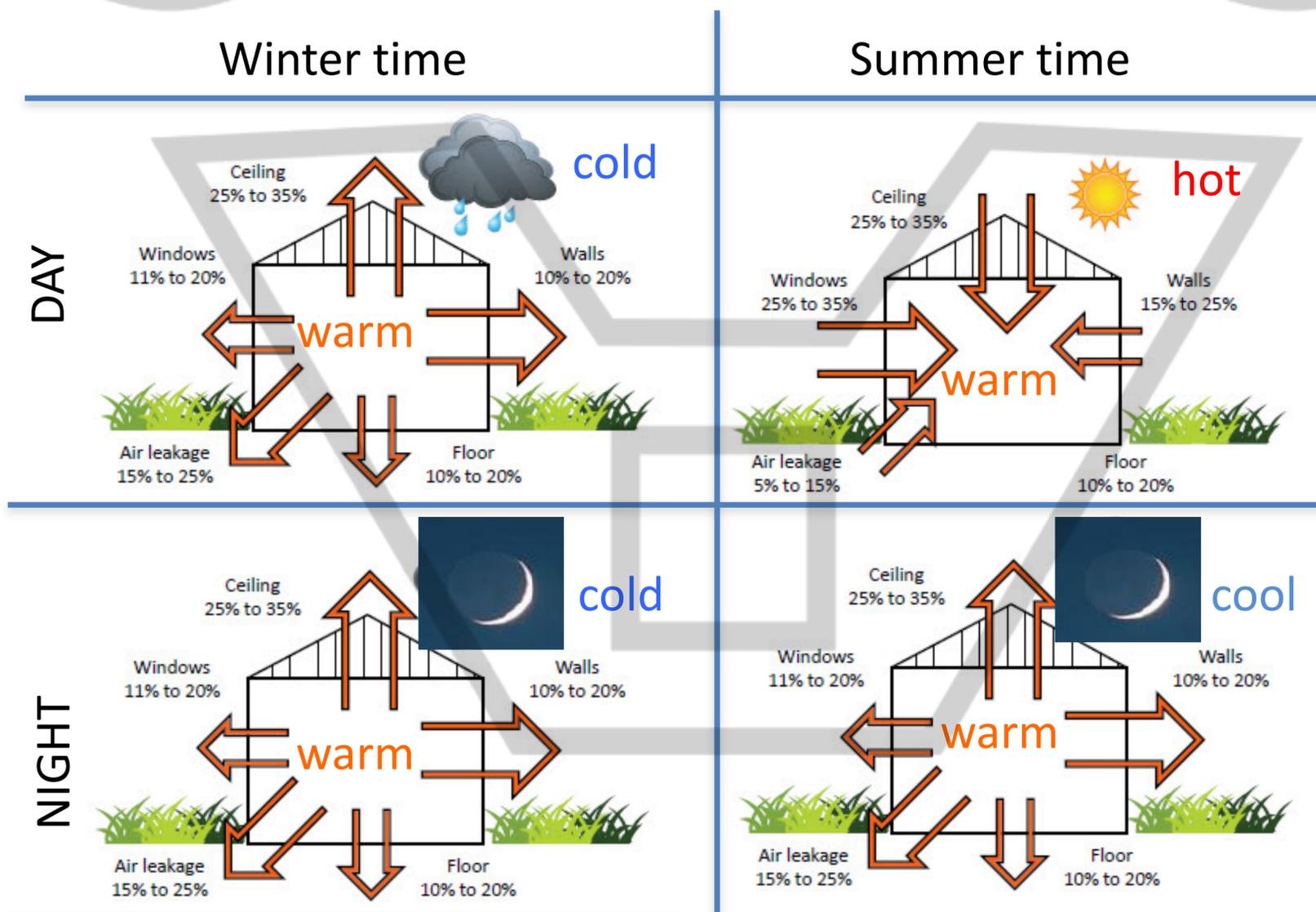
*Source: Photo and diagram courtesy Shuco.*

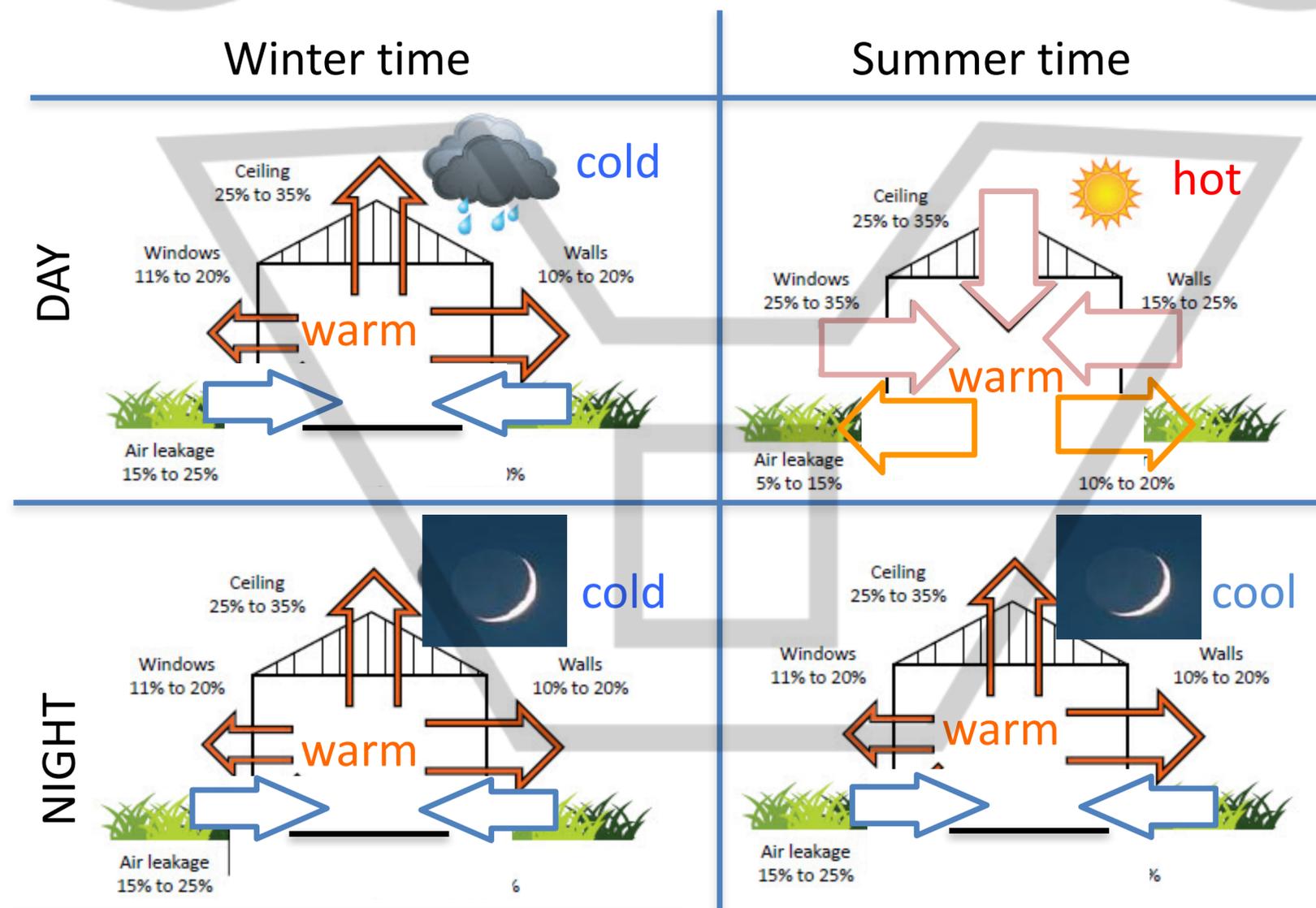
### 9.17

Wind rose for Seattle Boeing Field, showing frequency (darker color) of wind direction and velocity during summer afternoons.

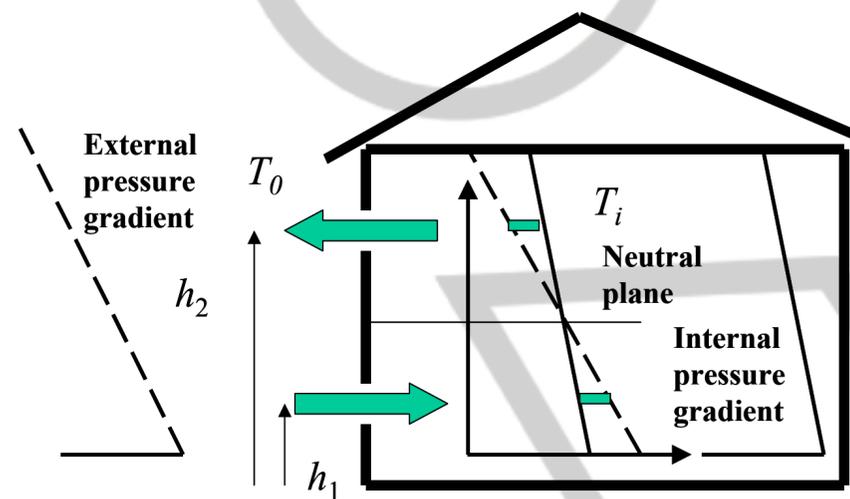
- The stack effect is magnified in taller buildings





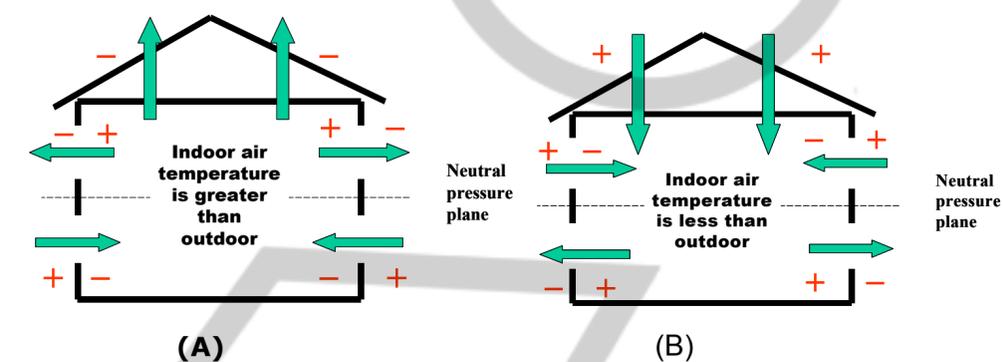


### Concept of the neutral level



26

### Stack driving flows in a building



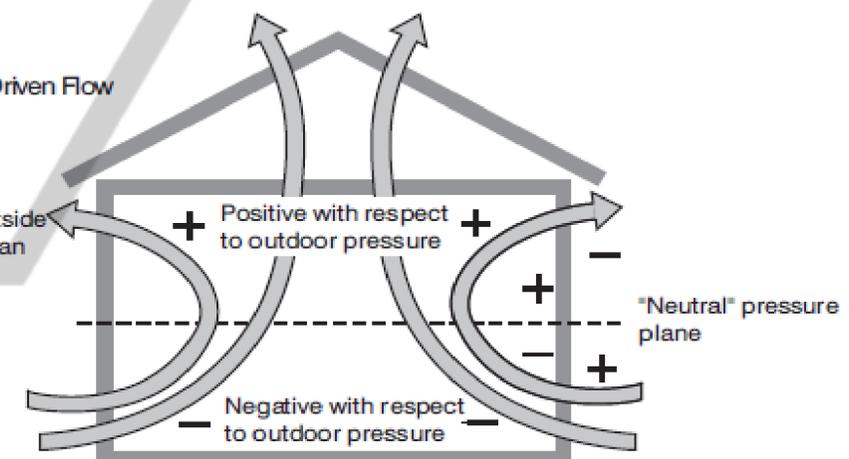
*Indoor air warmer than outdoor*

*Indoor air cooler than outdoor*

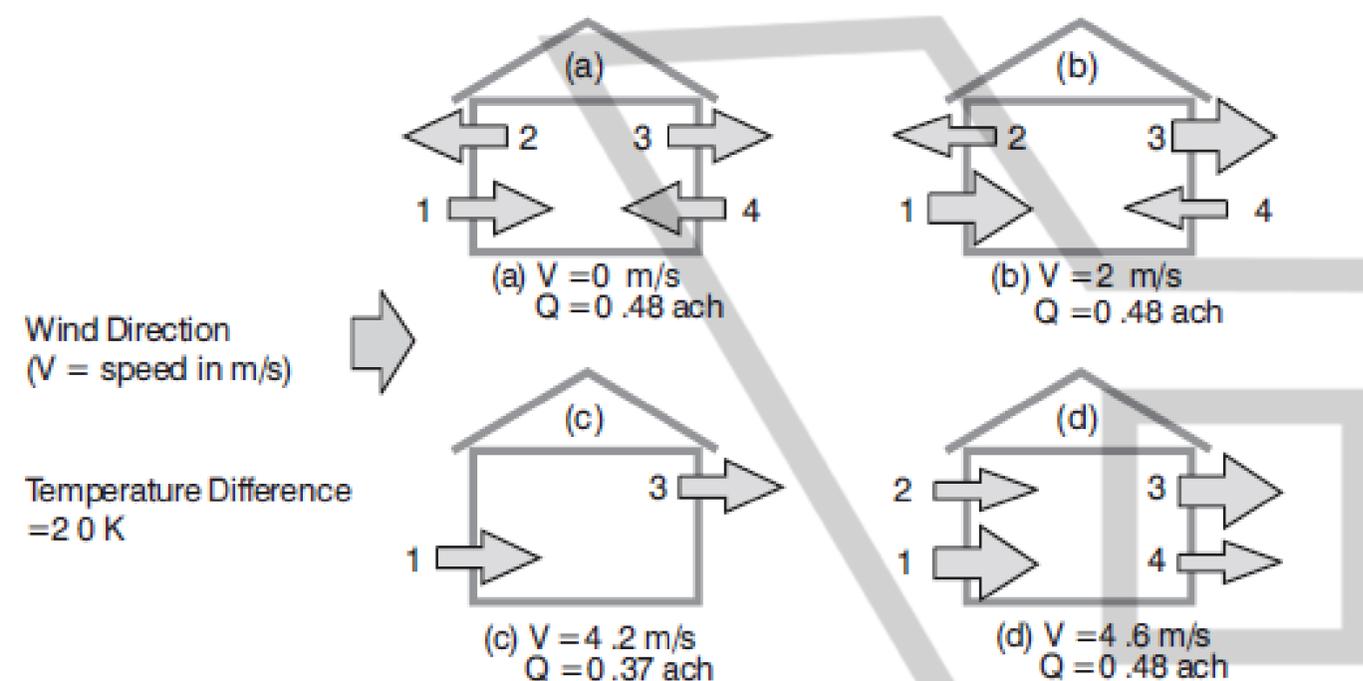
32

### (b) Stack Driven Flow

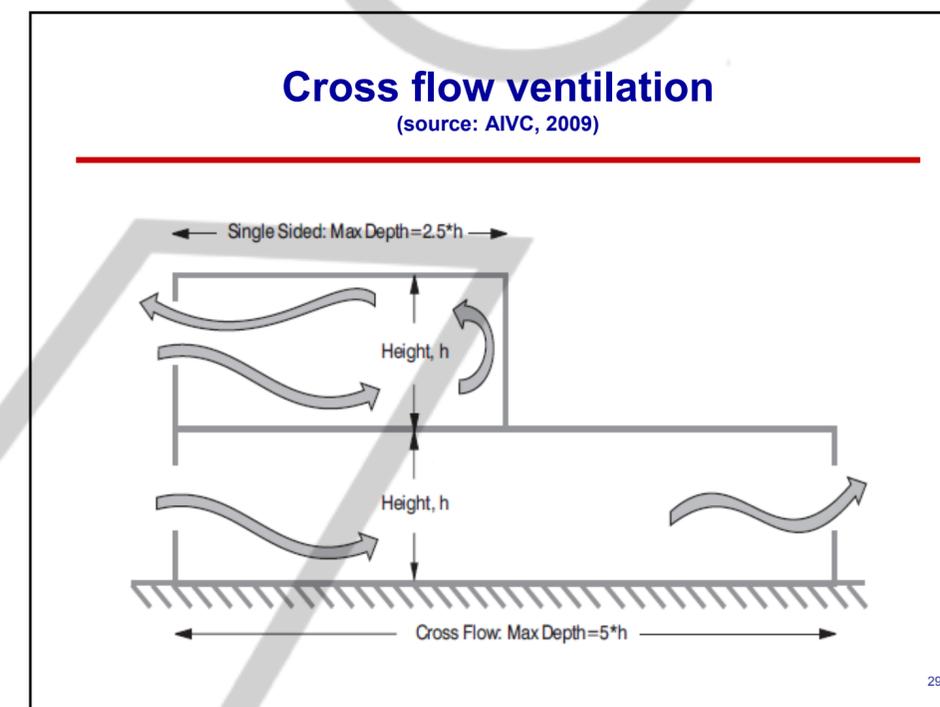
Flow pattern for outside temperature less than inside temperature



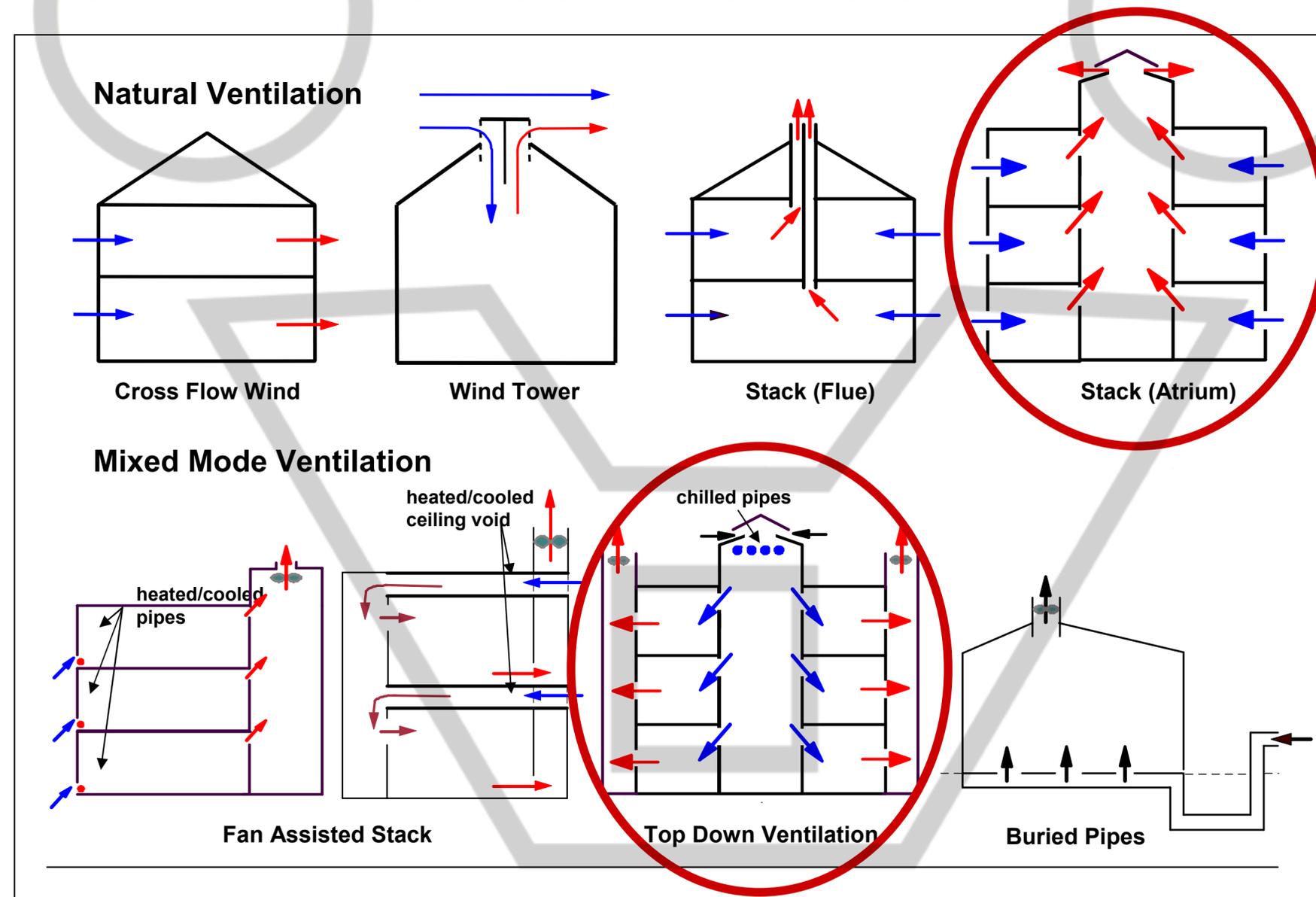
## Influence of wind and temperature (stack effect) on ventilation and air flow pattern



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



## Natural and Mixed Mode Ventilation Mechanisms



Courtesy of Martin Liddament via Yugu Li

### 3 MOVIMENTI DELL'ARIA PER **PRESSIONE**: CAUSE COMBinate

“Driving forces” of ventilation and infiltration:  $\Delta P$

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

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)**

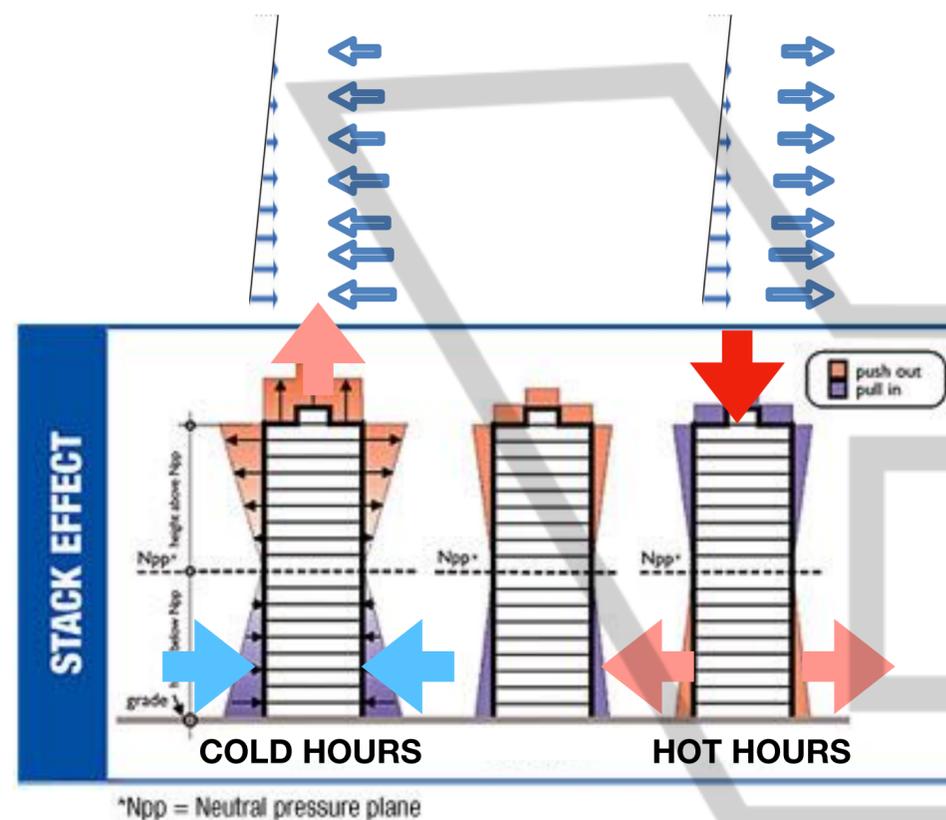
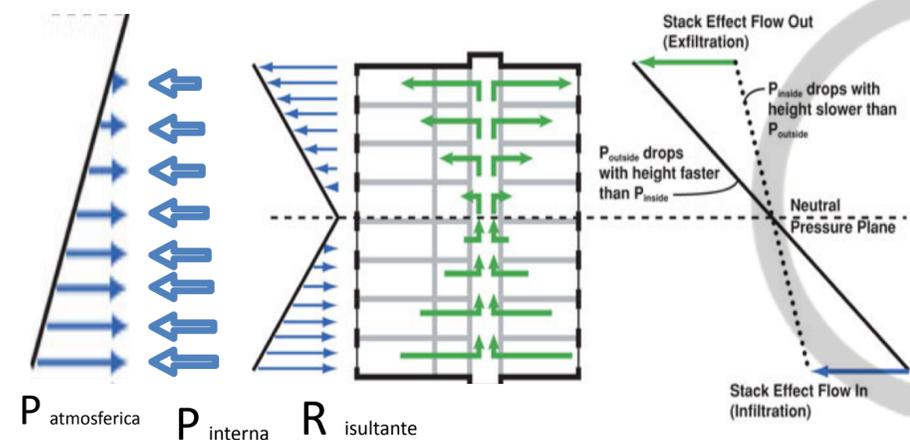
- Caused by the weight of a column of air located inside/outside a building
- Depends on air density and height above a neutral reference level
  - Density is a function of temperature (so it is temperature driven)

– **Mechanical air handling equipment (fans)**

- Fans are used to supply, recirculate, exhaust, and otherwise balance pressures and flows in buildings

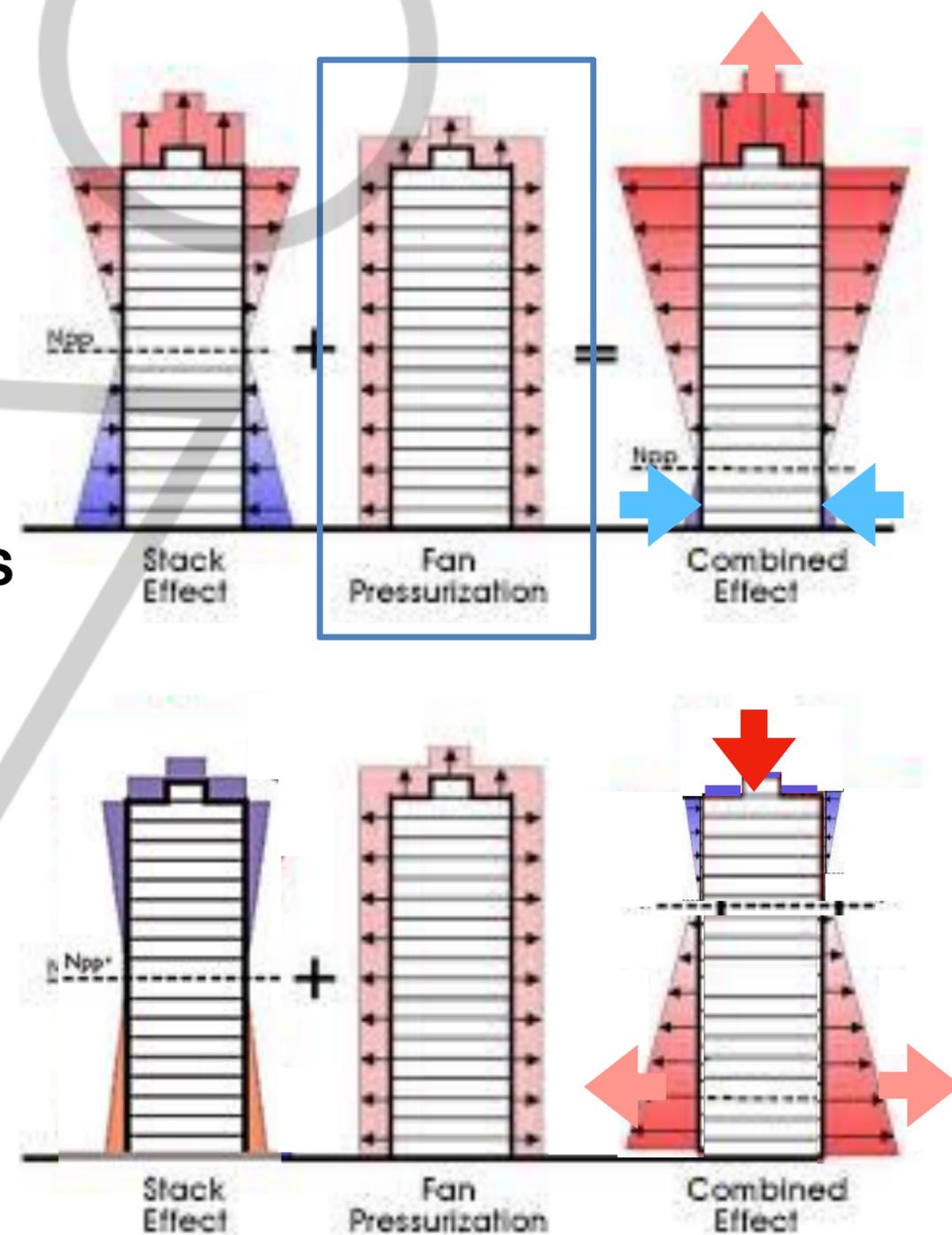
- The stack effect is magnified in taller buildings

# AIR MOVEMENTS IN HOT/COLD HOURS

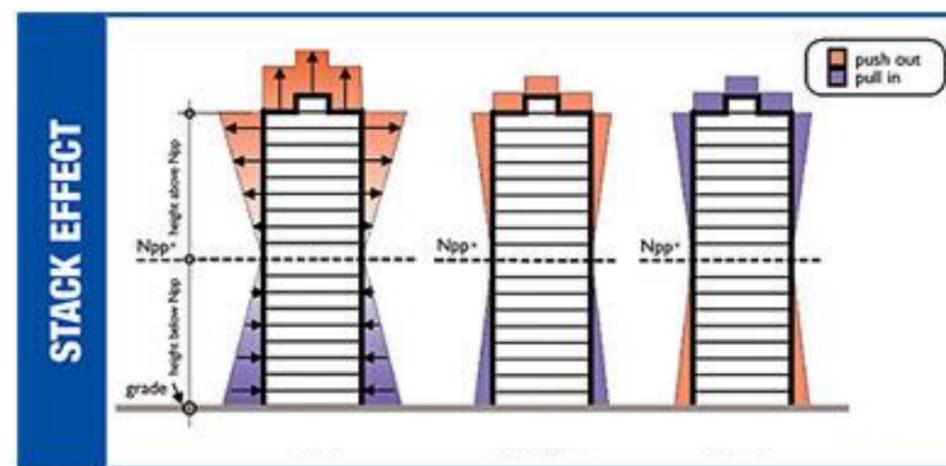
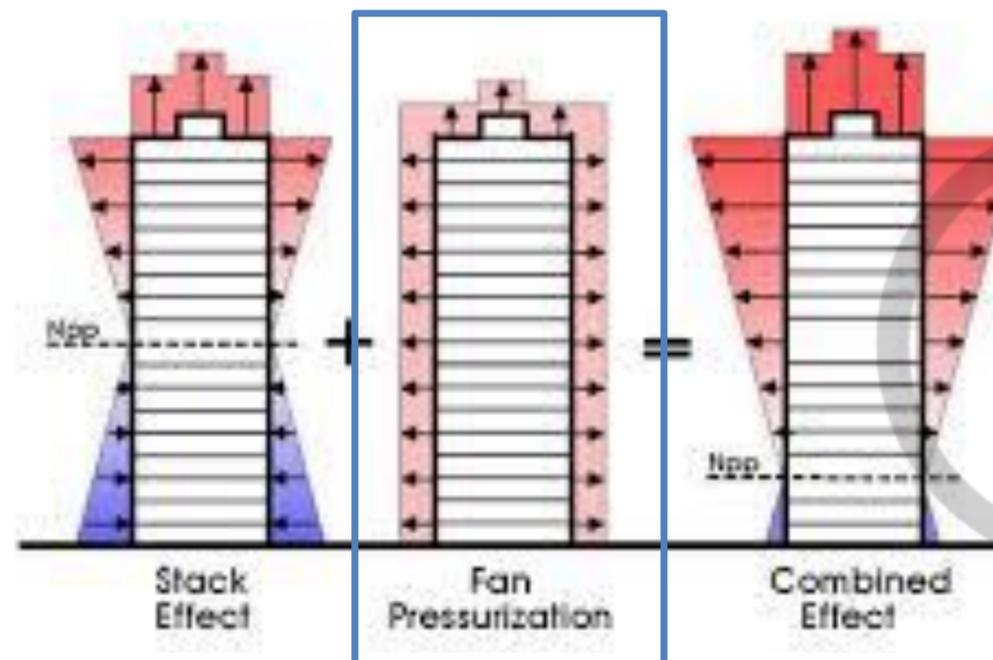


**COLD HOURS**

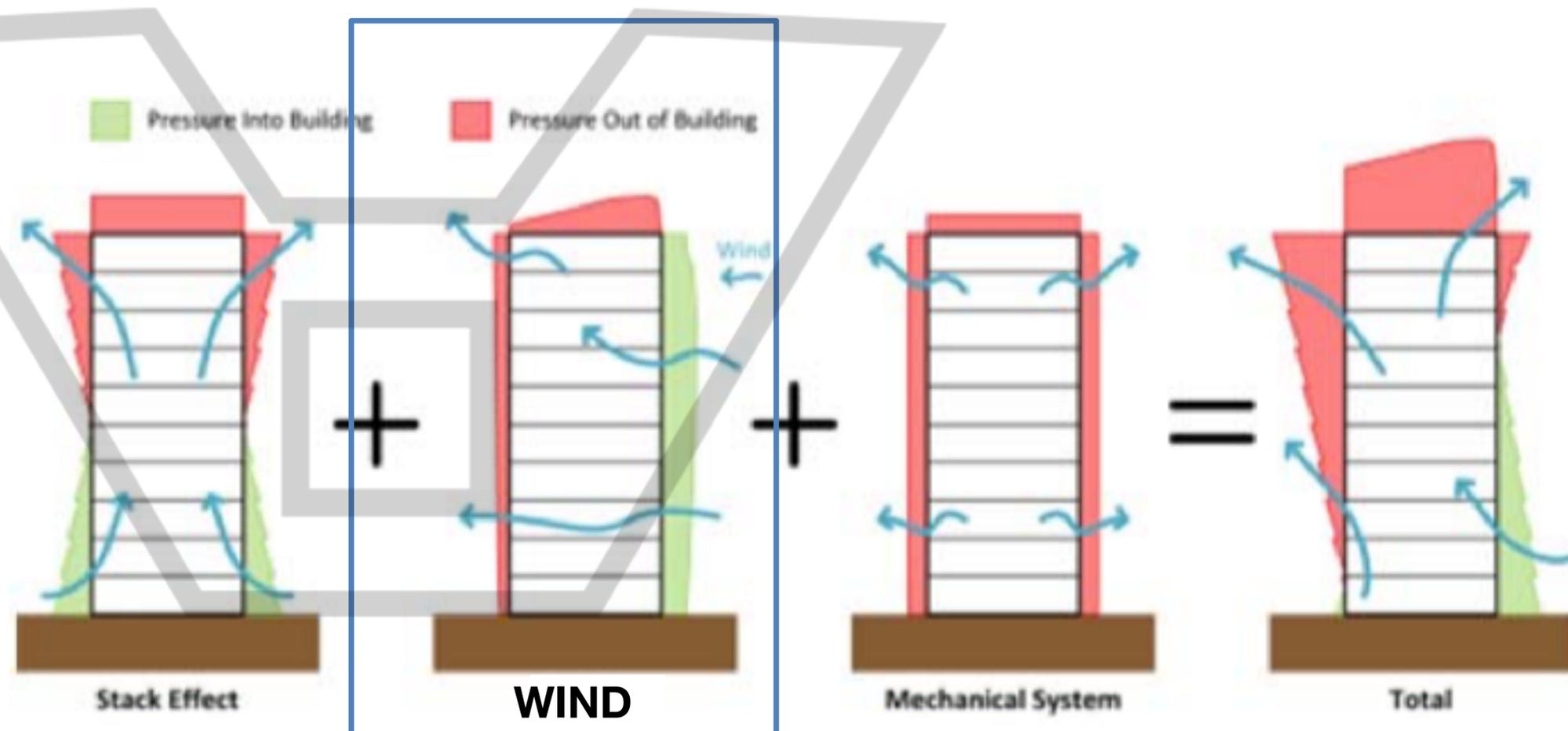
**HOT HOURS**



# AIR MOVEMENTS IN COLD WINDY HOURS



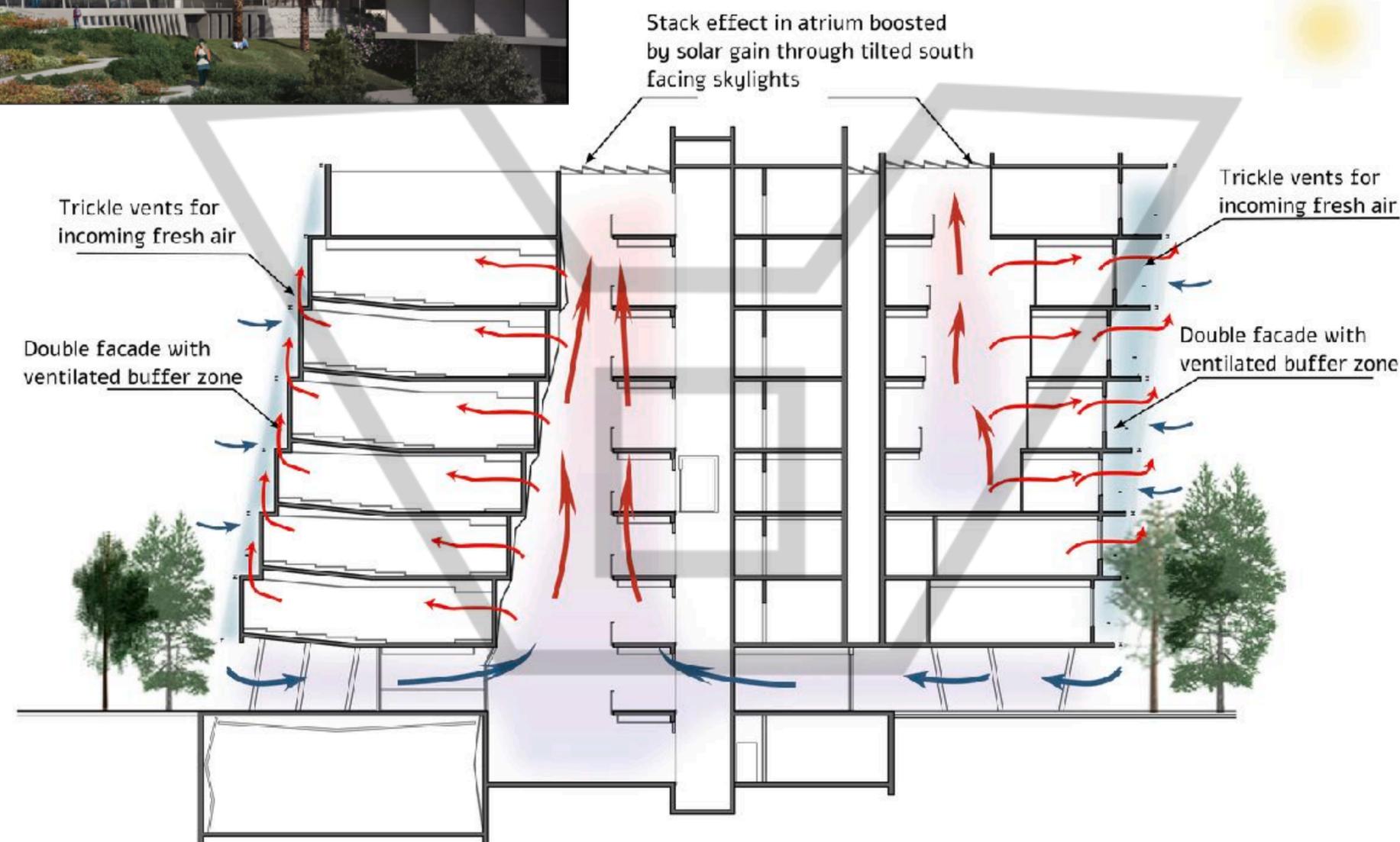
\*Npp = Neutral pressure plane





<https://www.archdaily.com>

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

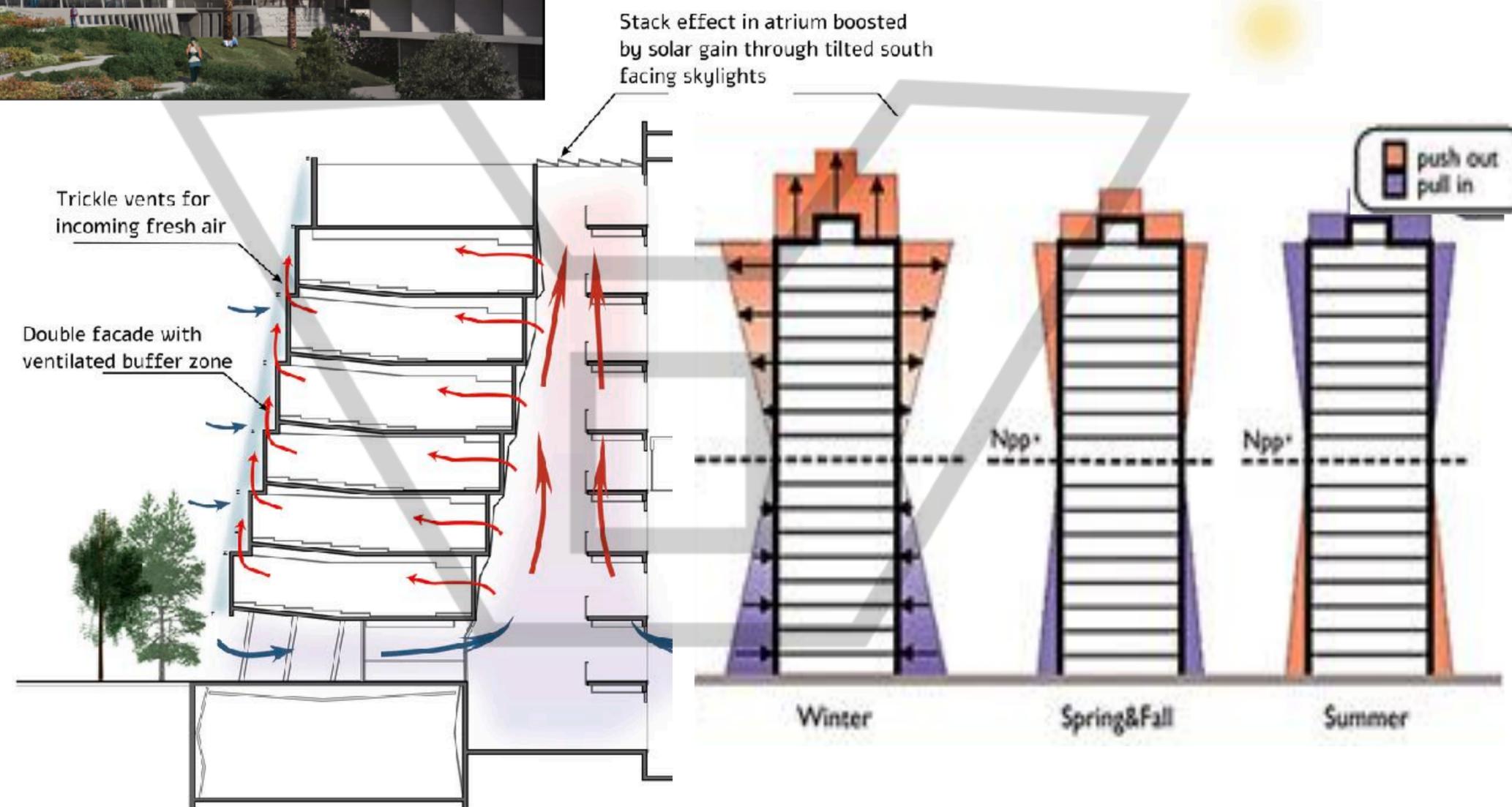


Climatic Diagram



<https://www.archdaily.com>

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



Climatic Diagram

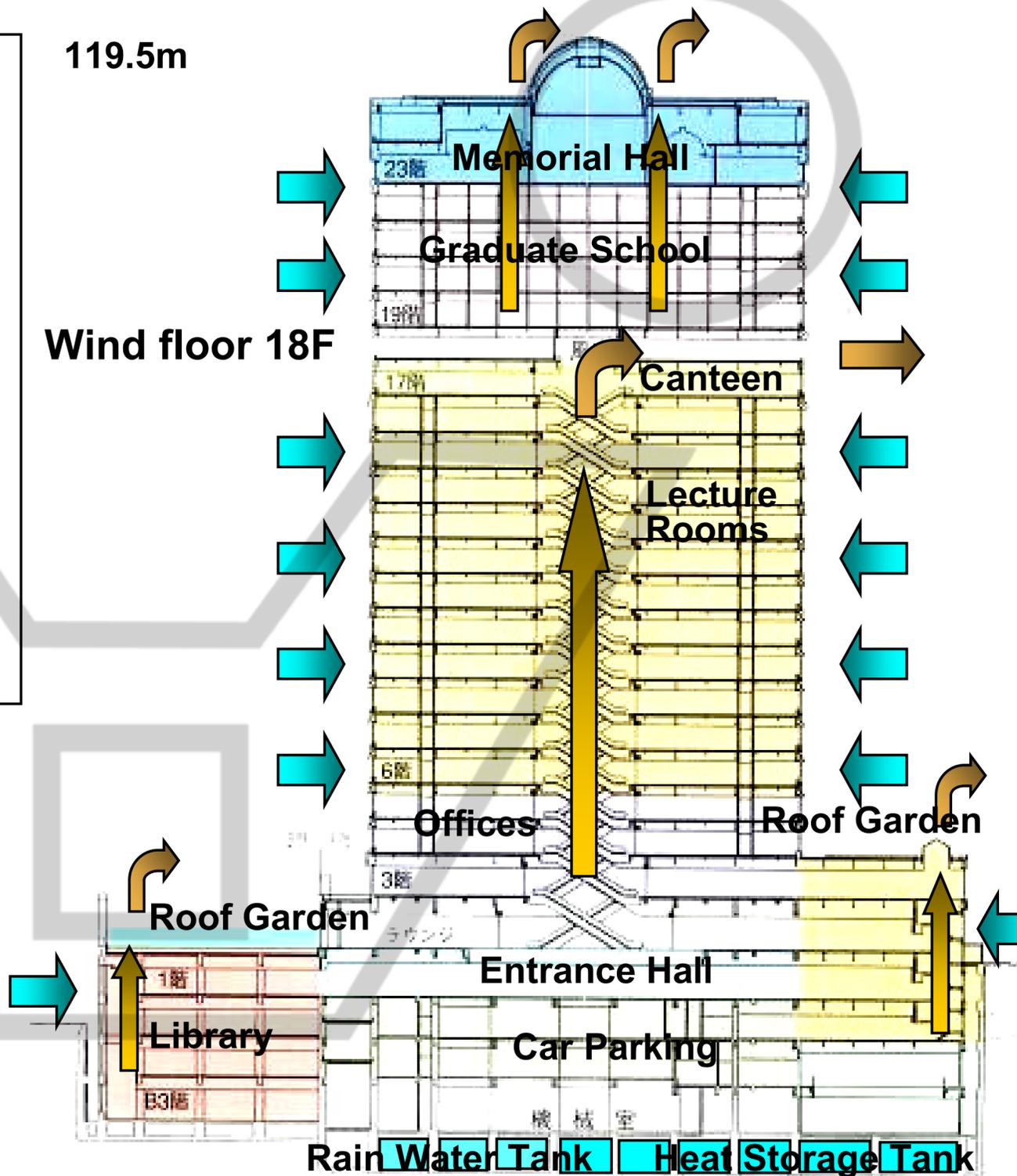
**Meiji University Liberty Tower, Tokyo, Japan**  
(source: Professor Toshihara Ikaga, Keio University)

**Wind Floor for Hybrid Ventilation**



Gross Floor Area: 59000 m<sup>2</sup>  
completed in 1998

34





**Hybrid System:**  
The hybrid system combines various aspects of the above systems and is used to classify building systems that do not "fit" into a precise category. Such buildings may use a layer of screens or non-glazed mate on either the inside or outside of the primary environmental barrier. The Tjibaou Center in New Caledonia by Renzo Piano may be used to characterize this type of Hybrid system.

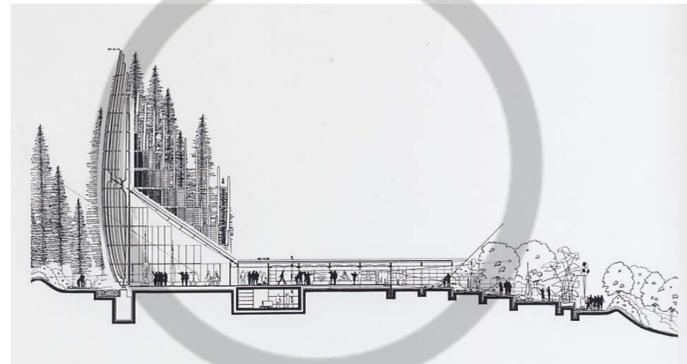
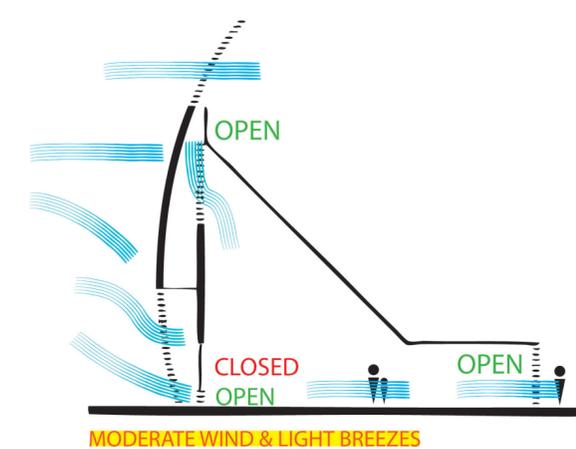
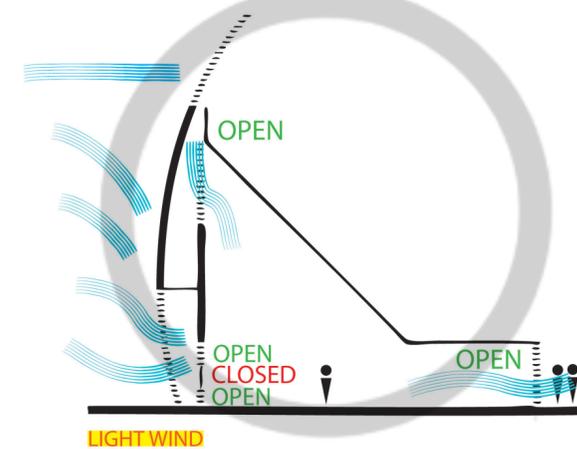
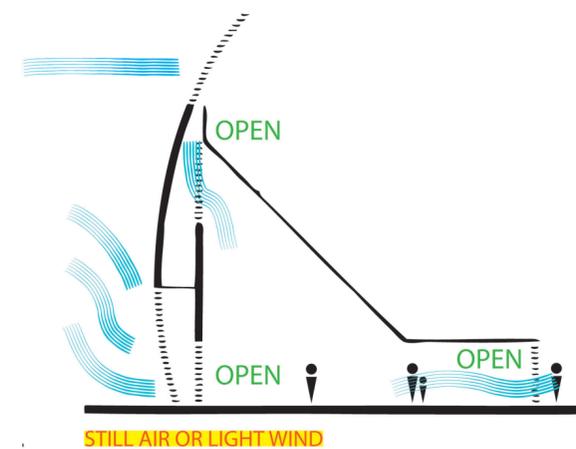
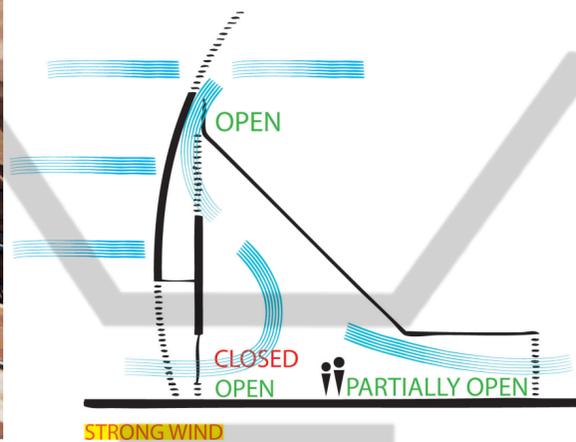


Figure 6:  
Cross section of the Tjibaou Center by Piano illustrating the use of a hybrid system

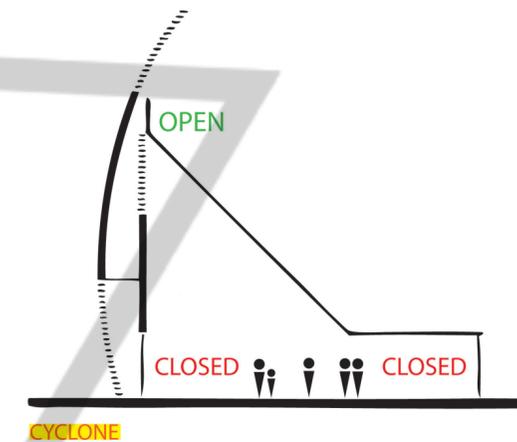
VENTILATION DUE TO WIND FORCES | pressure differential created by incoming force of wind



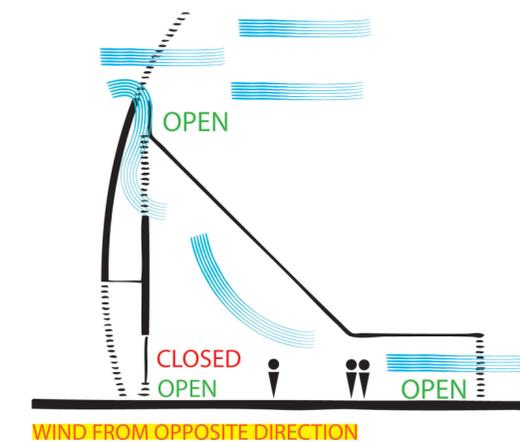
ventilation relies solely upon wind forces | the height of the building is not utilized



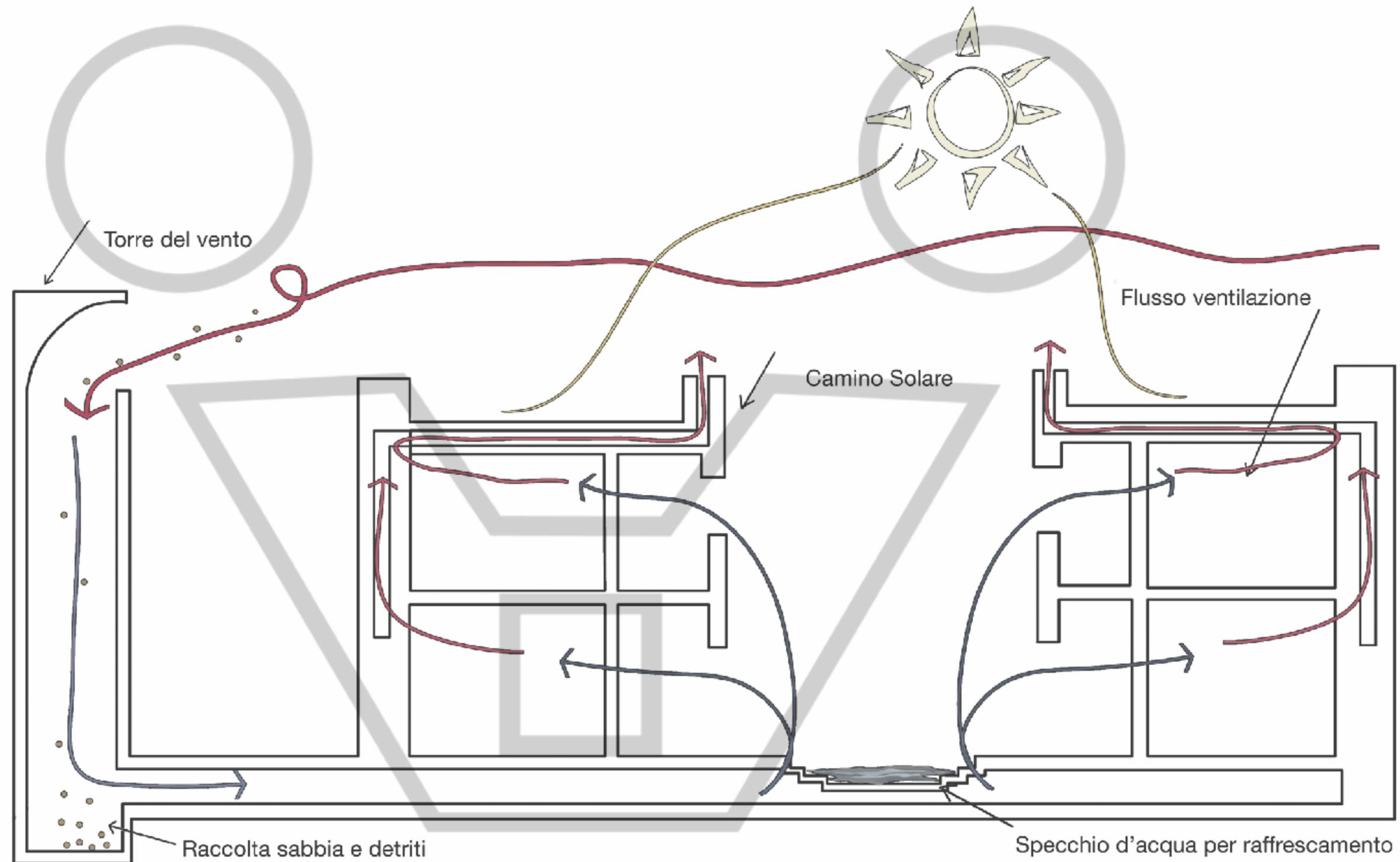
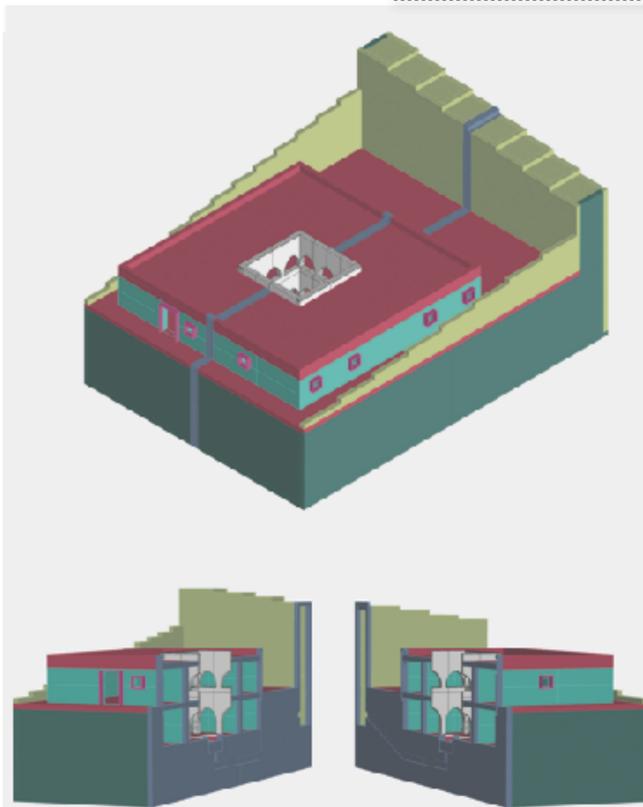
ventilation relies upon convection & the negative pressure created by the wind



all louvred openings are closed

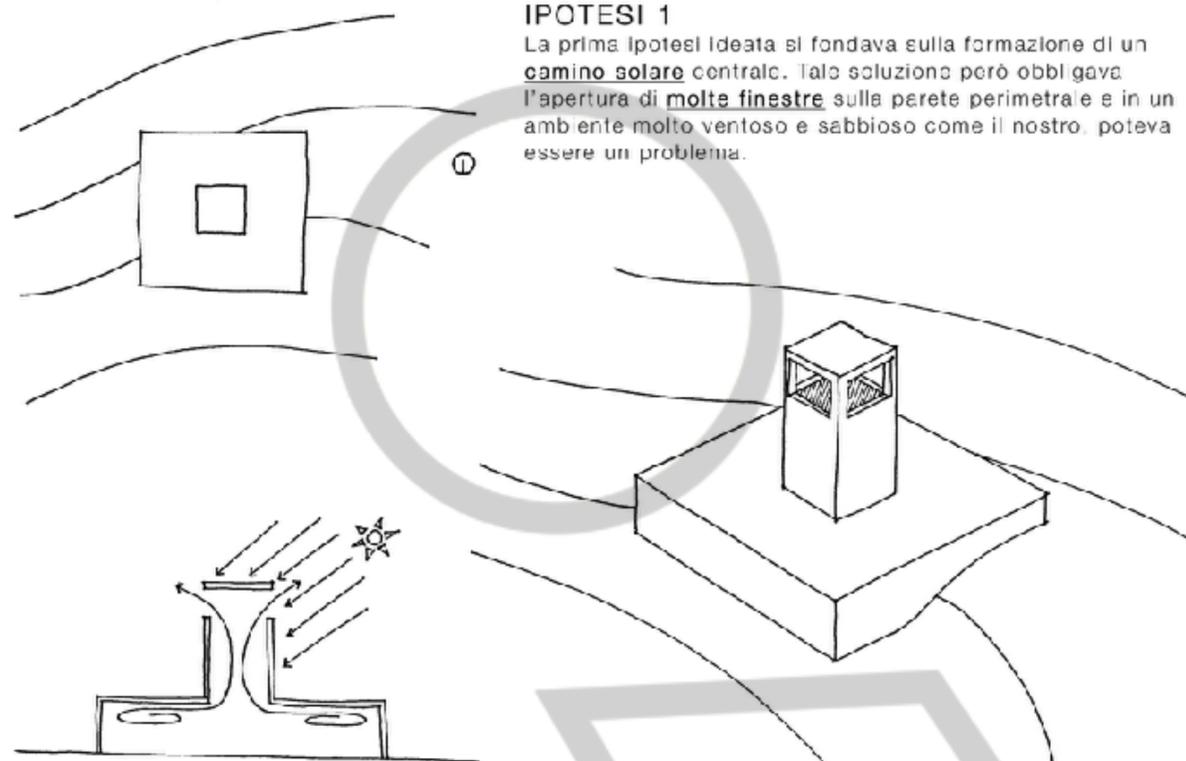


wind coming across lagoon rather than bay  
utilization of wind ventilation & stack ventilation



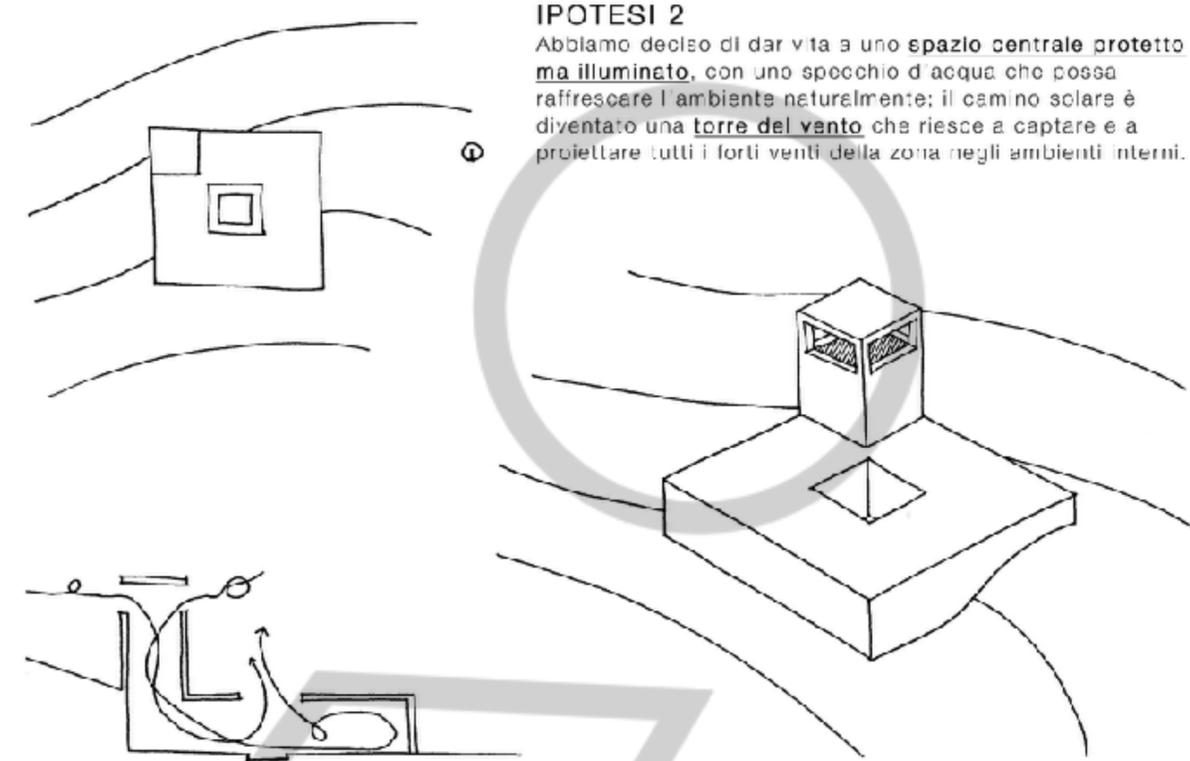
### IPOTESI 1

La prima ipotesi ideata si fondava sulla formazione di un camino solare centrale. Tale soluzione però obbligava l'apertura di molte finestre sulla parete perimetrale e in un ambiente molto ventoso e sabbioso come il nostro, poteva essere un problema.



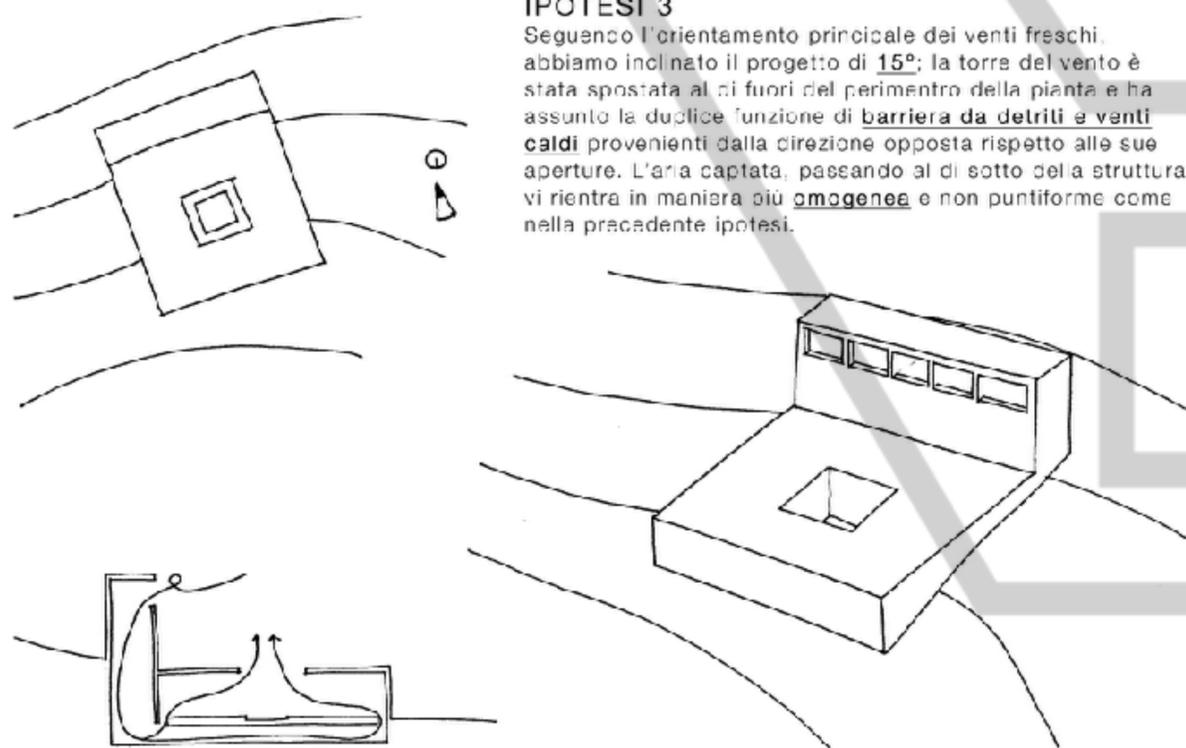
### IPOTESI 2

Abbiamo deciso di dar vita a uno spazio centrale protetto ma illuminato, con uno specchio d'acqua che possa raffreddare l'ambiente naturalmente; il camino solare è diventato una torre del vento che riesce a captare e a proiettare tutti i forti venti della zona negli ambienti interni.



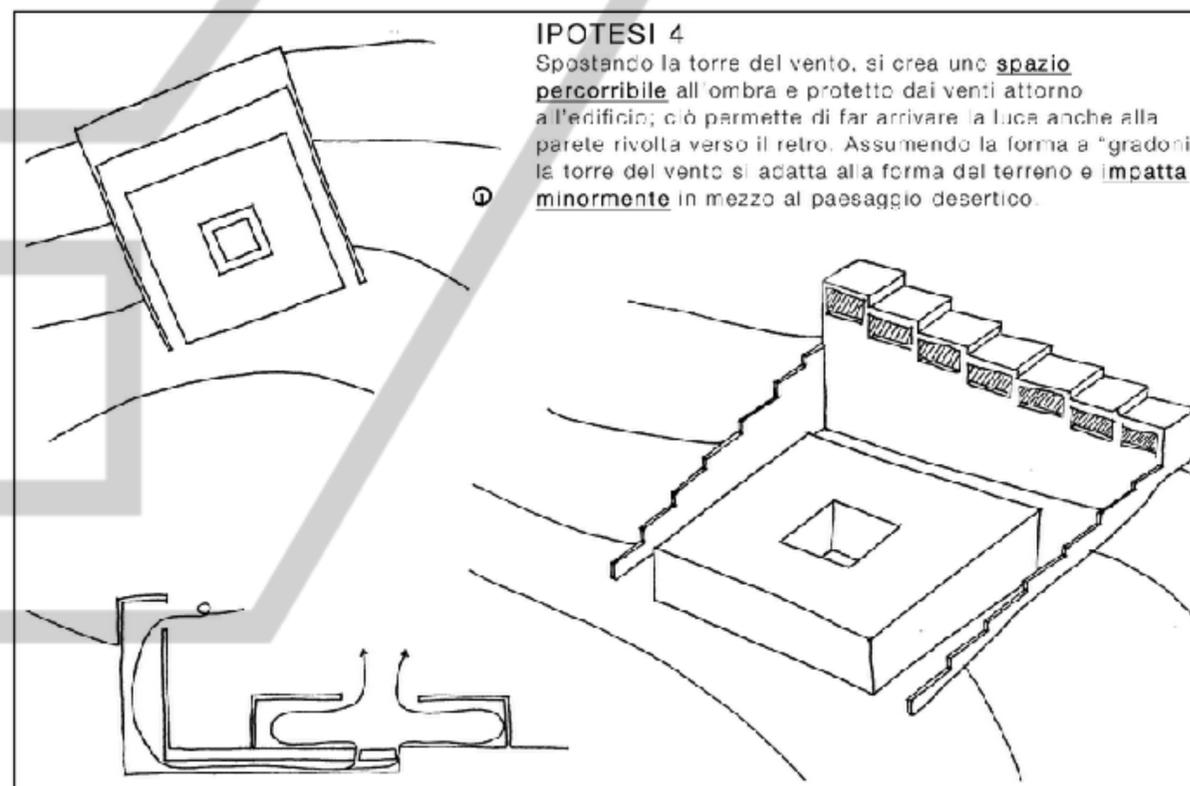
### IPOTESI 3

Seguendo l'orientamento principale dei venti freschi, abbiamo inclinato il progetto di 15°; la torre del vento è stata spostata al di fuori del perimetro della pianta e ha assunto la duplice funzione di barriera da detriti e venti caldi provenienti dalla direzione opposta rispetto alle sue aperture. L'aria captata, passando al di sotto della struttura, vi rientra in maniera più omogenea e non puntiforme come nella precedente ipotesi.



### IPOTESI 4

Spostando la torre del vento, si crea uno spazio percorribile all'ombra e protetto dai venti attorno all'edificio; ciò permette di far arrivare la luce anche alla parete rivolta verso il retro. Assumendo la forma a "gradoni", la torre del vento si adatta alla forma del terreno e impatta minormente in mezzo al paesaggio desertico.





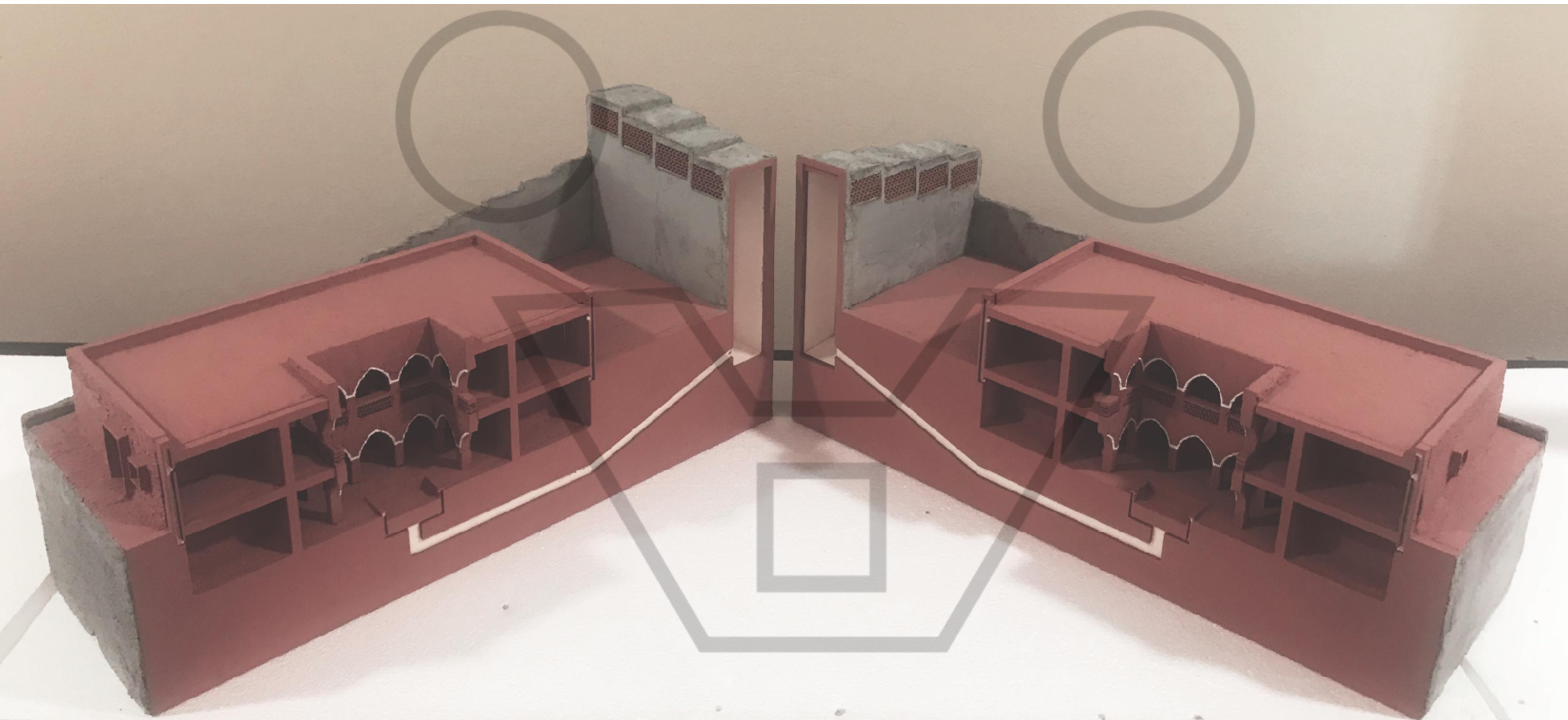
UNIVERSITÀ  
DEGLI STUDI  
FIRENZE  
Scuola di  
Architettura



**MAILAB**

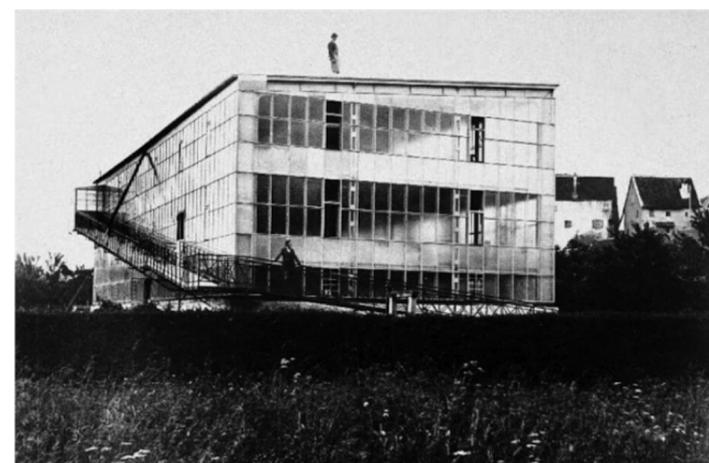
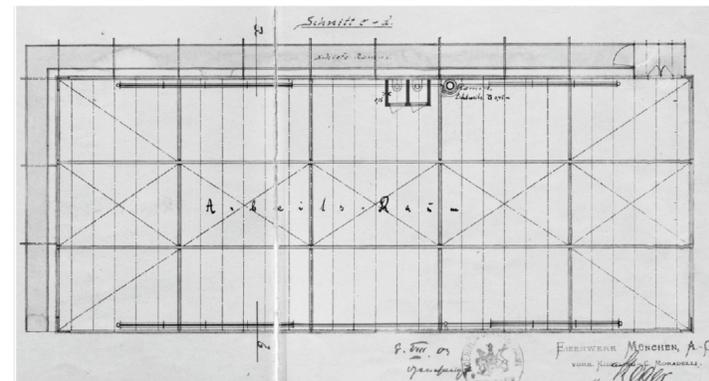
MULTIMEDIA | ARCHITECTURE | INTERACTION

ENVIRONMENTAL DESIGN  
prof. arch. Giuseppe Ridolfi



# The **DOUBLE SKIN FACADE**

THE FIRST EXAMPLE: STEIFF FACTORY in GIENGEN 1903



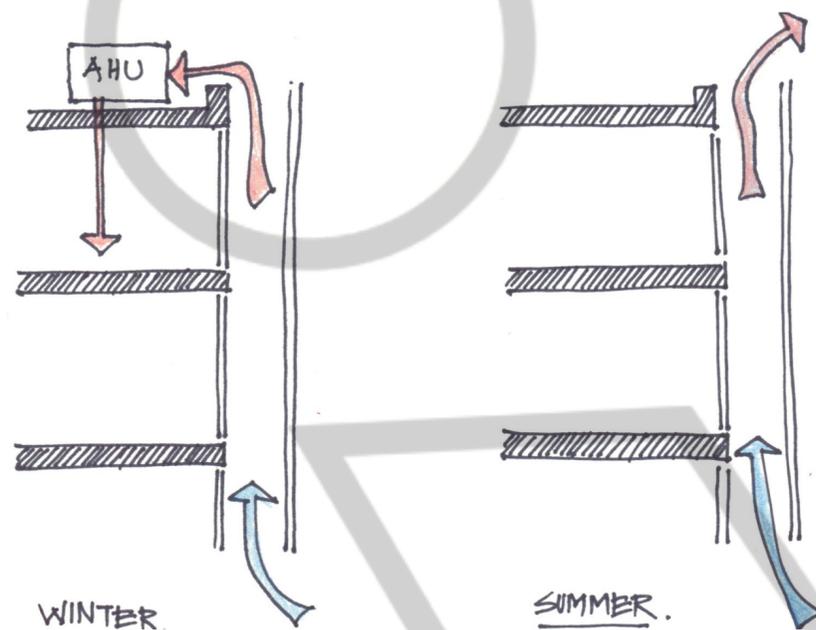
**THE ZUYEV WORKERS CLUB**  
ILYA GOLOSOV  
1926



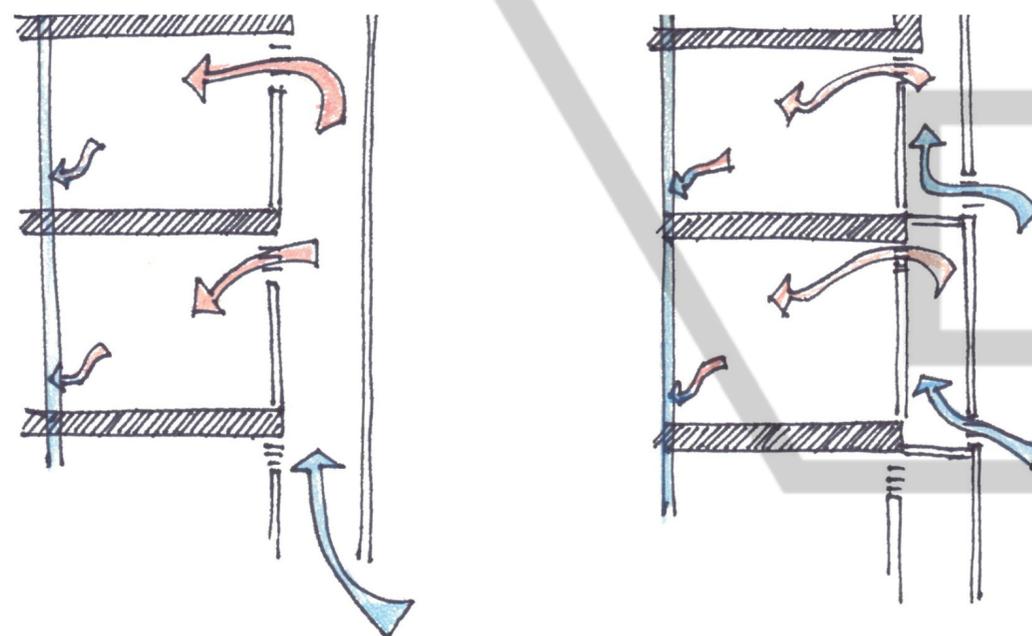
The Zuyev Workers Club. Ilya Golosov, 1926. A precedent of double skin glazed walls in Moscow before the Centrosoyuz.

## PRE-HEATING / REFRESHING SYSTEM

Double Skin Façade as a central direct pre-heater of the supply air

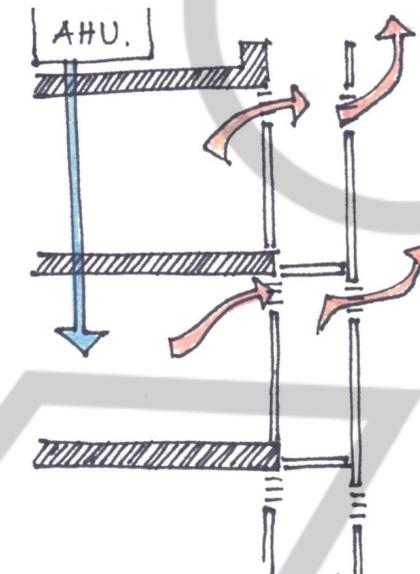


Double Skin Façade as an individual supply of the preheated air

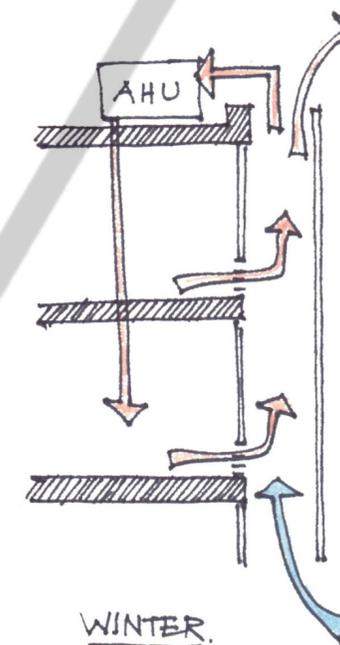


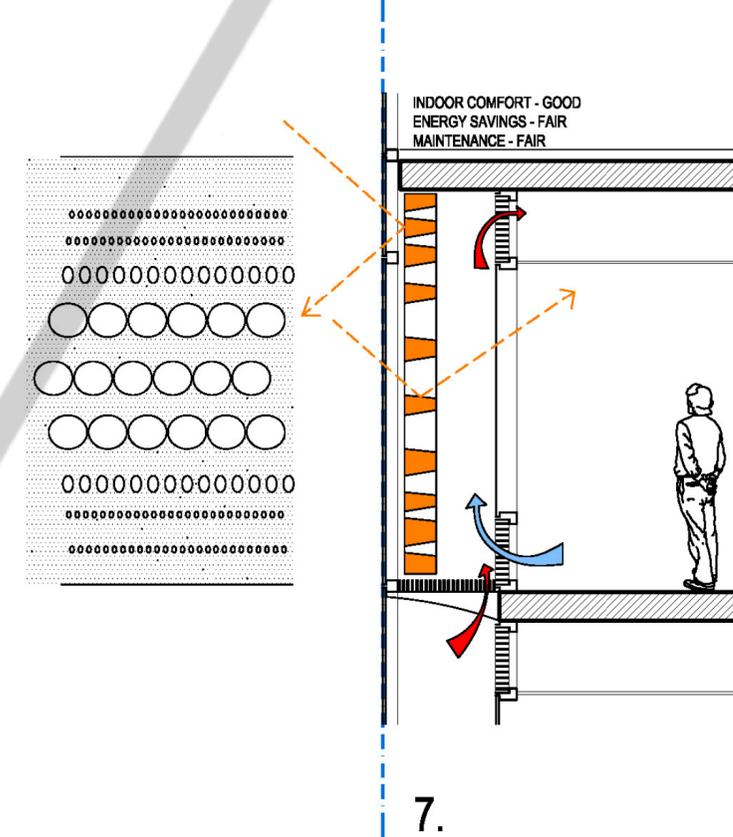
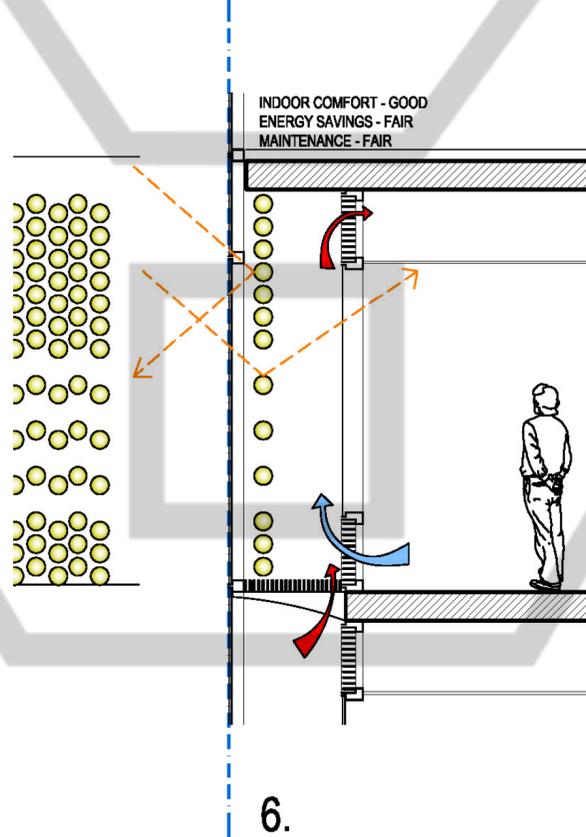
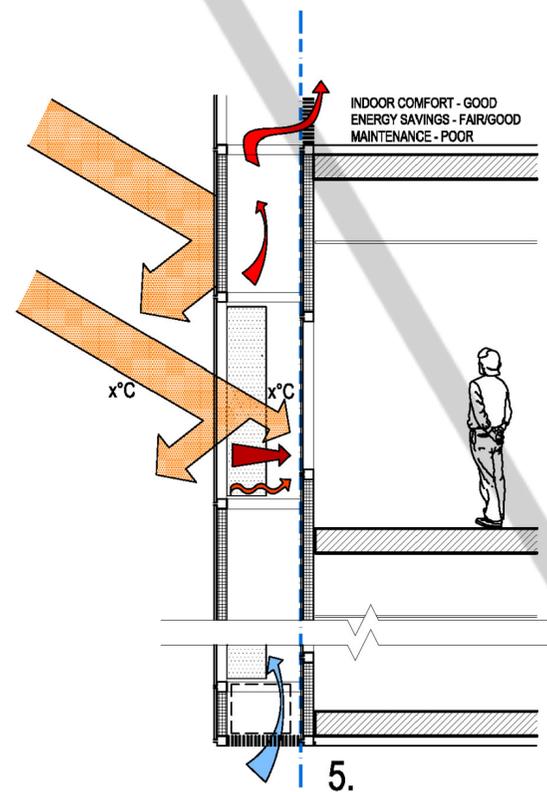
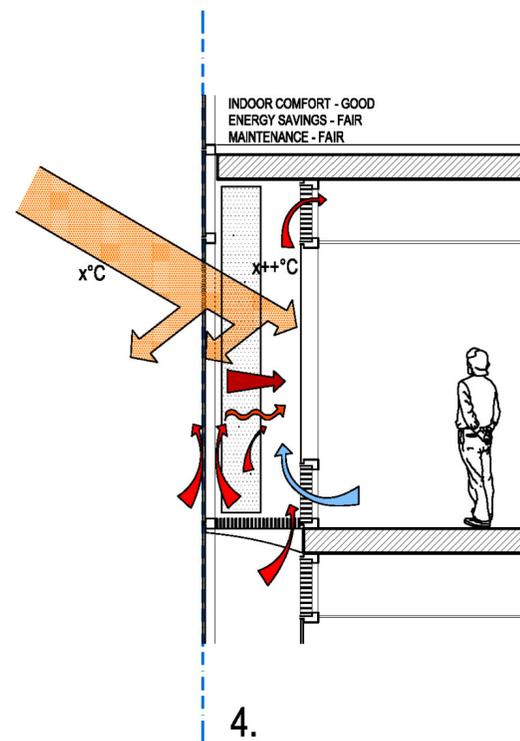
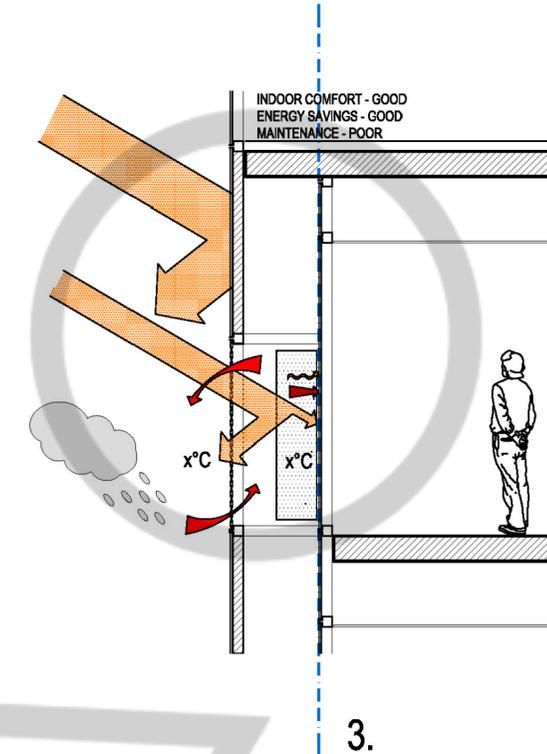
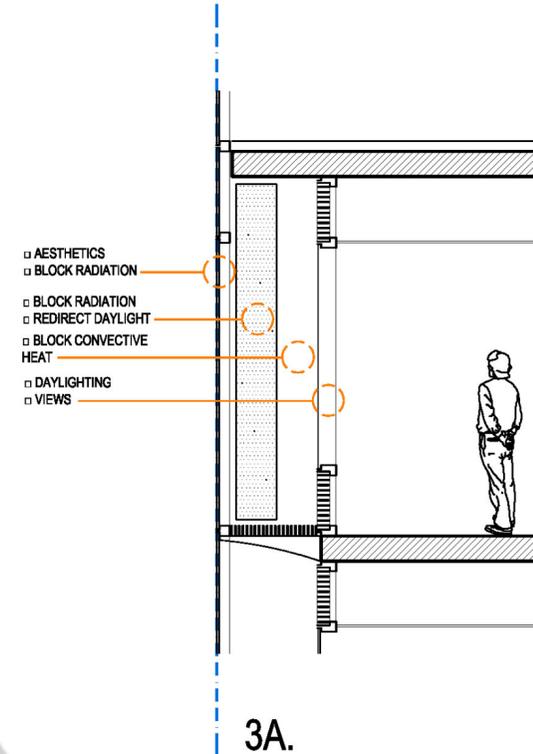
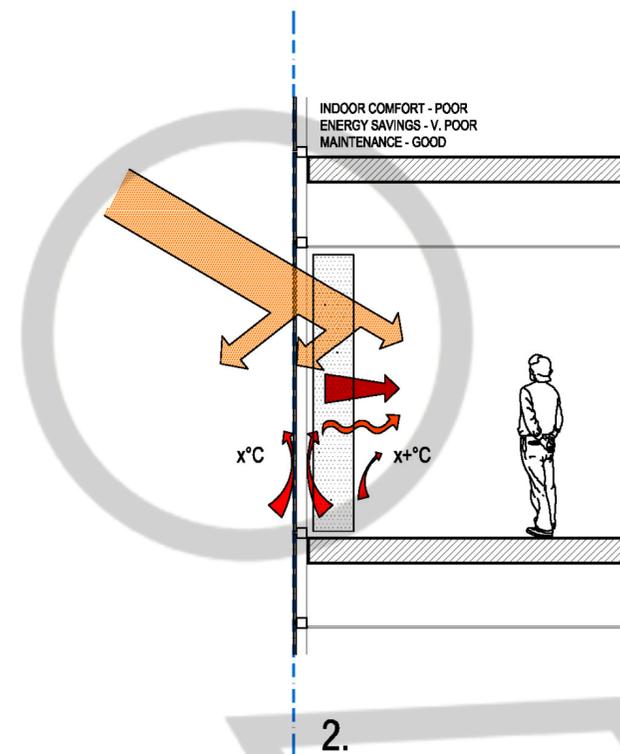
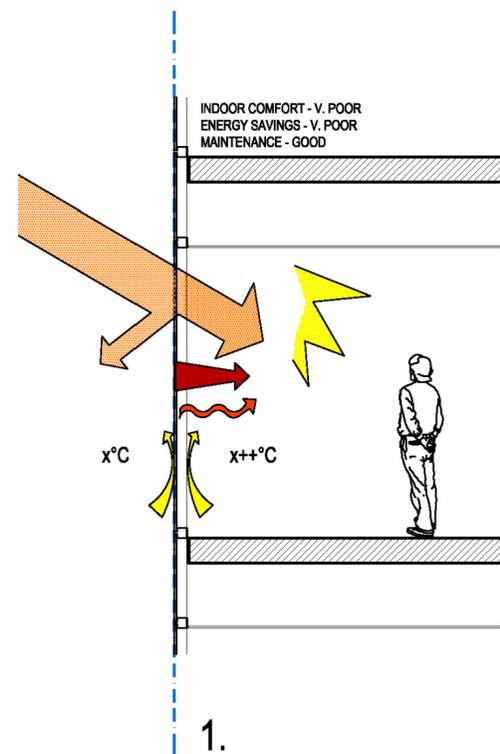
## EXHAUST DUCTING SYSTEM

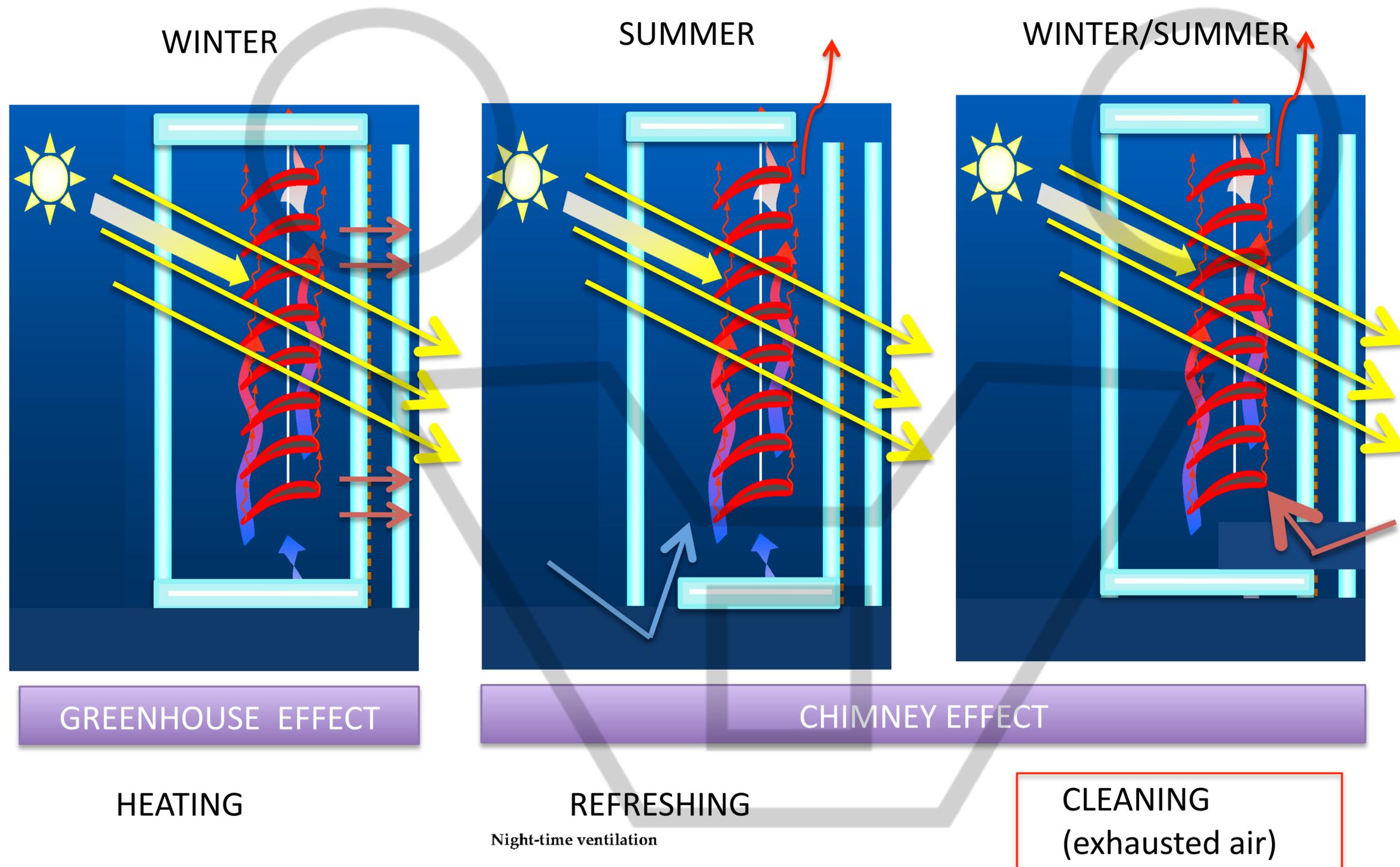
Double Skin Façade as an exhaust duct



Double Skin Façade as a central exhaust duct for the ventilation system







	<b>Summer</b>		<b>Winter</b>	
<b>Device</b>	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**

observer and office occupant, the wall section at the CDP does not greatly differ from a traditional façade system that incorporated both fixed and operable glazing panels.

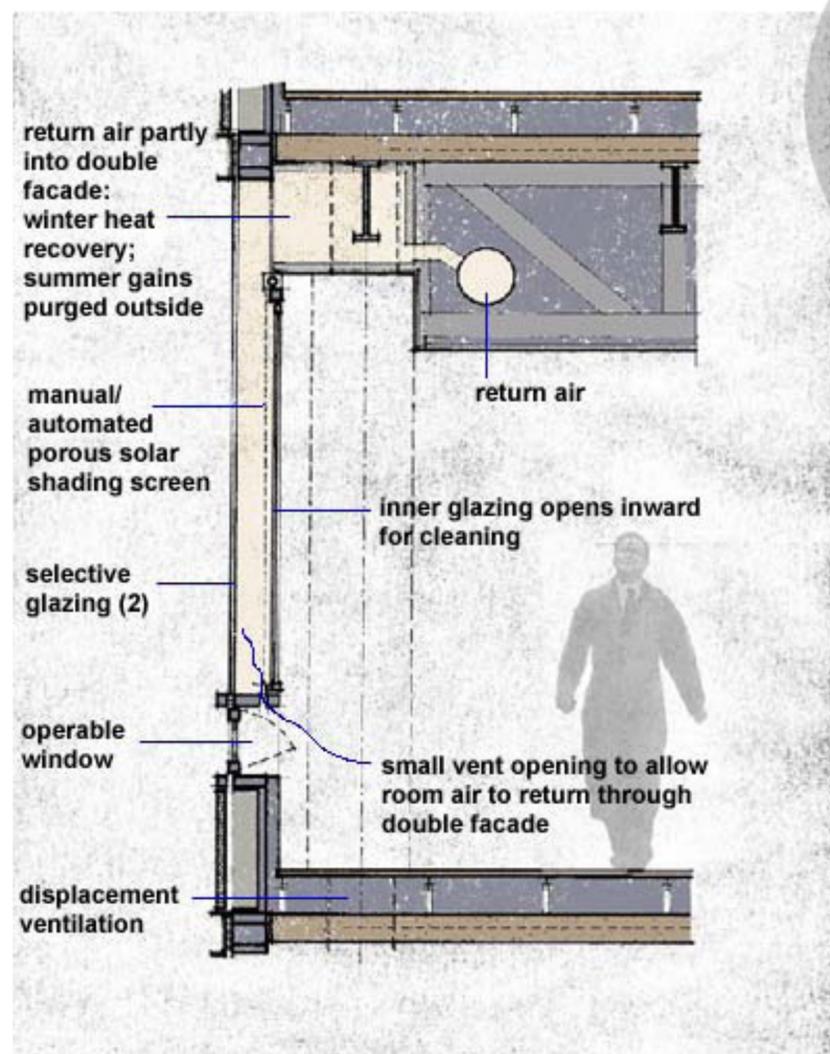
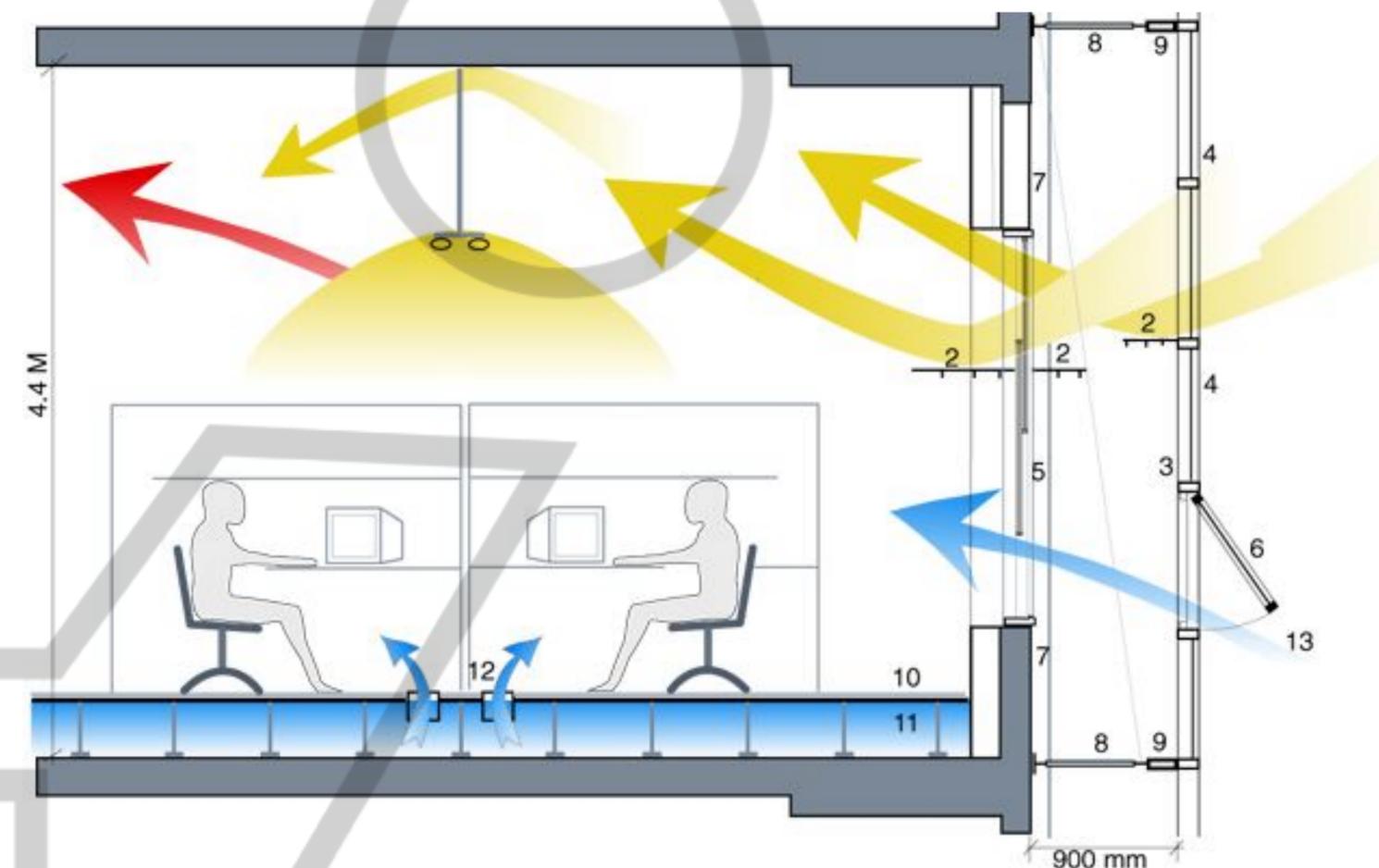


Figure 7:  
Wall section detail of the CDP



Figure 8:  
Interior view of the office space



- 1 Interstitial space- seasonal climate buffer zone
- 2 Daylight reflector and sunshade
- 3 Aluminum framed glazing curtain wall
- 4 Solar shade glass panel- ceramic frit glass panel reduces solar heat gain
- 5 Operable windows-existing restored
- 6 Operable windows- new mechanized
- 7 Existing exterior wall- exposed concrete
- 8 Curtain wall hangers
- 9 Steel reinforcing for curtain wall frame
- 10 Raised office floor
- 11 Air plenum in raised floor
- 12 Air diffusers
- 13 Natural ventilation possible in moderate temperatures

Figure 9:  
The room section at Telus, Vancouver

Environmental Design Course  
Prof. G. Ridolfi, PhD

# THE BUILDING ENVELOPE

