18MEO103T – Energy systems for Buildings

Unit – I Energy transfer in Buildings

Course Code	18MEO103T	Course Name	ENERGY SYSTEMS FOR BUILDINGS	Course Category	O	Open Elective	L	T	P	C
							3	0	0	3

Pre-requisite Courses	NiL	Co-requisite Courses	NIL	Progressive Courses	NIL
Course Offering Department	Mechanical Engineering	Data Book / Codes/Standards	NIL		

Course Learning Rationale (CLR):	The purpose of learning this course is to:
CLR-1 :	*Be familiar with the energy transfer in buildings*
CLR-2 :	*Study the solar passive heating and cooling systems*
CLR-3 :	*Be familiar with the lighting systems of buildings*
CLR-4 :	*Study the Heat control and ventilation methods in buildings*
CLR-5 :	*Be familiar with the Green buildings*
CLR-6 :	*Be familiar with the design and energy management of buildings*

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Learning 1: Level of Thinking (Bloom)	Learning 2: Expected Proficiency (%)	Learning 3: Expected Attainment (%)	PLO 1: Engineering Knowledge	PLO 2: Problem Analysis	PLO 3: Design & Development	PLO 4: Analysis, Design, Research	PLO 5: Modern Tool Usage	PLO 6: Society & Culture	PLO 7: Environment & Sustainability	PLO 8: Ethics	PLO 9: Individual & Team Work	PLO 10: Communication	PLO 11: Project Mgt. & Finance	PLO 12: Life Long Learning	PLO 13: PSO - 1	PLO 14: PSO - 2	PLO 15: PSO – 3
CLO-1 :	*Acquire knowledge on heating and cooling load calculations on energy efficient buildings*	*1,2 &3*	*90*	*80*	*H*	*M*		*M*										*H*	
CLO-2 :	*Understand the concept of solar passive heating and cooling*	*1,2*	*90*	*80*	*H*	*M*					*M*							*H*	
CLO-3 :	*Understand the concept of Day lighting and electrical lighting systems*	*1&2*	*90*	*80*	*H*					*L*	*M*							*H*	
CLO-4 :	*Recognize the design parameters influencing thermal design of buildings*	*1,2 &3*	*90*	*80*	*H*	*M*		*M*			*M*							*H*	
CLO-5 :	*Understand the concept of green buildings and certifications*	*1 &2*	*90*	*80*	*H*		*M*			*L*	*M*							*H*	
CLO-6 :	*Acquire knowledge on design and energy management of buildings*	*1,2 & 3*	*90*	*80*	*H*	*M*	*M*	*M*		*L*	*M*							*H*	

		Energy transfer in buildings	Passive solar heating & Cooling	Lighting systems of buildings	Heat control & ventilation	Green buildings
Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Concepts of energy efficient buildings*	*General principles of passive solar heating*	*Introduction to lighting systems of buildings*	*Introduction to heat control and ventilation*	*Introduction to green building*
S-2	SLO-1	*Conventional versus Energy Efficient buildings*	*Key design elements of passive heating*	*Glazing materials: Sources and concepts of optical materials*	*Design parameters influencing thermal design of buildings*	*Green building features and green construction materials*
S-3	SLO-1	*Climate and its influence in building design for energy requirement, Thermal properties of building materials*	*Direct solar heat gain by Trombe mass walls*	*Concepts of day lighting*	*Heat transmission through building sections*	*Green building rating tools*
S-4	SLO-1	*Codes and standards for the energy efficient buildings-ECBC codes*	*Passive cooling and its Key design elements, ventilation*	*Components of daylight factors and Recommended daylight factors*	*Effect of heating with orientation of buildings*	*Integrated ecological design, Sustainable site and landscaping*
S-5	SLO-1	*Energy balance for cooling and heating of buildings*	*Water walls, evaporative cooling*	*Day lighting analysis*	*Ventilation requirements for heat control in buildings*	*Indoor air quality, Water and waste management systems*
S-6	SLO-1	*Calculation of heating load, Heat losses and Internal heat sources*	*Convective air loops and solar chimney effects*	*Electrical lighting and Illumination requirement*	*Standards for ventilation*	*Green Globe, LEED, GRIHA, IGBC codes & certifications*
S-7	SLO-1	*Calculation of cooling loads of the building*	*Predicting ventilation in buildings, window ventilation calculations*	*Selection of luminaries and performance parameters*	*Ventilation designs, Energy conservation measurement*	*Standards for green building certifications*
S-8	SLO-1	*Low and zero energy buildings*	*Thermal insulation, load control, air filtration,*	*Electric lighting control for day lighted buildings*	*Natural ventilation methods*	*Economics, managing initial costs of green buildings*
S-9	SLO-1	*Future building design aspects*	*Odor removal and heat recovery in large buildings*	*Comparison of day and electrical lighting*	*Forced ventilation methods*	*Environment benefits of green buildings*

Learning Resources	1. *Means R.S., "Green building: project planning and cost estimating", Kingston, 2006* 2. *Kibert C.J., "Sustainable Construction: Green Building Design", 2nd edition, Wiley, 2007* 3. *Boecker J., Scot Horst, Tom Keiter, Andrew Lau, Markes Sheffer, Brian Toevs, Bill Reed, "Integrative Design Guide to Green Building", Wiley, 2009* 4. *Eicker U., "Low Energy Cooling for Sustainable Buildings", Wiley, 2009* 5. *Gevorkian P., "Alternative Energy Systems in Building Design", McGraw-Hill, 2010.* 6. *Harvey D.L., "Handbook on Low-Energy Buildings and District-Energy Systems", Earthscan, 2006.* 7. *Attmann O., "Green Architecture", McGraw-Hill, 2010* 8. *Kubba S., "Handbook of Green Building Design and Construction", Elsevier, 2012.* 9. *Majumdar, M., "Energy – Efficient Buildings in India", Tata Energy Research Institute, Ministry of Non-Conventional Energy Sources, 2002.* 10. *Energy Conservation Building Codes: www.bee-india.nic.in*

Learning Assessment											
	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate Create	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
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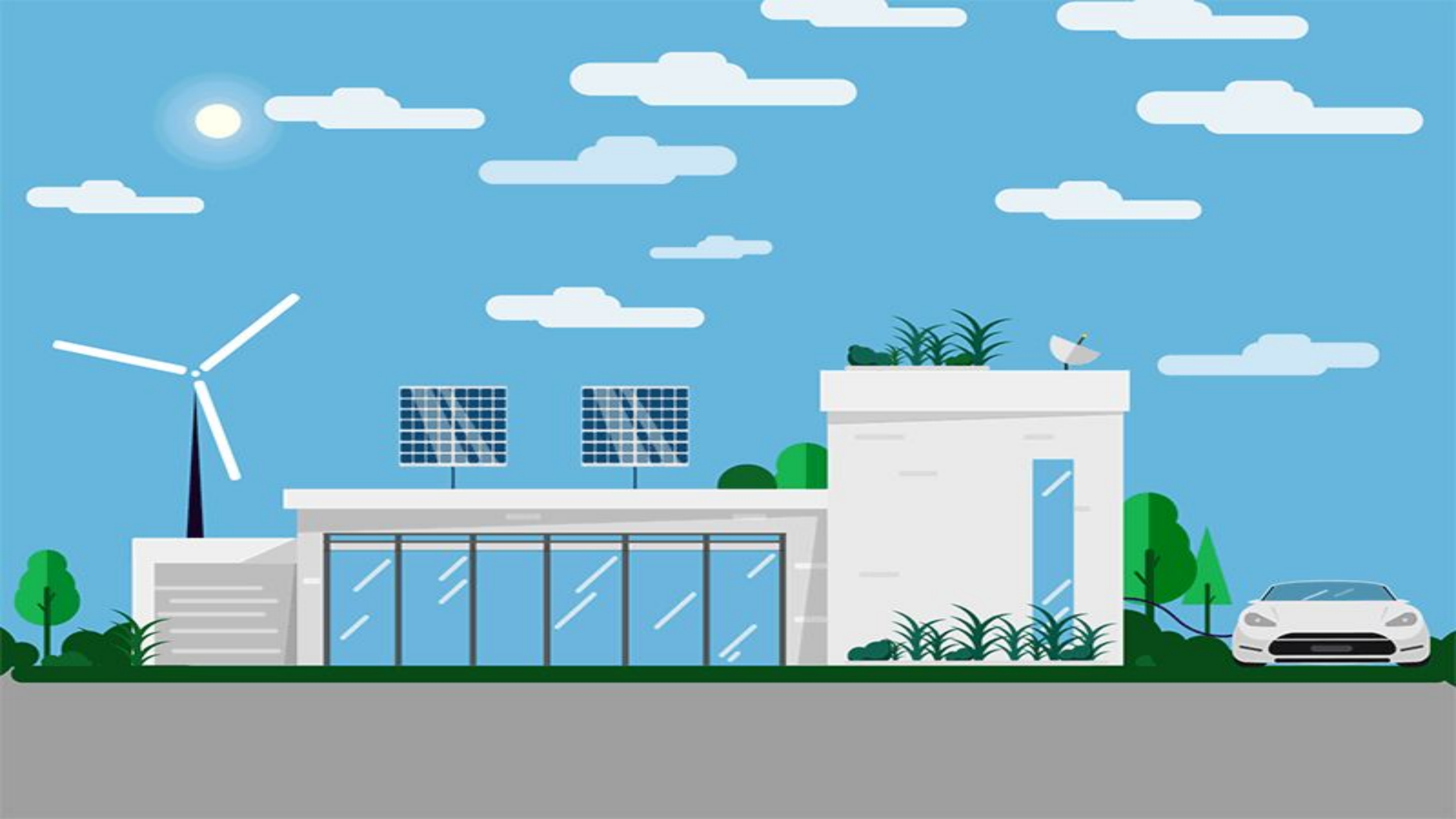
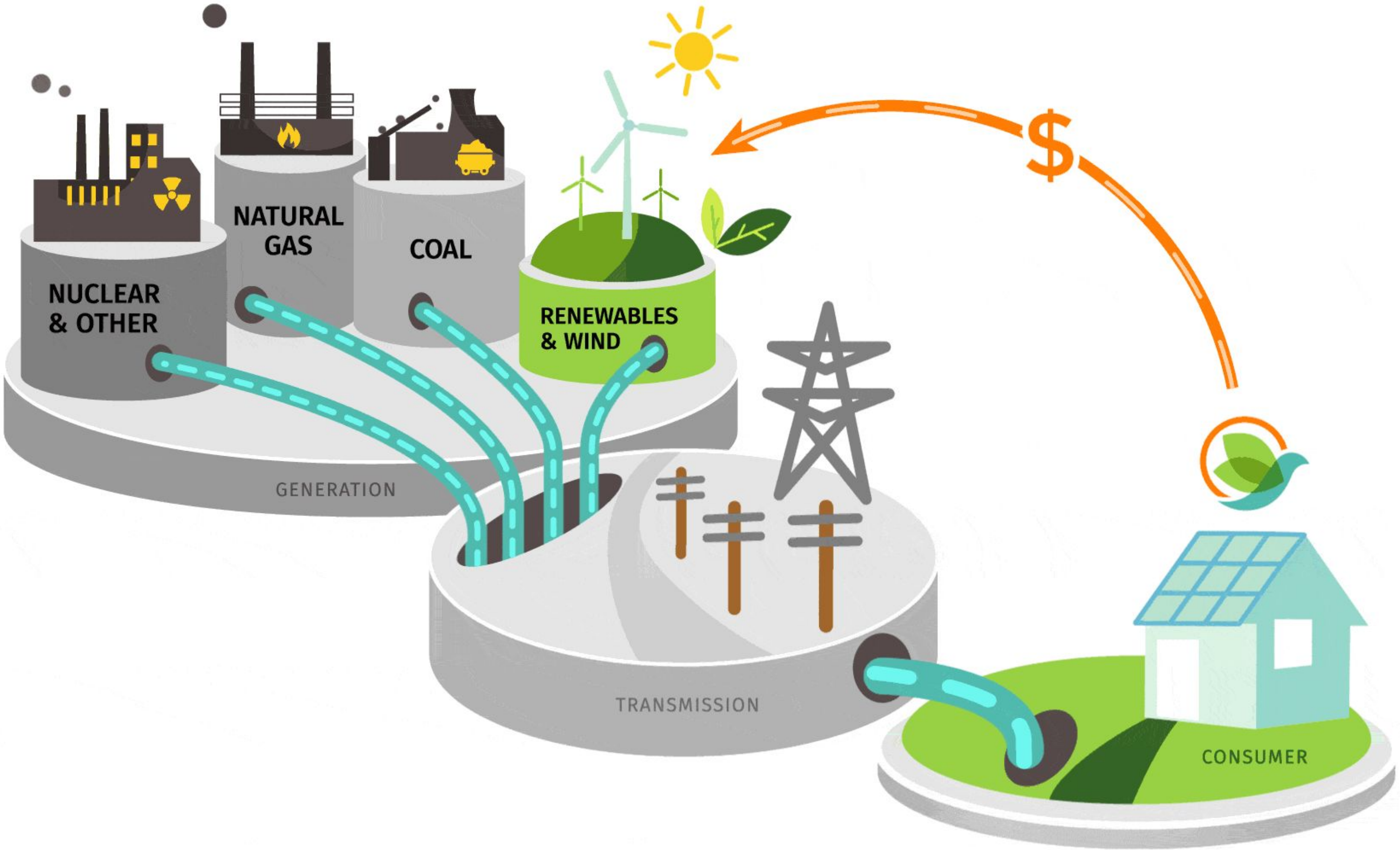



NATURAL GAS
COAL
NUCLEAR & OTHER
RENEWABLES & WIND
$
GENERATION
TRANSMISSION
CONSUMER

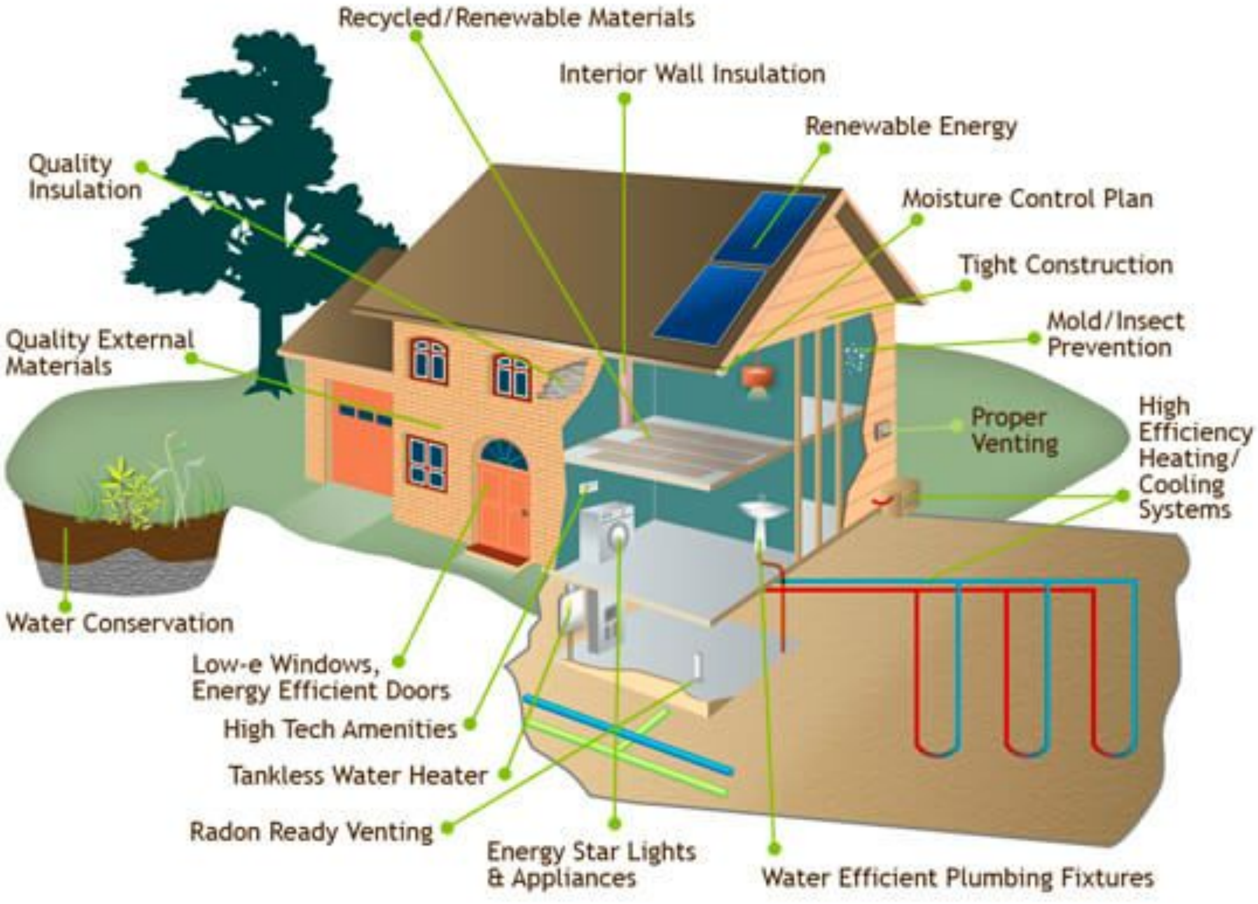
Importance/Benefits of energy-efficient buildings

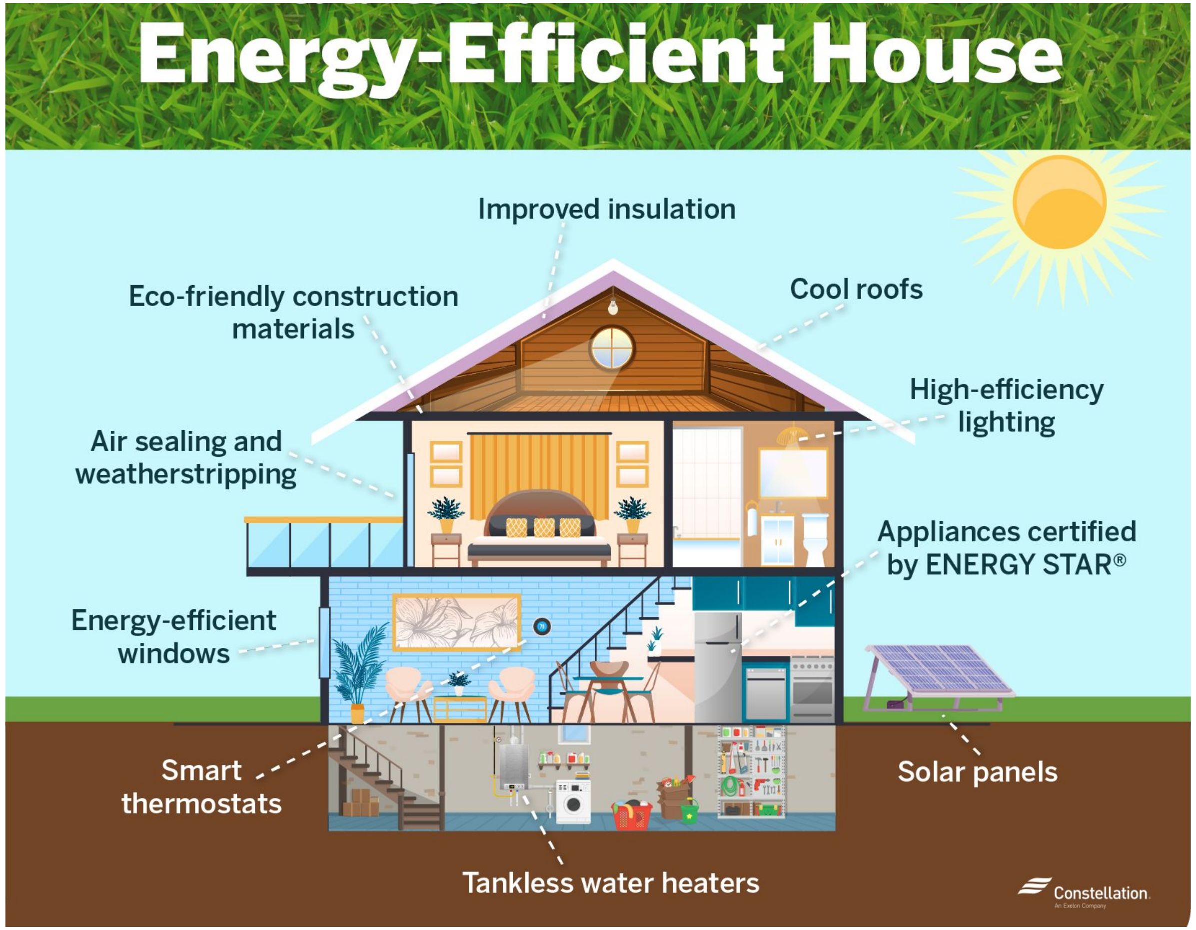
Increase in human comfort

Cut the Green House Gas emission

Reduce the Electricity bills

Concepts of energy-efficient buildings



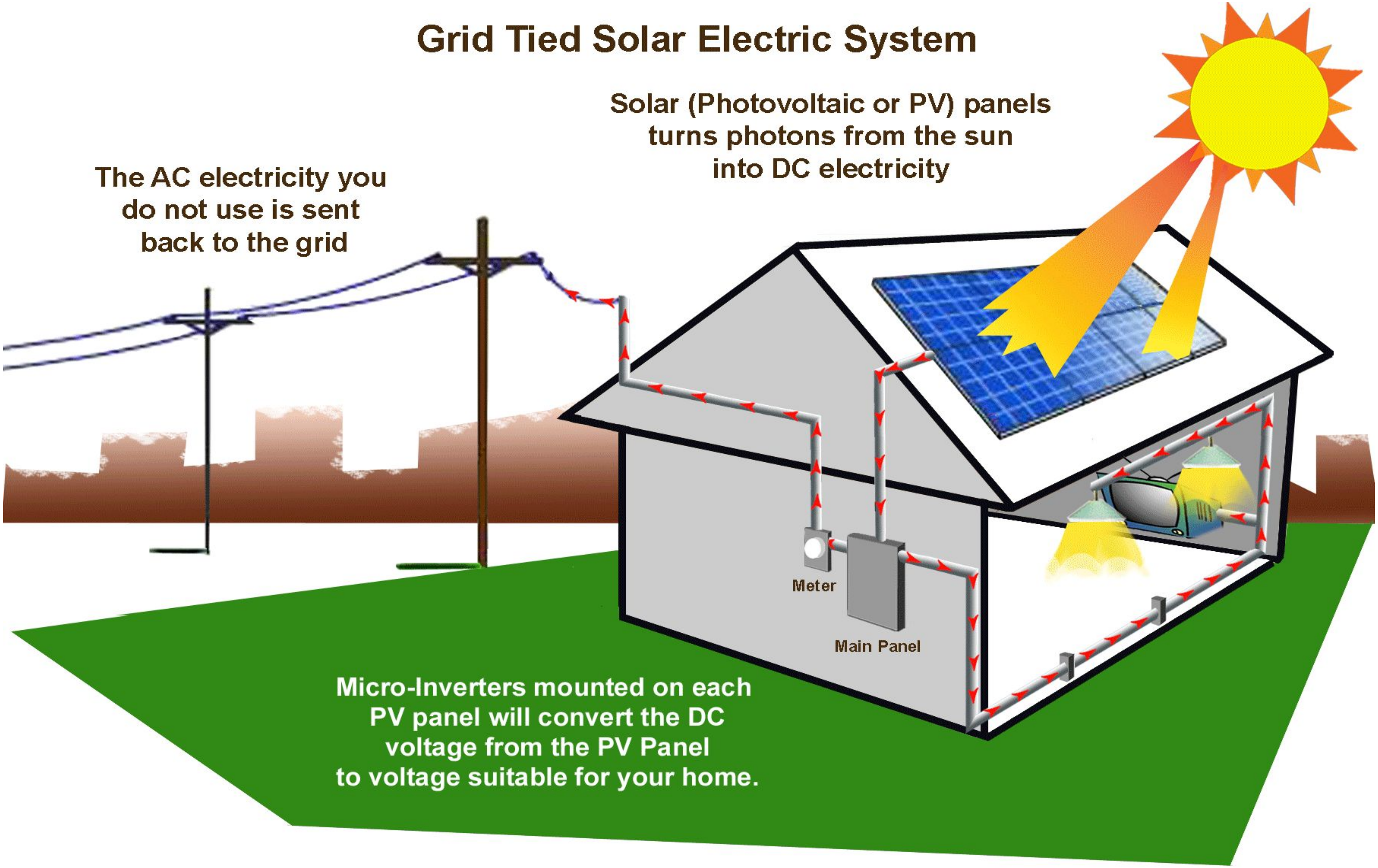


ENERGY EFFICIENCY IN BUILDINGS

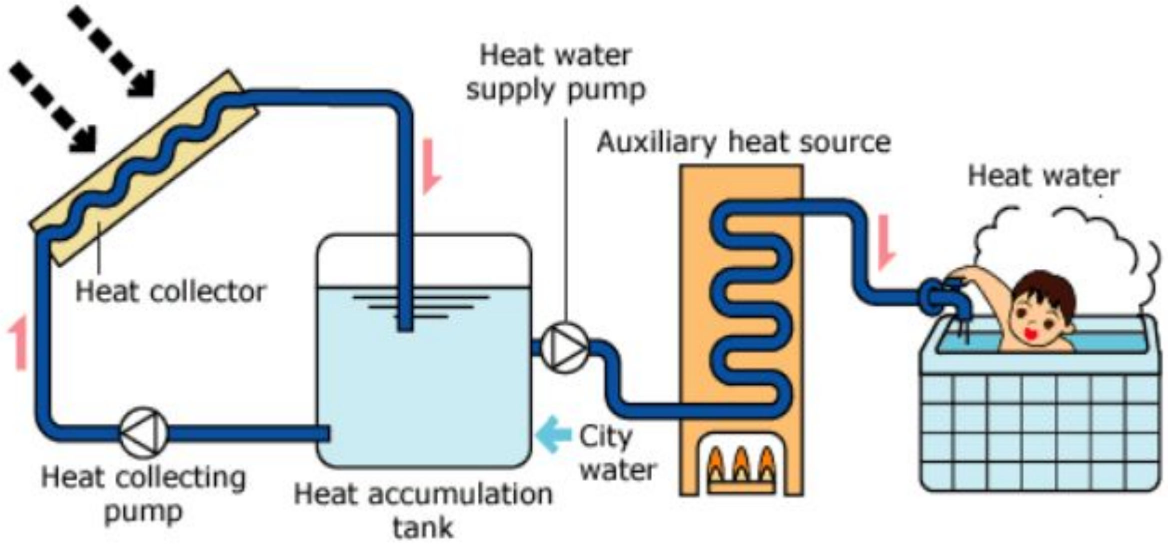
EE Measures for Buildings

Impacts Of Construction on environment

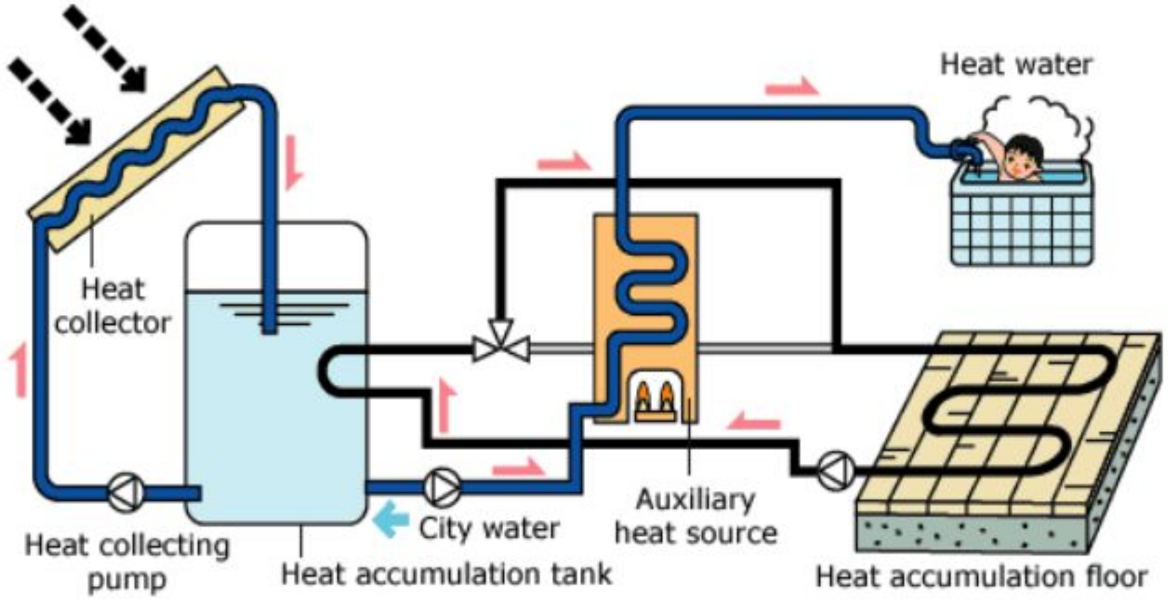
- ✓ Consume nearly 40% of raw materials.
- ✓ Consume 32% of total energy produced.
- ✓ Consume 17% of the fresh water.
- ✓ Consume 25% of global wood harvest.
- ✓ Responsible for Acid Rain.
- ✓ Generates
    - 25-40% of municipal solid waste.
    - 50% of world CFC production.
    - 30% of world CO_2 production.


Grid Tied Solar Electric System
Solar (Photovoltaic or PV) panels
turns photons from the sun
into DC electricity
The AC electricity you
do not use is sent
back to the grid
Meter
Main Panel
Micro-Inverters mounted on each
PV panel will convert the DC
voltage from the PV Panel
to voltage suitable for your home.

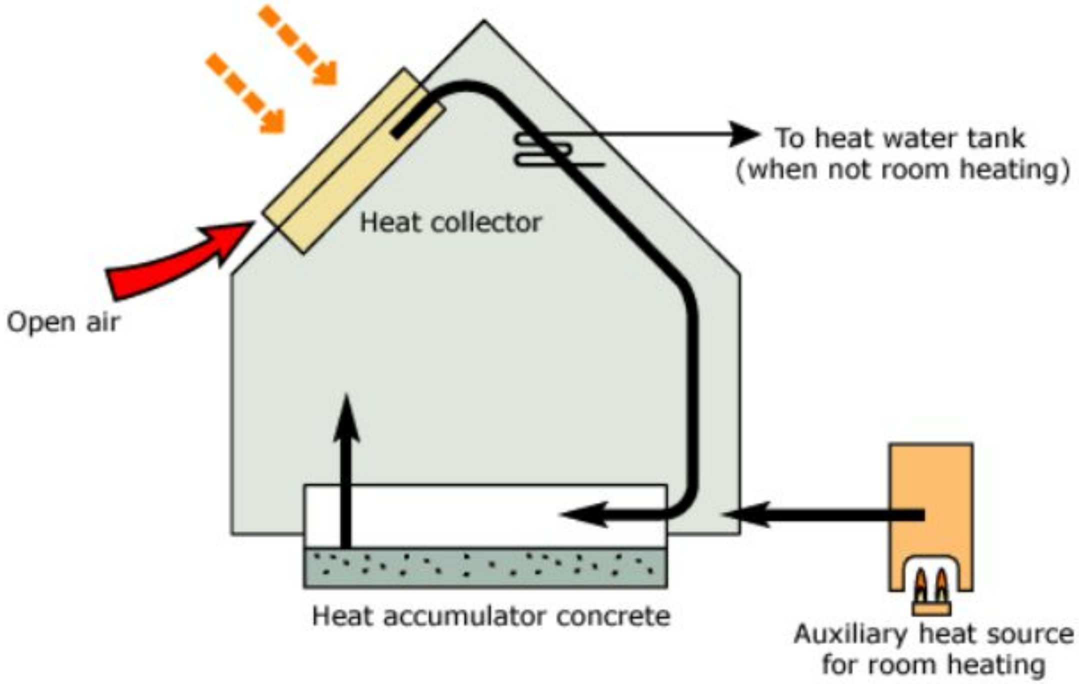
A: Water Heater System

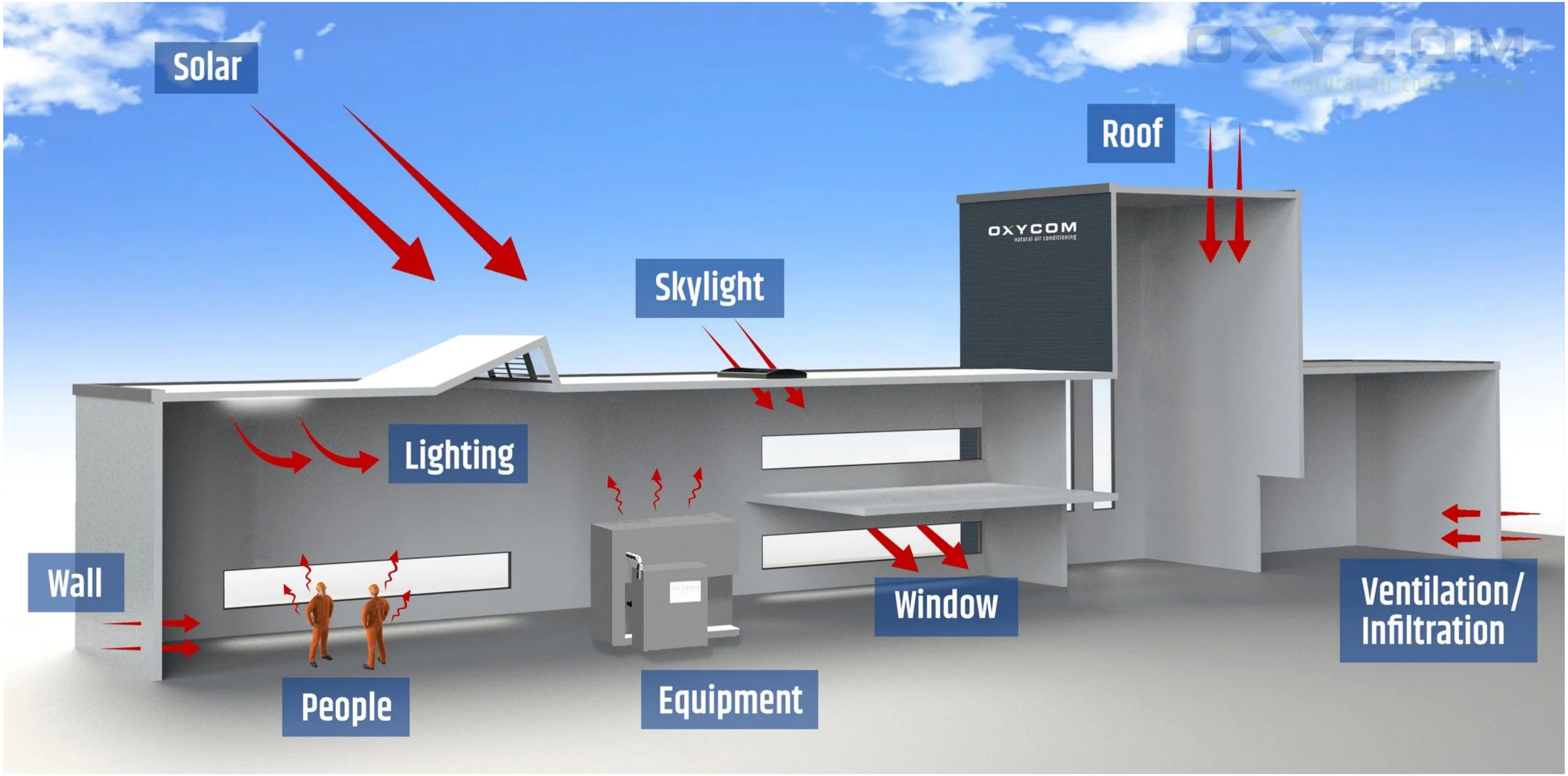


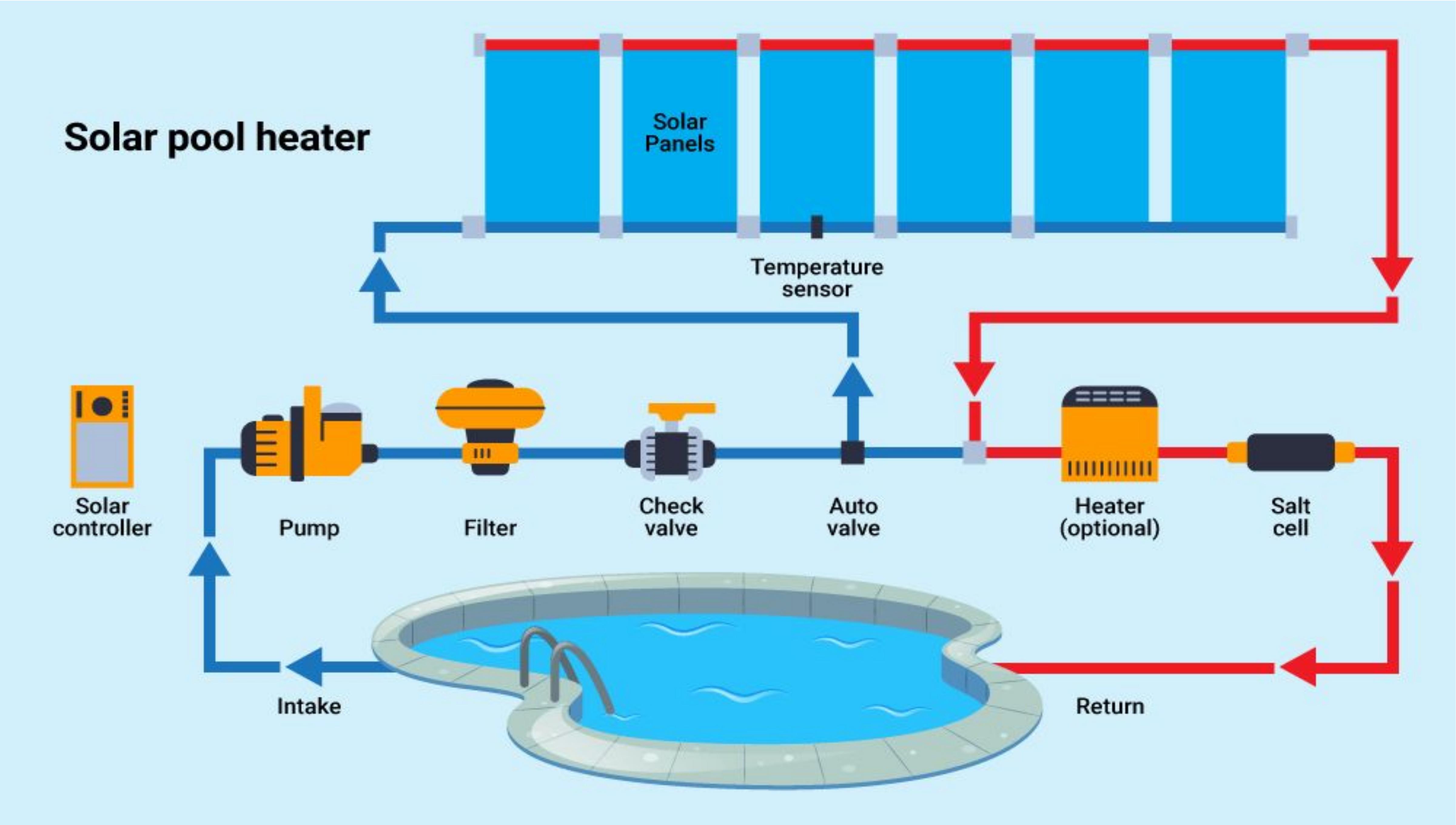
B: Room Heater/Water Heater System (Floor Heater)



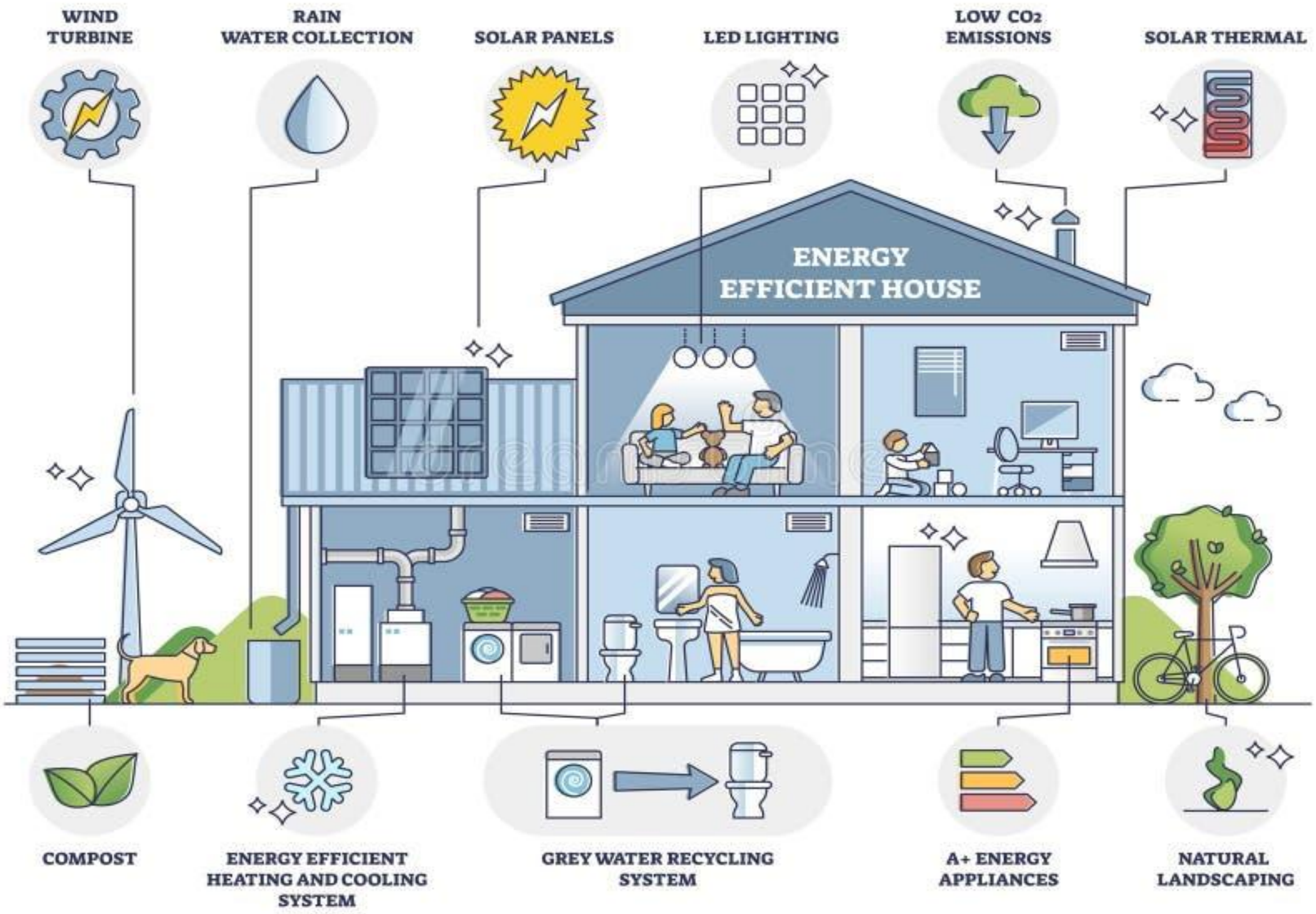
C: Room Heater, Water Heater System (Air Heater)




Solar
OXYCOM
natural air conditioning
Roof
Skylight
Lighting
Wall
People
Equipment
Window
Ventilation/
Infiltration



Solar pool heater
Solar Panels
Temperature sensor
Solar controller
Pump
Filter
Check valve
Auto valve
Heater (optional)
Salt cell
Intake
Return


WIND TURBINE
RAIN WATER COLLECTION
SOLAR PANELS
LED LIGHTING
LOW CO2 EMISSIONS
SOLAR THERMAL
ENERGY EFFICIENT HOUSE
COMPOST
ENERGY EFFICIENT HEATING AND COOLING SYSTEM
GREY WATER RECYCLING SYSTEM
A+ ENERGY APPLIANCES
NATURAL LANDSCAPING

Conventional building

Conventional buildings were built using non-energy-saving techniques; however, that does not mean they are unable to have energy-saving improvements made to them.

The cost of the building and the energy spent is high.

It depends on the external Energy sources

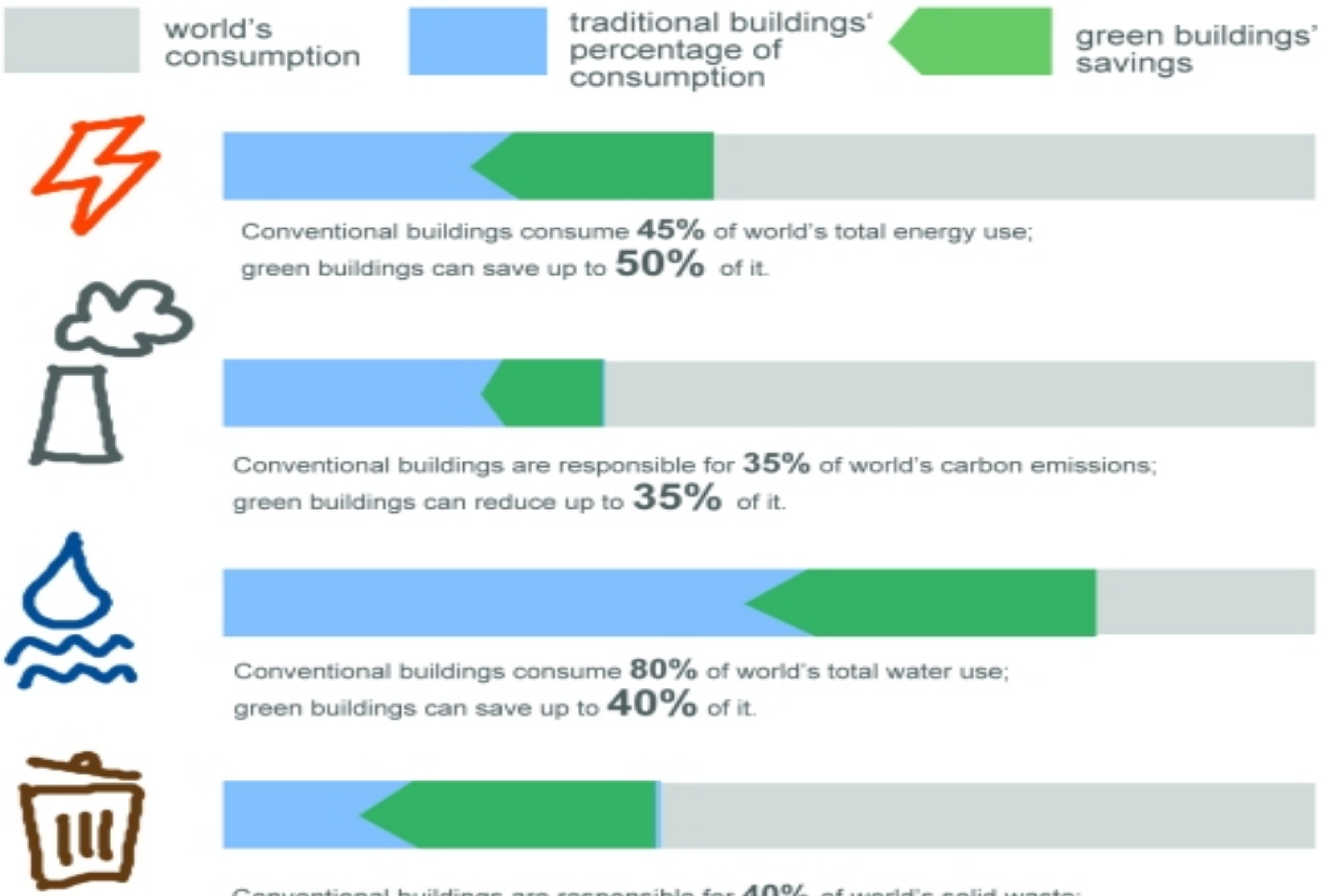
Energy Efficient Building

Energy Efficient buildings both increase a **building's** energy efficiency by using energy star appliances and improve the design of the **building.**

The cost of the building and energy spent is low.

It may partially depend on the external energy sources and sometimes fully not depend on the external Energy sources.

Conventional Building VS. Green Building



Conventional buildings consume **45%** of world's total energy use;
green buildings can save up to **50%** of it.

Conventional buildings are responsible for **35%** of world's carbon emissions;
green buildings can reduce up to **35%** of it.

Conventional buildings consume **80%** of world's total water use;
green buildings can save up to **40%** of it.

Conventional buildings are responsible for **40%** of world's solid waste;
green buildings can reduce up to **70%** of it.

Difference Between Conventional and Alternative Building Materials

Conventional Building Materials

Conventional building materials are those materials that have been traditionally used to make buildings, monuments, structures, etc.

Alternative Building Materials

Alternative building materials are environmentally friendly building materials.

Comparison Table

Parameters of Comparison	Conventional Building Materials	Alternative Building Materials
Flooring	Uses concrete flooring.	Uses wood flooring.
Concrete	Uses cement and other substances harmful to the environment.	Uses ‘green concrete’, which contains recycled items.
Aim	Does not have any environmental goals.	Aims to reduce environmental pollution.
Reinforcement	Steel reinforcement.	Bamboo reinforcement.
Wall System	Brick walls.	Walls are made of straw or bale.

Straw bale houses

Low Embodied Energy
Biodegradable

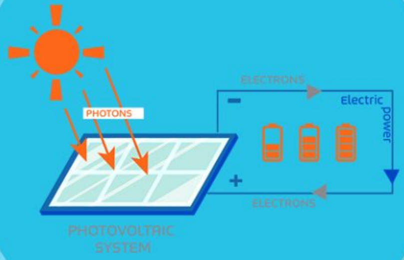
Produce energy

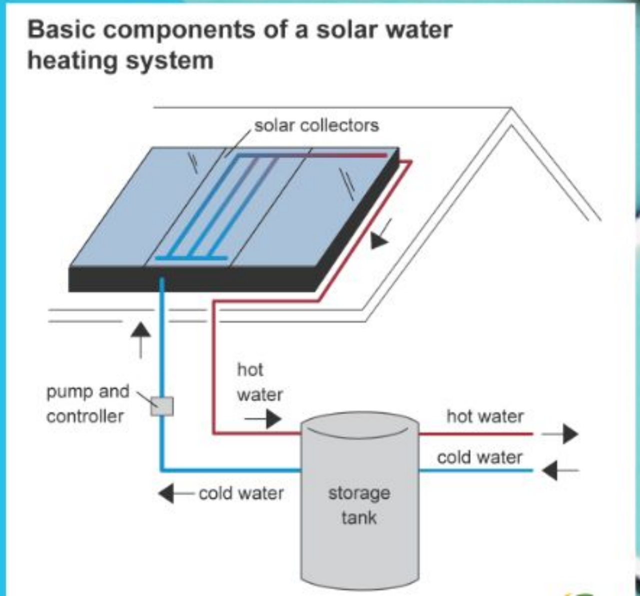
Solar photovoltaic

Micro wind turbine

Thermal solar panel

Solar photovoltaic

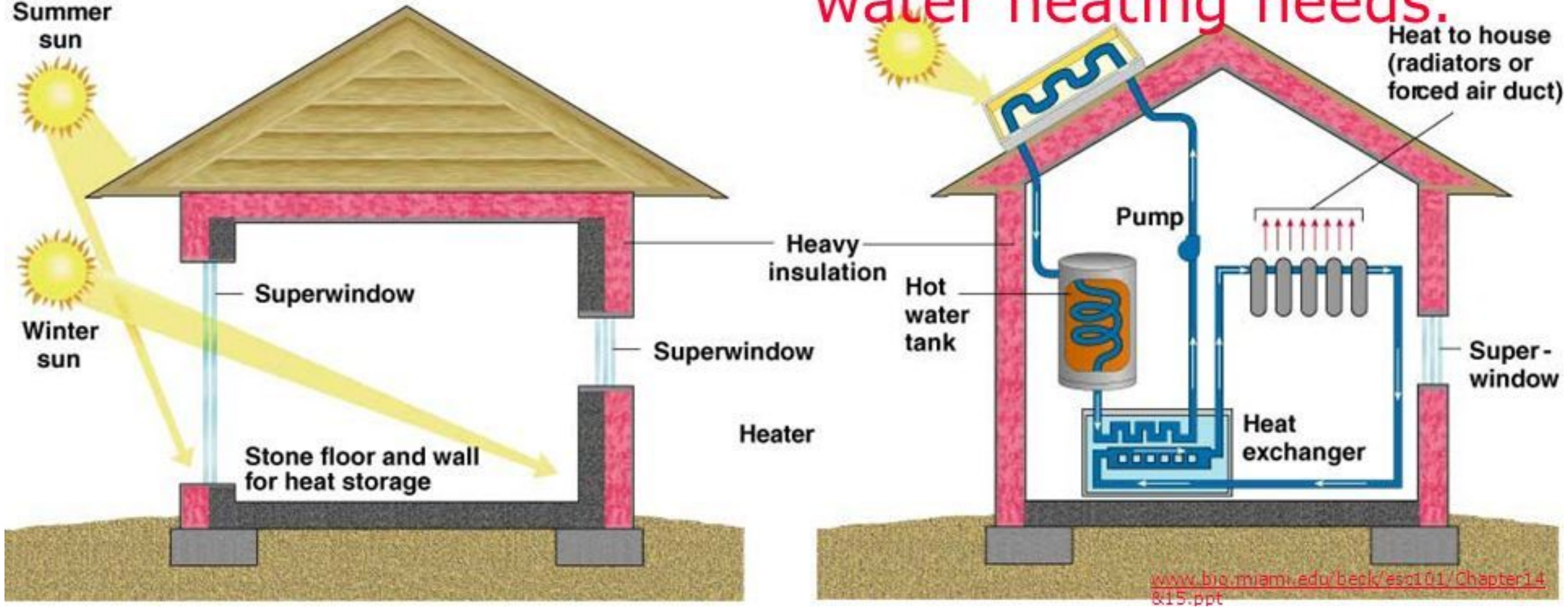




Solar Heating

Passive system: Absorbs & stores heat from the sun directly within a structure

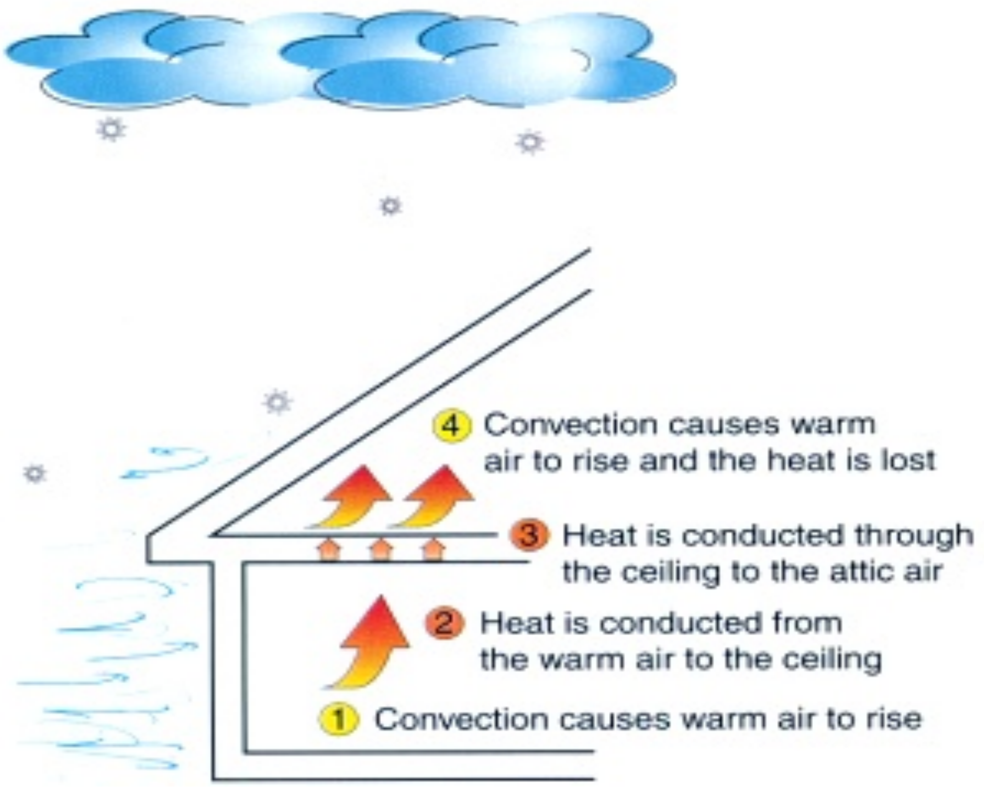
Active system: Collectors absorb solar energy, a pump supplies part of a building's heating or water heating needs.

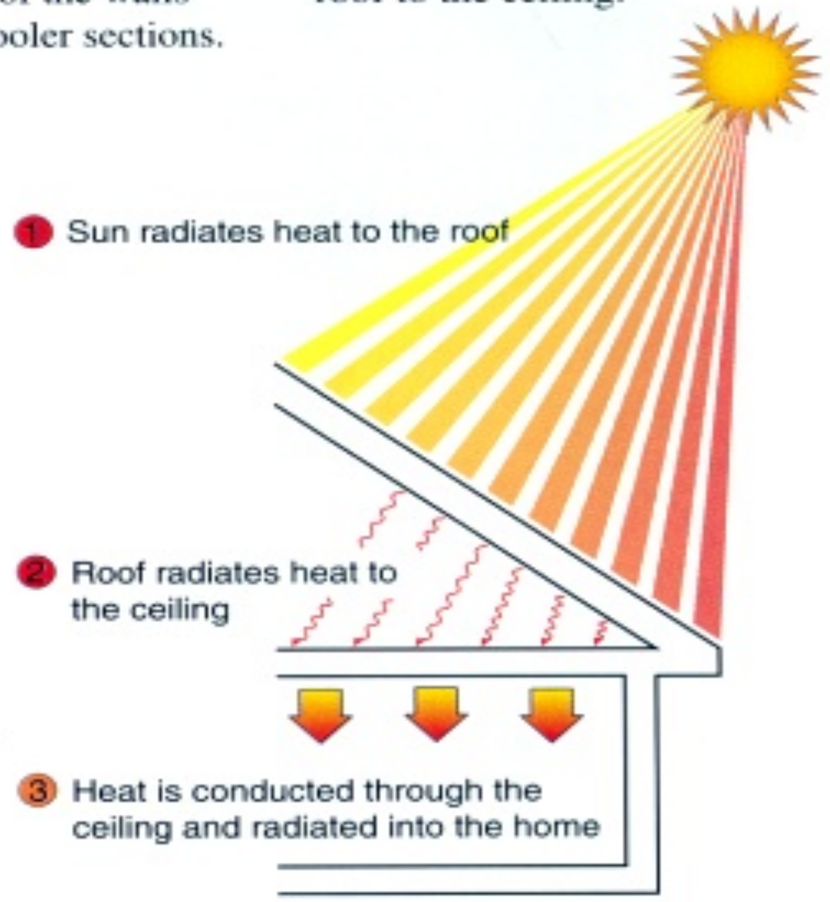


www.bio.miami.edu/beck/esc101/Chapter14&15.ppt

Your Home Loses and Gains Heat in 3 Ways

	Convection	Conduction	Radiation
Definition:	The transfer of heat by moving air.	The transfer of heat through a solid material.	The transfer of heat in the form of electromagnetic waves.
Example:	Warm air rises and transfers heat to the ceiling	Heat is transferred from warmer sections of the walls and ceilings to cooler sections.	Heat is transferred from the roof to the ceiling.

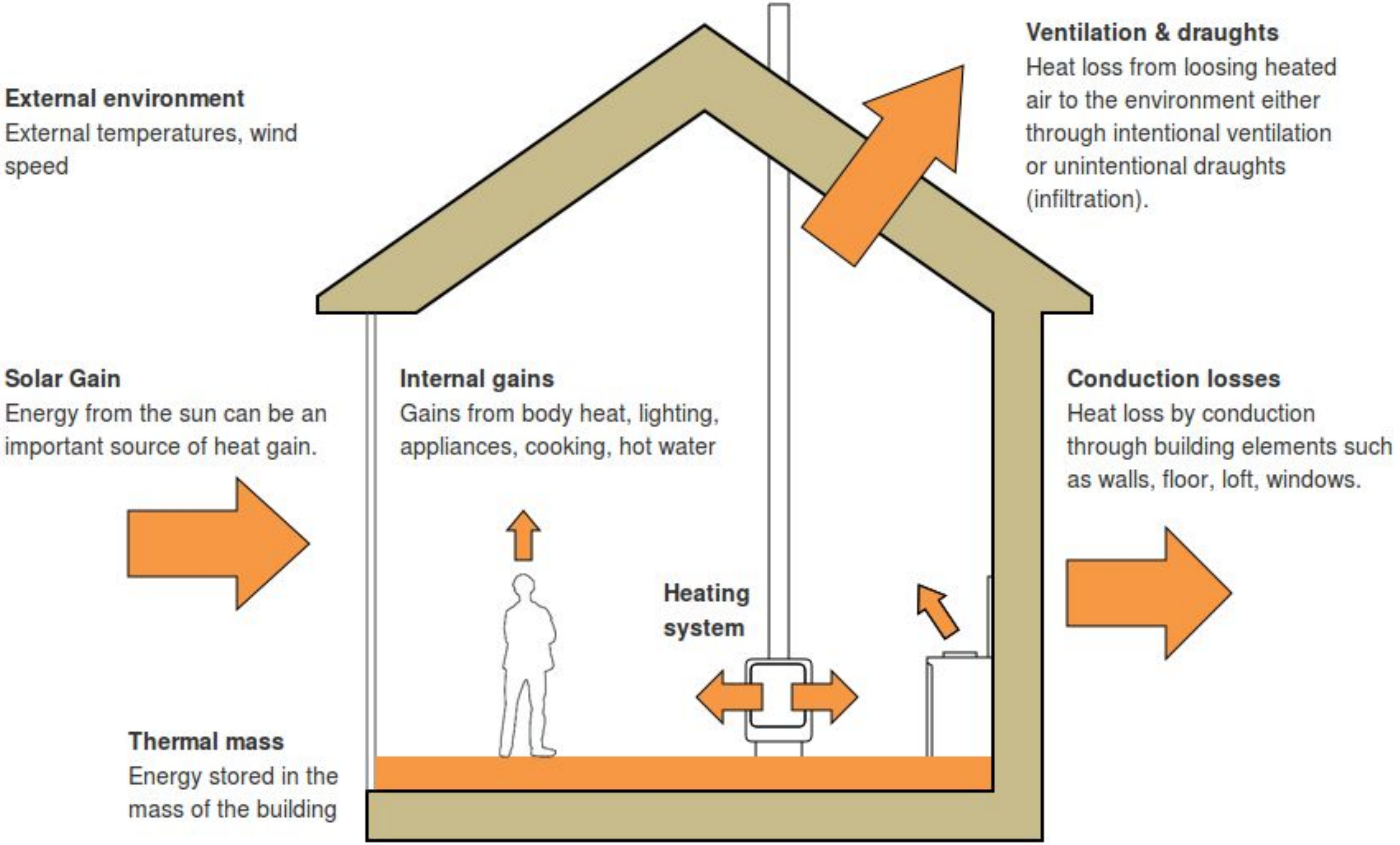




Thermal inputs

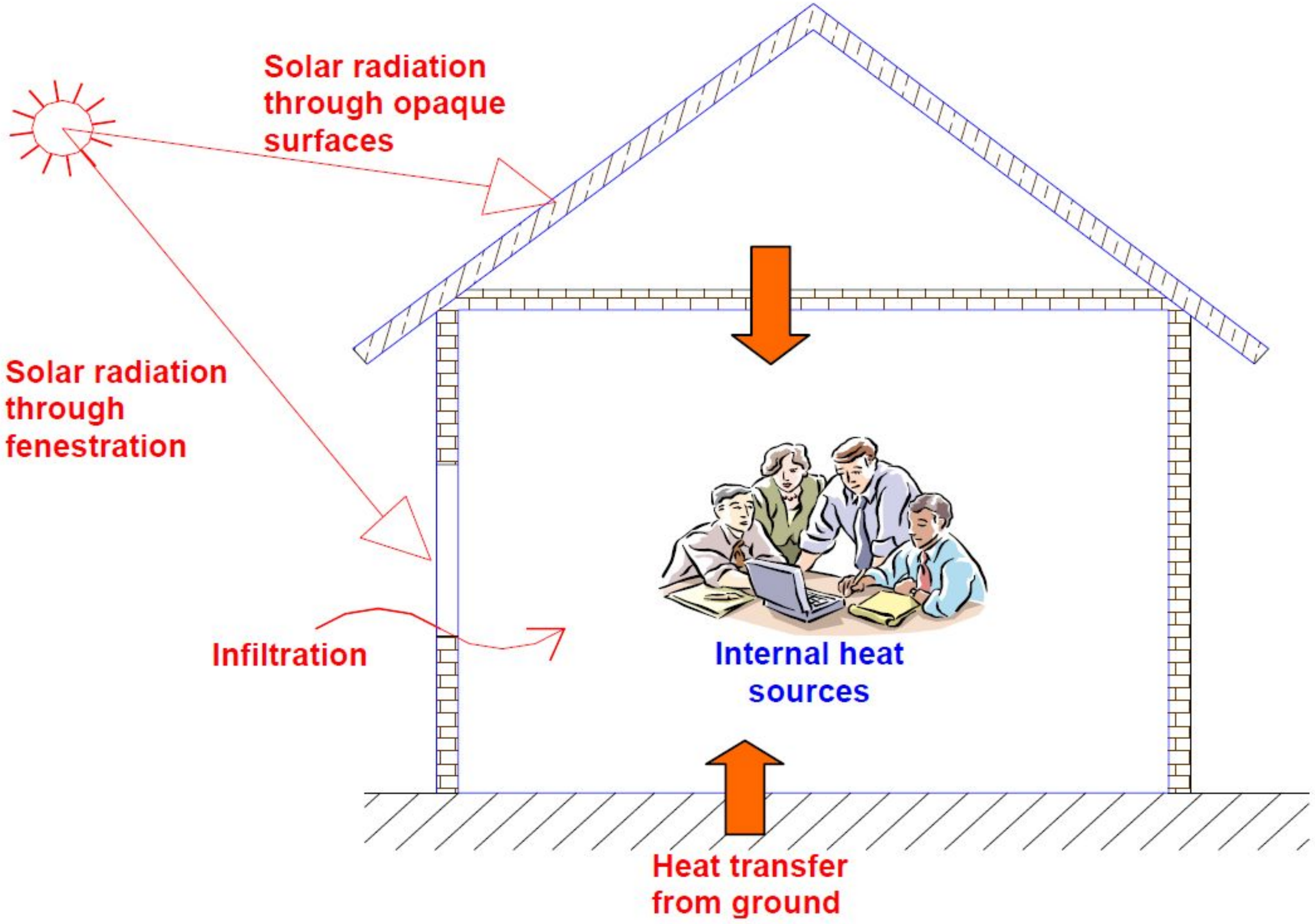
Thermal inputs come from different sources:

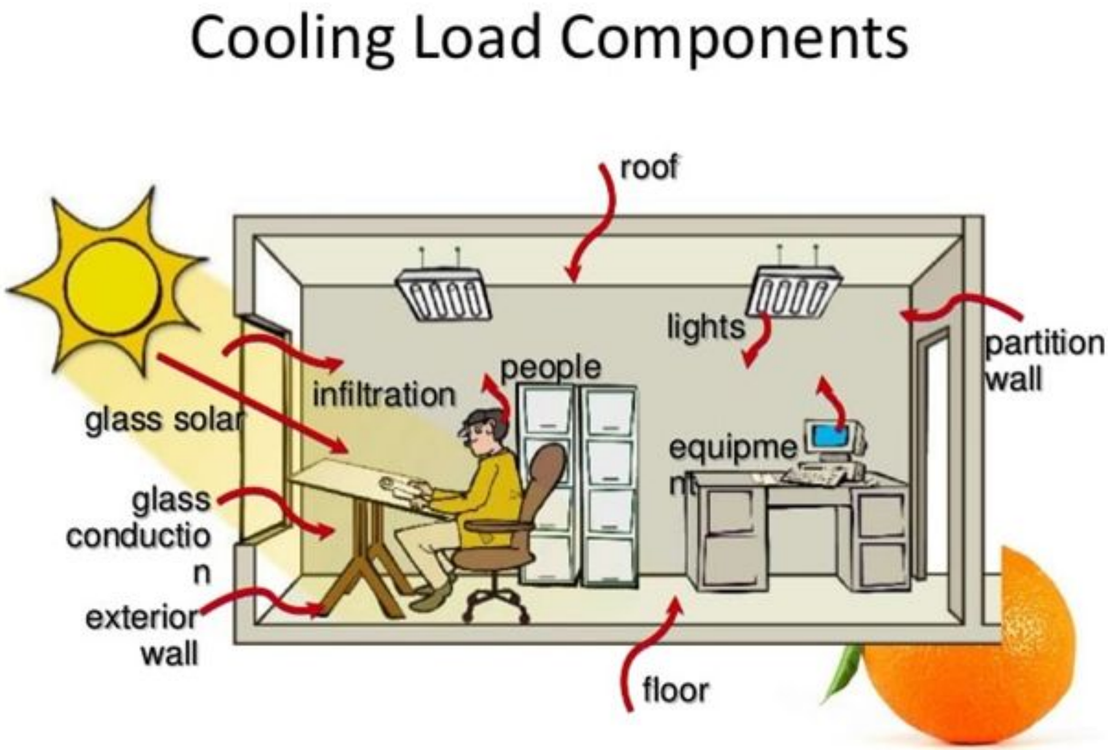
- Internal heat inputs into the home, such as the presence of occupants or the operation of household appliances
- Solar gains also contribute to heating the home and are therefore part of the heat gains in a building's energy balance.



- The total building cooling load consists of heat transferred through the building envelope (walls, roof, floor, windows, doors etc.) and heat generated by occupants, equipment, and lights.
- The load due to heat transfer through the envelope is called as external load, while all other loads are called as internal loads.
- The percentage of external versus internal load varies with building type, site climate, and building design.
- The total cooling load on any building consists of both sensible as well as latent load components.

Cooling load calculations – External Loads





Energy balance for heating and cooling of buildings

For any building there exists a **balance point** at which the solar radiation (Q_{solar}) and internal heat generation rate (Q_{int}) exactly balance the heat losses from the building. Thus from sensible heat balance equation, at balanced condition:

$$(Q_{solar} + Q_{int})_{sensible} = UA(T_{in} - T_{out})$$

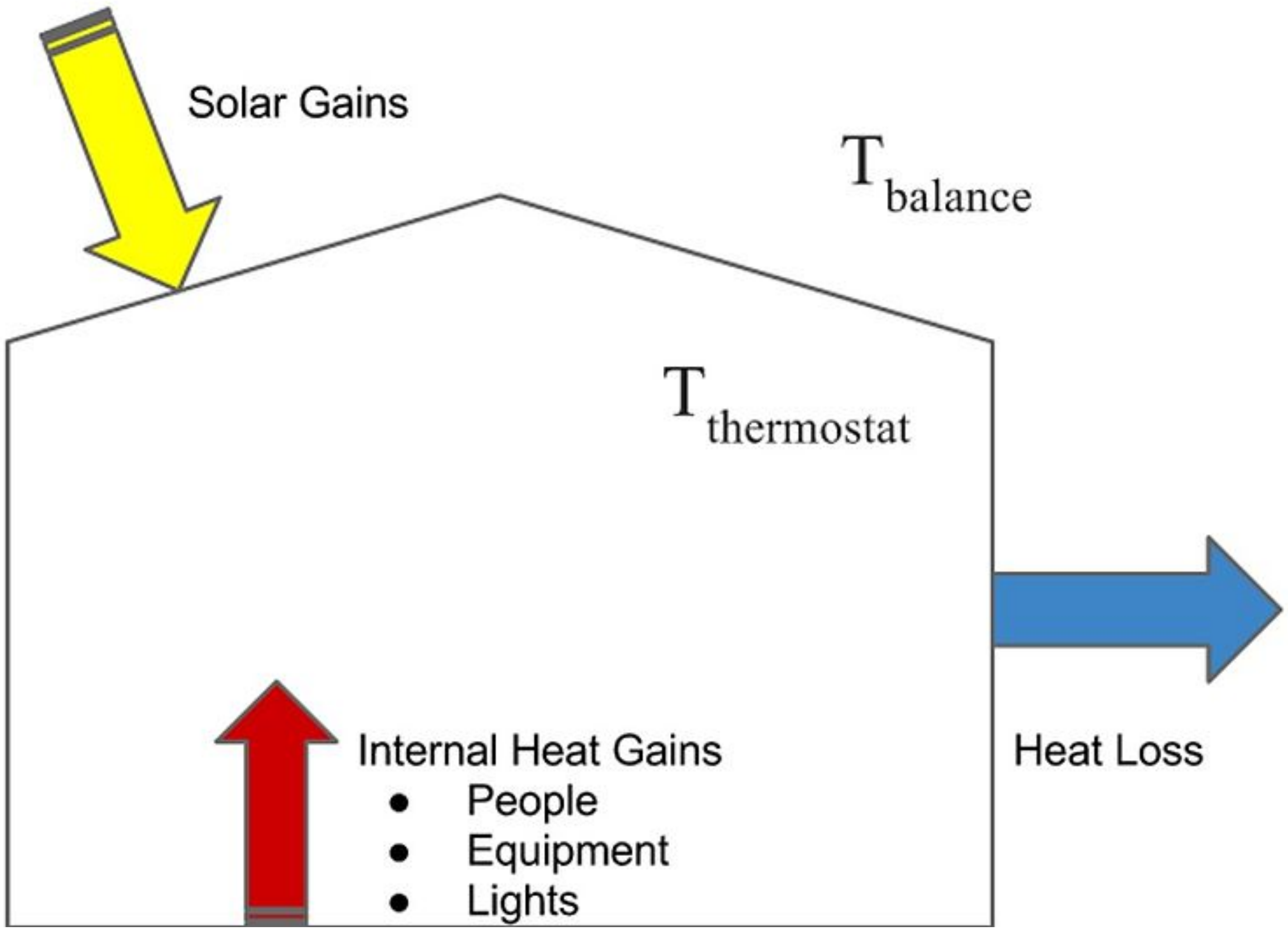
where UA is the product of overall heat transfer coefficient and heat transfer area of the building, T_{in} is the required indoor temperature and T_{out} is the outdoor temperature.

From the above equation, the outside temperature at balanced condition ($T_{out,bal}$) is given by:

$$T_{out,bal} = T_{in} - \frac{(Q_{solar} + Q_{int})_{sensible}}{UA}$$

- If the **external temperature is greater than the balanced outdoor temperature,** the building needs cooling.
- If the **external temperature is less than the balanced outdoor temperature,** the building needs heating.

The building **balance point temperature** is the outdoor air temperature when the heat gains of the building are equal to the heat losses.



Example problem-1

A building has an overall heat transfer coefficient (U) of 0.5 $W/m^2.K$ and a total exposed surface area of 384 m^2. The building is subjected to an external load (only sensible) of 2 kW and an internal load of 1.2 kW (sensible). If the required internal temperature is 25 °C, state whether a cooling system is required or a heating system is required when the external temperature is 3 °C. How will the results change if the U-value of the building is reduced to 0.36 $W/m^2.K$?

Answer:

From the energy balance,

$$T_{out,bal} = T_{in} - \frac{(Q_{solar} + Q_{int})_{sensible}}{UA} = 25 - \frac{(2 + 1.2) \times 1000}{0.5 \times 384} = 8.33^{\circ} C$$

Since the outdoor temperature at balance point is greater than the external temperature ($T_{ext} < T_{out,bal}$);

the building requires heating (Ans.)

When the U-value of the building is reduced to 0.36 W/m.K, the new balanced outdoor temperature is given by:

$$T_{out,bal} = T_{in} - \frac{(Q_{solar} + Q_{int})_{sensible}}{UA} = 25 - \frac{(2 + 1.2) \times 1000}{0.36 \times 384} = 1.85^{\circ} C$$

Since now the outdoor temperature at balance point is smaller than the external temperature ($T_{ext} > T_{out,bal}$);

the building now requires cooling (Ans.)

The Major Components of cooling load calculations:

1. Heat flow through exterior walls, ceilings, floors, doors and windows.
2. Heat by solar radiation.
3. Heat received from occupants.
4. Heat received by infiltrated air

Estimation of external loads

a) Heat transfer through opaque surfaces: This is a sensible heat transfer process. The heat transfer rate through opaque surfaces such as walls, roof, floor, doors etc. is given by:

$$Q_{opaque} = U.A.CLTD$$

CLTD is the cooling load temperature difference.

b) Heat transfer through fenestration: Heat transfer through transparent surface such as a window, includes heat transfer by conduction due to temperature difference across the window and heat transfer due to solar radiation through the window.

$$Q_{trans} = A_{unshaded}.SHGF_{max}.SC.CLF$$

where $A_{unshaded}$ is the area exposed to solar radiation, $SHGF_{max}$ and SC are the maximum Solar Heat Gain Factor and Shading Coefficient, respectively, and **CLF** is the Cooling Load Factor

Estimation of external loads

c) Heat transfer due to infiltration: Heat transfer due to infiltration consists of both sensible as well as latent components. The sensible heat transfer rate due to infiltration is given by:

$$Q_{s,inf} = \dot{m}_o c_{p,m}(T_o - T_i) = \dot{V}_o \rho_o c_{p,m}(T_o - T_i)$$

where $\dot{V}_o$ is the infiltration rate (in m^3/s), ρ_o and $c_{p,m}$ are the density and specific heat of the moist, infiltrated air, respectively. T_o and T_i are the outdoor and indoor dry bulb temperatures.

The latent heat transfer rate due to infiltration is given by:

$$Q_{l,inf} = \dot{m}_o h_{fg}(W_o - W_i) = \dot{V}_o \rho_o h_{fg}(W_o - W_i)$$

where h_{fg} is the latent heat of vaporization of water, W_o and W_i are the outdoor and indoor humidity ratio, respectively.

Estimation of internal loads

The internal loads consist of load due to occupants, due to lighting, due to equipment and appliances and due to products stored or processes being performed in the conditioned space.

a) Load due to occupants: The internal cooling load due to occupants consists of both sensible and latent heat components. The rate at which the sensible and latent heat transfer take place depends mainly on the population and activity level of the occupants.

$$Q_{s,\,occupants} = (\text{No. of people}).(\text{Sensible heat gain / person}).CLF$$

Since the latent heat gain from the occupants is instantaneous the CLF for latent heat gain is 1.0, thus the latent heat gain due to occupants is given by:

$$Q_{l,occupants} = (\text{No. of people}).(\text{Latent heat gain / person})$$

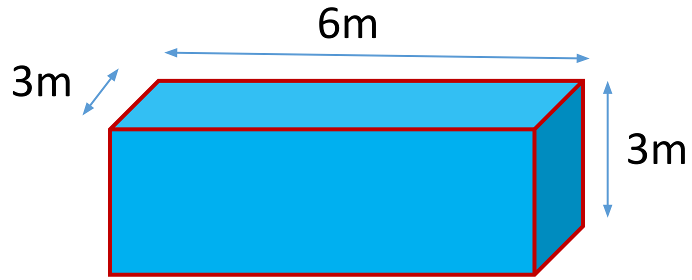
Estimation of internal loads

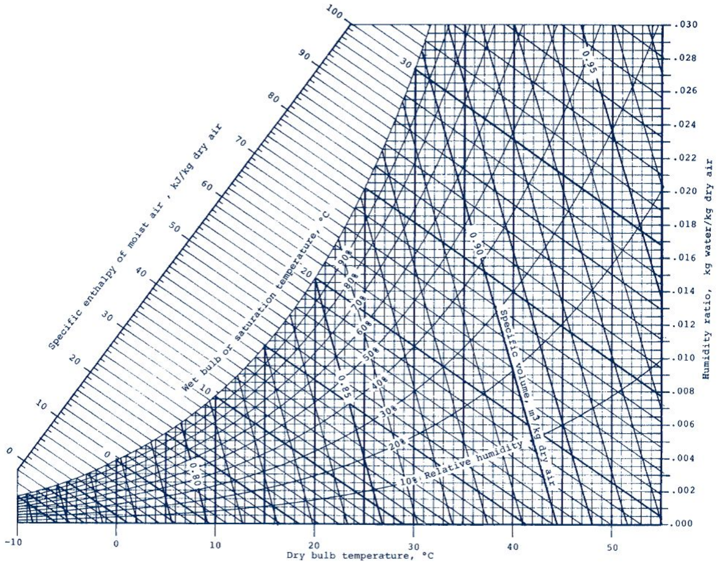
b) Load due to lighting: Lighting adds sensible heat to the conditioned space. Since the heat transferred from the lighting system consists of both radiation and convection, a Cooling Load Factor is used to account for the time lag. Thus the cooling load due to lighting system is given by:

$$Q_{s,lighting} = (\text{Installed wattage})(\text{Usage Factor})(\text{Ballast factor})\text{CLF}$$

2. An air conditioned room that stands on a well ventilated basement measures 3 m wide, 3 m high and 6 m deep. One of the two 3 m walls faces west and contains a double glazed glass window of size 1.5 m by 1.5 m, mounted flush with the wall with no external shading. There are no heat gains through the walls other than the one facing west. Calculate the sensible, latent and total heat gains on the room, room sensible heat factor from the following information. What is the required cooling capacity?

Inside conditions :	25°C dry bulb, 50 percent RH
Outside conditions :	43°C dry bulb, 24°C wet bulb
U-value for wall :	1.78 $W/m^2.K$
U-value for roof :	1.316 $W/m^2.K$
U-value for floor :	1.2 $W/m^2.K$
Effective Temp. Difference (ETD) for wall:	25°C
Effective Temp. Difference (ETD) for roof:	30°C
U-value for glass ;	3.12 $W/m^2.K$
Solar Heat Gain (SHG) of glass ;	300 W/m^2
Internal Shading Coefficient (SC) of glass:	0.86
Occupancy :	4 (90 W sensible heat/person) (40 W latent heat/person)
Lighting load :	33 W/m^2 of floor area
Appliance load :	600 W (Sensible) + 300 W(latent)
Infiltration :	0.5 Air Changes per Hour(ACH)
Barometric pressure :	101 kPa





For the inside conditions of a 25 °C dry bulb, 50 percent RH: wi = 9.9167 x 10^{-3} kg of water vapor/kg of dry air

For the outside conditions of 43 °C dry bulb, 24 °C wet bulb: wo = 0.0107 kg of water vapor/kg of dry air,

h_{fg} = 2501 kJ/kg, Specific heat moist Cpm = 1021.6 J/Kg.K, the density of dry air = 1.095 kg/m^3

Solutions

- **From psychrometric chart,**
- For the inside conditions of 25⁰C dry bulb, 50 percent RH:

  $W_i = 9{,}9167 \times 10^{-3}$ kgw/kgda

- For the outside conditions of 43⁰C dry bulb, 24⁰C wet bulb:

  $W_o = 0.0107$ kgw/kgda,

  density of dry air = 1.095 kg/m^3

- External loads:

a. Heat transfer rate through the walls: Since only west wall measuring 3m x 3m with a glass windows of 1.5m x 1.5m is exposed; the heat transfer rate through this wall is given by:

$$Q_{wall} = U_{wall}A_{wall}ETD_{wall} = 1.78 \times (9-2.25) \times 25 = 300.38 \text{ W (Sensible)}$$

b. Heat transfer rate through roof:

$$Q_{roof} = U_{roof}A_{roof}ETD_{roof} = 1.316 \times 18 \times 30 = 710.6 \text{ W (Sensible)}$$

c. Heat transfer rate through floor: Since the room stands on a well-ventilated basement, we can assume the conditions in the basement to be same as that of the outside (i.e., 43°C dry bulb and 24°C wet bulb), since the floor is not exposed to solar radiation, the driving temperature difference for the roof is the temperature difference between the outdoor and indoor, hence:

$$Q_{floor} = U_{floor} A_{floor} ETD_{floor}$$
$$= 1.2 \times 18 \times 18 = 388.8 \text{ W} \qquad \text{(Sensible)}$$

d. Heat transfer rate through glass: This consists of the radiative as well as conductive components. Since no information is available on the value of CLF, it is taken as 1.0. Hence the total heat transfer rate through the glass window is given by:

$$Q_{glass} = A_{glass} [U_{glass}(T_o - T_i) + SHGF_{max} SC]$$
$$= 2.25[3.12 \times 18 + 300 \times 0.86] = 706.9 \text{ W (Sensible)}$$

e. Heat transfer due to infiltration: The infiltration rate is 0.5 ACH, converting this into mass flow rate, the infiltration rate in kg/s is given by:

- m_{inf} = density of air x (ACH x volume of the room)/3600

  $= 1.095 \times (0.5 \times 3\times3\times6)/3600 = 8.2125 \times 10^{-3}$ kg/s

- Sensible heat transfer rate due to infiltration, $Q_{s,inf}$:

  $$Q_{s,inf} = m_{inf}c_{pm}(T_o - T_i)$$

  $$= 8.2125 \times 10^{-3} \times 1021.6 \times (43 - 25) = 151 \text{ W}$$

  (Sensible)

- Latent heat transfer rate due to infiltration, $Q_{l,inf}$:

  $$Q_{l,inf} = m_{inf}h_{fg}(W_o - W_i)$$

  $$= 8.8125\times10^{-3} \times 2501\times10^{3}(0.0107-0.0099)=16.4 \text{ W}$$

Internal loads:

a. Load due to occupants: The sensible and latent load due to occupants are:

$$Q_{s,occ} = \text{no.of occupants} \times SHG = 4 \times 90 = 360\ W$$

$$Q_{l,occ} = \text{no.of occupants} \times LHG = 4 \times 40 = 160\ W$$

b. Load due to lighting: Assuming a CLF value of 1.0, the load due to lighting is:

$$Q_{lights} = 33 \times \text{floor area} = 33 \times 18 = 594\ W\ (\text{Sensible})$$

c. Load due to appliance:

$$Q_{s,app} = 600\ W\ (\text{Sensible})$$

$$Q_{l,app} = 300\ W\ (\text{Latent})$$

- Total sensible and latent loads are obtained by summing-up all the sensible and latent load components (both external as well as internal) as:

$Q_{s,total}$ = 300.38+710.6+388.8+706.9+151+360+594+600

=3811.68 W (Ans.)

$Q_{l,total}$ = 16.4+160+300 = 476.4 W (Ans.)

- Total load on the building is:

$Q_{total} = Q_{s,total} + Q_{l,total}$ = 3811.68 + 476.4 = 4288.08 W (Ans.)

- Room Sensible Heat Factor (RSHF) is given by:

RSHF = $Q_{s,total}/Q_{total}$ = 3811.68/4288.08 = 0.889 (Ans.)

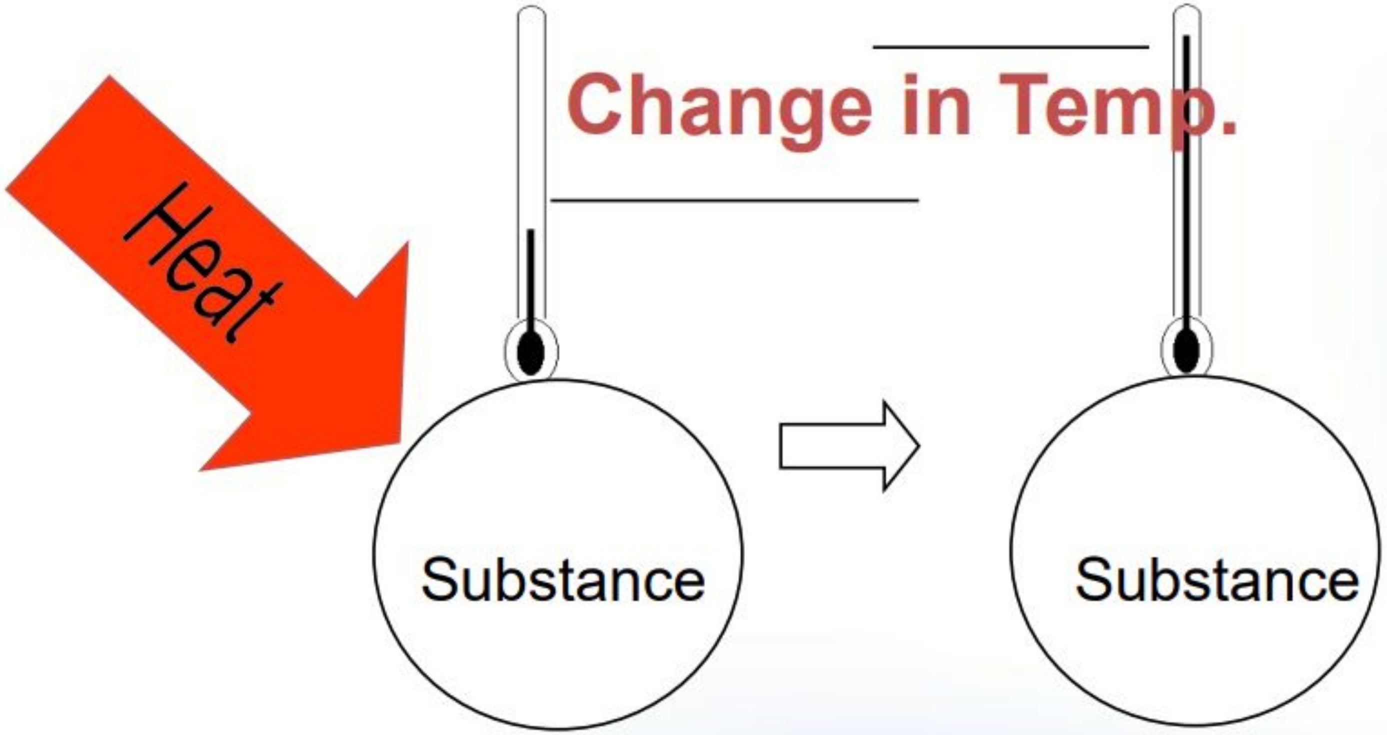
- To calculate the required cooling capacity, one has to know the losses in return air ducts.
- Ventilation may be neglected as the infiltration can take care of the small ventilation requirement.
- Hence using a safety factor of 1.25, the required cooling capacity is:
- Required cooling capacity = 4288.08 × 1.25 = 5360.1 W ≈ 1.5 TR (Ans.)

Note : 1 TR = 3.52 kW

Solar Time, h	Direction the sunlit window is facing								
	N	NE	E	SE	S	SW	W	NW	Horiz.
6	0.73	0.56	0.47	0.30	0.09	0.07	0.06	0.07	0.12
7	0.66	0.76	0.72	0.57	0.16	0.11	0.09	0.11	0.27
8	0.65	0.74	0.80	0.74	0.23	0.14	0.11	0.14	0.44
9	0.73	0.58	0.76	0.81	0.38	0.16	0.13	0.17	0.59
10	0.80	0.37	0.62	0.79	0.58	0.19	0.15	0.19	0.72
11	0.86	0.29	0.41	0.68	0.75	0.22	0.16	0.20	0.81
12	0.89	0.27	0.27	0.49	0.83	0.38	0.17	0.21	0.85
13	0.89	0.26	0.26	0.33	0.80	0.59	0.31	0.22	0.85
14	0.86	0.24	0.24	0.28	0.68	0.75	0.53	0.30	0.81
15	0.82	0.22	0.22	0.25	0.50	0.83	0.72	0.52	0.71
16	0.75	0.20	0.20	0.22	0.35	0.81	0.82	0.73	0.58
17	0.78	0.16	0.16	0.18	0.27	0.69	0.81	0.82	0.42
18	0.91	0.12	0.12	0.13	0.19	0.45	0.61	0.69	0.25

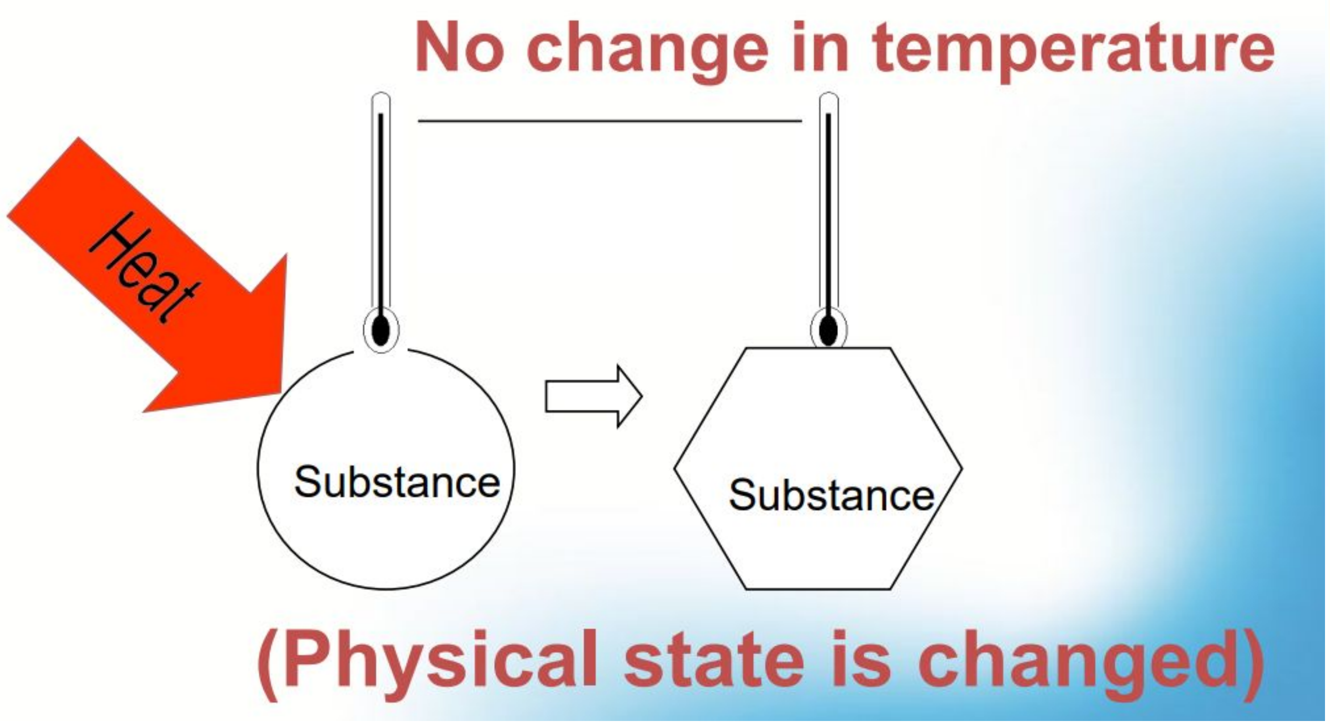
Cooling Load Factor (CLF) for glass with interior shading and located in north latitudes (ASHRAE)

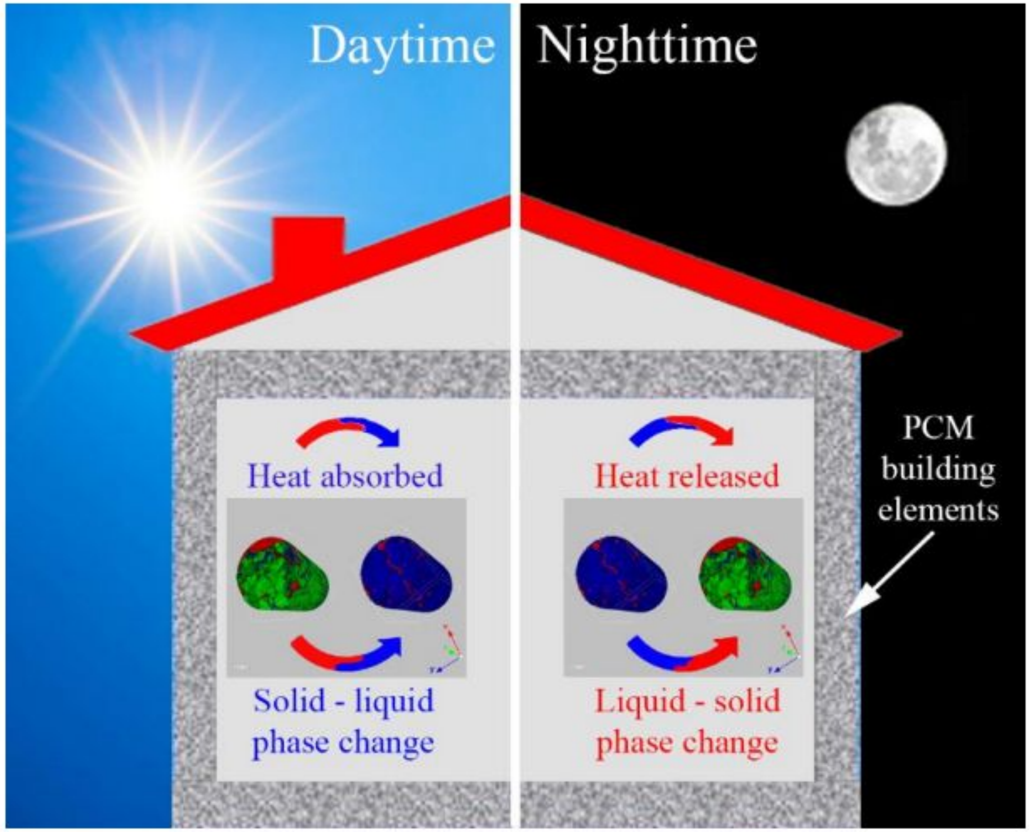
Sensible Heat

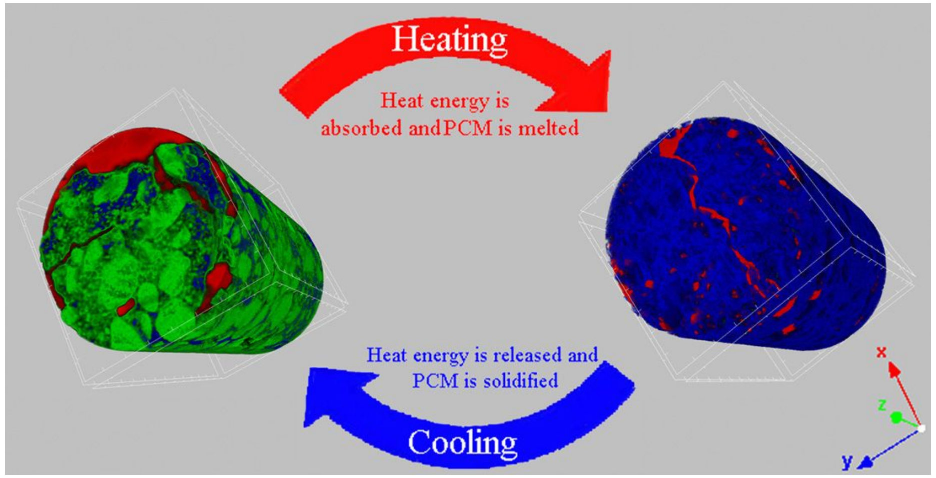


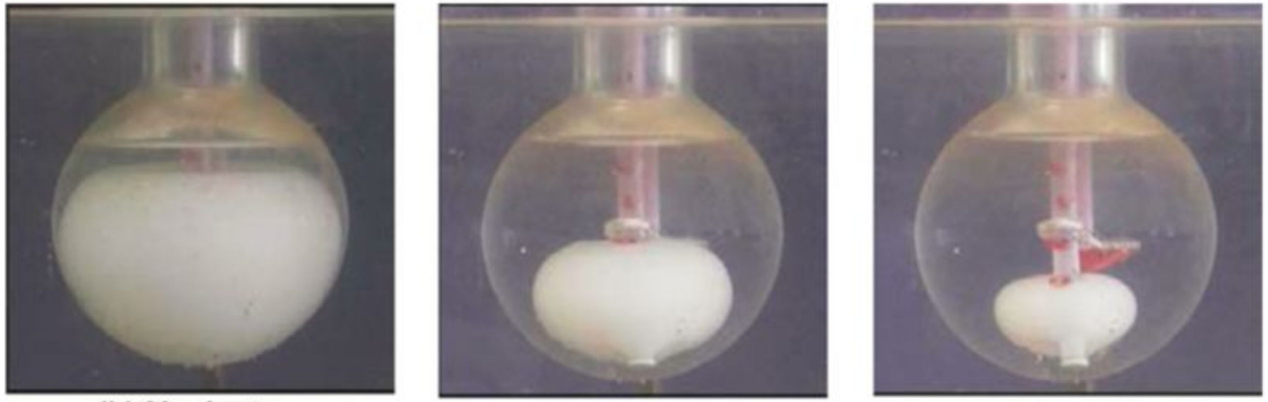
(No change in physical state)

Latent Heat









(b) 20 minutes (d) 50 minutes (e) 70 minutes

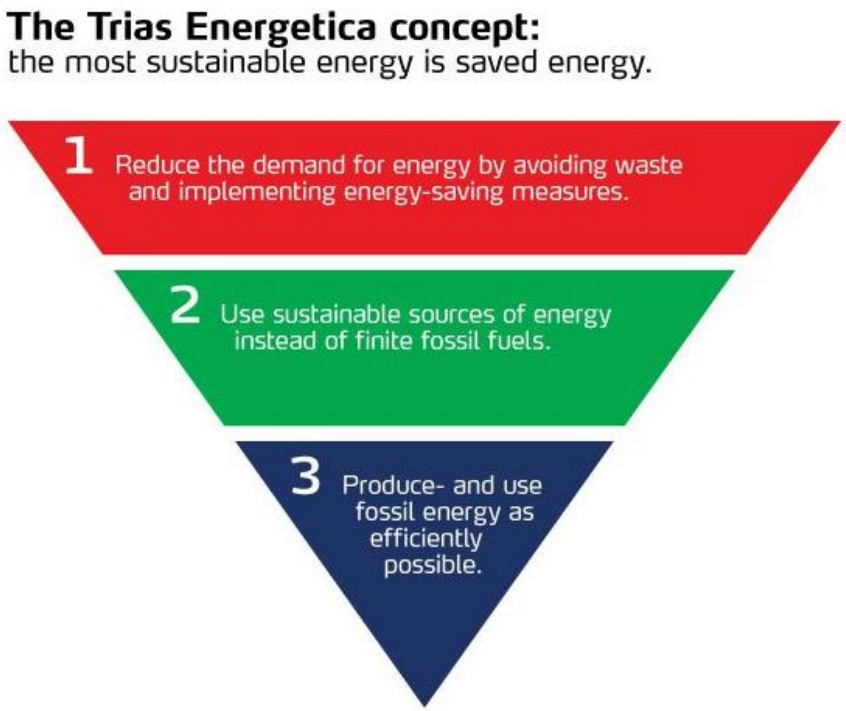
How to design and build an energy efficient building?

Energy efficient buildings (new constructions or renovated existing buildings) can be defined as buildings that are designed to provide a significant reduction of the energy need for heating and cooling, independently of the energy and of the equipment's that will be chosen to heat or cool the building.

This can be achieved through the following elements:

1. bioclimatic architecture: shape and orientation of the building, solar protections, passive solar systems
2. high performing building envelope: thorough insulation, high performing glazing and windows, air-sealed construction, avoidance of thermal bridges
3. high performance controlled ventilation: mechanical insulation, heat recovery

Only when the building has been designed to minimise the energy loss, it makes sense to start looking at the energy source (including renewable energy) and at the heating and cooling equipments.



Energy Efficient Building Examples

SUSTAINABILITY

Rated the world's largest 'LEED® Platinum' certified Hotel during inception, ITC Grand Chola currently meets close to entire electrical energy demand through self-owned wind farms and also achieves almost complete recycling of waste generated by hotel operations. Many such initiatives help the hotel deliver planet positive experiences.

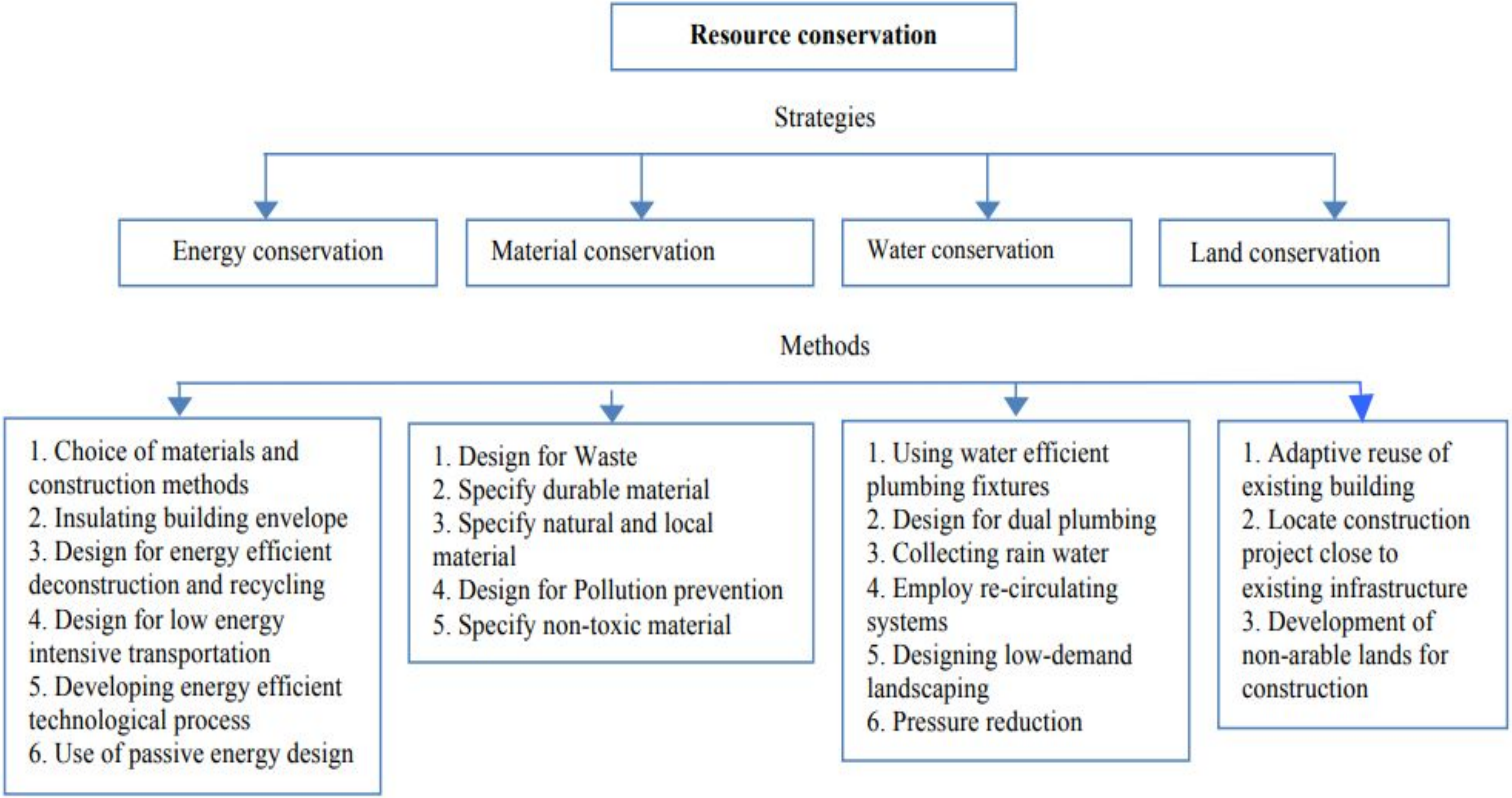
The hotel is world's second & largest LEED Zero Carbon - Certified Hotel **(as on Nov 2021)**

RGIA has been successful in saving energy for nearly 3.97 million kWh and has reduced its carbon footprint by 3331 tons.
Solar Energy 5 MW solar plant

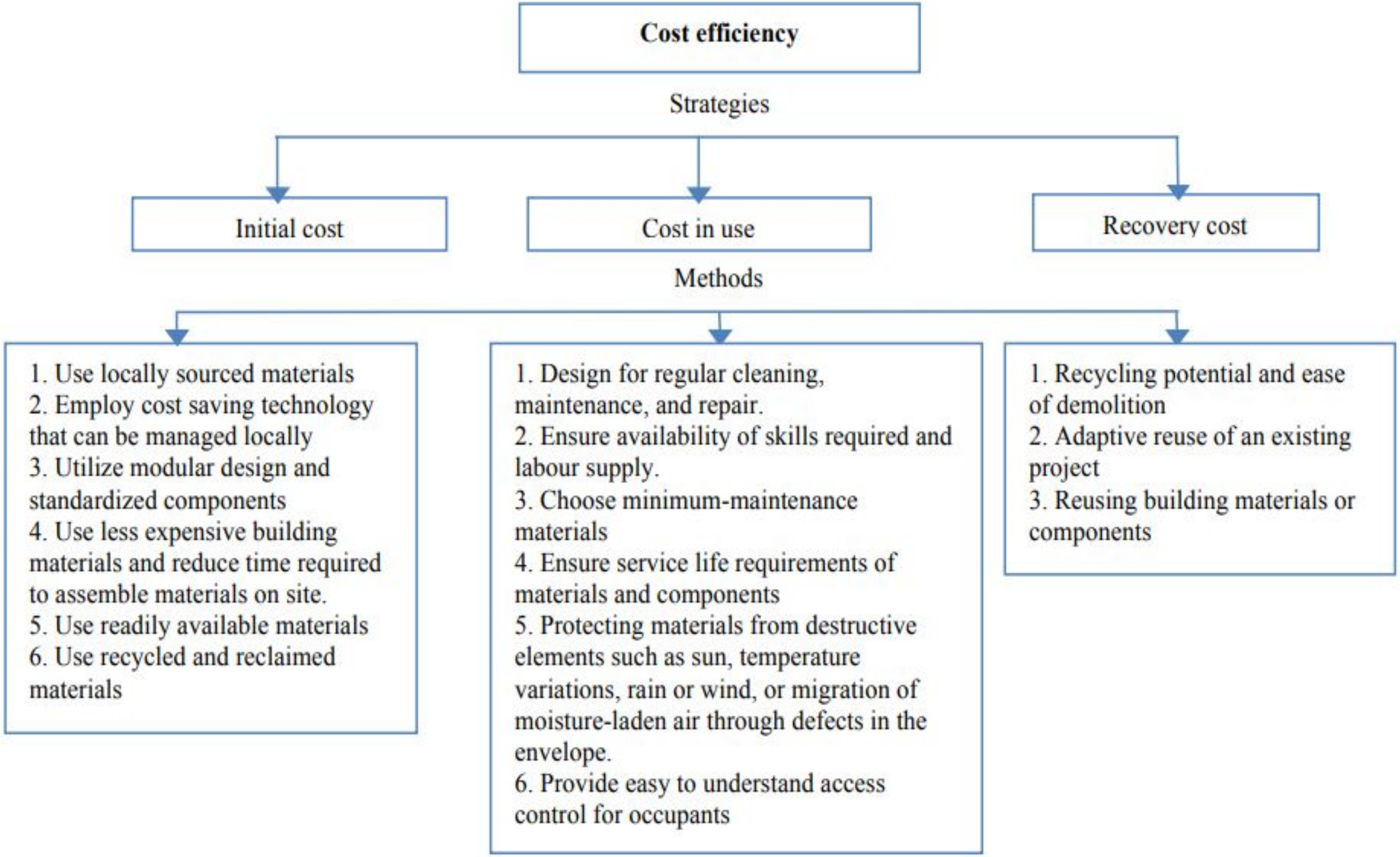
Khoo Teck Puat Hospital - Yishun Central, Singapore

Implementing sustainability in building construction

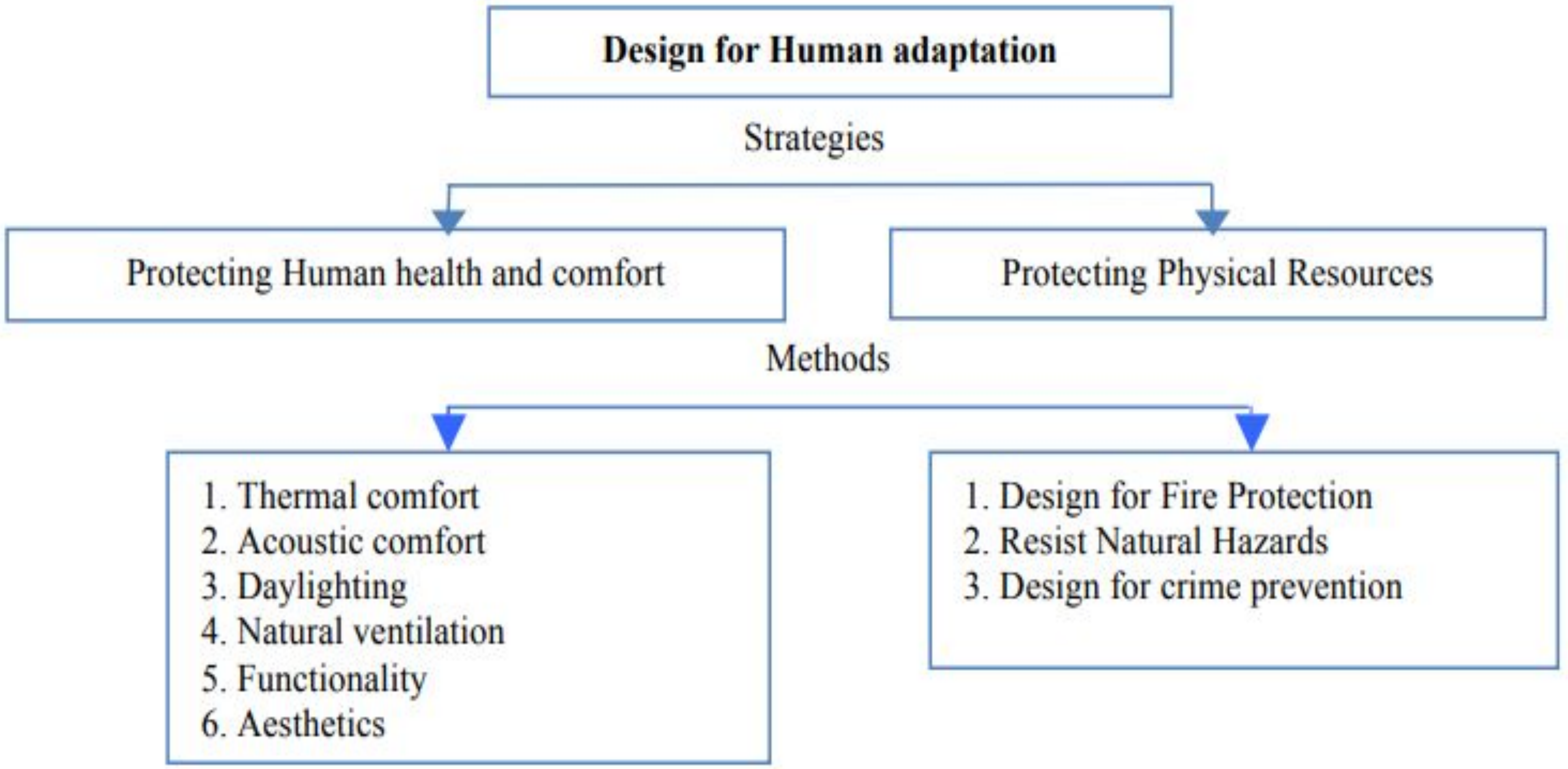
Implementing sustainability in building construction



Implementing sustainability in building construction



Implementing sustainability in building construction



Codes and standards for the energy efficient buildings-ECBC codes

ECBC stands for Energy Conservation and Building Codes.

It was first launched by the Minister of Power, Government of India, in May 2007.

Its purpose was to help promote energy efficiency in the building sectors. ECBC does so by setting design norms for:

- **Building Envelope** - Thermal performance requirements for walls, roofs, and windows
- **Lighting System** - Daylighting, lamps, and luminaire performance requirements
- **HVAC System** - Energy performance of chillers and air distribution systems
- **Electrical System**
- **Water Heating and Pumping Systems** - Requirements for solar hot-water systems

Purpose of Building Codes

- Health, safety, and well-being of the public
- Protection of human life
- Provide minimum requirements that must be met in a building project
- Constrain the location of structures, utilities, building construction, and landscape components placed on a site

Industry Associations	Standards	Descriptions
ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers)	**Push towards mandatory compliance. Some states are still lagging behind** ASHRAE 90.1, 62.1, 178 ASHRAE Standard 55 and 62.2	Standards for commercial ventilation facilities, healthcare facilities, Indoor Air quality, and thermal comfort
LEED (Leadership in Energy and Environmental Design)	**Optional for building aiming to attain LEED Certification** LEED O&M- Existing buildings LEED BD+C New Construction, Healthcare, data centers, etc.	The rating system provides criteria and benchmarks for all aspects of green design, operations and maintenance of buildings, including water efficiency.
NFPA (National Fire Protection Association)	**Mandatory compliance**	NFPA codes and standards provide a comprehensive and integrated approach to fire code regulations and hazard management.
Energy Star	**Optional** 100 ENERGY STAR scores for eligible commercial and institutional buildings through portfolio manager tool.	A voluntary U.S. Environmental Protection Agency (EPA) program adopted to evaluate the energy efficiency of buildings relative to others.


Sustainable Sites
Water Efficiency
Innovation in Operations & Regional Priority
LEED
Energy & Atmosphere
Indoor Environmental Quality
Materials & Resources

Sustainability

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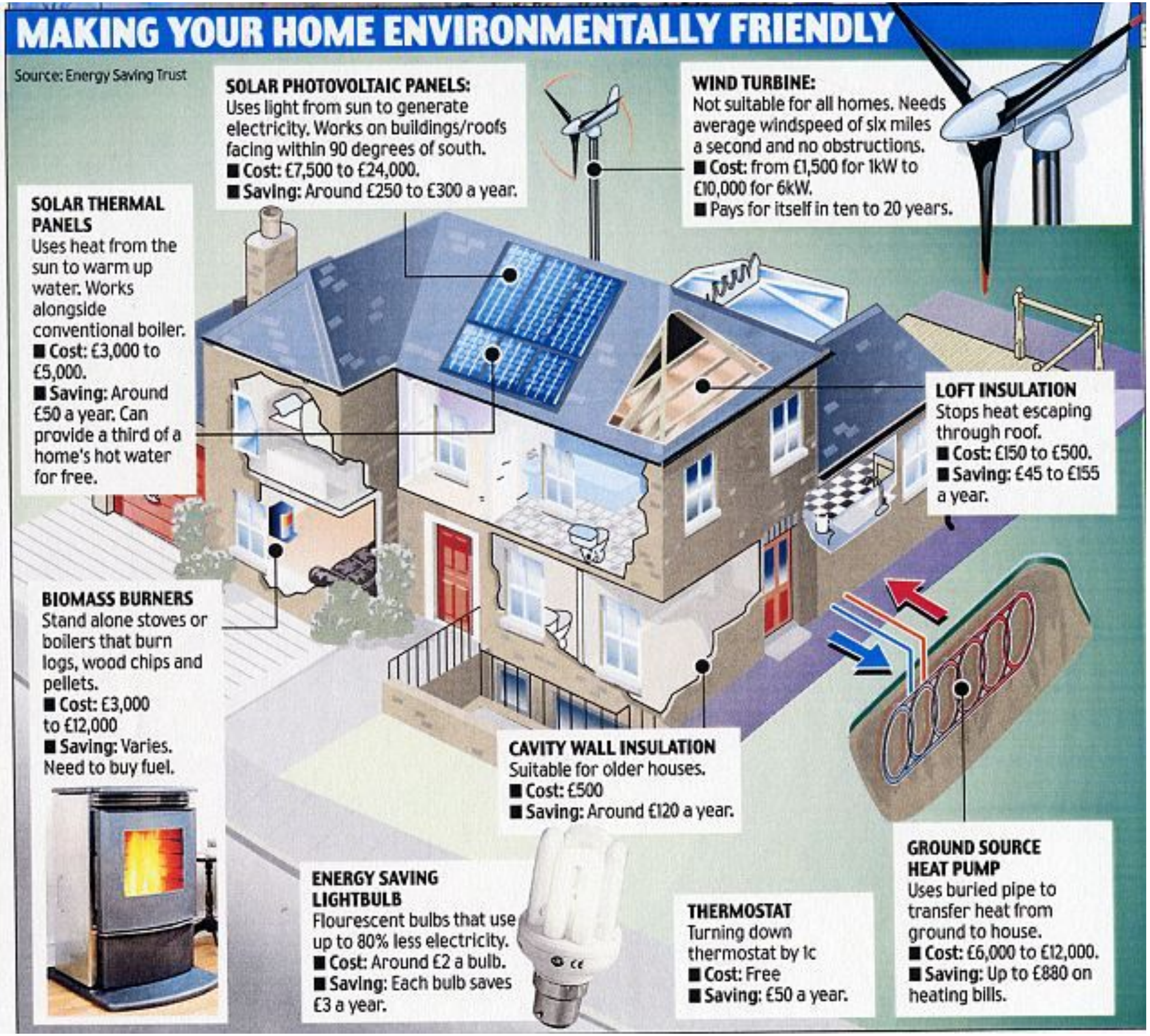
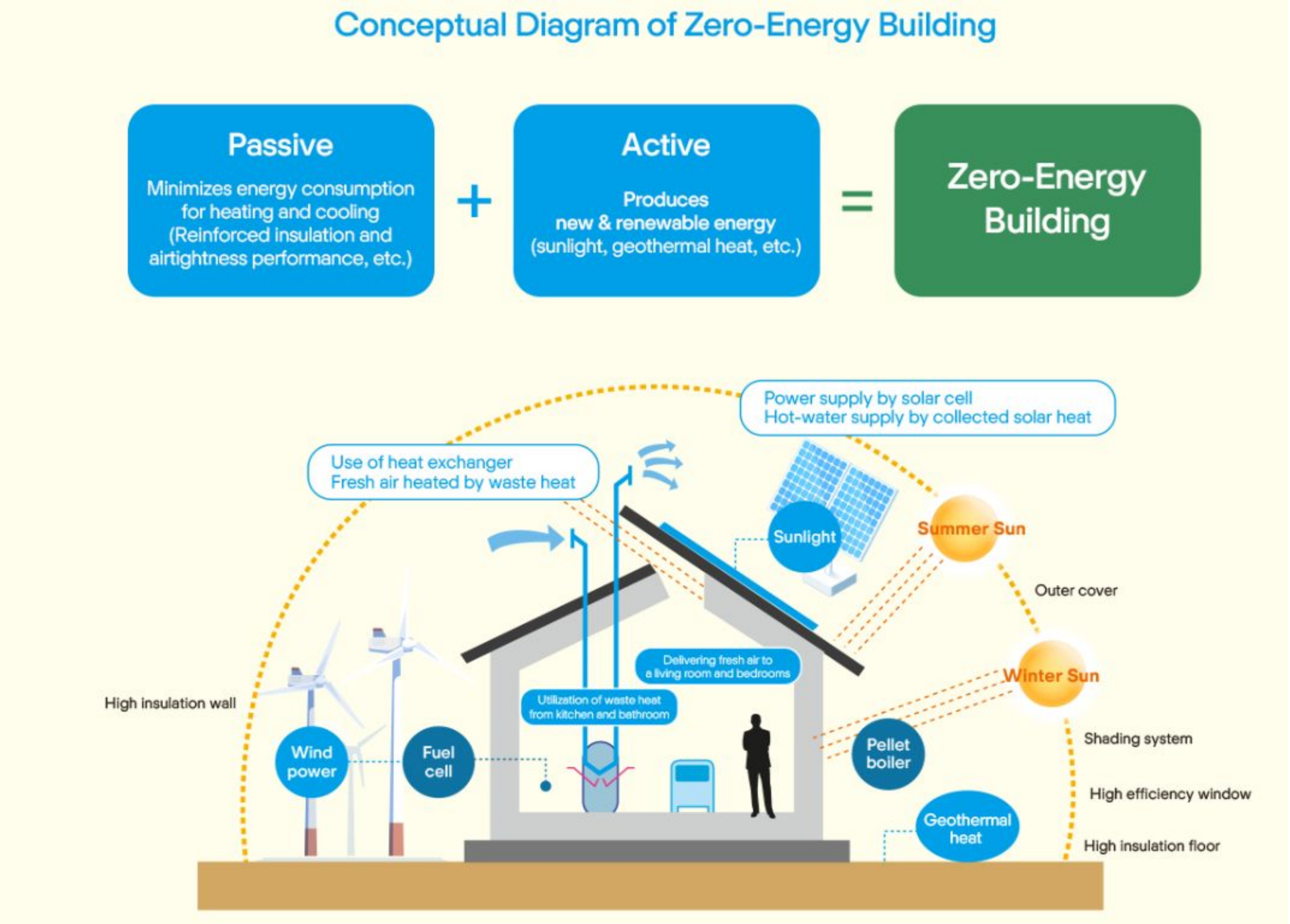


MAKING YOUR HOME ENVIRONMENTALLY FRIENDLY
Source: Energy Saving Trust
SOLAR PHOTOVOLTAIC PANELS: Uses light from sun to generate electricity. Works on buildings/roofs facing within 90 degrees of south. ■ Cost: £7,500 to £24,000. ■ Saving: Around £250 to £300 a year.
WIND TURBINE: Not suitable for all homes. Needs average windspeed of six miles a second and no obstructions. ■ Cost: from £1,500 for 1kW to £10,000 for 6kW. ■ Pays for itself in ten to 20 years.
SOLAR THERMAL PANELS Uses heat from the sun to warm up water. Works alongside conventional boiler. ■ Cost: £3,000 to £5,000. ■ Saving: Around £50 a year. Can provide a third of a home's hot water for free.
LOFT INSULATION Stops heat escaping through roof. ■ Cost: £150 to £500. ■ Saving: £45 to £155 a year.
BIOMASS BURNERS Stand alone stoves or boilers that burn logs, wood chips and pellets. ■ Cost: £3,000 to £12,000 ■ Saving: Varies. Need to buy fuel.
CAVITY WALL INSULATION Suitable for older houses. ■ Cost: £500 ■ Saving: Around £120 a year.
ENERGY SAVING LIGHTBULB Flourescent bulbs that use up to 80% less electricity. ■ Cost: Around £2 a bulb. ■ Saving: Each bulb saves £3 a year.
THERMOSTAT Turning down thermostat by 1c ■ Cost: Free ■ Saving: £50 a year.
GROUND SOURCE HEAT PUMP Uses buried pipe to transfer heat from ground to house. ■ Cost: £6,000 to £12,000. ■ Saving: Up to £880 on heating bills.

Low and zero energy buildings



Low and zero energy buildings

What is Net Zero Energy Building?

A **net-zero energy building** is also known as a zero energy building, defined as a building with net energy consumption, which means **the total amount of energy used by the building is equal to the amount of renewable energy created on-site.** Renewable energy means the energy generated by natural resources like solar, wind, water and etc.

It suggests four ways in which net-zero energy may be defined:

- Net Zero Site Energy
- Net Zero Source Energy
- Net Zero Energy Costs
- Net Zero Energy Emissions

Advantages:

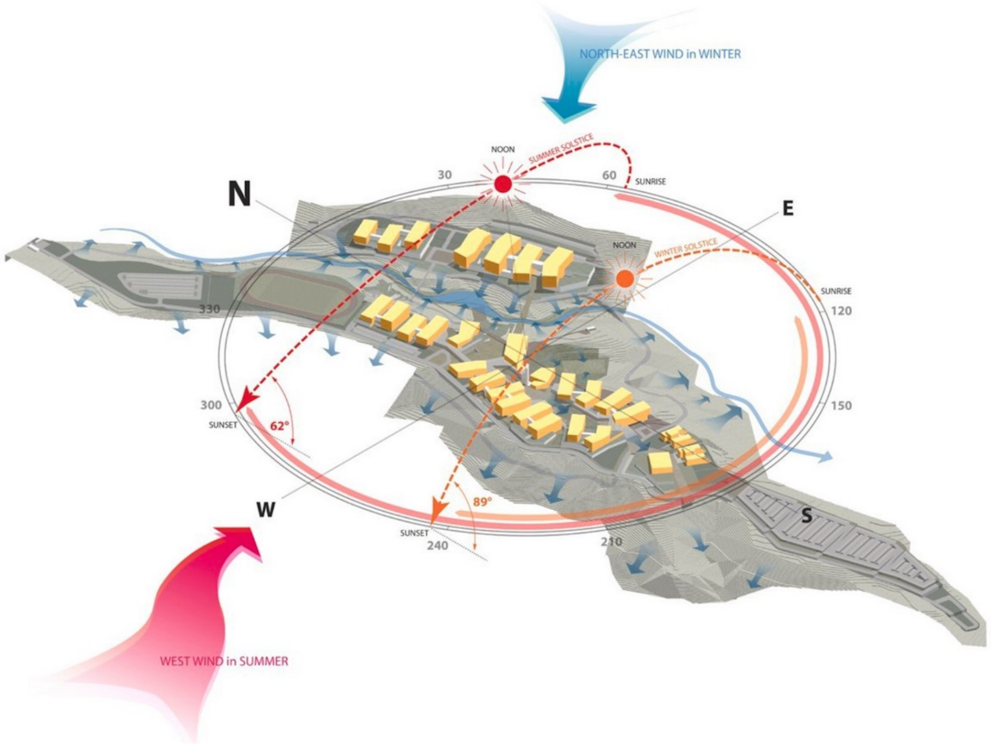
- Integration of renewable energy resources
- Reduced total cost of ownership and total net monthly cost of living
- Implementation of zero energy principles
- Reductions in operating carbon emissions
- Improved reliability

Disadvantages:

- Initial costs can be higher
- Very few designers or builders have the skills or experience required for building Zero Energy Buildings

Future building design aspects

Conducting a detailed climate and site analysis-a preliminary design solution



The following descriptions of how the sun impacts your house will help you determine its exact positioning relative to the four cardinal directions. If you have a compass, that helps too.

•East:

• The east side of the house will receive direct morning sun but will be shaded in the afternoon by the shadow of the building itself.

•West:

• The west side of the house will be shaded in the morning but fully exposed to the hot afternoon sun.

•South:

• **The south side of the house is most critical to passive solar design because it receives the most sunlight throughout the day but never as intensely as the east or west sides.**

•North:

• The north-facing side of the house is almost always in shade.

The task of an Architect

Architects can achieve energy efficiency in the buildings they design by studying the macro-and micro-climate of the site, applying bioclimatic architectural principles. Some common design elements that affect the thermal conditions are:

1. ***Orientation:*** The placement of the building in north-south direction, reduces the heat energy input in the building, increases overall ventilation and provide thermal comfort to the building .
2. ***Landscaping:*** Landscaping alters the microclimate of the site. It reduces direct sun from striking the building & heating up the building surfaces.
3. ***Materials of construction:*** Choice of building materials is very important in reducing the energy contents of buildings.

4. ***Location of water bodies:*** Water is a very good modifier of microclimate. It takes up large amount of heat in evaporation and causes significant cooling in hot and dry climate. On the other hand, in humid climates, water should be avoided as it adds to humidity.

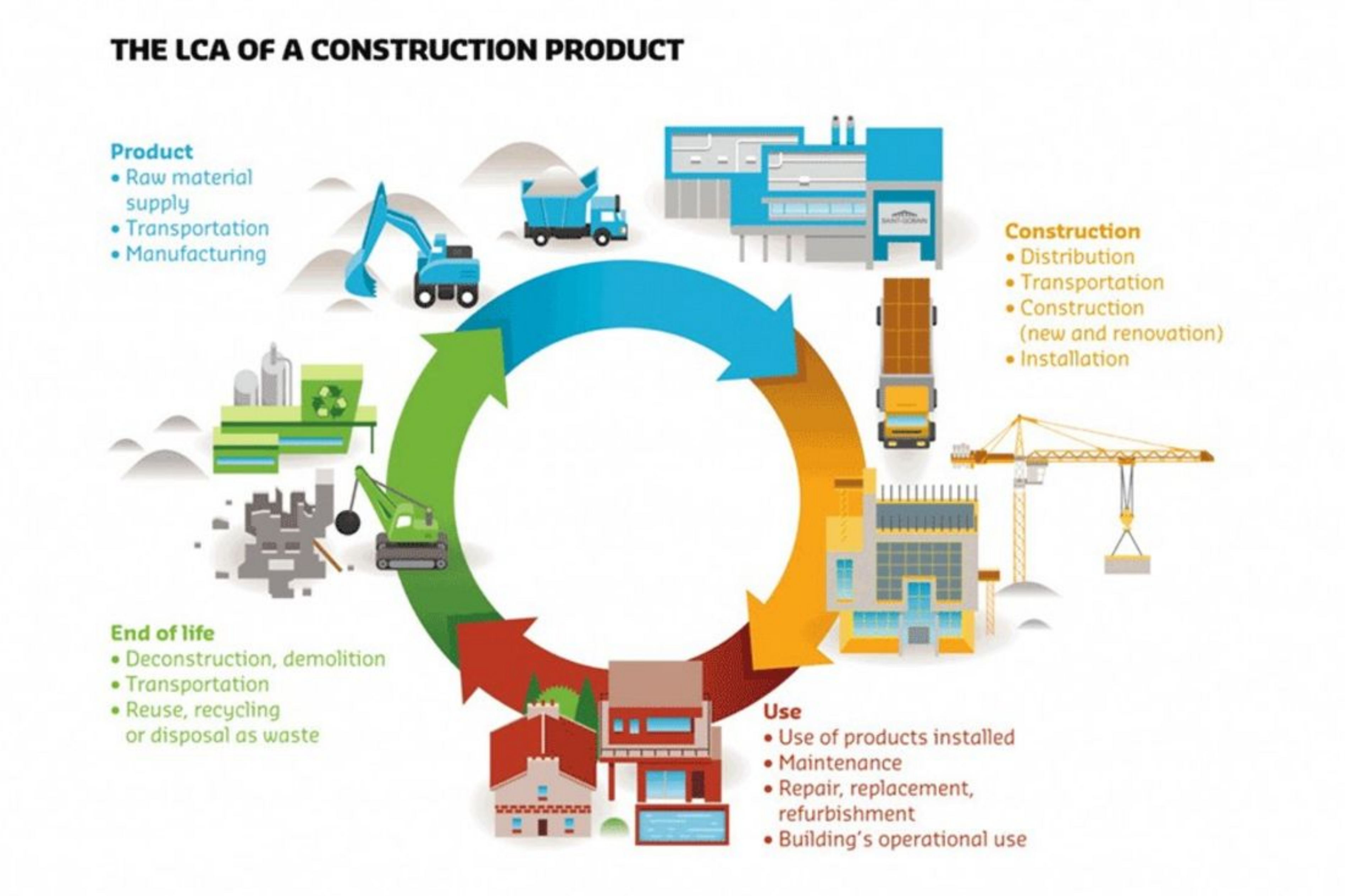
5. ***Building form/surface to volume ratio:*** The volume of space inside a building that needs to be heated or cooled and its relationship with the area of the envelope enclosing the volume affects the thermal performance of the building. For any given building volume, the more compact the shape, the less wasteful it is in gaining/ losing heat.

Also, the building form determines the airflow pattern a round the building, directly affecting its ventilation.

Some key energy saving measures:

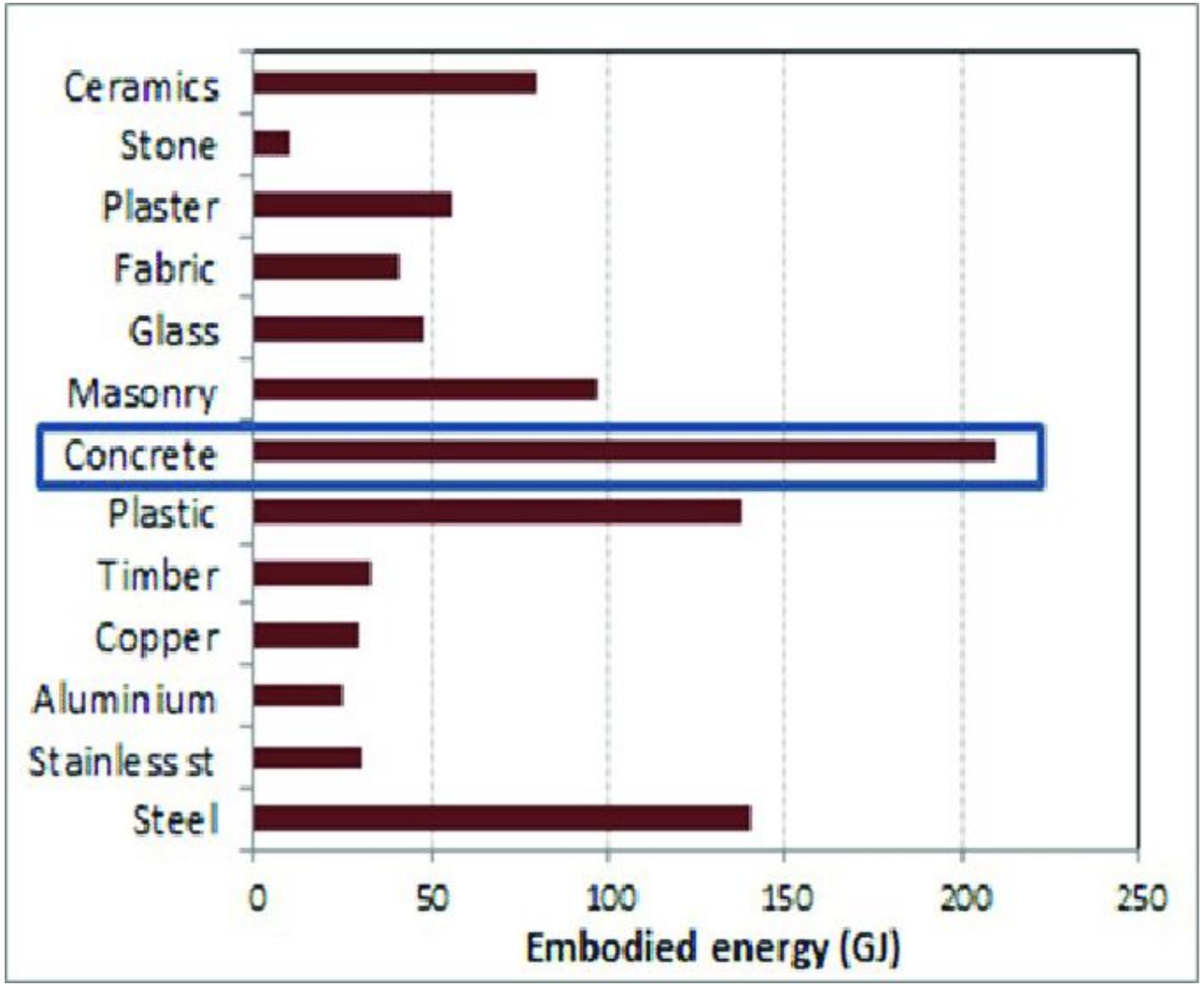
- Orient the building to have maximum exposure & maximum glazing along north and south facades.
- Restrict the glazing area to a maximum of 40-50% of the gross external wall area.
- Use atrium/skylights with adequate solar control to provide daylight access into deeper spaces.
- Use shading strategies for the east, west and south facades to minimize solar gain and reduce glare.
- Use rigid insulation such as extruded or expanded polystyrene, mineral wool for wall and roof.
- Use energy efficient glass with spectrally selective coating to take maximum daylight and yet have effective solar control.
- Energy efficient devices such as CFL’s, T-5 fluorescent lamps, electronic chokes, can be used to reduce consumption.

Embodied energy and the life cycle of materials



Embodied Energy of building materials

- Embodied Energy or Embodied Carbon refers to the sum impact of all greenhouse gas emissions attributed to the material during its life cycle.
- This cycle includes extraction, manufacturing, construction, maintenance, and disposal.



Adapting the Cradle-to-Cradle system of building

Using the right shading devices

Integrating landscape and vegetation

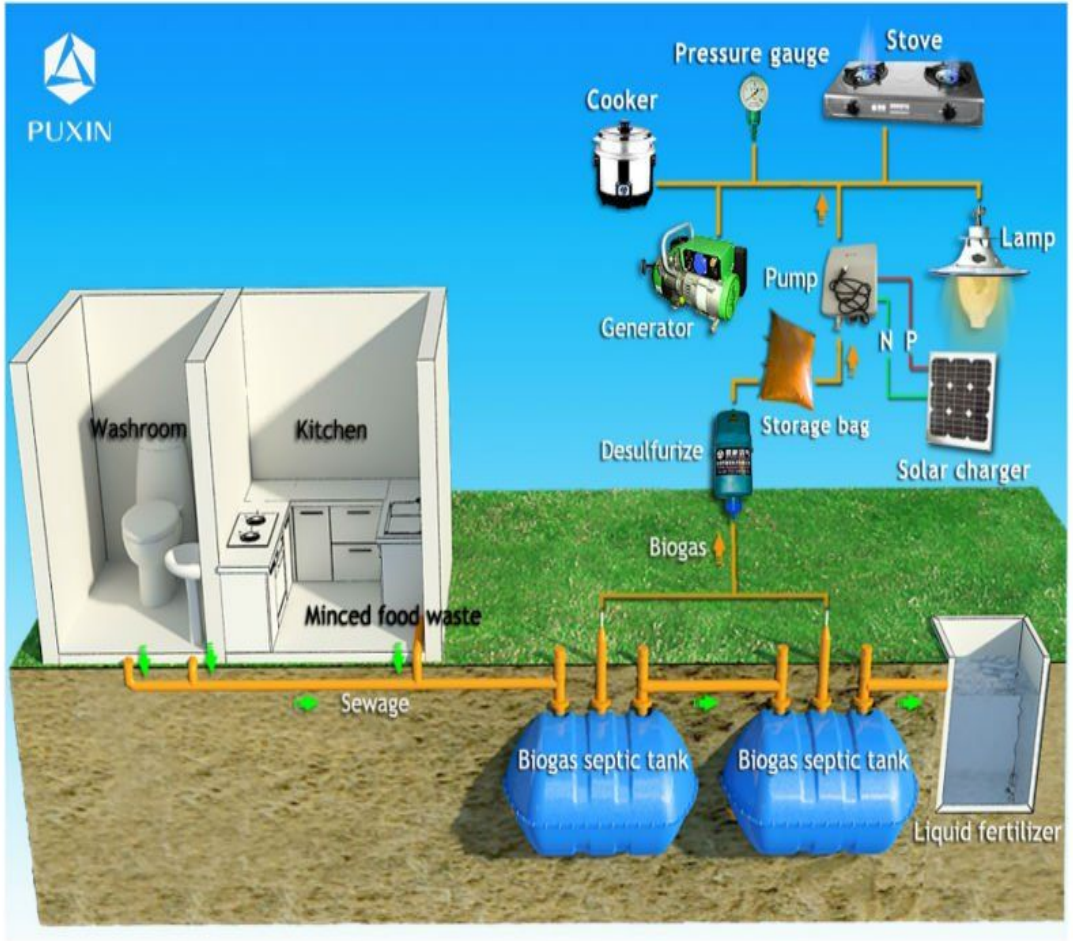
Optimizing daylighting

Example for lighting in buildings

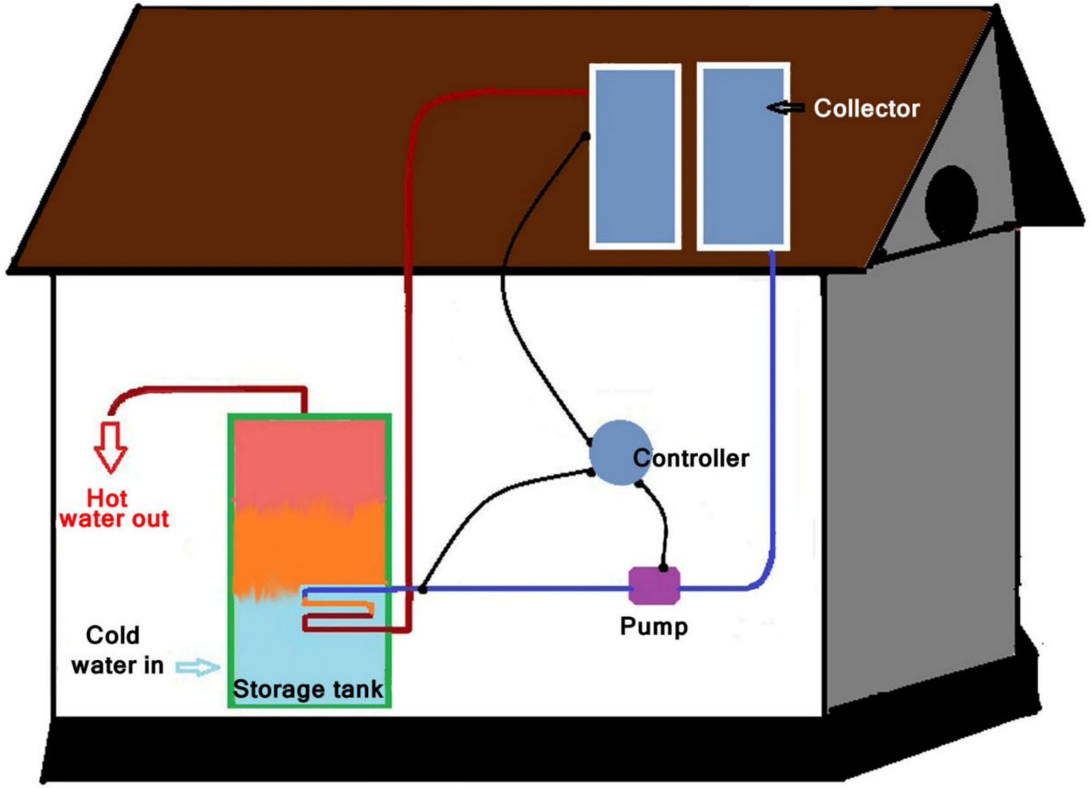
Solar house

House with Wind energy

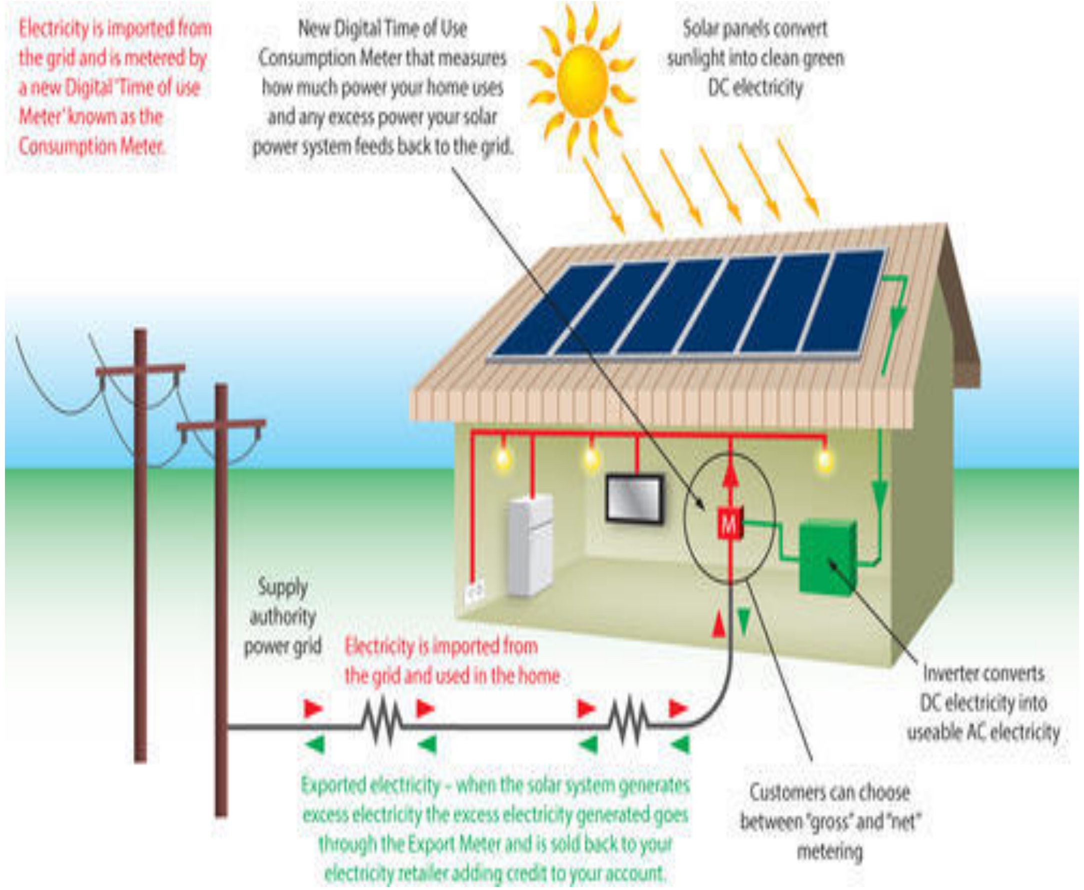
House with Biogas plant



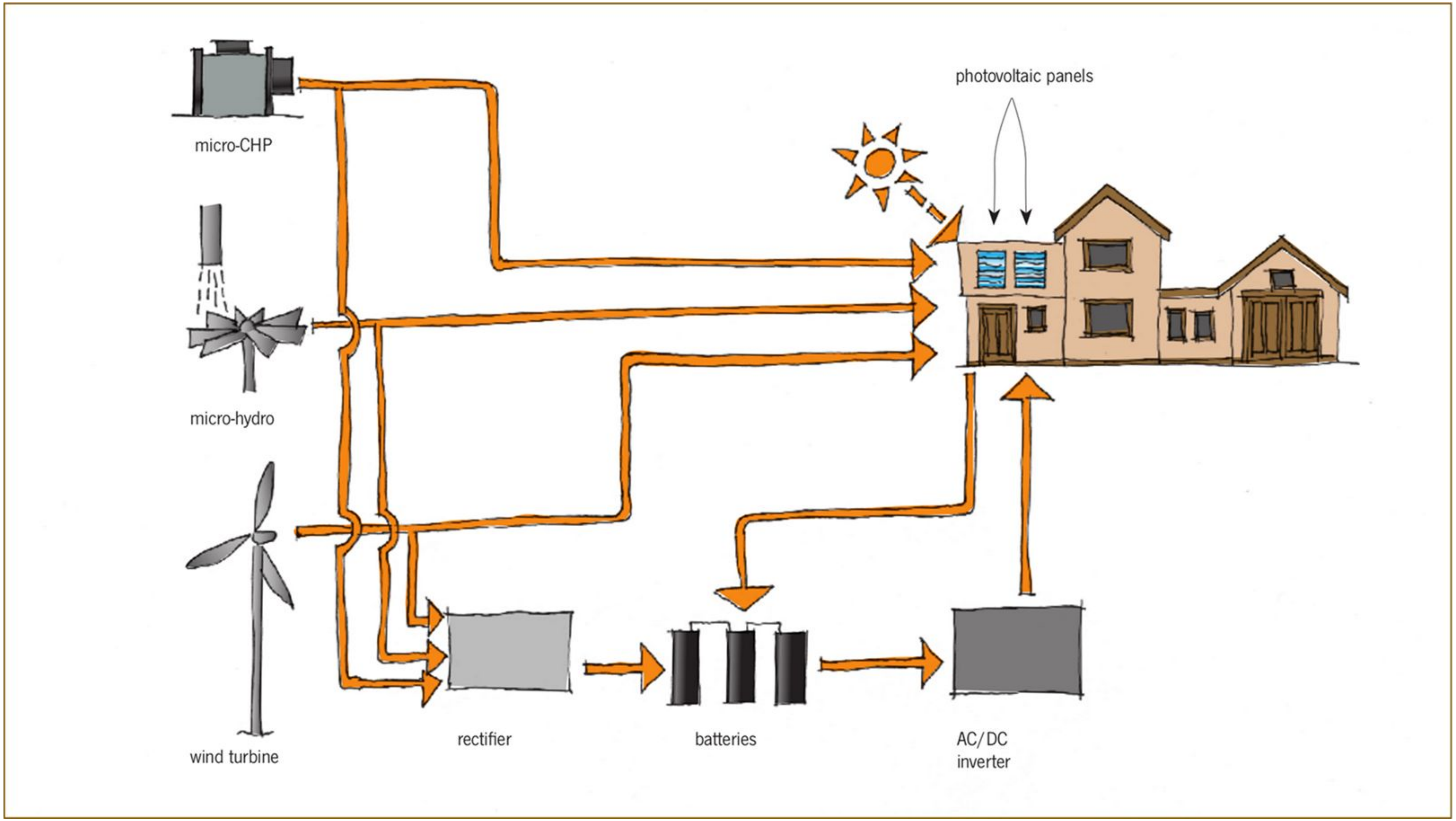
House with solar water heating



Solar operated power system in buildings



Using renewable energy sources and on-site energy generation



Choosing the right walling material to achieve thermal comfort