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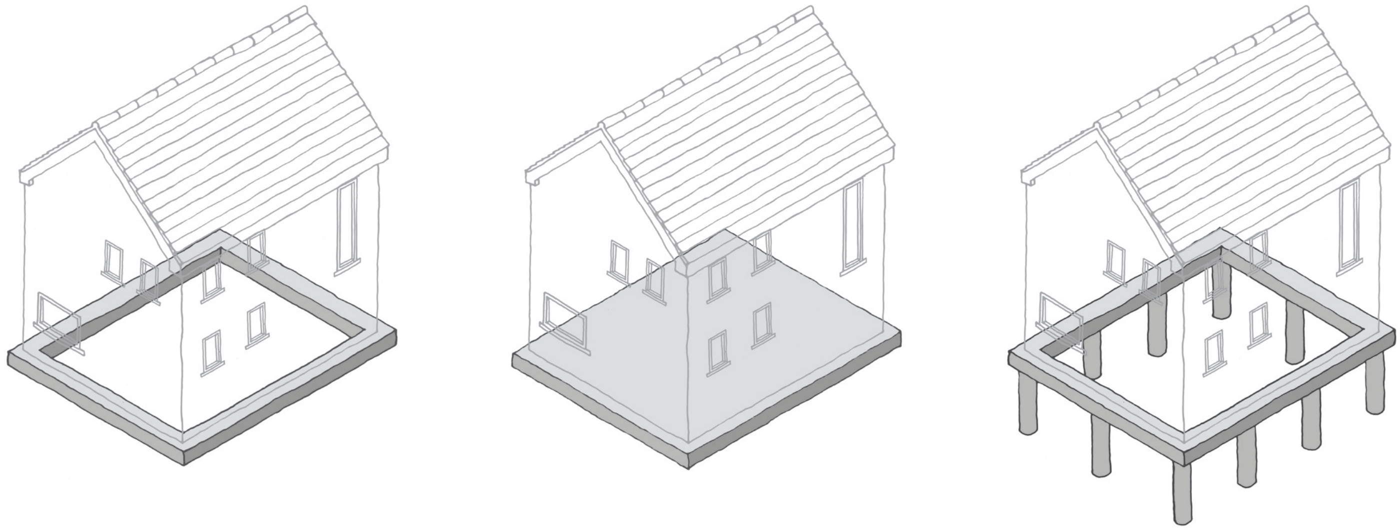
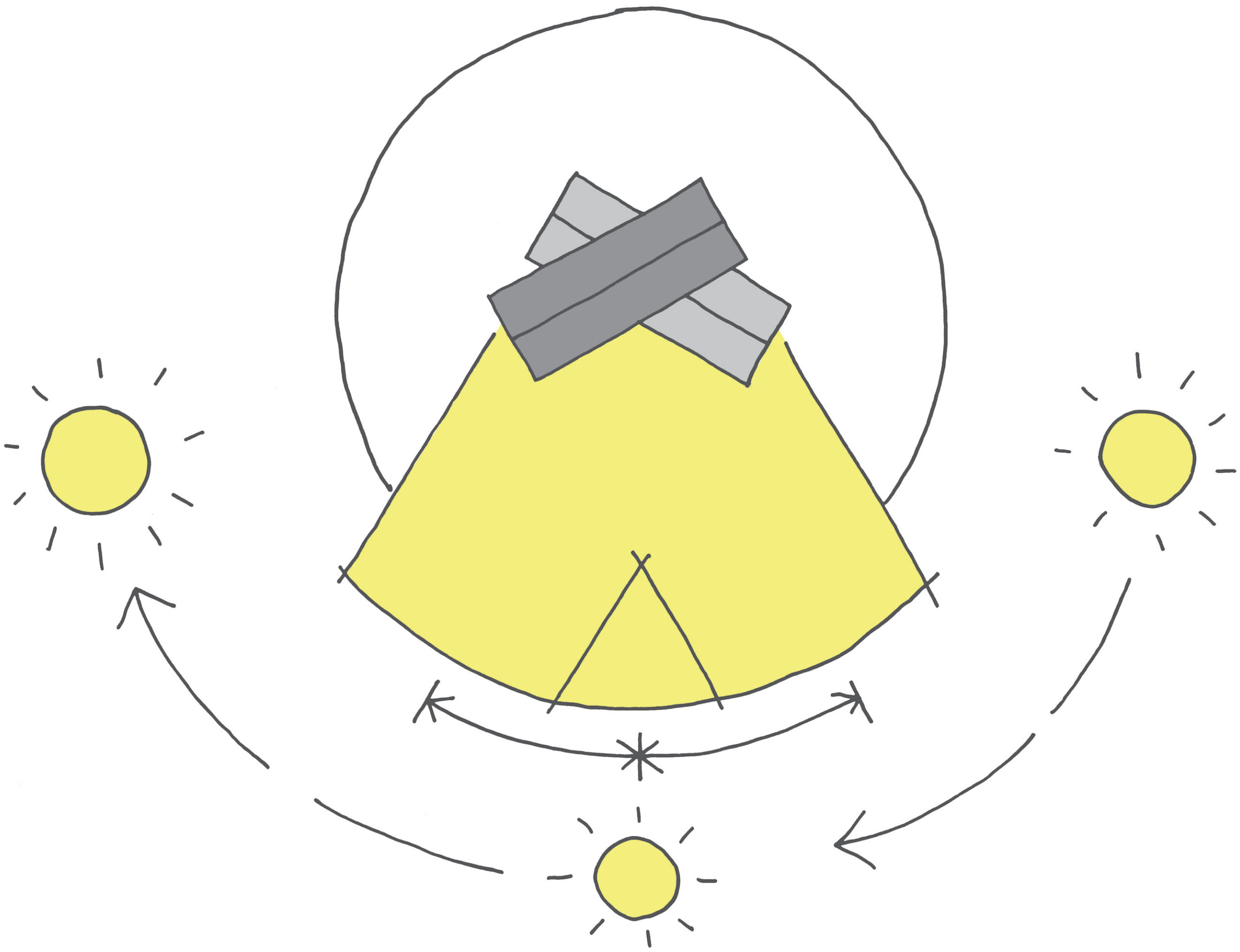


CHAPTER 21

Passive Design



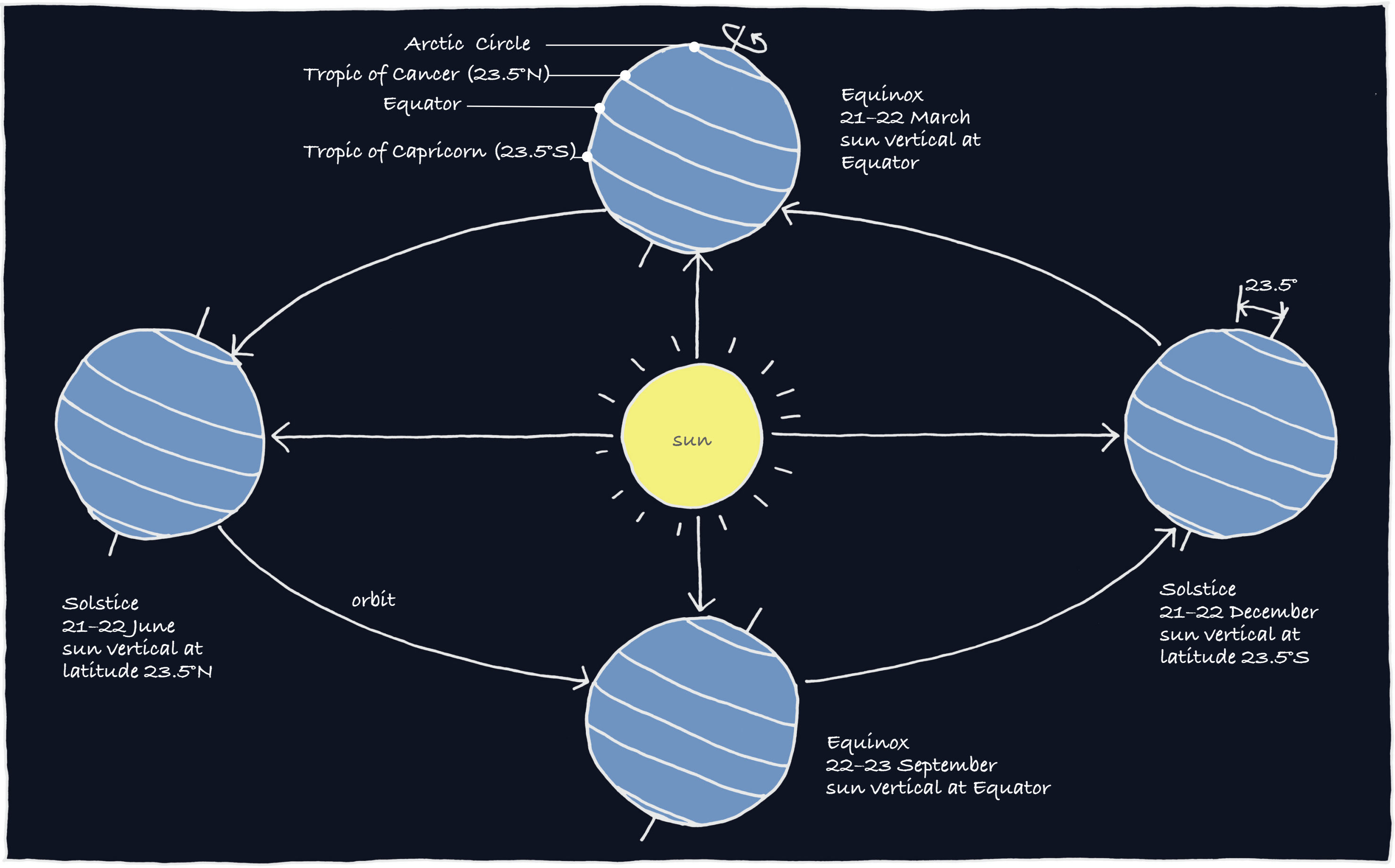
The design of low-energy housing is based on the concept of solar gain – capturing radiant energy from the sun to provide space heating, water heating and lighting.

Solar principles

When designing homes that capture the sun's energy, it is essential to understand the movement of the sun in the sky and how this changes with the seasons.

Earth's orbit

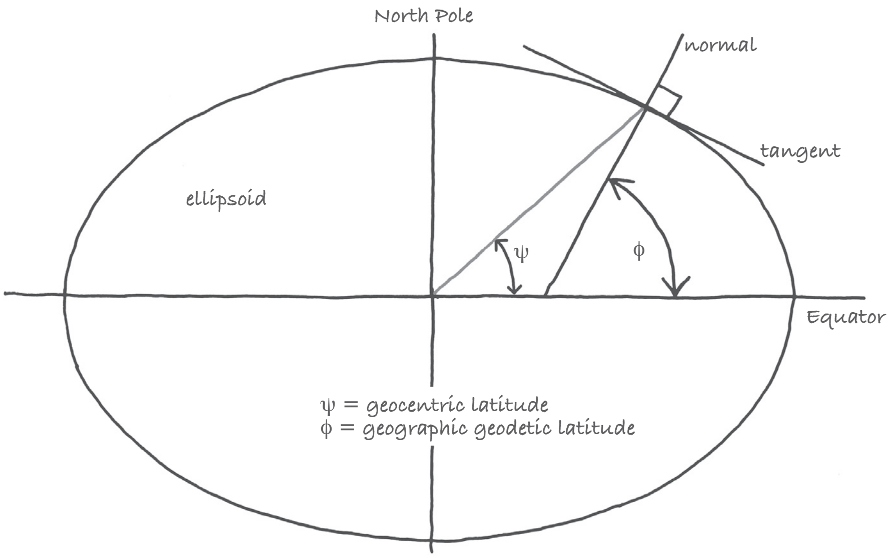
A year is the time taken for the earth to complete one orbit of the sun. The axis of the earth is tilted by 23.5° with respect to the plane that passes through the sun and the Equator. This tilt causes the change in radiation, length of day, and climate between summer and winter. If there were no tilt, there would be uniform climatic conditions throughout the year (i.e. no seasons). The intensity of radiation from the sun also varies with the season of the year. The angle at which radiation from the sun falls on a surface changes as the relative tilt and orbit of the earth around the sun changes.



21.01 The earth's orbit: the earth rotates about the sun once per year; it rotates on its axis (towards the east, or anti-clockwise) once every 24 hours; the axis is tilted at an angle of 23.5°. Seasons depend on position in orbit.

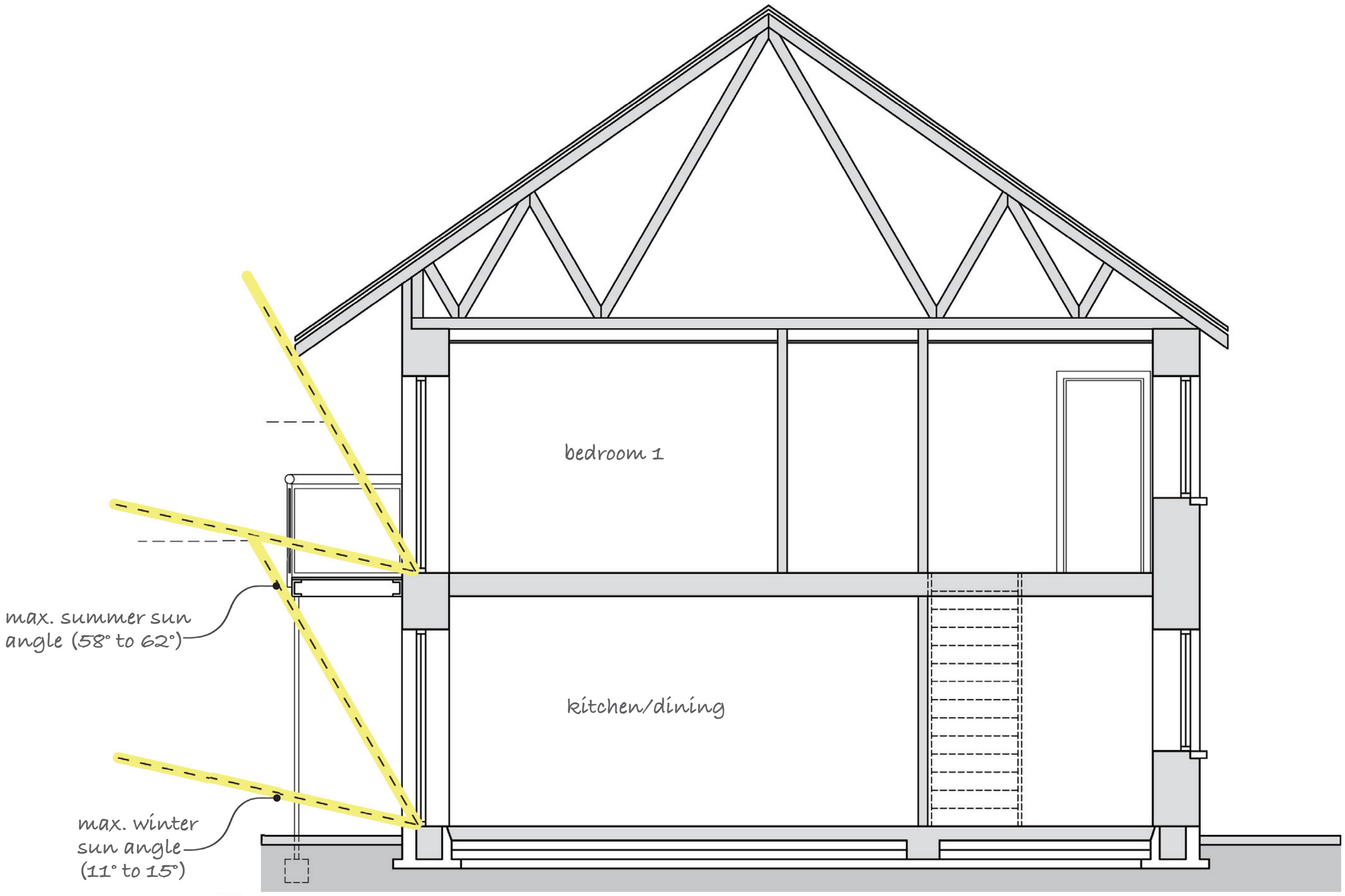
Latitude

Geographical latitude ϕ is a measure of the position of a point on the earth's surface above (north of) or below (south of) the Equator.

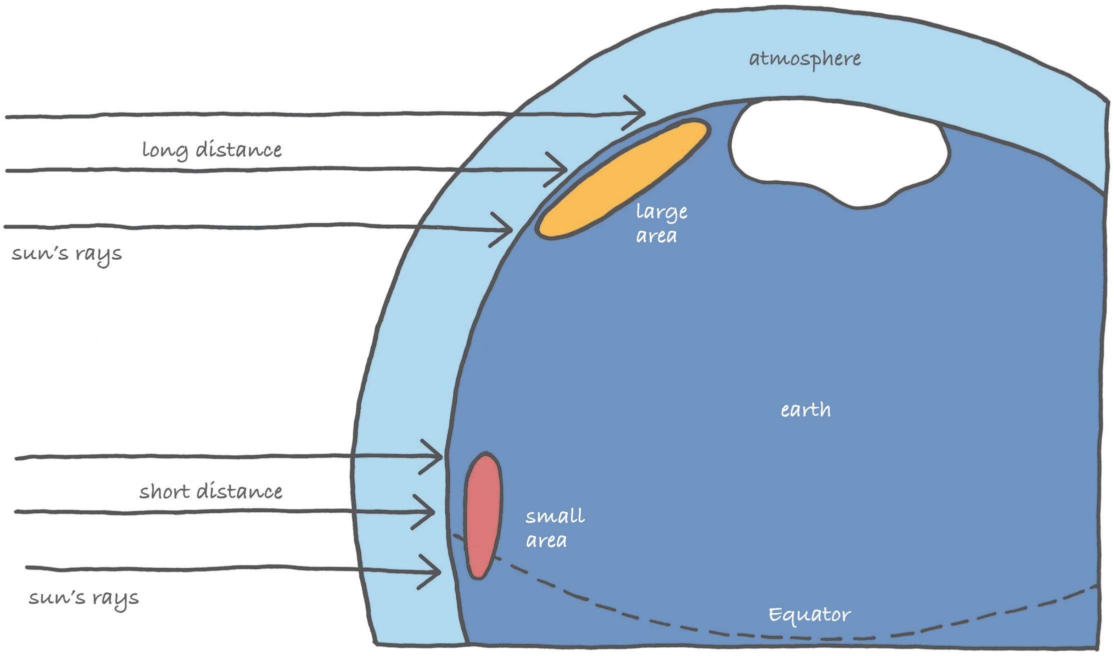


21.02 Latitude: the earth is an ellipsoid (flattened at the poles).

The radiation from the sun is at its most intense when it falls on the earth's surface at an angle of 90° to the surface – this happens at the Equator. The intensity of solar radiation decreases as latitude increases and the angle at which the solar radiation strikes the earth's surface decreases. This angle, called the altitude or sun angle, varies throughout the year. Ireland's position in the northern hemisphere means that the maximum sun angle ranges from approximately 11° to 15° in winter and from 58° to 62° in summer (depending on location).



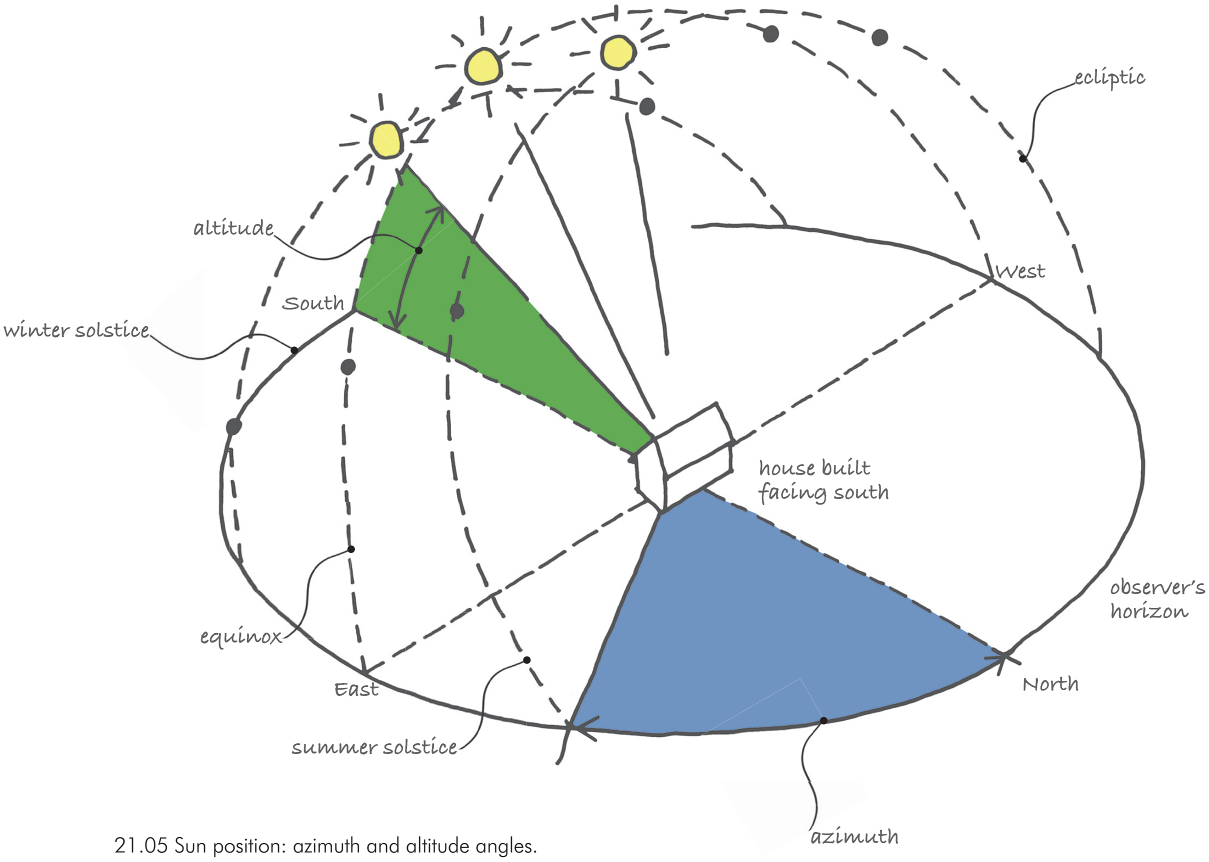
21.03 Maximum sun angle in Ireland varies from winter to summer.



21.04 Latitude: at higher latitudes the sun's energy is spread over a larger area, and is therefore weaker than if the sun is higher overhead and the energy is concentrated on a smaller area.

Sun position

The position of the sun relative to the earth doesn't change. It is because of the earth's orbit around the sun that the sun appears to move in the sky. The ecliptic is the apparent path of the sun in the sky. The position of the sun in the sky is described by two angles: azimuth and altitude.



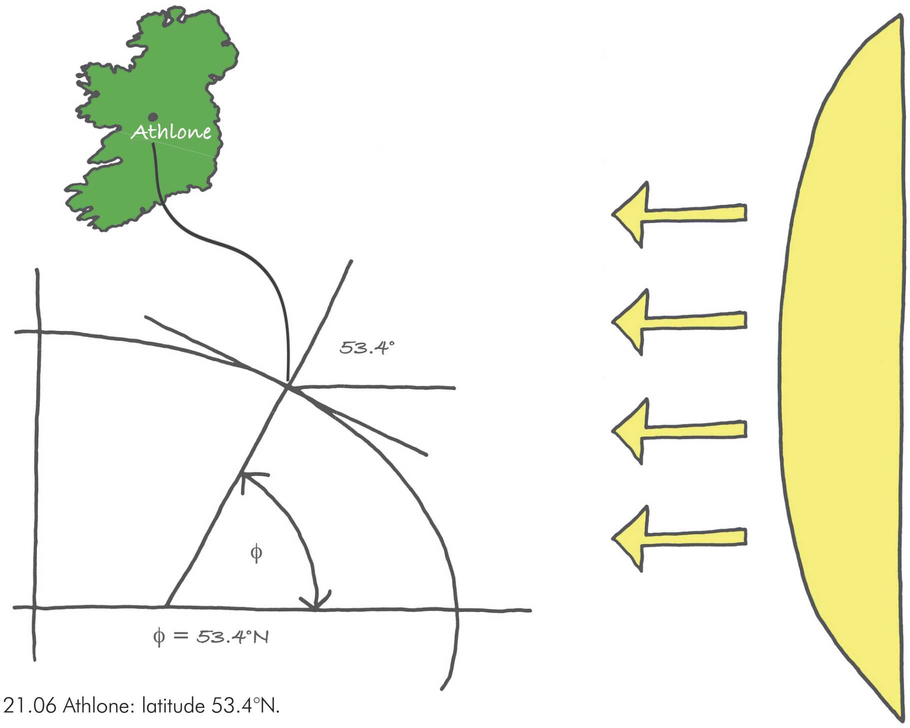
21.05 Sun position: azimuth and altitude angles.

Sun angle

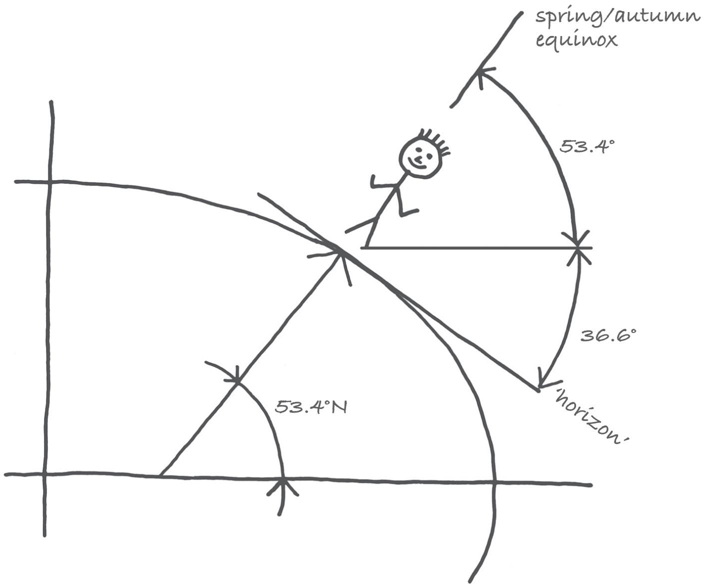
The amount and quality of solar energy we receive in Ireland is influenced by our position on the planet. Ireland's position in the northern hemisphere means that the sun is to the south (over the Equator) – therefore, the south-facing side (façade) of a building receives the most solar energy.

This fact is very important when designing buildings that are going to be primarily heated by the sun's energy (i.e. passive homes). For example, it is important to know the sun angle so that features, such as shading devices, can be included in the design to prevent overheating during the summer. The sun angle is also crucial to the positioning of solar panels to ensure maximum energy gain.

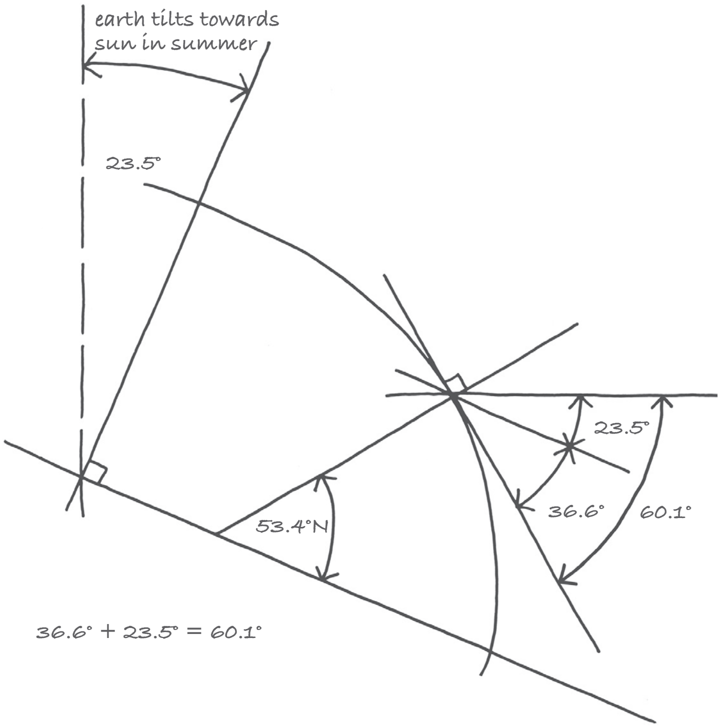
The sun angle varies because the earth is tilted on its axis. In the summer the earth is leaning towards the sun; in winter it leans away from the sun.



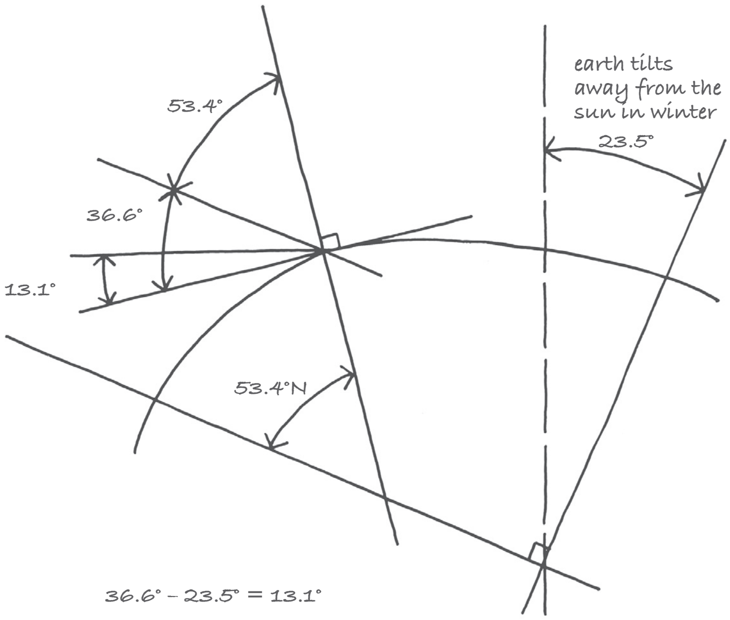
21.06 Athlone: latitude 53.4°N.



21.07 Athlone: maximum sun angle, spring/autumn equinox = 36.6°N.



21.08 Athlone: maximum sun angle, summer solstice = 60.1°N.



21.09 Athlone: maximum sun angle, winter equinox = 13.1°N.

Once the latitude of a site is known (which can be easily found online or by using Google Earth), the maximum sun angle can be calculated using these formulae:

season	maximum sun angle
spring/autumn equinox	90° – latitude = maximum sun angle
summer solstice	90° – latitude + 23.5° = maximum sun angle
winter solstice	90° – latitude – 23.5° = minimum sun angle

21.10 Maximum sun angle formulae

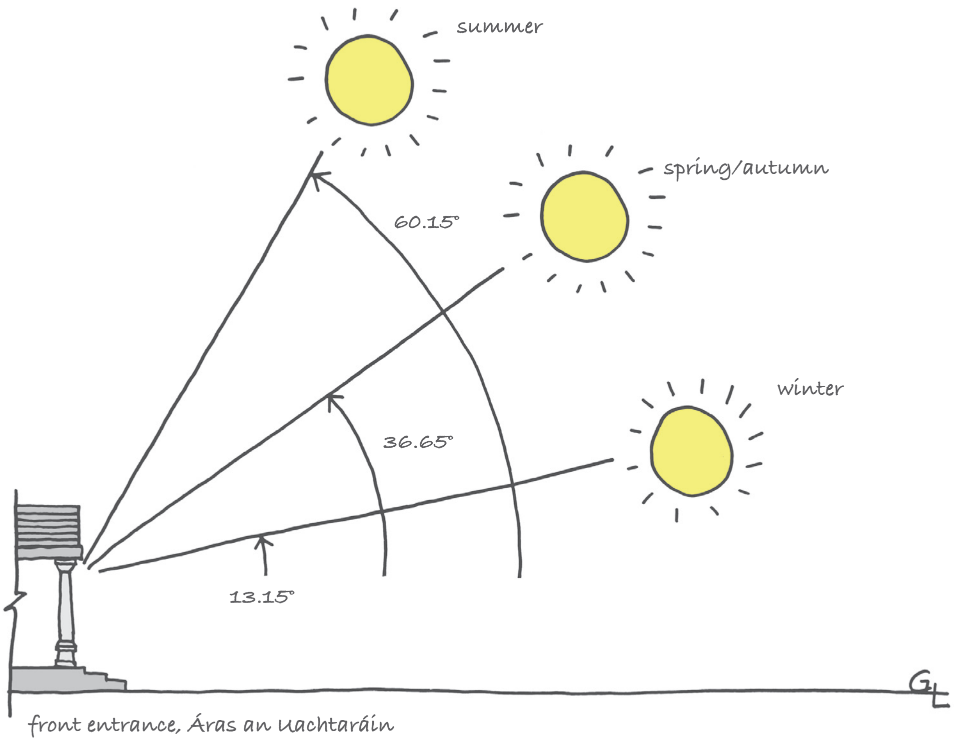
ACTIVITIES

Look up the latitude of your home using the Google Earth app. Calculate the maximum sun angle in summer, winter and at the equinoxes.

Worked example
Áras an Uachtaráin in the Phoenix Park, Dublin has a latitude of 53.35 degrees.

season	maximum sun angle
spring/autumn equinox	90° – 53.35° = 36.65°
summer solstice	90° – 53.35° + 23.5° = 60.15°
winter solstice	90° – 53.35° – 23.5° = 13.15°

21.11 Maximum sun angle example.

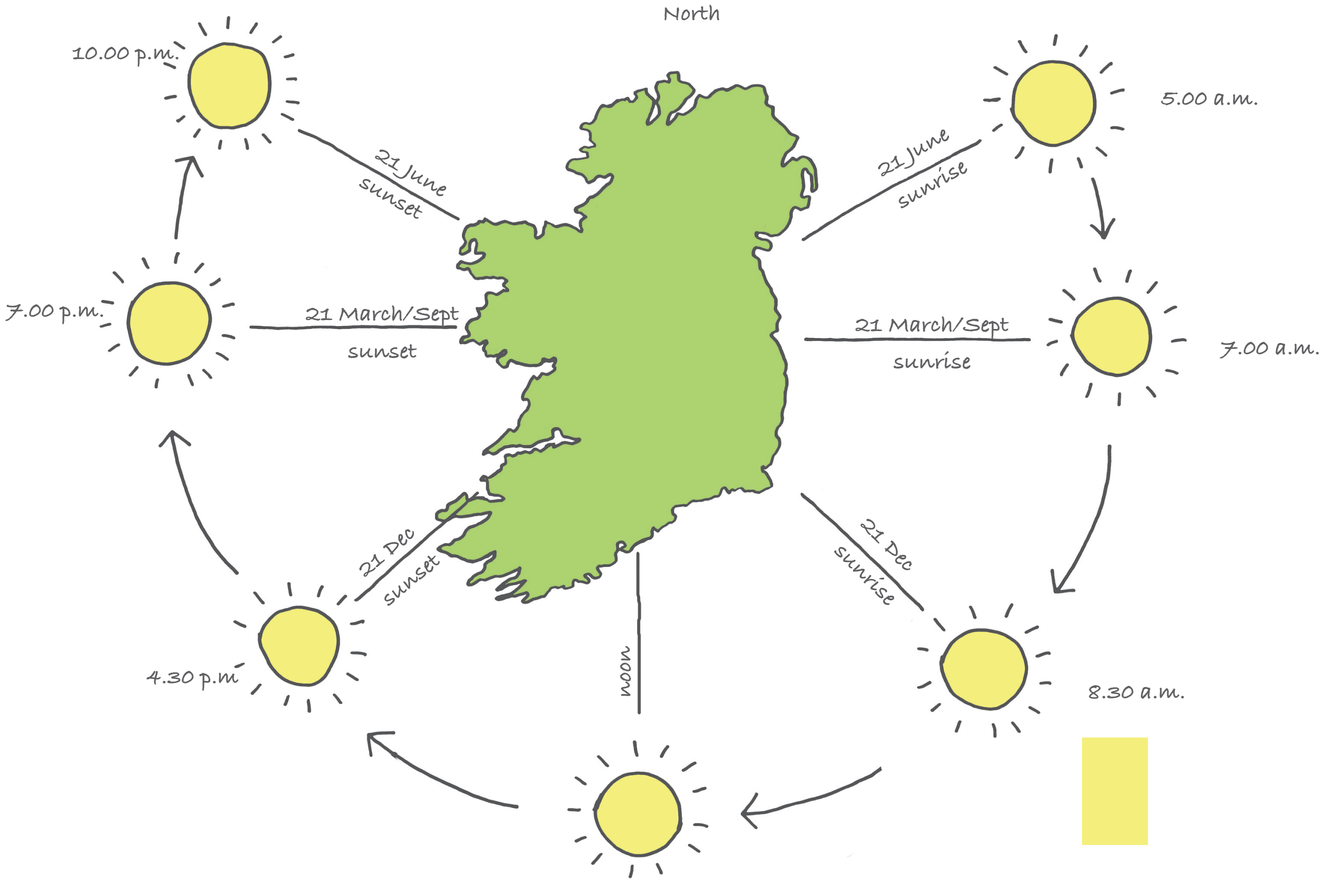


21.12 Maximum sun angle at Áras an Uachtaráin for each season.

	latitude	summer	spring/autumn	winter
Malin Head	55.39	58.11	34.61	11.11
Donegal	54.65	58.85	35.35	11.85
Athlone	53.42	60.08	36.58	13.08
Dublin	53.35	60.15	36.65	13.15
Galway	53.27	60.23	36.73	13.23
Limerick	52.66	60.84	37.34	13.84
Waterford	52.26	61.24	37.74	14.24
Cork	51.90	61.60	38.10	14.60
Mizen Head	51.45	62.05	38.55	15.05

21.13 Maximum sun angles at various locations throughout the year. Athlone, being in the middle of Ireland, has the average values.

Sun path



21.14 Simplified sunpath diagram showing approximate time and azimuth angle of sunrise and sunset in Ireland.

The position of the sun can be plotted using a sunpath diagram. This diagram provides an accurate picture of the sun's position when viewed from a particular point on earth at various times of the year.

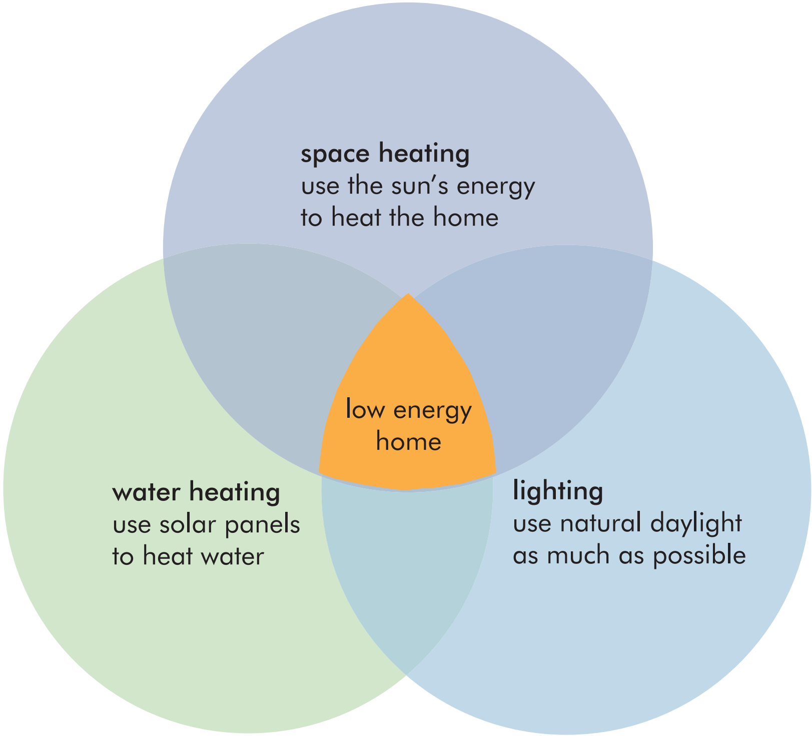
KEY PRINCIPLES

Simple facts about the sun's movement:

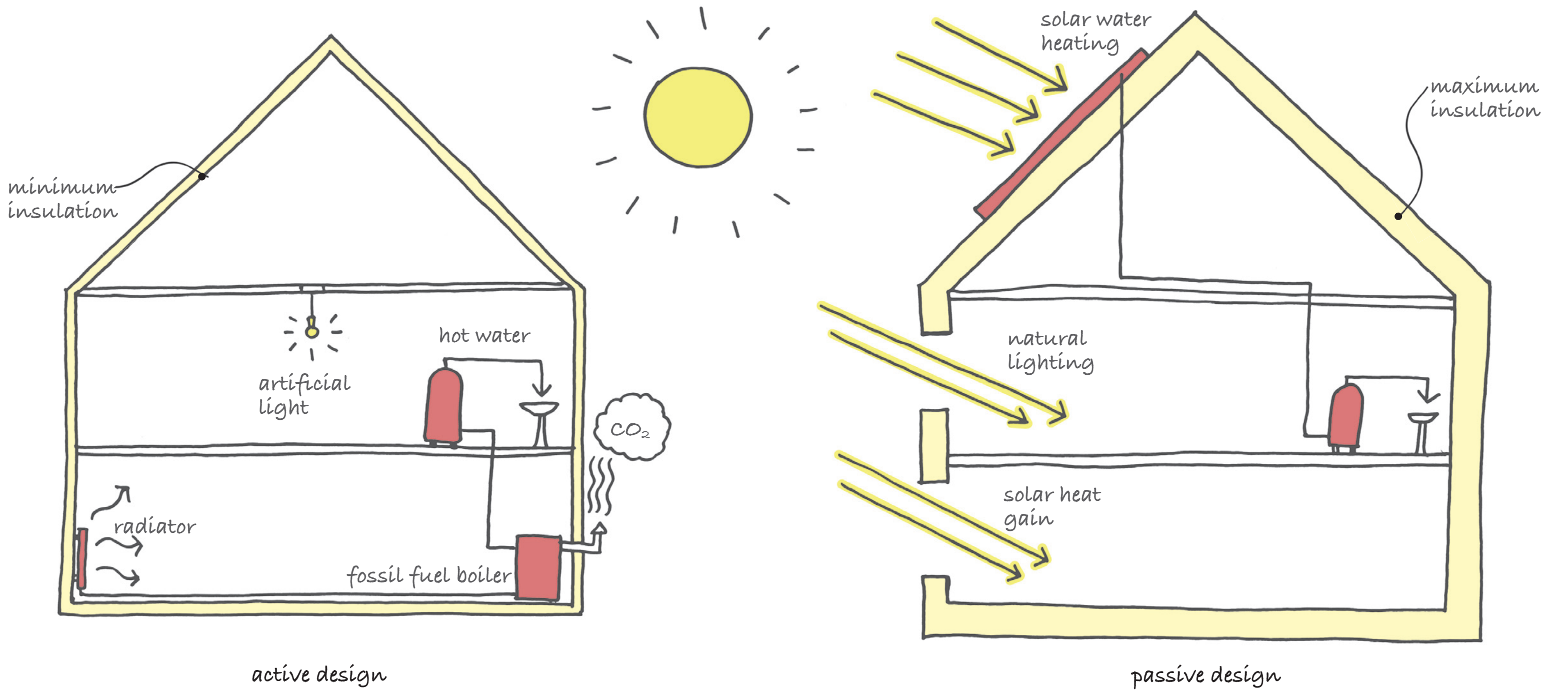
- the sun rises (morning) in the east and sets (evening) in the west
- the sun is approximately due south at noon
- the sun is higher in the sky in summer than in winter
- summer days are long; winter days are short.

Passive design

Passive design is a general term used to describe a way of designing buildings that uses sunlight to provide heat and light. Unlike active design, which relies on burning fuels to produce energy to provide space heating, water heating and lighting, passive design uses energy from the sun to do this. Almost every home built in Ireland over the last century was based on active design. These homes waste a lot of energy in providing a comfortable indoor environment. Creating sustainable homes means shifting from an active to a passive approach.



21.15 Passive design: low energy homes use solar gain to provide space heating, water heating and lighting.



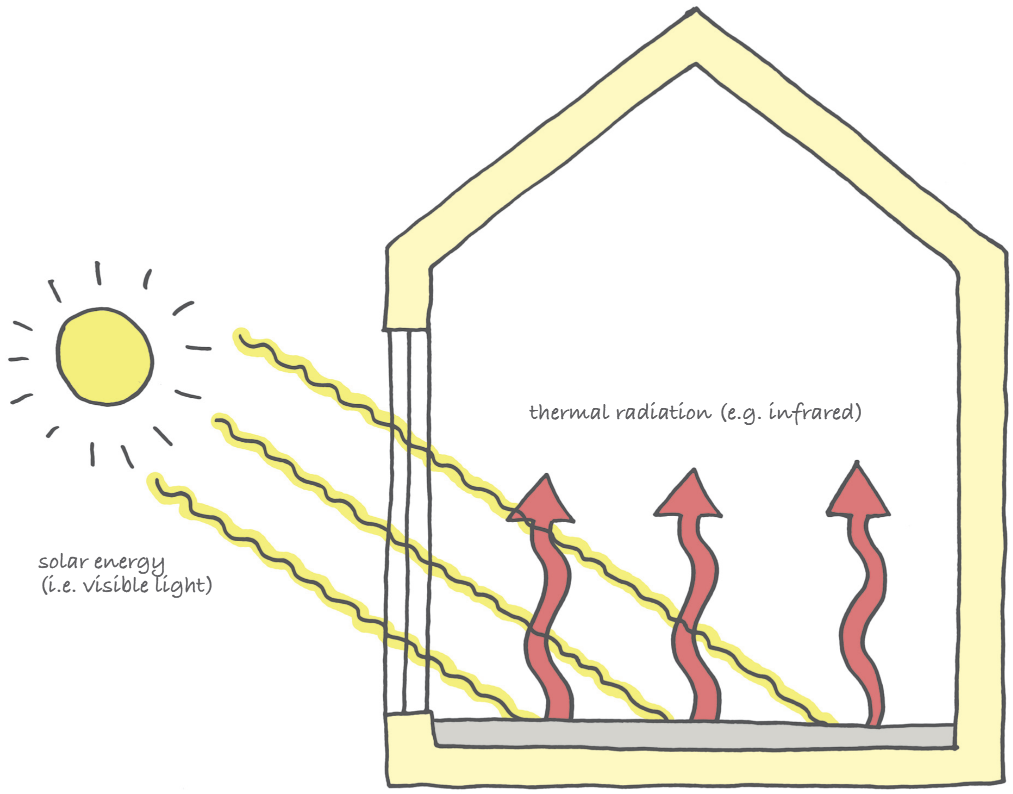
21.16 Active design (high energy consumption and high CO_2 emissions) versus passive design (low energy consumption and low CO_2 emissions).

Solar gain

Solar gain (also called solar heat gain) is a term used to describe the increase in temperature in a space or material that results from solar radiation.

The amount of solar gain increases with the strength of the sun, and with the ability of the material to absorb the radiation. Dark-coloured, rough-textured objects absorb solar radiant energy more readily than light-coloured, shiny objects. When an object is struck by sunlight it absorbs the solar energy (i.e. visible light plus a small amount of ultraviolet light) from the sunlight and later radiates this energy as infrared radiation.

When this happens in a building with low-e glazing the glass traps the energy (i.e. infrared radiation) inside. This is essentially the greenhouse effect. The application of low-emissivity coatings to the glazing makes the glass transparent to the visible light but not to the infrared radiation.

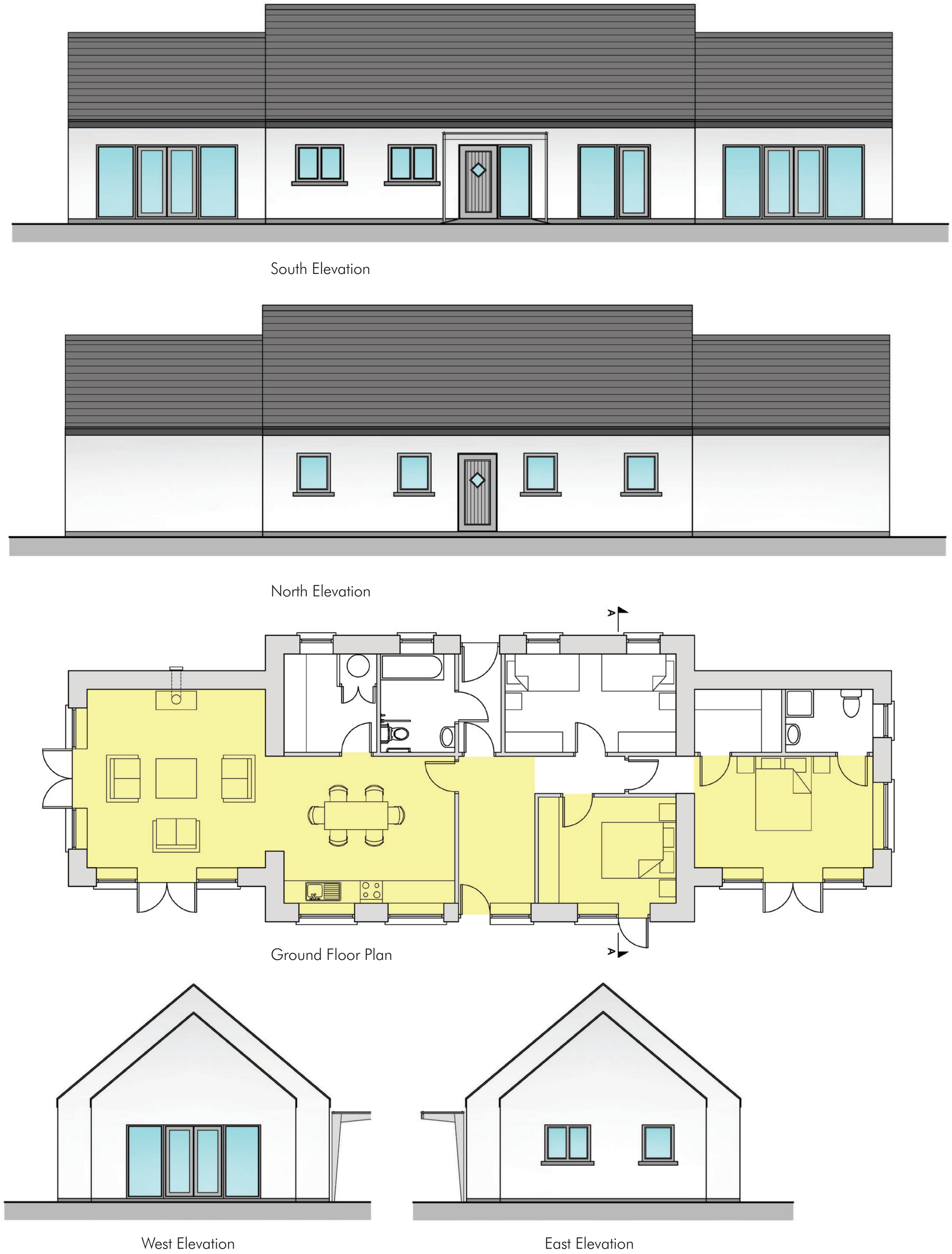


21.17 Solar gain: radiant energy from the sun warms the indoor spaces.

KEY PRINCIPLES

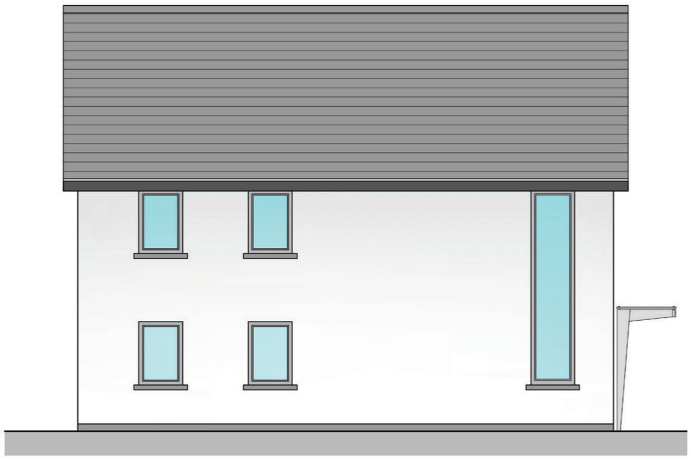
Homes designed to optimise solar gain have three features:

- a façade that faces south
- lots of glazing in the south-facing façade
- an interior layout that positions the main living spaces on the south side of the building.

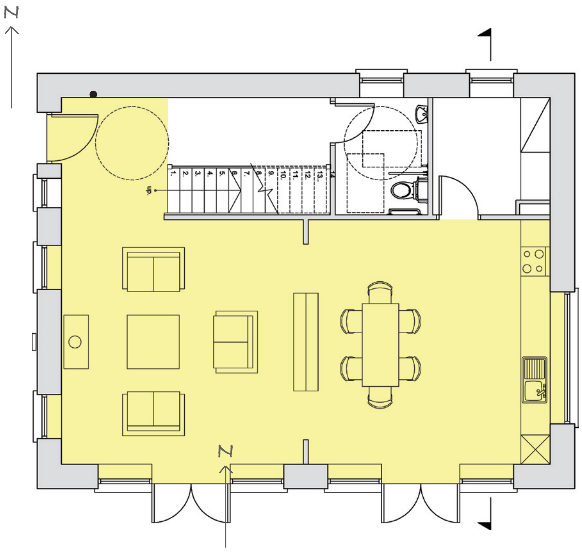


21.18 Single-storey house: orientation, glazing and interior layout combine to optimise solar gain.

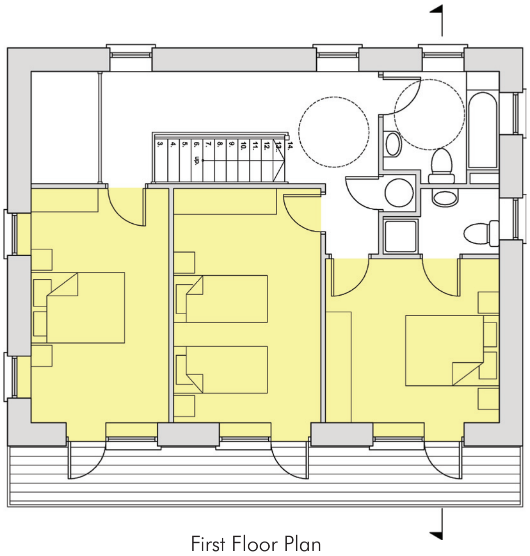
South Elevation



North Elevation



Ground Floor Plan



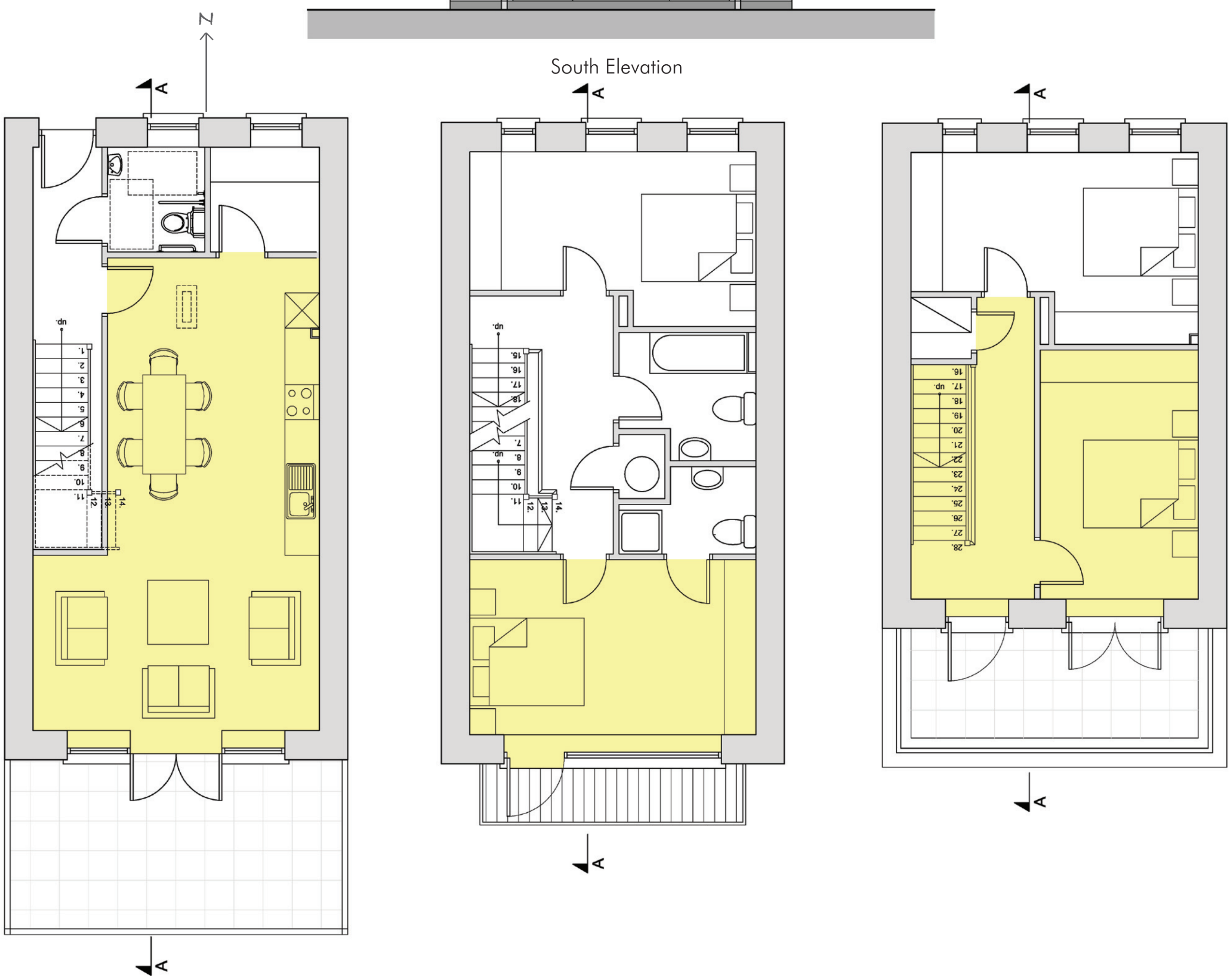
First Floor Plan

West Elevation

East Elevation

21.19 Two-storey house: orientation, glazing and interior layout combine to optimise solar gain.

South Elevation



Ground Floor Plan First Floor Plan Second Floor Plan

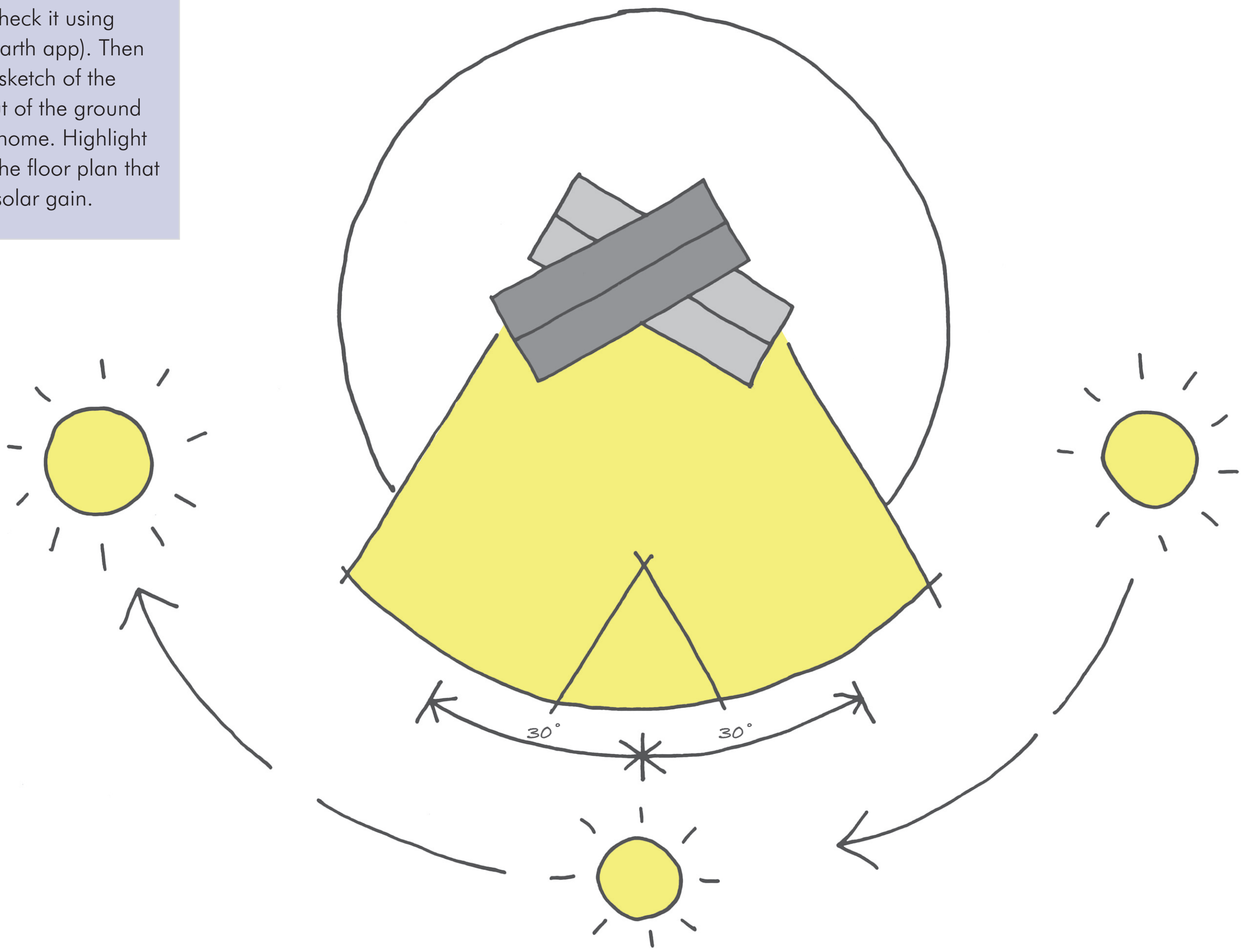
21.20 Three-storey house: orientation, glazing and interior layout combine to optimise solar gain.

Orientation

A passive house should be oriented within 30° of south. This orientation will maximise solar gain as the sun tracks across the sky. This is especially important during the cold winter months when the sun angle is low and the daylight hours are reduced.

ACTIVITIES

Sketch the orientation of your home (check it using the Google Earth app). Then make a neat sketch of the internal layout of the ground floor of your home. Highlight the areas of the floor plan that benefit from solar gain.

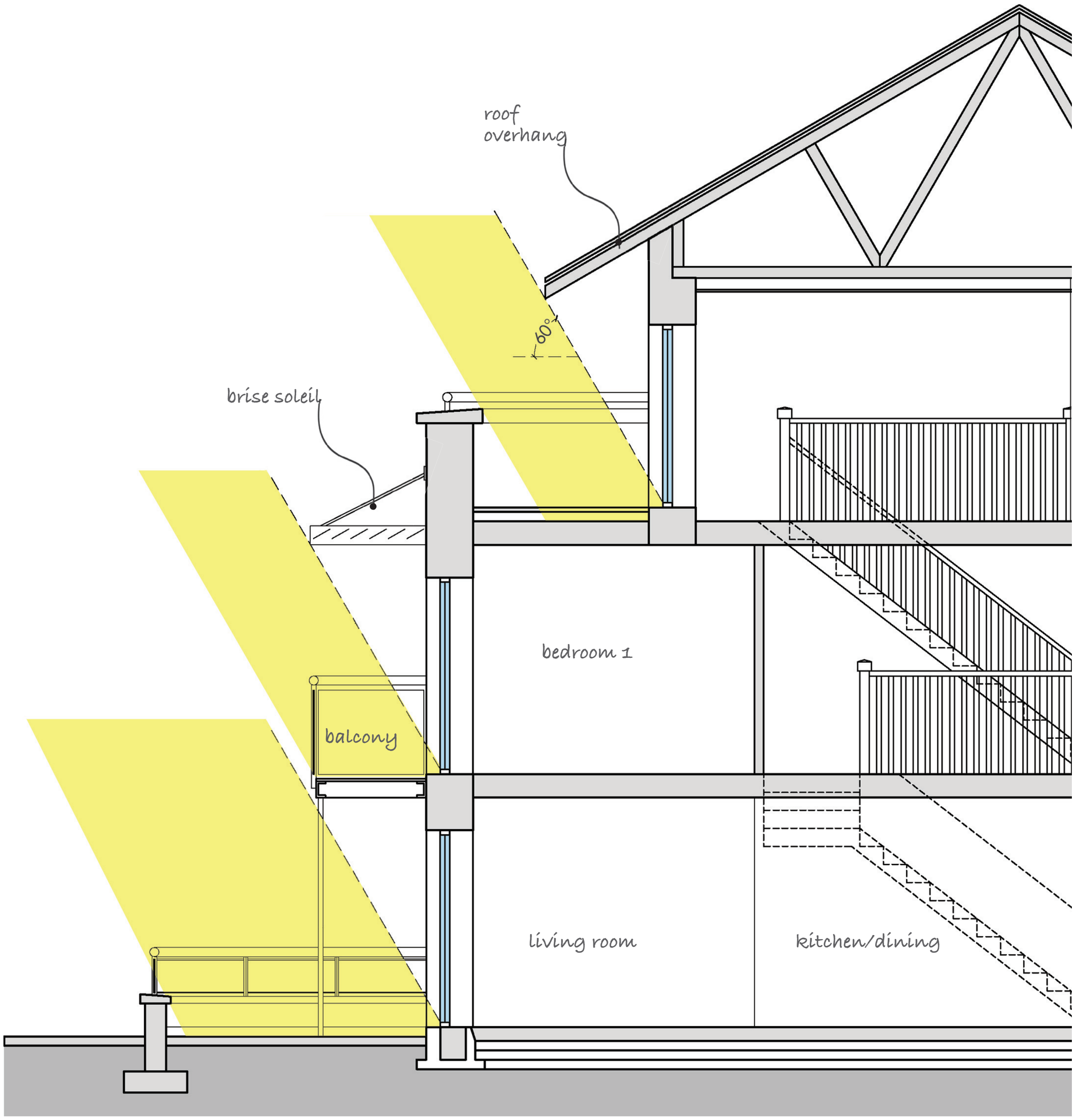


21.21 Orientation: the glazed façade should be oriented to within 30° of south.

Overheating and shading devices

Buildings that are designed to harness solar energy have the potential to overheat in the summer. This issue is addressed at the design stage. For example, if a building is being designed to the Passivhaus standard, a software tool called the Passivhaus Planning Package allows the designer to accurately calculate whether the building will overheat and to design preventative measures.

Shading devices are used to control solar gain through south-facing glazing during the summer. Permanent shading devices (e.g. brise soleils) that do not require adjustment by the occupant are preferable to those that do (e.g. shutters). Automated adjustable shading devices (e.g. blinds) are also used but these can be expensive and require regular maintenance. Planting (e.g. birch trees) can be used to the east and west. However, planting does not work on the south side of a building because the sun angle is too high. High thermal insulation of the building fabric also helps to keep the building cool during summer.

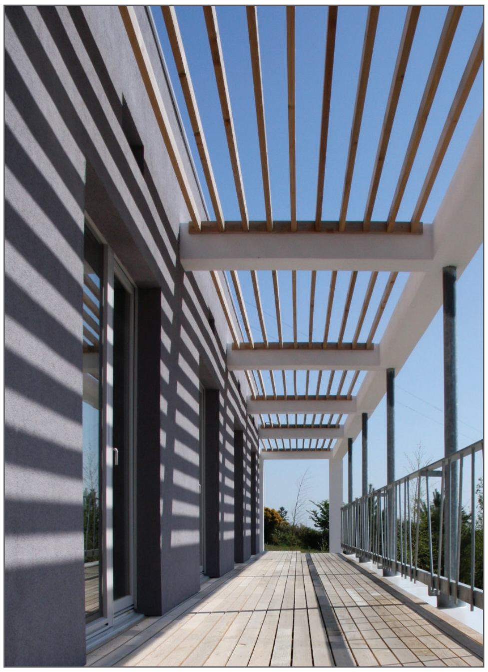


21.22 Shading devices: roof overhangs, brise soleils and balconies are commonly used to prevent overheating. Note: 60° is the average maximum sun angle in Ireland (see Chapter 20).

21.23 Shading devices: notice the shadow cast by the roof overhang on this home by Scandinavian Homes of Co. Galway.

21.24 Shading devices: roof overhangs and balconies are both used in this house, built by Cyril Mannion in Athenry, Co. Galway.

21.25 Shading devices: notice the stiped shadow pattern cast by the brise soleil on the first floor façade on this house in Co. Wicklow.



21.26 Shading devices: the brise soleil significantly reduces solar gain, preventing overheating.

REVISION EXERCISES

1 Describe the influence that a site's latitude has on solar gain.
2 Explain, using neat freehand sketches, how the earth's axis tilt has an effect on sun angle during summer.
3 Calculate the maximum sun angle during summer and winter at your home's location. (Hint: look up your home's latitude using the Google Earth app.)
4 Explain, using neat freehand sketches, the features of a home designed to optimise solar gain.
5 Show, using neat freehand sketches, how you would redesign the ground floor of your home to optimise solar gain. (Note: show before and after floor plans and indicate the direction of North.)