SUSTAINABLE HOMES:

EMBODIED ENERGY IN RESIDENTIAL PROPERTY DEVELOPMENT

A Guide for Registered Social Landlords

Sustainable Homes

CONTENTS

INTRODUCTION AND SUMMARY

This report was commissioned by Sustainable Homes as part of its work in promoting environmental good practice in social housing. The report has been prepared by Crane Environmental Limited.

Energy use is one of the most important environmental issues facing society. Without continuing supplies of energy we cannot maintain our current lifestyles. However, the fossil fuels (oil, gas and coal) from which we generate most of our energy are not inexhaustible, and burning them releases carbon dioxide (CO_2), one of the principal "greenhouse gases" which are thought to be responsible for global warming.

The Government is aiming to make a 20% cut in UK emissions of greenhouse gases below 1990 levels by 2010, whilst the Royal Institute of British Architects (RIBA) has stated that 'members should support the goal of reducing carbon emissions arising from building in construction and use by 30% against 1990 levels by 2010'.

In order to achieve these targets the Government is promoting energy efficiency in buildings through a number of measures including the Building Regulations, the Energy Efficiency Best Practice Programme and the Home Energy Conservation Act. It has also identified the importance of using materials more efficiently to reduce overall energy demand, stating that 'about 10% of national energy consumption is used in the production and transport of construction products and materials - embodied energy'.

This report:

- *examines the importance of embodied energy in relation to energy consumed in buildings in use;*
- *compares embodied energy figures for a range of materials and building types;*
- *suggests steps that Registered Social Landlords may wish to take in reducing total energy use of the homes they build and manage;*
- *considers the importance of embodied energy in the context of life cycle environmental impact;*
- *provides references and further reading on the subject of embodied energy.*

Generally, good practice will involve many of the following approaches, whatever the housing type:

Keeping embodied energy down

Minimising energy in use through high standards of insulation and any other practical means

Design for long life (at least 60 years and preferably more)

High proportion of recycled or recyclable materials

Using locally produced materials to minimise transport energy

Not installing ultra-high-tech equipment that offers only marginal energy savings in use

Avoiding systems with high maintenance requirements or which need frequent replacement

Avoiding systems which rely heavily on user regulation to achieve energy savings

Minimising embodied energy costs by including features from the outset

Using natural materials, as these tend to have lower embodied energy

The energy consumption associated with buildings and construction materials can be categorised as follows:

- *energy in use;*
- *embodied energy;*
- *inherent energy.*

Energy in Use

Registered Social Landlords (RSLs) are becoming increasingly familiar with the concept of energy in use – that is the energy required by the occupants of an existing or planned building, primarily for space heating, water heating and lighting – and of the need to reduce it. Reduction in energy demand through more efficient buildings brings benefits for the global environment as well as lower costs and improved quality of life for the occupants.

Buildings in use are the biggest source of energy demand in the UK, with homes accounting for approximately 30% (and offices 20%) of national energy consumption (i.e. as much as the industrial and transport sectors put together). Homes and offices accounted for the release of 579 million tonnes of carbon dioxide (MtCO_2) in 1990. It has been estimated that 20-30% of this energy demand could be saved through the application of cost-effective energy efficiency measures (HMSO 1998).

Embodied Energy

Energy is needed not only to run a building - it also takes energy to create the building products and build it. Put at its simplest, embodied energy is the energy needed to transform a product from raw materials in the ground to the final article. **The embodied energy of a building is therefore the total energy required to construct it - that is to win the raw materials, process and manufacture them as necessary, transport them to site and put them together.** It is the energy that has "gone in with the bricks" and which cannot be recovered during the lifetime of the building, no matter how efficiently it operates (but see section below on recycling).

However, product manufacturers may give embodied energy figures for their materials which take into account only some of the stages above. Clearly defined energy analysis boundaries are therefore critical in drawing useful conclusions on the embodied energy of a particular product.

Generally speaking, the more manufacturing processes a product goes through, the higher its embodied energy will be. For example, timber board materials have a much higher embodied energy than the equivalent size of rough sawn timber.

The energy embodied in new construction and renovation each year accounts for about 10% of UK energy consumption. Of this, approximately half is used in the winning and manufacture of the materials and half is used in transport (i.e. getting them to the processing plant and/or to site).

Inherent Energy

RSLs will not normally need to concern themselves with inherent energy but for clarity it is worth explaining how it differs from embodied energy. **Inherent energy is the chemical energy contained in a material – which can be released through combustion or chemical processing.** Thus the inherent energy of softwood (which can be released by burning) is high and will be much the same no matter which part of the world the wood came from. However, the embodied energy of a softwood grown and used locally will be much lower than that of an equivalent wood imported from the other side of the world. The latter will have been the subject of a great deal of primary (fossil fuel) energy used to transport it - but this is not stored in the material and is irrecoverable.

Timber and plastic contain inherent energy, whereas minerals and metals, by and large, do not.

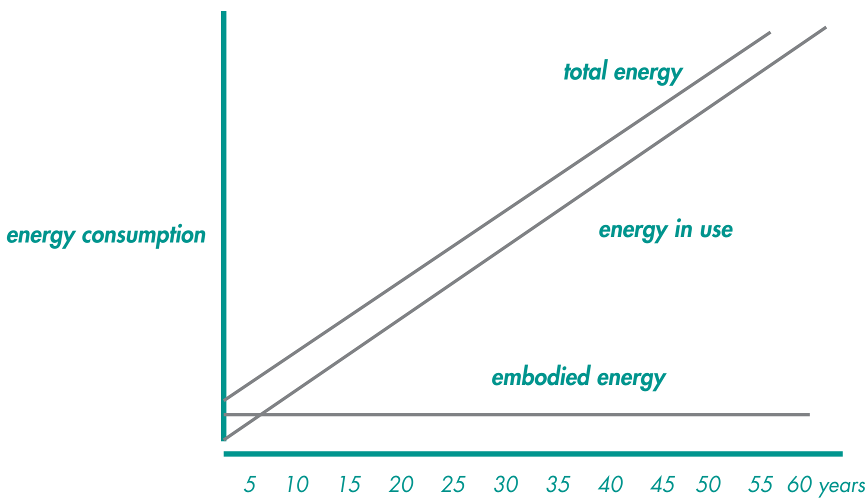
The Typical Building Energy Budget

To make sensible decisions about building design and energy efficiency, it is important to understand the relationship between embodied energy and energy in use.

As a general rule, the embodied energy of a given building will be overtaken by the energy in use fairly early in the building's life. For example, the Building Research Establishment (BRE) estimated in 1991 that, for a typical 3-bed detached house, energy in use would overtake embodied energy in a period of 2-5 years. Assuming the house had a life of 60 years before requiring major refurbishment (which is the minimum stipulated for new build by the Housing Corporation), the energy in use would exceed the embodied energy by 12-30 times.

Diagram 1 illustrates this and shows that, even with the maximum 5 year 'overtaking time' and a life of only 60 years, embodied energy accounts for only about 10% of the lifetime energy use of the building.

Diagram 1: Energy Consumption for a Typical Three-Bed House



If the overtaking time were lower and the lifetime of the house a more typical 100 years, then energy in use would be 40-50 times more significant than embodied energy (i.e. embodied energy would account for only 2-2.5% of total energy consumption).

The obvious conclusion from this example is that, **in minimising energy consumption over the lifetime of a building, reducing energy in use is far more effective than minimising embodied energy.** By and large this is a useful rule of thumb for RSLs using traditional building methods, although we discuss some qualifications overleaf.

The Energy Budget for an "Environmentally Friendly" Building

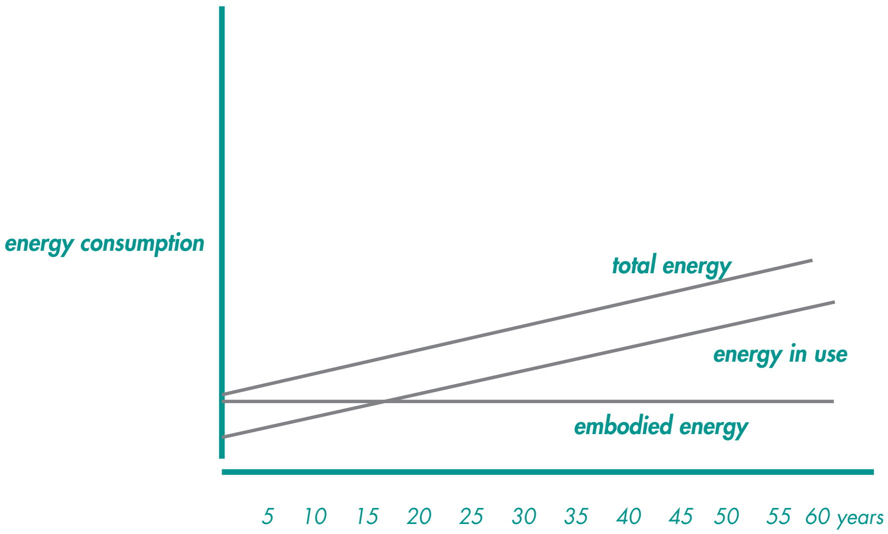
The previous example is for a typical house built to the standards required by the Building Regulations then in operation. Not only are the energy efficiency standards of the Building Regulations now more demanding, but many RSLs are voluntarily building to a higher standard still. Although detailed data for energy consumption under the new Regulations is not yet available, these changes will affect the energy budget in two ways.

i) For a given type of house, the embodied energy is likely to be slightly higher, since it will need more insulation and a slightly larger footprint to accommodate this. It may also include additional features such as heat recovery ventilation or even solar collectors and these will have their own embodied energy costs.

ii) Since the building operates more efficiently, energy in use will be less.

As a result, embodied energy becomes relatively more important and energy in use will take longer to overtake it. There are now several houses in the UK with zero demand for energy in use: that is to say, any net consumption of energy is from renewable sources such as wind and sun, rather than fossil fuels. In these cases, energy in use will never catch up with embodied energy, and the latter becomes all-important as the focus for reducing the lifetime energy consumption of the building. The energy graph for a low energy (but not zero energy) house is illustrated in Diagram 2 below.

Diagram 2: Energy Consumption for a Low Energy House



However, although the energy budget has changed, it is important to keep a long term perspective. Even if the embodied energy were doubled (which is very unlikely), the total energy consumption over the lifetime of the house will still be greatly reduced and the extra initial energy input will be recovered many times over (the commercial equation, however, may be more complex and we will examine this later on).

For RSLs, the clear conclusion is that, if energy saving is your goal, it is always better to incorporate effective and reliable features to minimise energy in use, even if this raises the embodied energy level of the house.

Although energy in use is undoubtedly more significant for most RSL developments, it is still worth reducing embodied energy **where this can be achieved without compromising performance standards or incurring other adverse environmental impacts.** In the following section we examine the options for achieving such reductions in relation to housing types and building materials.

How is Embodied Energy Measured?

The measurement of embodied energy from basic data is difficult, involving assessments of the energy expended in, for example, quarrying and crushing operations for aggregates, or oil inputs and moulding of plastics. Various methodologies are available and there is no single clear, correct and easy way to do it. Fortunately for RSLs there is no need to bother with this level of detail. In this paper we offer general guidance gathered from recent literature and provide references for those who need more information.

However, it is important when making decisions in relation to embodied energy to be sure that you are comparing like with like, and there are two particular points to note.

i) Whether you are using kiloWatt hours per tonne (kWh/t), kilojoules per kilogram (KJ/kg), gigajoules per square metre (GJ/m_2), or CO_2 equivalents, try to be sure that your information is based on "primary", rather than "delivered" energy. Primary energy represents the total energy used, while delivered energy is the energy received at the point of use and it can be substantially lower. Delivered energy data will therefore give misleadingly low figures and mixing the two will give spurious results.

ii) Another reason measurements of embodied energy may vary is that transport may have been excluded from the calculation. For materials with high bulk (e.g. timber, brick, sand etc.) transport energy will be a substantial element in the total.

If you see two different figures for the same material, it would probably be wise, for both of the reasons above, to adopt the higher one.

Embodied Energy and Building Types

Different building types have different levels of embodied energy associated with them. Generally speaking, the more "high tech" the construction method, the higher the embodied energy. It has been estimated that a timber frame bungalow has the lowest embodied energy of any common building type, whereas the most energy- expensive form is a low rise flat. This is likely to have fairly deep foundations and a concrete and steel shell (rather than structural timber), but will not have the economies of scale (which can apply to energy as well as finance) of a high rise flat.

Table 1 below gives some examples of embodied energy data by building type.

Table 1: Embodied Energy by Building Type

Type of Building	Embodied Energy		Embodied CO_2 (Kk CO_2/m^2)
	Delivered (kWh/m^2)	*Primary (kWh/m^2)*	
House	140-280	280-500	500-1000
Flat	125-220	250-360	800-1200
Office	140-280	280-500	500-1000

(One kilowatt hour (kWh) is one thousand Watts used for one hour. One kWh will boil approximately 8 kettles of water.)

However, as stated before, for the forms of construction generally adopted by RSLs, the embodied energy will soon be overtaken by energy in use. Unless it is unusually well insulated, a bungalow is the least efficient performer in use and the lifetime energy consumption of a flat is likely to be considerably lower. **Once again, the priority should normally be to minimise energy in use.**

Building Materials

It has been calculated that some 9,730 million kWh per annum were used in the production of UK construction materials in the mid-1980s. A high proportion of the energy used to manufacture these products (some 67%) was associated with:

- *aggregates - low embodied energy*
- *cement - moderate embodied energy*
- *brick and clay products - moderate embodied energy*
- *wood - moderate embodied energy (depending on source)*
- *glass - relatively high embodied energy*
- *steel - relatively high embodied energy*
- *plaster and plasterboard - moderate embodied energy*

Source: (West, Atkinson & Howard 1994)

In fact most of these materials have only low to moderate embodied energy per tonne as far as extraction and processing are concerned, but the quantities used by the industry are high. (The most energy-intensive materials include aluminium, steel, concrete and ceramic tiles.) In addition, the bulky materials, including mineral aggregates (gravel, sand, crushed rock), cement, brick and wood, are energy-intensive to move and are often moved large distances, increasing their embodied energy still further. The general rule is therefore to **buy from as local a source as possible, particularly for bulky materials**.

In Table 2 below are some examples of embodied energy figures taken from the literature for a range of materials. None of the figures for the same material group are the same and in some cases they vary quite widely. This reflects the different approaches taken by various researchers in calculating embodied energy and the difficulties in achieving a consensus. However, the ranges of figures are similar and useful conclusions can still be drawn about the various groups of materials.

Table 2: Embodied Energy of Building Materials

	Embodied Energy in kWh/tonne from 3 different sources		
Materials	*Krogh & Hansen, Danish Building Research Institute*	*Boonstra & Knapen, Netherlands*	*CIRIA 1995*
Concrete	11	17	
Cement			174 (wet process kilns) 106 (dry process kilns)
Gypsum			31-200 (plaster) 167-220 (plasterboard)
Bricks	60		76
Steel	834	473	
Softwood	144	306	195-250 (imported) 158 (indigenous)
Mineral fibres	528	389 (rockwool)	
Plastics	2224	2029 (pvc pipes)	1629 (pvc)
Glass	528		
Bitumen	278		
Paint	667		

Foundations, Basic Structure and Cladding

The lowest embodied energy can be achieved through timber frame housing, provided that the timber has not travelled too far - and in fact this can also give low energy in use. In addition, it can be built off shallow, excavated pile foundations, which are the least energy-intensive foundation type, although these are rarely used in the UK. In fact, there is little tradition of timber framing in the UK at all and home-grown construction timber of the right quality can be hard to find. However, some housing associations are now investigating timber frame as a way of bringing down development costs: if adopted, it could bring energy saving benefits as well.

Where timber frames are used for new houses in the UK, they are generally clad with brick – although greater embodied energy savings can be realised with timber cladding. Many RSLs would regard timber cladding as a fire and maintenance problem, although it is widely used in other countries.

Traditional masonry is a reasonable alternative. Ground conditions will dictate whether this is built off strip foundations or more energy-intensive driven or bored deep-piled foundations.

As far as possible, avoid the use of aluminium and high-tech claddings, which often have very high embodied energy.

Roofs

Traditional pitched timber roofs with tile or slate covering have relatively low embodied energy. Steel framed roofs are not so good and flat concrete and asphalt roofs should be avoided.

Windows

Timber framed single-glazed windows have the lowest embodied energy, but double-glazed units have a short energy payback - probably about one year. However, studies for Linacre College, Oxford, indicated that some high tech glazing systems (e.g. triple glazing with plastic frames) will never recover their embodied energy. *(Evans 1993)*

Internal Partitions

Traditional studwork and plasterboard partitions have low embodied energy, although if noise insulation is taken into account they may not be much better than a block wall. Avoid high-tech plastic and/or aluminium partitioning, not only in new housing, but also when fitting out your association's office.

Insulation

In terms of embodied energy, and indeed many other environmental measures, insulation made from recycled newsprint is excellent. However, there is still relatively little experience of using this and it is not suitable for cavity insulation in masonry buildings (although it can be used in the walls of timber buildings, where transmission of damp is not a problem and sections of insulation can be relatively easily replaced if necessary).

The next choice would be glass or mineral fibres, provided these are of low density, followed finally by foam-based products.

Whichever kind of insulation is chosen, there may be little advantage in using a thickness of over 150-200mm unless ventilation systems are fitted with heat exchangers.

Finishes and Fitout

Generally, products based on natural materials will have lower embodied energy - and will be less likely to have harmful health effects than their synthetic counterparts. Here are some examples:

Do Use:

- Linoleum
- Wool/hessian
- Paints with natural pigments
- Wood

Don't Use:

- Vinyl floor covering
- Synthetic carpets
- Synthetic pigments
- Formica, plastics

Once again, it is generally true that the more processed and artificial a product is, the more embodied energy it is likely to have. Use of alternatives with a high content of natural materials also brings benefits in terms of reduced pollution and a healthier indoor environment.

Heating

Gas-fired heating systems have much higher embodied energy than electric ones, due to the extra equipment required – but this will be recovered in about one year as a result of greater efficiency in use. Condensing boilers also have slightly higher embodied energy than traditional types, but this is also soon recovered.

Recycling of Materials

Recycling of building materials makes environmental sense - and not only by saving on embodied energy. Unfortunately, the UK track record on this is not good, with only a small proportion of demolition waste being re-used. By contrast, Danish law now requires that a minimum of 80% is re-used.

Scope for increased recycling can be incorporated into a design in two ways:

i) recycled materials can be specified for the original development;

ii) the specification can ensure that, even where new material is used, as much as possible can itself be recycled at the end of the building's life.

With RSLs now frequently involved in very large developments there may be real procurement and quality assurance difficulties in the first option and building-in recyclable materials becomes even more important. Some of the obvious candidates would be brick, roof coverings, hardcore, copper wiring and plumbing, lead and zinc, door and window furniture, and possibly even timber doors and windows themselves, subject to their condition.

Materials that are hard to recycle include concrete (except as hardcore), upvc and mixed plastics. In reality, timber is also hard to re-use on a large scale although, in theory, wholesale recycling of elements such as roof trusses should be possible.

For building materials generally, the preference should be for those that have low embodied energy, provided that energy efficiency in use is not compromised and provided that energy savings are not outweighed by other environmental impacts; (see Life Cycle Environmental Assessment).

Commercial and Energy Paybacks

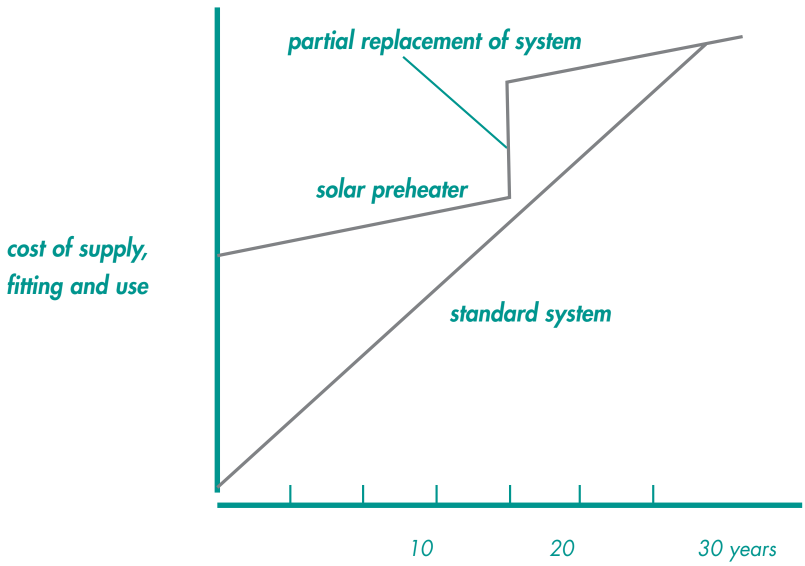
As discussed in 'The Energy Budget for an "Environmentally Friendly" building', it is possible to build a house with zero energy in use (i.e. with no input of fossil fuels or mains inputs of any kind, including water) and there are already a small number of these in the UK. Houses of this kind will have exceptionally high insulation standards, probably some kind of solar and/or wind-based heating and electricity generating apparatus and possibly a battery storage system.

However, underlying the drive towards greater energy efficiency in buildings is the problem of diminishing returns. It is easy to make improvements to an inefficient structure or design but, as it becomes more efficient, so the difficulty (and cost) of further improvements will increase. Generally speaking, the closer the "zero input" target is approached, the greater the cost and volume of building materials required, particularly if the occupants are not expected to adopt a novel or Spartan lifestyle.

For example, fitting draft stripping to a leaky old house might cost £50-100 and pay for itself in the first year through reduced fuel bills, as well as improving the quality of life for the occupants.

At the other end of the scale however, if it costs an extra £1000 to fit a solar water preheater to the roof of an already energy-efficient new house, but it only saves £50 per annum on fuel bills, the payback period is 20 years. That would be discouraging enough but, if the collector tubes needed replacing every 20 years at an additional cost of £500, then the financial payback period would be 30 years. In purely commercial terms, that would not represent good value, particularly given that the £1000 is a capital cost which, strictly speaking, should also include rolled up interest, whereas the fuel savings will only accrue over time. This example is illustrated in Diagram 3 below.

Diagram 3: Financial Payback for a Solar Water Preheater



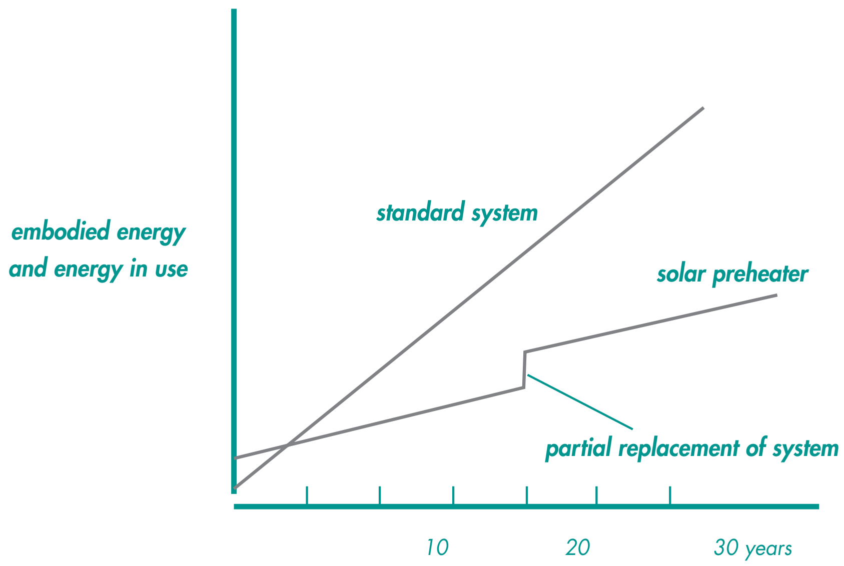
(Note that the diagram is concerned with the **extra cost** of the preheater system. The initial cost of the standard system is therefore shown as zero).

However, for the purposes of environmentally responsible building, the commercial payback calculation is only one element needed in the overall assessment. Also important is the calculation of the **energy payback period**. This is the time required for an energy saving addition (which may have high embodied energy) to pay for itself in terms of reduced total energy consumption (i.e. embodied energy plus energy in use).

Taking the two previous examples, there is no doubt that draft stripping will still emerge as an environmentally sound course of action, with an energy payback even shorter than the commercial one. This is because most of the installation cost relates to human labour (which involves little primary energy use), rather than the embodied energy of the materials.

The case for the water preheater is less clear but again it is likely that the energy payback will be very much shorter than the commercial one. The system will require glass vacuum tubes for solar collection, extra plumbing and an additional hot water tank - all of which have some embodied energy value. However, the purchase price and the cost of specialist labour are probably out of proportion to this - particularly in the UK, where there is no mass market for solar water heating and little expertise in installation. Although data is not available, the energy payback period could be as little as five years, and this is illustrated in Diagram 4.

Diagram 4: Energy Payback for a Solar Water Preheater



(Note that the diagram is concerned with the **extra embodied energy** of the preheater system. The embodied energy of the standard system is therefore shown as zero.)

If an energy saving addition makes sense financially, it almost certainly makes sense in energy budget terms too – but not necessarily the other way round.

Life Cycle Environmental Impacts

Sustainability in building involves more than just energy efficiency. Although energy in use is a critical consideration, there are certainly other environmental impacts that may be of greater importance than embodied energy.

Some of these are shown in the table below.

Inputs:

- raw materials
- water resources
- loss of wildlife habitat
- land and landscape
- damage to local commuities
- waste
- transport

Outputs:

- water pollution
- air pollution
- soil pollution
- damage to landscape and ecology
- noise and vibration
- waste
- traffic generation

Over the life-cycle of a product or a building, these impacts can be considerable. However, they can often be ameliorated by good environmental practice or by choosing alternative materials.

The life-cycle of a product includes consideration of the following stages:

LIFE-CYCLE STAGE	EXAMPLES OF ENVIRONMENTAL IMPACT
pre-production (eg. mineral extraction)	water pollution air pollution damage to ecology and landscape social impacts transport waste
production (eg. manufacturing of componenents)	water pollution air pollution waste
construction	water pollution air pollution damage to ecology and landscape transport waste
in use and maintenance	water pollution local air pollution traffic generation indoor environment/health considerations environmental aspects of paint removal and repainting
end of life	ecological and landscape implications water pollution air pollution from incineration scope for recycling/amount actually recycled disposal of demolition waste

Life Cycle Information

Some form of life-cycle information and guidance is available on a large range of products, but the methodology for assessing environmental impact is not always clear. This has led in the past to accusations of lack of scientific rigour and counter-claims, particularly from trade organisations with an interest in a specific product. Some examples of the sort of guidance available are included in the further reading section.

One of the most interesting developments in this field is an environmental impact estimating tool called **Envest**, being developed by the Centre for Sustainable Construction at BRE. It is a software tool that will allow designers to vary building design in order to identify those elements with the greatest influence on the overall environmental impact. Environmental impacts are judged using an "Ecopoints" system based on life-cycle impacts. The tool will allow the designer to produce more sustainable designs and will include consideration of embodied energy as well as operational energy demands. A commercial version will be available by March 2000.

In the meantime, RSLs with a commitment to more sustainable housing development should try to assess the full range of environmental impacts (including those related to energy) of products and building methods.

UPVC Windows: An Example of Life Cycle Assessment

This section examines some of the issues outlined above in relation to uPVC windows.

The embodied energy of uPVC is actually lower than most other plastics and a good deal lower than steel or aluminium. However, there are other important environmental impacts arising during the life cycle of the material.

Pre-production:

uPVC is made primarily from oil and rock salt and approximately eight tonnes of oil are required for every tonne of uPVC. The environmental risks of the extraction and global transport of oil are well known and do not require repetition here. However, it is worth emphasising that oil is a finite resource and that known reserves are likely to be exhausted by the middle of the 21st century.

Production:

Production of uPVC is associated with the release of organochlorides and, in particular, dioxins. These are thought to cause cancer and damage to animal (and human) reproductive systems and immune systems, even when present in very small quantities. They are also very persistent compounds capable of accumulating in ecosystems remote from sources of pollution – a process that could continue for many years even if production were stopped immediately.

Construction:

There are no particular problems associated with installing uPVC windows at the construction stage and the fact that no external preservatives are required is an advantage. Until recently it was also thought that no painting was necessary either; however, special paints are now available for uPVC, which are presumably intended to lengthen the life of the product. Where used, these will have a significant environmental impact in themselves. If, on the other hand, they are not used, the lifespan may be reduced and replacement required, with an earlier repetition of the impacts associated with production and disposal.

In Use:

The energy efficiency of uPVC in use is comparable to timber (which is relatively good) and is very much better than steel or aluminium. However, the situation in relation to maintenance is very unclear (see the previous comments on painting), and this raises questions not only about its environmental impact but also about its long-term practical and commercial viability for RSLs.

As yet the lifespan of uPVC, with or without painting, is not clearly established. However, it is known that inferior formulations soon become brittle and break up. One of the ways this can be avoided is by the inclusion of various additives, including heavy metals, to stabilise the material, but this again will increase the overall environmental impact. In addition, it is difficult to repair frames or catches and damage to either will often require replacement of the entire unit.

End of life:

Because uPVC degrades over time and because there are so many different formulations in use, the material is not easily recyclable. In the UK only 10% recycled content is allowed in new uPVC. This means that the bulk of the uPVC now being used will have to be treated as waste at the end of its life, and this presents difficulties in relation to final disposal.

Incineration of uPVC is undesirable, since it releases dioxin and other organochlorides, and leaves a residue of toxic salts that are almost as bulky as the original material. The usual alternative to incineration would be landfill. However, this can cause soil and ground water contamination through leaching out of the heavy metal additives.

Conclusions on uPVC

Although uPVC is a reasonably thermally-efficient material, there are problems associated with the toxicity of production by-products and the products of disposal. Some environmental commentators consider the dangers, particularly from dioxin, to outweigh any of the energy advantages of uPVC.

Other plastics with higher embodied energies, but without the chlorine, would perhaps be a better choice if they were available. It is already possible to obtain rainwater goods made of glass-reinforced polyester (GRP) as an alternative to uPVC and it may be that GRP window frames will also be marketed in future. Meanwhile, sustainably-managed timber treated with a water-based stain or paint containing natural pigments appears to be a good all-round choice, combining practicality, energy-efficiency and low environmental impact.

GOOD PRACTICE GUIDELINES

Although some RSLs are beginning to experiment with zero energy housing, development decisions will, for the majority, continue to be heavily influenced by cost and the financial payback may be seen as more important than the energy budget. In fact, since the direct savings from reduced fuel consumption benefit the tenant rather than the landlord, even features with short financial paybacks may be considered unaffordable.

However, the situation on energy saving is changing year by year as regulations become more demanding, the culture of developers and contractors responds to wider environmental concerns and the cost of equipment and installation comes down. In addition, many social landlords are recognising that reducing fuel poverty helps them as well as their tenants, since well heated and ventilated properties require less maintenance. There are also a number of grants available from time to time offering help with the installation of energy saving features - and in these cases it may be the energy payback calculation which counts.

In conclusion, the summary on page 1 can be re-stated, good practice will involve many of the following approaches, whatever the housing type.

- **Keep embodied energy down - but without compromising efficiency in use or overall environmental impact.**
- **Minimise energy in use through high standards of insulation and any other practical means.**
- **Design for long life (at least 60 years and preferably more).**
- **If possible, specify a high proportion of recycled or recyclable materials.**
- **Purchase locally produced materials to minimise transport energy.**
- **Do not install ultra-high-tech equipment that offers only marginal energy savings in use.**
- **Avoid systems with high maintenance requirements or which need frequent replacement.**
- **Avoid systems which rely heavily on user regulation to achieve energy savings (e.g. use intelligent, self-regulating passive stack ventilation rather than user-controlled systems).**
- **Minimise embodied energy costs by including features from the outset rather than retro-fitting.**
- **Use natural materials, as these tend to have lower embodied energy and fewer environmental impacts than heavily processed ones.**

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