Principles of eco-design for houses

from http://www.theyellowhouse.org.uk/ by George Marshall

Much more info can be found on the website itself!

From all the many theories behind environmental design, this section pulls out just five core ideas. They are all important, and they provide the tools for approaching most design challenges. There are also some excellent books that talk in far more detail about these concepts

PRINCIPLES OF ECO-DESIGN: 1. WORKING WITH THE SUN
The contribution of the sun to a house's internal heat is called the solar gain. A fundamental principle of solar design is that it aims to maximise the solar gain in the winter and minimise it in the summer. To achieve this solar design combines three strategies- glazing, orientation, and thermal mass.

Controlled glazing is the vital component of environmental design. Glass allows 90% or more of the energy in the suns rays to pass through and then traps the resulting heat. Glass can let in indirect daylight (so we can avoid using electric lights) whilst keeping out draughts.

However, there are problems with glass too. It is a very poor insulator - a sheet of glass has about the same insulating power as a sheet of hardboard. Double glazing is twice as good (or half as bad) because the small air gap between the sheets of glass is a good insulator. Even so, double glazing still only has the insulating power of a single layer of bricks. As long as the sun is shining through the glass, it is receiving more energy from the sun than it is losing through heat loss. When the sun sets the glass find it hard to hold in that heat and starts undoing all its gains.

So the use of glass is a juggling act - having enough glass to benefit from the free heat of the sun, enough glass to let in plenty of daylight, but not so much that the house overheats during sunny days and freezes at night. There are two keys to this problem- orientation and thermal mass. Orientation first:

PRINCIPLES OF ECO-DESIGN: Orientation
Orientation refers to the location of a house and direction to which a house points. Orientation is crucial for determining the amount of sun a house receives, because the direction and height of the sun in high Northern latitudes like Britain changes dramatically throughout the year. On the 21st December, the shortest day of the year, the sun can barely be bothered to get up at all. It rises at 8.30 in the South East, drags itself barely 12 degrees above the horizon in the South at noon, and sinks exhausted at 3.30 in the South West. On the 21st June, in contrast, it bursts out of bed at 4.45am. By 6am it is already higher than it was at noon in December, and it keeps rising higher until by noon it is over 60° in the sky. The day is also correspondingly longer- 17 hours. From these seasonal changes we can draw three conclusions that effect all solar design.

1. Only surfaces facing South receive sun all year round. The dominant direction of the sun is from the South, especially in winter. For this reason, solar panels and windows that will capture solar warming in winter, should face as close to South as possible. Solar receipts start to fall noticeably outside the band South-South-East to South-South-

West. Surfaces facing South-East or South-West receive 10% less solar energy during the year than surfaces facing due South.

2. Surfaces facing North are in the shade all year round. Whilst most sun is received in the arc South East to South West, the adjacent quadrant, North-East to North-West, receives very little sun except at the peak of summer. For this reason solar design concentrates insulation and minimises glazing on this side of a house. New build solar houses often bury this side of the house in the ground and put all glazing on the South side of the house.

3. The winter sun is low, the summer sun is high. Vertical South facing windows work best for maximising solar heating in the winter as they capture the low winter sun. Some solar houses even have their windows angled 11 degrees back from the vertical to perfectly face the winter sun.

For the same reasons, surfaces that are more horizontal receive most of their sun in the summer. This is a problem for glazed roofs and skylights which receive little sun in winter but may well overheat rooms in summer. They usually need special shading or air vents. The angle which receives the most sun across the year is, not surprisingly, 45°. For this reason it makes excellent sense to mount solar panels flush with a pitched roof.

The high summer sun is a blessing when if comes to designing shading for vertical windows. Only a small overhang is needed to completely shade a vertical South facing windows in summer. This is another strong argument for maximising South facing glazing. East and West facing windows can be a huge nuisance in summer. They receive no direct sun in winter, but they fully face the low evening and morning sun in summer. West facing rooms are particularly prone to overheating and will need curtains or shades.

We can sum up these principles to say: a well functioning eco house will have as much of its glazing as possible in vertical windows facing between South East to South West, and as few windows as possible facing North East through to North West .

PRINCIPLES OF ECO-DESIGN: Solar principles in existing houses

Of course, very few people have the opportunity to build a new eco-house and apply these principles fully. We are stuck with the houses we've already got, which meet solar principles by accident rather than design. However, there are still ways that we can apply the solar principles to existing houses:

1. When buying a house. An unshaded South facing roof is needed for solar panels. The ideal house is one that faces North in the front and has unshaded South aspect at the back- this opens up all kind of creative options for conservatories and solar extensions on the private rear side of the house. Solar panels can be attached to the roof without affecting its appearance on the street side. A South facing front is less useful but it is still possible to build a good sun porch. Be careful to avoid South facing houses with large areas of glazing on the North side.

2. When building extensions, porches and conservatories. There is a lot more design flexibility when building new structures, which can fully apply solar design principles. Whether a conservatory is an asset or a drain on the house's energy depends entirely on its design and orientation.

3. When fitting new windows. New windows should be positioned according to solar principles. On the North side of the house, windows should have a lower glazed area and preference given to skylights to bring in as much daylight as possible. On the South side, vertical windows should have as large an area of glazing as possible. Skylights on the

South side should be sized carefully.

When fitting new windows there is a rare opportunity to make changes to overall window size and shape. Reducing the size or blocking in a window is relatively easy, though careful attention needs to be made to insulation. It may be possible to achieve energy savings as large by replacing the existing window with high performance windows. It is a relatively easy matter to expand a window downwards by knocking out the wall under the existing window.

PRINCIPLES OF ECO-DESIGN: 2. THERMAL MASS

The thermal mass of the house is a measure of its capacity to store and regulate internal heat. Buildings with a high thermal mass take a long time to heat up but also take a long time to cool down. As a result they have a very steady internal temperature. This is sometimes called the thermal flywheel effect because, like a flywheel, the thermal mass can store and even out fluctuations in temperature. Buildings with a low thermal mass are very responsive to changes in internal temperature- they heat up very quickly but they also cool down quickly. They are often subject to wide variables in internal temperature.

Everything inside the house contributes to its thermal mass according to its capacity to absorb and store heat, known as its 'thermal capacity'. The best materials for storing heat are those that are very dense, heat up slowly, and then give out that heat gradually. Brick, concrete and stone have a high thermal capacity and are the main contributors to the thermal mass of a house. Water has a very high thermal capacity, so it is well suited to central heating systems. Air has a very low thermal capacity- it warms up fast but cannot stay warm for long. Only when the walls and floors in a building have warmed up will the air stay warm.

Eco-buildings are usually designed to have a high thermal mass for several reasons:

1. To hold over daytime solar gain for night time heating. A high thermal mass balances out the fluctuations in temperature that come from solar gain, soaking the extra daytime heat into the body of the building and releasing it slowly at night. The flywheel effect is most pronounced when the suns rays hit a wall or floor with high thermal capacity. For this reason eco-buildings are often designed with a dark coloured solid masonry wall and solid floor behind South facing windows.

2. To keep houses cool during the day in summer. A high thermal mass will reduce fluctuations in internal temperature during the summer. If a house has good ventilation during the night, its thermal mass can be cooled and it can then maintain that cool interior through the heat of the following day. In the extreme case of desert regions where daily temperatures can vary by up to 40°, traditional houses are usually designed to have extremely thick walls to moderate the internal temperature.

3. Increase the efficiency of a central heating boiler. A high thermal mass favours small boilers working at maximum efficiency, slowly and steadily raising the temperature of the building and then turning themselves off for sustained periods. Buildings with a low thermal mass, by comparison, tend to have much wider fluctations in temperature, and the boiler is constantly switching on and off to compensate.

PRINCIPLES OF ECO-DESIGN: Thermal mass in existing houses

The positioning of exterior wall insulation can affect the thermal capacity of a house significantly. Only the building mass on the inside of the insulated envelope functions as a heat store. When cavity insulation is installed the thermal mass of a wall is halved, though the impact this has on overall on performance is slight. The impacts become more significant for internal insulation which removes any useful thermal capacity from a wall.

Thermal mass can be increased when there is new building. In an extension, for example, thermal capacity can be increased by pouring a concrete slab over insulation and by finishing the floor with stone paving or tiles rather than wood or carpet. This makes particular sense in situations where sunlight is directly shining on the floor. The thermal capacity of a wall can be increased by painting it a dark colour. This is standard practice in eco-buildings and can easily be replicated on walls opposite South facing windows. Internal walls behind radiators can be encouraged to store heat by painting the back of the radiator and the wall behind it a dark colour (black is best).

PRINCIPLES OF ECO-DESIGN: 3. STACK EFFECT

When air warms it expands, becomes less dense than the surrounding air, and rises. This process is called convection and is the main process by which heat moves around a room and the house. When rooms are sealed, convection is a sealed circuit of hot air rising over radiators and then sinking as it cools to be heated again.

In reality, though, we don't want rooms or houses to be fully sealed; ventilation with fresh air is vital in a healthy house, and convection plays a leading role in natural ventilation. Hot air rises and escapes through small gaps in the building fabric at the top of the house. As it does so it draws in new cold air through similar gaps at the bottom of the house. The powerful suction created by escaping warm air is called the stack effect, or sometimes the chimney effect because it is the same process that draws smoke up a chimney or smokestack.

Like many other environmental principles, the stack effect can either be a problem or an opportunity. It is the main motor generating draughts and the loss of hot air; and often the largest single cause of heat loss in a home. It requires particular attention when draughtproofing a house. However, when carefully controlled it can produce a low and effective level of natural ventilation. If respected and built into the house design, the stack effect is by far the most effective way of keeping a house ventilated in summer. Over the past ten years environmental building has paid increasing attention to generating a stack effect to create natural ventilation, especially in large buildings. In a typical design tall chimneys at the top of the building create a powerful draw and fresh air is pulled into the building through specially placed controllable vents around the outside wall.

PRINCIPLES OF ECO-DESIGN: Stack effect in existing houses

In existing houses particular attention needs to be paid to the role of the stack effect in creating draughts and heat loss. A thorough draughtproofing must pay particular attention to places at the top of the house where hot air can escape.

The stack effect can be utilised in any house to support ventilation and summer cooling by providing easy routes for air (vents vetween rooms, doors open during the day) and providing adjustable vents high in the house..

PRINCIPLES OF ECO-DESIGN: 4. THERMAL ZONING

We like different temperatures in different rooms- we like bathrooms to be very warm, living rooms to be a comfortable cosy temperature, and bedrooms to be cooler. An efficient eco-house recognises these differences and creates different thermal zones for the different rooms.

Hot zone	20-23°	Bathrooms, airing cupboards, rooms for drying clothes, kitchen
Warm zone	18-21°	Living rooms, study, children's bedrooms
Cool zone	16-18°	Adult bedrooms
Cold zone	under 16°	Rooms that are not in use, storage rooms, garage, basement

These are approximate figures for living temperatures. There are very great energy savings to be made from cutting just a couple of degrees off these temperatures. We live at the low end of these ranges and find that the maximum temperature we need is 19 degrees.

Thermal zoning tries to ensure the best match possible between the distribution of rooms and the distribution of the available heat. The ideal thermal zoning is:

- Hot zone
  The ideal place for hot rooms is in the very centre of the house, with no external walls so that the heat can radiate out into the rest of the house. The next best option is with a South facing window (which may be better for a bathroom where natural lighting and good ventilation is desireable.

- Warm zone
  The main living rooms need constant warmth and light and are best placed on the South side of the house with large windows and good thermal capacity to hold any thermal gain through the evening. Kitchens can generate a great deal of heat. The ideal location for a kitchen is therefore facing into the centre of the house, with the cooker placed on an internal wall.

- Cool zone
  Adults tend to make little use of bedrooms except for sleeping and do not need to be especially warm. In a well insulated house a large part of their heating can be supplied by warmth rising from a well heated room below. Adult bedrooms can be placed on the cooler side of the house. However, they need good light and an easterly window or skylight is preferred.

- Cold zone
  Little used rooms are best located along the colder and darker North side of the house. Rooms that need to be heated occasionally, such as a spare bedroom, perform better with a low thermal capacity with insulation on the inside of the room. Storage rooms need to be kept dry but heat, light, and thermal capacity are of little concern, though the preference is for constant cool temperatures. Basements and rooms under the stairs, if dry, are perfect for storage. Durable items can be stored outside the insulated envelope altogether- such as under the eaves or in unheated sheds. In both cases the main concern is keeping them dry.

PRINCIPLES OF ECO-DESIGN: Thermal zoning in an existing house
Thermal zoning is an important consideration in newly designed environmental houses. However, in an existing house the configuration of rooms was decided by the original architect or builder. One has to adapt to the existing layout, deciding which rooms are used, and which bedrooms are used for adults, and children.

There is more opportunity for applying thermal zoning for changes in room use or new building. In the Yellow House, thermal zoning was a major consideration in the decision to place the new bathroom, the utility/drying room and the kitchen at the centre of the house.

PRINCIPLES OF ECO-DESIGN: 5. EMBODIED ENERGY
If we want to reduce the total environmental impact of a building, we must consider the impact of the materials that have gone into its construction. Clearly no house can claim to be an eco-house if it is constructed from materials that had a major environmental impact elsewhere.

For these reasons, the concept of embodied energy is central to good environmental design. The embodied energy of a building material is the energy that has been required to extract, process, and manufacture it and then to transport it to the building site. The embodied energy in the structure of a new house is considerable, exceeding the total energy required to heat that house for the next 20 years.

In terms of the energy of manufacture, the highest embodied energy is found in metals (steel requires 57,000kWh to produce one cubic metre), and highly processed industrial products (hardboard and MDF require 2,000 kWh to produce 1m3). The middle range of materials are simpler to make but require a lot energy in their manufacture (bricks and concrete blocks need 700kWh/m3). The lowest embodied energy is in materials that require only simple processing (building timber needs 180kWh/m3) or those made from salvaged materials or local natural materials, which require virtually no energy.

The issue of embodied energy divides new eco-buildings into two distinct families. One kind of eco-building aims to obtain the lowest possible energy consumption with the most efficient available technology, such as high performance insulation and solar panels. Such buildings have a high embodied energy which they hope to justify with large savings in their energy consumption, or even to generate and export a surplus of energy. The other kind of eco-building aims to achieve the lowest possible embodied energy by using salvaged materials or simple local materials (straw bales, rush matting, mud bricks). Such buildings will usually perform less well in terms of annual energy consumption, and are less durable, but often have a lower overall environmental impact over the course of their lifespan.

Embodied energy is usually a good guide to wider environmental impacts, especially for toxic waste and atmospheric pollution. There are two main exceptions to this:

Cement and Concete, which has a mid range emobodied energy, but a disproportionately high impact on climate change. When limestone is burnt to make lime it releases an equal weight in carbon dioxide. Taken as a whole, the cement industry produces 5% of the worlds human carbon dioxide emissions.

Timber has a low embodied energy, but can have a very high environmental impact if taken from old growth forests.

PRINCIPLES OF ECO-DESIGN: Embodied energy in an existing house
Renovating an existing house will always use less energy than building a new house. Even if a new house is extremely energy efficient, it will be many years before it can pay off the energy embodied in its structure. An existing house, by contrast, will only have to justify the embodied energy of the materials used for the renovation. There are plenty of ways that the energy cost of renovations can be reduced still further.

- Avoid materials that have the highest embodied energy. Glu-lam laminated wood beams will perform as well as RSJ steel beams with a tenth of the embodied energy. At a pinch concrete lintels are better than steel. Hardboard, MDF and chipboard are bonded with formaldehyde and are best avoided altogether and replaced with real wood, if grown sustainably.

- Use salvaged materials. Salvaged materials effectively have no embodied energy other than transport and should be used whenever possible. They can be obtained from local demolition sites or council dumps. Most salvage yards sell timber, tiles, bricks and slates .

- Use local raw materials in any new building. For new building (such as extensions), use local materials such as local stone, straw bales, mud bricks, etc and prepare them on the site. The Centre for Alternative Technology has many books on these eco-build techniques.

PRINCIPLES OF ECO-DESIGN: SIX PRINCIPLES FOR MAKING PRIORITIES
Text books on ecological building are full of illustrations of mud brick and adobe houses, straw bale walls, insulation from old newspapers, compost toilets. All well and good, but in the real world we are faced with a set of external considerations that temper such fantasies: can I afford it; will it pass

building control; will anyone ever want to buy it? So, a sense of proportion is vital. Here are six principles that can guide all your decisions.

ONE: THE BEST MATERIALS ARE RE-USED

TWO: ENERGY CONSERVATION HAS PRIORITY IN THE ECO-HOUSE

THREE: ASPIRE TO SELF SUFFICIENCY

FOUR: LIVE LIKE GRANNY!

FIVE: IF YOU DO IT NEW, DO IT WELL

SIX: RESPECT THE ECO-HOUSE NO-NOS

PRINCIPLES OF ECO-DESIGN: PRINCIPLE ONE: The best materials are re-used
We must be clear that so called "environmental" materials are not actually good for the environment, they are merely less damaging then non-environmental materials. So, re-used materials will almost always be the best option, even when they are materials that would otherwise be seen as a poor environmental choice (lead, PVC, rainforest plywood).

There are three inarguable reasons for re-use. Re-use avoids the hidden environmental costs of materials including transport; it reduces waste (building waste is the main content of landfills yet recycling schemes concentrate on domestic waste) and it can be substantially cheaper than buying new materials.

The only reservation about reuse concerns products that directly consume energy, especially heavy energy consumers such as boilers, cookers and fridges. There is a point at which it is better to replace an old inefficient product with an energy efficient new one. If they are old, and a more efficient product exists, replace them.

PRINCIPLES OF ECO-DESIGN: PRINCIPLE TWO: Energy conservation has highest priority in the eco-house
There are many ways we can reduce our environmental impact. However, we should be absolutely clear- the greatest environmental impact of the average house is from the fossil fuels it burns for its energy. No amount of eco-certified bamboo flooring or low phosphate washing powder can ever compensate for the impact of climate a gas guzzling house. So, when there is a limited budget and a conflict of interest, prioritise energy conservation. And, there is the added bonus: saving energy saves money.

PRINCIPLES OF ECO-DESIGN: PRINCIPLE THREE: The eco-house aspires to self sufficiency
The more that a house can meet its own needs, the less of a demand it is making on the wider environment. Examples of self sufficiency technologies include: solar space and water heating; using waste grey water and rain water; saving and reusing waste heat; electricity generation from windmills and solar panels; food production from the garden or local allotment. A house that reduces its consumption is a highly efficient low-cost house, but a house nonetheless. It is when the house starts meeting its own needs that it becomes a true eco-house.

PRINCIPLES OF ECO-DESIGN: PRINCIPLE FOUR: Live like granny
Our grandparents were brought up in a world in which electricity was expensive and not to be taken for granted; cars were a luxury that virtually no one could afford; all bottles and jars were recycled; all food was organic; local communities were strong and crime rates were lower than we can imagine. We could do a lot worse than living like our grandparents- mending our clothes before we throw them out, turning off lights when we leave the room; getting a "work-out" on the allotment, riding a bicycle to work, enjoying simple pleasures.

PRINCIPLES OF ECO-DESIGN: PRINCIPLE FIVE: If you do it new, do it well
This is another Granny principle - if it’s worth doing, it’s worth doing well. When you do work on

the house, spend the extra to do it to the highest possible standard of craftsmanship. If you buy a new appliance or boiler, buy the best you can afford. If you can’t afford to do it well, hold off until you can. Shoddy work and cheap products are always a false economy and a waste of resources.

PRINCIPLES OF ECO-DESIGN: PRINCIPLE SIX: Respect the eco-house no-nos

There are some things that fail so many environmental criteria that they can be declared out of bounds for any eco-house. They are:

- Rainforest and timber from intact ancient forests
- Large single glazed windows on North facing sides
- Heated conservatories or garages
- Gas patio heaters
- Curtains draped over radiators
- Electric clothes dryers
- Heated out-door swimming pools and hot tubs
- Incandescent light bulbs