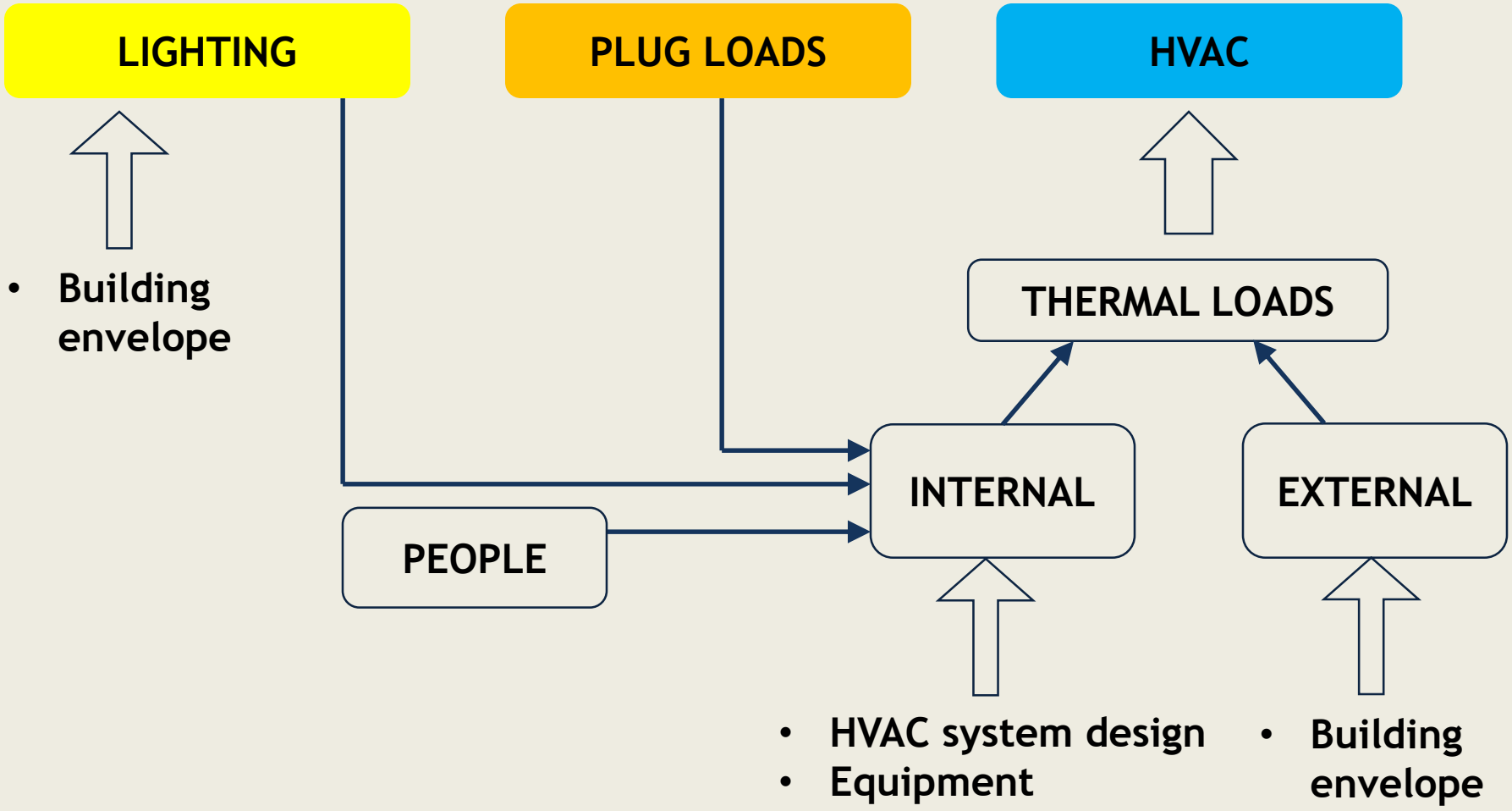
BEEP
BUILDING ENERGY
EFFICIENCY PROJECT

Passive Design Strategies

Building Energy Use



Climate

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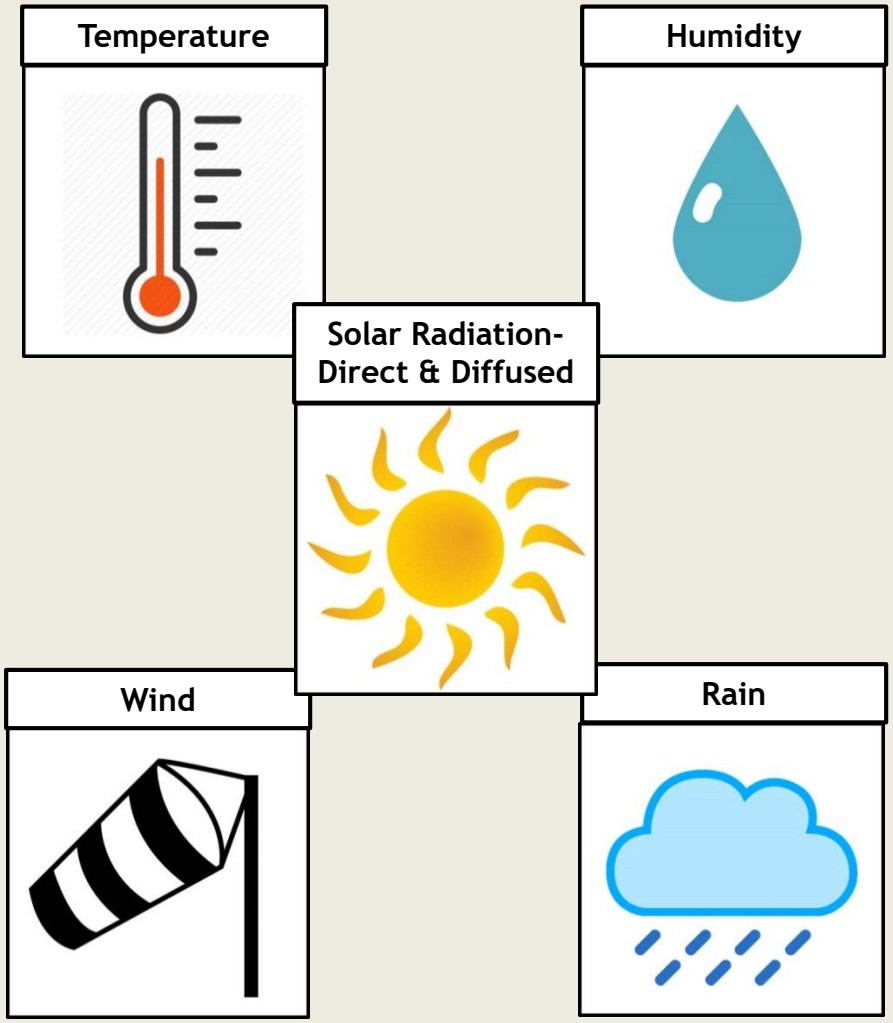
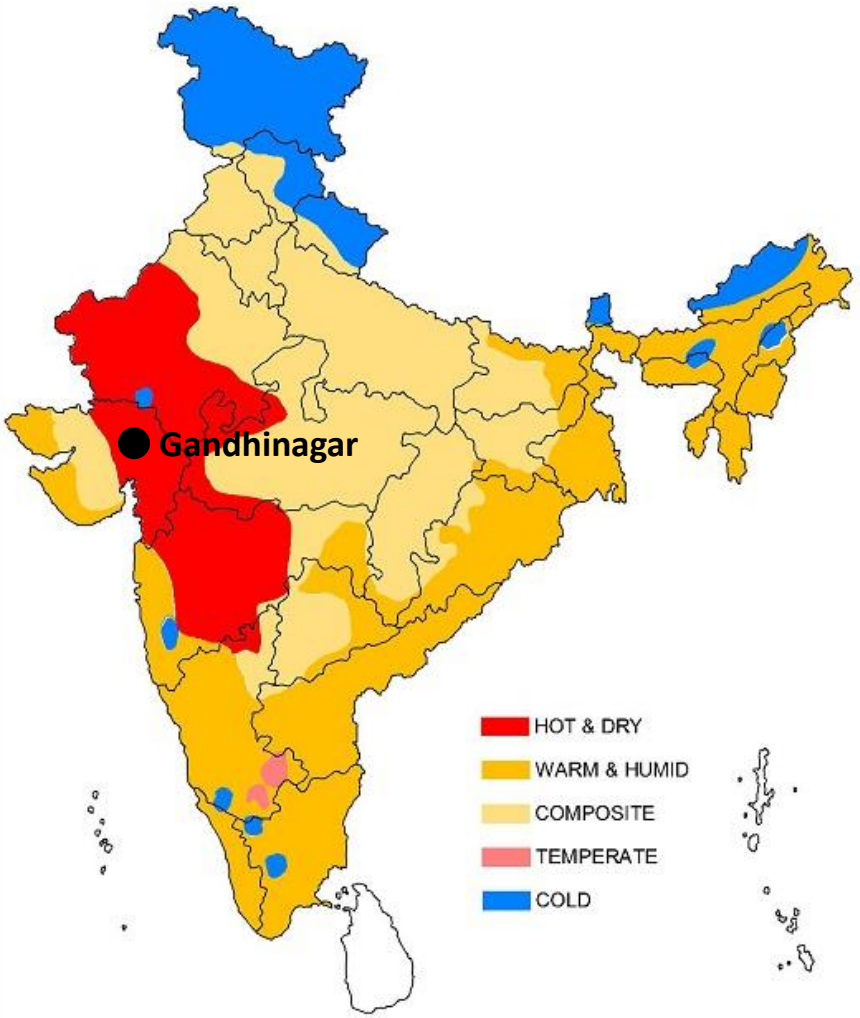
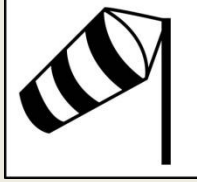




Gandhinagar Climate

- Average Annual Temperature Range: 20°C - 35°C
- Average summer temperature 35°C. **Maximum temperatures reach 45°C.**
- Minimum temperatures in winter between 10°C - 15°C

- **Summer daytime relative humidity between 20 to 60%**
- Highest humidity in July and August (Monsoon). Daytime humidity between 60 to 80%



- **Average annual wind speed 2 – 3 m/s**
- Highest wind speeds in May-Jun, reaching 10 m/s. Wind direction W and SW
- Monsoon winds from SW and winter winds from NE

- Avg. Annual daily global radiation: 5.8 kWh / m^2 / day
- **Annual global radiation: 2100 kWh / m^2** ; Diffused radiation: 760 kWh / m^2
- **High number of sunshine hours: approximately 3100 hours**

- Avg. rainy days in a year: 35
- Average annual rainfall: 750 mm

PASSIVE DESIGN STRATEGIES

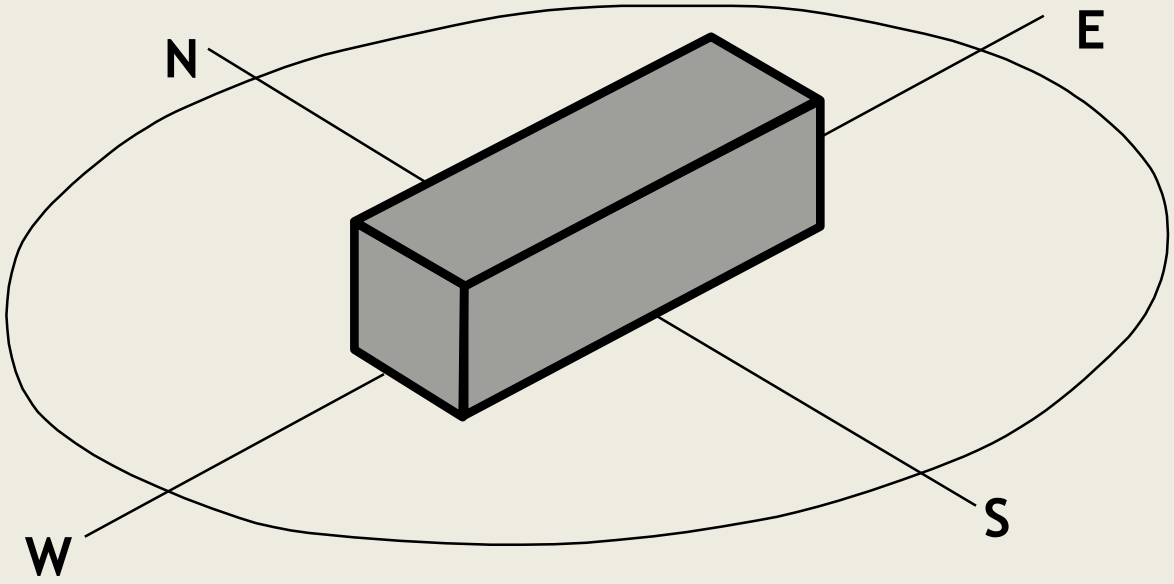
Passive Design Strategies

1	BUILDING MASSING AND ORIENTATION	
2	BUILDING ENVELOPE	ROOF AND WALLS
		WINDOWS
		AIR LEAKAGE
3	DAYLIGHTING	
4	NATURAL VENTILATION	

1 BUILDING MASSING AND ORIENTATION

Building massing and orientation

- Massing is the overall shape and size of the building
  - Orientation is the direction the building faces



Good building massing and orientation helps minimise external energy loads and harness solar and wind energy for human comfort

Ahmedabad Sun Path

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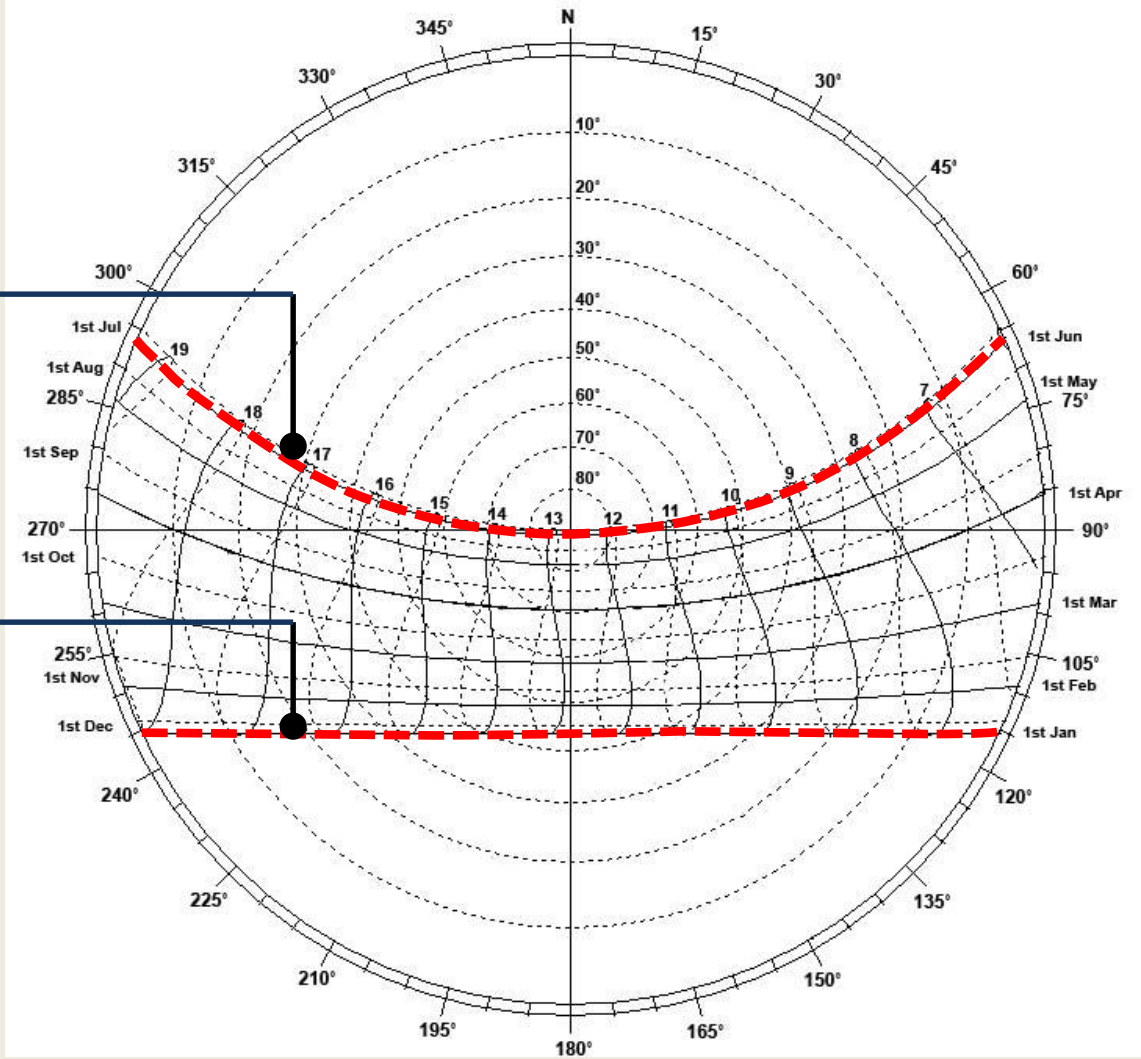
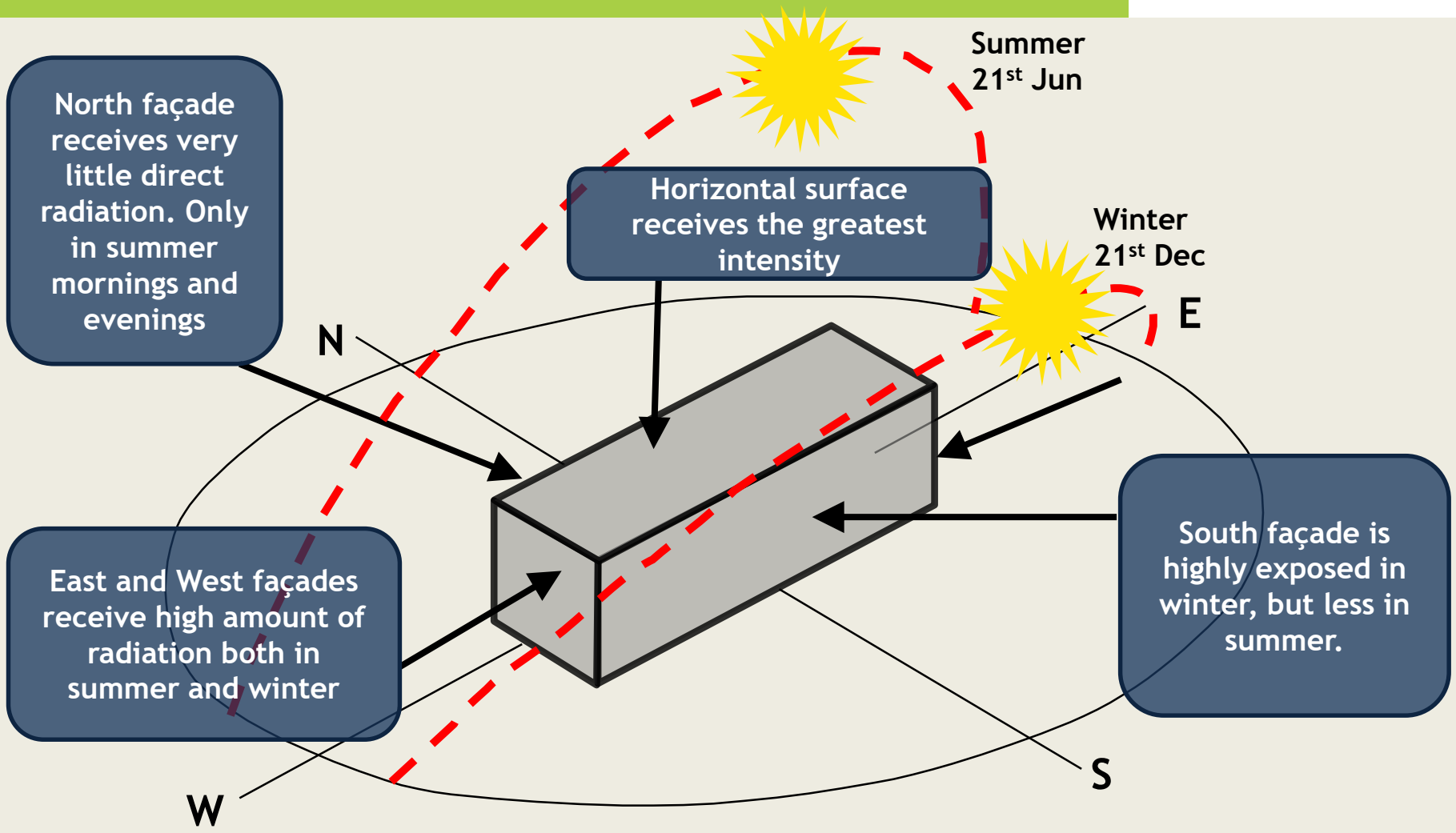
Summer
21st Jun

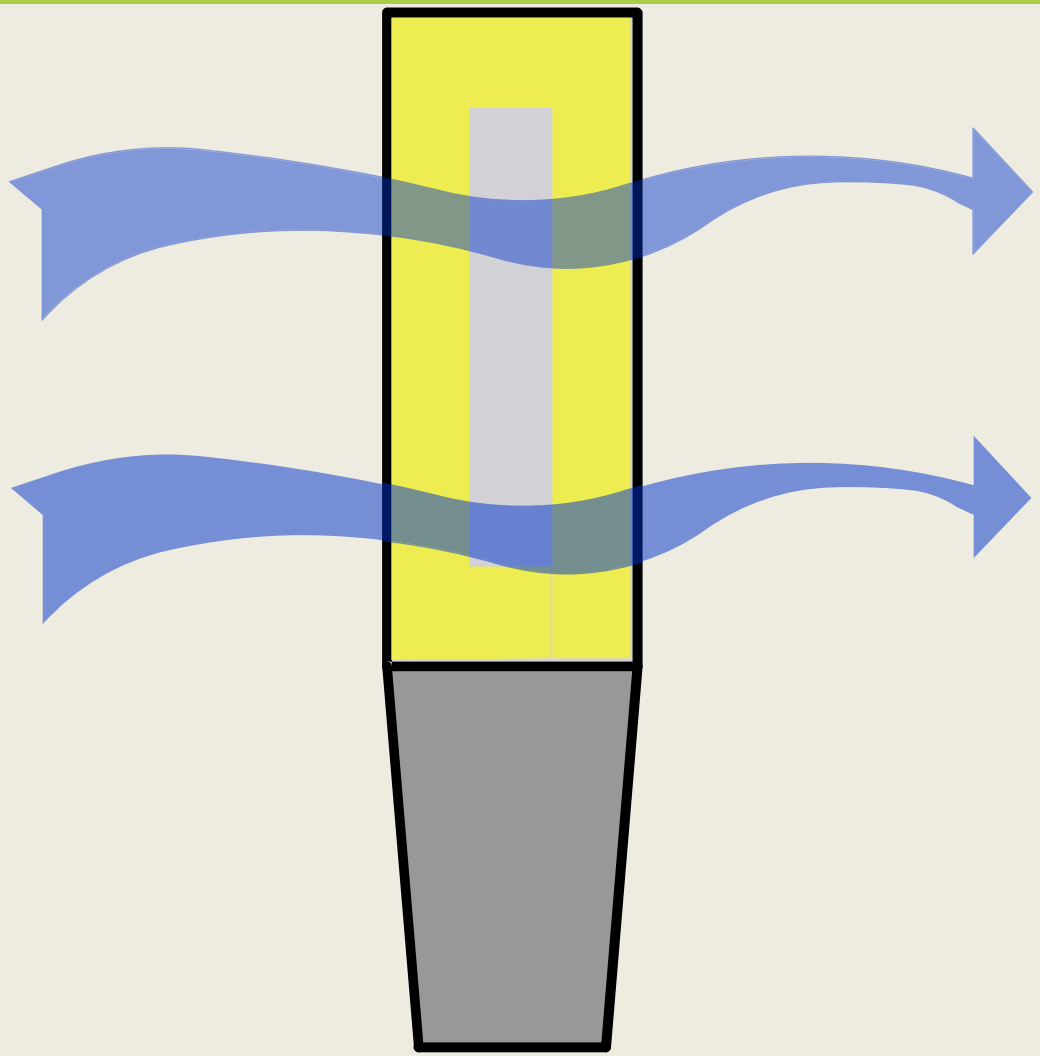
Winter
21st Dec



Sun exposure in different directions



Remove / Reduce Internal Gains



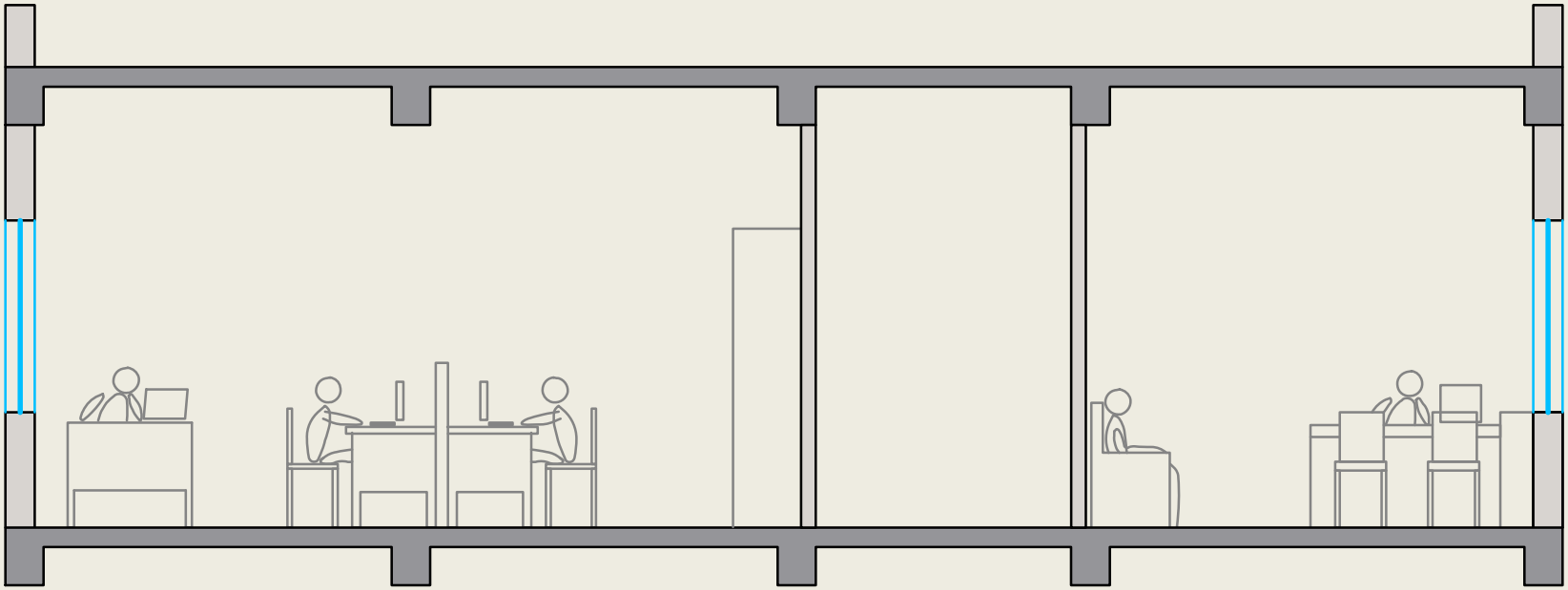
Daylight

Ventilation

1	BUILDING MASSING AND ORIENTATION	
2	BUILDING ENVELOPE	ROOF AND WALLS

Significance of building envelope

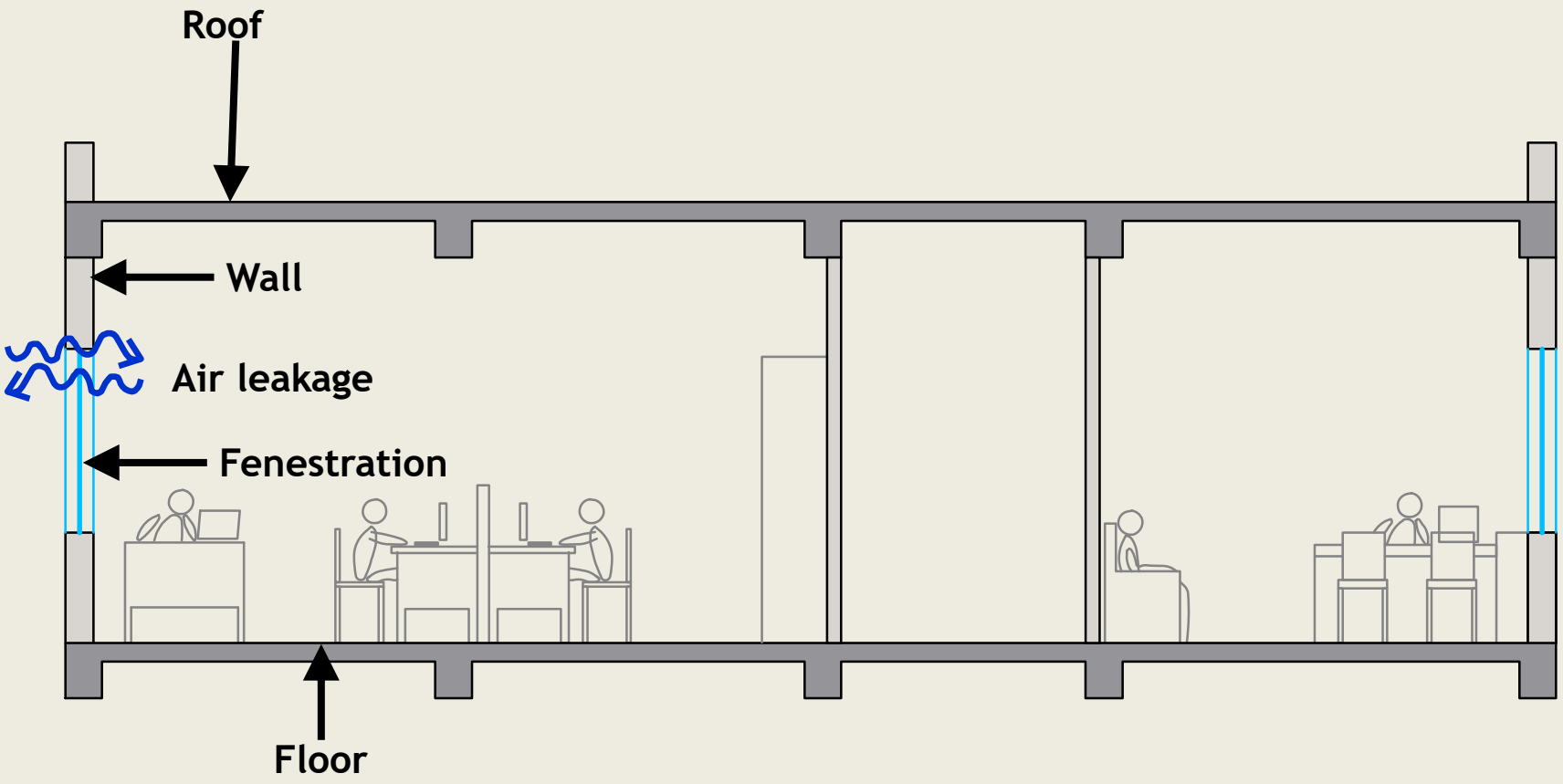
The building envelope is the boundary between the conditioned interior of a building and the outdoors.



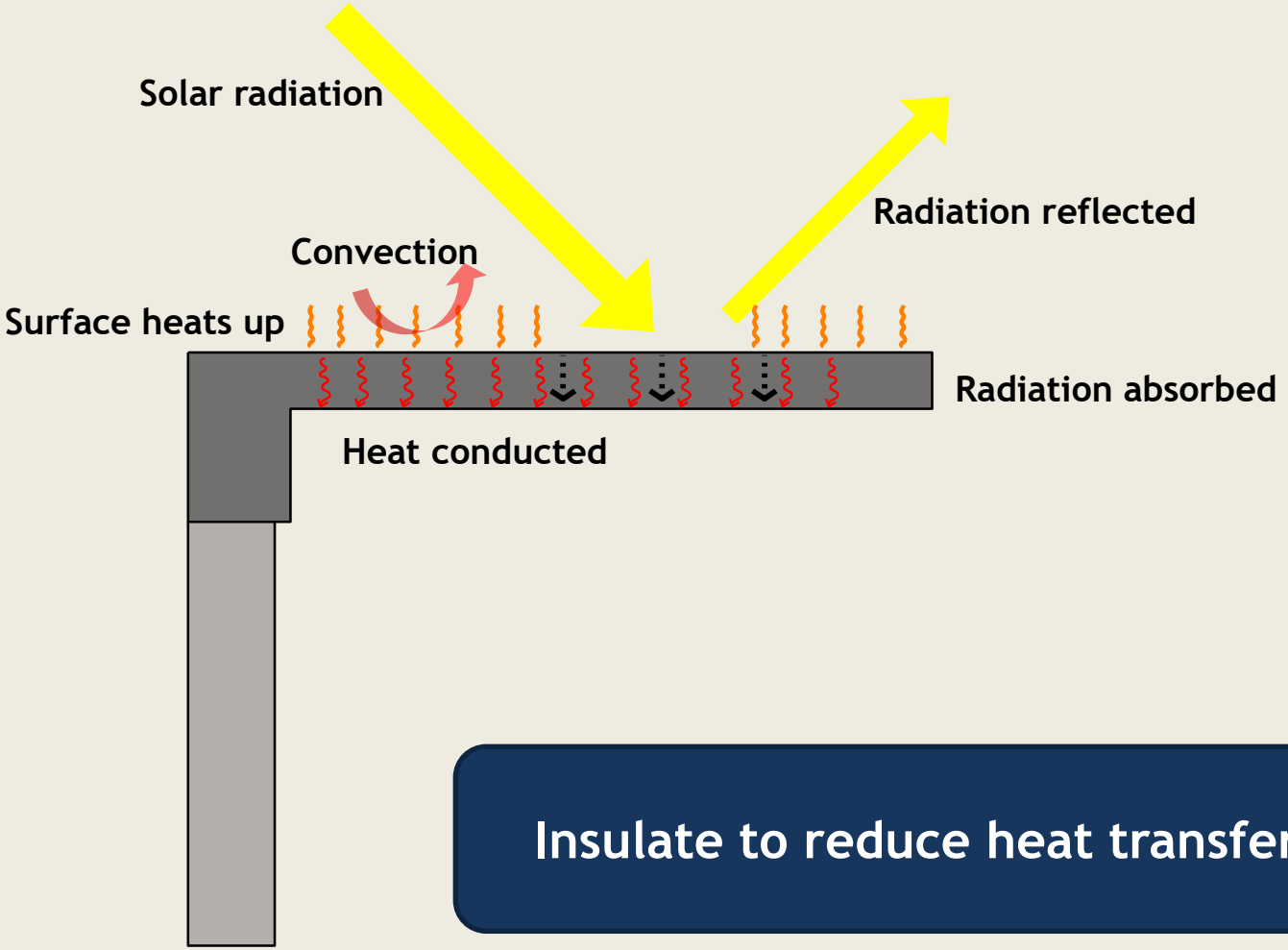
The building envelope is first a protection and shelter.

It should meet this need of the occupants while reducing energy consumption.

Energy Loads: Building Envelope Components

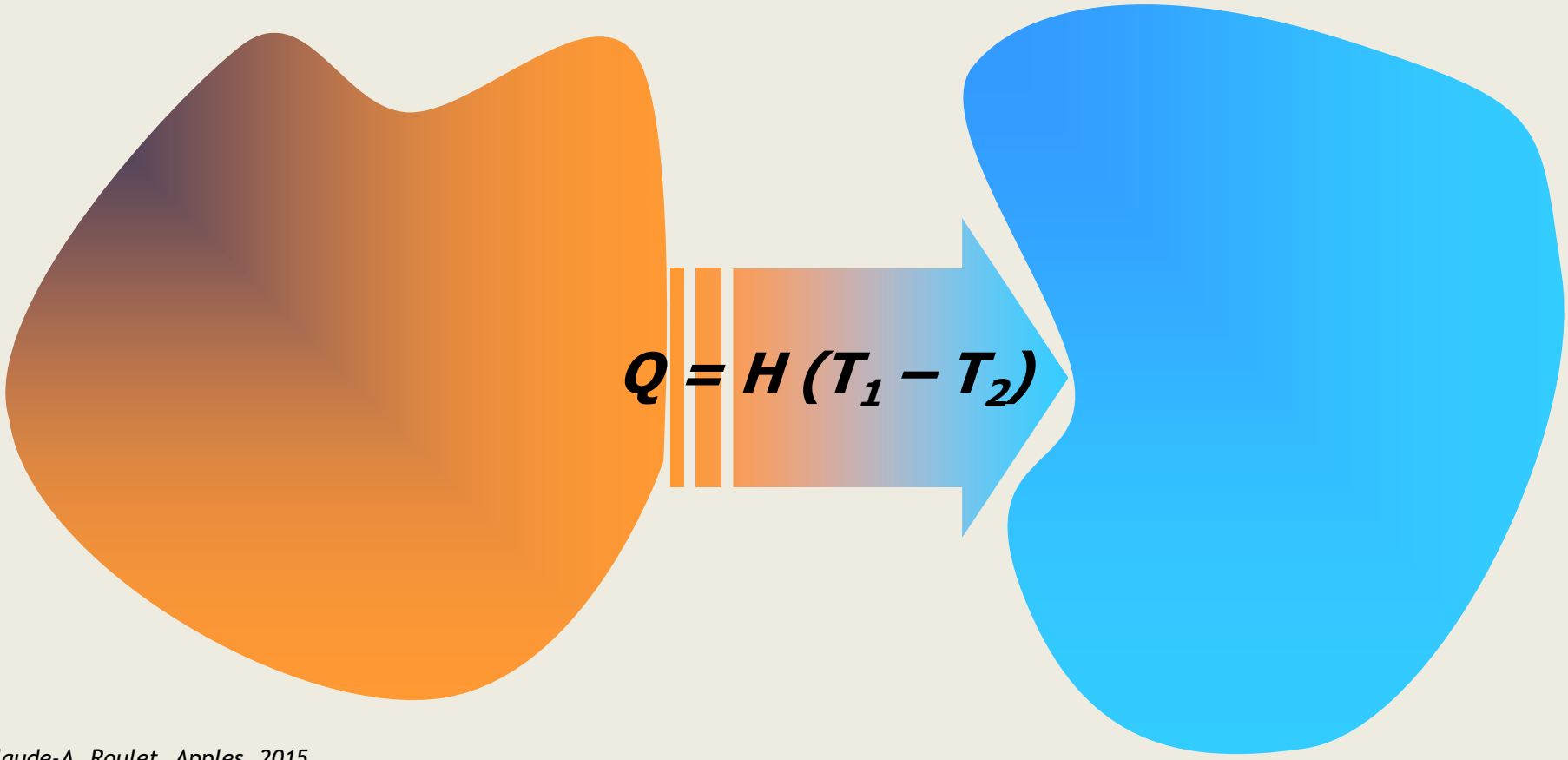


Heat transfer through Roof and Walls



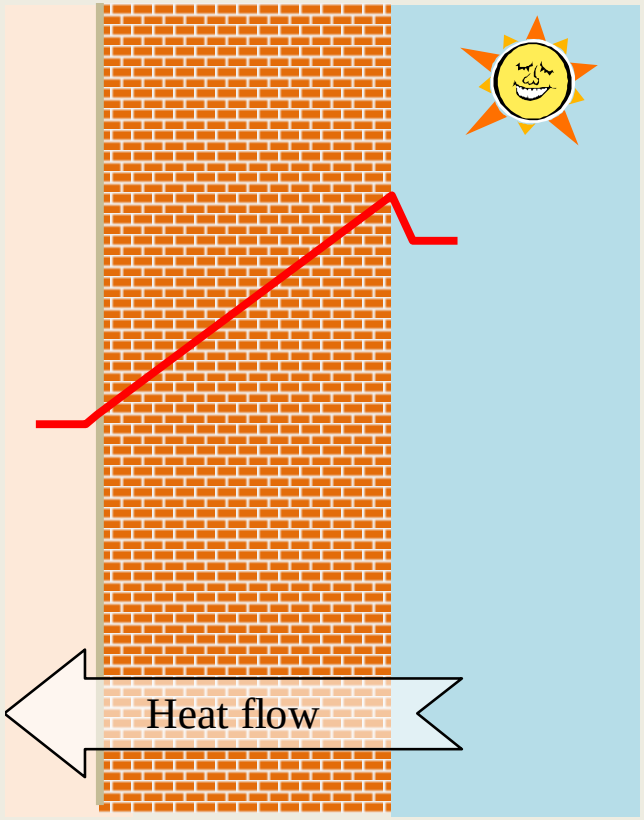
Insulate to reduce heat transfer

Heat flows naturally from Hot to Cold.

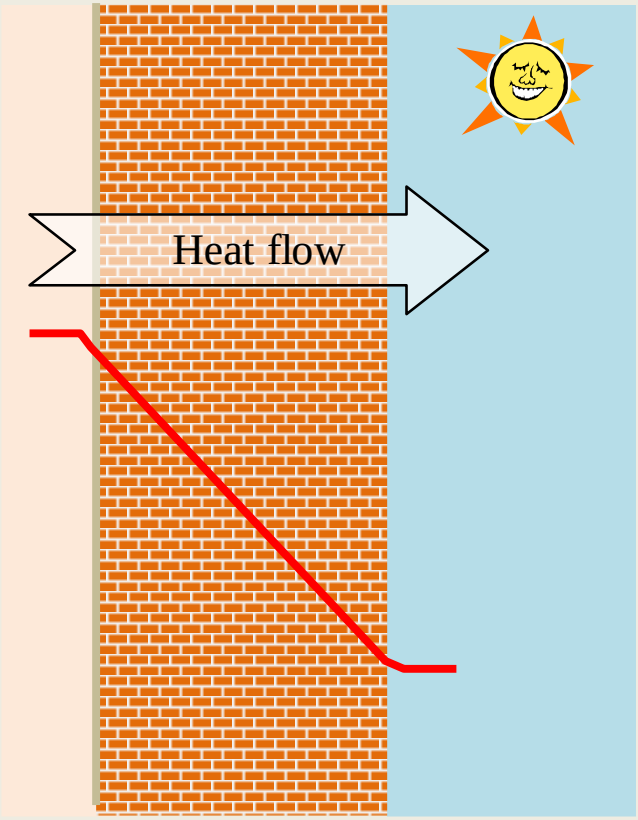


Heat Flow in Buildings

When Hotter Outside



When Colder Outside



Thermal insulation

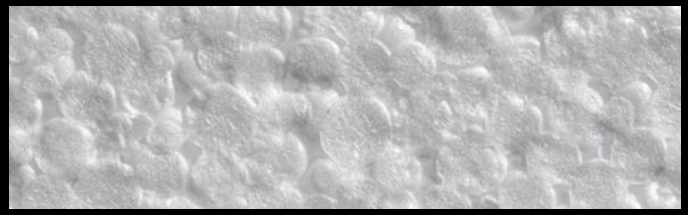
- A material that restricts the transfer of heat
- In buildings, material that restricts the heat transfer better than structure materials

Different Insulation Materials

Mineral fibre insulation

Vermiculite

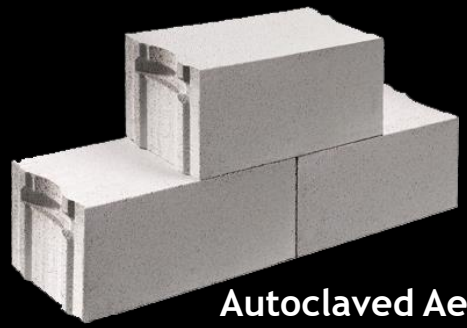
Glass foam insulation



Expanded Polystyrene (EPS)

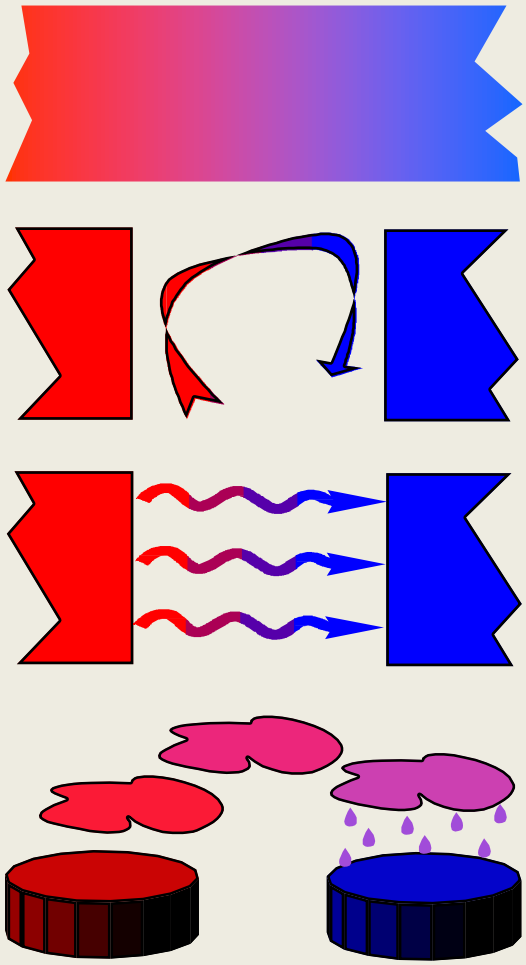
Extruded Polystyrene (XPS)

Polyurethane Foam (PUF)



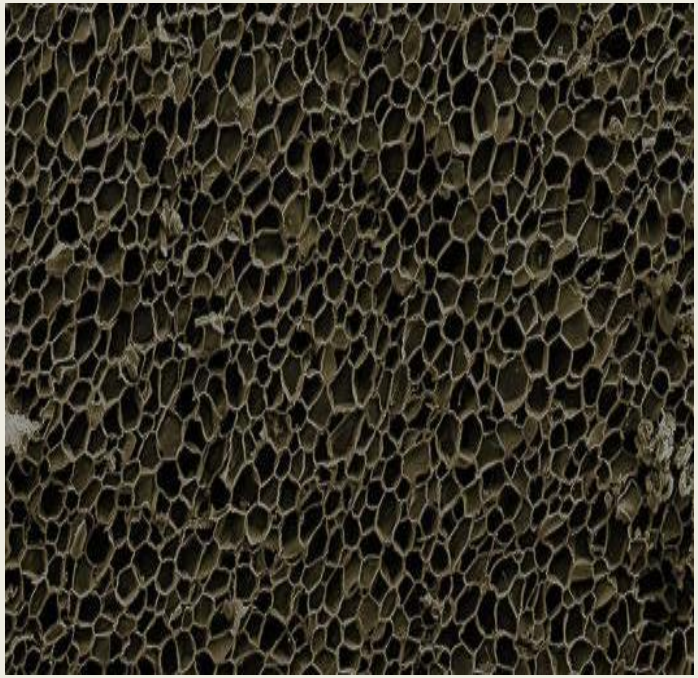
Autoclaved Aerated Concrete (AAC)

How does a Material Insulate ?



- Reduce the density of matter to reduce **conduction**
- Lock or suppress any fluid to avoid **convection**
- Using opaque or even reflecting materials to reduce **radiation**
- Keep the product dry to avoid **evaporation-condensation**

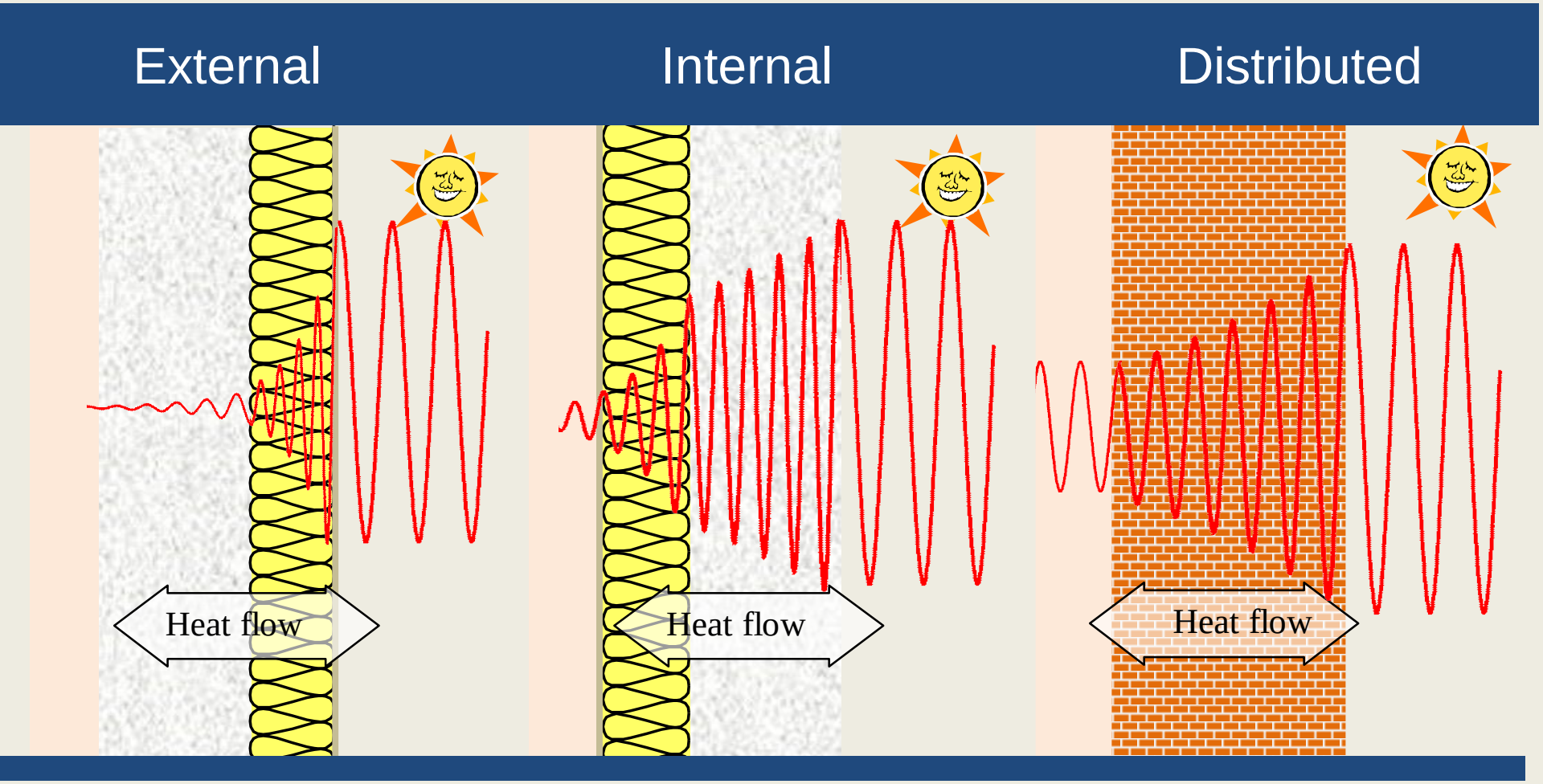
Locked Air: Main thermal insulation material in Buildings



- Air is a poor thermal conductor
- Air is locked in foam bubbles or between fibres, preventing convection
- Bubbles walls and fibres are themselves opaque to thermal radiation

Characteristics of insulating materials	Insulating power	Density	Fire résistance	Water vapour diffusion	Resistance to water	Compression strength	Traction strength	Heat resistance	Absorption of vibrations	Absorption of aerial noise	Cost at given insulation	Grey energy
Light mineral wool	+	- -	++	- -	0	- -	- -	+		++	$	- -
Dense mineral wool	++	+	++	- -	0	0	-	++	++	+	$	0
Hemp fiber	0	- -	0	- -	- -	0	- -	0		++	$	- -
Wood fibers	0	++	0	- -	- -	+	- -	+	+	++	$$	-
Wood straw -cement	-	++	+	- -	- -	+	0	+	0	+	$$	-
Cellulose flakes	+	- -	0	- -	- -	- -	-	0		++	$	- -
Cork	+	++	+	+	-	+	0	++	+	-	$$	- -
Glass foam	+	+	++	++	++	++	++	++	- -	-	$$$	0
Cellular concrete	- -	++	++	-	-	++	+	++	- -	-	$$$	0
PUR	++	-	0	-	0	+	+	++	-	- -	$	++
EPS	+	- -	+	+	0	+	+	0	-	- -	$$$	-
Graphited EPS	++	- -	+	+	0	+	+	0	-	- -	$	-
XPS	++	0	+	++	+	+	++	0	-	- -	$	+
Silica aerogel	+++	- -	+	- -	++	- -	-	+	++	- -	$$$$	+++

Insulation Application

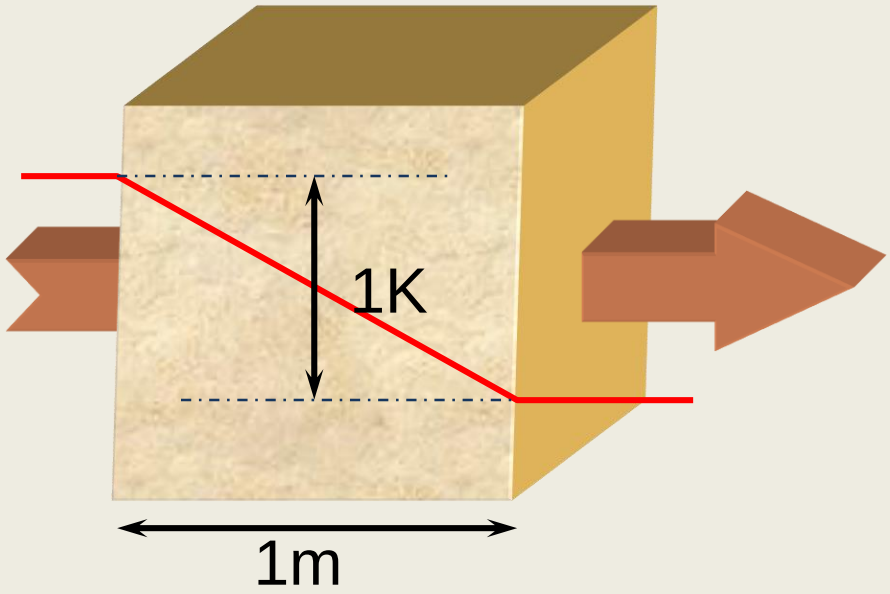


Thermal Conductivity K

Property denoting a material's inherent ability to conduct heat. It is an intrinsic material property and is temperature dependent

$$q = - \kappa \frac{\Delta T}{d}$$

Amount of heat transferred in
1 second through
1 m^2 of an homogeneous layer
1 metre thick, under a temperature difference of
1 degree.



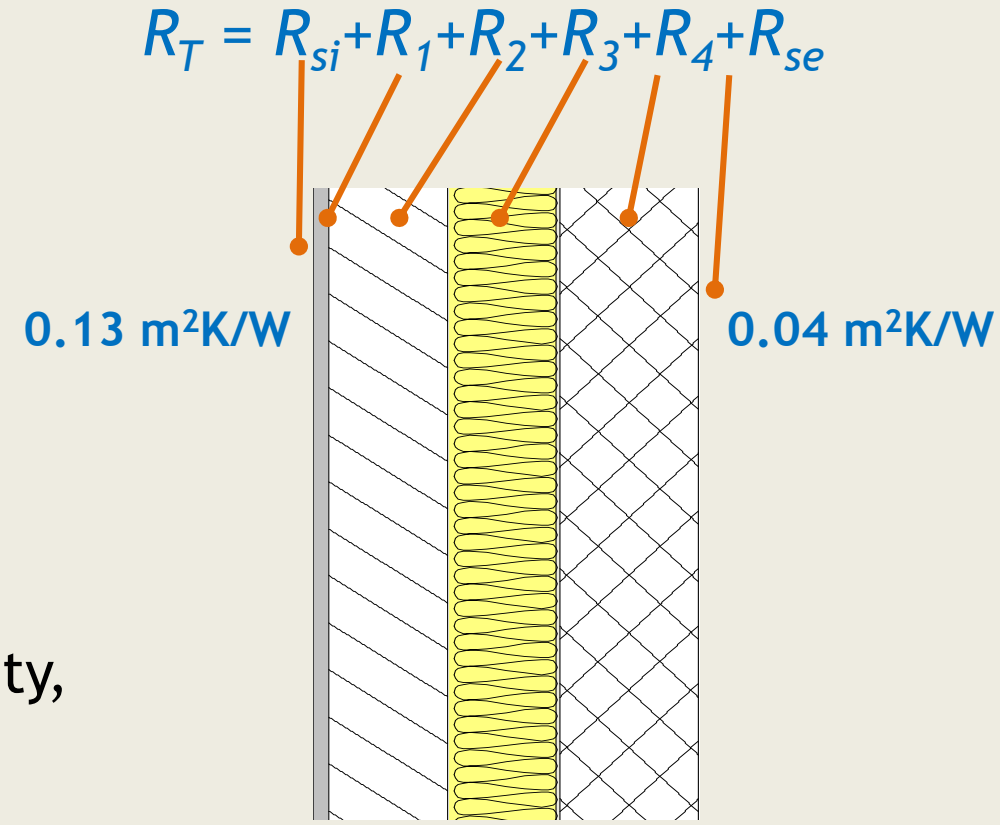
Smaller the thermal conductivity of a material, better is the thermal insulation provided by it.

Thermal Resistance: R value

Resistance of a layer of material, with thickness “d” to heat transfer

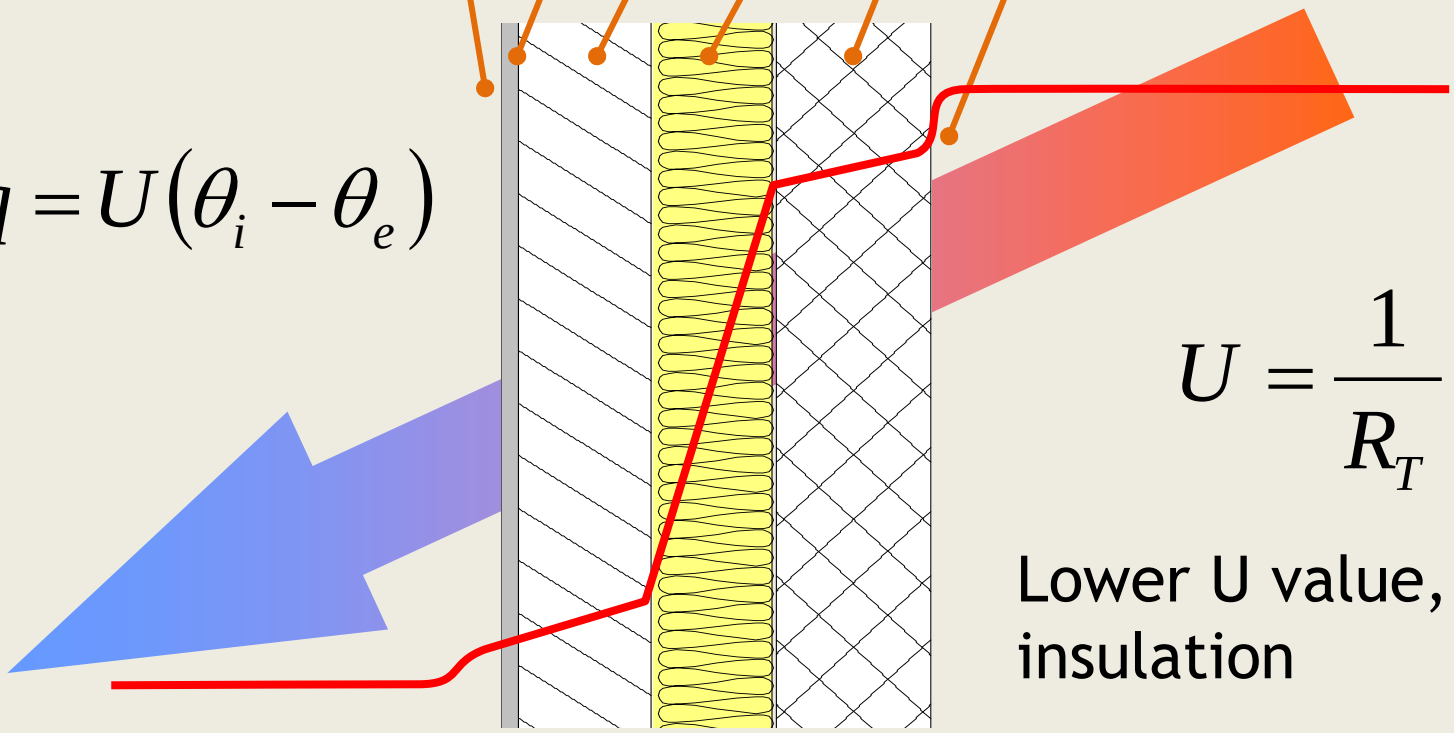
$$R = \frac{d}{\kappa}$$

- Higher R value, better insulation
- More material thickness, higher R value
- Lower thermal conductivity, higher R value



Heat Transfer Coefficient: U value

$$R_T = R_{si}+R_1+R_2+R_3+R_4+R_{se}$$



$$q = U(\theta_i - \theta_e)$$

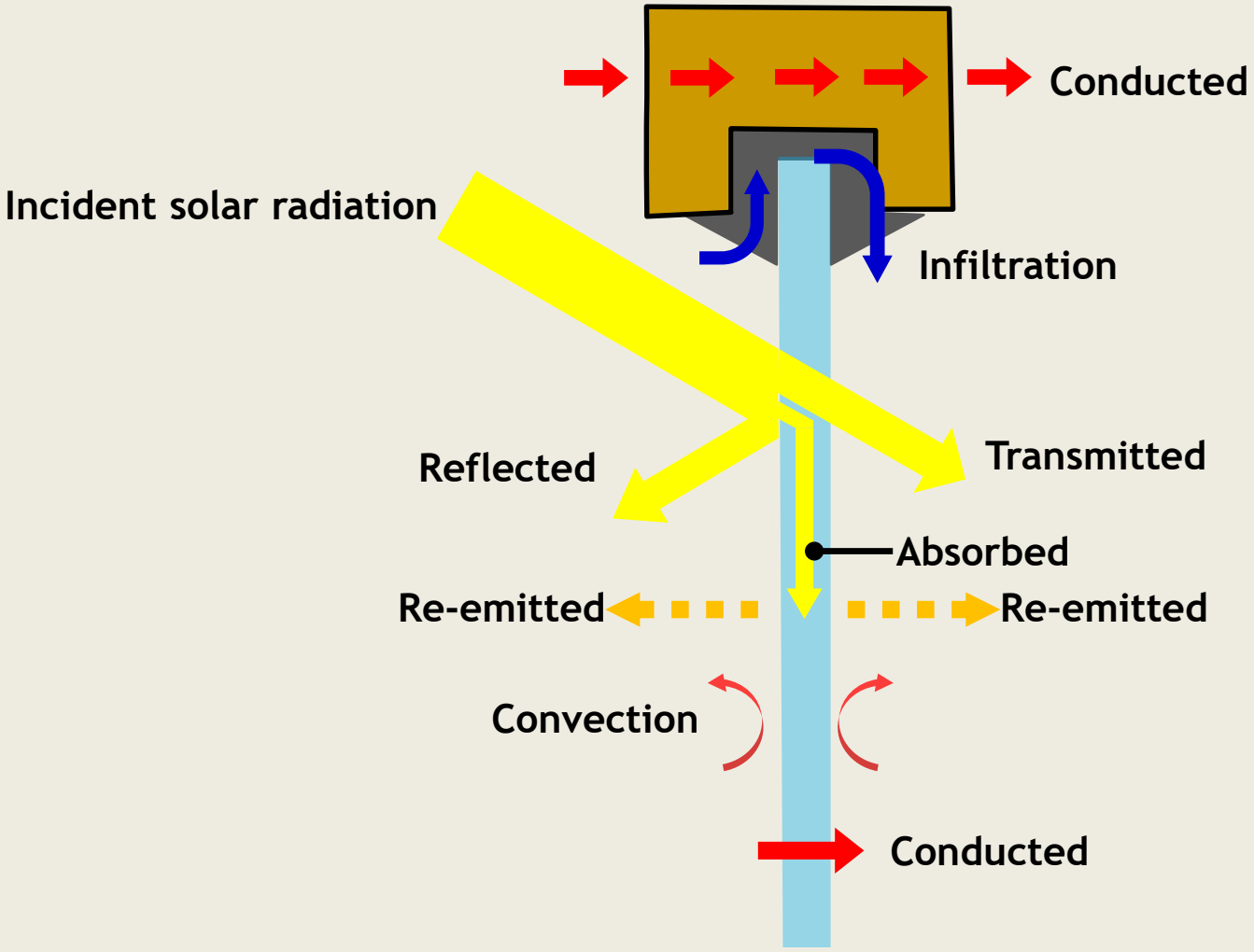
$$U = \frac{1}{R_T}$$

Lower U value, better insulation

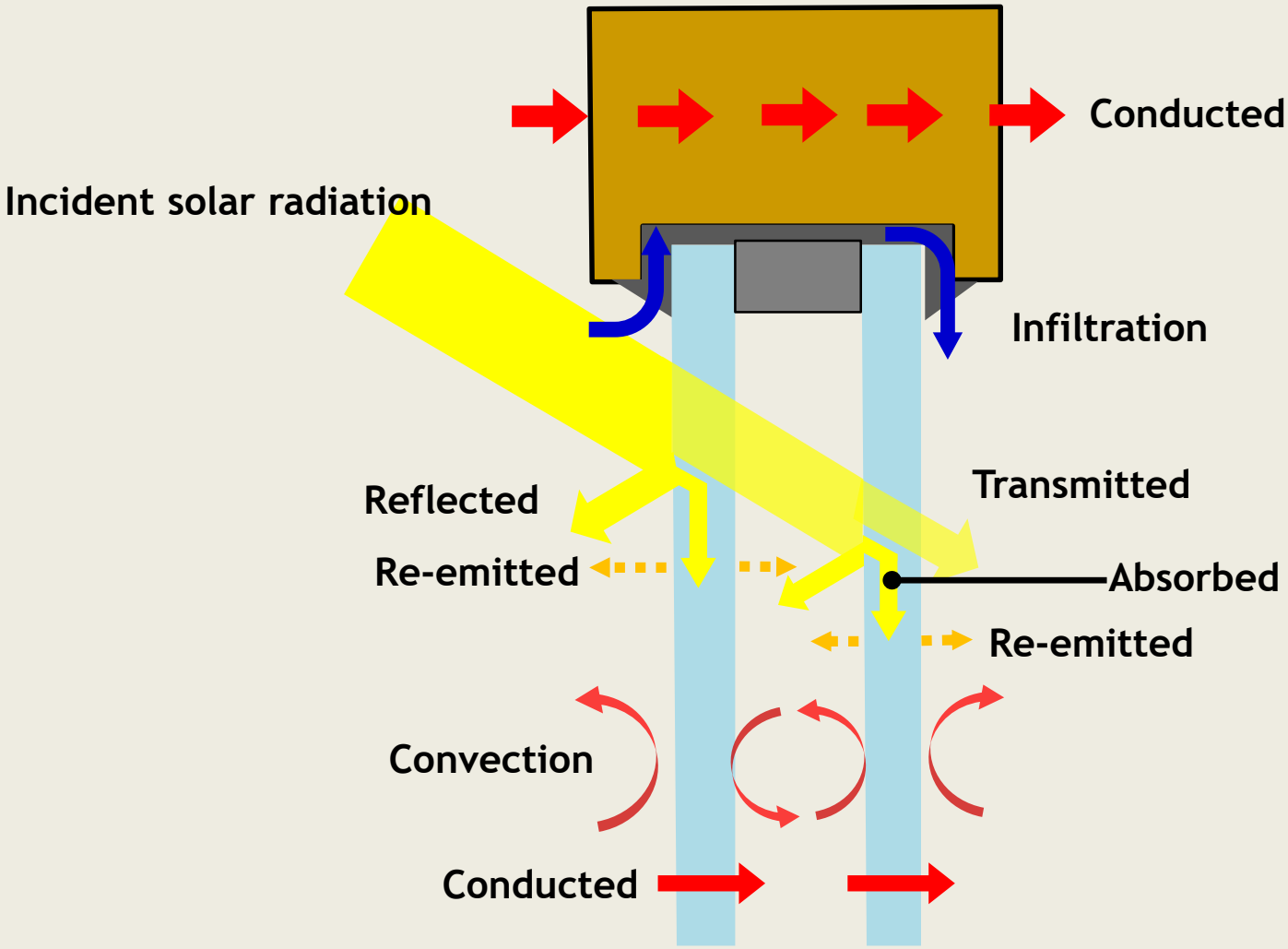
Envelope component	Climate Zone	24-h. use buildings, hospitals, hotels, call centers, etc.		Day-time use buildings & other building types	
		Max U-value W/(m²K)	Min. R-value of insulation alone m² K/W	Max U-value W/(m²K)	Min. R-value of insulation alone m² K/W
Roofs	Composite	0.261	3.5	0.409	2.1
	Hot & Dry	0.261	3.5	0.409	2.1
	Warm & Humid	0.261	3.5	0.409	2.1
	Moderate	0.409	2.1	0.409	2.1
	Cold	0.261	3.5	0.409	2.1
Opaque walls	Composite	0.440	2.10	0.440	2.10
	Hot & Dry	0.440	2.10	0.440	2.10
	Warm & Humid	0.440	2.10	0.440	2.10
	Moderate	0.440	2.10	0.440	2.10
	Cold	0.369	2.20	0.352	2.35

1	BUILDING MASSING AND ORIENTATION	
2	BUILDING ENVELOPE	ROOF AND WALLS
		WINDOWS

Heat transfer through Windows- Single Glazing



Heat transfer through Windows- Double Glazing



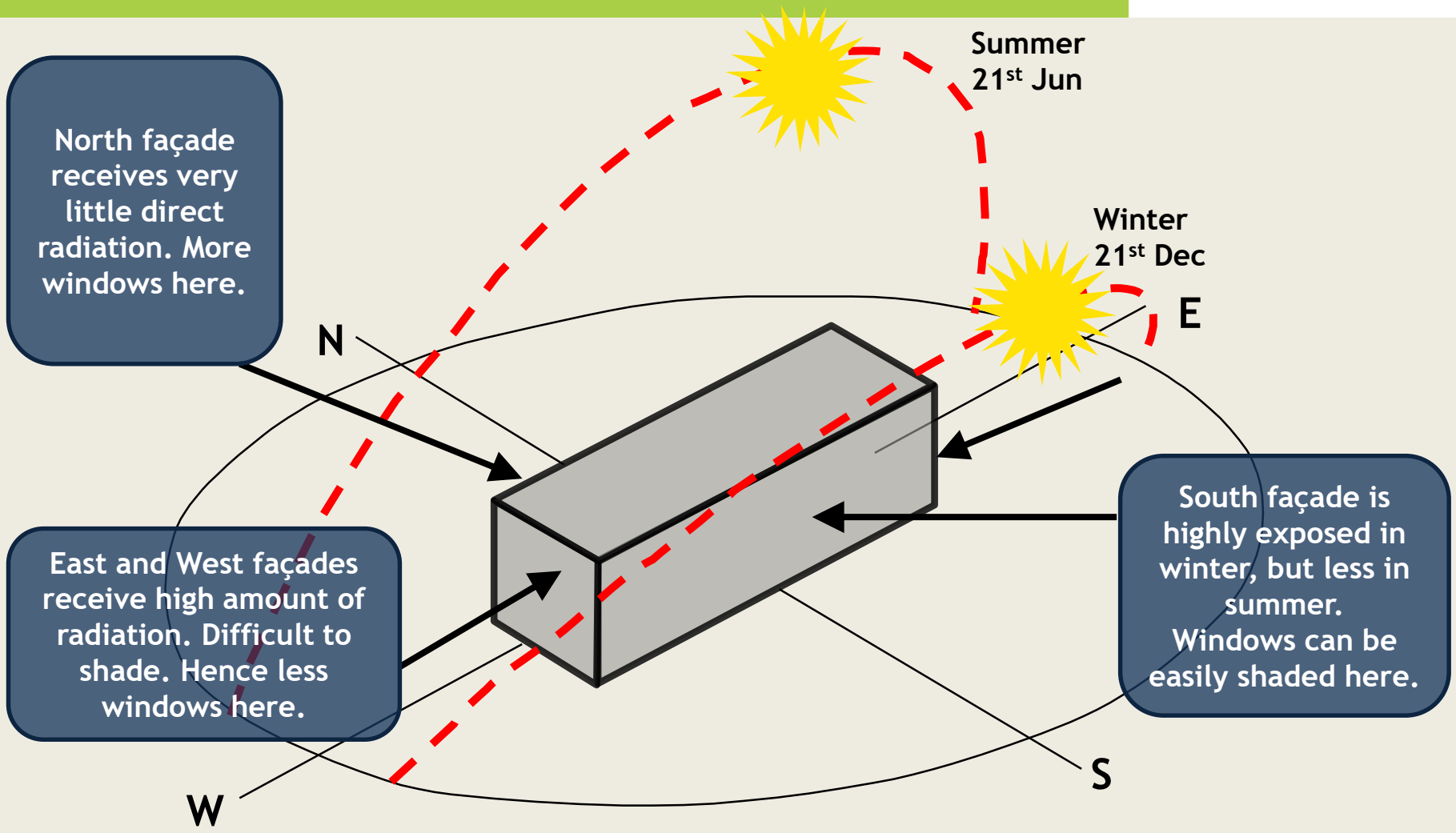
Design decisions for windows

Placement and Area (Window-Wall-Ratio)

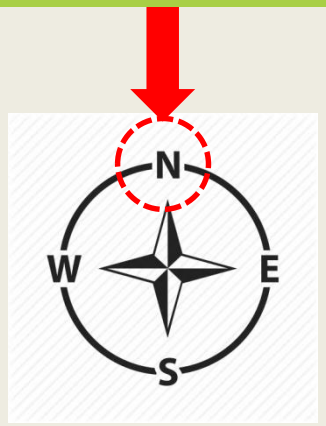
Solar Protection

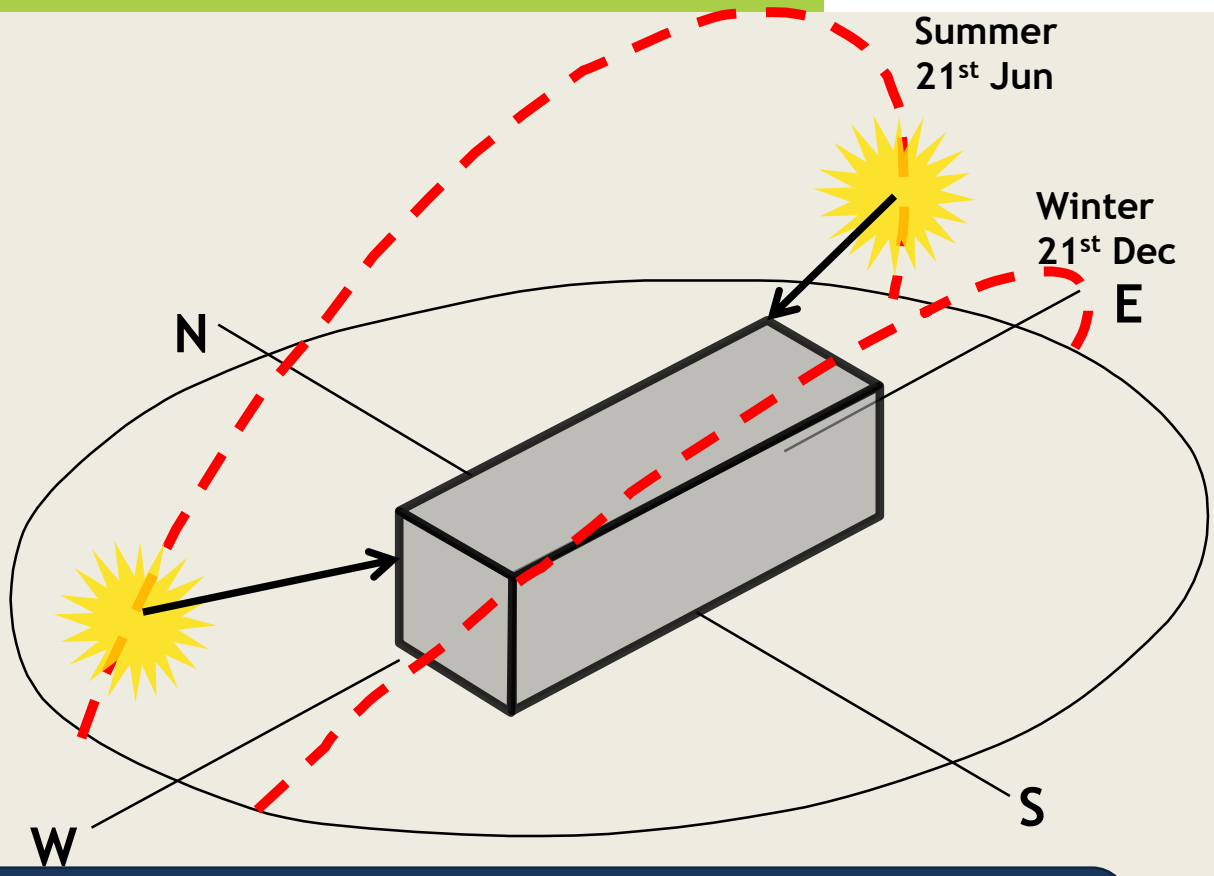
Glazing and Frame Properties

Placement & Area (Window-Wall-Ratio)



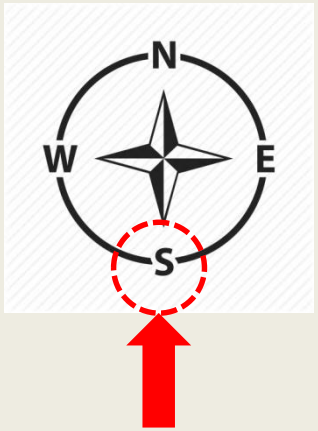
Solar Protection

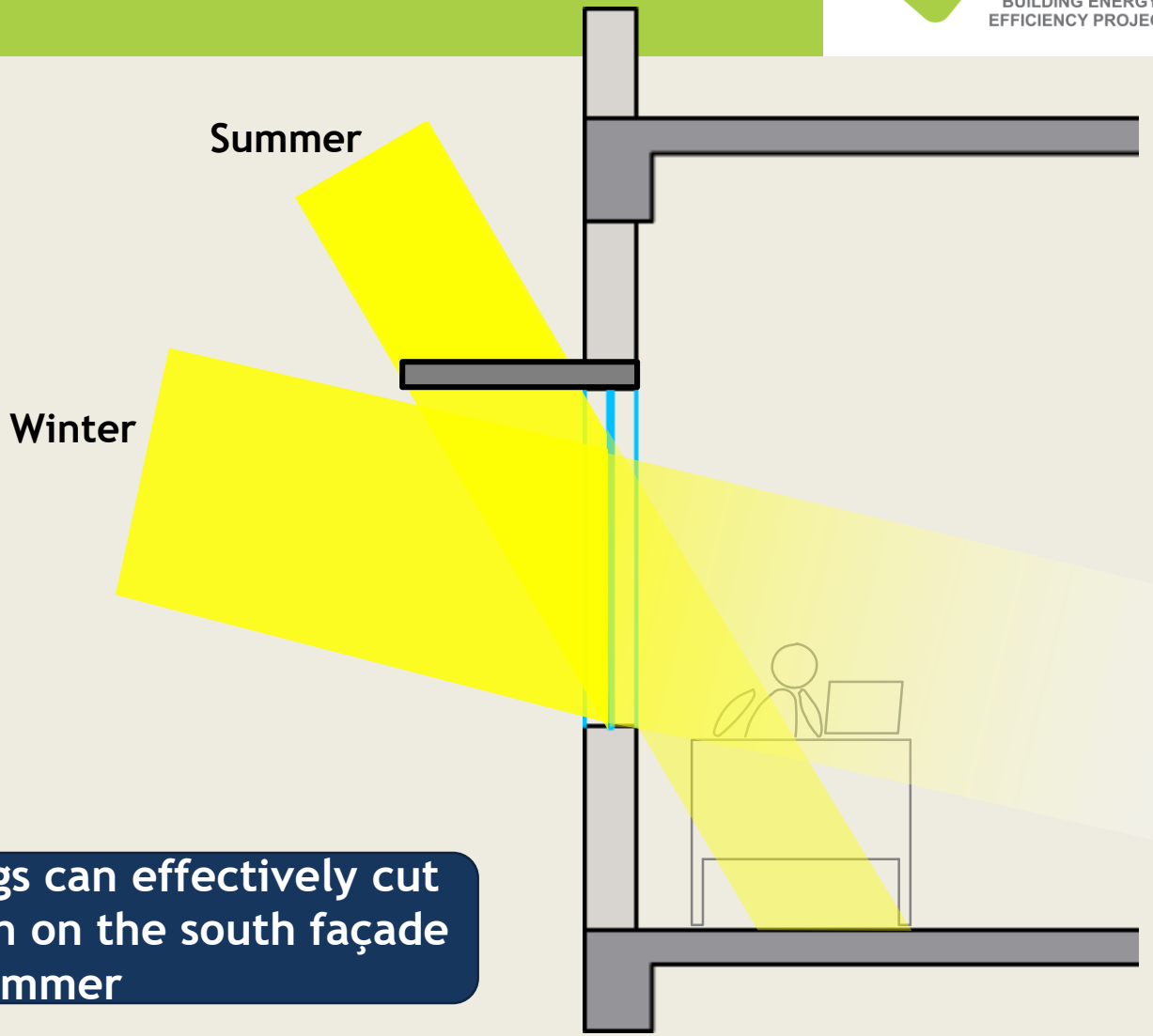




- North-facing windows receive almost no direct sunlight. Only in summer mornings and evenings.
- Vertical fins or small recess into the wall can shade adequately

Solar Protection





Horizontal overhangs can effectively cut direct solar radiation on the south façade in summer

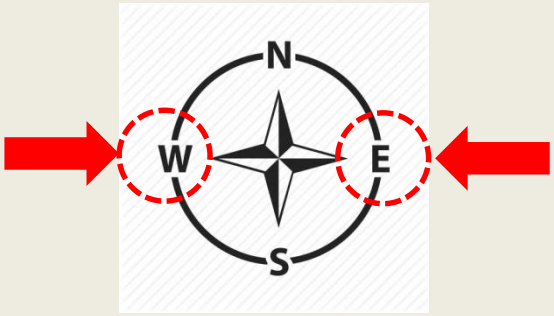
South face Shading

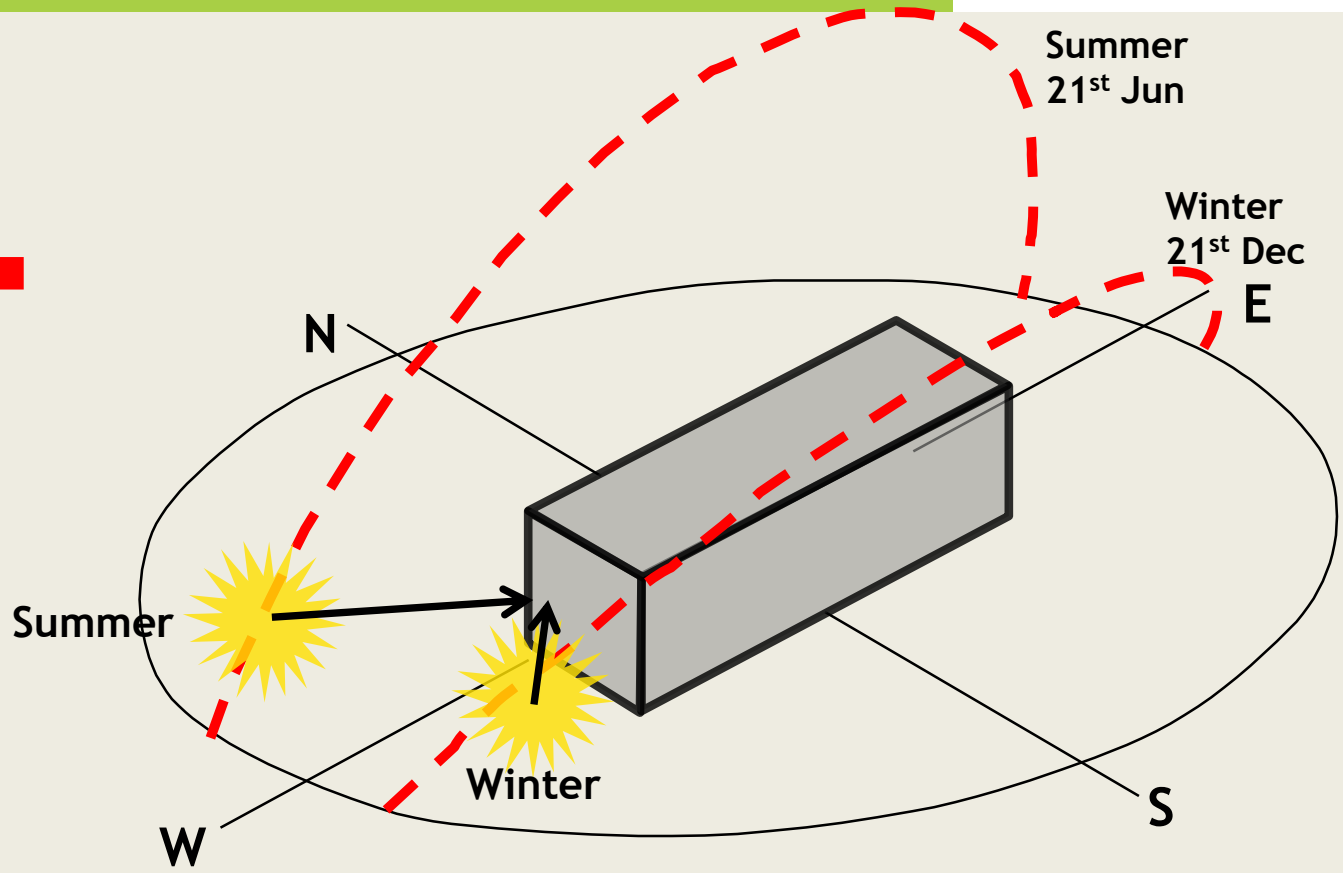
INFOSYS, HYDERABAD

South face Shading

INFOSYS, HYDERABAD

Solar Protection





- Low sun on east west facades
- Solar azimuth angle also changes

Dynamic shading most effective on east west facades

External Movable shades

External Movable shades

COMMUNICATION BUILDING, EPFL, LAUSANNE

ROLEX LEARNING CENTRE, EPFL, LAUSANNE

External Movable shades: India

GOLCONDE, PONDICHERRY

External Movable shades: India

SABARMATI ASHRAM, AHMEDABAD

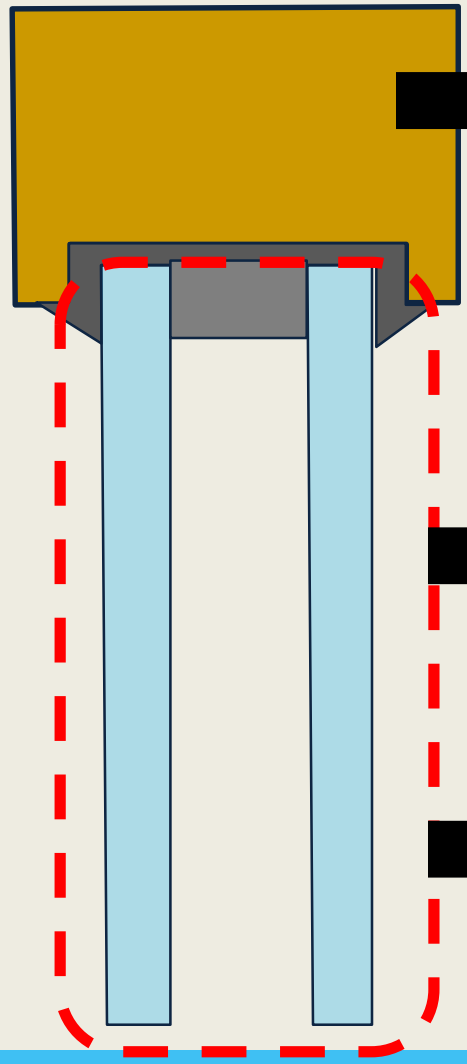
External Movable shades: India

SAFAL PROFITAIRE, AHMEDABAD

External Movable shades: India

SAFAL PROFITAIRE, AHMEDABAD

Window Glazing & Frame



Heat transfer through
- Conduction

→ U factor

Heat transfer through
- Conduction
- Convection
- Radiation

→ U factor
→ SHGC

Light → VLT

Solar Heat Gain Coefficient (SHGC)

SHGC is the ratio of solar (radiant) heat gain that passes through the fenestration to the total incident solar radiation that falls on it.

SHGC is a dimensionless number between 0 and 1.

FACTORS INFLUENCING SHGC:

- Solar protection or shading
- Type of glass & number of panes
- Tints & Coatings on the glazing
- Gas fill between glazing layers

U Factor

As with opaque envelope components, U-factors measure thermal conductivity through the window components.

FACTORS INFLUENCING U FACTOR:

- The size of the air gap between glass panes
- Coatings on the glazing
- Gas fill between glass panes
- Frame construction

Visible Light Transmission (VLT)

VLT is the ratio of visible light that passes through a glazing unit to the total visible light incident on it.

FACTORS INFLUENCING VLT:

- Colour of glass
- Tints & Coatings on the glazing
- Number of glass panes

Different Glazing Types

Glazing type	Glass pane thickness (mm)	U factor W/(m²K)	SHGC	VLT
Single clear glazing	6	6	0.81	0.89
Double glazing (clear)	6	2.7	0.7	0.79
Double glazing (low-e)	3	1.8	0.71	0.75
Triple glazing (clear)	3	2	0.67	0.74
Double glazing, argon filled (low-e)	6	1.4	0.57	0.73

Source: www.wbdg.org/resources/windows.php, Whole Building Design Guide

Double glazing (low-e) SKN Envision	**6**	**1.5**	**0.33**	**0.55**

Source: Saint Gobain

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		AIR LEAKAGE

Air Leakage

Normal air movement in and out of buildings – infiltration and exfiltration – is known as air leakage and is usually measured using air changes per hour (ACH).

As it is uncontrolled and admits or expels conditioned air, it leads to more energy consumption in conditioned buildings.

It is estimated that up to 1/3rd of a building's HVAC energy is wasted due to air leakage.

Source: Wikipedia

Envelope Airtightness to reduce Air Leakage

Reducing air leakage by making the building envelope airtight is estimated to save 5% to 40% of heating and cooling energy.

An air tight envelope is needed in all buildings, in all climates, except those without any mechanical ventilation for fresh air, i.e. naturally ventilated buildings. Thus, air leakage rates are often specified with consideration of mechanical ventilation for fresh air.

Source: IEA (2013), *Technology Roadmap: Energy Efficient Building Envelopes*, OECD/IEA, Paris.

Prescribed Minimum Air Leakage Rates

Air leakage rates for European Union, United States and advanced housing programmes

	Northern European Union without ventilation (code)	*Northern European Union with ventilation (code)*	*United States, residential (code)*	*Passivhaus residential guideline*	*Typical for very tight new houses with ventilation*	*Old leaky houses*
Performance metrics, air leakage at 50 Pa	2.5 ACH to 3.0 ACH	1.0 ACH to 0.6 ACH	≤ 3.0 ACH cold climate; ≤ 5.0 ACH hot climate	≤ 0.6 ACH	Approximately 0.2 ACH	10 ACH to 20 ACH

Source: IEA (2013), *Technology Roadmap: Energy Efficient Building Envelopes*, OECD/IEA, Paris.

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		WINDOWS
		AIR LEAKAGE
3	DAYLIGHTING	

Design decisions for Daylight

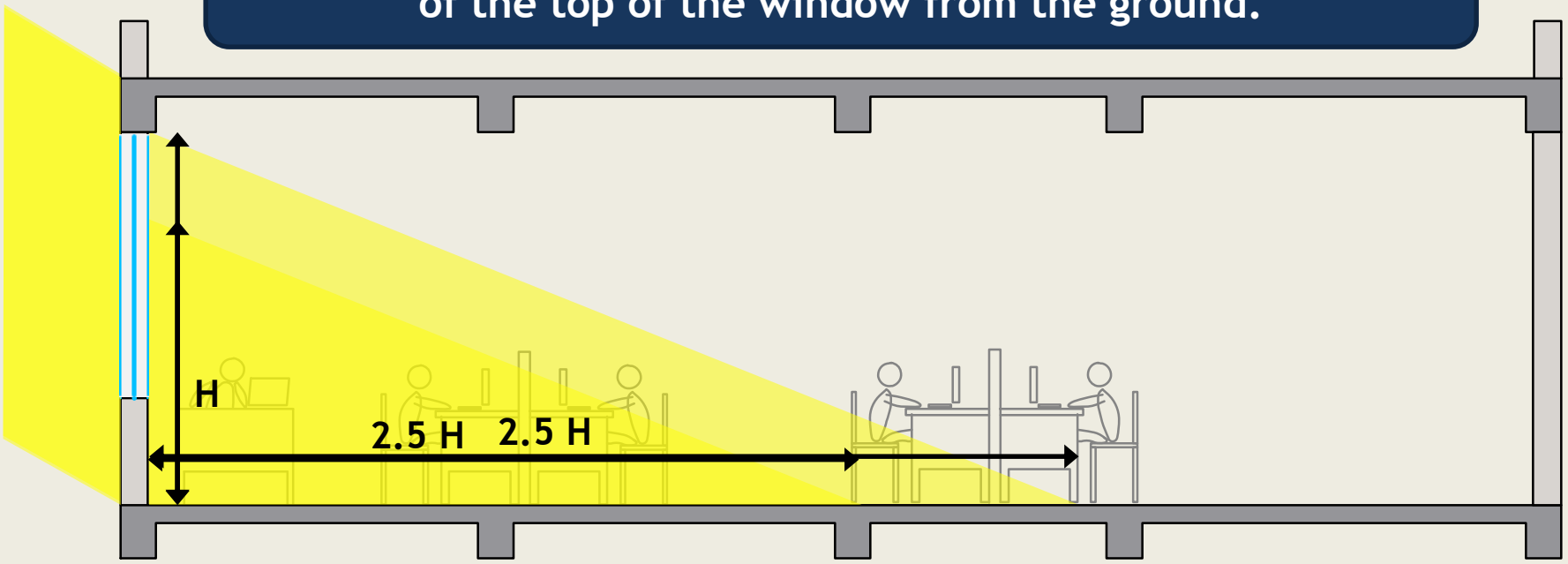
Space geometry

Light reflecting features

- Light shelves etc.
- Internal surfaces

Space Geometry

Daylight penetrates into a room roughly 2.5 times the height of the top of the window from the ground.



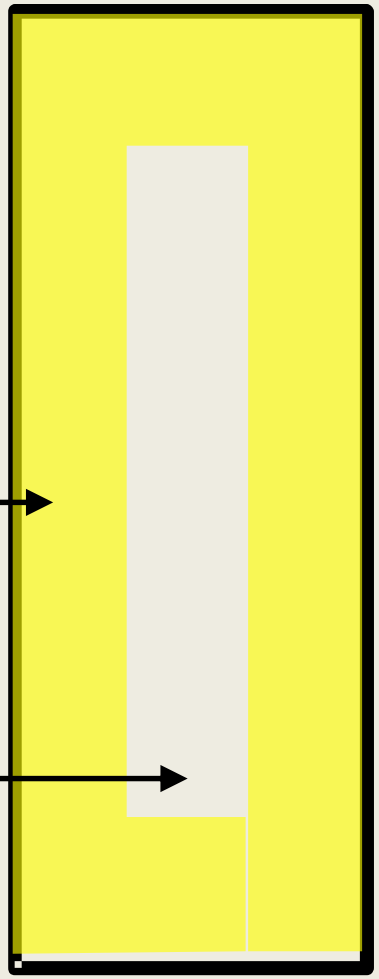
- Higher the window, deeper the daylight penetration in the room
- Usually, daylight penetration in the room is between 6m to 8m from the fenestration

Space Geometry

Shallow floor-plates provide daylight access to greater floor area

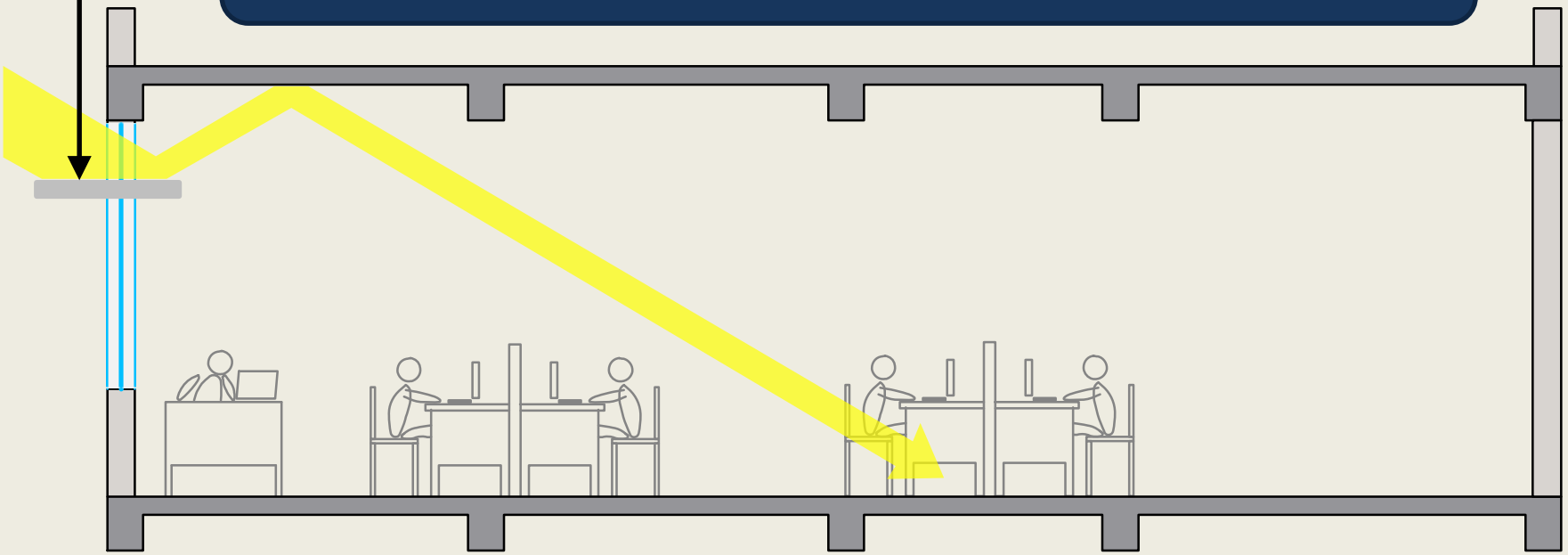
Building spaces can be zoned to place areas requiring more daylight near the perimeter.

Areas requiring less daylight placed in the centre of the floor-plate



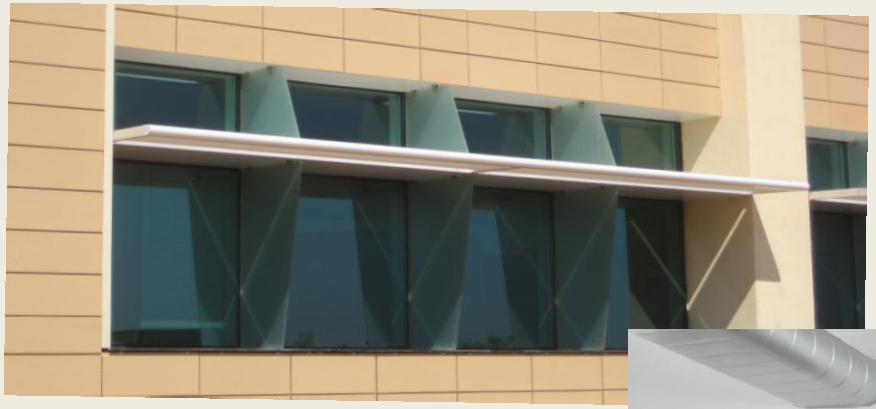
Light Reflecting Features

Light shelves help better day light distribution while also providing shading

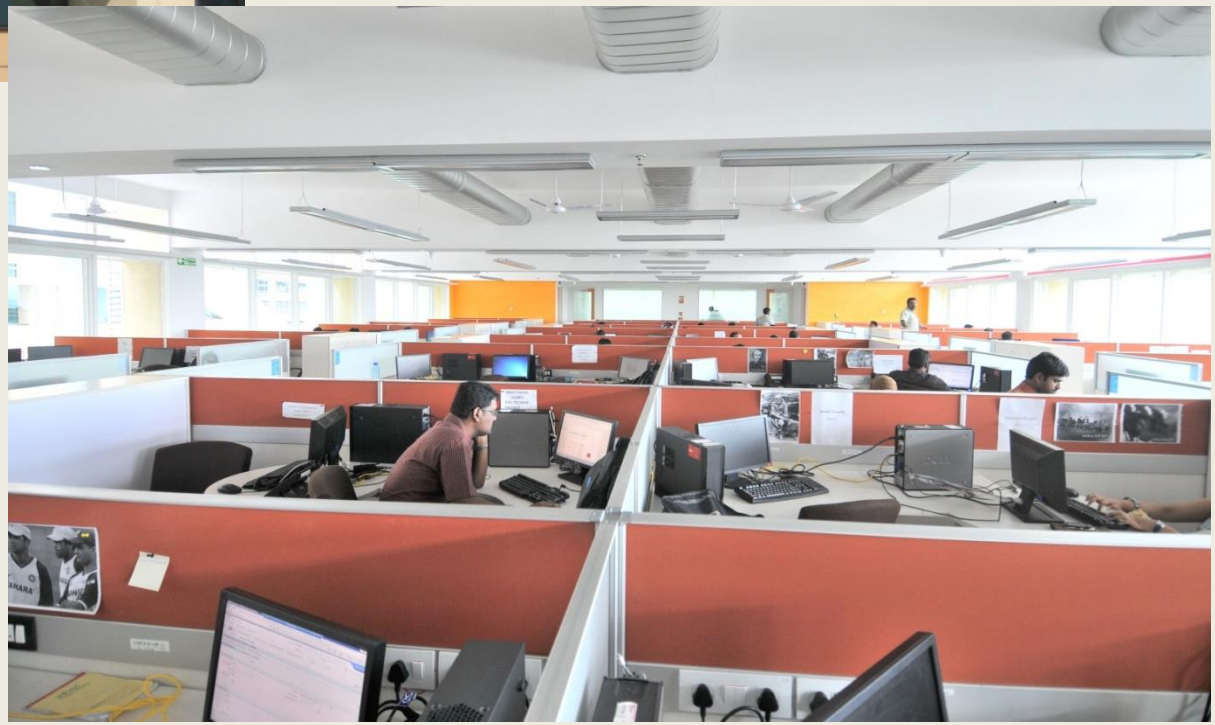


- Lighter colours on interior surfaces reflect light better.
- Helps in daylight distribution and reducing glare.

Daylighting Example



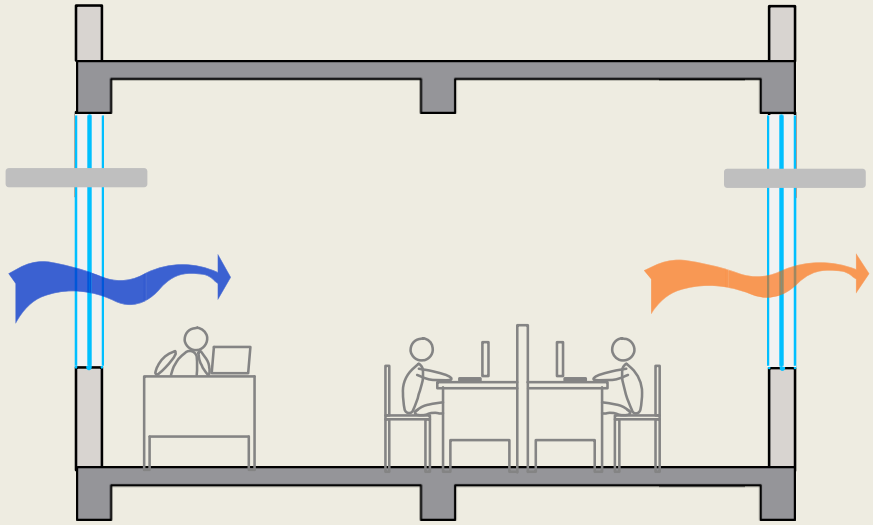
INFOSYS, HYDERABAD



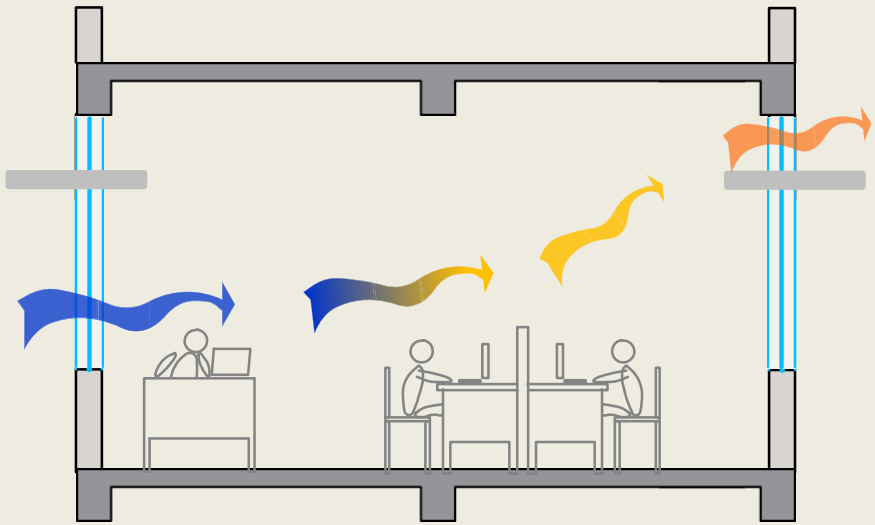
1	BUILDING MASSING AND ORIENTATION	
2	BUILDING ENVELOPE	ROOF AND WALLS
		WINDOWS
		AIR LEAKAGE
3	DAYLIGHTING	
4	NATURAL VENTILATION	

What is Natural Ventilation?

Natural ventilation is the process of *supplying and removing air through an indoor space without using mechanical systems.*



Wind driven natural ventilation



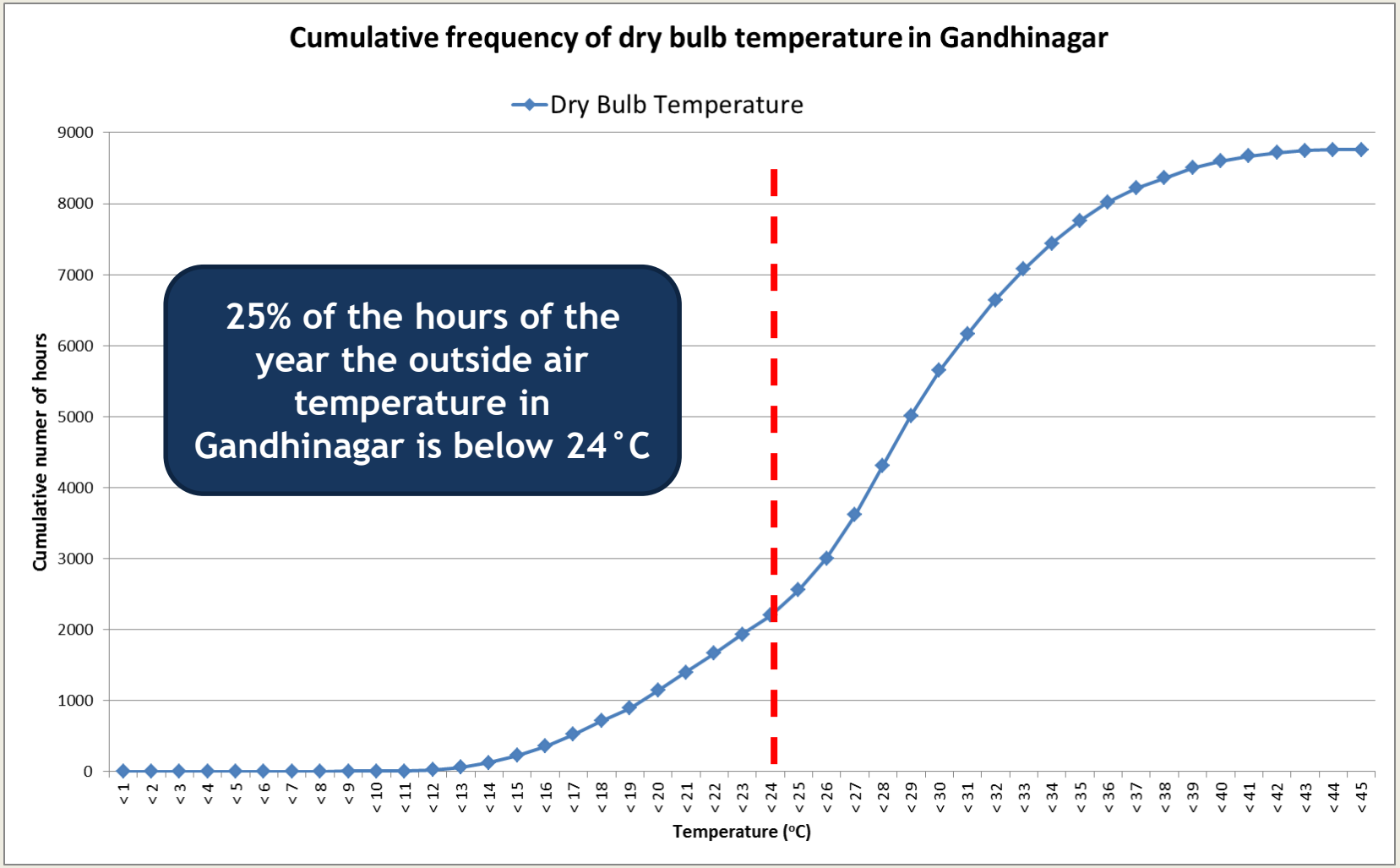
Buoyancy driven natural ventilation

Purpose of Natural Ventilation

- To provide an acceptable indoor air quality (IAQ)

- To provide thermal comfort by providing a heat transport mechanism
  - **Cooling of indoor air by replacing or diluting it with outdoor air as long as outdoor temperatures are lower than the indoor temperatures.**
  - **Cooling of the building structure i.e. Thermal mass of building.**
  - **A direct cooling effect over the human body through convection and evaporation.**

Potential for Natural Ventilation in Gandhinagar



Communications Building, Federal Institute Of Technology, Lausanne

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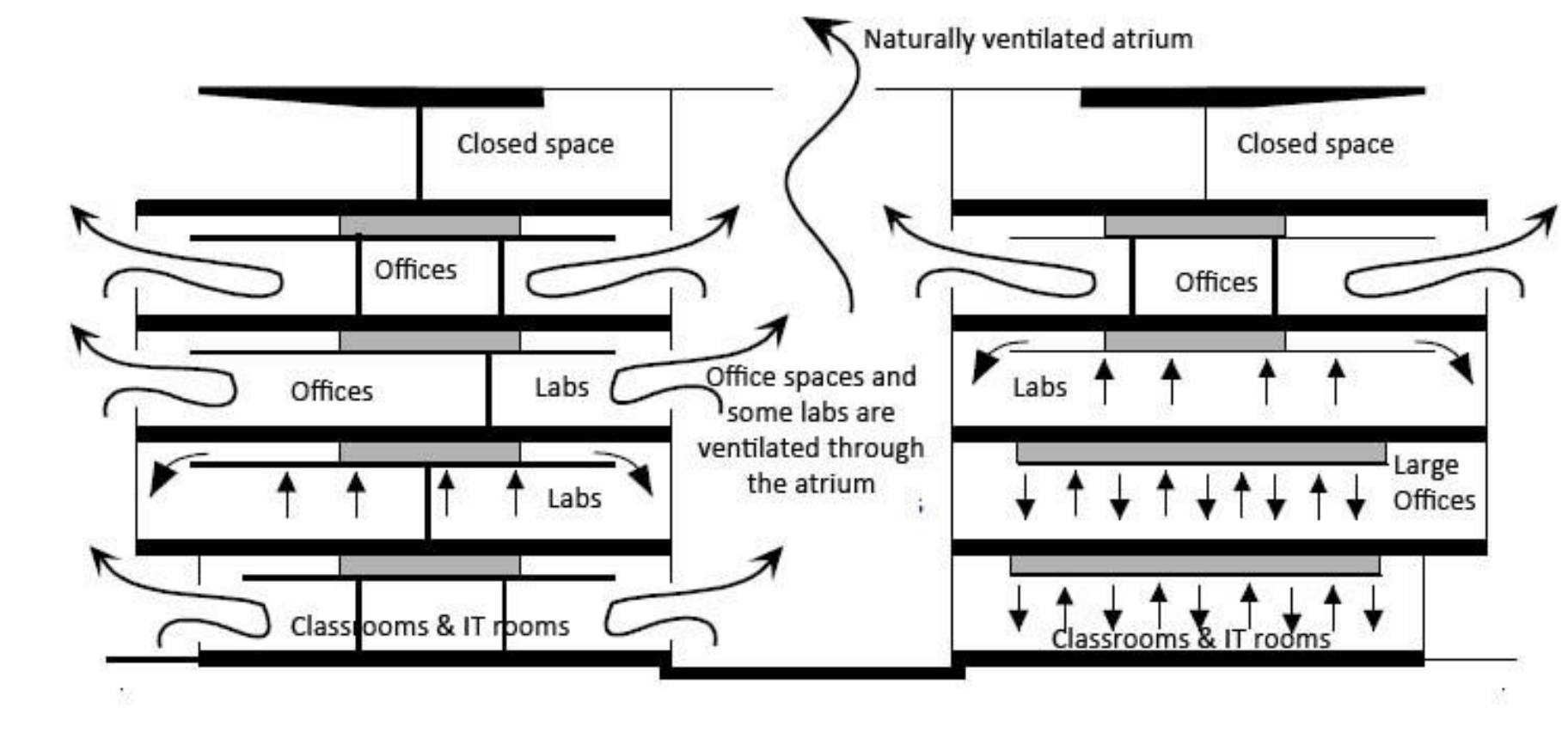
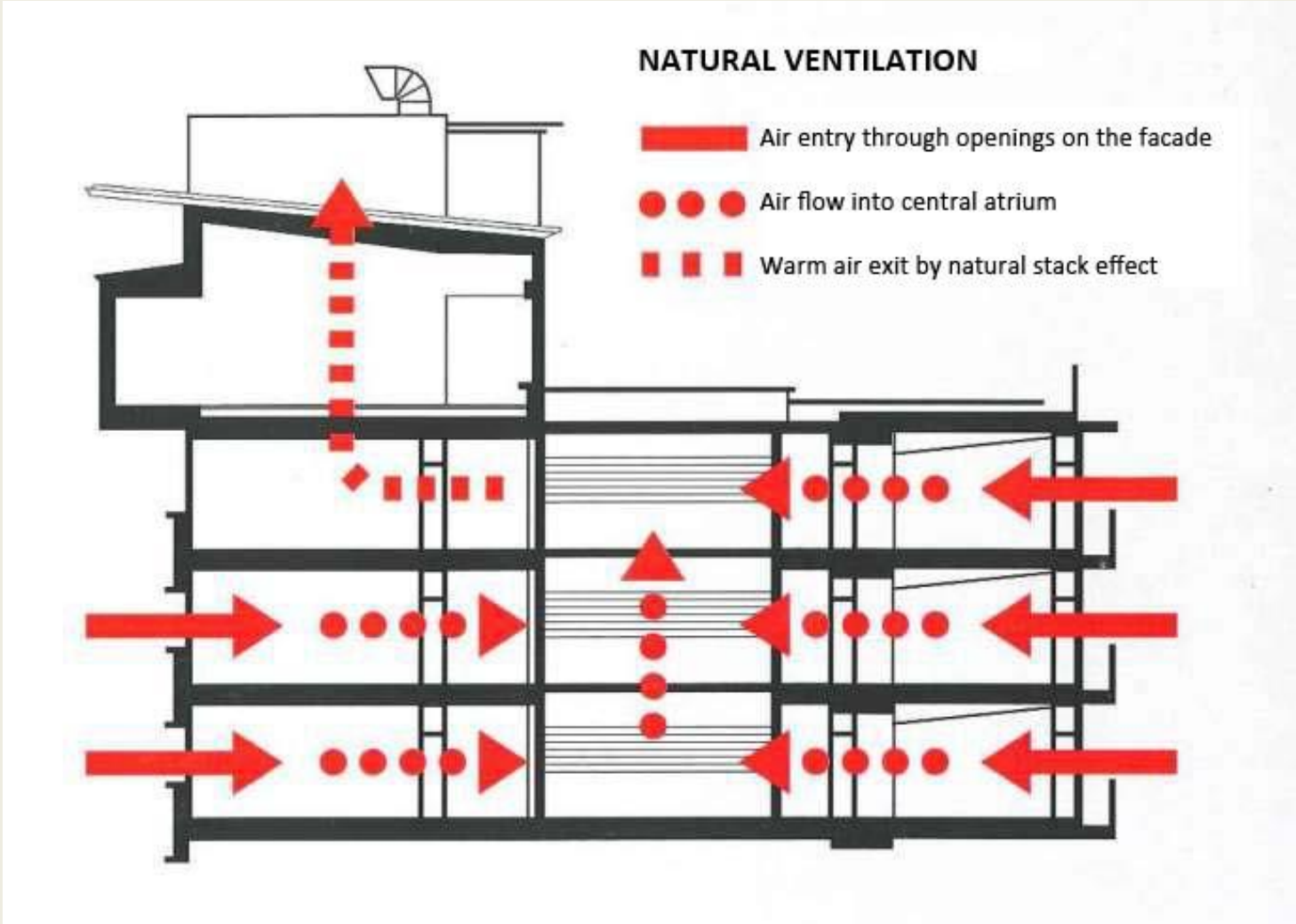


Swiss Federal Office For Statistics, Neuchâtel

Swiss Federal Office For Statistics, Neuchâtel



Swiss Federal Office For Statistics, Neuchâtel

RECAP OF PASSIVE DESIGN MEASURES

Recap of Passive Design Measures

1 BUILDING MASSING AND ORIENTATION

- Buildings with longer facades towards north and south
- Shape the building to mutually shade

Recap of Passive Design Measures

2 BUILDING ENVELOPE

- Insulation on the roof and walls to reduce heat transfer
- Seal air -conditioned buildings to prevent air leakages
- Shade windows to cut-off direct solar radiation from falling on the windows
- High performance window frame and glazing

Recap of Passive Design Measures

3	DAYLIGHT

- Place large windows on north and south facades
- Zone building spaces to place areas needing daylight at the perimeter
- Place windows higher up on the wall, near the ceiling for better daylight distribution
- Light shelves to reflect light deeper into the room
- Light coloured internal surfaces for better light reflection

Recap of Passive Design Measures

4 NATURAL VENTILATION

- In Gandhinagar, natural ventilation is feasible in late nights during summer and the winter months.
- Natural Ventilation useful only when outside temperature is lower than inside temperature
- Different operation schedule for windows and other openings at different times of the year
- Shallow floorplate assists better ventilation
- Atriums and openings at different levels assist stack ventilation
- Provide operable windows (with proper sealing) to have the option of natural ventilation

THANK YOU