U-Values

TASK
Pupils can read through some of the information below, look through books or the internet and try in a page to summarise the following points

- What are u-values?
- Why do we need them?
- When are they needed?
- Do you personally think that their importance will increase over time?
- Do you think house and home magazine articles consider these in their articles? Or do you think home programmes on the television consider these values?
- Try to find some examples from the television or magazines.

http://www.bre.co.uk/filelibrary/rpts/uvalue/BR_443_(2006_Edition).pdf

http://www.syec.co.uk/factsheets/U_value_factsheet.pdf

U-Values

Heat loss: The facts.
U Values

A U value is a measure of heat loss. It is expressed in W/m^{2}k, and shows the amount of heat lost in watts (W) per square metre of material (for example wall, roof, glazing, and so on) when the temperature (k) is one degree lower outside. The lower the u value, the better the insulation provided by the material.
The Building Regulations http://www.communities.gov.uk/planningandbuilding/buildingregulations set out minimum requirements for all the elements of new buildings.
The U value currently required for a new-build external wall is approximately 0.3. As a comparison, the U-value of a straw-bale wall is 0.13, and of a solid 225mm (9") brick wall, 2.0. It's worth noting that the Building Regulations currently require a U value for glazing of 1.8. This is achieved with a double-glazed unit with an air gap of around 20mm and one pane of low emissivity glass, which lets light through, but tends to limit heat loss. So when someone tells you how fantastic double glazing is, suggest a comparison with a solid brick wall, which is never considered to be well insulated!

The insulation value of a solid brick wall can be *quadrupled* by lining the wall with approximately 50mm (2") of insulated plasterboard.

Since 2006 you may well need Building Regulations approval for insulation improvements. **Check with your local council.**

http://www.theyellowhouse.org.uk/themes/insula.html#in11

Insulation

In this section:

THE SECRET OF AN ECO-HOUSE
What's the secret of an eco-house? Insulation, insulation, INSULATION!. Solar panels, turf roofs, windmills, heat pumps - they are all wonderful, very fancy and visible. What really makes the difference is loads of insulation - not visible, not sexy, but vital. This is especially true in Britain where the sunshine is, to say the least, limited. In fact the last decade has seen a new generation of experimental eco-houses where the only eco-feature is astonishing thicknesses of insulation - so much that they can heat themselves entirely with the waste heat from daily living. One of the first was at the Centre for Alternative Technology.

So, how much insulation? Insulation takes energy to manufacture (a great deal of energy in the case of mineral wool) so there is a point at which any additional insulation becomes pointless- it will take more energy to make than it will ever save. Research suggests that this point comes at a thickness of one metre. With existing buildings it is fair to say, the more insulation the better, but with two main considerations:

• Heat will always find the easiest way out so insulation needs to be as equally distributed as possible. There is no point in having a metre of insulation in the loft when all the heat is going out through leaky single glazed windows;

• In any existing property there are always practical limits to the thickness of insulation; the size of the cavity; the availability of head space in the loft; the space between the floor joists.

You will have a lot more freedom with any new construction. In this case there is a beautiful logic to insulation-it costs very little extra to double or even triple the insulation required by current building regulations: the cost of the extra thickness and scarcely more labour. This additional insulation is one of the best investments you can make in your home.

INSULATION: **COLD BRIDGES AND CONDENSATION**
Like many physical forces (weight, fluids, electricity) heat will always escape first through the point of least resistance. Places where there are weaknesses in the insulated envelope of the house are called cold bridges or thermal bridges, because they literally provide a "bridge" for heat to escape. What is more, these are places where condensation can form, bringing with it all its associated structural and health problems. The better insulated a building, the greater the problem posed by cold bridges which is why environmental architects obsess on the design details that minimise cold bridges, especially

around windows. The main areas for cold bridges are:

- Where there is a break in the insulation. For example, if insulation is only placed between the roof joists, the joists will act as cold bridges
- At corners. Especially where walls meet the ground
- Around windows and doors. Condensation may also form on metal window frames
- Where there is a disruption of a wall cavity. Anything crossing the cavity can be a cold bridge- in the Yellow House every other concrete block crossed the cavity greatly reducing the potential of cavity insulation. Solid lintels over doors and windows are classic cold bridges, and advanced designs either insulate around them or use two lintels with a break in between.
- Where metal pipes or structural steel cross insulation or a wall cavity. Metal is a very good conductor of heat, and therefore makes a powerful cold bridge. Typically this is a problem where pipes enter a cold loft space (also a problem for draughts).

Cold bridges can be largely eliminated with careful insulation: ensuring that loft insulation covers joists or rafters; insulating around pipes; adding extra insulation at corners and around the base of external walls when insulating floors.

INSULATION: **THE JARGON OF INSULATION**

The world of insulation has its own arcane jargon that needs to be mastered when specifying the most efficient materials and fittings. There are three ratings used for estimating heat loss: the k rating, the R rating, and the u value. (More information on k, R, u values below: what they mean, how they are calculated, and how to use them to assess your house's energy loss.)

However, even if you do not have a head for maths, you may still need to know what these ratings mean in practical terms. Any manufacturer of building products and external fixtures such as doors and windows should know the R or u of their products. If you are looking for the lowest heat loss, all you need to know is:

R value - the higher the better
u value - the lower the better

Armed with this information, you can make direct comparisons between different products and materials. For example, normal off the shelf double glazing with aluminium frames has a u-value of 3.5. The high performance double glazing we used has a u-value of 1.6, half the level of heat loss.

The difference in thermal performance between seemingly similar products can be dramatic, which is why it's so important to keep an eye on the R and u values. Normal 75mm concrete blocks have an R of 0.07. Solar concrete blocks have an R of 1.36. A wall built of normal concrete blocks will therefore lose nearly 20 times as much heat as a wall built of solar blocks.

Any good builder should be able to calculate the R and u values for you and can advise you about the relative costs of different insulation options for achieving the lowest heat loss.

INSULATION: **INSULATION MATERIALS**

The standard materials for insulation are glass and mineral fibre, and expanded foam sheet. Their insulation performance is excellent, they are highly water resistant, and are reasonably fire retardant. Sadly, their manufacture involves quite high environmental impacts. They use a great deal of energy to make. Expanded polystyrene, polyurethane, and polyisocyanurate (PIR) use HCFC gases in their manufacture which are powerful greenhouse gases. There is some evidence to suggest that mineral and glass fibre insulation may be carcinogenic, but even after years of study there are no conclusive findings.

Because of these concerns we looked at some of the more "environmental" insulation products on the market including wool and cellulose waste from recycled paper. We found that these materials are considerably more expensive and have a lower performance than the mainstream industrial products.

Given that the space available for insulation was limited by the existing structure, using these materials would have led to a lower energy performance. However, it is worth researching environmental insulating materials for any new build project. Both these products would have worked well in a new build property with greater design flexibility and a higher budget.

In most places then we used expanded polyisocyanurate (PIR) sheeting which is often sold as 'Celotex', the brand leader, and mineral wool.

INSULATION: **INSULATION PRIORITIES FOR RENOVATION**
In an average house the main sources of heat loss are:

draughts	25%
roof	15%
windows	20%
walls	30%
floors	10%

These figures are averages and will vary greatly from house to house - a terraced house has half the area of external walls of a detached house and so roofs and windows are a greater priority. In a house with an unheated basement, floors will be less important, in a flat the windows may be the most important.

So the priorities for insulation will depend on the individual house and what has already been done to it- every time some improvement is made to the house, the remaining sources of heat loss will become relatively more important. Generally speaking the order of priorities for insulating an existing property is:

1. draughts - a major source of heat loss that is very cheap to reduce substantially. Tackle this first (for more information on draughts).

2. roof - it is very easy and cheap to insulate an unoccupied loft space (and vital for a converted loft space). A well insulated roof makes a large difference to the comfort of sleeping in upstairs rooms.

3. windows - secondary internal glazing or good quality double glazing. Replacing single glazing makes a very significant difference to the internal comfort on cold nights. If you are not replacing the windows, a thorough draughtproofing will produce immediate gains.

4. walls - certainly worth insulating if you have a cavity, or if you have completed the above.

5. floors - a low priority but likely to become a major source of heat loss in an otherwise well insulated house, especially in floors suspended over a ventilated void.

INSULATION: **ROOF INSULATION IN THE YELLOW HOUSE**

75% of the new insulation was inside the roof. Because there was no underlay behind the existing tiles, insulating materials had to be waterproof and so only 'Celotex' PIR sheet insulation was appropriate. Building control required a 50mm gap behind the tiles for ventilation, so the maximum thickness possible between the 100mm rafters was 50mm of insulation (or equivalent).

This would have been sufficient to exceed current building regulations, and most conversions go no further. We wanted to double the existing standards so we decided to add further sheets of 35mm thickness laid across the rafters on the inside- a small loss of head space for a large gain in insulation. What is more, the additional sheets prevent the rafters from acting as cold bridges (above).

Another reason for laying an additional sheet across the rafters is as insurance against the loosening of the insulation. It is hard to obtain a perfect tight fit of insulation between rafters, and it is likely to be further loosened as the rafters shift with time. Once loosened, cold air may be able to force its a way around, compromising the insulation.

After fixing 50mm of PIR insulation between the rafters all obvious gaps were filled by polyurethane foam from an aerosol can (not good environmentally, but a justifiable vice). Then sheets of insulation were laid lengthwise across the rafters and similarly sealed. 9mm plasterboard sheets were then laid narrow side on across over the Celotex and nailed in place. The aim was to create a patchwork of layers without adjoining gaps. The final roof had a u-value of less than 0.2, compared with the u-value of 0.35 required by building controls.

It is important to remember that the walls in the loft adjoining the neighbouring attics are also effectively external walls as neither of the attics on either side is occupied. In this case any insulation will abut into the loft space, so it needed to be thinner than we would otherwise have wanted. We opted for a good performance thermal plaster board which projected only 4cm. With the clinker block wall, it gave a pretty miserable u-value of 0.49. Fortunately these side walls only had a quarter of the area of the rest of the roof.

The roof above the extension could not rise significantly above the level of adjoining roofs in the terrace and so, with space again at a premium, expanded PIR sheeting was the best option. The extension is on the cold north side of the house, so we specified 100mm thickness under the turf roof.

INSULATION: **TURF ROOF**
The turf roof on the extension was a small extravagance. Tiles require lots of energy to make and add to the sterile urban landscape. Water runs right off and floods the sewers every time it rains. Reflection of heat in summer greatly increases the temperature in towns. All this could be avoided with turf roofs. And, wouldn't the world be beautiful if all roofs were covered in wild grasses and flowers? Contrary to popular conception, green roofs do not have great insulating qualities unless they are very thick in which case they need to be supported by steel or reinforced concrete both of which have major environmental impacts. In a lightweight construction such as our extension roof the turf is so thin that it makes little difference to heat loss- the insulation was from sheets of Celotex. However, a grass roof has very little embodied energy compared with fired tiles and seemed to us to symbolise eco-building - we look out of the office windows and see nothing but green all the way down to the garden.

We looked at several green roof systems and finally chose a low weight system from Index a company with a good track record. The cross section of the extension roof had 7 layers: turf; a foam vegetation mat containing nutrients; a root barrier; a layer of reinforced waterproofing; 100 mm of expanded polystyrene foam insulation; sarking boarding (bought from a salvage yard); cavity and joists; plaster board and skim. Taken together these gave the roof a u-value of only 0.15, twice as good as the standard required by building controls.

In theory the grass roof cost only £300 more than a standard tile roof. However in our case we found that it needed additional parapets on either side and a dispiriting amount of eco-nasty lead flashing which added a further £500 to the cost. Of greater concern was the delay incurred by the Oxford City Council building inspector who had never seen a grass roof before and took three weeks of quibbling before he finally agreed to the scheme. We love the grass roof but would think twice before installing one again.

INSULATION: **INSULATING THE WALLS**
30% of the heat loss in an average house is through the external walls (and even more if the house is old and detached), so wall insulation is important in an ecohouse. It may not be the priority though - draught proofing and insulating the roof provide greater immediate returns. After these, walls and windows are the next concerns.

There are three forms of insulation for external walls: external, cavity and internal. Each have relative pros and cons. Where there is an existing cavity, usually only in houses built after 1920, the cheapest option is usually to fill the cavity with blown insulation. The most common method is to inject a chemical foam (Urea-formaldehyde) - however there are well based concerns about the impacts of formaldehydes on health and this should be avoided. Alternatives include blown mineral wool and polystyrene beads. This is also one use for which blown cellulose from waste newspaper is recommended. The main problem will be finding an installer experienced in using it. When building a new wall, a 75-100mm cavity with mineral wool batts is the best option.

Houses built before 1930 usually have solid external walls and here the only options are to attach internal or external insulation. Internal insulation is usually sheets of thermal plaster board nailed to the wall with a skim of plaster. Alternatively insulation can be fixed between wooden battens and finished with standard plasterboard. It does take some of the area away from the room, but has the advantage of leaving the external appearance unchanged - important for historic attractive brick buildings. Internal insulation costs less than external insulation and makes particular sense on external walls which need replastering anyway- plasterboard being a cheaper option than a full re-plastering. It should only be done by a qualified contractor to ensure that all edges are properly sealed - otherwise moisture from the room may pass through and condense on the cold wall behind the insulation.

External insulation is usually sheets of expanded polystyrene foam fixed onto the wall with specialist non corrosive bolts, then rib-lathed and rendered. It protrudes from the original front of the house, but with skilful detailing it need not be obvious. External insulation makes good sense for houses which need to rendered anyway.

In addition to price, the main consideration should be performance, and in this respect external insulation wins hands down. It covers many cold breaks and hotspots on the wall. Because the insulation is on the outside, the entire wall operates as a heat store, reducing variations in the internal temperature. There are so many advantages to having a high thermal mass in a building, that this is the best insulation method for a full eco-house.

At the rear of the house we increased the insulation further by building the flower bed right up to the level of the windows. We sealed the outside wall with bituminised paint to make a dampproof membrane. We then laid tiles, taken from the demolished extension, interlocking like a vertical roof, to protect the sealed wall and act as a root barrier. The bed was then filled with earth. This form of insulation, known as berming, appears in many new build eco-houses.

INSULATION: **YELLOW HOUSE- WALL INSULATION**
For all the above reasons we decided on external insulation for the existing walls which were badly scarred by the disastrous stone cladding and needed to be rendered. What is more, external insulation is the only effective insulation for our concrete block walls which are of a curious construction in which every second block crosses the cavity. These crossing blocks operate as cold bridges and will greatly reduce the effectiveness of any cavity insulation. The southwest facing front wall was faced with 50mm PIR foam sheets, the northeast facing rear wall was faced with 70mm sheets. Both were then covered with lathe and rendered. With additional insulation the walls achieved u-values of 0.3 and 0.23 respectively compared with 0.45 required by building regulations.

The new external walls of the extension were constructed from standard 100mm concrete blocks on the outside, a 75mm cavity filled with glassfibre batts, and 150mm concrete solar blocks in the inside. It is worth noting that concrete solar blocks, which cost 50% more than conventional concrete blocks, have 10 times greater insulating quality. Standard 100mm concrete blocks with cavity insulation which would have been sufficient to meet building regulations but the decision to use the thicker solar blocks on the inside nearly doubled the insulation performance of the wall.

INSULATION: **FLOOR INSULATION**
The main source of heat loss through floors is draughts, and the greatest energy savings are likely to be made through carefully sealing filling all gaps in the floor and skirting boards (more on draughts).

In the Yellow House we dealt with the three forms of floor - suspended wooden floor, new concrete slab floor, and old concrete slab floor - each of which required a different form of insulation.

Suspended floors are usually insulated with glass or mineral fibre hung between the floor joists. In some older houses the floor joists have been laid on bare earth, in which case insulation (wool or loose fill) can simply be packed around the joists. The floor in the front room of the Yellow House is suspended over a 1.5 metre void - surprisingly large - so the netting could be attached from underneath the floor without pulling up the floor boards.

The kitchen floor was concrete poured direct on the earth. It was a shoddy building technique for the 1930s and it was not surprising that the floor was sagging in the centre. There are two options for uninsulated solid floor; build a new insulated layer on top or rip it up and start again. Because the kitchen floor is at the centre of the house it is a relatively minor source of heat loss, so we decided to keep it. Adding a new layer of insulation would have created an ugly and dangerous step up to the kitchen, but as a compromise we covered it with 4mm cork tiles. The rise in floor level is undetectable, but even 4mm of cork is useful insulation. As a material cork performs as well as any standard industrial insulation of the same thickness.

We decided to dig up the old concrete floor in the old extension and start from scratch. We laid 50mm expanded polystyrene sheets on top of hardcore with screed on top. We doubled the thickness of the sheets along the external walls which is a cold bridge area.

INSULATION: **WINDOWS**
There is no avoiding the fact that windows are a mixed blessing - they let in light and sun and are a key component in an environmental home, but they are also require large holes in the insulated envelope of the house. Even the best performing windows lose five times as much heat as the same area of wall.

There are four strategies for reducing the heat loss through windows:

1. placement according to the sun. As far as possible, consider the movement of the sun when putting in new windows. An eco-house will concentrate its windows on the sunny south side and minimise the windows on the cold north side. (More on solar orientation...)

2. use skylights for light, windows for sun. On all but the sunniest days, diffused daylight is reflected downwards through clouds. Skylights function far better for catching this daylight. On the north side of the house, where the emphasis is on minimizing glazing, preference should be given to skylights where possible. Vertical windows are better for catching direct sunshine. They maximise the low winter sun- between November and March the noon sun is never more than 30° above the horizon- and progressively block the sun as it rises higher in the sky into the summer. Skylights have the unfortunate quality of being poor at catching winter sun, and very effective at catching summer sun- which is why glazed roofs and south facing rooms with skylights often overheat. (More on solar orientation...)

3. use low heat loss windows. There is an enormous difference between different types of windows- the chart below shows the level of heat loss (called the u-value) of different types of frame and glazing:

	U-VALUE (heat loss per square metre)
Single glazed, solid metal frame	5.6
Single glazed, wood frame	4.3
Double glazed, solid metal frame	3.9
Double glazed metal frame with thermal break	3.2
Double glazed wood frame	2.5
Double glazed wood frame, argon and low-e glass	1.6
	Explanation of u-value...(below)

As these figures show, the kind of frame is almost as important as the glass. Double glazed windows with solid metal frames are scarcely much better than single glazed windows with wooden frames. Many of the aluminium replacement windows fitted in the 1980s, including those in the Yellow House, are of this type and may have severe condensation problems on the inside of the frame. Sadly, if you want an energy efficient house you may well have to replace them again. Although metal windows should be avoided, well designed PVC windows have a similar performance to wood. However, the manufacture of PVC is extremely polluting, and they can age badly. Our advice is: ignore the sales talk about savings on maintenance - get good wooden frames and look after them.

The new generation of low energy glazing has argon gas in the sealed cavity between the panes, which has far better insulation qualities than normal air, and low emissivity glass on the inner pane which reflects heat back into the room. Pilkington K is the UK market leader in low-e glass. This low energy double glazing performs as well as triple glazing, and matches the heat loss of a standard 1930s uninsulated brick cavity wall (they both have a u-value of 1.6). It does not cost much more, and it is well worth paying the little extra (the glazing for four windows and three doors in our **extension** only cost £60 more than standard double glazing).

INSULATION: **4. curtains and blinds**
Normal loose hanging curtains make surprisingly little difference to night time heat loss. But then why would we expect a few sheets of cloth to make much difference, after all a tent isn't exactly easy to keep warm on a freezing day. The reason curtains appear to make a difference in old houses is that they block draughts, and they make the room "feel cosy". Realistically, though, it makes more sense to draught proof windows and improve the glazing. Curtains are more a matter of taste than efficiency.

It is important to note that curtains can also be positively harmful to energy efficiency if they are hung over radiators. Heat rising from the radiator can be trapped uselessly behind the curtain - heating the glass and little else.

Ecodesign books sometimes talk of "insulating curtains". These would have to be home-made (we've never found a manufacturer in the UK, but list one in the US) curtains of insulation sewn between fabric. In order to avoid downdraughts from the window they must fit snugly into a pelmet at the top and a tuckslot at the bottom. In theory an insulating curtain with 60mm mineral wool reduces the u-value of a double glazed window by 75% to 0.6. However they very hard to clean, and there are potential health issues with sharing a living space with mineral wool. A better option might be to convert old duvets into curtains, or make insulation shutters from timber and insulation sheeting. Our feeling is that all these options represent a major intrusion into the living space and are not appropriate for a normal house - though they would be justified in a solar house where there are very large areas of glazing.

Blinds are of greater use than curtains for insulation. Any blind installer will sell insulating fabric which has a reflective backing, though none seem to be able to give information on the actual performance of these materials. Insulating blinds are only effective when they tightly fit guide rails which discourage downdraughts. Where they come into their own is for blocking the heat of direct sunlight in summer. South facing skylights and conservatories, such a great asset in winter, can become a menace in summer without shading. The best shading is external - overhangs and external blinds. Otherwise, internal blinds are a great help, and again blackout blinds with guide rails are the most effective. We fitted the Velux skylights with the Velux own brand blackout blinds - although expensive we could not find a cheaper source of comparable value.

A final word on blinds: the much maligned Venetian Blinds are wonderful for eco-houses. They are the only window covering that can provide privacy, allow a view out and allow in almost all direct sunshine. What is more you can precisely control the degree of closure and the amount and the direction of sunlight. They have no insulating quality, but then neither do net curtains which create privacy by blocking out the view and most sunlight.

INSULATION: **WINDOWS IN THE YELLOW HOUSE**
All the windows and doors in the extension and all the skylights in the roof were the high performing

combination of Pilkington K glass with argon in the cavity. All frames were plantation pine. We found that it was far cheaper to order the components (frames and glass) separately and then pay a builder to fit them than to bring in a specialist window company.

The skylights in the mezzanine are both placed high on the South West facing roof to maximise solar warming. The larger skylight (196 x 114) is a central pivot to allow cleaning and is positioned to allow a view over the fields opposite. The smaller skylight (196 x 86) is positioned as close to the ridge as possible to pull hot air from the house during the summer through the stack effect. It has a top pivot to allow protect the desk below from rain. This skylight also has a Velux insulating blind to control solar gain in the summer. We also close it on frosty nights in winter. We could find no option to buying the Velux own brand blinds which are rather overpriced but well made.

The existing windows and front door were double glazed, but the aluminium frames had no thermal break. In winter they positively sucked the heat out of anyone who stood in front of them. By morning they were dripping with condensation. Fire regulations insisted that the side light in the front bedroom window was widened and this provided the excuse we needed to bite the bullet and replace both front windows with the same specification as the extension. Again it was cheaper to buy the components and pay the builder to fit them. Both front windows have full width venetian blinds.

The two back bedrooms still have the old aluminium windows which will be changed in the next two years. The front door will be replaced in 2002 as part of the new front porch.

INSULATION: **INSULATION INSTRUCTIONS FOR BUILDERS AND ARCHITECTS**
Builders and architects usually try to achieve standards of insulation that comply as closely as possible to the current building regulations. These standards are very low by European standards and can very easily be increased substantially without relatively low cost. Certainly if you are having new building work done it makes far more sense to spend a little extra on insulation when you have the chance- the returns in comfort and energy savings pay off immediately.

When looking for a builder ask for two quotes; one for the standard job to comply with current building regulations, and one for the better insulated version aiming for the values in the chart below. Even these were easy to exceed in the Yellow House. In many cases the additional cost should only be the extra materials. For example, a 100mm sheet of expanded polystyrene insulation will cost 60% more but entail no extra labour. It is possible to double the performance of external walls by using solar concrete blocks and filling a wider cavity- again no increase in labour is involved.

U VALUES TO AIM FOR IN AN ECO-HOUSE				
	Typical property	2000 Building Regulations	u-values to aim for	Yellow House
External Walls	0.46 to 2	0.45	0.3 or less	0.23
Windows, doors, skylights	3 to 5	3.3	2 or less	1.6
Flat/sloping roof		0.35	0.2 or less	0.15
Insulation in unconverted loft with a pitched roof	0.37-1.6	0.25	0.2 or less	0.2 (behind mezzanine)
Insulation in loft conversion		0.35	0.25 or less	0.2
Ground floors		0.35	0.25 or less	0.2
				Explanation of u-value...(below)

INSULATION: **MORE ON U-VALUES: CONDUCTIVITY, RESISTIVITY**
Each material has a different capacity to transmit and radiate heat, known as its Conductivity, which is measured as the watts of energy transmitted by a cubic metre of material (one square metre in area and one metre thick) per degree centigrade difference in temperature between the two sides. The

conductivity of a material is given as a k value, (confusingly also sometimes written as the Greek symbol l pronounced "lamda"). This is written as W/m°K or W/m°C (watts per metre per degree temperature). A comparison of k ratings gives a good idea of the relative conductivity of different materials. The lower the k rating of a material, the less energy it can transmit and therefore the better its insulating quality. We can apply this to two common materials at opposite ends of the conductivity scale; concrete and fibre glass

• Concrete has a high conductivity with a k of around 1, which is to say that one square metre of a block of concrete that is one metre thick will transmit 1 watt of energy when there is 1 degree difference in temperature between its two sides. If there were a temperature difference of 10°C between the sides, it would transmit 10 watts.

• Fibre glass, a high performance insulating material, has a k rating of 0.035. That is to say that a metre thickness of fibre glass transmits nearly one thirtieth as much energy as concrete.

A k rating is based around the standard thickness of one metre which is useful for making comparisons between materials, but fails to take account of varying thickness of materials. Resistance, expressed as R value, shows the performance of one square metre of material in the thickness actually used. R is calculated as the thickness of the material in metres divided by the k rating. It is written as m2°K/W or m2°C/W, the area of a given material required for it to transmit one watt of energy for a one degree temperature difference between its two sides. If we apply this to the examples above:

• A standard 75mm thick concrete block with a k rating of 1 will have a resistivity of 0.075metres divided by one, which would give an R of 0.075.

• A standard cavity wall filling of 50mm of fibreglass with a k rating of 0.035 would have an resistivity of 0.050 metres divided by 0.035, giving an R of 1.42

R gives us the resistivity - the capacity of a material to resist the transmission of heat. However what we need to calculate heat loss is the inverse of this- its capacity to transmit heat. This is given by the final and most important term on the heating designers lexicon, the u-value. The u-value is easily calculated by dividing one by the R value. This is written as W/m2°K or W/m2°C and is the watts of energy transmitted by a square metre given a one degree difference in temperature between its two sides. Don't worry about the confusion between C and K - they are both the same unit of temperature in this case. If we apply this to the examples above:

• The u value of the concrete blocks is one divided by 0.075, which is 13.3. This is to say that one square metre of concrete blocks will transmit 13 watts of heat if there is one degree temperature difference between its two sides.

• The u value of the 50mm fibreglass wall filling is one divided by 1.42, which is a u of 0.7. One square metre of 50mm fibreglass will therefore transmit only 0.7 watts of energy (assuming, again, a one degree temperature difference).

To work backwards and convert a u-value into an R value, you need to divide one by the u-value. Thus, if you knew that the u-value of the fibreglass was 0.7, its R value would be 1 divided by 0.7, which would take us back to an R of 1.42.

Although a given thickness of any material can be given by both R values and u values, in practice R values are used to rate the thermal performance of individual materials, whilst u-values are used to rate the performance of the final combinations of materials such as in a wall.

A typical external wall may be composed of four to five layers: two layers of blocks or bricks on either side of a cavity (filled or empty), with a final layer of plaster or render on one or two sides. To calculate the R-value of the entire wall we need to add together the R values for each thickness of material. To calculate the u value of the entire wall we then divide one by this combined R value. For example:

• Consider a simple cavity wall composed of the two materials already used in the examples above;

two layers of 75mm concrete blocks surrounding a cavity of 50mm of fibreglass. The first step is to combine the R values: 0.075 (block) + 1.42 (fibre glass) + 0.075 (block). The total R value is therefore 0.185. The u- value of such a wall would therefore be 1 divided by 1.57, which is 0.64.

Note that there is no shortcut in this process. It is not possible to get a combined u-value by simply adding together the individual u-values. So, if you knew the R value for the concrete and the u-value for the fibreglass, you would have to work backwards, calculate the R value of the fibreglass, and then calculate the combined u-value from the sum of the R values.

Summary
There are three ratings for heat transmittance: the k-value, the R value and the u-value. The K value gives the comparative conductivity of materials of one metre thickness. R value gives the resistance of a specified thickness of material. The u-value gives the heat loss of one square metre of a specified thickness of combined materials. In each case the value given is for a difference on temperature between the two surfaces of one degree centrigrade.

TYPICAL HEAT TRANSFERENCES OF DIFFERENT MATERIALS				
	k	typical thickness (mm)	R	u
Brickwork	0.84	100	0.12	
Concrete Blocks	1.12	100	0.09	
Solar concrete blocks	0.11	100	0.9	
Clinker blocks	0.36	100	0.21	
Plasterboard	0.16	12.5	0.06	
Plywood	0.14	18	0.07	
Chipboard	0.11	18	0.8	
Timber	0.14	100	0.71	
Unventilated cavity			0.18	
Plaster/render	0.5	2.5	0.03	
Celotex PIR insulation	0.019	50	2.63	
Fibre glass/mineral wool	0.035	50	1.43	
Thermal board	0.02	3	0.15	
Brick & concrete block Cavity wall				0.6
Tiled roof with no felt				0.53
Tiled roof with felt				1.9
Single glazed window				4.5-5.5
Double glazed window				2.5-3.5
Solid timber door				3
U values for Windows.. (above)				