Introduction

Over the last few decades there has been a growing public awareness of the need to make more efficient and equitable use of the world’s non-renewable resources - fossil fuels and natural minerals. Carbon dioxide (CO$_2$) is produced when fossil fuels are burned, and so using fossil fuels contributes to the greenhouse effect and climate change. As oil and gas reserves decline and CO$_2$ reduction is demanded, we will need to use energy more efficiently and rely increasingly on renewable energy resources such as biomass, solar, hydroelectric and wind energy.

Energy use in Ireland

Domestic energy accounts for more than a fifth of Ireland’s total energy use. About 60% of domestic energy is used for space heating and 24% for heating water. Just 3% is used for cooking and 13% for lighting and for appliances such as washing machines, TVs etc. While many domestic appliances can be made more energy efficient others are difficult to improve, particularly those that require heat - e.g. tumble dryers, hair dryers and toasters.

Heating and Insulation

By far the best way to save energy in the home is to save on heating. In terms of the fabric of the structure this can be achieved by:

- making the house more airtight by preventing draughts.
- improving insulation standards.
- avoiding large temperature fluctuations by utilising thermal mass.

Heat is lost from a house by conduction through the floor, walls, windows, doors and roof. The conductive efficiency of such elements is usually expressed in terms of U-values. The external walls of a house typically comprise several layers such as concrete, insulation and plaster. These resist the flow of heat at different rates. The greater the thermal resistance the lower/better the U-value. The units are watts per square metre Kelvin (W m$^{-2}$ K).

Table 1. Sample U-values (W m$^{-2}$ K) for different building elements

<table>
<thead>
<tr>
<th>Element</th>
<th>Construction</th>
<th>U-value (W m$^{-2}$K)</th>
<th>Max. U-value, 2007 Regs. (W m$^{-2}$ K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall</td>
<td>300 mm cavity wall, not insulated</td>
<td>1.76</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>350 mm cavity wall with 140 mm modern insulation</td>
<td>0.20</td>
<td>0.27</td>
</tr>
<tr>
<td>Floor</td>
<td>solid concrete ground floor, not insulated</td>
<td>0.80</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>solid concrete ground floor, with 100 mm modern insulation</td>
<td>0.21</td>
<td>0.25</td>
</tr>
<tr>
<td>Window</td>
<td>wooden frame, single glazed</td>
<td>4.80</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>wooden frame, double glazed, 20 mm gap, Low-E (low emissivity coating)</td>
<td>1.70</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Current (2007 amended) building regulations specify maximum U-values for building elements. Table 1 shows how the U-value for a wall, floor and window can vary depending on the element type selected. The affect of appropriate design and insulation for typical elements can clearly be seen.

Fig.2 illustrates cavity wall construction and highlights the benefits of improved insulation.

Fig. 2. Uninsulated cavity wall: U-value 1.76 W m$^{-2}$ K; Insulated with 140 mm modern insulation: U-value 0.20 W m$^{-2}$ K

Thermal Mass and Placement of Insulation

One of the main forms of constructing external walls of houses has been to use two layers of concrete block with a cavity between them; the cavity should contain a suitable insulating material.

The temperature of the outer leaf (layer) of the wall varies with the outside temperature. The insulated inner leaf has a more stable temperature; it acts as a heat store, absorbing heat when the inside temperature rises during the day and releasing it when the air temperature drops at night.

By using the thermal mass of concrete in this way the inside air temperature can be kept relatively stable resulting in a more efficient and comfortable living environment. This effect can be enhanced by using concrete for internal partition walls and floors.

Another form of construction, shown in Fig.3, is the externally insulated single leaf concrete block wall. This wall type, used in the construction of the A-1 rated house illustrated in Fig.4, easily supports concrete upper floors and makes full use of the thermal mass of both wall and floor. This keeps the home cool in summer and warm in winter.

Fig. 3. 215 mm solid block wall with 300 mm external modern insulation: U-value 0.10 W m$^{-2}$ K

Fig. 4. A zero carbon emissions house (Courtesy of the Irish Concrete Federation)
Building Energy Rating (BER)

Since the beginning of 2009 all buildings offered for sale or rent must be assessed by a registered BER assessor and have a Building Energy Rating Certificate. The rating has a 15-point scale (Fig. 5) indicating the energy used per square metre of floor area in kW h m\(^{-2}\) per annum. It also indicates the calculated CO\(_2\) emissions in kg m\(^{-2}\) per annum. A BER includes the energy used for heating, lighting, pumps and fans but does not include energy for cooking, refrigeration or laundry.

A house properly designed to take advantage of solar gain would significantly reduce its primary energy requirements.

Two buildings with the same floor area and the same insulation standards might not be equally energy efficient if the building shapes are different. For example a 20 m \(\times\) 5 m building has the same floor area as a 10 m \(\times\) 10 m building. However it has 25% more wall area and would require a 25% better wall U-value to achieve the same energy efficiency. In general, more compact designs save energy. Apartments, having less external wall area, have lower energy requirements.

The BER labels and values shown in Table 2 are provided by Sustainable Energy Ireland and are representative of a typical 110 m\(^2\) semi-detached house.

### Table 2. Indicative CO\(_2\) emissions and running costs for different rating bands

<table>
<thead>
<tr>
<th>BER Labels</th>
<th>Annual Primary Energy* in kW h</th>
<th>CO(_2) (tonnes per annum)</th>
<th>Typical Cost @ 7 c per kW h</th>
</tr>
</thead>
<tbody>
<tr>
<td>A2</td>
<td>4,215</td>
<td>1.1</td>
<td>€295</td>
</tr>
<tr>
<td>B1</td>
<td>10,357</td>
<td>2.5</td>
<td>€725</td>
</tr>
<tr>
<td>C1</td>
<td>16,786</td>
<td>4.1</td>
<td>€1,175</td>
</tr>
<tr>
<td>D1</td>
<td>24,929</td>
<td>6</td>
<td>€1,745</td>
</tr>
<tr>
<td>D2/E1</td>
<td>32,571</td>
<td>7.9</td>
<td>€2,280</td>
</tr>
<tr>
<td>F</td>
<td>45,643</td>
<td>11</td>
<td>€3,195</td>
</tr>
<tr>
<td>G</td>
<td>58,429</td>
<td>14.4</td>
<td>€4,090</td>
</tr>
</tbody>
</table>

* Annual primary energy includes electricity, oil and natural gas. Values shown are estimated and based on standardised occupancy/use.

CRH

CRH is a leading international building materials manufacturer and distributor. The company was founded in Ireland in 1970 by the merger of Irish Cement Ltd. and Roadstone Ltd. and now operates in 35 countries globally with 2008 annual sales of over €20 billion. CRH shares are listed on the Irish, London and New York stock exchanges. The product range is vast and includes cement, lime, aggregates, asphalt, ready-mixed concrete, pre-cast concrete products, clay products, glass and insulation materials.

CRH companies manufacturing in Ireland include Irish Cement Ltd., Roadstone–Wood Ltd., Clogrennane Lime Ltd. and Aerobord Ltd.

CRH is committed to energy efficiency in both the production and use of the products which it supplies to the construction industry. Some of the most energy efficient buildings in the world are being constructed in Ireland using products manufactured by CRH companies.

In order to operate in an environmentally responsible manner, CRH companies:

- comply with all relevant environmental legislation
- strive to achieve best practice in the industry
- proactively address the challenges of climate change
- optimise the use of resources and energy
- promote innovation in environmental products
- actively support local community development.

Production facilities are regularly upgraded in order to minimise both emissions and the generation of waste.

CRH is committed to investing in a wide range of environmental improvements across all its activities worldwide. Plant upgrades typically include process yield optimisation, increased recycling, improved energy efficiency, abatement of emissions and improvements in ergonomics and safety. Many of its production facilities have received awards in recognition of their environmental achievements.

For more information on CRH visit [www.crh.ie](http://www.crh.ie).
CRH
The Energy Efficient Building
Teaching Notes

Syllabus References

The appropriate syllabus references are:

**Leaving Certificate Physics**

**Leaving Certificate Construction Studies**
Part 1: Construction theory and drawing (p. 4)

**General Learning Points**

The following information can be used to inform discussion on the lesson.

- Energy efficiency in buildings will be increasingly important in the future.
- At present heating accounts for more than 80% of typical domestic energy use.
- The quality, quantity and method of placement of the insulation in a house largely determine the heating costs.
- Concrete within a building acts as a heat store when the inside air temperature rises during the day and as a heat source when the air temperature drops at night.
- U-values express the conductive efficiency of a wall, window etc. Lower U-values indicate better insulation.
- Energy can be conserved by proper use of insulation, draught exclusion, using low-energy appliances and use of alternative energy sources.

**Learning Outcomes**

On completion of this lesson, students should be able to understand:

- The importance of minimising domestic energy use
- The contribution of space and water heating to domestic energy use
- The importance of insulation in minimising the running costs of a house
- The effect of the thermal mass of concrete within a building.
- What U-values indicate
- The possible contribution of various energy saving measures.
The Energy Efficient Building
Exercises

Experiment

Investigation of temperature changes in concrete

Equipment and materials: concrete block, black paint, white paint, datalogger, two or more temperature probes, electric drill and masonry bit (to be used under supervision), goggles.

A suitably qualified person should drill a hole in the long edge of the concrete block so that the sensor of a temperature probe can be placed near the centre of the block. Paint the block white and allow it to dry.

Stand the block on a long edge in a shaded part of the room. Insert a temperature probe into the centre. Place a second temperature probe nearby, but not touching the block. Set up the data logger to monitor the probes for a week.

As the room temperature changes over the course of several days so will the temperature of the centre of the block. However, changes in the block temperature will lag behind those of the air.

Record:

1. Print a graph showing the temperature changes and estimate the time lag. What does the result indicate? (The diagram shows an idealised result.)

2. Add horizontal lines to the graph to indicate the maximum and minimum air and block temperatures. What does the result indicate?

Extension Activities:

1. Repeat the investigation using a block that is painted black.
2. Repeat the investigation using three blocks placed flat on top of one another, with the drilled block in the middle.

True/False Questions

a) About 20% of domestic energy is used for space heating. T F
b) About 20% of domestic energy is used for cooking. T F
c) U-values express the overall conductive efficiency of walls, windows etc. T F
d) U-value units are watts per kelvin per square metre (W K⁻¹ m⁻²). T F
e) The thermal mass of concrete in a building helps to stabilise the temperature. T F
f) A higher the U-value the better the insulation. T F
g) Buildings with the same floor area and the same quality of insulation would be equally energy efficient. T F
h) The thickest layers in a wall have the best insulating effect. T F
i) A BER certificate includes an estimate of the annual CO₂ output of a building. T F

Check your answers to these questions on www.sta.ie

Examination Questions

Leaving Certificate Physics (HL) 2008, Q. 7
(a) Define resistivity and give its unit of measurement.

An electric toaster heats bread by convection and radiation. What is the difference between convection and radiation as a means of heat transfer?

Leaving Certificate Physics (HL) 2006, Q. 12
(c) Define (i) power, (ii) specific heat capacity.

400 g of water at a temperature of 15°C is placed in an electric kettle. The power rating of the kettle is 3.0 kW. Calculate

(i) the energy required to raise the temperature of the water to 100 °C;
(ii) the energy supplied by the kettle per second;
(iii) the least amount of time it would take to heat the water to 100 °C.

In reality, the time taken to heat the water will be greater. Explain why. (specific heat capacity of water = 4200 J kg⁻¹ K⁻¹)

Leaving Certificate Construction Studies (HL) 2007, Q. 5
(a) Using the following data, calculate the U-value for the external wall of a house, built in the 1970s:

External plaster thickness 16 mm
Block outer leaf thickness 100 mm
Cavity (un-insulated) width 100 mm
Block inner leaf thickness 100 mm
Internal plaster thickness 13 mm

Thermal data of external wall:
Conductivity of plaster (k) 0.430 W/m °C
Conductivity of blockwork (k) 1.440 W/m °C
Resistance of external surface (R) 0.048 m² °C/W
Resistance of cavity (R) 0.170 m² °C/W
Resistance of internal surface (R) 0.122 m² °C/W
(b) Using the following data, calculate the cost of the heat lost annually through the un-insulated external wall:

- Area of external wall: 145 m$^2$
- Average internal temperature: 18 °C
- Average external temperature: 5 °C
- U-value of wall as calculated at (a) above
- Heating period: 10 hours per day for 42 weeks per annum
- Cost of oil: 68 cent per litre
- Calorific value of oil: 37,350 kJ per litre
- 1000 watts = 1 kJ per second.

**Did You Know?**

**Zero Carbon House**

By building Ireland’s first Zero Carbon Emissions Concrete House (e.g. Fig. 5), the Irish Concrete Federation wanted to demonstrate the ease of use of concrete products in achieving the highest standards of energy and carbon efficiency. Using passive house design principles and then maximising the solar gain through the thermal mass characteristic of concrete, this house achieves both Zero Carbon Emissions as well as an A1 BER Rating. This is achieved by creating very low energy requirements which is then complemented with an efficient suite of renewable technologies.

CRH companies provided cement and insulation products used in the construction of this house.

**Zero Carbon Emissions** means there is no carbon footprint from the operational use of the house in relation to its primary energy requirements, i.e. space heating, water heating, lighting, ventilation and any motive power required for these uses. Concrete will clearly continue to be the material of choice for Irish homes into the future.

**Solar heating panels**

The maximum solar radiation on the Earth’s surface when the Sun is directly overhead (midday at the equator) is about 1000 W/m$^2$ and the average is about 540 W/m$^2$. The average available solar energy per day in Ireland (Dublin) varies from about 0.65 kW h in winter to about 4.5 kW h in summer. A two square metre solar panel could provide up to 80% of the hot water requirement for a household during the summer and up to 20% in the winter.

**Heat recovery from air and water outlets**

Much of the heat used in providing hot water goes down the drain with the waste water from showers, washing machines, sinks etc. Much of this can be recovered by using the outflow to heat some of the incoming water. The benefit is however relatively small for the investment.

**Smart control of lights**

So-called ‘smart’ control systems can turn on lights in rooms, hallways and on stairs when people are detected in the area. Lights may be turned off automatically after a suitable interval.

**Revise the Terms**

Can you recall the meaning of the following terms? Reviewing terminology is a powerful aid to recall and retention.

- cavity, CO$_2$ emissions, concrete, conductive efficiency, domestic energy, fossil fuel, inefficient, insulation, kelvin, kW h, mineral, per annum, plasterboard, primary energy, renewable, solar heating panel, temperature fluctuation, thermal mass, thermal resistance, U-value, watt, wind energy.

Check the Glossary of Terms of this lesson at www.sta.ie.

You can find this, and other CRH lessons, on www.sta.ie.