Teacher's Notes – Energy Budget

Slide 1

The Earth receives almost all its energy from the Sun.
The amount of energy we receive from the Sun depends on

- how much energy the Sun emits - which varies on an 11 year cycle with the amount of sun-spot activity. The 'little ice age' in the Middle Ages was probably due to a reduced amount of sun-spot activity. People had 'frost fairs' on the frozen Thames.
- The distance between the Earth and the Sun. This varies with the time of year (the Earth is closer to the Sun in January than it is in June) because the Earth's orbit is not quite circular, and over longer timescales as the Earth's orbit around the Sun changes shape.
- The relative sizes of the Earth and Sun. These don't change much over time!

Slide 2

- The amount of radiation scattered by the atmosphere depends mainly on how much cloud there is. If you think of an image of the Earth from space, it looks green, blue and white. The white colour of the clouds implies that a lot of the Sun's radiation is being reflected back out to space.

Slide 3

- The amount of energy absorbed by the atmosphere depends on the composition of the atmosphere. Some incoming solar radiation is absorbed by ozone and oxygen molecules (ultraviolet) and water and carbon dioxide (infrared). Particles in the atmosphere, such as soot or volcanic dust, can also affect this.

Slide 4

- The amount of radiation reflected by the Earth's surface similarly depends on what type of surface there is – ice and snow reflects almost all the visible solar radiation, so it appears white, water and vegetation reflect the blue and green parts of the spectrum respectively, and absorb the other colours (the reds, yellows, purples).
- The remaining energy is absorbed by the surface and heats the surface of the Earth – the top 10s of cm of soil/ rock and the top 10s of metres of the oceans.

Slide 5

The amount of energy radiated by the surface of the Earth depends only on the temperature of the surface of the Earth. The type of radiation is also determined by the temperature – at the temperature of the Earth, most of the energy it loses is in the form of infrared radiation. The quantity of radiation lost is proportional to $T4$, where T is the Earth's temperature in kelvins (K).

Slide 6

Most of this outgoing radiation is absorbed by gases in the atmosphere – mainly water vapour and carbon dioxide.

Slide 7

The atmosphere re-radiates as much as it absorbs but, because of the structure of the atmosphere (denser close to the surface than higher up) we end up with more being radiated back down than is radiated up and out.
The radiation that is re-radiated downwards is re-absorbed by the Earth's surface.
This is the Greenhouse Effect. If we didn't have any atmosphere, the Planet would be 33°C cooler!
NB: Greenhouses are actually kept warm because the glass also stops convection, so this is a slightly inappropriate comparison.

Slide 8

We also include two other small losses of heat from the Earth's surface :

- due to thermal convection (the surface of the Earth heats up the layer of air closest to it, by conduction, which then rises and carries the heat high into the atmosphere)
- due to latent heat release – water on the surface of the Earth heats up and some evaporates. It gets carried by the wind to somewhere in the atmosphere which is cooler and condenses, releasing energy back into the atmosphere.

Slide 9

What is the net energy at the top of the atmosphere?
342 – 107 – 235 = 0
The Earth (planet and atmosphere) receives as much energy from the Sun as it loses to space

What is the net energy of the centre of the atmosphere?
67 + 78 + 24 + 350 – 324 – 165 - 30 = 0
The atmosphere receives as much energy from the Sun as it loses to Space

What is the net energy of the surface of the Earth?
168 + 324 – 78 - 24 – 390 = 0
The surface of the Earth receives as much energy from the Sun as it loses to space

All the elements of the Earth/atmosphere system lose as much energy as they gain. Therefore, their temperature stays the same.

How can very small changes to, for example, the infrared surface radiation absorbed by the atmosphere, change this balance?
Even a very small change to this balance – for example if the atmosphere absorbs 1% more and therefore reradiates 1% more back to the surface - can result in big changes in temperature over time.