Using model houses to investigate the effect of different types of house insulation

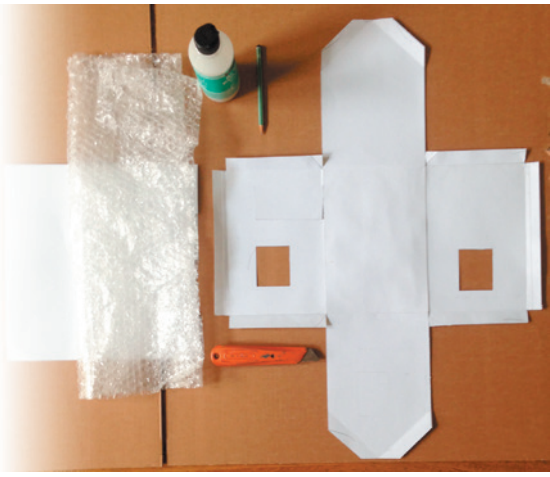

Figure 1

Model houses are used to investigate which type of insulation has the most effect on the ambient temperature of the house. This is very relevant for the level 3 course as the bench mark for *Energy sources and sustainability* - *SCN 3-04a* requires pupils "*to explain how materials can be used in building design to reduce heat loss, for example double glazing.*" Wooden model houses for this investigation are now difficult to source from science equipment suppliers. Here we show how model houses can be made from old cardboard boxes. The houses are simple to make and robust.

Requirements

PVA glue, a pencil, Sellotape, double sided sticky tape, cardboard, stiff transparent plastic from packaging, a metal ruler, a Stanley knife, a cutting board, templates for the model house [1], bulldog clips, a 12 volt 24 watt filament bulb in a socket with two 4 mm connectors, a 12 volt power supply, a -10°C to 110°C thermometer, bubble wrap and A3 sheets of card, a thermal imaging camera (In 2014, SSERC gave every local authority a thermal imaging camera to lend to schools. These are available on loan from your local authority). The thermal imaging camera is not essential but does enable visual displays that highlight where the heat loss has been reduced when the house is insulated.

Figure 2

Constructing the house

Place the template [1] on the sheet of cardboard from which the house is being made (Figure 1). Draw round the template using a pencil. Fold in the flaps on the template along the dashed lines and draw dashed lines along the new edge of the template; this gives the lines the house needs to be folded along when constructing it. Place a cutting board beneath the cardboard. Cut round the outline of the house on the cardboard using a Stanley knife. Score along the dashed lines using a ruler and the Stanley knife, as this makes folding the cardboard much easier (Figure 2). Cut out the windows and cut round three sides of the door, do not cut along the dashed line as that forms the door hinge.

Put glue along the folding line of cardboard on the gable ends (Figure 3). Fold the cardboard >>

Figure 3

Figure 4

Figure 5


Figure 6


Figure 7


Figure 8


Figure 9

over and hold it in place with a clip (Figure 3). This strengthens the gable ends.

Put glue along the flaps on the side of one end of the house (Figure 4). Fold the flaps behind the gable end. Hold the flaps in place using weights (Figure 5).

Do the same with the gable on the other end of the house. The base of the house is complete (Figure 6). The house needs windows which are made from the stiff transparent plastic. Cut four 8 cm x 8 cm rectangles of the transparent plastic. This enables single and double glazing to be compared.

Place sticky tape round the edges of the plastic window (Figure 7), and stick it to the inside of the house so the plastic covers the window opening and the sticky tape seals the opening. This ensures no air can escape through the window (Figure 8).

Repeat for the second window. Sticking the window to the inside enables the double glazed house to be easily identified as the second pane is stuck to the outside of the house. Make the ceiling from a piece of card by drawing round the base of the house and adding 1 cm flaps along each side. No flaps are needed at the gable ends. Position the ceiling on top of the side walls (Figure 9).
In the gable end furthest from the door, make a hole in the centre of the gable end about 5 cm from the base of the house so the thermometer is held firmly by it (Figure 11). Draw round the roof template and cut out the roof. Score along the centre roof line to enable the roof to be bent in half so it sits on the two gable ends (Figure 10). To increase the strength of the roof tear a strip of brown paper from the cardboard and using PVA glue stick the paper over where the cardboard has been scored and bent. Doing this also holds the roof in the correct shape.

The investigation

Open the door of the house and place the 12 volt, 24 watt light bulb in its holder inside the house (Figure 11). Insert the thermometer through the hole in the gable end so the -10°C mark is at the hole. This ensures the thermometer can be kept in the same position throughout the experiment (Figure 11). The same heat source, a light bulb, is used throughout the experiment.

Make sure the bulb is at least 5 cm from the walls of the house. Set the power supply to 12 volts and connect the light bulb to it. Replace the ceiling and the roof of the house (Figure 12). Switch on the light bulb and wait till the temperature on the thermometer becomes stable, typically 20 minutes. This gives the equilibrium temperature for the house. Take a photo of the house with a thermal imaging camera (Figure 13).

Loft insulation, cavity wall insulation and double glazing can be investigated. The effect on the final equilibrium temperature reached by the house for each type on insulation can be found. Finally, the equilibrium temperature of the house which >>


Figure 10

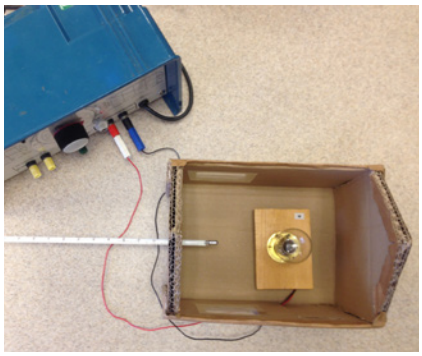
Figure 11

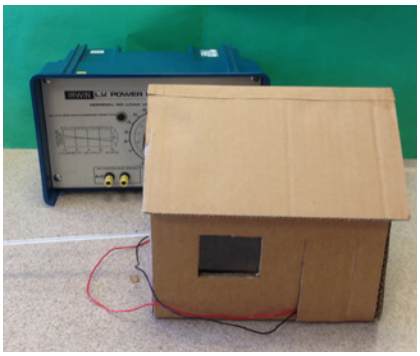
Figure 12 - House with no insulation.

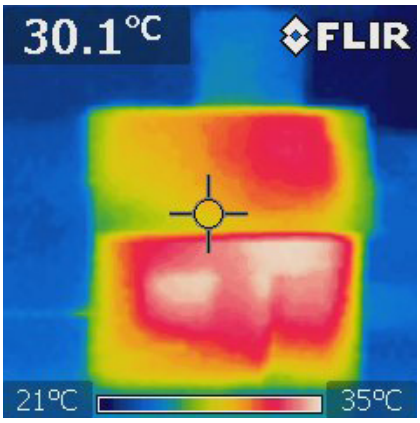

Figure 13 - Thermal image of the house with no insulation.

is fully insulated can be found. Pupils could simply be given bubble-wrap and extra glazing and instructed to insulate the house appropriately. To have more control over the experiment the different types of insulation can be made so they are easily slotted into place and can be reused when required.

Loft insulation is made from bubble wrap. Draw round the base of the house and cut out two pieces of card the same dimensions as the base of the house. Cut a piece of bubble wrap the same size as the two pieces of card. Stick double sided sticky tape down around the edge of each of the card rectangles and stick them either side of the bubble wrap, (Figure 14). This deters pupils from popping the bubble wrap. Adjust the size so the loft insulation sits on top of the ceiling and the roof fits snugly over the gable ends (Figure 15). Replace the roof, switch on the light bulb and wait till the temperature of the house is steady. Record the final temperature. Take a photo with a thermal imaging camera (Figure 16).

This thermal imaging photo when compared with the reference photo (Figure 13) clearly shows that heat loss through the ceiling has been reduced as the roof is not as hot. Remove the loft insulation.

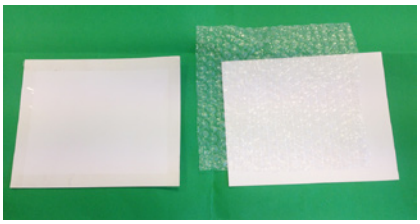
Figure 14


Figure 15

Cavity wall insulation can be made using bubble wrap. Draw round the house template for the sides of the model house alone on a piece of card, the other parts of the house can be folded out of the way (Figure 17). Cut out the door and the windows. Apart from one corner join the pieces of card together using sticky tape. Place double sided sticky tape round the sides of the rectangle. Place bubble wrap on top so the bubble wrap sticks to it and cut the bubble wrap to size. Cut the windows and door out. Position the insulation inside the house with the card next to the house walls. Place card on the inside of the walls coated with bubble-wrap so the card fits snugly against the bubble wrap and mark where the folds need to be made in the card. Remove the card and fold it along the marked lines. Replace the card and draw round the openings for the windows and

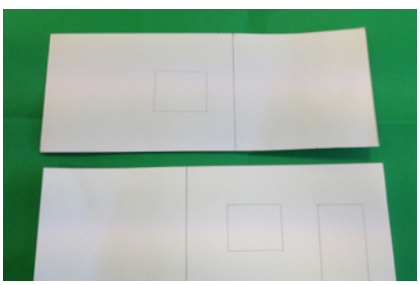
Figure 17

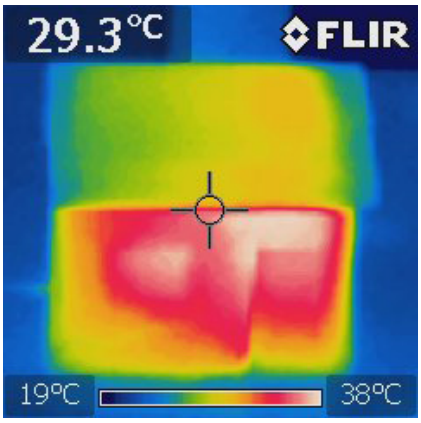

Figure 16 - Thermal image of the house with loft insulation.

door. Remove from the card again and cut out the windows and door. Stick double sided tape around the side of the bubble wrap closest to the ceiling. Replace the card and stick it to the other side of the bubble wrap (Figure 18). Make a hole in the cavity wall insulation for the thermometer. Replace the ceiling and the roof. Switch on the light bulb and wait till the temperature of the house remains steady. Record the temperature and take a photo with the thermal imaging camera (Figure 19).

This thermal imaging photo when compared with the reference photo, (see Figure 13) clearly shows that heat loss through the walls has been reduced as the outside of the walls are not as hot. Remove the cavity wall insulation.

The house can be double glazed. Put sticky tape around all four sides of two 8 cm x 8 cm pieces of rigid plastic (Figure 20). Stick the window onto the outside of the house to form a sealed cavity between the >>


Figure 18

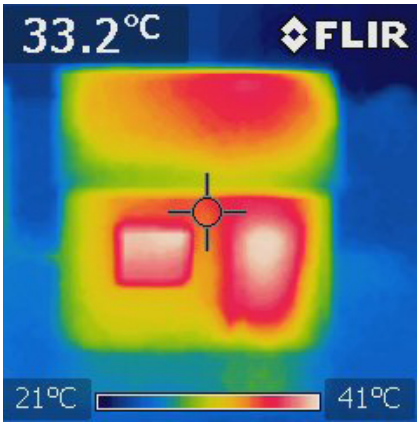

Figure 19 - Thermal image of the house with cavity wall insulation.

two windows (see Figure 21). Replace the ceiling and the roof. Switch on the light bulb and wait until a steady temperature is reached. Take a photo of the house with the thermal imaging camera (Figure 22). Record the final temperature. Comparing the thermal imaging photo with the reference photo (Figure 13), it is clear that double glazing has reduced the heat loss from the window as the window is no longer white so must be at a lower temperature.

Finally have the house fully insulated and see what effect insulation has on the final temperature. Place the light bulb inside the house which has loft insulation, cavity wall insulation and double glazing. Switch on the light bulb and wait until the temperature is steady. Record the final temperature and take a photo with thermal imaging camera (Figure 23).

This thermal imaging photo when compared with the reference photo (Figure 13), clearly shows that heat loss through the ceiling, walls and windows has been reduced.

Results

Type of insulation	Final temperature (°C)
None	47
Loft	51
Cavity wall	55
Double glazing	50
Loft, cavity wall and double glazing	60

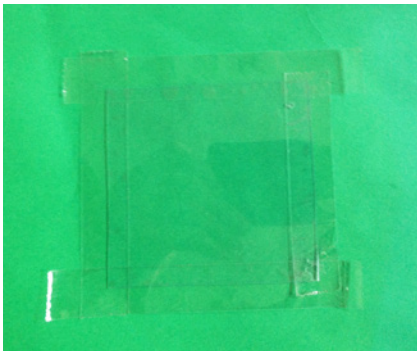
Figure 20

Summary

The thermal images show clearly the effect the insulation of a house has on heat loss from the house. This should help pupils appreciate the need for insulation to improve the energy efficiency of buildings. The same heat source is used throughout the experiment, yet the well-insulated house had a final temperature of 60°C and the un-insulated house had a final temperature of 47°C. Using bubble wrap as the insulating material helps reinforce the fact that trapped air is a good insulator. To see the effect temperature difference has the model house could be placed in a cool room so the temperature difference across the walls is greater. Having completed the investigation pupils should be able to satisfy ***SCN3-04a*** *- I can use my knowledge of the different ways in which heat is transferred between hot and cold objects and the thermal conductivity of materials to improve the energy efficiency of buildings*.

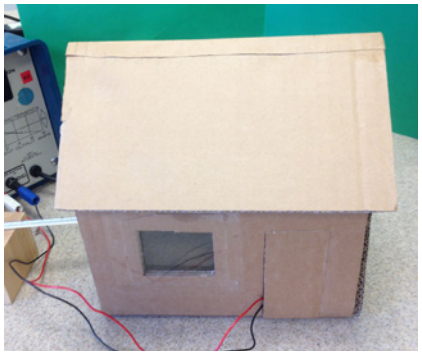
Figure 21 - Double glazing.

This activity also helps with the Level 3 skills. It lends itself to relating findings to scientific knowledge and understanding and drawing conclusions based on the results gathered in relation to an aim.

Safety notes

There is no need to use a mercury-in-glass thermometer for this investigation. An alcohol thermometer is suitable and, if it does break, a spill will be much easier to clean up.

If the model house is built and used as described in this article, the cardboard will never become hot enough to present a fire risk. <<

Reference

[1] Templates can be downloaded from www.sserc.org.uk/subject-areas/physics/physics-other-resources/model-houses/ (accessed August 2019).

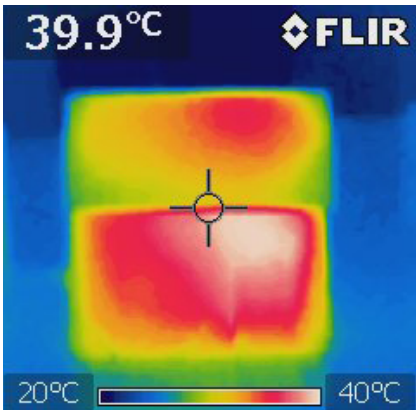

Figure 22 - Thermal image of the house with double glazing.

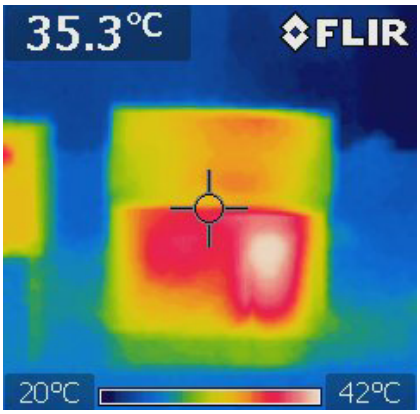

Figure 23 - Thermal image of the house with loft insulation, cavity wall insulation and double glazing.