Designing a Passive Green House

Vasilis Maroulas
ARUP, Buildings London

Athens, EcoWeek 2010

Sir Ove Arup founded his practice in London in 1946 based on a belief in ‘total design’ the integration of the design process and the interdependence of all the professions involved, the creative nature of engineering, the value of innovation and the social purpose of design.

Arup has three global business areas, buildings, infrastructure and consulting, and our multi-disciplinary approach often means that any one project involves people from any or all of the sectors or regions in which we operate.

Our fundamental aim is to achieve excellence in all we do by bringing together the best professionals in the world to meet our clients' needs.

We summarise our approach in one statement: **'We shape a better world.'**

This encapsulates our team-working, creativity, belief in sustainability and global nature as well as recognising the significant role we, with our clients and collaborators, play in forming new environments.

Kolkata Museum of Modern Art, India

The Greenhouse, Barratt

California Academy of Sciences, USA

National Aquatics Centre,
Beijing, China

Fresh water Resource
Institute, Australia

The Kingspan 'Lighthouse'

What is Sustainability?

What is sustainability?

A dictionary definition

- to “sustain,” “to endure,” “to maintain,” “to keep going continually”

The long term view

- Projects that improve the areas in which they build, when measured over the long term.

The triple bottom line

- Social responsibility
- Environmental stewardship
- Economic viability

"Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs."

Source: Brundtland Report, 1987

designing sustainable buildings

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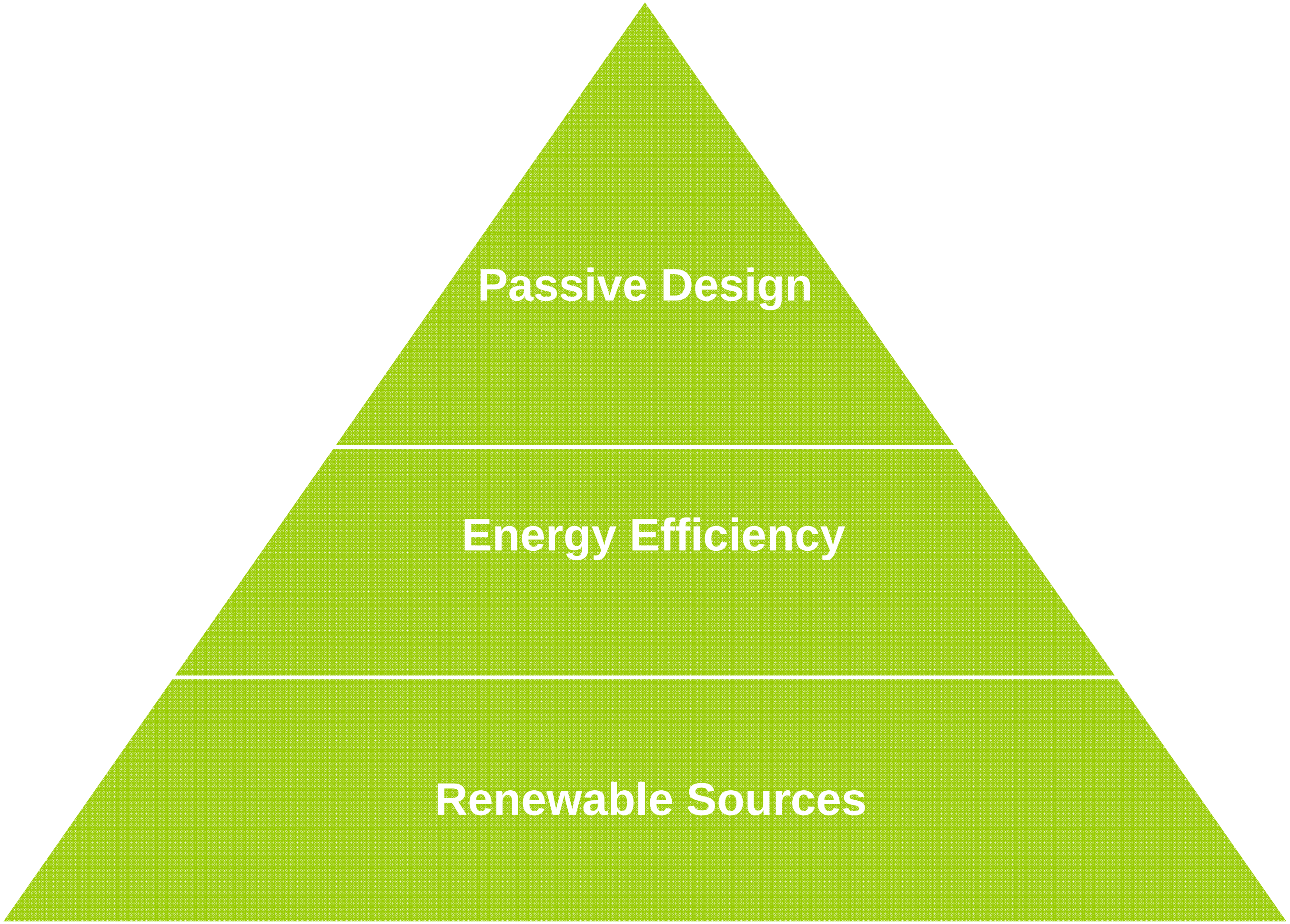
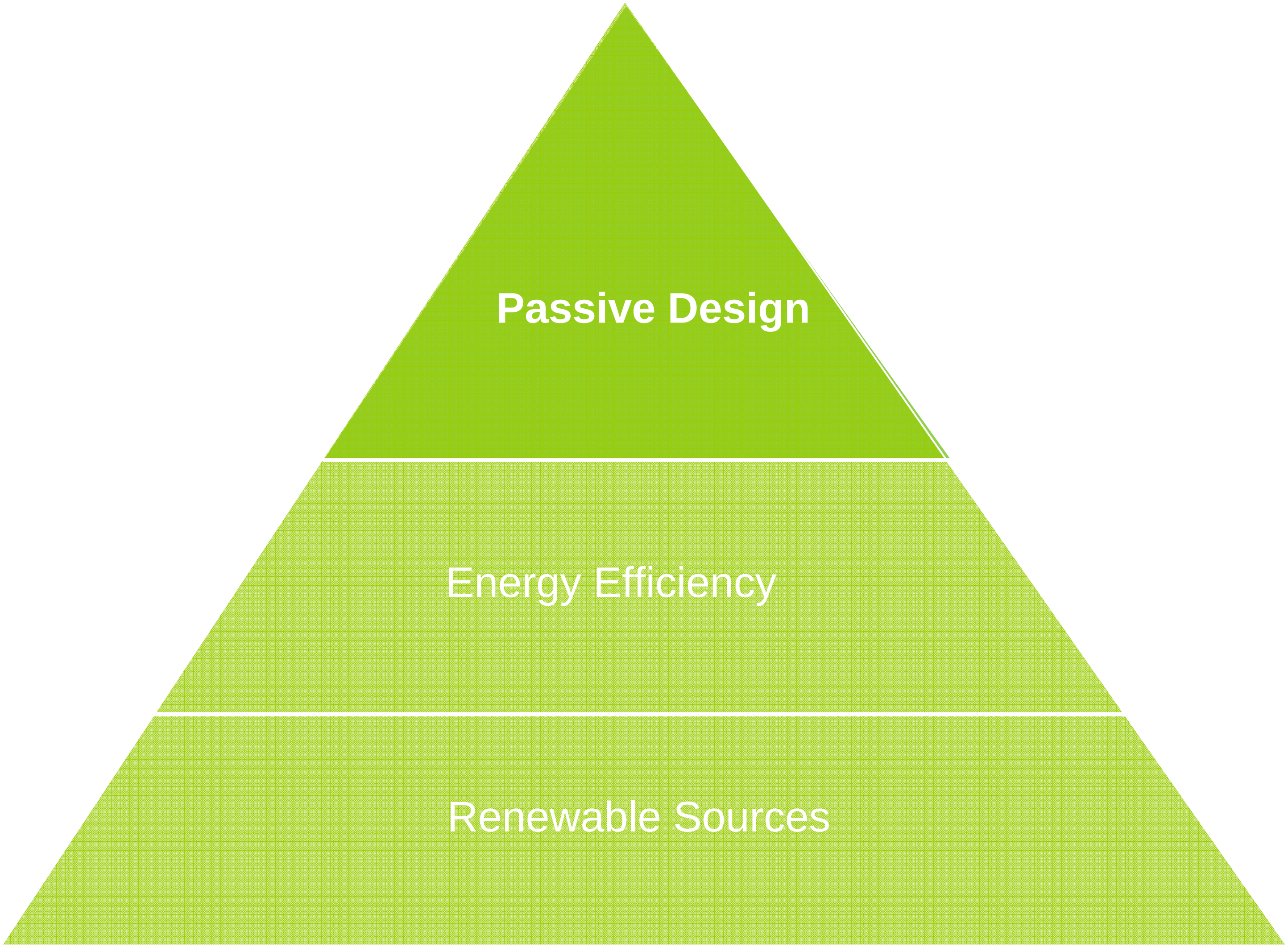
Designing Sustainable Buildings

“ On every project we aim to help our clients imagine how their buildings might be ”

1. carbon neutral

Carbon Neutral Strategy




Passive Design
Energy Efficiency
Renewable Sources

A. Passive Design

I. External Environment

II. Building Shape – Orientation

III. Spatial Arrangement

IV. Fabric

V. Air Tightness

VI. Shading

VII. Natural Daylight

VIII. Double Skin

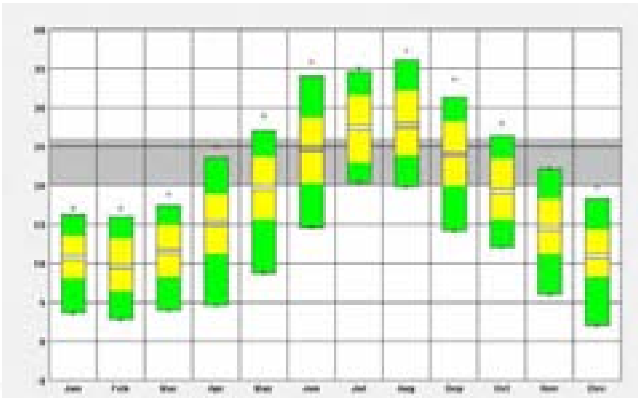
IX. Passive Heating

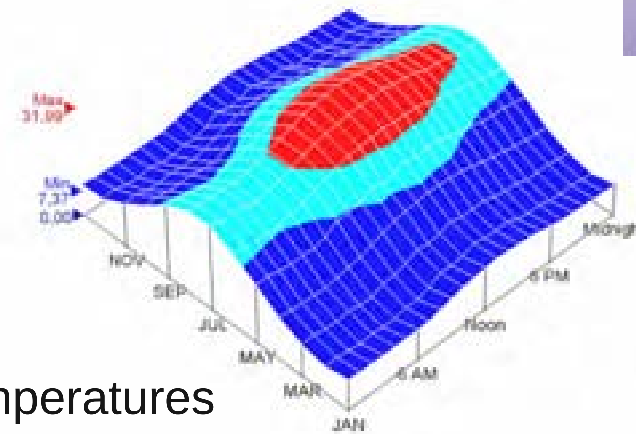
X. Natural Ventilation

XI. Thermal Mass

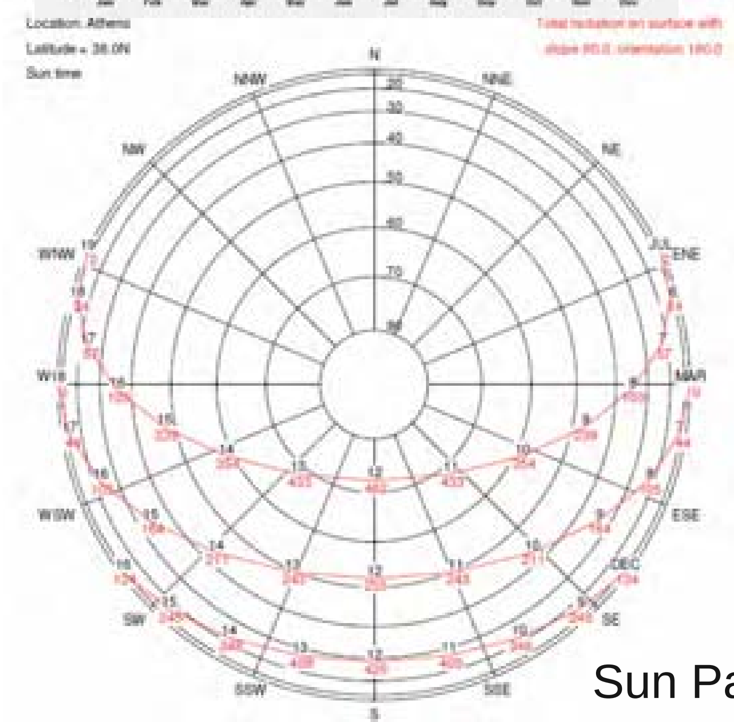
XII. Green Roofs

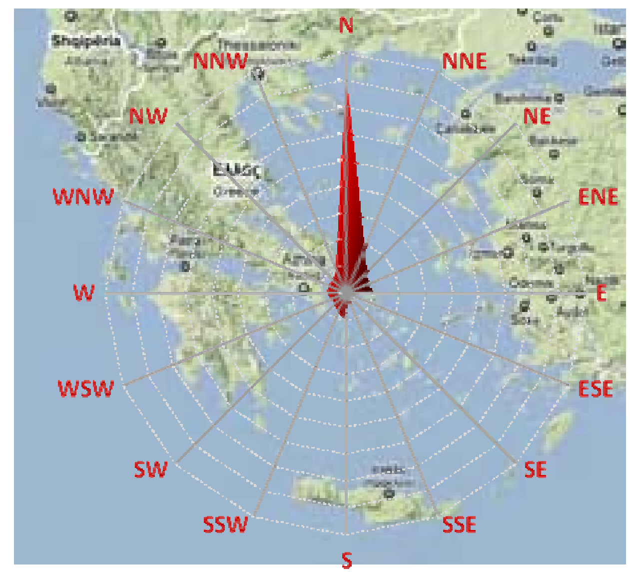
External Environment





External Temperatures

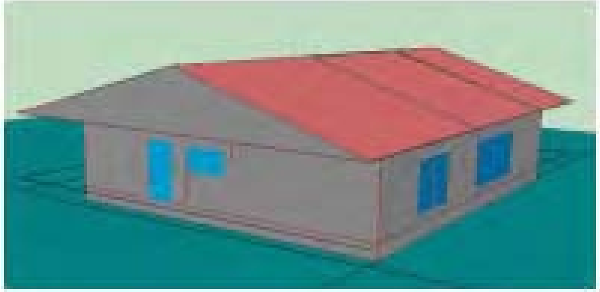


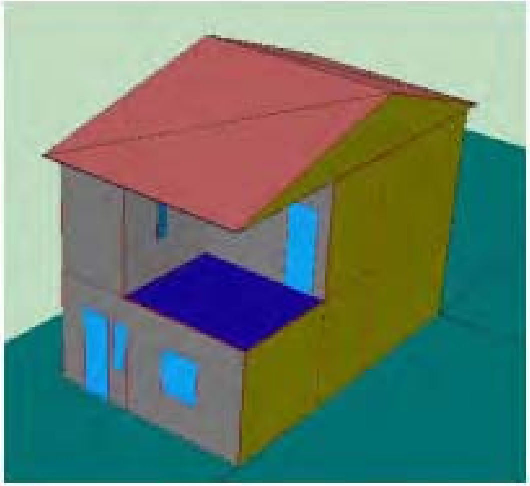


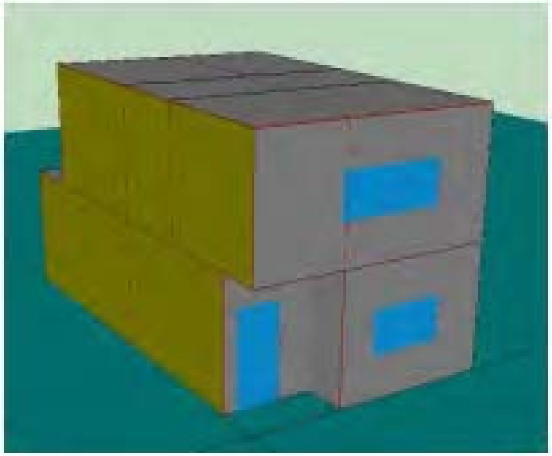
Sun Path Diagrams

Wind Rose

Building Shape

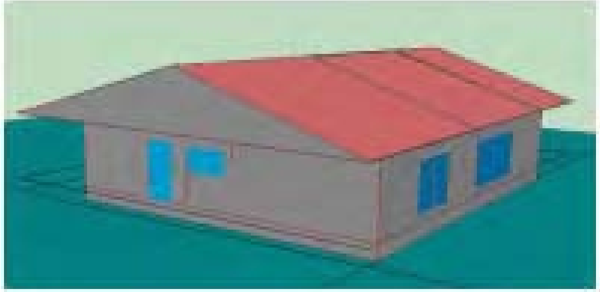






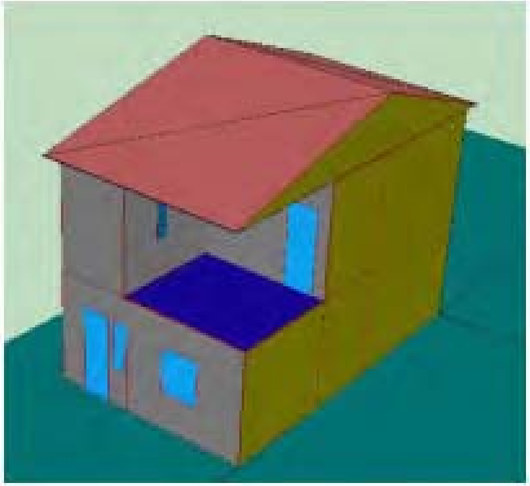
Source: The Passive House Standard, University of Nottingham

Building Shape



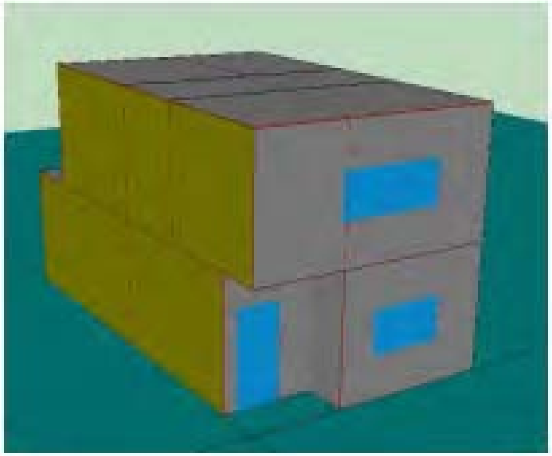
Low

Compactness (TV/A): 1.24 m



Medium

Compactness (TV/A): 1.31 m



High

Compactness (TV/A): 1.70 m

Compactness: total treated volume / heat loss surface

Source: The Passive House Standard, University of Nottingham

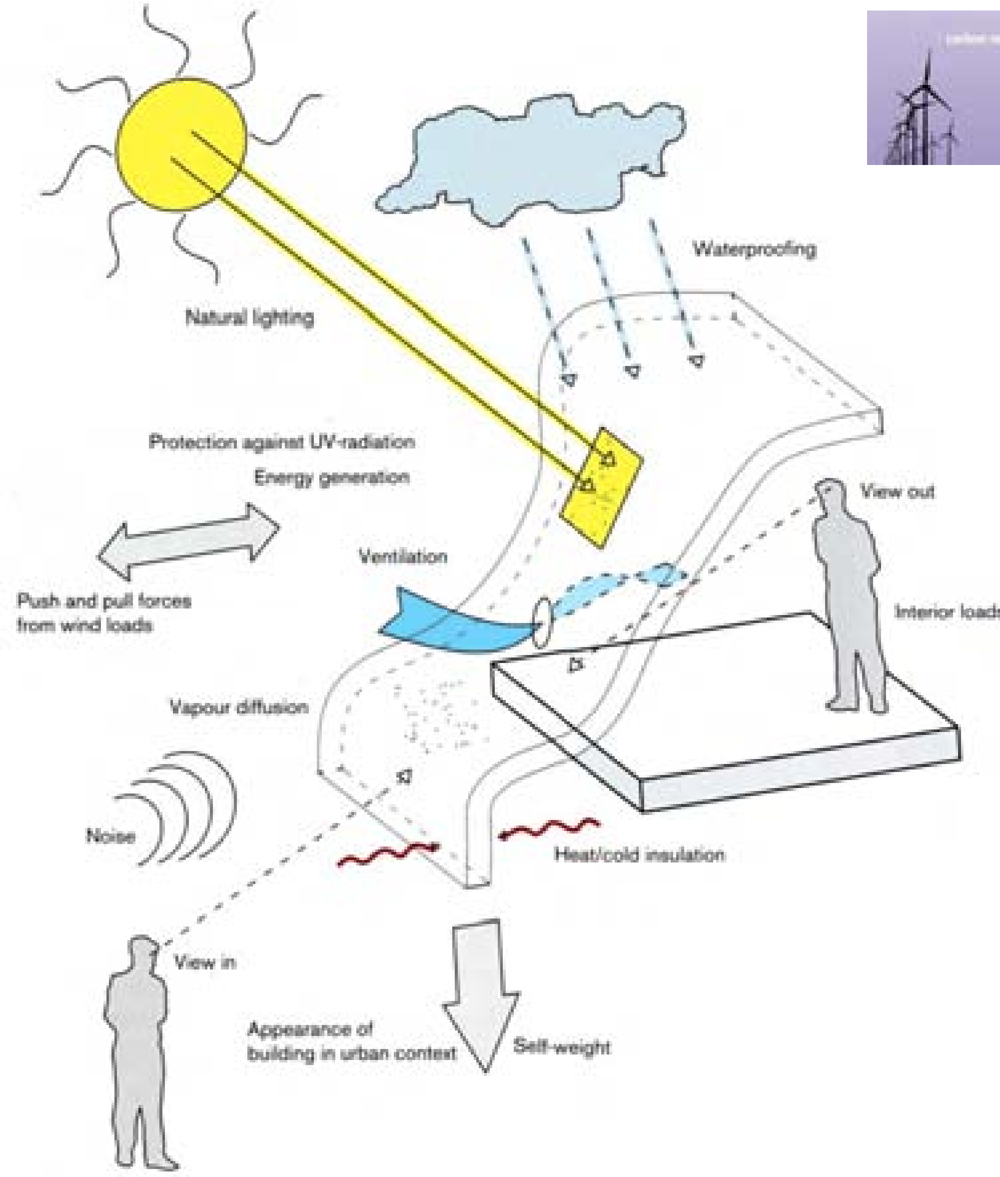
Building Orientation

- Orientate it west to east
- Optimise depth/height ratio for natural ventilation
- Reduce facade exposure to east and west
- Maximise glazing area in south facade....but shade in summer to reduce solar gains

Spatial arrangement

- Lounges, Sitting Rooms
- Bedrooms
- Kitchens, Back of House areas
- Open plan kitchen

The Building Envelope



‘The first line of defense'

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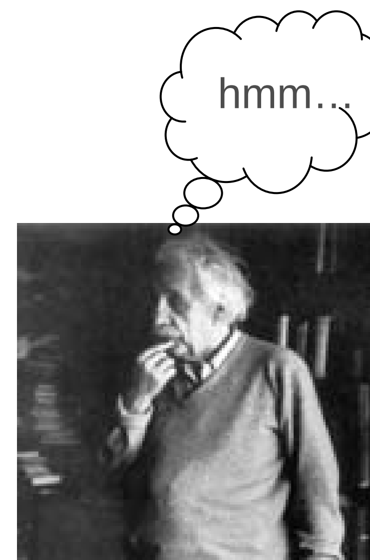
what is often required from a façade?

we want	but also…
acceptable thermal comfort	low energy demand
daylight	no glare
openness/transparency	privacy
natural ventilation	no noise pollution
innovation	guaranteed performance



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Fabric Insulation

ΔΟΜΙΚΟ ΣΤΟΙΧΕΙΟ	ΣΥΜΒΟΛΟ	Συντελεστής θερμοπερατότητας [W/m^2.K] ΚΛΙΜΑΤΙΚΗ ΖΩΝΗ			
		Α	Β	Γ	Δ
Εξωτερική οριζόντια επιφάνεια σε επαφή με τον εξωτερικό αέρα (οροφές)	k_D	0,50	0,40	0,38	0,35
Εξωτερικοί τοίχοι σε επαφή με τον εξωτερικό αέρα	k_W	0,60	0,50	0,44	0,33
Δάπεδα χώρων διαμονής σε επαφή με τον εξωτερικό αέρα (pilotis)	k_{DL}	0,50	0,40	0,40	0,30
Δάπεδα σε επαφή με το έδαφος ή με κλειστούς μη θερμαινόμενους χώρους	k_G	1,50	1,00	0,38	0,35
Διαχωριστικοί τοίχοι σε επαφή με μη θερμαινόμενους χώρους	k_{WE}	1,50	1,00	0,70	0,50
Ανοίγματα (παράθυρα, πόρτες μπαλκονιών κα)	k_F	3,20	3,00	2,80	2,60
Γυάλινες προσόψεις κτιρίων μη ανοιγόμενες και μερικώς ανοιγόμενες	k_{GF}	1,80	1,80	1,80	1,80

Κανονισμός Ενεργειακής Απόδοσης Κτιριακού Τομέα (ΚΕΝΑΚ)

Fabric Insulation

Key Issues

- Cold Bridging
- Curtain walling limited U value

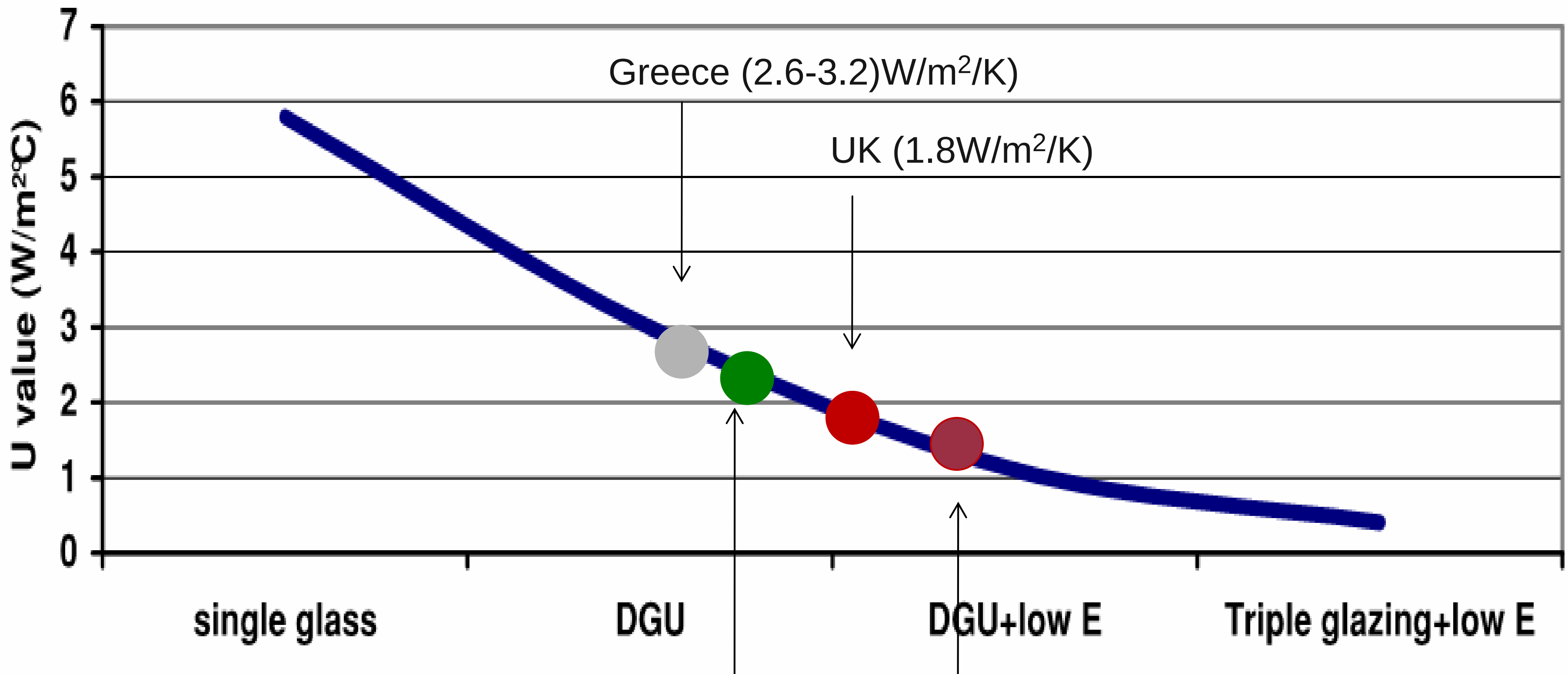
Portugal PassivHaus 100mm

Curtain Wall !?!?

'The Green House': cavity wall, 250mm!!

'BedZed': cavity wall, 300mm!!

Glazing Units Thermal Transmittance



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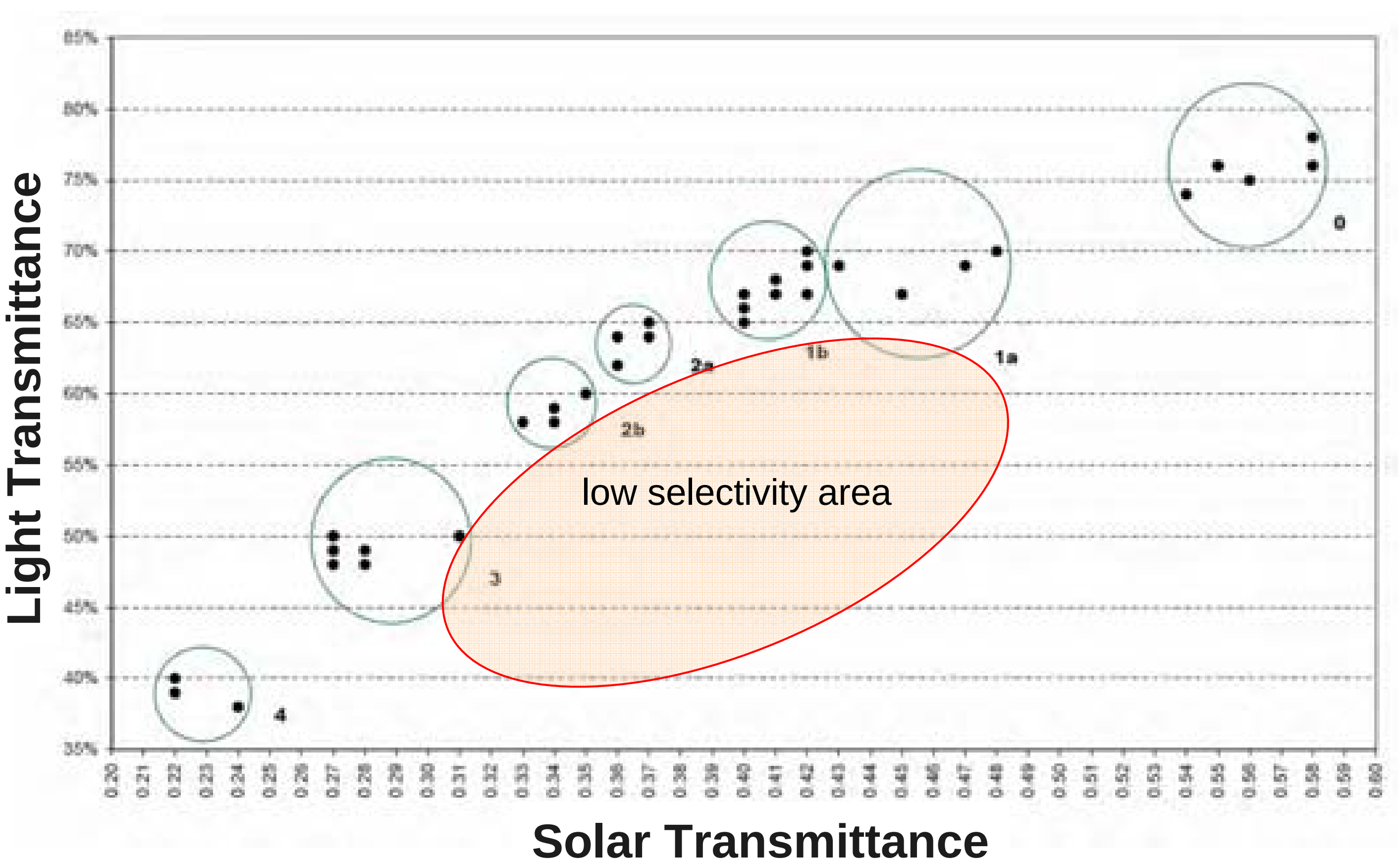
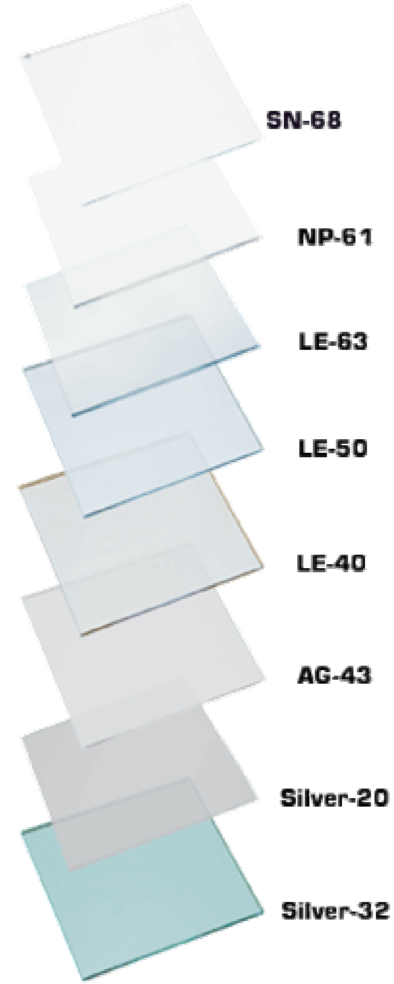
Glazing: Total Solar Energy Transmittance, G-value





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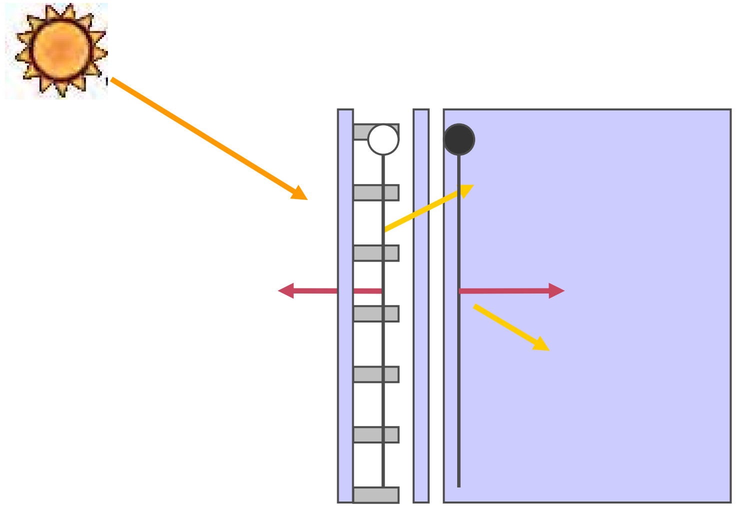
Shading (External, Internal, Interstitial)

Shading properties - position

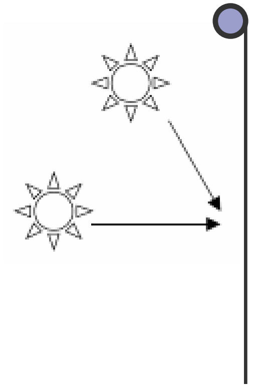
- External shading (fixed)
  - √ cooling
  - x heating
  - x view
- Internal shading
  - x cooling
  - √ heating
  - √ view
- Intermediate shading and double skin façades
  - √ cooling
  - √ heating
  - √ view



shading properties - types

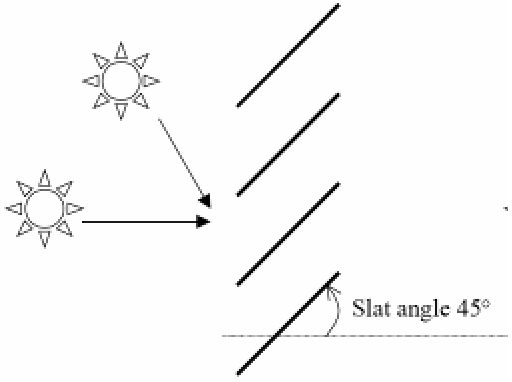
- Independent from sun position:
  - roller blinds

Static properties when applied

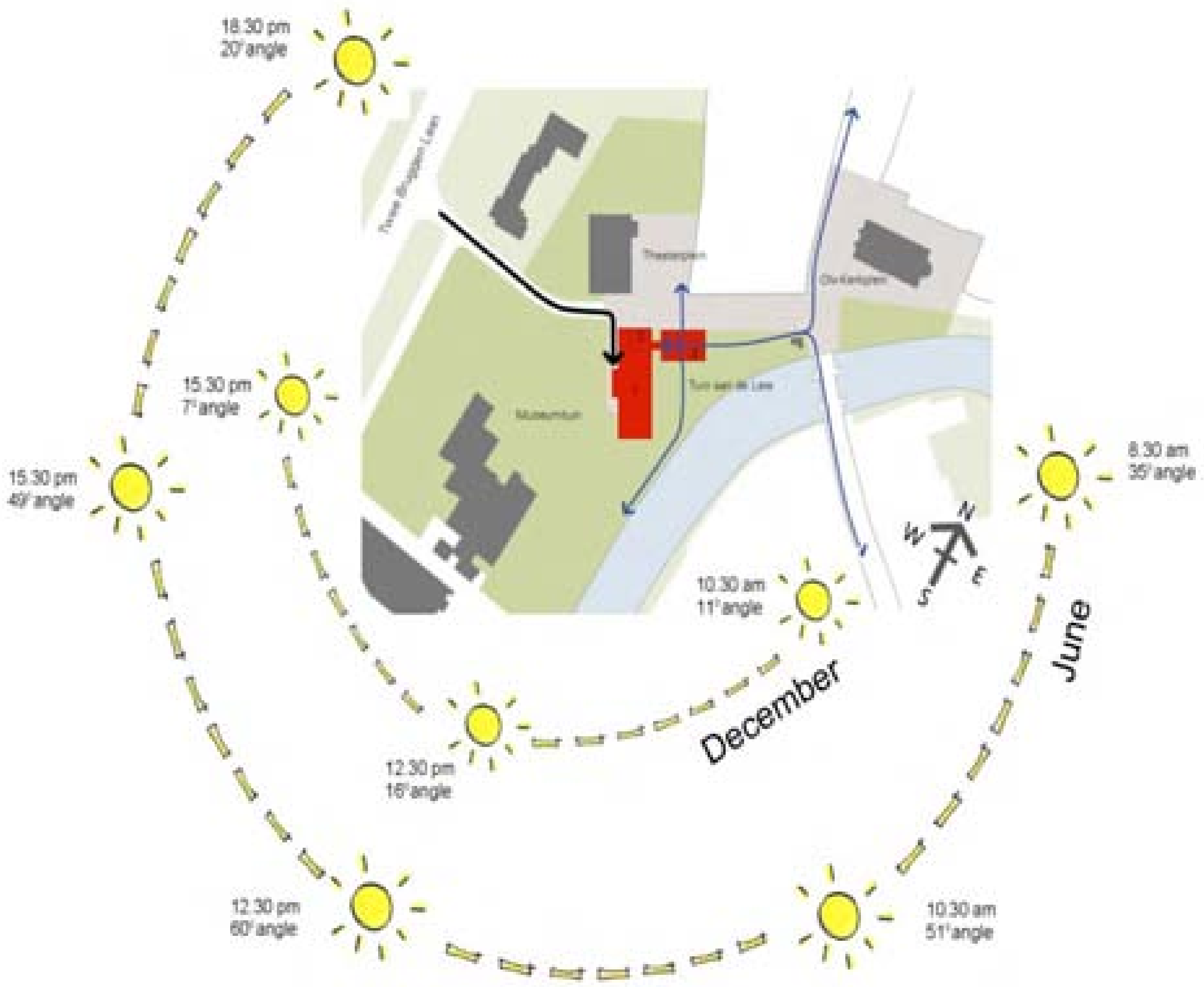


- Dependent on sun position
  - slatted blinds (venetian, louvres)
  - Overhangs (balconies
  - fins

Dynamic properties when applied



Case Study I: Building in Deinze, Belgium



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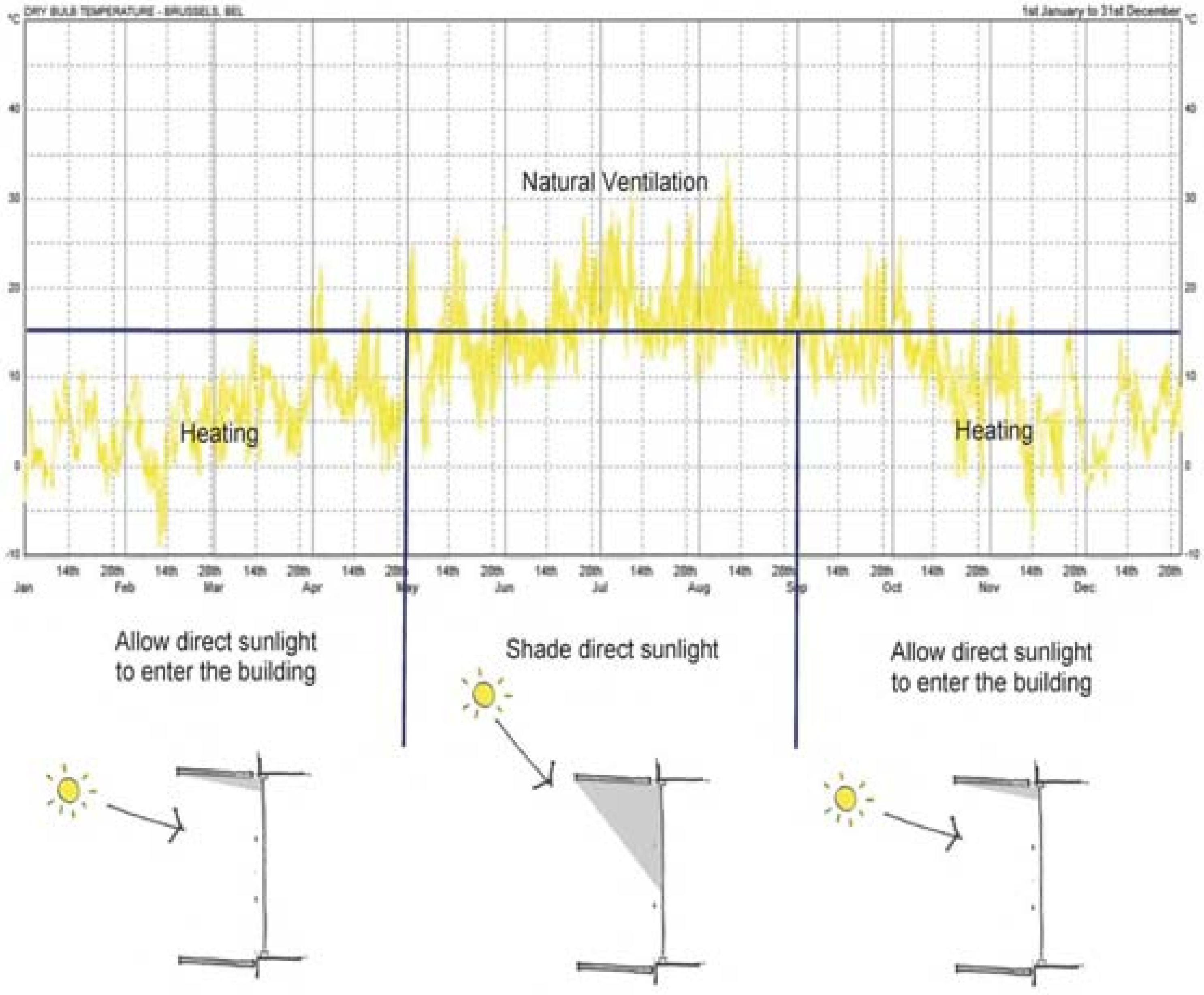
DRY BULB TEMPERATURE - BRUSSELS, BEL
1st January to 31st December
Natural Ventilation
Heating
Heating
Allow direct sunlight to enter the building
Shade direct sunlight
Allow direct sunlight to enter the building

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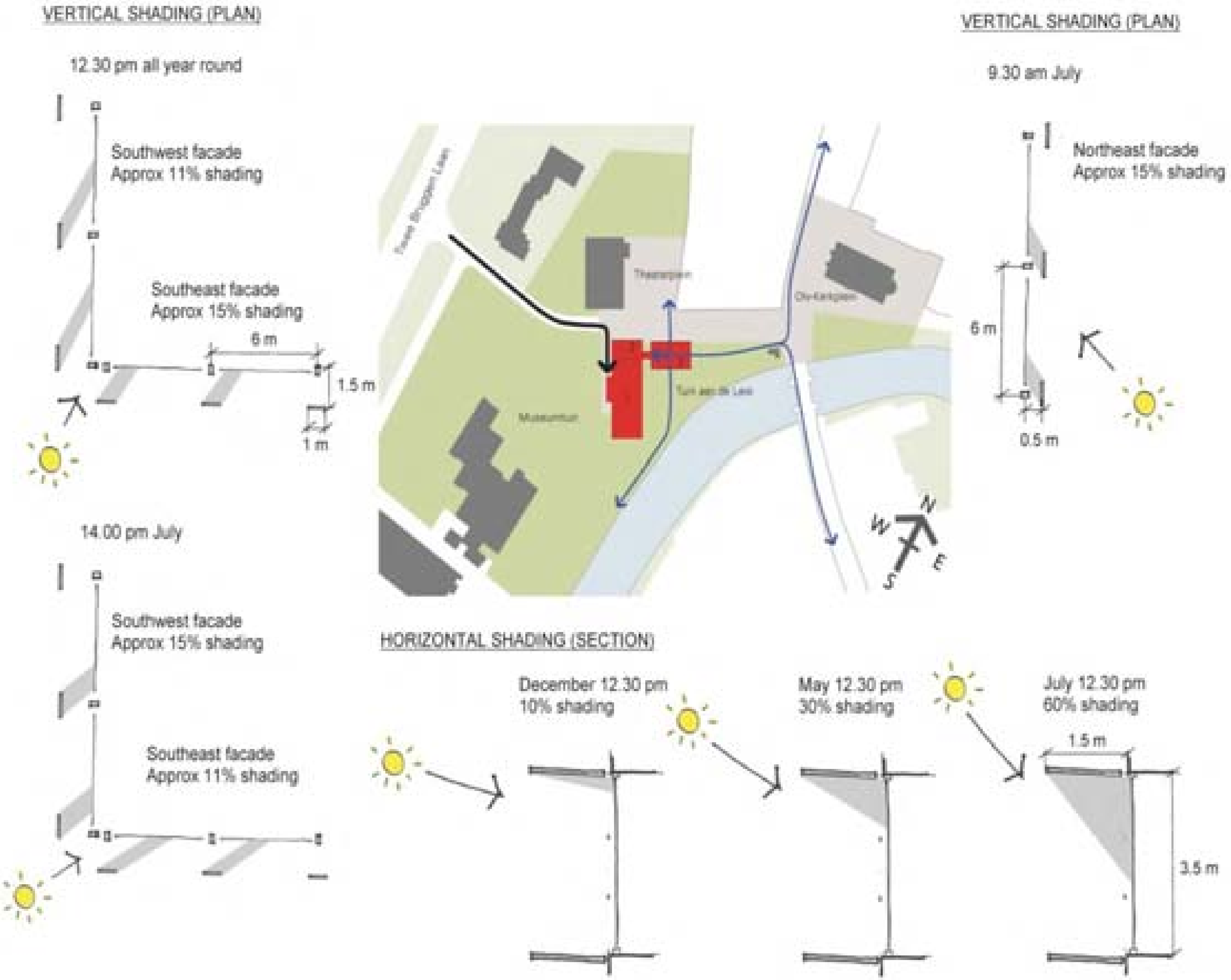

VERTICAL SHADING (PLAN)
12.30 pm all year round
Southwest facade
Approx 11% shading
Southeast facade
Approx 15% shading
6 m
1.5 m
1 m
14.00 pm July
Southwest facade
Approx 15% shading
Southeast facade
Approx 11% shading
VERTICAL SHADING (PLAN)
9.30 am July
Northeast facade
Approx 15% shading
6 m
0.5 m
N
W
E
S
HORIZONTAL SHADING (SECTION)
December 12.30 pm
10% shading
May 12.30 pm
30% shading
July 12.30 pm
60% shading
1.5 m
3.5 m

ASSUMPTIONS:

Reflectances:

Walls:	50%
Ceilings:	70%
Floors:	20%
Exterior:	20%

Transmittances:

Glazing:	80%

Daylit areas

annual_time_from_9.0_to_18.0_between_300.0_lux_and_3000.0_lux

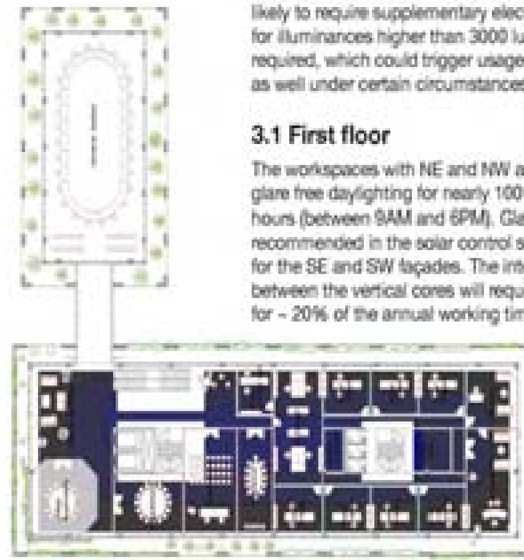
0.00 10.0 20.0 30.0 40.0 50.0 60.0 70.0 80.0 90.0 100.

3 Climate based daylighting analysis

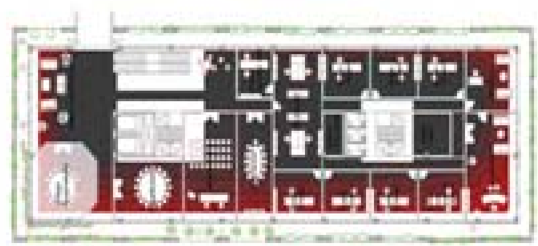
The diagrams in this page and in the following pages show useful daylight illuminance plots, i.e. in this case the percentage of working hours when interior illuminance is between 300 lux and 3000 lux. If the illuminance is lower than 300 lux, interior spaces are likely to require supplementary electric lighting, while for illuminances higher than 3000 lux glare control is required, which could trigger usage of electric lighting as well under certain circumstances.

3.1 First floor

The workspaces with NE and NW aspect benefit from glare free daylighting for nearly 100% of the working hours (between 9AM and 6PM). Glare control (as recommended in the solar control section is required for the SE and SW façades. The interior space between the vertical cores will require electric lighting for ~ 20% of the annual working time.



Dark areas



Glary areas

Natural Daylight

Daylight can be divided into two distinct sources:

- Sunlight

- Skylight

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Daylight

Sunlight

direct radiation

Daylight Skylight – diffuse radiation

Average Daylight Factor recommendations:

Average Daylight Factor

5% or more	The room has a bright daylit appearance. Daytime electric lighting is usually unnecessary.
2 – 5%	The room has a daylit appearance but electric lighting is usually necessary in working interiors.
Below 2%	Electric lighting is necessary, and appears dominant. Windows may provide an exterior view but give only local lighting.

Average Daylight Factor recommendations:

Average Daylight Factor

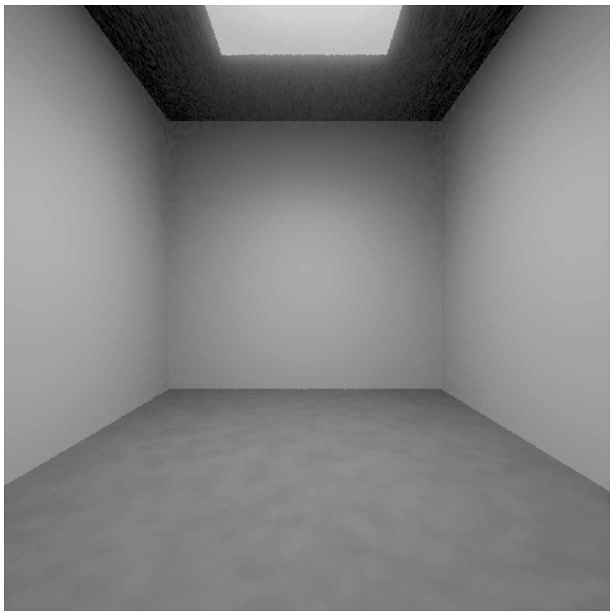
5% or more	The room has a bright daylit appearance. Daytime electric lighting is usually unnecessary.
2 – 5%	The room has a daylit appearance but electric lighting is usually necessary in working interiors.
Below 2%	Electric lighting is necessary, and appears dominant. Windows may provide an exterior view but give only local lighting.

Dwellings:

Bedrooms > 1%
Living Rooms > 1.5
Kitchens > 2%

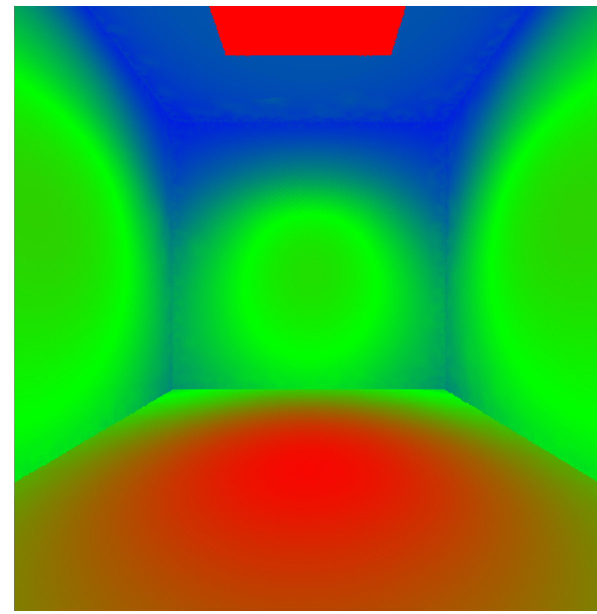
Daylight Assessment Techniques:
Combination of techniques

A project can use a number of techniques during the daylight design process



Visualisation

Scale model

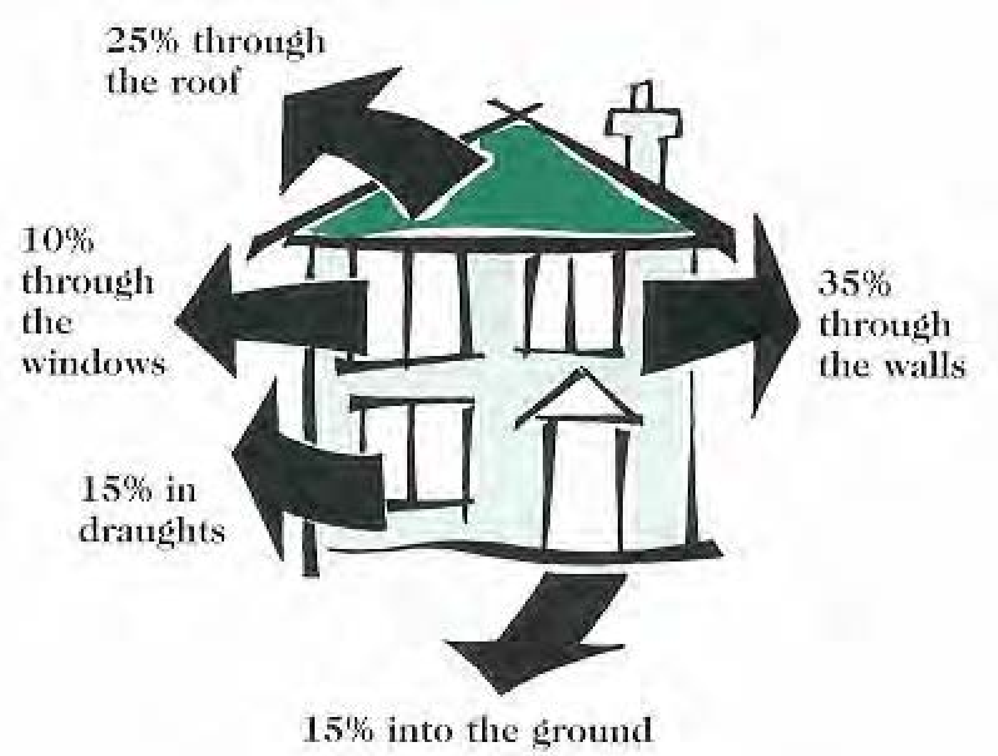


Illuminance analysis

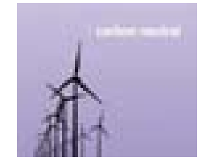
Air Tightness

Key Issues to consider

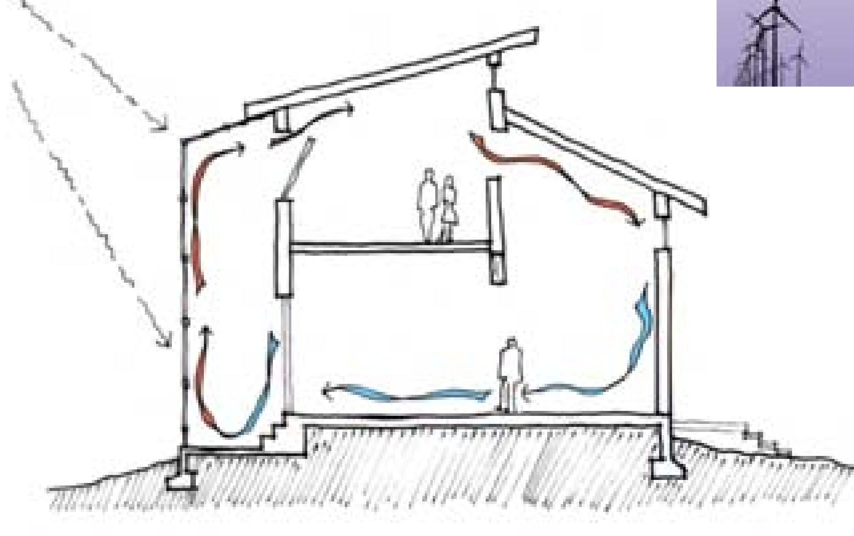
- Discuss with environmental consultant the air tightness levels
- Specify the materials and construction to achieve the targeted Air Tightness
- Ensure the contractor conducts a test

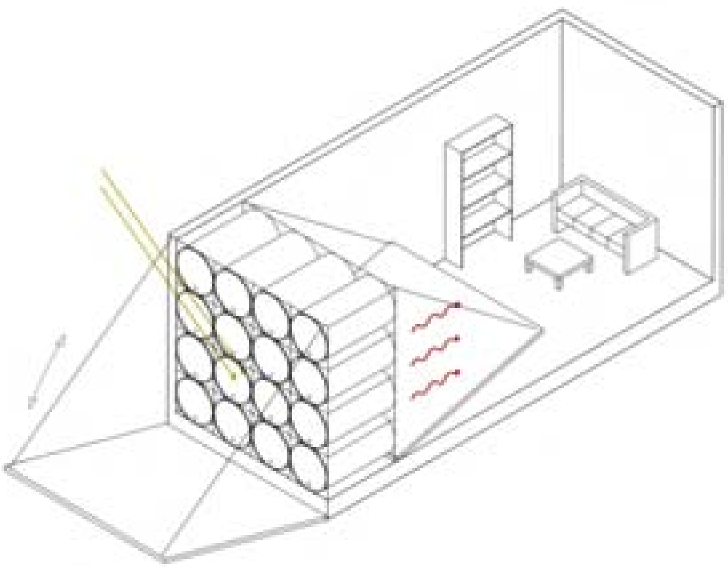


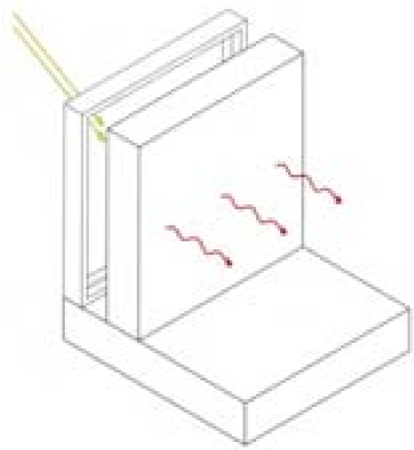
Passive Heating



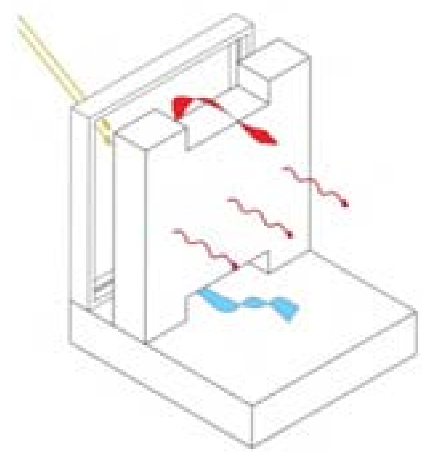
Use solar gain to passively heat the house







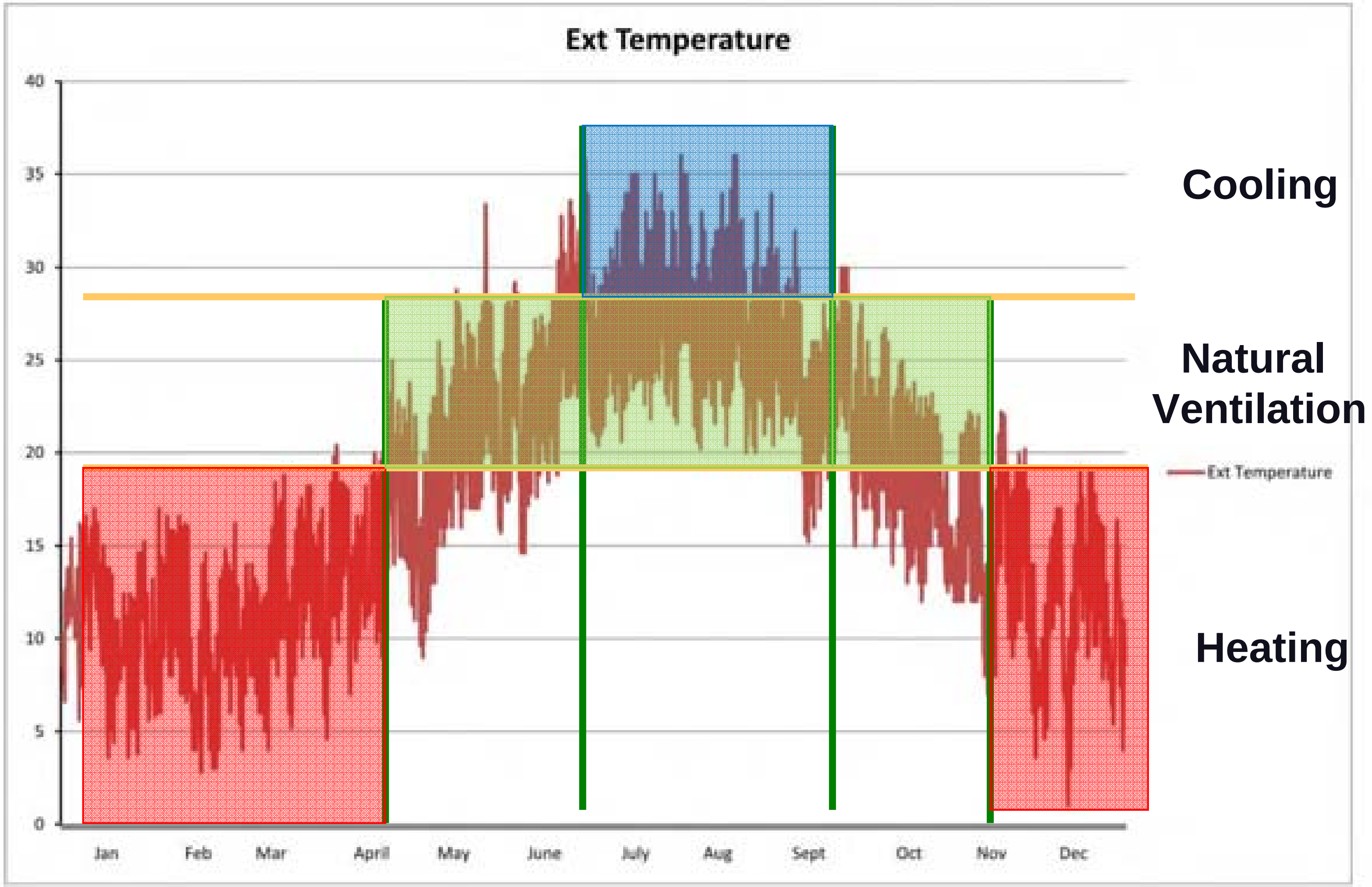
Trombe wall



In Mexico they use barrels of oil

Indirect solar gain

Passive Cooling



Passive Cooling potential in Athens

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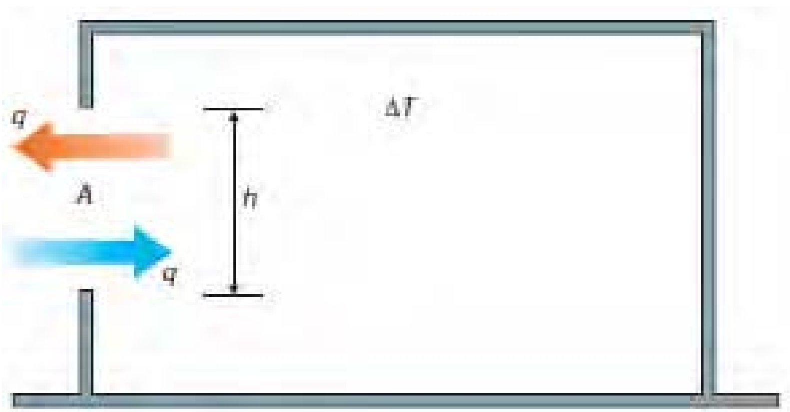
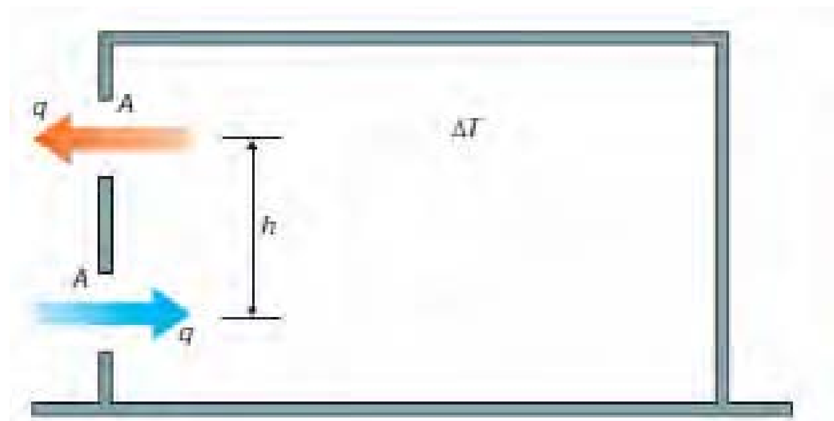
Natural Ventilation

Single Sided, Single vent



Source: CIBSE AM10

Single Sided, Two vents



Source: CIBSE AM10

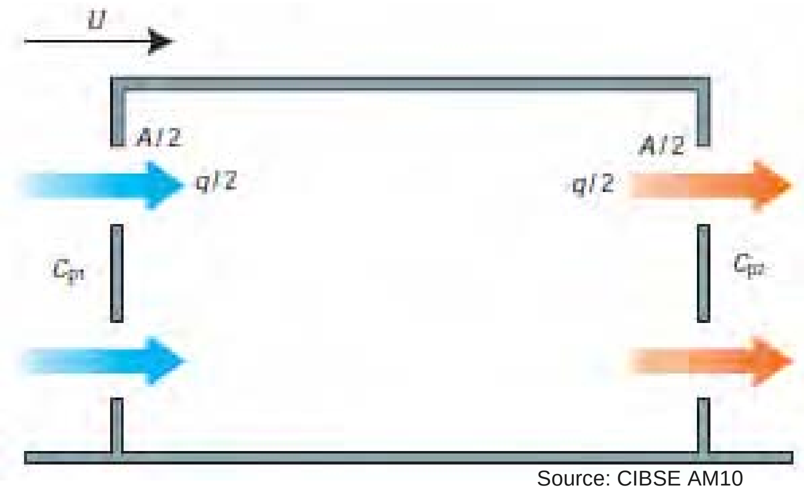
<u>Rules of Thumb</u>

Depth of room = 2 x height of room

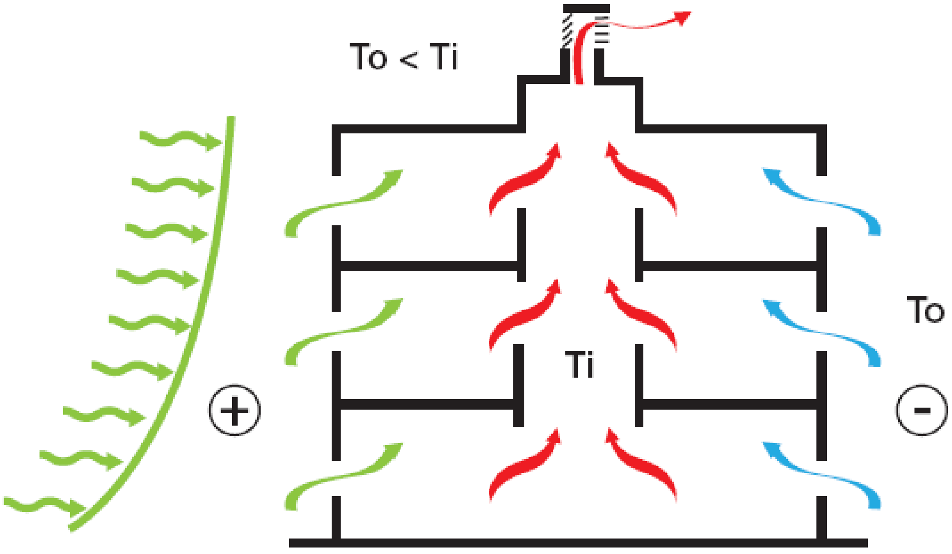
Depth of room = 2.5 x height of room

Natural Ventilation

Cross flow ventilation



Stack ventilation

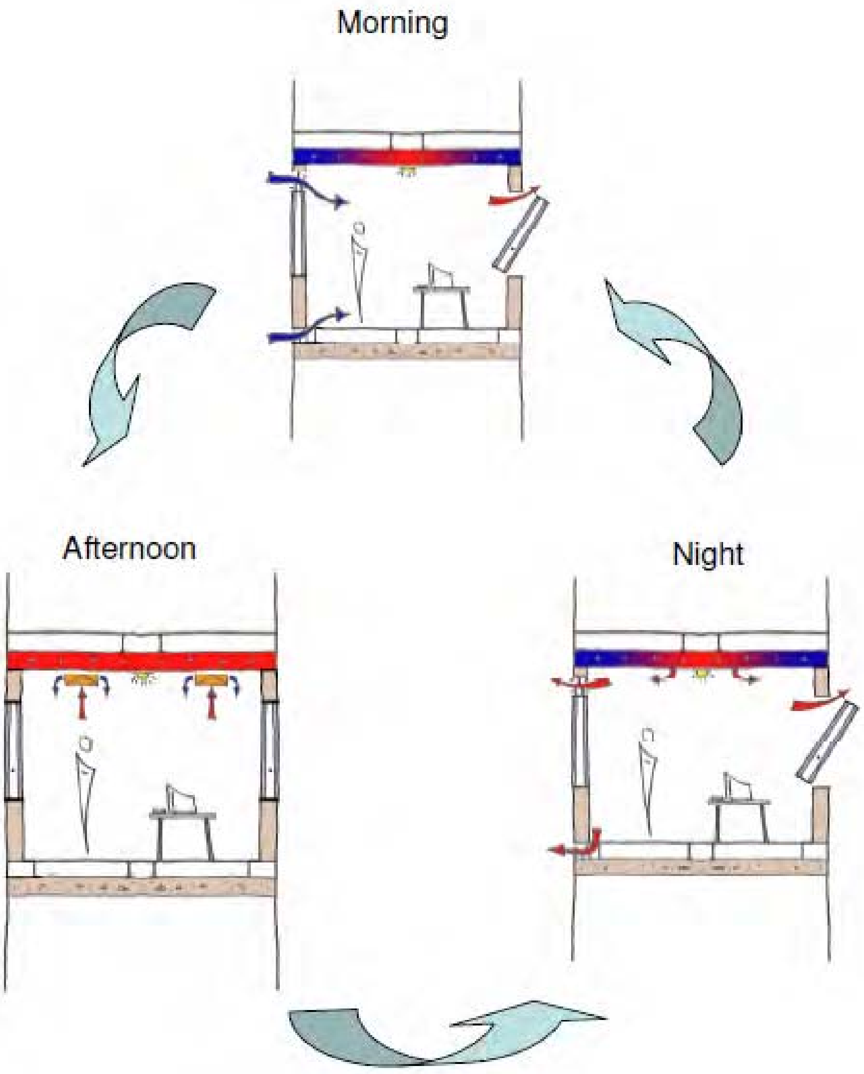


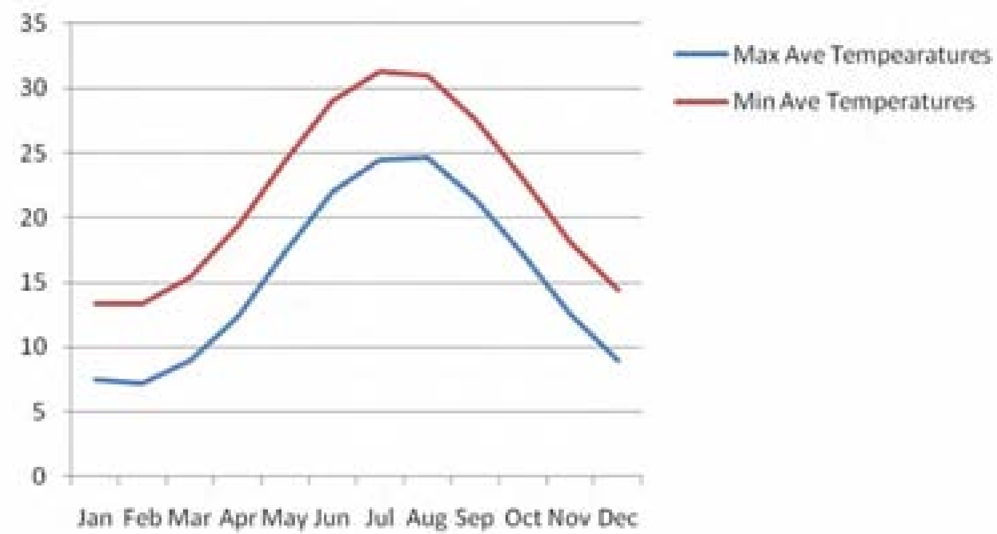
Rules of Thumb

Depth of room = 5 x height of room

Size of windows: 5% of floor area (purge)

Thermal Mass & Night Cooling

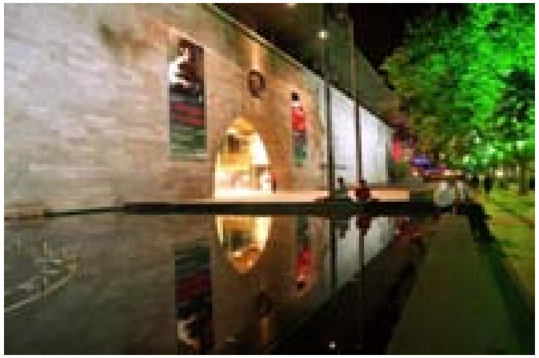




Passive Cooling

- Sea breeze
- Ponds (high humidity) at prevailing winds
- Wind Breaks
- Deciduous trees provide shading in summer and allow solar gains in winter

Sea Breeze



Pond - Tree

Ponds

Wind Breaks

Ponds

Green Roofs

- Improves thermal performance
- Improves air quality
- Reduces Noise
- Habitat

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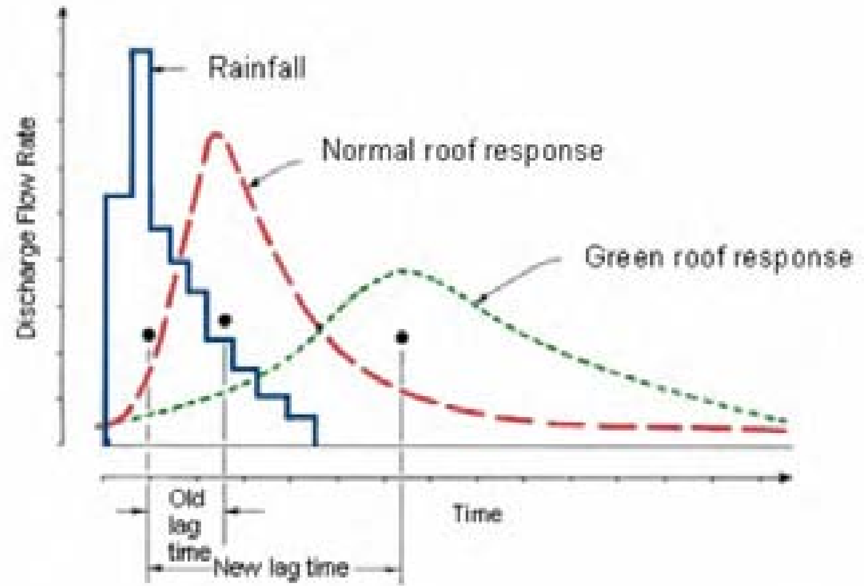
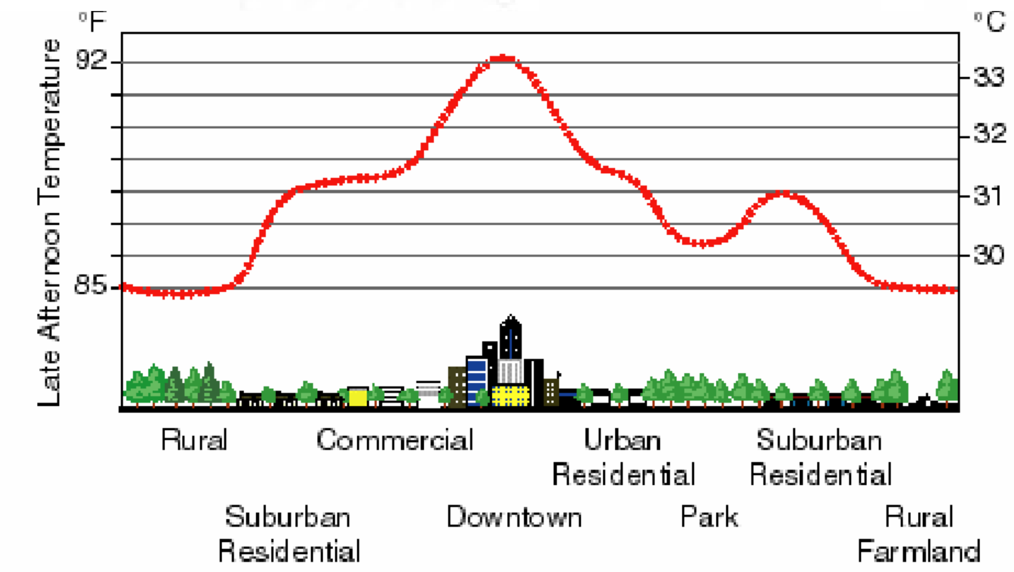
Green Roofs: The main benefits



Storm run off



Urban Heat Island Effect

Green Walls

- Can cool a building significantly

- Evergreen walls can insulate in winter by reducing the wind chill

- Visually attractive

- Environmental benefits

- Protects the wall of the building from heavy rain and hail

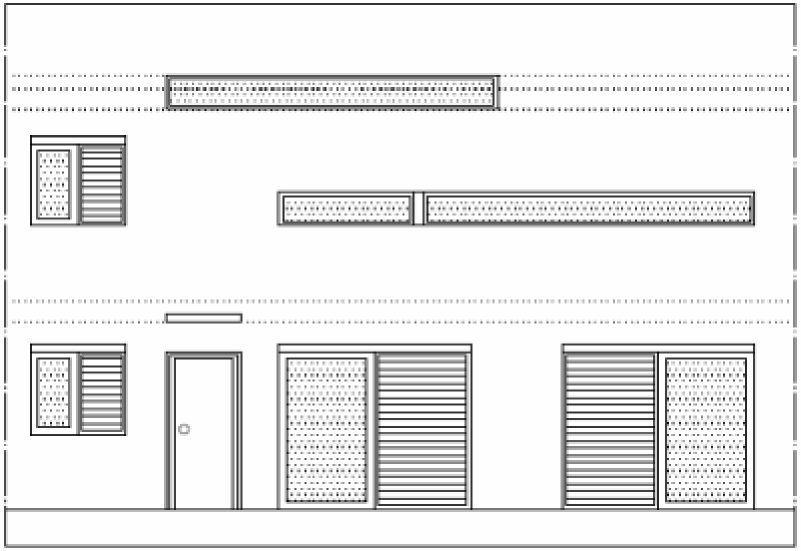
PassivHaus Spain

3 to 4 bedroom house 100m^2

Source: The Passive House Standard, University of Nottingham

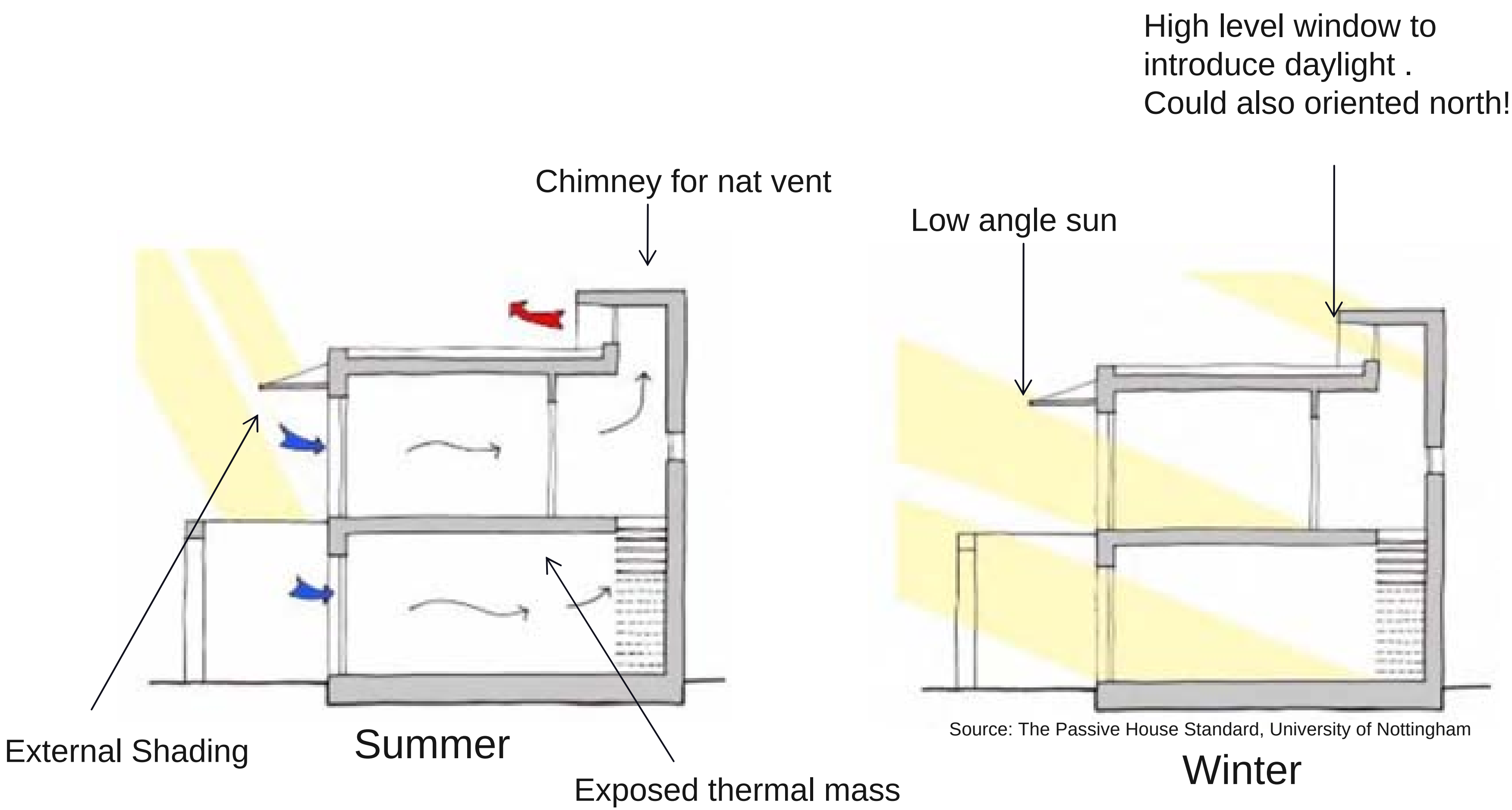
Low Energy House in Seville

- No mechanical ventilation
- South orientation: lower levels or solar radiation in summer when undesirable
- Easy to control solar ingress with
- movable shadings
- North: minimum glazing to meet daylight requirements



North Facade 10% glazing
South Facade 50% glazing

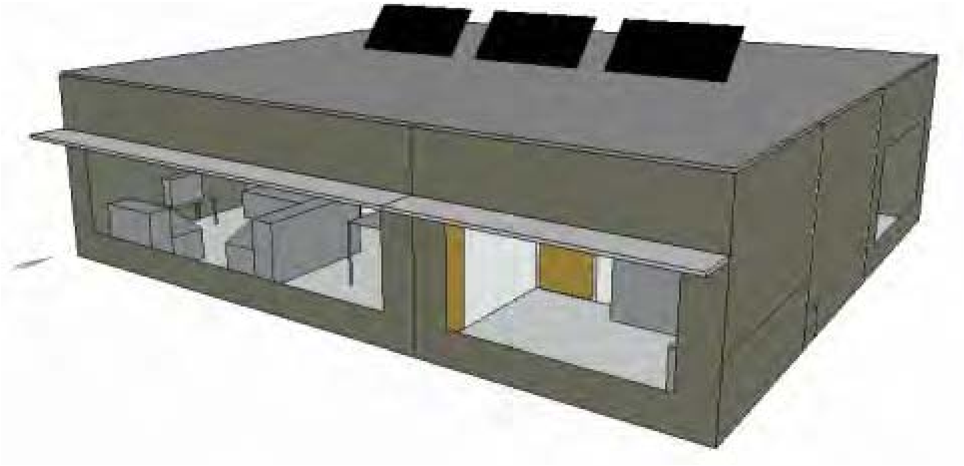
PassivHaus Spain



Source: The Passive House Standard, University of Nottingham

PassivHaus Portugal

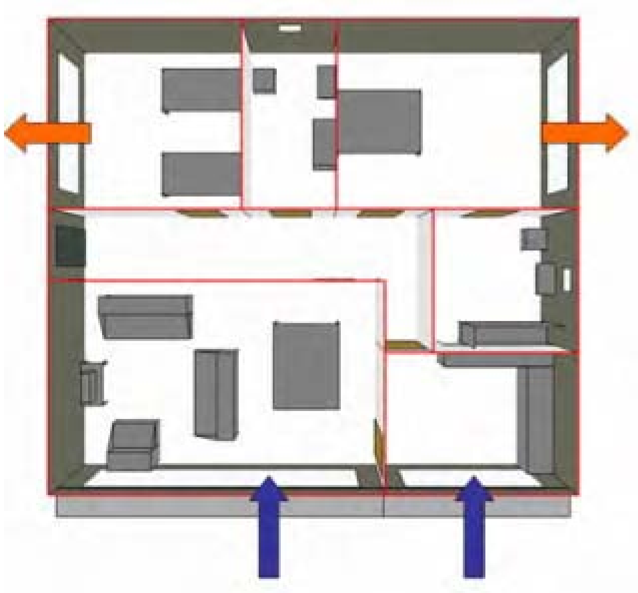
- Relation to the sun
- Ventilation for cooling
- Thermal mass using brick partitions
- Insulation and air-tightness not the main focus
- Exterior venetian blinds in all windows



Source: The Passive House Standard, University of Nottingham

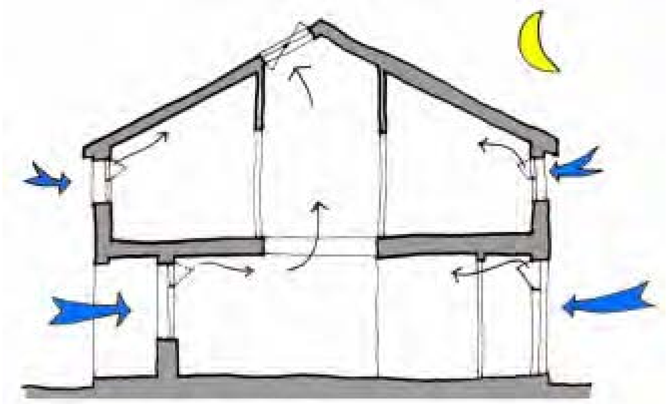
PassivHaus Portugal

- 100-150mm of insulation
- Non insulated floor slab but only in the perimeter
- South: 60% glazing area
- East and West 20% glazing area
- Glazing U value: 2.9 -1.9 $W/m^2/K$
- Solar panels installed facing south
- Large diurnal temperatures difference

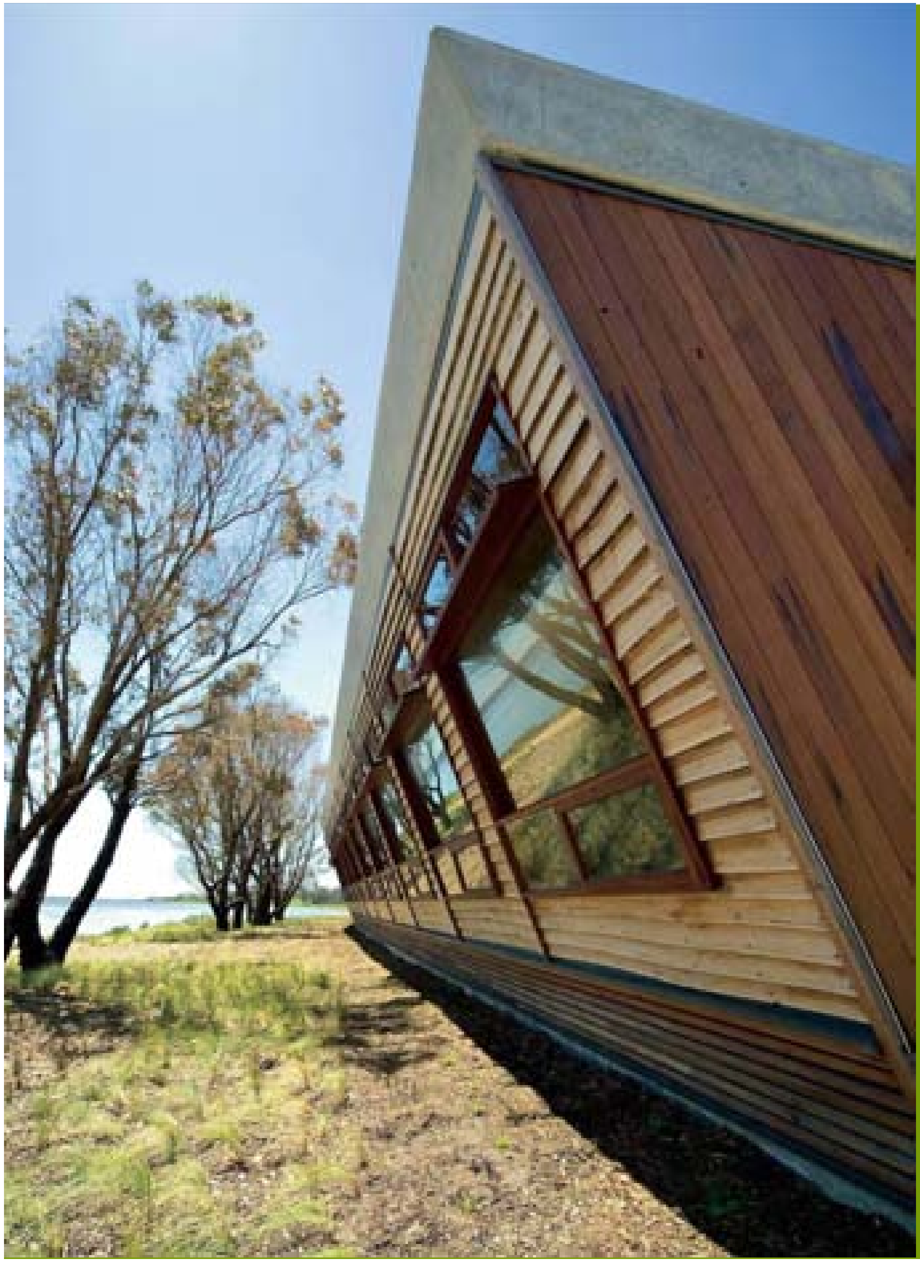


Source: The Passive House Standard, University of Nottingham

Natural ventilation



Night Cooling



PROJECT CASE STUDY II

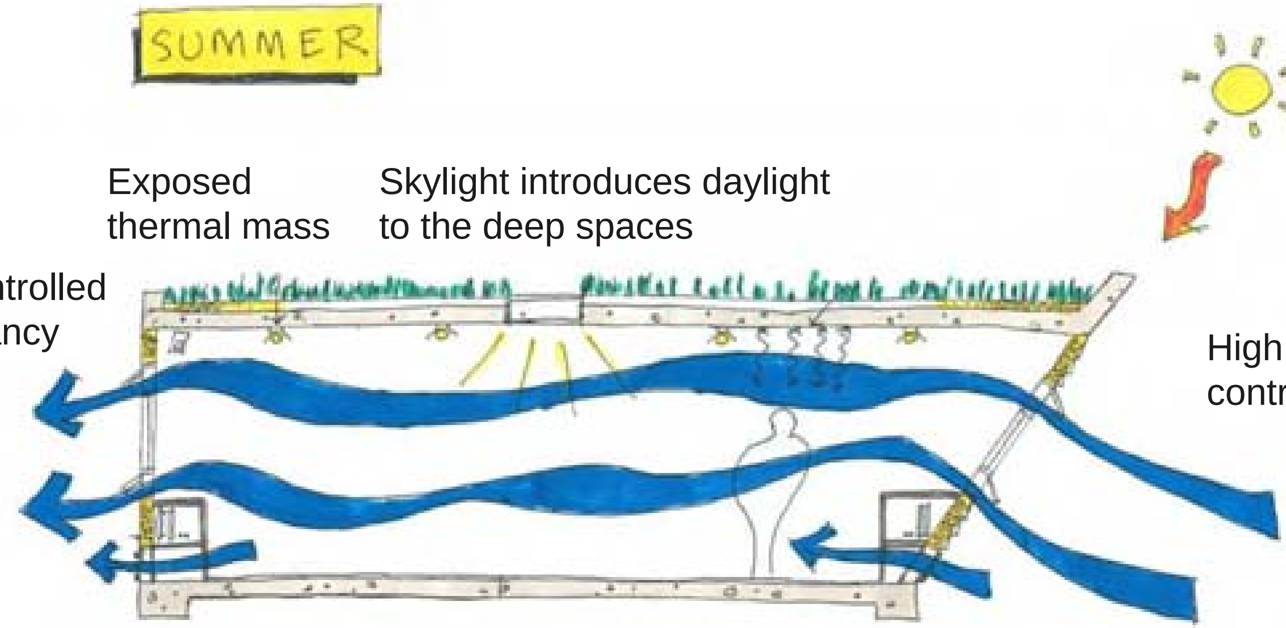
DPI MARINE & FRESHWATER RESOURCE INSTITUTE

Client: Victoria Department Of Primary Industries
& Resources Sa

Architect: Lyons Architects

Completed: November 2004

New environmentally and energy efficient "intelligent" research, development and education centre with a number of sustainable characteristics allowing the building to create a comfortable internal environment for occupants by responding to the seasons. The Centre has been designed in a unique way - almost from the inside out. The concrete structure is exposed on the inside and timber cladding insulates from the outside, maximising the benefits of thermal mass. Its walls and ceiling absorb heat in summer and naturally warm its interiors in winter



Exposed thermal mass

Skylight introduces daylight to the deep spaces

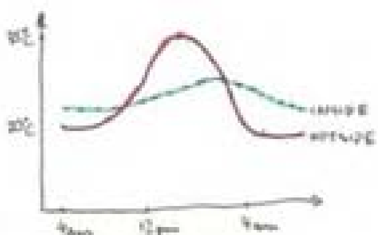
Lighting controlled with occupancy sensors

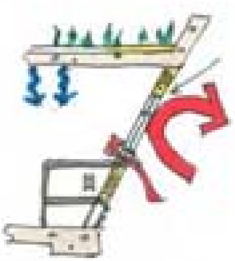
High level opening controlled by BMS

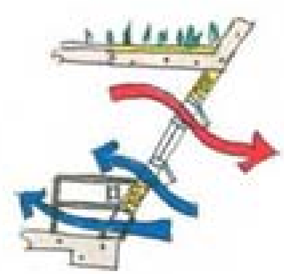
Sea breeze for natural ventilation

Narrow open plan for cross ventilation

Low level opening controlled by occupants







High ambient temperatures
Building sealed
Radiant cooling

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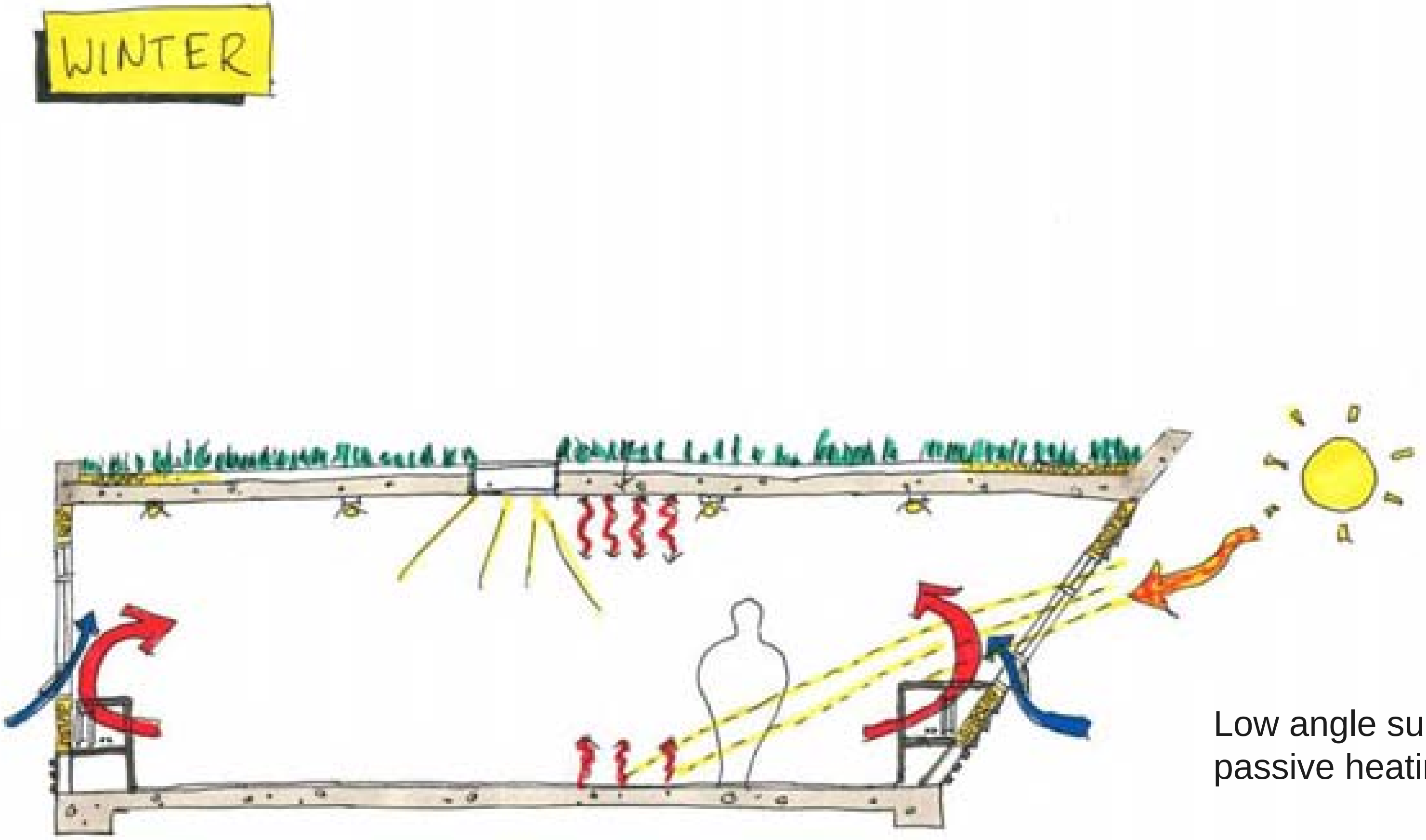
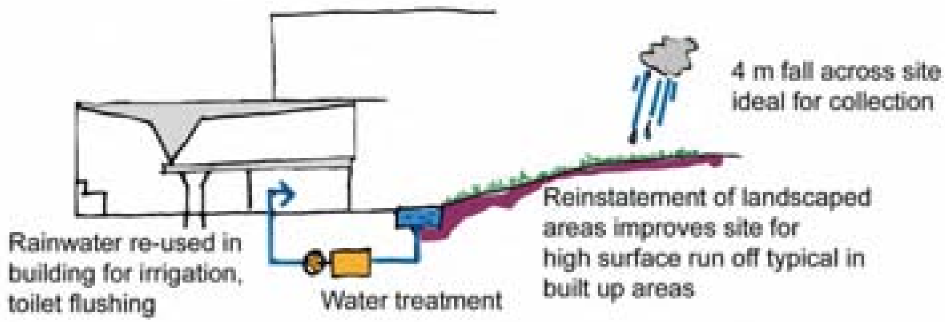


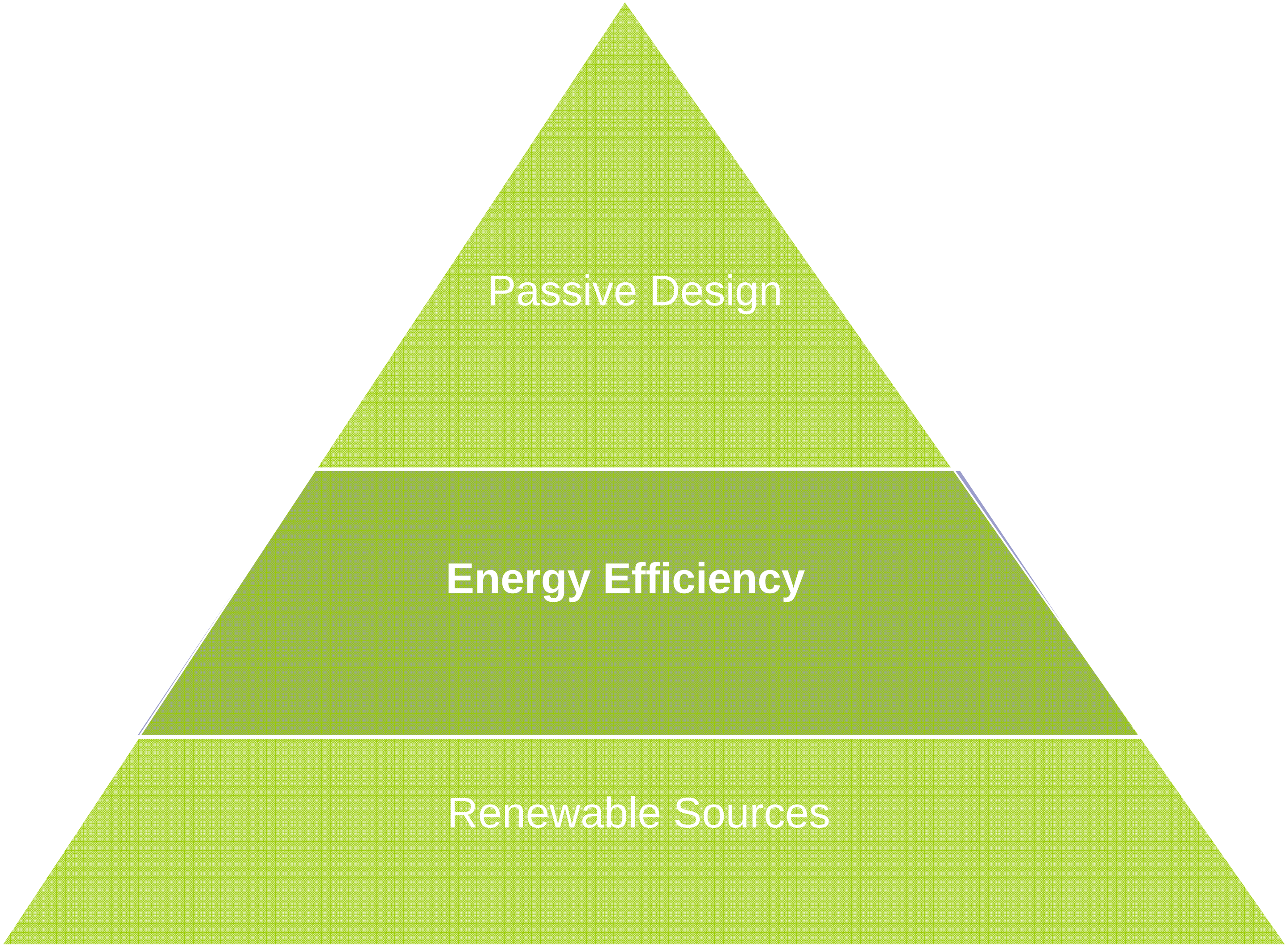
Low angle sun
passive heating

Minimum fresh air through windows
behind the heating elements

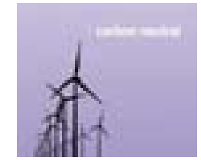
Well insulated envelope
Reduces heat loses

Rainwater Collection



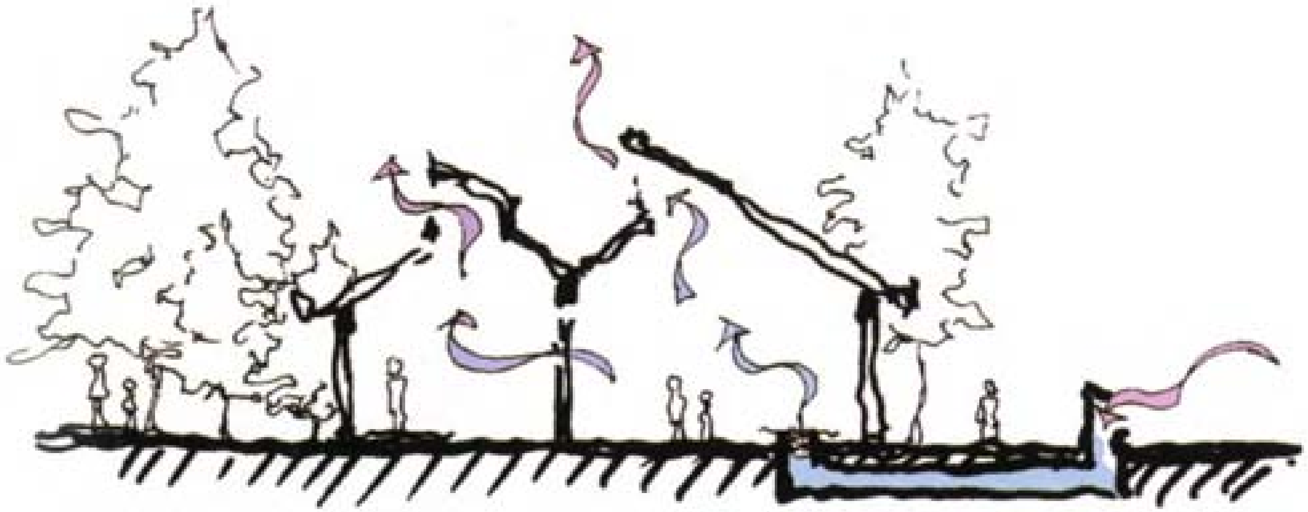

Passive Design
Energy Efficiency
Renewable Sources

Energy Efficiency

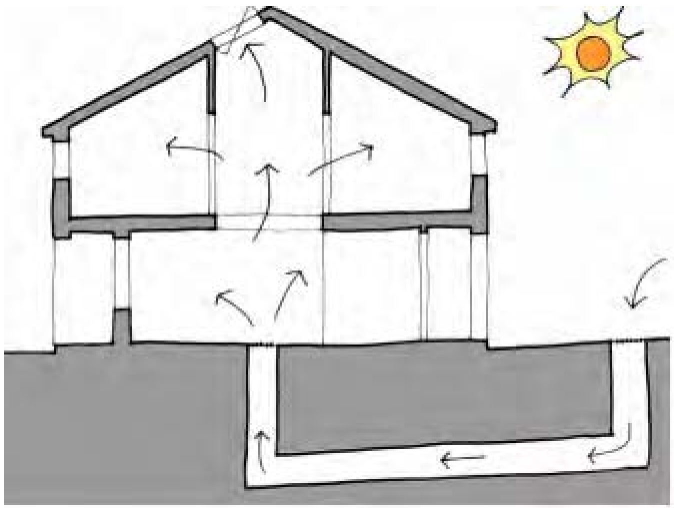


- Ground Cooling
- Mechanical Ventilation with Heat Recovery
- Ground Source Heat Pumps
- Combined Heat & Power Units – CHP
- Combined Cooling Heat & Power - CCHP

Earth Cooling Tubes

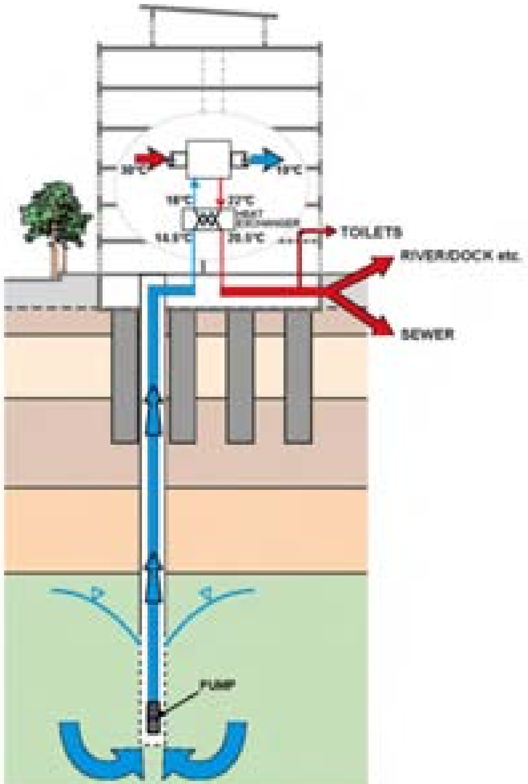


Key Architectural Issues

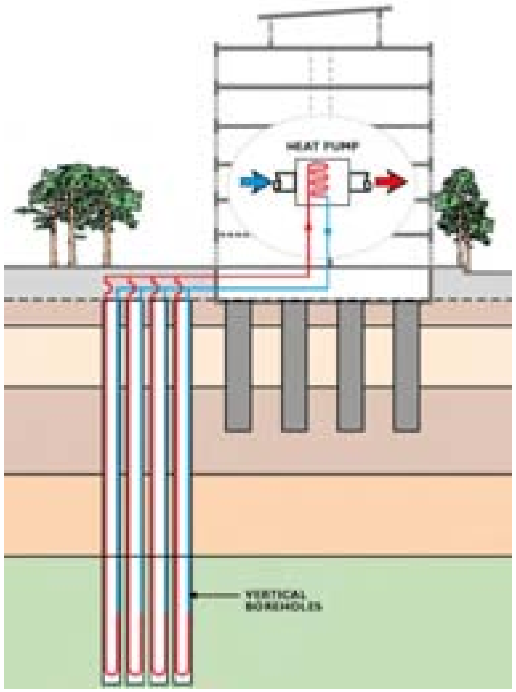


- Design for low level air diffusers in the rooms
- Provide shading
- Materials, durable non-corrosive
- Maintenance, risk of bacterial growth
- Buried 1.5-2m deep

Ground Source Heat & Cooling Systems



Open Systems



Closed Systems

- Vertical or horizontal loops
- Energy Piles

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GSHP using Boreholes

- Borehole output – 35W/m
- Usual depth of borehole – 15 to120m
- Boreholes laid out on a 6 x 6m grid.
- Cost of boreholes is £800-1200 / kWt capacity
- CO_2 emissions of a typical office reduced by approximately 45%
- If the electricity used to drive the pump can be generated from renewables, the system can be carbon neutral

‘Typical’ Greek House

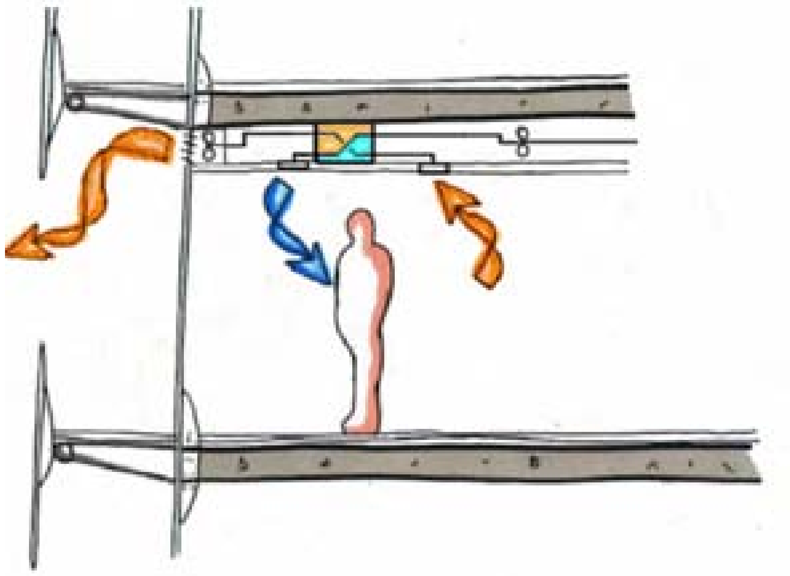
A/C Fuel Source	Oil/Electricity*	Gas/Electricity	GSHP
Co2 emissions	5105	6,185	427
Payback period	5.8	7.3	

*Including maintenance cost

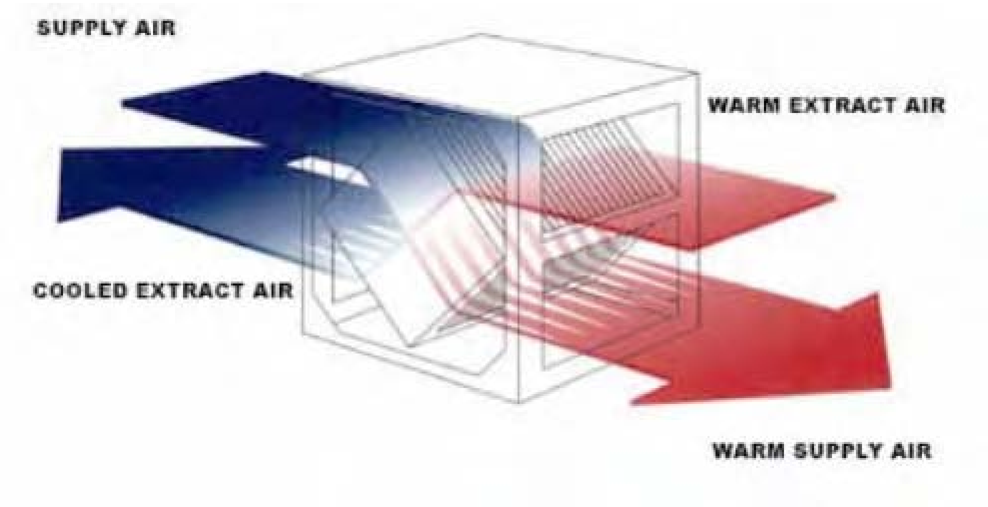
Key Architectural Issues

- Invisible technology
- Requires very little space (i.e. a cupboard of a single house)
- Noise
- Consider shading the horizontal installations
- Couple with appropriate heating (underfloor) and cooling system
- Appoint Competent contractor

Mechanical Ventilation with Heat Reclaim



Heat Reclaim

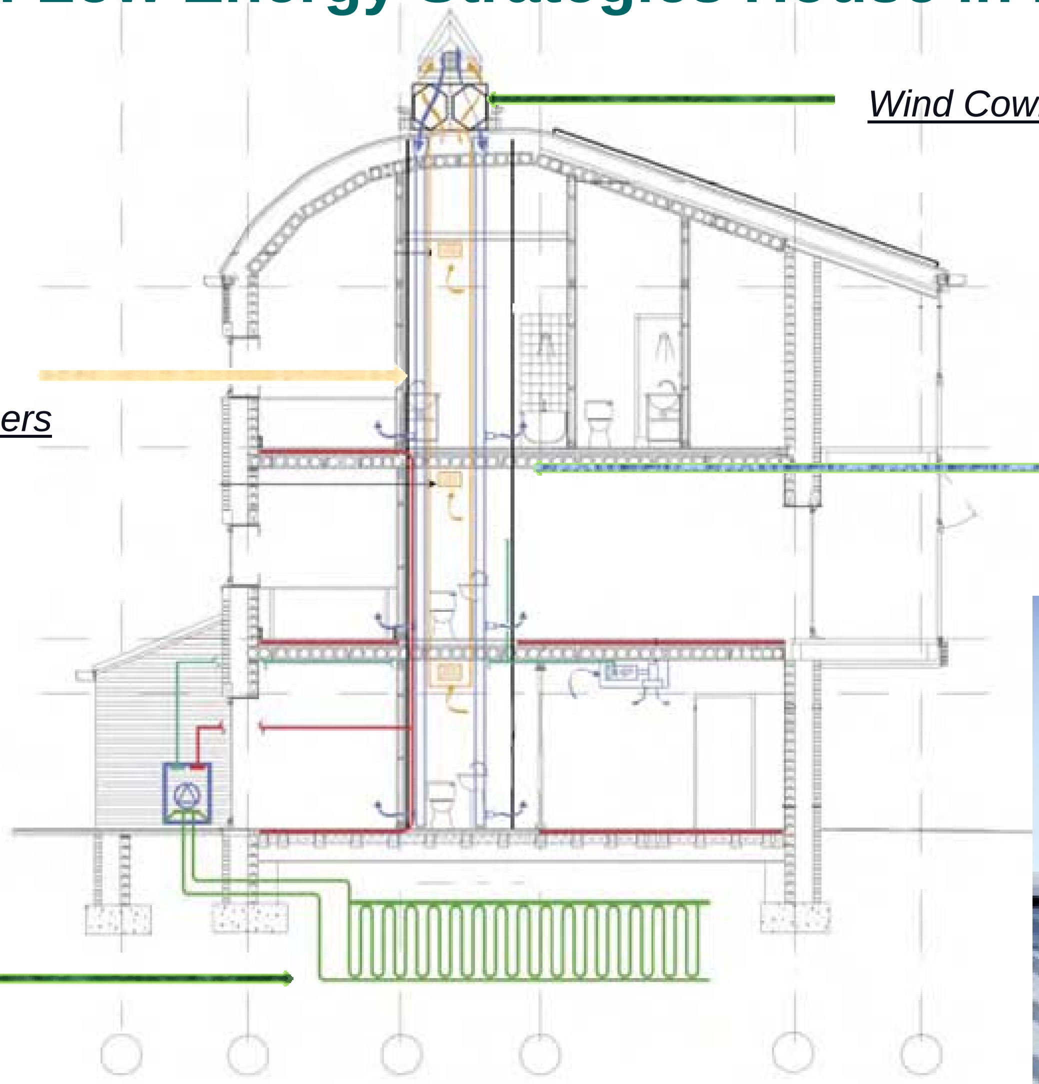


Energy recovery ventilator

MVHR Key Architectural Issues

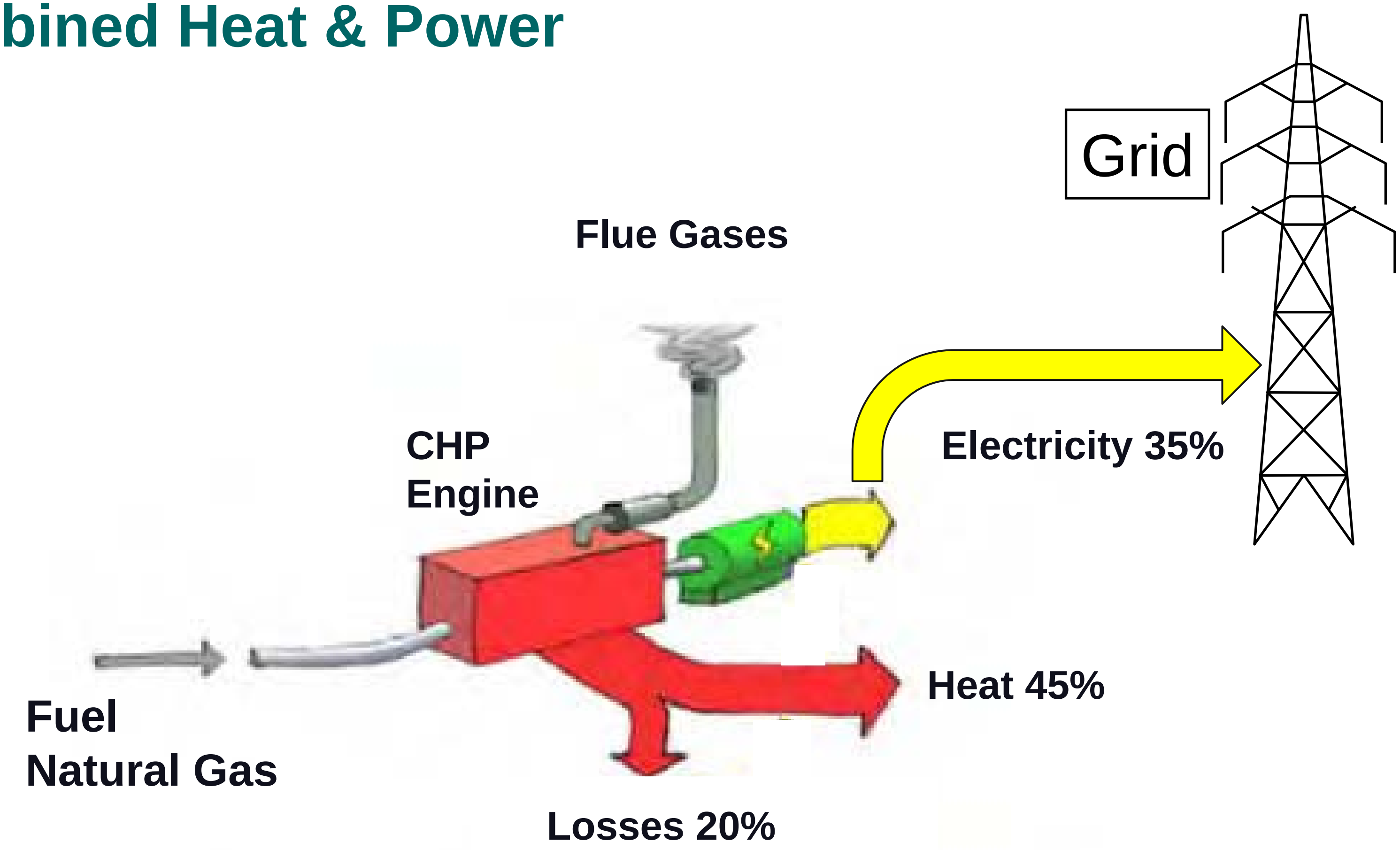
- Space for heat exchanger component, ceiling void, cupboard
- Air ducts need access to the outside (i.e. louvres on the façade)
- Suitable for open plan kitchen
- Energy saving potential dependant on size of house

Case Study III: Low Energy Strategies House in Beijing



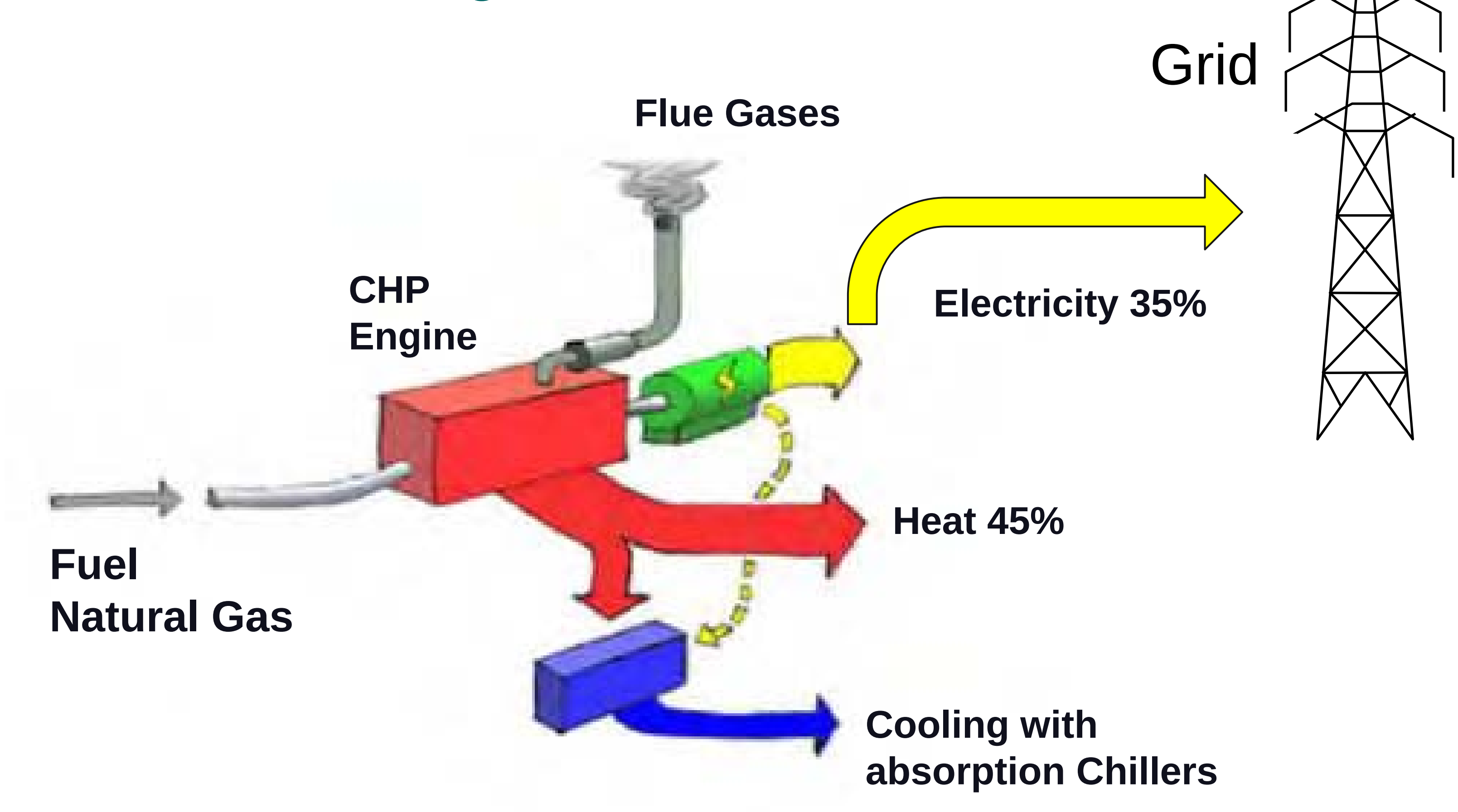
Source: Passivent

Combined Heat & Power



Use Biomass Fuel to make it carbon neutral

Combined Cooling Heat & Power

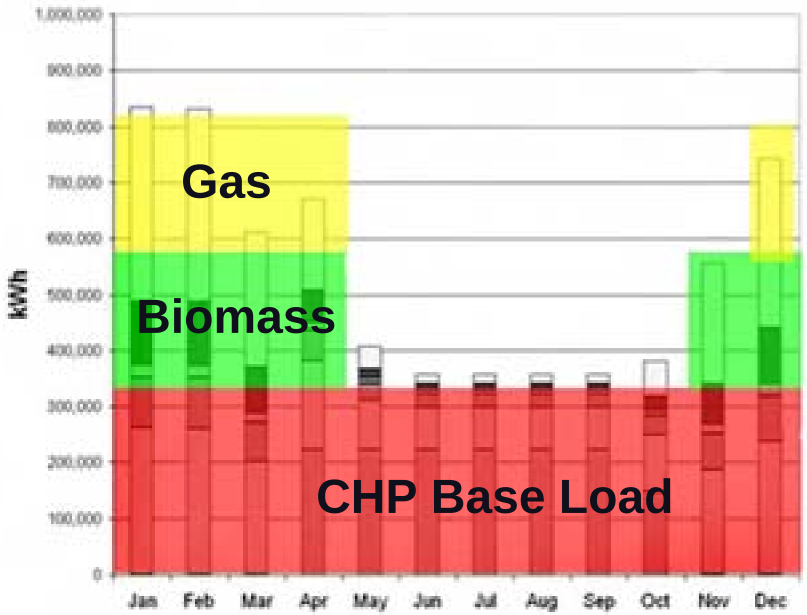


CHP - CCHP Key Architectural Issues

- Applicable to developments rather than individual house
- Study carefully its engineering feasibility
- Space for installation maintenance, replacement strategy
- Large space on the roof for heat rejection equipment
- Appoint competent contractor

Case Study IV : Mixed Use Residential, London with CCHP

- CHP to hot water requirements and base cooling load in summer
- Biomass to cover heating requirements base load in winter
- Gas supply to meet the peak loads



31% better that notional building
(as per UK Energy Regulations)

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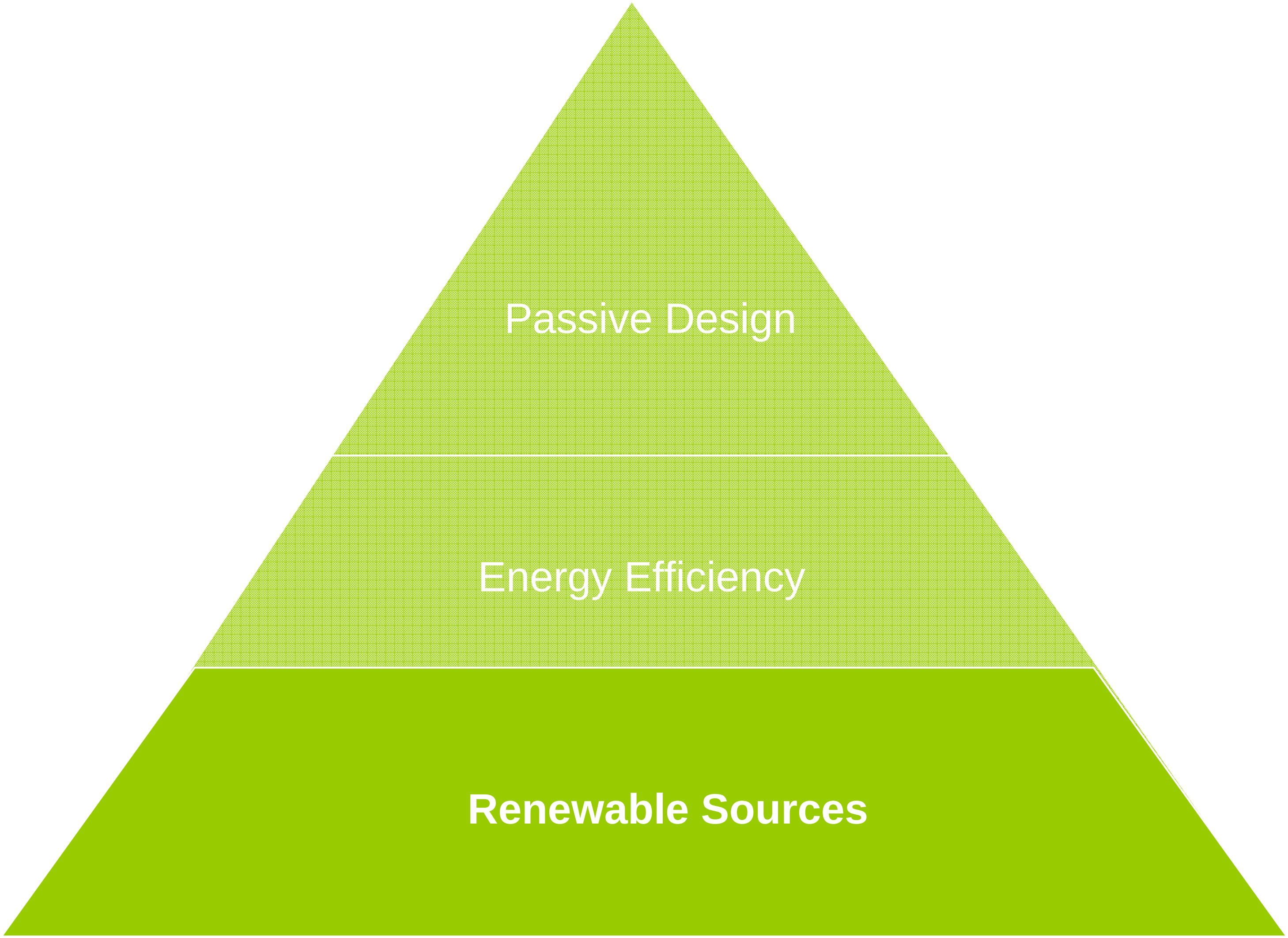
Passive Design
Energy Efficiency
Renewable Sources

Renewable Energy

- Wind Turbines and BIWT
- Photovoltaics and BIPV
- Solar Thermal
- Hydro Power
- Biomass


Middelgrunden Copenhagen 20x2MW_(c) www.lm.dk


© Proven


© XCO2

Building Integrated Wind Turbines

Key Architectural Considerations

- Fixing of turbines to the building structure
- Vibration
- Noise transmission
- Stiffening of the building structure

© XCO_2

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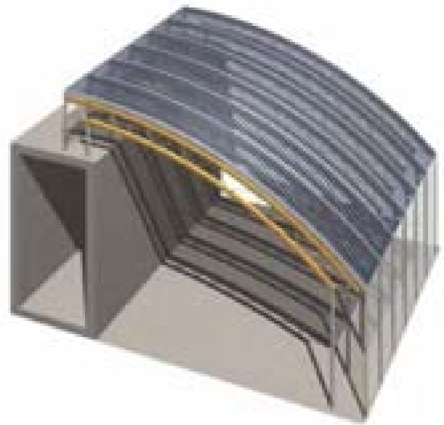
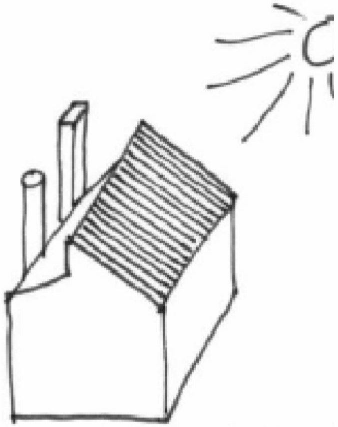
Photovoltaics



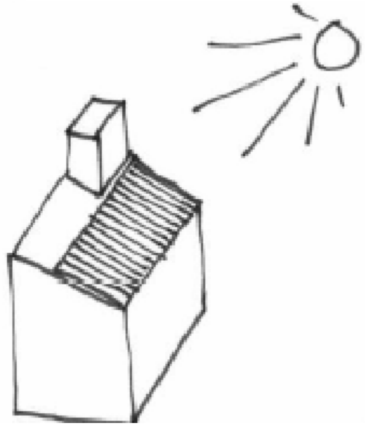
Source: Colston Hall redevelopment

Source: BP HQ Cape Town

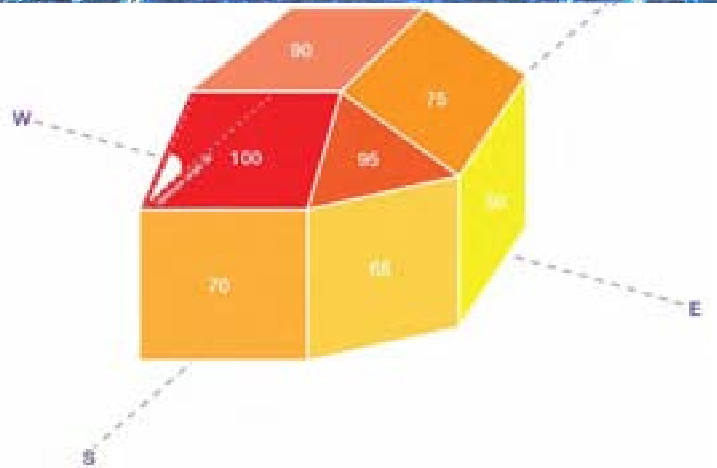
Key architectural considerations



Put obstructions to north

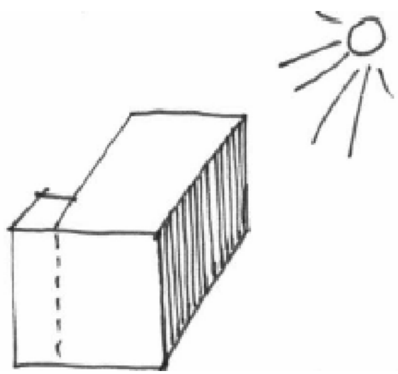


Put plantrooms to north



<u>Rules of Thumb</u>

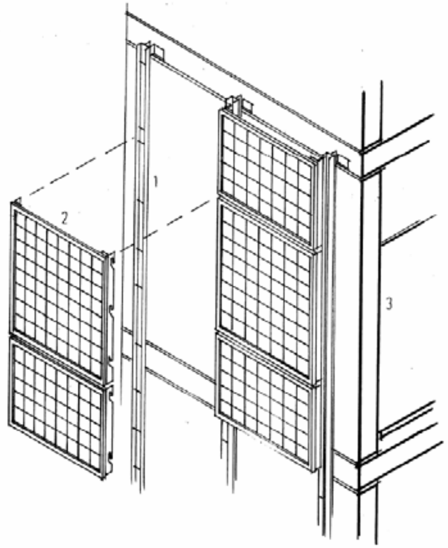
- Optimum angle latitude ± 15deg
- 1sqm surface for 100Watt power
- Cost 8,000€ for an average home



Staircases not shading PV

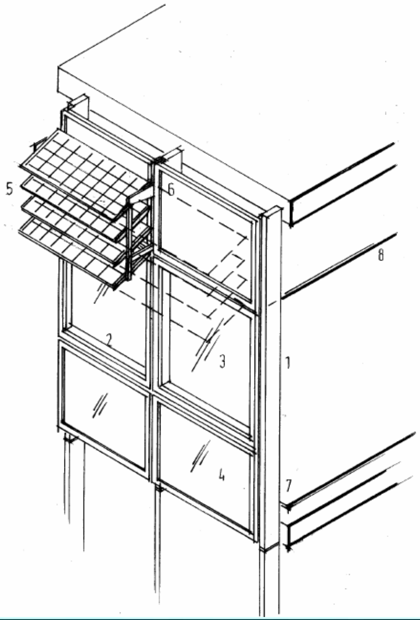
Building Integrated Photovoltaics

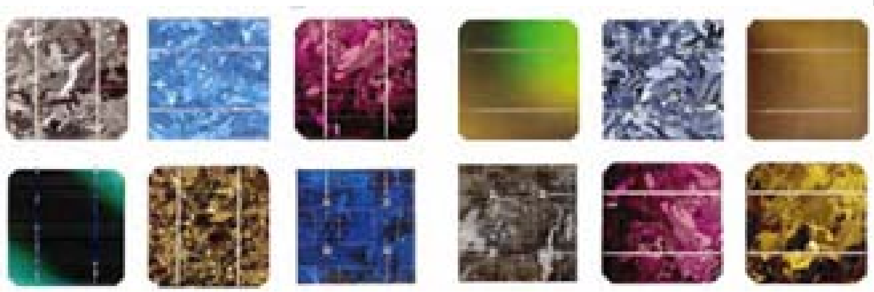
Rainscreen



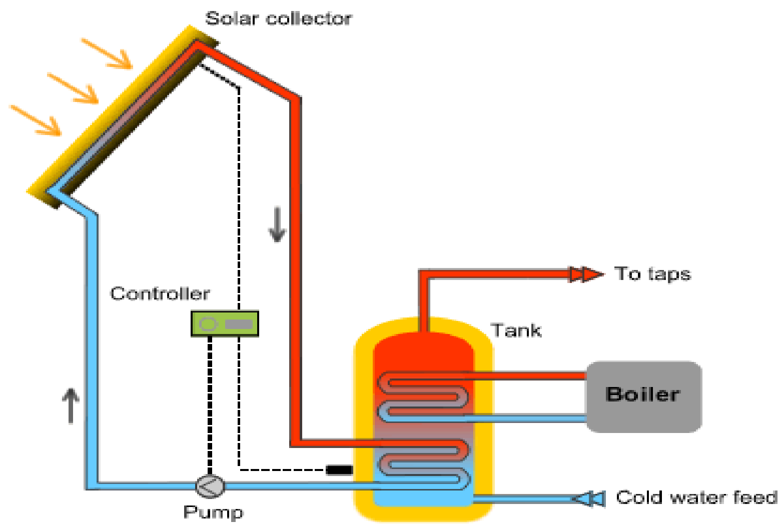
Cladding/curtain wall

Shading elements





Solar Hot Water Heating



‘Typical’ Greek House

Required roof area 2,5sqm

Hot water fuel Source	Oil	Gas	Electricity	Solar
CO2 emissions	3,960	2,940	14,835	0
Payback replacement period	11.8	17.9	8	-

Solar Hot Water Heating & Space Heating

For Heating

- Meet 40% of the annual demand
- Low grade heat - underfloor heating system
- Required roof area 15-20% m^2 of heated space
- Requires water storage

Hot water fuel Source	Oil	Gas	Electricity	Solar
CO2 emissions	3,960	2,940	14,835	0
Payback replacement period	11.8	17.9	8	-

Micro-Hydro Turbines

- River source
- Reliable source of power (as long as it rains)
- River to grid efficiency of 50%
- Tested technology in Greece
- Run of the river schemes **vs** energy storage schemes

Water Storage

To store just 1 kWh of electricity (enough to keep power and lighting on in the **bedroom** and **lounge for 1hour**)

18m^3 storage tank (18tn!!)

Biomass Heating

- An established energy source
- A low/zero carbon fuel
- A proven technology.
- Fuel can be wood chips, pellets, energy grasses or logs.
- Boilers range in size from 10kW to 10MW.

Wood chip

Wood pellets
(available in Greece)

‘Typical’ Greek House

Heating fuel Source	Oil	Gas	Electricity	Biomass
Co2 emissions	3960	2940	14835	0
Fuel cost	1023	667		1449

<u>Wood pellets cost</u>

250€/tn in Greece
170€/tn in Europe

Biomass Boiler cost =3x Gas boiler cost

Key Architectural Considerations

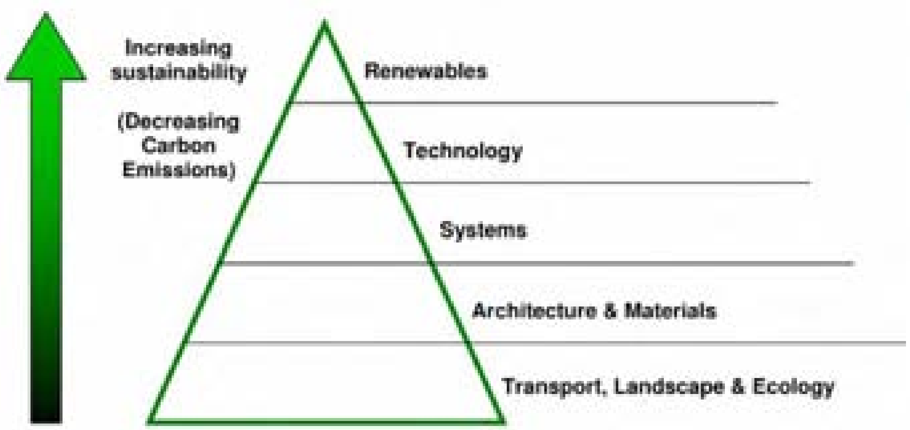
- Large plantrooms
- Large fuel storage
- Access to ground level for deliveries
- Flues

Case Studies

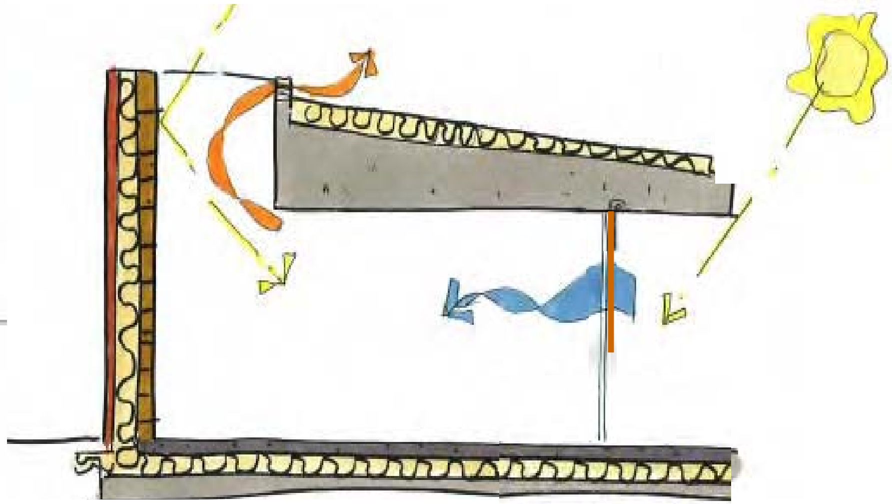
Case Study V:
Zero Carbon House

Residential villa, 2,000sqm
Oxfordshire UK
David Chipperfields Architects

100% ‘reduction in ‘regulated’ carbon emissions



Sustainable Design Hierarchy



Passive Design, Reducing Demand

No cooling

- Thick insulation
- Triple glazing

To reduce heat loss in winter

- Shading
- Mass

To reduce heat gain in summer

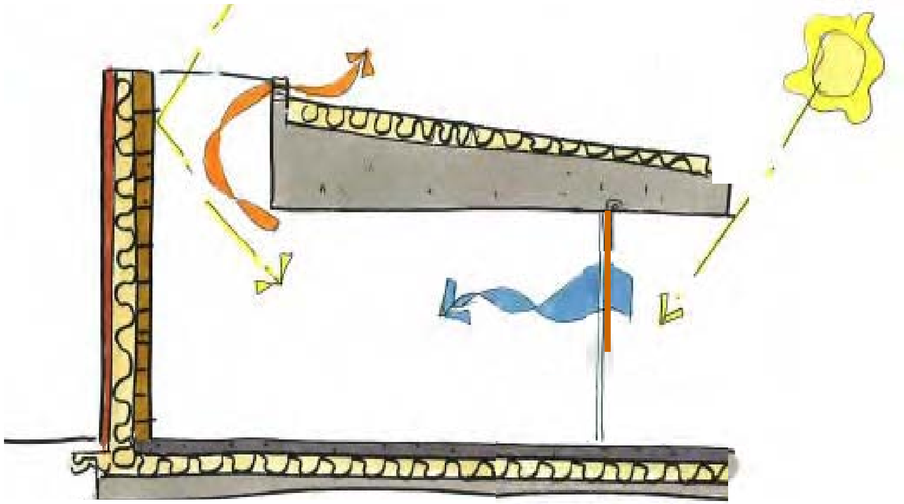
Passive Systems to temper air

No A/C

- Natural ventilation

  - opening windows and skylights

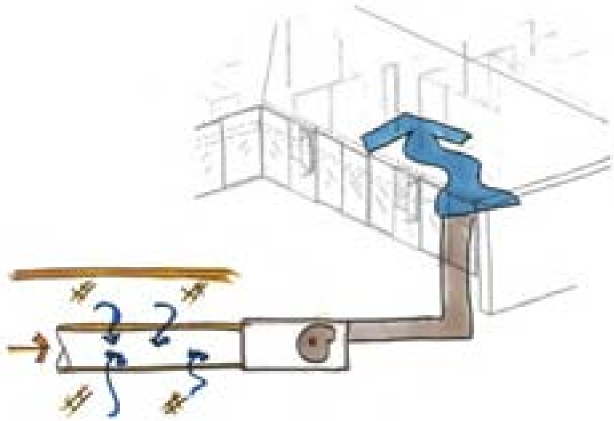
  - secure night time ventilation



Active Cooling

- Earth tube air tempering

  mechanical ventilation



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Renewables: Carbon Footprint
% reduction in carbon emissions

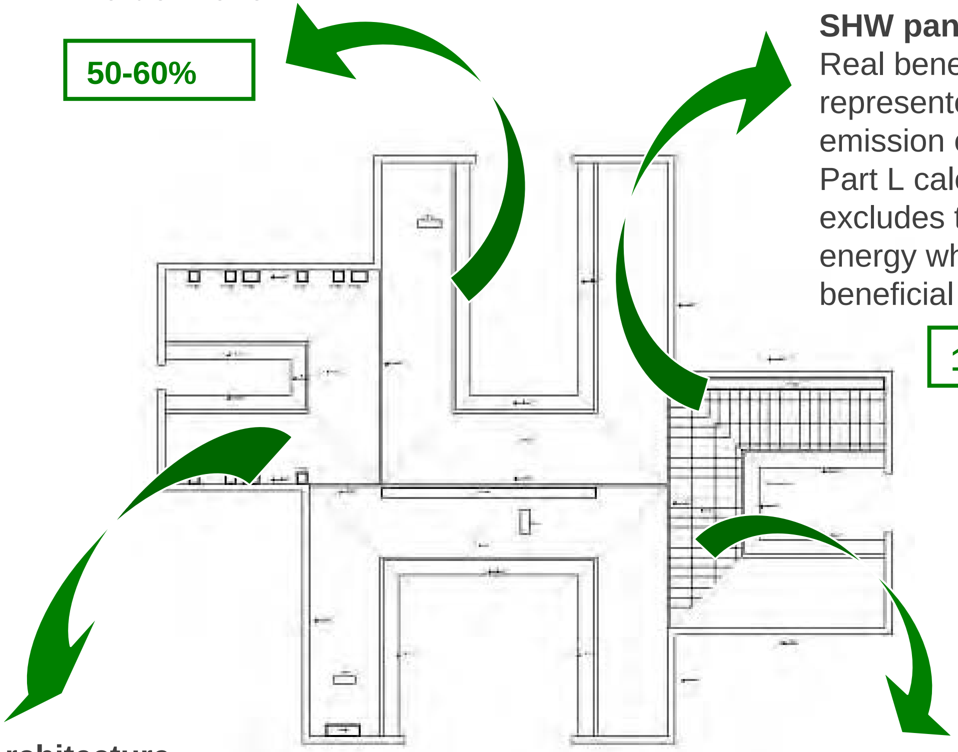
Biomass Boiler

PV cells

Solar Hot Water

Biofuel Boiler

50-60%



SHW panels
Real benefits not represented by carbon emission calculation.
Part L calculation excludes the pool energy where SHW is beneficial

1-2%

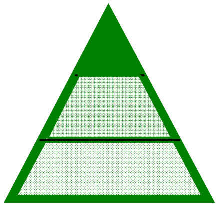
Architecture
Well sealed
Good performing envelope
shading

15-20%

Photovoltaic Panels

15-20%

=<u>100%</u>
<u>Reduction</u>



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Case Study VI: Zero Carbon House

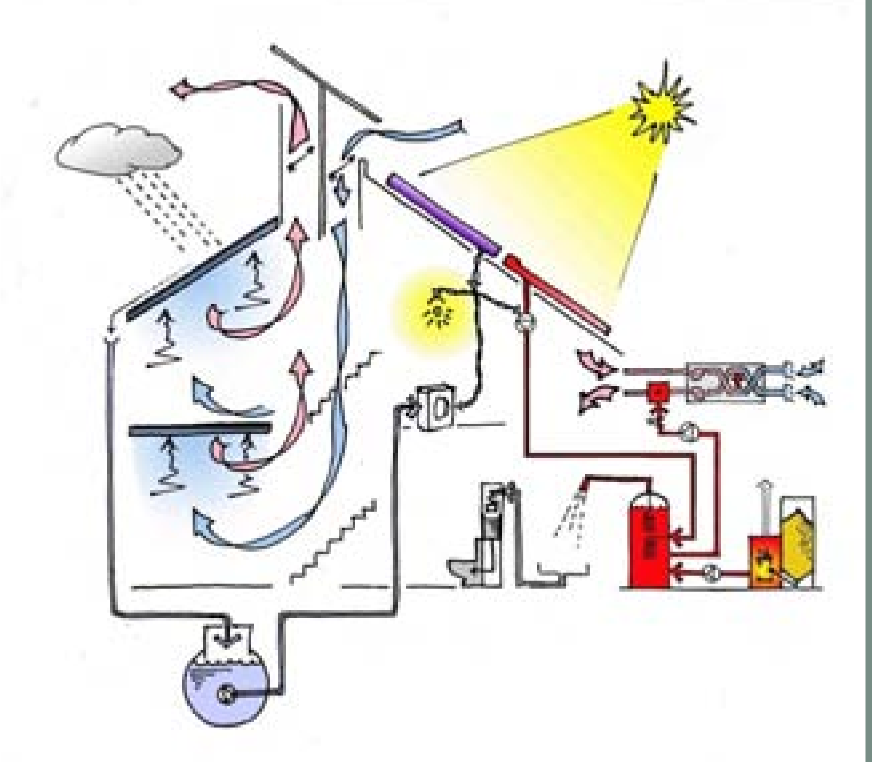
THE KINGSPAN ‘LIGHTHOUSE’

Client: Kingspan Group Plc

Architect: Sheppard Robson

Completed: 2007

The Kingspan Lighthouse, the first house to be awarded **Level 6 of the Code for Sustainable Homes.**
The Kingspan Lighthouse produces all its own energy from renewable sources, on a net annual basis.



- Natural Ventilation
- Biomass pellet boiler
- 4m^2 solar thermal panels
- 40m^2 photovoltaic panels
- Rainwater Harvesting
- Upside-down living
- Phase change materials to reduce overheating risk

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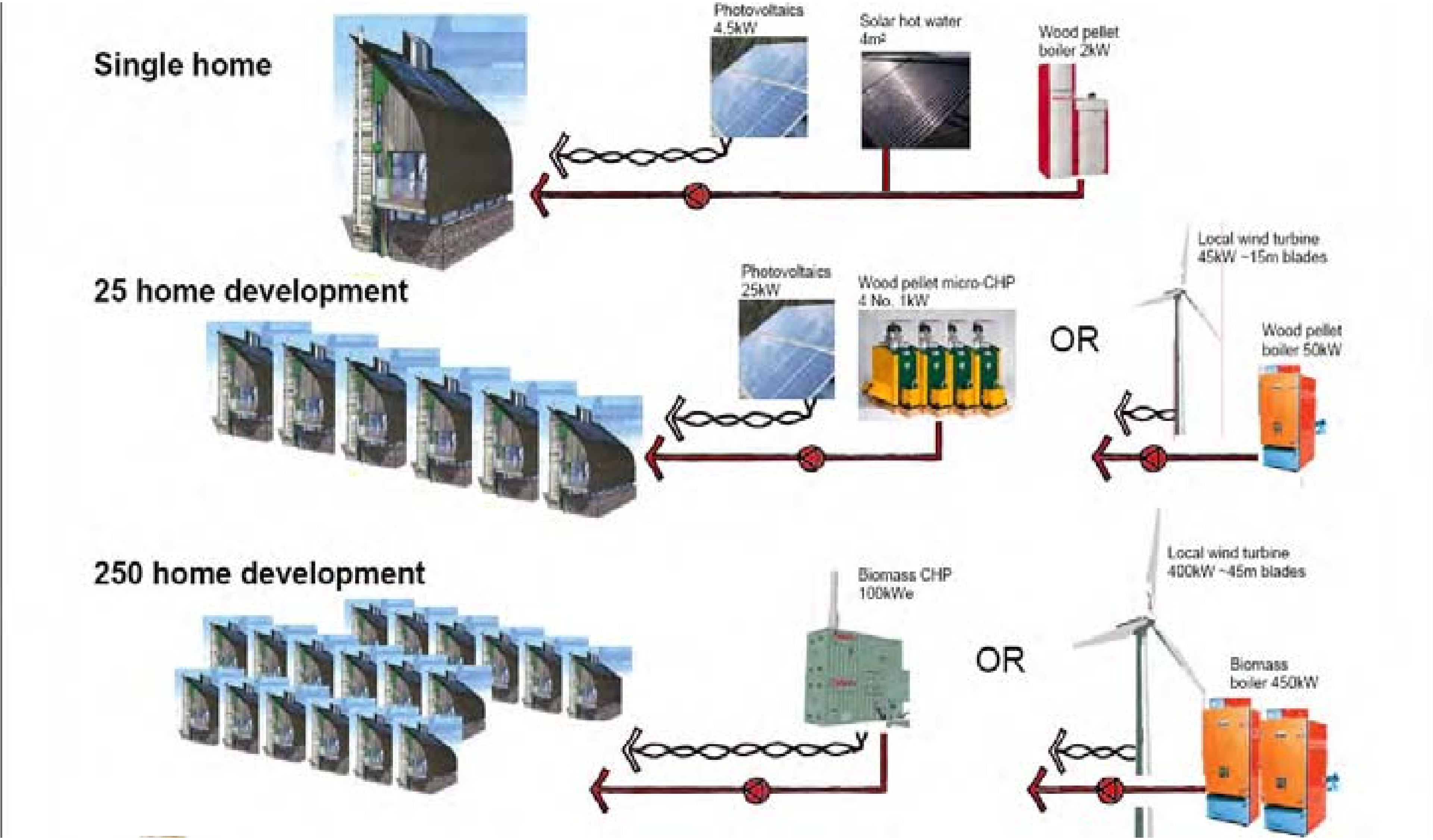
Energy Supply Options



Case Study VIII: Residential Block

K2 APARTMENTS

Architect: Designinc Ltd

Completed: February 2007

K2 is the first medium-density, multi-level sustainable public housing project in Victoria.

The 96 unit social housing block, is a model of energy conservation and sustainable building design.

Key objectives of the building design were to minimise greenhouse gas emissions. make use of reusable and recycled construction materials and minimise habitat degradation through efficient water use and pollution control.

- 20kW Photovoltaics
- Cross natural ventilation
- Exposed thermal mass
- Rainwater re-use for potable water !?
- Greywater reuse for toilet flushing
- Recycled materials, using fly ash for cement
- Use recycled steel

Case Study VII: Zero Carbon House

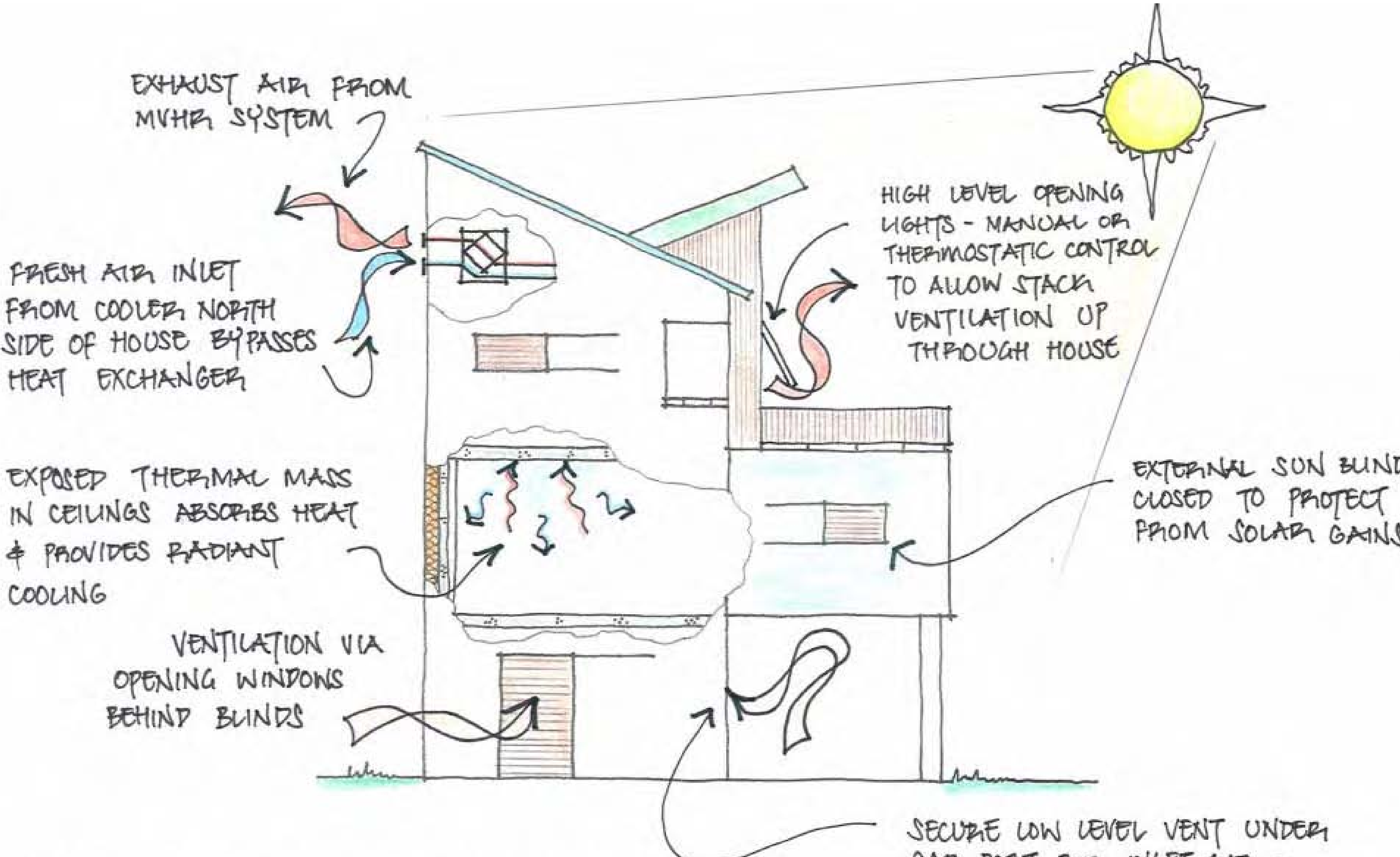
THE GREENHOUSE, BARRATT

Architect: Gaunt Francis Associates

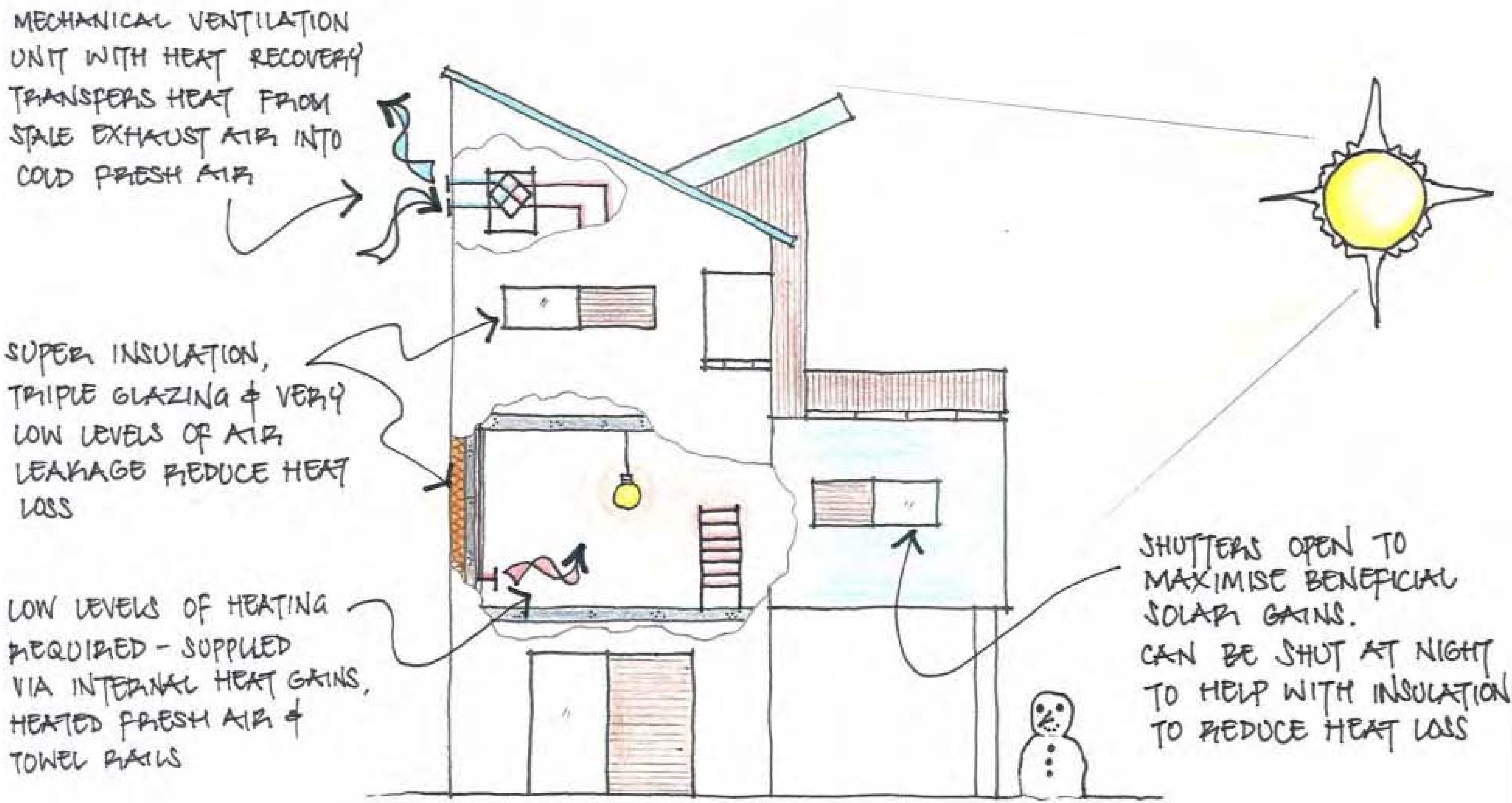
- 100% renewable energy sources to achieve zero net carbon emissions in use.
- Incorporates a renewable energy supply.
- Total water strategy using greywater recovery.
- First CfSH Level 6 zero carbon home by a volume house builder.
- Mail on Sunday's 'Home of the future'.
- Aerated concrete panels for walls, wrapped with insulation and specialist render.
- Motorised solar blinds and automated secure passive ventilation - achieving excellent daylight levels.
- Solar thermal and air source heat pump, with a whole house mechanical ventilation system with heat recovery.

The Barratt Green House

- High insulation and air tightness levels
- Greywater recovery
- Low water appliances and rainwater recovery



BUILDING PHYSICS - SUMMER DAY



BUILDING PHYSICS - WINTER

Thank you for listening!

Questions?

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vasilis.maroulas@arup.com

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"A design team which produces a total, balanced, efficient design can help to produce a better environment"

Sir Ove Arup