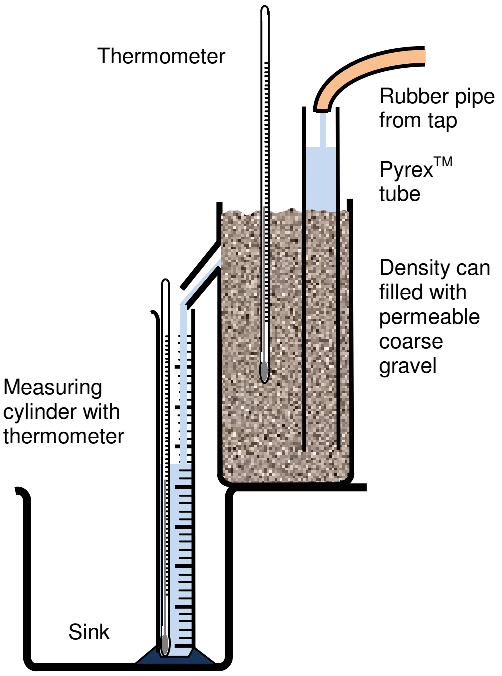
Rock power: geothermal power simulations
Modelling geothermal power sources – renewable or not?

Add water to a heated gravel-filled density can, to model three types of geothermal power source, like this:

Fill the density can with coarse permeable gravel, carefully insert a vertical Pyrex^{TM} tube until it nearly reaches the bottom, as shown in the diagram. Then heat the apparatus up in an oven or on a hot plate (eg. to 100°C); beware of the safety risk from the hot can. Once hot, add a thermometer or temperature probe to the top of the gravel, and get a container ready with a thermometer to catch overflowing water and measure its temperature.



Then use this set-up to model these forms of **geothermal power source**:

- **'Hot dry rocks'.** Model this by adding water steadily to the Pyrex^{TM} tube and catching the overflow, whilst monitoring the temperature of the gravel and overflow water. 'Hot dry rocks' are rocks like granite that have become warm over millions of years of decay of the radioactive minerals they contain. The heat can be extracted by drilling two boreholes into the granite, ensuring these are connected by cracks, then pumping water around the system.

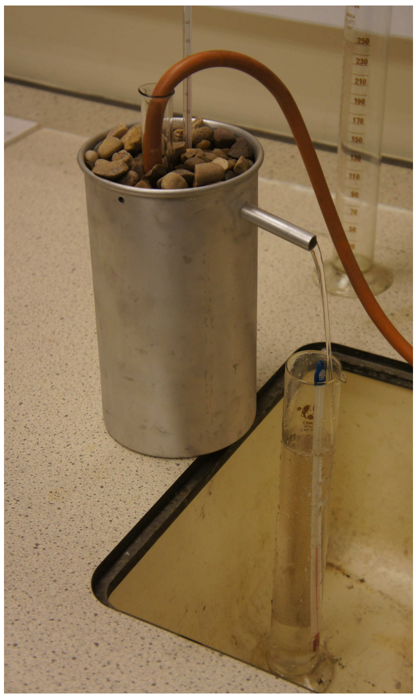
- **'Hot wet rocks'.** Simulate this as described above, but first, fill the hot can with water until it just overflows, then leave it for some time (eg. 5 minutes). This models how water trapped in deep permeable rocks (aquifers) that are insulated by thick sequences of overlying rocks, can accumulate geothermal heat. 'Extract' the heat by adding water to the Pyrex^{TM} tube, as above, monitoring the gravel and overflow water temperatures.

- **'Hydrothermal power'**. To model this, stand the density can on a hot plate and repeat the activity. Hydrothermal power is extracted where there is a source of geothermal heat near the Earth's surface, as found in places like Iceland, Italy, Japan, New Zealand and the Yellowstone area of the USA. 'Extract' the heat from the model by adding water down the Pyrex^{TM} tube, as above.

- Use what you have found from these simulations to discuss which, if any of these geothermal power sources is renewable.

Alternatively, run just one of these models, and use the findings to discuss how the other two might work.

Finally, discuss the proposition, found in many science textbooks, that 'geothermal energy is renewable'.



The geothermal power model 'in action'

Photo: Chris King

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The back up

Title: Rock power: geothermal power simulation

Subtitle: Modelling geothermal power sources – renewable or not?

Topic: Using a density can filled with gravel to model different forms of geothermal power source.

Age range of pupils: 14 – 19 years

Time needed to complete activity: 15 mins per run

Pupil learning outcomes: Pupils can:
- describe the different situations in which geothermal power can be extracted from rocks;
- explain how a density can of hot gravel can be used to model these forms of geothermal power;
- discuss whether or not these forms of geothermal power can be regarded as renewable.

Context:
These simulations clearly show that:
- **'hot dry rocks'** geothermal power is not renewable, since the temperature of the gravel steadily falls as heat is extracted by the overflowing water, so that the temperature of the overflowing water also falls, over time. This is because the heat is extracted much more quickly than it is being generated by radioactive decay in the rock.
- **'hot wet rocks'** geothermal power is not renewable because it taps into 'fossil heat' accumulated over recent geological time, as a rate much faster than it is being accumulated.
- **'hydrothermal power'** can be extracted renewably, if heat is removed at a slower rate than it is accumulating from the heat source below. However, most hydrothermal power stations extract heat more quickly than it is accumulated, so they only have a finite life and will eventually close. In these cases, heat is being extracted at non-renewable rates.

Note: You can do the first demonstration just by pretending the density can has been heated, by touching it and pretending to burn your fingers – whole classes have been convinced by this!

A fourth source of power, which is sometimes described as 'geothermal', is 'ground source heat pumps' where water from an underground or surface source has its heat extracted for warming buildings and is recycled. However, since some 98% of the power in these systems comes from solar heating of the Earth's surface, and only around 2% is true geothermal power from the Earth, this is not geothermal power in the sense described above. Air-source heat pumps are also available, where heat is extracted from the air, rather than from the ground.

Following up the activity:
Ask pupils to research how 'ground source heat pumps' work, and whether or not this power source can be described as 'renewable'. *It can, since heat can only be extracted at the same rate as it accumulates.*

Underlying principles:
- The Earth generates heat, called geothermal heat.
- The Earth's heat is generated by radioactive decay in the rocks of the Earth (with a component of original heat from the formation of the Earth).
- Earth's heat flows to the surface and can be tapped through the three forms of geothermal power, described above.
- Such power is usually not renewable, because the heat is normally extracted at a faster rate than it accumulates.

Thinking skill development:
If one run of the activity is carried out, and pupils are asked to use this to discuss how the set-up might behave in the two other circumstances, they will use the mental 'construction' of one model and apply it to the two other models, generating 'cognitive conflict'. Discussions around the models, and their links with reality, involve metacognition. Linking each model with its 'real world' operation involves bridging.

Resource list:
- a large density or displacement can (density cans are also called 'Eureka cans' because they are designed to use the Archimedes method of measuring density)
- permeable coarse gravel to fill the can to above spout level
- a Perspex^{TM} tube long enough to penetrate nearly to the bottom of the gravel, and stick out of the top
- an oven or hot plate (a hot plate is needed for the 'hydrothermal power' simulation)
- heat-proof mits or gloves to be used in moving the hot container
- a thermometer or temperature probe to go in the gravel (reading to higher than 100^{o}C in case the can is heated to over 100^{o}C)
- containers to catch the overflow (eg. several measuring cylinders)
- a thermometer to go in the overflow containers
- a sink or basin
- a source of flowing water

Source: The model was described by Adrian Cook in the Earth Science Teachers' Association's '*Science of the Earth*', '*Rock power! – geothermal energy resources'* unit (1991), published by Geo Supplies, Sheffield. It was based on an activity originally described in '*Introducing Earth Science'* by James Bradbury (1986) published by Blackwell, who gave permission for its use.