BioRegional

solutions for sustainability

BedZED: Toolkit Part I

A guide to construction materials for carbon neutral developments

BedZED village square

Written by Nicole Lazarus

BioRegional

BioRegional Development Group

BioRegional Development Group is an independent environmental organisation working with industry, retail and public sectors to bring sustainable practice into the mainstream. Established in 1994, BioRegional work in housing, construction, forestry, paper, textiles, energy and food industries to create sustainable living solutions that are easy, attractive and affordable. By using local resources wisely, we can increase our quality of life whilst leaving space for wildlife and wilderness.

This report is intended to be of practical use in reducing the environmental impacts of construction. Nicole Lazarus will be glad to hear from any readers with feedback and examples of its application.

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Biffaward Programme on Sustainable Resource Use

Objectives

This report forms part of the Biffaward Programme on Sustainable Resource Use. The aim of this programme is to provide accessible, well-researched information about the flows of different resources through the UK economy based either singly, or on a combination of regions, material streams or industry sectors.

Background

Information about material resource flows through the UK economy is of fundamental importance to the cost-effective management of resource flows, especially at the stage when the resources become 'waste'.

In order to maximise the Programmes full potential, data will be generated and classified in ways that are both consistent with each other, and with the methodologies of the other generators of resource flow/ waste management data.

In addition to the projects having their own means of dissemination to their own constituencies, their data and information will be gathered together in a common format to facilitate policy making at corporate, regional and national levels.

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1 Introduction

The Beddington Zero (Fossil) Energy Development (BedZED) is a mixed-use scheme in South London initiated by BioRegional Development Group and Bill Dunster Architects. BedZED has been developed by London's largest housing association, the Peabody Trust. The scheme comprises 82 homes and 3,000m^2 of commercial or live/work space. The first units were complete in March 2002 with total completion and occupation in September 2002.

The scheme enables people to live sustainably, within their share of the earth's renewable resources, without sacrificing a modern, urban and mobile lifestyle. It aims to achieve this within the cost restraints of a social housing budget. BedZED makes a sustainable lifestyle easy, attractive and affordable.

BedZED challenges conventional approaches to housing by tackling sustainability in every area from the outset. It slashes heat, electricity and water demand, eliminating the need for space heating and reducing water consumption by a third. It has designed facilities and services that make it easy to reduce waste to landfill, recycle waste and reduce car use. BedZED achieves the high densities recommended in the Urban Task Force report whilst still providing a healthy internal environment with unprecedented access to green space and sunlight.

In addition to the sustainability of the finished BedZED product, every aspect of construction was considered in terms of its environmental impact. Materials used in construction were carefully selected for low environmental impact, sourcing locally where possible and sourcing reclaimed and recycled materials where possible.

This report describes the choices of construction materials made on BedZED, it quantifies the environmental benefits of these choices and describes how the materials were sourced, specified and used. The report provides case studies for individual materials and cost comparisons with alternatives.

This report is funded by Biffaward. It also forms part of the Tool Kit for Carbon-Neutral Developments project funded by the DTI's Partners In Innovation programme. Data from this project will also feed into a national mass balance study of the flow of materials around the UK, funded by Biffaward, and it will inform an eco-footprinting analysis, funded by WWF-International.

Contents

2 Summary

Materials in construction make up over half of our resource use by weight. They account for 30% of all road freight in the UK. The construction and demolition industries produce over 4 times more waste than the domestic sector, over a tonne per person living in the UK. The environmental impacts of extracting, processing and transporting these materials and then dealing with their waste are major contributors to greenhouse gas emissions, toxic emissions, habitat destruction and resource depletion.

Looking more specifically at the housing industry, the environmental impacts of the materials in a house are less significant than the actual performance of the house over its lifetime. Domestic household energy consumption accounts for 29% of the UK's CO_2 emissions. By comparison, the materials used in a house's construction account for just 2-3%. Consequently, the BedZED scheme has been designed primarily for long term energy efficiency during use. It then goes further by minimising the embodied impacts of the construction materials used to achieve that design.

BedZED employs state of the art energy efficiency, with super-insulation, double and triple glazing and high levels of thermal mass. BedZED meets all its energy demands from renewable, carbon-neutral sources, generated on site, and so eliminates the 29% contribution to CO_2 emissions and global warming. In achieving this energy efficient carbon-neutral design, BedZED invests in more construction materials than standard houses. However, as this report shows, the embodied environmental impacts of BedZED's construction materials are within the same range as standard UK housing. The total embodied CO_2 of BedZED is 675kg/m^2, whilst typical volume house builders build to 600-800kg/m^2. Despite the increased quantities of construction materials, the procurement of local, low impact materials has reduced the embodied impact of the scheme by 20-30%.

The BedZED project has shown that in selecting construction materials, major environmental savings can be made without any additional cost. In many cases, the environmental option is cheaper than the more conventional material. For example, highly durable timber framed windows are cheaper than uPVC and saved some 6% of the total environmental impact of the BedZED scheme and 12.5% of the total embodied CO_2. Recycled aggregate and sand are cheaper than virgin equivalents and are available as off-the-shelf products. Pre-stressed concrete floor slabs save time and costs on site and by using less materials saved some 7% of the BedZED's environmental impact compared with concrete cast in-situ. New FSC softwood from certified, sustainably managed woodlands is available at no cost premium, while local FSC green oak weatherboarding is cheaper than brick and shows a life cycle cost saving over imported preserved softwood. Reclaimed structural steel and timber are available cheaper than new and offer 96% and 83% savings in environmental impact.

BedZED sourced 3,404 tonnes of reclaimed and recycled materials, 15% of the total materials. All of the recycled and reclaimed materials used were either cheaper than the conventional option or the same price, even after additional staff time was spent on sourcing the material. High grade reclaimed materials such as doors or structural steel are not off-the-shelf products and there needs to be a willingness to work at securing a reliable supply of materials. Long lead times and storage space are particularly helpful in making reclaimed and recycled materials possible.

BedZED's local sourcing policy was able to source 52% of the materials from within the target 35 mile radius. The average sourcing distance was 66.5 miles. Compared with national average haulage distances, this was 40 miles less and saved 120 tonnes of CO_2 emissions, some 2% of the scheme's embodied CO_2. The local sourcing policy cost nothing and required no specialist expertise.

3 Materials in Construction

This chapter sets the context for the use of materials in construction. It relates the environmental impacts of construction materials to the total impacts of human activity in the UK.

420 million tonnes of materials are used in construction in the UK each year. This equates to 7 tonnes per person. The total consumption of all materials in the UK amounts to some 678 million tonnes or 11.3 tonnes per person[1]. So construction accounts for over half of our resource use by weight! By selecting construction materials wisely, we can really reduce our environmental impact.

Every activity involved in extraction, processing and delivery of construction materials results in energy consumption, pollution and waste. The capacity of the earth's natural systems to absorb these environmental loadings has reached or is approaching it's limit in many areas. The most prominent and topical of these is the increasing production of greenhouse gases and the earth's capacity to absorb them. Hence this report looks at the embodied CO_2 associated with each construction material. Waste to landfill in the UK has reached its limit as suitable landfill sites are running out. Other such critical issues include toxic emissions to water and air, acid deposition and ozone depletion.

There are a number of references about construction materials, their manufacture and their impacts. These include the *Green Building Handbook* by Woolley, Kimmins & Harrison and *Greener Building* by Keith Hall and Peter Warr.

Aggregates

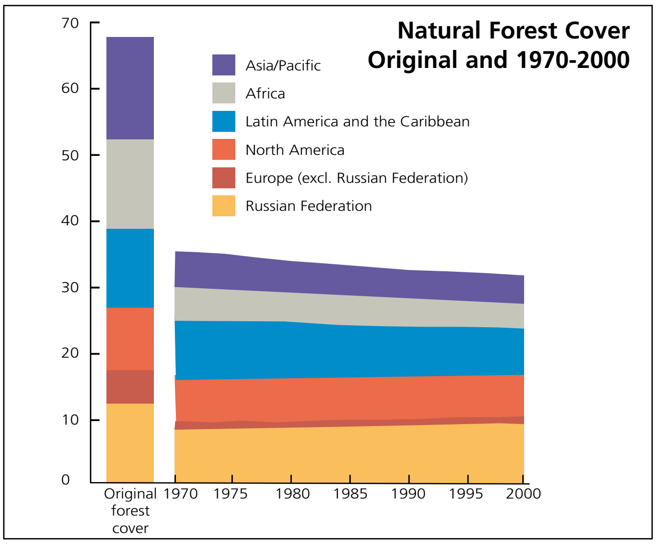
Aggregates make up over 50% of construction materials by weight, some 240 million tonnes/ year. 4 tonnes of aggregates are used per person in the UK each year. An average new house requires some 60 tonnes of aggregate[2]. Virgin aggregates are a finite resource and their rapid consumption is not sustainable. Extraction of aggregates results in loss of land, disturbance to neighbours, ecological damage both on land and in water courses and effects the landscape.

18% of the UK aggregate demand is now met from recycled sources. The new aggregates tax (April 2002) has further incentivised the use of recycled aggregate products by adding £1.60/ tonne to virgin aggregate.

Timber

The world's forests currently cover about 30 million square km, about one fifth of the Earth's land surface. Forest areas have declined by 50% since the advent of agriculture. In temperate forests, most of this reduction occurred over 100 years ago. In contrast, the reduction in tropical forest area has occurred within the last 100 years. In the last 30 years, natural forest cover has reduced by 11%[3].

Logging for timber is one of the two main activities responsible for this deforestation, the other being clearance for agriculture. There are two critical implications of deforestation. One is the loss of biodiversity in the world, the loss of habitats and species forever. According to WWF's Living Planet Report 2000, the state of the Earth's ecosystems has declined by about 33% over the last 30 years. The other is a reduction in the earth's capacity to absorb CO_2. Deforestation reduces the quantity of growing trees in the world and this drop of absorption capacity is proving critical at a time of increased CO_2 emissions, leading to global warming and worldwide climatic instability. Although timber is theoretically a renewable resource, it can only be considered as such if it comes from sustainably managed woodland. The use of certified sustainable timber is a very positive mechanism for moving towards sustainability creating an economy that fosters the conservation of forest resources. The highest accreditation for timber is the internationally certified scheme by the Forest Stewardship Council (FSC).



1 Office of National Statistics
2 Quarry Products Association
3 Living Planet Report 2000

Reclaimed materials

70 million tonnes of waste is produced from construction and demolition every year in the UK. A large proportion (75%) of this is recycled with only 25% going to landfill[1]. But the recycling is generally as very low grade products such as chip for particle board or crushed rubble for earthworks. The potential for high grade re-use of waste materials is enormous. Where a waste material is re-used in its existing state without significant processing or alteration, it is generally refered to as a reclaimed material as opposed to a recycled material.

There is a flourishing reclaimed material economy in the small scale reclamation and salvage yards around the country but these cater for the individual DIY enthusiasts or deal in high value architectural salvage. The thousands of tonnes of bricks, timber and steel sections, doors and paving slabs could be re-used directly and provide a local sustainable material resource to the construction industry. The supply chain for such low value, bulk materials is very dependent on efficient handling and transport systems. BedZED has pioneered a number of reclaimed material supply chains and proved that in some cases it can be done economically. *(see chapters 6,7 and 10)*

Recycled materials

Recycling of construction and demolition waste, as opposed to reclaiming, involves altering the material in some way to produce another material. It introduces extra processing stages and extra journeys compared with reclaimed and therefore can be more environmentally damaging. It does, however, supplant the use of virgin materials. It also diverts those waste materials from landfill.

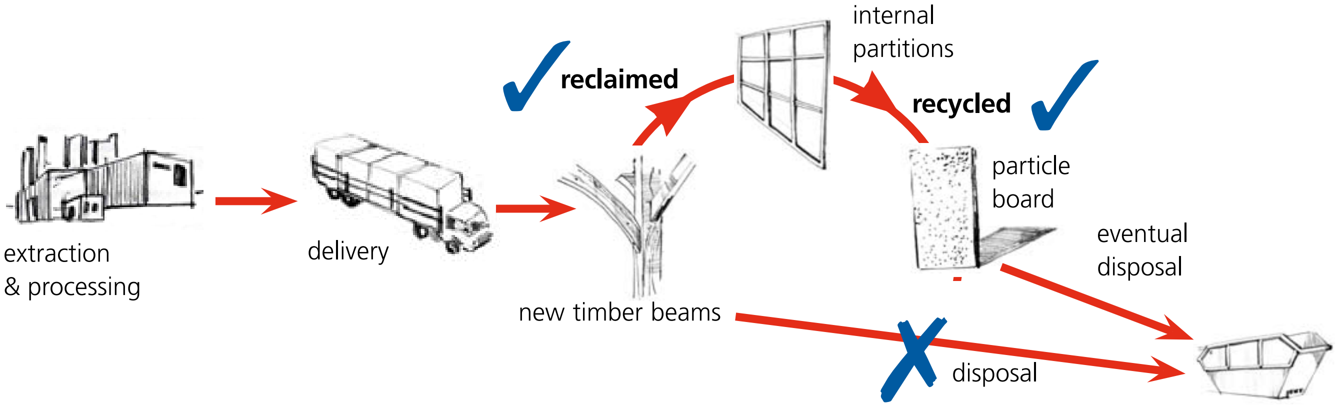
New standards and specifications for recycled materials are being developed in many areas and the use of crushed concrete for aggregate and chipped up pallets for particle board is common practice. In 1989, 40% of all steel on the market was recycled - ie. Old steel melted down and reformed. Recycled steel has a lower environmental impact than virgin steel but still has a much higher embodied energy than reclaimed.

The introduction of the landfill tax and the new aggregates tax has made recycled sand and aggregate replacements significantly cheaper than new.

Haulage

The movement of construction materials around the UK accounts for about 30% of all road freight. In 2000, this represented some 0.5 billion tonne kilometres[2], which has

UK transport of construction materials produces 28 million tonnes of CO_2 per year



Giving new life to old timber: saving forests and reducing pressure on landfill sites an embodied CO_2 burden of 28 million tonnes, equivalent to 500 kg per UK resident or 4% of an individual's total CO_2 burden.

Every 100 tonnes of material transported 10 miles produces 91kg of CO_2 equivalent emissions. If the average distance of transportation of all the materials on a construction project the size of BedZED (22,000 tonnes) is reduced by just 10 miles, then 30 tonnes of CO_2 equivalent emissions are saved – 100kg/BedZED resident. BedZED set out to source its materials as locally as possible with a target sourcing radius of 35 miles. The results of this policy are reported in chapter 8.

Housing Construction in Context

The materials used to build homes require energy consumption during their extraction, production and transportation. This energy consumption has associated CO_2 emissions known as the embodied CO_2 of the materials (see chapter 4). Table 1 shows the embodied CO_2 of a typical home and relates that

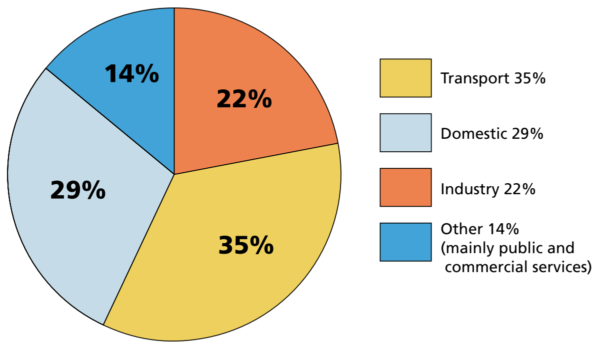
to the total CO_2 emissions in the UK. It shows that the construction of our homes accounts for some 3% of our annual CO_2 burden. As the UK achieves the Kyoto targets in greenhouse gas reduction across all sectors, this percentage will increase unless the construction industry can keep up with overall carbon reductions.

Embodied CO_2 in construction for domestic dwellings	300 – 1,000 kg/m^2[3]
Embodied CO_2 for volume house builders	600 – 800 kg/m^2[1]
Average 3-bedroom semi-detached house: Floor area / Occupants / Life-span	100m^2 / 3.5! / 60 years
Embodied CO_2 / person/year	286 – 381 kg
UK Total CO_2 equivalent emissions/person/year	12,300 kg[1]
Embodied CO_2 of volume domestic dwellings as % of total CO_2 emissions	2.3 – 3.1%

Table 1

The embodied CO_2 of homes is less significant than the energy consumption and CO_2 emissions during their life times. Domestic dwellings account for 29% of UK energy consumption (see Fig.1). BedZED was therefore designed primarily for exceptional energy efficiency during use. Construction materials and products were selected to meet the thermal design criteria. Choices in low impact, low embodied energy materials were considered after thermal requirements had been met. Chapter 9 reports on the embodied CO_2 of BedZED.

Figure 1: UK Energy Consumption[4]



1 Building Research Establishment
2 Freight Transport Association
3 Movement for Innovation, best to worst case data
4 Royal Commission on Environmental Pollution

4 Measuring Environmental Impacts of Materials

Most material choices on BedZED have been made on the basis of clear environmental benefits. Reclaimed steel is much better than new. UK grown FSC certified timber is better than imported non-FSC timber, as discussed in chapter 2. When such choices can be made cost-neutrally, there is no need for sophisticated analysis. When there is a cost premium or a life cycle implication, it can be helpful to have some method of quantifying the comparative environmental benefits of the alternatives in order to put the issue in context and make an informed decision.

In this report, three different assessment methods have been used to quantify environmental benefits: embodied energy/embodied CO_2, environmental profiling and eco-footprinting. This chapter describes the methodology of each.

Embodied energy and embodied CO_2

The embodied energy of a material is the energy required the abstract, process, manufacture and deliver it. Some materials require large amounts of energy to manufacture. For example, sheet aluminium requires some 200 GJ/tonne as compared with sheet steel which has an embodied energy of some 34 GJ/tonne. Timber tends to have a very low embodied energy of 13GJ/tonne whilst chipboard, which is more highly processed, has a higher embodied energy of 36GJ/tonne[a].

The embodied energy of a material needs to be considered over the lifespan of the material, for example aluminium is a highly durable material with a long lifespan of 60 years and is therefore an appropriate solution in some cases, despite its high embodied energy.

Energy consumption itself does not constitute an environmental burden. It is often more useful to consider a material in terms of its embodied CO_2 rather than embodied energy. CO_2 emissions are generated in abstraction, manufacture and delivery and it is the CO_2 emissions that contribute to greenhouse gases and lead to global warming.

Embodied CO_2 is not directly proportional to embodied energy. It depends on the specific energy sources of a process. Electricity generation generally has efficiencies of around 30%, as compared with heat generation efficiencies of around 80%. Processes that require high grade electrical energy will result in higher CO_2 emissions than those that run on low grade heat energy. Heat demands in industry can sometimes be met from waste heat from some other part of the process, further reducing embodied CO_2. It also depends on the energy source for that particular process. In Scandinavia, most of the power used in the aluminium industry comes from hydro-electric schemes and therefore has no embodied CO_2 in its manufacture[b].

The embodied energy and CO_2 data used in this report are supplied by the BRE[3] and are based on UK national averages.

+ This method quantifies the specific impact of CO_2 emissions, widely considered to be the most urgent current environmental issue.

– This method takes no account of toxic emissions, habitat loss or any other environmental issues.

BRE Environmental Profiling

BRE Environmental Profiling uses Life Cycle Assessment methodology and complies with an internationally established approach for analysing impacts of products and processes. It measures environmental performance throughout a product's life, through manufacture, operational use in a building and in demolition. The system has been developed by the BRE and it measures a material's impacts in 12 areas:

1. **climate change**
2. **fossil fuel depletion**
3. **ozone depletion**
4. **human toxicity to air**
5. **human toxicity to water**
6. **waste disposal**
7. **water extraction**
8. **acid deposition**
9. **ecotoxicity**
10. **eutrophication**
11. **summer smog**
12. **minerals extraction**

The impact of the material in each area is compared with the average impact of each UK citizen and given a "score" known as an Ecopoint score. 100 Ecopoints represents the total environmental impact of an average UK citizen. Low ecopoints represents low environmental impact.

The scores in each of the 12 areas are brought together using a subjective weighting system based on a consultation exercise with a broad range of interest groups. Further information on this methodology and definitions of the above impact areas are contained in Appendix 2.

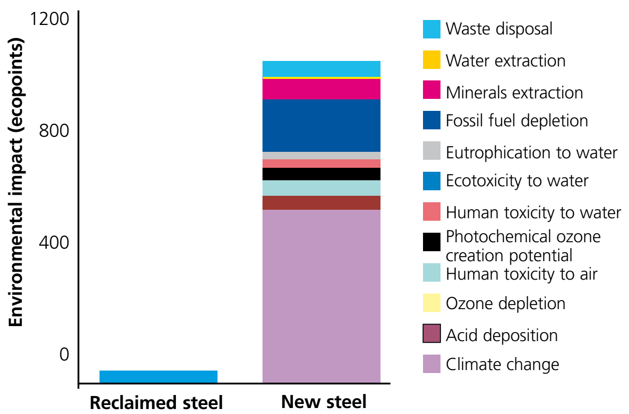
+ This method provides a comprehensive method for comparing materials and combinations of materials. It usefully combines a wide range of environmental issues and brings them together into one figure.

– The relative weightings of the 12 impact areas are subjective and only represent perceived importance.

This method makes no reference to what ecopoint score is actually sustainable given the earth's finite capacity.

Despite a significant weighting in the BRE's consultation exercise, wildlife and habitat loss has not been incorporated into this system due to difficulties in measuring impacts.

Example of Environmental Profiling for structural steel



Eco-footprinting

Ecological Footprint analysis is an accounting tool that represents the environmental impacts of a process or a person's lifestyle as an area of land[6]. It measures the area of biologically productive land that is required to meet the needs of a given product or population. It compares this area with the actual available area on earth and informs as to whether we are living within the earth's capacity.

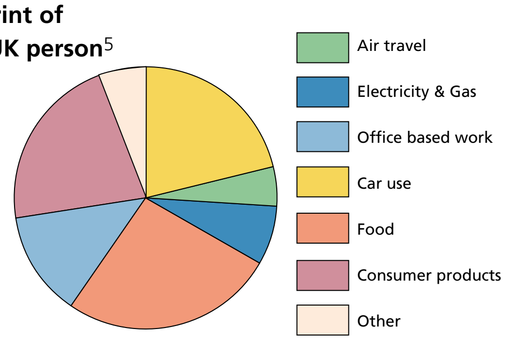
The actual available biologically productive area on earth is 2.18 hectares per person. (based on 1996 population). In the UK, the ecological footprint of each person is 6.29 hectares. This means that we need 3 planets to sustain our current UK lifestyles[4].

A person's ecological footprint is made up of the footprints of all their activities, products consumed and waste produced. It includes the area of forest required to absorb the CO_2 emissions attributable to that person. It includes a share of the area taken up by infrastructure, food and timber growing and fishing. A person's energy consumption has an eco-footprint, as does their food consumption, transport, work activities and leisure activities. Each consumer product has an eco-footprint as does each construction material.

At BedZED, the target is for residents to live within their allowable eco-footprint of 2.18 hectares. All activities such as energy consumption, transport and food supply have been designed to minimise eco-footprint. In order to measure the total eco-footprint of a BedZED home, the eco-footprint of the constituent building materials must be added up. Data is available on the footprint of most basic building materials.

Eco-footprints are the area of land required over the course of a year, measured in hectares. In this report, building material consumption is reported as a one-off event rather than annual consumption. Eco-footprints are therefore measured in hectare-years. A material with a footprint of 10 hectare years requires either 10 hectares over 1 year, 5 hectares over 2 years or 2 hectares over 5 years etc. For further information on this, please read *Sharing Nature's Interest*[6]. Chapter 9 reports on BedZED's total eco-footprint. Case studies in Chapter 6 report on the relative eco-footprint of some material choices.

Eco footprint of a typical UK person[5]



+ This method relates what we do to the actual sustainable carrying capacity of the earth.

Eco-footprinting does not rely on any subjective weightings.

– This is a relatively new tool and there is not always data available on the impacts of a product.

Eco-footprinting has not yet been developed sufficiently to take toxic pollution impacts into account.

a To put in context, typical 3.5 person dwelling uses 81GJ/year in heat and power
b although hydro-electric schemes have other significant environmental impacts on, for example, river ecology)
3 Building Research Establishment
4 Living Planet Report 2000, WWF
5 BioRegional Solutions 2002
6 Sharing Nature's Interest by Chambers, Simmons & Wackernagel

5 Overview of BedZED Construction Materials

This chapter describes the main components that make up a ZED building and the reason for each material choice. Numbers in boxed brackets indicate a case study number, eg [6]. More details on that material can be found in its case study in chapter 6.

Groundworks

BedZED took the unusual approach of looking at what it had available on the site and using it. BedZED is built on a brownfield site, previously used for sewage sludge spreading. On testing, localised areas of heavy metal contamination were identified. The contaminated soil was contained and dealt with on site as much as possible, rather than exporting the problem. While excavating for foundations, all material was stored with contaminated and uncontaminated fill piled separately. The project had the advantage of space for soil storage on what would become the football pitch - an unusual luxury for a high density city development.

As much as possible of the contaminated soil was buried and capped under the new homes which were raised 1200 mm above street level. The levels of the buildings were designed to optimise this soil disposal whilst not making the buildings so high as to be oppressive. The change in height assisted the urban design and streetscape, avoiding any homes being overlooked by workers. Some 75% of the contaminated soil was used on site.

The site geology was gravel beds and so about 1,862 tonnes of excavated material below the topsoil was re-used as subgrade under the roads.

The team did look at using the gravel reserves on the site for concrete aggregate. An on-site sieving and batching plant were investigated but proved uneconomic in this instance. On larger contracts the economies of scale would work. Since there is a large scale batching plant within 1 mile of the site, the environmental savings would have been minimal anyway. All batch concrete, sand and gravel for BedZED was sourced from the local plant only one field away.

Rainwater storage tanks

BedZED foundations were made of mass concrete using reclaimed shuttering ply. Rainwater storage tanks that formed part of the foundation were an "off-the-shelf" product made of weldable poly-propylene.

Building Envelope

The material choices in the building envelope are largely decided by the thermal requirements of the BedZED design. The building physics that achieves zero space heating requirement in the south facing homes is dependent on:

- super-insulation,
- super efficient glazing with reduced areas to north, east and west
- air tight specification,
- passive solar gain,
- thermal mass (heavy weight materials with high thermal inertia that can store heat during warm periods and radiate warmth during cooler periods)
- wind driven heat recovery ventilation
- sunspace buffer zones on south elevations
- careful room zoning to take advantage of incidental heat gains (heat from electric appliances and human activity)

These features also work to greatly reduce the heating need in the commercial and live/work areas.

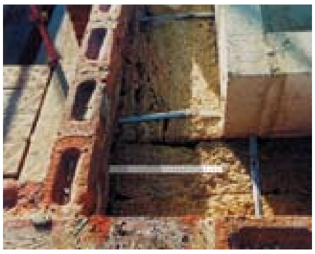
BedZED walls are a mixture of:

a) brick and block cavity construction
b) timber stud weatherboarding with cavity and blockwork.

Floors and roofs are of pre-cast concrete. Each terrace block sits in a jacket of 300mm of insulation. Windows are mainly on the south elevation and are either double or triple glazed with low emissivity glass.

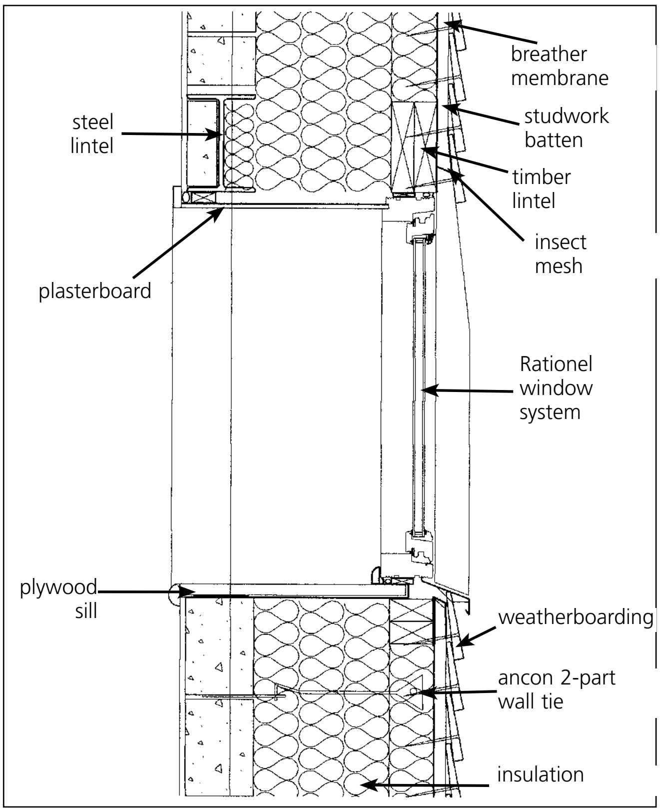
The concrete blocks and concrete floors all provide thermal mass with exposed radiant surfaces. Thermal mass provides a very stable thermal environment and avoids large temperature fluctuations.

Brick and block construction is a standard building technique and is therefore easily adoptable by mainstream builders. The extra large 300mm cavities provided some design and buildability issues that were overcome with special cavity wall ties and bespoke design details around window reveals. Air tightness around windows and door openings was critical and was achieved using clear silicon sealants.


Super-insulation with wall tie

Insulation

The walls are insulated with rockwool, the ground floors with expanded polystyrene and the roofs with extruded polystyrene. Many insulation materials were considered including hemp and Warmcell recycled newspaper. The insulation products used offered the best durability for each application. In the full fill cavity wall situation where non-biodegradable and vermin proof properties are necessary, rockwool provided the best thermal performance and value for money. However, in ground floors and roofs, the compressive load made the expanded and extruded polystyrene necessary. Cradle to grave analysis shows that the thermal performance of the insulation products used at BedZED offset the one-off environmental impacts of manufacture within a few years[1]. Their 60 year design life therefore offers considerable net environmental gains. [15]



Wall/window construction

Bricks & Blocks

The bricks came from the local brickworks just 20 miles away, in keeping with the local vernacular. They offer very pleasing colour variation.[14] In order to achieve the stringent air tightness specification, bricks were laid on fully filled mortar beds as opposed to the standard furrow joints. The dense concrete blocks came mainly from Purfleet and Medway and provide cost effective acoustic insulation between properties.[10] Rammed earth party walls were considered but would have needed to be too thick. They would not have satisfied standard home insurance requirements that are required for getting a mortgage, therefore making the homes very difficult to sell.

Floors

Pre-stressed concrete hollowcore floor slabs were used. Other floor solutions considered were in-situ concrete, beam and block, standard precast concrete and timber joisted floors within dwellings. Pre-stressed concrete was found to provide the best value for money, best quality finish and saved time on site compared with the in-situ solution. The need for thermal mass ruled out the timber option. The pre-stressed solution offered considerable material savings in steel, cement and aggregate, thereby reducing environmental impact compared with other concrete options. [9]

Weatherboarding

Weatherboarding is a local feature of the area and in keeping with local architecture. It provides a really attractive elevation in combination with the local brick.


Brick/weatherboarding combination

Oak weatherboarding was chosen over softwood for its durability. Although more expensive than softwood, the maintenance savings to the Peabody Trust over the lifetime of the buildings justified the extra capital cost. Local oak was chosen over imported oak for the many environmental

[1] dk-Teknik 1995

benefits. By sourcing local FSC certified oak from the woodlands of Croydon and South East England, the project was able to purchase a product that injected cash into the good management of our local woodland resource, supporting conservation of valuable ecological habitat. [1]

Windows

All windows are either double or triple glazed. The triple height conservatories on the south elevation

of all buildings are effectively quadruple glazed by way of double glazing on each side of the sun space. All north, east, west and rooflight windows are triple glazing. Timber frame windows were chosen over aluminium or uPVC for embodied energy and environmental impact reasons.

Locally manufactured windows with local oak and chestnut window frames were not possible this time due to a number of factors. Local window manufacturers were not of a size used to dealing with an order as large as the BedZED window order. Neither were they experienced in producing such high performance air tight glazing. There was sufficient local hardwood available to meet the order but the local manufacturers were charging a premium for the use of oak or chestnut. All these problems could be overcome with time but not within the BedZED construction programme.

The BedZED windows were therefore ordered from a Danish company who produce high performance windows as a standard product. Rationel source their timber from Scandinavia, with 40% holding FSC accreditation. Despite the long delivery journey, Rationel offered the best lifetime thermal performance, the lowest cradle to grave environmental impact and the best value for money.[5]

Double glazed windows have one low-E[1] pane and are argon filled. Triple glazed windows have two low-E panes and are krypton filled.

Aluminium

Rooflights are triple glazed with aluminium frames. The frames have thermal breaks to prevent cold bridging. There were no off-the-shelf timber framed triple glazed rooflights available at the time of construction. Aluminium is also used for copings and window sills, taking advantage of the durability of the material. Aluminium offers a highly durable product in the least accessible areas of the building where maintenance work would be most problematic and costly. Aluminium therefore makes up some 0.02% of the materials on BedZED. It's careful and thoughtful use in the most appropriate locations gives the best life cycle impacts.

Damp-proofing

The damp proof course for the buildings is Visqueen high density polythene. The water catching cavity trays that divert moisture out of the walls at the base of each cavity are made from Zedcor bituminised polyethylene. This material, instead of being pre-formed, is adaptable and can be tailored on site to any shape. This allowed design flexibility without attracting excessive cost.

Steel frame

The workspace areas are built using steel frame construction. New structural steel has a high embodied energy but on BedZED, 95% of the workspace structural steel is reclaimed. The sections are retrieved from demolition sites within the 35 mile radius.[8] [a]

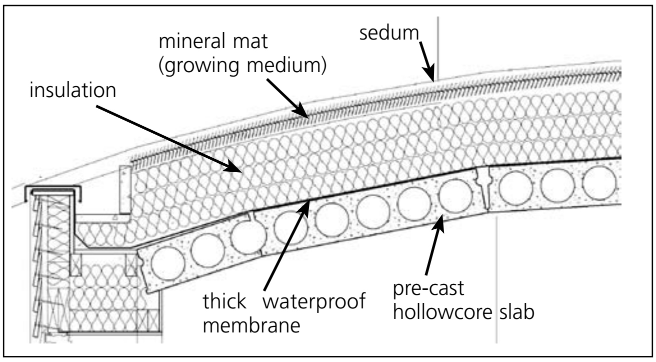
The use of reclaimed structural steel in the workspace makes large spans possible so that the units can be left as open as possible allowing long term flexibility for the changing needs of business tenants. New structural steel is only used in curved locations such as the slightly arched link bridges. There is no technical reason why on future projects reclaimed steel could not be passed through a steel bender.

sedum roof and grass turfed sky gardens

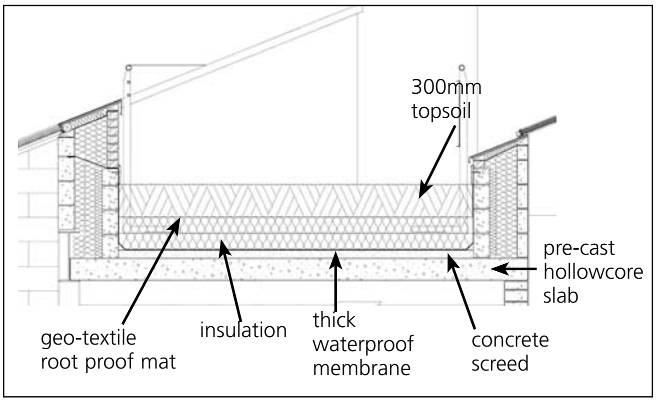
Green roofs

Above the workspaces are small private turfed sky gardens ensuring that even 1-bedroom second floor flats have access to private outdoor green space. The higher curved roof that has no regular access is planted with a low maintenance sedum mat.

The green roofs are a proprietary product with 20 year performance guarantee. They consist of a root resistant bitumen membrane laid on the concrete roof slab, then a polyethylene foil layer. Then a 300mm expanded polystyrene insulation board is overlain with topsoil or a mineral fibre growing medium.



sedum roof



sky garden

The sedum roof will provide useful insect and bird wildlife habitat undisturbed by human activity. It is hoped that after a few years, plant growth on both upper and lower roofs will provide significant levels of biodiversity. This may be possible because, for example, the highest recorded levels of biodiversity in the UK are in a suburban back garden in Leicester. A research project is being carried out to measure and record the insect species that colonise the sedum roofs.

Internal Fit Out

Internal partitions are timber stud with plasterboard facing. 90% of the timber in the studwork is reclaimed [2]. Plasterboard is from a local source. These partitions offer a low impact, low embodied energy solution with partitions that can be easily moved or removed during the lifetime of the building, giving occupants long term flexibility in interior layout.

The mezzanine floor in the workspace is made of reclaimed timber floorboards [2] while the timber floor sunspaces in the dwellings are made from local ash. Some 80% of all exterior studwork and interior joists are UK grown FSC certified softwood [3]. Interior planed skirtings and cover strips are Scandinavian softwood certified under the PEFC Scheme (see p30). FSC certified plywood is used in all locations except the kitchens and window reveals [4].

Interior timber doors are FSC certified softwood. A pilot study sourcing 150 reclaimed doors was also carried out. The lessons and recommendations for sourcing reclaimed doors are written up in case study [7].

Interior Finishes

Finishing materials have been avoided all together where possible. For example, concrete floor slabs were chosen with sufficiently good underside finish as to remove the need for plastering or a suspended ceiling. Blockwork in workspace units is simply painted without plaster finish. Blockwork party walls in dwellings however are plastered and concrete floors are finished with a sand/cement screed from the plant 1 mile from the site. Tiles were sourced from a UK manufacturer that uses UK clay. Linoleum flooring was used in kitchens and bathrooms. Linoleum is a linseed oil based product with a very low environmental impact, offering the same performance in use as uPVC vinyl flooring.

[a] Note the use of reclaimed not recycled steel. Recycled steel is common practice, but nonetheless has a high embodied energy from melting and reforming, albeit less than virgin steel.)

[1] low emissivity

Kitchen units were made to be extremely durable, built out of birch-faced ply instead of MDF or chipboard with softwood studwork and beechblock worktop instead of formica [6]. BedZED homes are designed to be low allergy homes, avoiding the use of formaldehyde and VOC emitting products where possible.

uPVC is avoided on the job where possible, but there were no cost-effective alternatives to uPVC wiring, water pipes or cable sleeves. No uPVC was used in the exterior cladding, the window frames or any interior finishes. The quantity of uPVC in BedZED is tiny compared with conventional schemes.

Paint

An attempt was made by the design team to replace vinyl based emulsion with more environmentally benign alternatives from Ecotec. This paint is made from water, chalk, talcum, powdered marble, vinegar, titanium dioxide, cellulose, natrium hydroxide and salt. The painting contractor was not receptive to this non standard specification and difficulties were encountered in achieving a smooth finish. So a mixture of both types of paint have been used on the project. On future schemes we believe that eco emulsion is a viable alternative to conventional emulsion type products.

Landscaping

All earthworks for landscaping were done using on-site excavated material. Crushed concrete was used instead of fresh aggregate as road sub-base. [11]

Approximately 30% of the hard landscaping is covered with porous paving. This is part of the surface water treatment strategy that filters surface runoff and returns it to the natural water-course rather than collecting it and sending it into mains sewerage. This strategy replenishes natural waterways and attenuates flooding.

Porous paving requires a specific aggregate size distribution for its sub-base in order to provide enough water storage capacity for a 1 in 100 year storm. The crushed concrete aggregate available at the time was not of sufficiently good quality for the porous paving so fresh limestone aggregate had to be used for sub-base in these locations. Since that time, the new Days Aggregates plant at Purley can now offer recycled aggregate at the right specification.

Reclaimed paving slabs are a very low value material with relatively high handling and storage costs. A lot of work was done to source reclaimed paving. Local Authorities offered it free but the collection, handling and storage arrangements were not achievable this time within the programme [15]. Paving slabs were bedded in recycled crushed green glass which was used instead of virgin sand. This recycled product is new on the market and is cheaper than virgin sand. [12]

Landscaping for the development made use of native species plants. Native plants are most suited to providing habitat for local ecology. Insect species adapted for native plants will thrive, providing more food for birds and so the benefits travel up the food chain. The centre feature in the village square is an English oak. Cherry, field maple and ash trees are also planted around the site.

Bollards are made from reclaimed railway sleepers.

6 Material Case Studies

Chapter 5 gave an overview of all the materials used at BedZED. This chapter 6 provides details of some of the more unusual materials. It compares the BedZED material with conventional alternatives and describes design, quality and sourcing issues, contractual arrangements and cost implications. Each of the 15 case studies quantifies the environmental impact of the material and compares with the conventional choice. The case studies are graded according to:

How easy it was to achieve

Cost-effectiveness

The significance of the environmental benefits

All gradings are relative to the conventional material choice for that purpose.

The Case Studies included are:

1 **LOCAL TIMBER**
- **Oak weatherboarding**
- **Ash floor boards**

2 **RECLAIMED TIMBER**
- **Internal studwork**
- **External studwork**
- **Bollards**
- **Floor boards**

3 **FSC CERTIFIED TIMBER**

4 **PLYWOOD**

5 **WINDOW FRAMES**

6 **KITCHEN FITTINGS**

7 **RECLAIMED DOORS**

8 **RECLAIMED STEEL**

9 **RECLAIMED PAVING SLABS**

10 **CONCRETE FLOOR SLABS**

11 **RECYCLED AGGREGATE**

12 **RECYCLED SAND**

13 **LOCAL CONCRETE BLOCKS**

14 **LOCAL BRICKS**

15 **INSULATION**

The results of all 15 case studies are summarised in Chapter 7.

Timber Case Studies

Introduction

Case studies 1-7 relate to timber based products and as such are subject to similar environmental impact considerations.

Procurement

The carpentry and joinery work on BedZED was commissioned in seven sub-contractor packages:

Each package was put out for competitive tender to a number of short-listed contractors. Tender information gave timber specifications including the following definitions:

A LOCAL:
Timber sourced from a woodland within 35 miles of BedZED

B HOME-GROWN:
Timber sourced from a woodland in the United Kingdom

C RECLAIMED:
Timber must be post-consumer waste from demolition or some other process

D FSC CERTIFIED:
Timber must carry the Forest Stewardship Council's trademark

Research into the availability and cost of local, home-grown, reclaimed and FSC timber was carried out prior to the letting of each package. This ensured that realistic sourcing specifications were put forward with recommended suppliers. Alternative timber suppliers suggested by contractors were accepted if their products met the same criteria.

Local oak weatherboarding vs Softwood	
	Fairly easy
	Lifetime saving
	Modest

Local oak weatherboarding vs Brick	
	Fairly easy
	Saving
	High

Local oak weatherboarding vs uPVC	
	Fairly easy
	Cost premium
	High

CASE STUDY 1 : LOCAL TIMBER

Introduction

The majority of timber used in construction in the UK is imported and the use of any home-grown timber is a break from the norm. Local timber is rarely used in mainstream construction. However, the 35 mile radius around BedZED includes the area known as the Weald, where extensive woodland estates are managed commercially. BedZED was therefore able to access large quantities of local hardwood. The project also benefited from timber products from one of BioRegional's own projects managing the tree resources in the London Borough of Croydon.

Weatherboarding

Timber cladding was selected to reflect a traditional feature seen on older buildings in the Sutton area.

Local historic weatherboarding

Performance specification

The BedZED cladding needed to be durable without the use of environmentally damaging treatment products. It needed to be visually attractive and to remain so for decades. The local green oak chosen for this application is rich in tannins, which offer natural resistance to the weather and insect attack. Green oak is traditionally used for cladding in South East England and is known for its durability. The cladding weathers to an attractive silver colour.

Construction contract

A number of approved local timber suppliers were visited and specified in the tender documents that went out to the joinery contractors. Alternative suppliers with the same environmental credentials were also used subject to approval by the Design Team.

Timber source

All the weatherboarding is FSC certified and sourced from the woodlands of South East England. By purchasing FSC certified oak from this area, the BedZED project actually injects funds into the sustainable management of local woodlands for their ecological and recreational value, supporting the conservation of an irreplaceable natural resource.

Brick and weatherboarding – west elevation

30% of the weatherboarding order was supplied from London Borough of Croydon woodlands managed by BioRegional Forestry. These woodlands, traditionally managed as coppice with standards, had ceased to be commercially worked and as a result had declined in wildlife and recreational value. New management plans were drawn up to reinstate traditional management patterns, funded by the sale of timber and timber products from the woodlands. In a world first, London Borough of Croydon's entire woodland holding, including street and parkland trees, has now been FSC certified.

English Woodlands Timber, who supplied the balance of the weatherboarding order, had recently been accredited to FSC standards. Fresh sawn FSC certified timber products can be supplied with no extra lead time and with no price premium. BedZED was the firm's largest FSC certified order. They have since received a number of other enquiries about FSC certified products.

Detailing green oak weatherboarding

Local FSC green oak weatherboarding

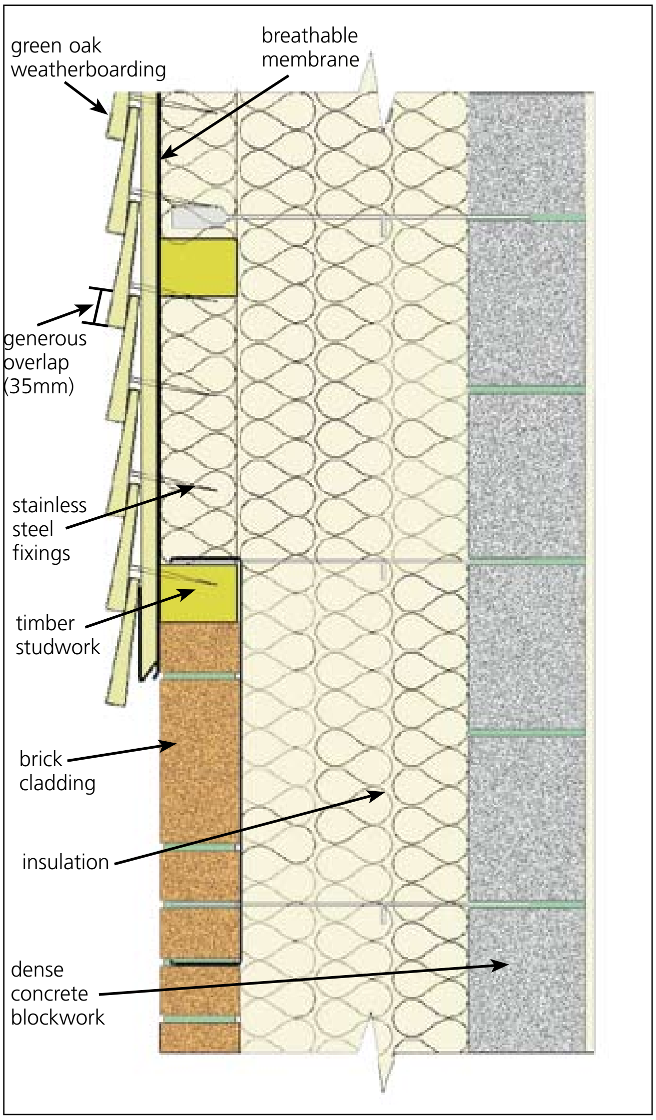
Stainless steel fixings must be used as the natural tannins in the oak react with alternative fixings, staining the timber. As the timber weathers, the natural tannins leach out and can stain surrounding areas. If this is considered a problem, plastic sheeting can be used to protect these areas during construction. Green oak will move, depending on the amount of moisture in the air. It is therefore necessary to allow a generous overlap of 35mm between boards. At BedZED the weatherboarding is backed by a breathable membrane which prevents water penetration into the building. Periodic movement of the weatherboarding ensures ventilation of the membrane to exclude damp air. TRADA's (Timber Research and Development Association) Timber Cladding Manual covers all aspects of cladding design and construction. It is available from TRADA publications (01494 569602) priced at £15 for TRADA members and £20 for non-members.

Cost analysis

The total weatherboarding supply costs were £36,000 with rates at £1.50-£1.60 per metre run. Oak is about twice the price of softwood, adding some £18,000 to the build costs. However, by using the naturally weather resistant oak regular repainting or preservative treatment is avoided. A study with Peabody Trust's maintenance department shows that softwood weatherboarding would require two coats of paint or preservative every 5 years, costing £21,000. The oak option therefore delivered a life cycle cost saving within 10 years, as well as environmental benefits.

Common weatherboarding alternatives that do not require preservative treatment would be imported larch or cedar. Quotes for these alternatives, based on a similar sized order, give £1.50/m for larch or £4.90/m for cedar.

Brick cladding throughout would have cost an extra £25/ m^2 installed (£60,000 total) and would not provide the same architectural quality. uPVC mock weatherboarding would be cheap and durable but would incur significant toxicity and CO_2 impacts to the environment in its manufacture. uPVC was also considered to be visually unappealing.



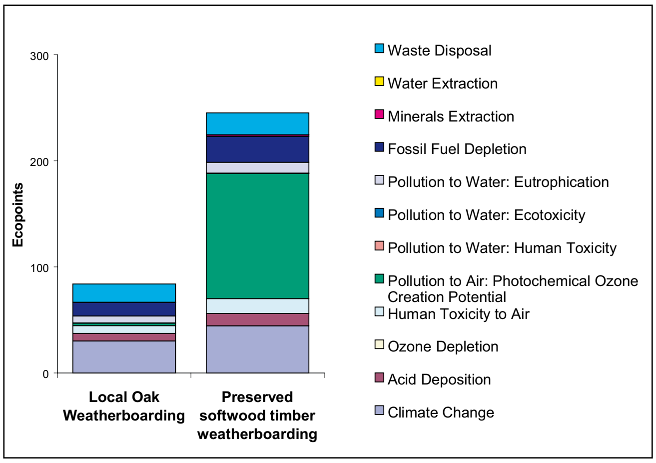
Weatherboarding detail

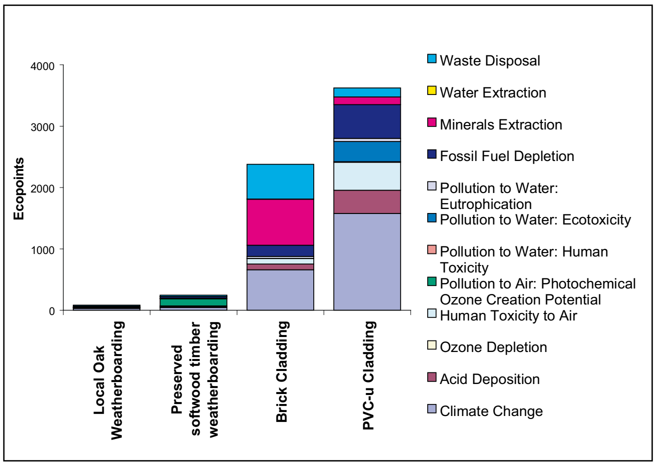
Quantified environmental benefits

BRE have used Environmental Profiling methods to compare the 3,500m^2 of local oak weatherboarding with three other cladding options:

- treated softwood timber as typically consumed within the UK, ie 70% imported from overseas, predominantly Scandinavia;
- a single skin of brickwork cladding and
- a solid uPVC cladding system.

BRE were not able to take account of the FSC accreditation of the oak and the biodiversity/green space benefits associated. The benefits shown in the softwood comparison are due to the saving in transport and the lack of any preservative treatment.





Saving from using BedZED Specification

	Preserved softwood timber weatherboarding	Brick Cladding	uPVC Cladding
Ecopoints	161	2,300	3,500
Embodied CO_2 ($kgCO_2$ eq (100 years))	4,630	204,000	503,000
Embodied Energy (GJ)	170	2,600	9,200

Recommendations

Although green oak cladding is widely used in conservation work, it has largely been replaced by the more stable seasoned cedar and larch in the mainstream construction industry. Timber cladding has generally become less fashionable, and even in areas where it was traditionally used, brick and uPVC are now favoured. As a result, green oak weatherboarding is a material unfamiliar to the construction industry and therefore considered a risk. It does have a more rustic finish than cedar, which may not be appropriate in all applications. However, its use at BedZED has shown that, with appropriate detailing, green oak weatherboarding can be a cost effective, attractive solution.

Ash Floorboards

Locally grown ash hardwood was used for the interior sunspaces. This was a relatively small quantity of timber and ash provided a beautiful, durable hardwood finish for a relatively small extra cost over that of softwood.

2.85m^3 of local ash was used at a cost of £20/m^2. Softwood would have cost less but would have a shorter lifespan and would require regular maintenance. Ash provided the best value for money in quality and life cycle terms.

Contacts

BioRegional Development Group: 020 8404 4880
English Woodlands Timber: 01730 816941

Reclaimed stud-work (internal) vs New	
Ease	Fairly easy
Cost	Saving
Environmental benefit	High

Reclaimed stud-work (external) vs New	
Ease	Difficult
Cost	Cost premium
Environmental benefit	High

Reclaimed Floorboards vs New	
Ease	Easy
Cost	Saving
Environmental benefit	Modest

CASE STUDY 2: RECLAIMED TIMBER

Introduction

Identifying sources of reclaimed timber

There are two routes for sourcing reclaimed timber.

Reclamation yards

The Salvo website provides listings of reclamation yards by region and by construction material. Yellow Pages proved another useful source of local contacts.

A range of reclamation businesses were approached to supply to BedZED. Many smaller yards were unable to cater for the large scale of supply. Those in architectural salvage market tended to be too highly priced.

Ashwells Recycling in Essex are a large reclamation yard within the 35 mile radius of BedZED. They have an extensive timber stock and were able to offer de-nailing, preservative treatment, milling at their on-site sawmill and delivery at a competitive price.

Sourcing direct from demolition sites

Sourcing timber direct from demolition sites for processing by an on-site team was also explored. Reclaimed timber could be obtained extremely cheaply by this route, sometimes for free, but the costs of labour and equipment for the on-site processing were difficult to predict. Space constraints on-site and the unpredictable costs made this an unattractive option on this occasion.

Internal Studwork

Reclaimed studwork

54,000m of 50x100mm and 75x100mm reclaimed timber studwork was used in the internal plasterboard partitions at BedZED. The partition studwork is neither structural nor exposed to any weathering. It is not visible once installed and so does not require any sanding, grading or durability treatment. This low specification timber was easy to source economically from reclamation yards. It was cheaper than new softwood.

Reclaimed timber stored on site

Minimum lengths

For reclaimed timber, the shorter the length, the cheaper the price per unit length. Reclamation yards can sell long lengths more easily, but to take a large quantity of short lengths off their hands merits a good price. Economies of buying short lengths have to be balanced with the practicalities of working and possibly increased wastage. At BedZED, we worked with 2.5m minimum lengths, as compared with standard building supplier lengths of 3m and above.

NHBC/Building Regulations

The use of untreated reclaimed timber for internal use was initially challenged but eventually approved by the NHBC.

Cost comparison

Reclaimed timber for internal studwork was 14% cheaper than using new imported FSC certified softwood. The total value of reclaimed timber used was £28,215, compared with £32,766 quoted for new. Additional staff time in sourcing the timber is estimated at £1,200, leaving a project saving of £3,351.

Construction contract

The partition joinery package was tendered competitively on the basis of new, FSC certified timber. Tenderers were then asked for a rate reduction for the free issue of reclaimed timber. Responsibility for sourcing and delivering the reclaimed timber was with the Construction Managers, GTCM.

Quality issues

Ashwells guaranteed all timber to be denailed. Any sub-standard timber was returned to the supplier and replaced free of charge. Joiners working on the project were happy to consider using reclaimed timber for this use again.

Risk allocation

The Construction Manager purchases the reclaimed timber on behalf of the Client. There is a risk to the Client as with any free-issue materials. The reclaimed timber supplier holds the risk associated with the quality of the timber.

External studwork

Performance specification

The studwork for the weatherboarding has a structural function and requires timber classified as C16. The reclaimed timber therefore needed visual stress grading by a specialist contractor, Hutton and Rostrom. Stress grading was carried out at the reclamation yard prior to delivery to save abortive haulage miles.

Durability

The NHBC Standard, Chapter 2.3, grades different timber species into categories of durable, moderately durable, perishable and all sap wood. The NHBC also stipulates that external studwork should be classed as durable. Any species not classified as durable require preservative treatment to be used in this application. The classification categories are based on newly harvested timber and are not designed for reclaimed timber. They do not take into account the fact that timber harvested some 50-100 years ago is denser and more durable than the same species being harvested now. Current plantation timber is grown as fast as possible and has lower density and reduced durability.

The reclaimed timber supply consisted of a mixture of species not easily identifiable by visual inspection. Some samples were identified using laboratory techniques and then used as benchmarks for identifying the remainder at the suppliers yard. The timber was a mixture of Pitch Pine and Douglas Fir. Most of the Pitch Pine came from dismantled dock retaining walls and had been under water for decades. It had been well preserved and was high quality timber.

Under current NHBC guidelines, it is necessary to treat Douglas Fir and American Pitch Pine but not Caribbean Pitch Pine. On the BedZED project it was cheaper to treat all the timber than to separate the different species.

In future projects, we would seek to avoid preservative treatment. Further discussions are needed with the NHBC to see which of the non-durable timbers could be used without treatment as structural members.

Treatment

If treatment is necessary, either the double vacuum or CCA tanalising are the applicable methods for soft wood. Hard wood is generally in the durable category and does not require treatment.

Construction contract

The external joinery package was tendered competitively on the basis of new timber. Tenderers were then asked for a rate reduction for the free issue of reclaimed timber for studwork. Responsibility for sourcing and delivering the reclaimed timber was with the construction managers.

Quality Issues

Difficulties were experienced in moisture content. The first reclaimed timber deliveries had very high moisture content due either to the preservative treatment process or poor storage. Subsequent deliveries arrived dry.

Cost comparison

Reclaimed timber was purchased at a lower cost than new timber (£15,086 reclaimed compared with £19,822 new). However, the need for both stress grading and preservative treatment increased the cost of reclaimed timber for this application to £21,533. Reclaimed timber was therefore used for only a small proportion of the external studwork at BedZED. The remainder of the order was met with new, UK grown, FSC certified timber.

Street furniture – bollards

Ashwells Recycling produce reclaimed timber street furniture to order. A range of bollards made from railway sleepers have been installed at BedZED at a price of £68.50 each.

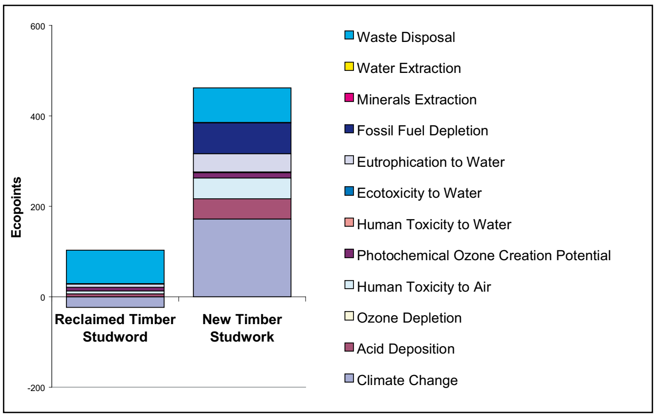
Floor boards to workspace mezzanine

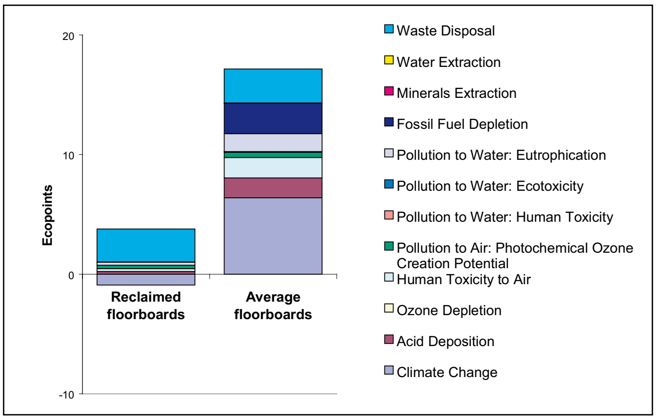
The reclaimed timber floorboards for the mezzanine floors of the BedZED workspaces were from Ashwells. They were bought direct by the joinery contractor. This timber was reclaimed 'onion timber' - lengths of timber used as spacers between crates on cargo ships - that would otherwise be wasted. The 'onion timber' was cheaper than new.

Quantified environmental benefits

BRE have compared the impacts of using 350m^3 of reclaimed timber studwork (mainly internal) and 700m^2 of reclaimed floorboards from the Ashwells yard in Essex with new timber. New timber has been based on kiln dried timber as typically consumed in the UK, eg 70% imported, predominantly from Scandinavia.

Saving from using BedZED Specification	Reclaimed Studwork	Reclaimed Floorboards
Ecopoints	380	14
Embodied CO_2 ($kgCO_2$ eq (100 years))	63,640	2,370
Embodied Energy (GJ)	1,060	39.5
Eco-footprint (ha years)	174	1,060





Why reclaimed timber has a net negative climate change impact

Both reclaimed timber and new timber carry a positive environmental benefit by holding "sequestered" carbon dioxide (i.e. carbon stored in the timber). They have the same environmental impacts on disposal as the wood decomposes/burns and releases the gas. More CO_2 is sequestered in growing the timber than is released on disposal as over 30% remains sequestered in timber which is reused or recycled into other products, such as chipboard. Despite this, the impacts of logging, sawmilling and transport of new timber give a net positive CO_2 emission and climate change impact. Because of the small amount of processing and transport required for the reclaimed timber, it has an overall net negative CO_2 emission, thus making the overall climate change impact negative.

Recommendations

Factors that help in the successful use of reclaimed materials are long lead times, early design information and therefore early availability of cutting schedules.

Storage space on site enables the Construction Managers to order large quantities of standard sections before design information is finalised. Costs of reclaimed timber vary enormously so the flexibility to buy timber early if a good deal comes up helps to make cost savings compared with new timber.

The early purchase system is further helped if the designers use just a few commonly available section sizes, as was done on BedZED.

Reclaimed timber is variable in appearance. This needs to be taken into account when considering applications for reclaimed timber.

It costs the reclamation yard time and wasted material to cut timber to specified lengths. So flexibility in minimum lengths helps to keep costs down.

Large scale supply is made much more possible if reclaimed timber suppliers can identify the timber species and offer the timber in batches, similar to purchasing new timber.

The requirement to treat timber for durability for external use adds cost and complicates the supply chain. It is recommended that NHBC review their classification system in the reclaimed context.

Where stress grading is required, good organisation is essential to reduce the number of visits required by a qualified grader. There are currently very few qualified visual stress graders and it would be more cost-effective if the reclamation yard or a member of the project team were qualified in this skill. TRADA (01494 569600) run courses in visual stress grading of softwoods to BS 4978 or temperate hardwoods (oak) to BS 5756: 1997.

Contacts

Ashwells Recycling:01375 892576
Salvo: www.salvoweb.com
Hutton & Rostrum, stress grading: 01483 203221
Ellis & Moore, Structural engineering consultants: 020 7281 4821

vs	Non-FSC Timber
FSC Timber	Fairly easy
	Neutral
	Medium

CASE STUDY 3 : CERTIFIED TIMBER

Introduction

Forest certification schemes

Forest certification is a system of forest inspection plus a means of tracking timber through a "chain of custody", – following the raw material through to the finished product. The forest inspection checks for good management against environmental, social and economic criteria. The chain of custody system ensures that products claiming certification actually come from certified forests.

Forest Stewardship Council (FSC)

The Forest Stewardship Council (FSC) is an independent, non-profit, non-governmental organisation founded in 1993. The FSC label is carried by forest products derived from forests independently certified in accordance with FSC principles and criteria. These include recognition of indigenous people's rights and forest workers conditions, long-term economic viability, protection of biodiversity, conservation of ancient natural woodland, long-term responsible management, and regular monitoring.

FSC is considered the highest form of accreditation, particularly for biodiversity and conservation.

Pan European Forest Certification (PEFC)

The PEFC scheme, a voluntary private sector initiative, was launched in 1999 as a self-certifying alternative to FSC. The Pan European Forestry Criteria were defined by the consensus of forest owners and managers and timber producers across Europe. The PEFC logo is awarded to products from certified forests managed according to the criteria of "sustainable forestry practice" appropriate to each region. Regional inspections are by independent third party auditors but individual woodlands are self-certified.

Finnish Forest Certification System (FFCS)

The FFCS includes requirements for forest management, wood chain of custody certification and the carrying out of external auditing. The system, which is based on regional group certification, is voluntary for forest owners and requires an audit to be carried out by a third, impartial party. The system does not include its own produce label, although it is planned to be compliant with other international certification and labelling schemes. The scheme is based on similar criteria as FSC but has not been accepted by FSC to date due to some concerns over clear felling of ancient forests in northern Finland and also some bog draining activities that improve productivity but destroy valuable habitat.

UK Woodland Assurance Scheme (UKWAS)

This forestry standard put forward by the UK government has been approved by the UK forestry industry, NGO's and by the FSC. The scheme involves independent assessment and qualifies products for the FSC logo. Most major timber producers, including Forest Enterprise, are within this scheme, meaning that most UK grown timber is FSC compliant.

All certification schemes are expensive for small woodland producers, timber mills and timber merchants. This issue is being addressed and improved with schemes like the Independent Forest Group Scheme. For further information see www.fsc-uk.demon.co.uk.

Construction contract

FSC timber was specified in all joinery tender packages except in local or reclaimed timber applications. Responsibility for sourcing certified timber was with the contractor.

Chain of Custody

Timber merchants and mills need "chain of custody" certification in order to sell FSC timber on with the FSC logo.

When a timber merchant can supply FSC timber, but does not hold "chain of custody" certification themselves, timber must be ordered in complete lorry loads, with packaging intact, to carry forward its FSC accreditation. If lorry loads are broken up, there is no way of assuring that FSC timber is being sold on. Ordering complete lorry loads is not always practical as this requires a large order. It is preferable to use a timber merchant with "chain of custody" certification.

A supplier's 'chain of custody' number provides proof that products are FSC certified. The number appears on invoices. In addition to invoice references, BedZED construction managers requested that chain of custody details be included on delivery notes. This enabled them to check materials as they arrived on site and so be able to turn away any uncertified material.

Certified timber used at BedZED

200m^3 of FSC certified timber was used on BedZED. This was mainly for external studwork, weatherboarding and internal joists. The softwood studwork and joists were sourced from Howie timber yard in Scotland and were supplied by Watford Timber. The hardwood timber was sourced locally and supplied

by BioRegional and English Woodlands Timber. Some higher grade timber for internal joinery applications was impossible to source within the UK and so a mixture of Scandinavian timber with PEFC certification and Finnish timber with FFCS certification was purchased.

Availability

At the time of BedZED's construction in 2000-2001, Scandinavian FSC timber was difficult to secure. Despite preliminary claims by suppliers that is was available, when it came to placing an order and asking for certification paperwork, availability disappeared. UK FSC timber, on the other hand, was available and was used extensively.

Scandinavian FSC timber is now widely available but care must be taken to keep chain of custody certificates in place.

Cost comparison

FSC and other certified timber is claimed to be available at most main timber merchants at no extra cost. UK grown timber was found to be 7% more expensive than Scandinavian with or without FSC accreditation.

Conclusions

Timber production from FSC certified woodlands is widespread in the UK and abroad. Millions of hectares of productive forests in Sweden, Poland and the Baltic states are acquiring FSC certification.

However, FSC certified timber used in construction with full chain of custody documentation in place is extremely rare. The current system makes it very difficult for contractors to source and maintain accreditation. The vast quantities of FSC timber being produced are not reaching their applications with accreditation intact.

In order for FSC specification to be adopted widely throughout the construction industry, chain of custody issues for Clients, contractors and timber merchants need to be addressed. In particular, more timber merchants with chain of custody are needed. FSC-UK report that Travis Perkins are in the process of certification. For lists of certified suppliers contact FSC-UK.

Recommendations

Always specify FSC accreditation for new timber and insist on chain of custody certificates.

A review of the practicalities of certifying timber at the downstream end of the supply chain is needed.

Contacts

Watford Timber: 01923 711888
Howie: 01556 610876
BioRegional Development Group: 020 8404 4880
English Woodlands Timber: 01730 816941
FSC – UK:01686 413916

CASE STUDY 4 : PLYWOOD

3,274m^2 of FSC plywood was used in all hidden applications. There is only one supplier of FSC certified plywood in the UK. This is Creffields who buy from Gethal Amazonas in Brazil. It is made from certified tropical hardwood and therefore supports a company employing sustainable logging practices in a critical world forest resource.

FSC certified plywood is currently only available in lower face qualities (B/BB and BB/CC grades). Visible plywood for window surrounds and kitchen units needed a higher quality and so Russian birch-faced ply was used.

FSC plywood of this grade cost £26/sheet as compared with £16/sheet for non-FSC equivalent.

Contacts

Creffields - 0118 945 3533

FSC Plywood vs	Non-FSC
	Easy
	Cost premium
	Modest

FSC ply from Creffields

Russian birch faced ply

vs	uPVC
Timber	Easy
	Saving
	High

vs	Aluminium
Timber	Easy
	Neutral
	High

CASE STUDY 5 : WINDOW FRAMES

The BedZED Design Team sought to avoid high impact materials such as uPVC and aluminium. So when it came to selecting window frames, timber was the obvious choice.

With triple height conservatories and 3,500m^2 of glazing, the windows package makes up 3% of the total construction costs and a much higher percentage of the material costs. The specification of these significant items is key to the buildings thermal performance and the quality of the internal environment.

Options explored

The Design Team explored the best environmental option - frames made from locally sourced hardwood. This long life and low maintenance material has lower life cycle costs than softwood alternatives which would require a £14,000/year maintenance programme and more frequent replacement. Using a locally distinctive product adds character to a development; whilst creating a demand for locally grown timber products brings neglected UK woodlands into economically viable management.

However, local joinery companies were reluctant to work with local chestnut, when their experience lay in producing softwood frames. There was little local expertise in manufacturing high performance, triple glazed, airtight windows. Also, the scale of the contract was too large for the companies operating locally. These factors led to prohibitively high quotes.

The geographical net had to be spread wider. Danish window specialist Rationel were able to meet both stringent performance demands and cost criteria. Rationel source 40% of their timber from FSC certified sources.

Design considerations

A key element of the design was keeping the windows as large as practically possible. Even with wooden frames, the metal spacers between the glass panes act as cold bridges. Large panes have less perimeter length than lots of smaller panes.

It is important for designers and suppliers to use "overall" U-values and not the typically quoted "mid-pane" U-values. Overall U-values will be worse but will more truly reflect the window's thermal performance.

Cost comparison

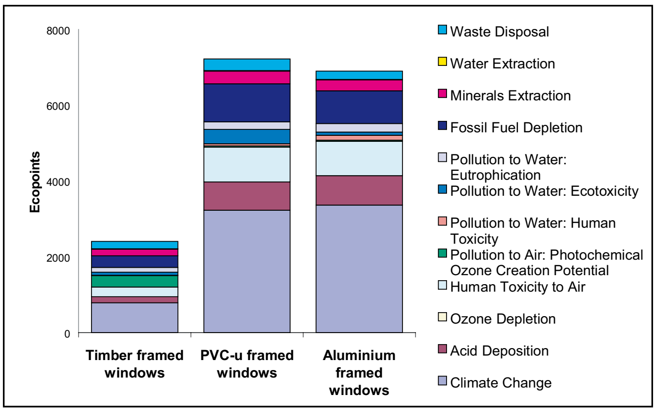
Timber windows are typically cheaper than aluminium or uPVC but can attract higher maintenance costs. The Rationel windows on BedZED are high specification in terms of air tightness, thermal performance and also durability. Their costs are higher than most timber windows but maintenance costs are lower.

The supply cost of Rationel windows on BedZED (excluding installation) for double and triple glazed ranged between £130/m^2 and £300/m^2. Equivalent aluminium frame windows from Alcoplan ranged from £185/m^2 to £275/m^2. uPVC windows from Ankers & Sons in the same price range only achieved U-values of 1.9W/m^2, as compared with 1.0-1.6W/m^2 for Rationel's timber windows.

Quantified environmental benefits

BRE have compared the BedZED softwood timber framed windows from Denmark with the conventional choice of uPVC windows manufactured in the UK and with aluminium framed windows (all double glazed).

BRE are aware that better quality LCA data on uPVC is now available and they are hoping to work with the British Plastics Federation in the near future to update this data.



Saving from using BedZED Specification		
	uPVC windows	Aluminium windows
Ecopoints	4,800	4,500
Embodied CO_2 ($kgCO_2$ eq$^{(100\ years)}$)	793,900	838,000
Embodied Energy (GJ)	12,000	9,750
Eco-footprint (ha years)	176[1]	186[1]

Beechblock vs Melamine	
Easy	
Lifetime saving	
High	

CASE STUDY 6 : KITCHEN FITTINGS

Requirements

A standard Peabody Trust kitchen consists of MDF units with parana pine frames and a formica work surface. In revisiting this specification the BedZED Design Team sought to:

- reduce the environmental impact
- increase the durability of the kitchen
- maintain a healthy internal environment by minimising off-gassing from kitchen fittings
- create a stylish kitchen and
- deliver the kitchen within budget.

BedZED kitchen

John Dight Kitchens, who manufactured kitchens for BedZED, worked with the Design Team to achieve the final product.

Kitchen units

Frame

John Dight Kitchens uses a Brazilian parana pine frame for kitchen units. This timber, considered to combine the properties of a hardwood and softwood, is chosen for its strength and durability. Reclaimed and FSC certified softwood could not compete in terms of strength and ability to take and hold a screw. As the frame is crucial to the durability of the kitchen, it was decided to retain the parana pine frame.

Carcassing

The standard MDF carcass was replaced by birch-faced plywood to reduce off-gassing of formaldehyde, which is implicated in sick building syndrome. The ply finish is also considerably more durable than MDF or chipboard options. As yet, there is no FSC certified plywood on the market with sufficiently good face quality for use in this application. There is no plywood manufactured in the UK. The plywood was sourced from Russia and is bonded using a fish-based glue rather than a formaldehyde-based alternative.

Doors

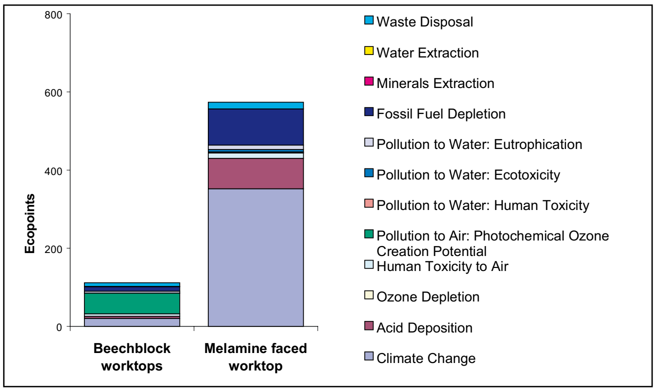
A variety of materials, including recycled plastic and local hardwoods, were explored for kitchen unit doors. However, for cost reasons, 18mm birch faced ply was chosen.

Work surface

A number of options for work surface finish, including recycled plastic and tiles, were explored. A block beech work surface was chosen. The beech wood is from Romania. The small sections required for this surface enable off-cuts of timber, which would otherwise be wasted, to be used.

Quantified environmental benefits

BRE have compared the 279m^2 of solid 40mm beechblock worktops with a typical melamine faced chipboard. The beechblock worktops use a small amount of PVA glue to bond solid timber; in comparison, the chipboard worktops use synthetic resins to bond chips of timber, much of it post consumer waste or waste from sawmills. Despite the low impact of the recycled timber, the chipboard has high impacts due to the processing involved in resin and board manufacture.



It should be noted that BRE are currently working with the Wood Panel Industries Federation to obtain better LCA data for chipboard and hope in the near future to update this data.

Saving from using BedZED Specification	
Ecopoints	462
Embodied CO_2 ($kgC0_2$ eq(100 years))	107,700
Embodied Energy (GJ)	1,160
Eco-footprint (ha years)	24[1]

Cost comparison

The materials for the BedZED kitchen units added about 20% additional cost to the standard Peabody Trust model. However, this higher initial investment is reflected in a low maintenance and longer life product. The whole life cost of the kitchen will therefore be reduced. From an environmental point of view, investing in a more durable product results in lower resource use in the long term.

[1] The eco-footprint saving for case studies 5 and 6 is an under-estimate due to lack of data.

VS New imported FSC

Reclaimed Doors

Difficult

Cost premium

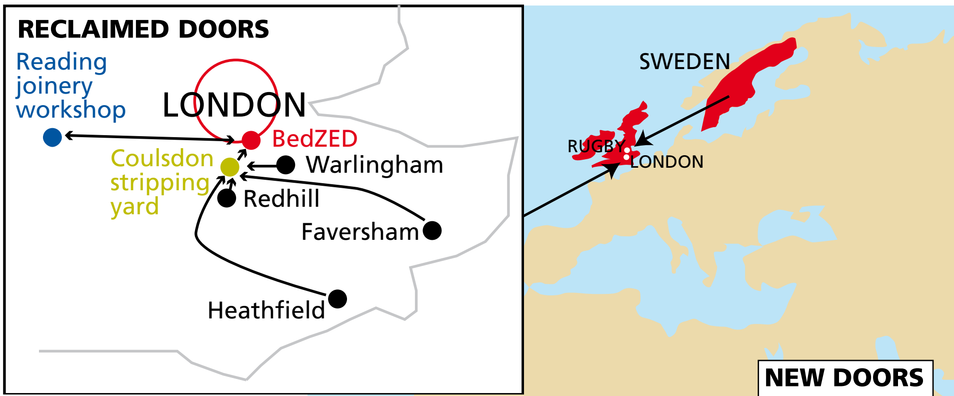
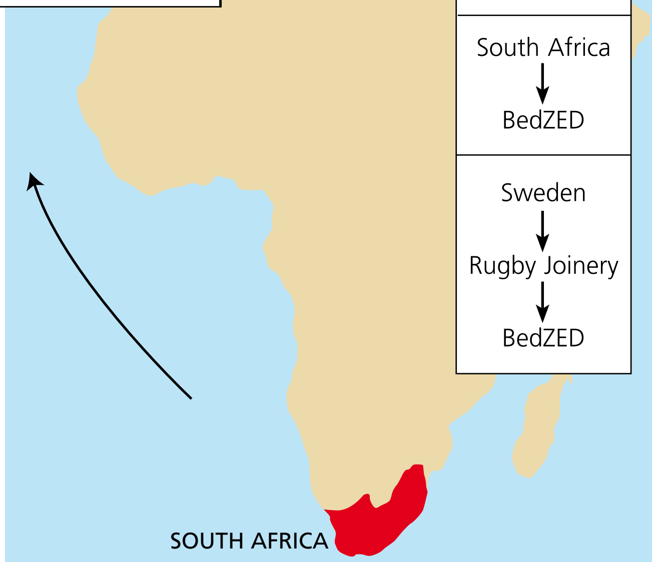
Modest

CASE STUDY 7 : RECLAIMED DOORS

Background

South East England is home to 100's of reclamation yards with stores of old doors of varying sizes and qualities. There are also a host of door restoration companies selling beautifully restored solid wood doors at a premium price. Demolition companies skip thousands of doors every year because reclamation yards do not have the turnover to accept them all. Currently, the only market for these reclaimed doors are individual enthusiasts and historic refurbishment companies. Supply outstrips demand.

At BedZED, there are some 476 internal doors. 350 of these could potentially come from reclaimed sources. BioRegional set out to pilot the sourcing of 150 of these from the reclamation and salvage industry and very quickly realised there was no-one who could meet an order of that size. Demolition companies, reclamation yards, architectural salvage merchants - none would take on the supply contract. Instead, BioRegional set up a supply chain based on a lot of good will.

New door prices vary from £70 – £700 (with ironmongery). On the BedZED budget, we were looking at the cheaper end of the market. In order to proceed with the reclaimed door option, we needed to obtain them for around £100 each delivered and ready to install.

Supply Chain

A number of reclamation yards around London, Surrey and Sussex were visited. Prices ranged from £10-£20/door based on a commitment to buy large quantities. BioRegional staff would spend a few hours with a representative from the yard, picking through all the doors at each site, selecting those of correct size, style and quality. A batch of doors would be bought and then the specifications were left with the yard staff to send further batches when stocks had been replenished. This hand-over of specifications eliminated the need for further BioRegional visits.

The doors were all sent to a Coulsdon stripping yard local to the BedZED site where a bulk discount was negotiated. (£7/door). The stripping yard agreed to deliver to the BedZED site for free. They also agreed to provide an element of quality control and to return any sub-standard doors to the reclamation yard they came from.

From BedZED, the joinery contractor took the stripped doors back to their workshop in Reading on return journeys of delivery vehicles. At the workshop, the joiners finished the doors, including trimming, filling, lipping and any remedial works. Excluding ironmongery, the cost of this work averaged out at £45/door.

How well did it work?

Once the supply chain was in motion, doors were coming through at about 20/week at an average cost of £67 each (excl. ironmongery). The supply chain was, however, dependent on lots of individuals making it work. A number of sub-standard doors got through the system and had to be rejected. On one particularly bad delivery, there was a 50% rejection rate. This led to abortive costs to the Client. The supply chain was consuming considerable staff time to keep it running smoothly and the doors were unpopular with the joinery contractor.

B&Q supply softwood panel doors made from FSC certified timber for £25. They are lower quality than the reclaimed doors but supply was cheap and simple and the FSC criteria was met, so the reclaimed door scheme was abandoned in favour of the B&Q doors.

Cost comparison

Item	Reclaimed	Rugby Joinery	B&Q
Door cost	15	175	25
Stripping	7		
Trimming and finishing	45		
Fix doors	32		40
Ironmongery	55	225	80
Fix ironmongery	80		
Supply and fix architrave,stops & frame	150		150
Total	**384**	**400**	**295**
Additional staff time	20		
Total	**404**		

Reclaimed doors were coming through slightly cheaper than the industry standard door from Rugby Joinery but could not compete with B&Q. Additional staff time involved in sourcing reclaimed doors and ensuring quality control was estimated at 20 person days. Costed at £150/ day, this adds an additional £20 to the price of each door.

Some of the more detailed lessons learned at BedZED are described below.

Door sizes

In sourcing reclaimed doors, there is a choice to be made between fitting the door frames to the doors or vice versa. Door frame kits in standard sizes are very cheap (£150 supplied and fitted) and the preferred option of volume joiners. Reclaimed doors are not standard sizes as they have often been trimmed or were made to imperial measurements. They can be trimmed to fit but side trimming must be limited to 15mm. Otherwise the joints are at risk. Trimming the bottom is less of a problem. Narrow doors can be lipped to bring them up to the required width but lips of over 30mm were considered unsightly. These trimming and lipping limits set the tolerances and size range that can be accepted for a given door frame size.

Disabled access

Where a new build development requires disabled access, doorways need to be 800mm wide. Most reclaimed doors were made at a time before disabled access was considered so wider doors are much less common. Old external front doors are usually wide enough but they tend to be 50mm thick and heavy. They are beautiful doors but they are more collectable and so cost more and are scarcer.

Style

There are many combinations of panelled doors from different eras. In sourcing 350 doors, it was possible to match up similar styles within each dwelling to quite a large extent but not in every case. Even similar styles are rarely identical. Clients and home buyers would hopefully see this as an interesting feature of the home rather than an imperfection.

Colour

Reclaimed doors were bought in their painted state and only after stripping was the timber colour revealed. On some occasions, the colour was not satisfactory and the door was rejected. Darkly stained wood was rejected and we learned to check for staining before selecting a door. Different timber species of varying colours were used in different historical eras. With experience, the style of a door can suggest its era and therefore hopefully its species and colour.

Ironmongery

In some cases it was possible to use the old latch system and just install a new handle. Unfortunately, this did not translate into a cost saving because handles and latch assemblies are ordered together.

Acrylic paint

Modern doors are commonly painted with acrylic paint which does not come off in the caustic soda stripping process we were using. We learnt to avoid selecting these.

Recommendations

In order for reclaimed doors to be used in large quantities by house builders and in refurbishment, the doors need to be available in bulk from one supplier. Door restoration companies can supply fairly large numbers if given sufficient lead times but their prices are not competitive for low budget housing. They provide a high quality extremely attractive historic item but it will cost £150/door or more, excluding ironmongery.Rather than buying from reclamation yards, doors can be bought from demolition contractors direct if a suitable demolition job is going on at the right time. This arrangement requires long lead times, storage space and some luck.

BedZED has shown that it is possible for reclaimed doors to be supplied for under £100/door (excl. ironmongery and fitting). New doors of comparable quality would cost £250 or more. But in order to supply at this price, Clients need to be willing to accept a variety of styles. Long lead times and storage space help enormously.

Reclaimed doors can never compete with B&Q £25 doors on cost alone, but for finished quality, durability and aesthetic appeal, they must be the best value on the market. On future projects, reclaimed doors can be achieved if the supply chain works smoothly. The lessons learnt on the BedZED experience will be used to set up a simpler system of supply with better quality control.

The ideal solution to widespread use of reclaimed doors is for a reclamation yard to specialise in doors. This company would hold large stocks of doors already stripped and stored in dry conditions. Ideally, they would trim the doors to uniform sizes, collect up batches of matching styles and sell the doors in bulk batches of 10, 20, 50 etc. The company could also stock door frame kits to match the sizes they sell. Under these circumstances, large orders could be met and economies of scale would become significant.

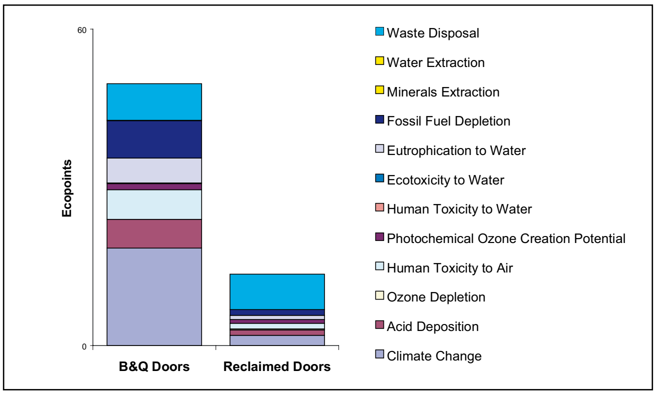
Feedback from purchasers of properties at BedZED suggests that reclaimed doors would be a popular selling feature of any property. Further work by BioRegional, in partnership with a reclamation company, will establish the viability of such a business.

Quantified environmental benefits

The BRE has used its environmental profiling method to quantify the reduced environmental impact of reclaimed doors compared with the B&Q FSC doors from South Africa that were actually used.

The B&Q doors are based on data for manufactured kiln dried timber consumed in the UK, but with an additional transport impact for the shipping from South Africa. The sustainability of the forest management in terms of biodiversity, land use and social impacts are not included within the assessment. This would reduce the impact and the ecopoints score of the B&Q doors if it were included.

The reclaimed doors were sourced from sites up to 35 miles away, brought to BedZED, then transported in batches to a joinery workshop. The paint stripper uses a caustic soda process to strip the doors.



Saving from using BedZED Specification	
Ecopoints	-36
Embodied CO_2 (kgCO_2 eq(100 years))	-5,370
Embodied Energy (GJ)	-97
Eco-footprint (ha years)	-48

Note, the savings are negative as the impact of using B&Q doors is greater than the impact of using reclaimed doors.

Contacts

Sussex Demolition, Warlingham, Surrey - 01883 626122
Ajeer Ltd, Heathfield, Sussex - 01424 838555
Eco-merchant, Faversham, Kent - 01795 530130
Hedway, Redhill, Surrey - 01737 762033
Handmade Door Company, Redhill, Surrey - 01737 773133
Drummonds, Hindhead, Surrey - 01428 609444
West 7, Hanwell, West London - 020 8567 6696
CSM Stripping, Coulsdon, Surrey - 0208 668 4443
Salvo www.salvoweb.com

Reclaimed Steel vs New steel	
Ease	Fairly easy
Cost	Neutral
Environmental benefit	High

CASE STUDY 8 : RECLAIMED STRUCTURAL STEEL

98 tonnes of reclaimed structural steel has been used on BedZED. This amounts to 95% of the structural steel on the scheme and is mainly used in the steel frames in the workspaces. The sections are retrieved from demolition sites within the 35 mile radius.

Reclaimed steel

Design

The engineers specified a range of section sizes that could be used for each piece. Connection details were designed to accommodate this range of sizes. This approach, at an early design stage, allowed for flexibility in sourcing the reclaimed sections.

Steel framed workspace

Once reclaimed steel sections had been identified, The Historic Sections Book was used to obtain allowable stresses.

Quality

Prior to ordering any reclaimed steel, the structural engineers carried out a visual inspection of the material, checking:

- Date of manufacture
- Condition ie. Rust or scaling
- Number of existing connections either bolted or welded
- Suitability for fabrication

Reclamation process

Sand blasting, fabrication and painting of all new and reclaimed structural steel took place in the steelwork contractor's workshop. The reclaimed steel required an extra pass through the sand blaster and treatment with a zinc-rich coating.

Curved steel sections

It was not possible to use reclaimed steel for the curved sections on BedZED. The local section bender was unwilling to pass reclaimed steel through their machine. Due to time and programme pressures, the contractors proceeded with new steel for these pieces rather than finding an alternative company. There is no technical reason why reclaimed steel should not be curved on future projects.

Cost comparison

On BedZED, using reclaimed steel was 4% cheaper than using new. The cost average was £300/tonne, although this price varied considerably according to the source. The comparative tender price for new steel was £313/tonne.

The cost of additional staff time in sourcing reclaimed steel and the visual inspection has been estimated at £1,000, making the use of reclaimed steel effectively cost neutral.

Construction contract

The steelwork package was tendered competitively on the basis of new steel. Tenderers were then asked for a rate reduction for the free issue of reclaimed steel. Cut off dates for the placements of orders for new steel were agreed and responsibility for sourcing and delivering the reclaimed steel was with the construction managers.

Sourcing/Availability

Reclaimed steel

There are not vast quantities of good quality reclaimed structural steel stored in reclamation yards. It requires active searching and probably some luck to find the right materials. For this reason, it is important to build in as much flexibility as possible and to allow for long lead times.

In the absence of sourcing from a yard, the ideal situation is to identify a steel source in a building that is about to be demolished and to have it extracted carefully.

Risk allocation

The Construction Manager purchased the reclaimed steel on behalf of the Client. There was a risk to the Client as with any free-issue materials. The structural engineer, Ellis & Moore held the risk associated with the structural integrity of the steel.

Quantified environmental benefits

BRE have compared the impacts of the recalaimed steel with new. They have allowed for one additional grit blasting prior to use. Overspecification of the reclaimed beams was very small (<0.5%), as most of the reclaimed beams were in good condition, and were standard sizes.

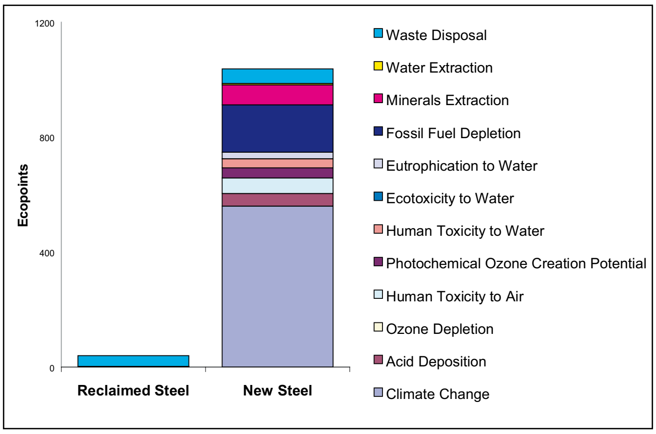
The environmental impacts of new steel are based on the typical mix of steel sections manufactured from virgin (BOF) and recycled (EAF) steel consumed in the UK.

Saving from using BedZED Specification	
Ecopoints	1000
Embodied CO_2 (kg$C0_2$ eq$^{(100\ years)}$)	81,580
Embodied Energy (GJ)	2,580
Eco-footprint (ha years)	137

These savings reduce BedZED's total eco-footprint by approximately 3.8%.

In addition

As a spin off from BedZED, 11.5 tonnes of reclaimed structural steel was also used on the entrance building to the Earth Centre, resulting in 303GJ embodied energy savings, 21 tonnes of CO_2 saved and an eco-footprint reduction of 12.6 hectares.



Contacts

Ellis & Moore Consulting Engineers: 0207 281 4821
Joy Steel Contractors: 020 7474 0550
Reclaimed steel suppliers:
SGB Major Projects - 01342 835555
Civil Steel Services Ltd - 01322 337766

CASE STUDY 9 : RECLAIMED PAVING SLABS

Reclaimed slabs vs	New slabs
	Difficult
£	Neutral
	Medium

BedZED uses 1,800m^2 or 270 tonnes of concrete paving slabs for hard landscaping. BioRegional researched the possibility of using reclaimed paving but did not find a way to make it work.

Most local authorities have a programme of work where old paving is ripped up and replaced. Although this work is usually taking place because of damaged paving slabs, with a little extra care, a large proportion of the slabs can be taken up undamaged and can be used again. Some local authorities save them and re-use them within the borough but most skip them. During BioRegional's enquiries, a number of local authorities offered them to BedZED for free.

Paving slabs are a very low value material with high handling and storage costs. Co-ordinating the local authority programme for collecting the slabs with the BedZED construction programme for installing the slabs was not possible without additional storage space. BedZED required a large quantity of slabs all at once, while local authorities usually stagger their programme of replacement in order tominimise disruption. The need to store the slabs off site meant incurring double handling costs.

Saving from using BedZED Specification	
Embodied CO_2 (kg$C0_2$ eq$^{(100\ years)}$)	– 56,549
Eco-footprint (ha years)	– 27

Cost comparison

In order to transport the slabs without damaging them, they need to be stacked on pallets and secured with metal straps (banding). The cheapest quote we got for this was 95p per slab. A batch of 490 slabs were identified in Woking, where delivery would have cost 84p per slab. If storage could have been found on site at BedZED, the slabs would have cost £1.79 each, as compared with £2 each new.

Recommendations

As with all reclaimed materials, the key to success is long lead times and storage space. With these, the slabs can be taken from local authority works as they become available. The cost of the storage site would be the one most critical factor in making this reclaimed material economically viable.

As disposal charges rise, it should become possible to actually charge local authorities for taking the slabs away. This will help to bring the net costs down below those of new slabs.

Concrete slabs vs In-situ concrete

- Easy
- Saving
- High

CASE STUDY 10 : CONCRETE FLOOR SLABS

BedZED uses 8,000m^2 of pre-stressed concrete floor slabs. They were used in preference to reinforced in-situ concrete. This solution used less materials and involved less embodied energy than in-situ concrete. It also saved time and costs on site.

Concrete is the best material for the BedZED floors as it provides thermal mass, acoustic insulation and performs a structural function.

Design

The concrete slabs were designed with a screed finish top surface and an exposed soffit. No plastering or suspended ceiling was included, eliminating ceiling materials, reducing environmental impact and labour time, simplifying the build programme and achieving cost savings.

The joint between slabs was designed with a lip so they could be grouted from above.

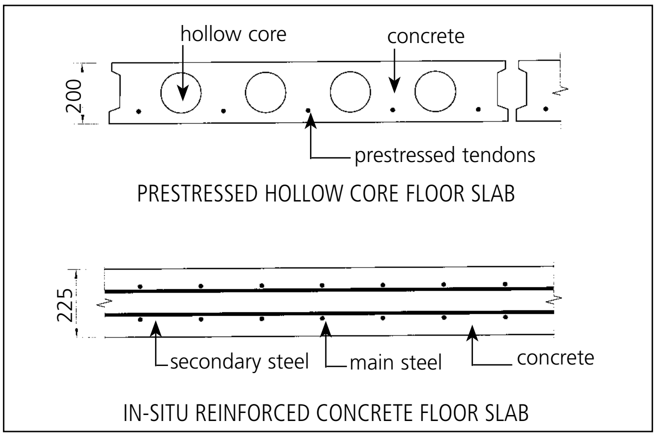
Quality

Installation of the slabs involved craning them in, suspended by chains. Initially, some chipping occurred but this was quickly resolved. The product used on BedZED is not designed for an exposed finish. The interesting finish to the soffit created by the speckled air bubble pockets is considered a feature.

The slabs have a slightly arched camber along the length of their span. In some cases, the camber between adjacent slabs does not match and this can be seen in the ceiling from below. The effect is minimal and has been accepted by Peabody and most of the buyers, but care is needed during installation. The screed finish to the top surface ensures that camber differences do not show from above.

	Pre-stressed	In-situ
Thickness	200mm	225mm
Self weight	2.9 kN/m^2	5.4 kN/m^2
Steel content	4 kg/m^2	13 kg/m^2
Concrete content	292 kg/m^2	537 kg/m^2
Total steel content	32 tonnes	104 tonnes
Total concrete content	2,336 tonnes	4,296 tonnes
Steel saving	72 tonnes	
Concrete saving	1,960 tonnes	

Pre-stressed vs Standard reinforced



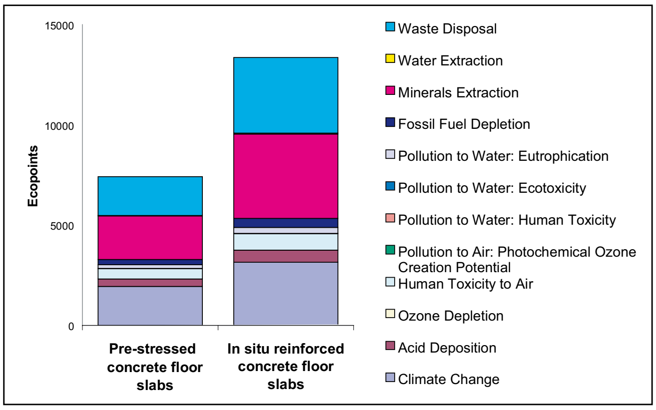
Construction contract

The slabs were designed, supplied and installed by Tarmac following competitive tender.

Cost comparison

There is no simple way to compare cost with the in-situ option, but a significant saving is achieved. The need for formwork and scaffolding is avoided. The programme is speeded up because there is no concrete setting time before work can continue; no concrete drying time before occupations can occur; no plastering or suspended ceiling work.

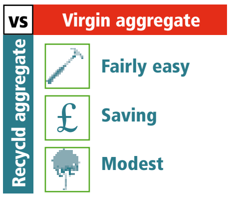
Quantified environmental benefits



Saving from using BedZED Specification	
Ecopoints	5,940
Embodied CO_2 (kgCO_2 eq(100 years))	392,600
Embodied Energy (GJ)	3,270
Eco-footprint (ha years)	297

Contacts

Tarmac Topfloor Limited (01335 360601)



CASE STUDY 11 : RECYCLED AGGREGATE

BedZED used 980 tonnes of recycled aggregate made from crushed concrete. The material was supplied as a graded product (Type 1) and was used in the road sub-base. It replaced the same quantity of virgin limestone aggregate.

Procurement

The crushed concrete was bought direct by the groundworks contractor, Edenway Contractors Ltd. Edenway used two local suppliers, Day Aggregates Ltd and George Killoughery Ltd. Product Datasheets are available from Day Aggregates.

The contractor has used this product before and is using it on other jobs whenever it is acceptable to the client. Edenway experienced no difficulties in obtaining or using this product and it brings them a cost saving. Day Aggregates say that they have been selling this product for 10 years but that sales have increased since the introduction of the aggregates tax in April 2002.

Cost comparison

Recycled aggregate	£9/tonne
Virgin aggregate	£12.50/tonne
Cost saving	£3.50/tonne
Total cost saving on BedZED	£3,430

The aggregates tax implemented in April 2002 (since BedZED construction) has increased the price of virgin aggregate by a further £1.60/tonne, making potential cost savings even greater.

Porous paving

Approximately 30% of the hard landscaping is porous paving. The guarantees for the porous paving are conditional on very strict sub-base aggregate grading in order to ensure sufficient water storage capacity. Crushed concrete available at the time of construction did not meet this specification so it was not possible to use it under these zones. A suitable supplier has now been identified.

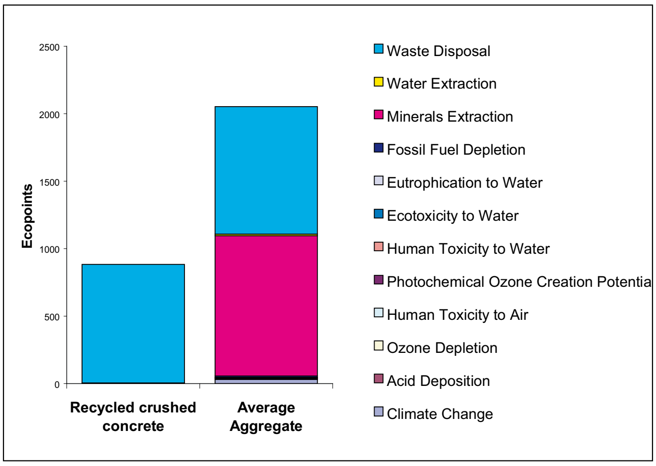
Recycled aggregate in concrete

The Team looked at the possibility of using crushed concrete as aggregate in the structural or mass concrete at BedZED. The conclusions were that although it is theoretically possible, the British Standards, Building Regulations, Building Control and the NHBC are not sufficiently familiar with this option. Specification guidelines are not fully developed and this would be an added layer of complexity in an already innovative project that would not work within our programme and budget.

There are current research projects and demonstration projects in the UK using recycled aggregate and it is hoped that established guidelines will be in place so that it can be done next time. (further info. - BRE 01923 664000)

Quantified environmental benefits

The environmental impact of the recycled aggregate used on BedZED has been compared with virgin aggregate typically sourced in the UK.



Saving from using BedZED Specification	
Ecopoints	**1,170**
Embodied CO_2 ($kgC0_2$ eq$^{(100\ years)}$)	**8,840**
Embodied Energy (GJ)	**132**
Eco-footprint (ha years)	**2**

Contacts

Edenway Contractors Ltd - 020 8450 8474
Day Aggregates Ltd - 020 8380 9600
George Killoughery Ltd, Mitcham - 020 8648 3737

Recycled sand vs Virgin sand

- Easy
- Saving
- Modest

CASE STUDY 12 : RECYCLED SAND

BedZED used 279 tonnes of recycled crushed green glass. It was used in the hard landscaping as bedding for paving slabs and replaced the same quantity of virgin sand.

Procurement

The recycled product was bought direct from Day Aggregates by the groundworks contractor, Edenway Contractors Ltd. It is an off-the-shelf product. Product Datasheets are available from Day Aggregates.

Edenway is now suggesting this product to other Clients and using it whenever possible. They experienced no difficulties in obtaining or using this product and it brings them a cost saving. Day Aggregates say that sales have increased since the introduction of the Aggregates Tax in April 2002.

Safety

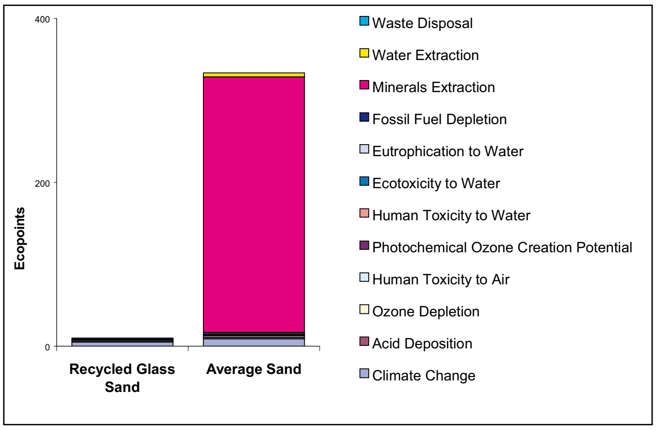
Risk assessments and COSSH statements were prepared by the suppliers. The finely ground glass is similar to sand in consistency but may be slightly sharper to touch. Gloves can be worn while handling. No safety issues arose on site at BedZED.

Cost comparison

Recycled crushed glass sand cost £10.75/tonne from Day Aggregates. This was approximately £2/tonne cheaper than virgin material, saving the project £558 (~ 15% of the material cost). The aggregates tax implemented in April 2002 (since BedZED construction) has increased the price of virgin aggregate by a further £1.60/tonne, making potential cost savings even greater.

Quantified environmental benefits

The environmental impact of the recycled glass sand used on BedZED has been compared with virgin sand typically sourced in the UK.



Saving from using BedZED Specification	
Ecopoints	320
Embodied CO_2 (kgCO_2 eq(100 years))	1,330
Embodied Energy (GJ)	17
Eco-footprint (ha years)	1

Contacts

Edenway Contractors Ltd - 020 8450 8474
Day Aggregates Ltd - 020 8380 9600

vs	National average
Local blocks	Easy
	Neutral
	Modest

CASE STUDY 13 : LOCAL CONCRETE BLOCKS

Concrete blockwork at BedZED

BedZED uses 3,000 tonnes of dense concrete blocks. Forming the internal skin of the cavity walls, these blocks make up a large part of the thermal mass strategy, with 2,000kg/m^3 of concrete soaking up heat at warm times and releasing it through its exposed radiant surface at cooler times.

As one of the most significant bulk items on the project, the Team looked for a supplier who could meet this large order from within 35 miles. Jewsons were able to source 80% of the order from Purfleet and Medway. The remainder had to come from Ipswich, bringing the average sourcing distance up to 45 miles. This improves on the UK average delivery distance for this material of 93 miles.

Construction contract

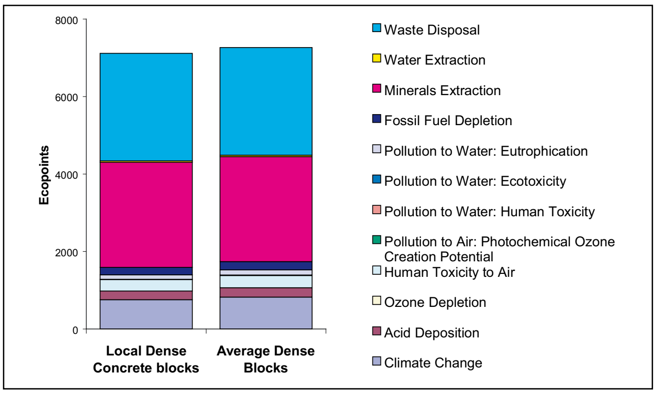
The blocks were free-issued to the brickworks contrator.

Contacts

Jewsons: 020 7732 0707

Quantified environmental benefits

The BRE have quantified the reduced environmental impact due to this local sourcing policy.



Saving from using BedZED Specification	
Ecopoints	147
Embodied CO_2 (kg$C0_2$ eq$^{(100\ years)}$)	21,970
Embodied Energy (GJ)	290
Eco-footprint (ha years)	16

CASE STUDY 14 : LOCAL BRICKS

vs	National average
Local bricks	Easy
	Neutral
	Modest

BedZED uses 390,000 bricks (1,584 tonnes) sourced direct from the local brickworks at Cranleigh, just 20 miles from site. The average transport distance for bricks in the UK is 93 miles. BRE have quantified the reduced environmental impact due to this local sourcing policy .

Wastage

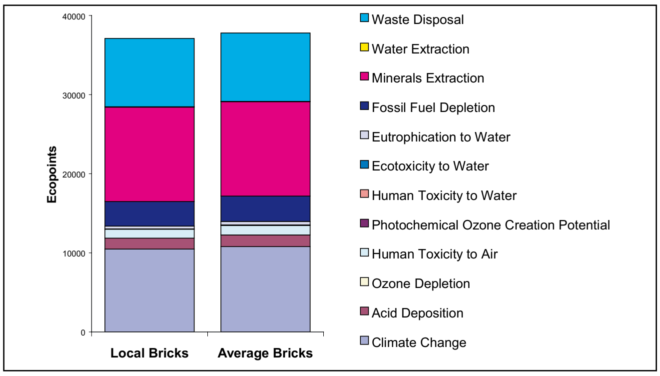
The bricks were free-issued to the brickworks contrator with a maximum wastage allowance of 3%. Any wastage beyond that resulted in extra costs to the contractor. This incentivised low wastage levels.

Reclaimed bricks

The possibility of reclaimed bricks was explored but rejected as the costs would be twice the price of new for an inferior product.

Contacts

Cranleigh Brick & Tile Co. Ltd. - 01403 823251



Saving from using BedZED Specification	
Ecopoints	69
Embodied CO_2 (kg$C0_2$ eq$^{(100\ years)}$)	10,221
Embodied Energy (GJ)	134
Eco-footprint (ha years)	13

CASE STUDY 15 : INSULATION

Energy consumption in domestic dwellings makes up 29% of UK energy consumption, while the embodied energy of domestic dwellings makes up only some 2-3%. Investment of embodied energy in super-insulation pays back in energy efficiency within a few years[1]. A well installed, durable insulation product will go on producing significant energy savings for 60 years.

BedZED buildings sit in a jacket of 300mm of insulation. Insulation materials used are shown in the table.

	Application	Quantity (m^3)	Supplier
Rockwool	wall cavities	2,200	Rockwool
Expanded polystyrene	ground floor slab	1,520	Combat
Extruded	roofs	1,200	Poliglas

BedZED's traditional cavity wall construction means that moisture may enter the cavity. Insulation materials must therefore be non-biodegradable for durability. This rules out some of the natural insulation products on the market such as hemp or sheep's wool. Rockwool and polystyrene products were chosen for their excellent thermal performance, dimensional stability, durability, familiarity to contractors, cost effectiveness and off-the-shelf availability.

Rockwool was used in preference to polystyrene products for its lower embodied energy (approximately $^1/_5$th)[2]. However, roof and floor applications required polystyrene products with 330kPa compressive strength. Expanded polystyrene was specified in preference to extruded polystyrene because of less damaging blowing agents during production. Extruded polystyrene was selected for the green roof application because of its closed cell structure that does not allow water penetration.

expanded polystyrene insulation for ground floors

rockwool insulation in walls

Unfortunately, despite specifications to the contrary, a rushed programme and late production of information from contractors meant that the wrong insulation product was installed in the roof. BedZED regretfully was fitted with extruded polystyrene blown with HCFC, a gas that has significant ozone damaging potential. Insulation blown with recycled CO_2 should have been used. The environmental impact of this error is very significant, adding some 100kg CO_2/m^2 to the overall embodied CO_2 of the scheme, additional to the figures quoted in Chapter 9 and the Summary.

Designers and specifiers must take care in specifying polystyrene insulation products. The following table summarises the range offered by Poliglas.

Product	Blowing agent	Thermal conductivity (W/mK)	Ozone damaging potential	Global warming potential
–	CFC (now illegal)		Yes	
Glascofoam	HCFC (illegal 1-Jan-2002)	0.026	Yes – $^1/_{20}$th of CFC[2]	
Glascofoam HR	HFC	0.026	No	Yes – 3200 times that of CO_2[2]
Glascofoam N	Recycled CO_2	0.036	No	No
Expanded polystyrene	Pentane	0.026	No	No

Glascofoam N blown with recycled CO_2 has a higher thermal conductivity (lower thermal performance) than its HFC and HCFC alternatives, but it is cheaper and so greater thickness can achieve the same thermal performance for the same cost.

Recommendations

Use rockwool in preference to polystyrene products.

Where polystyrene products are being used, designers must take care to specify materials that are CFC-, HCFC- and HFC-free.

Specify expanded polystyrene or, in specifying extruded polystyrene, specify recycled CO_2 as the blowing agent.

Contacts

Rockwool - 01656 862621
Combat - 0117 937 3757
Poliglas - 020 8977 9697

1 Dlk-Teknik
2 Green Building Handbook

7 Case Studies Summary

Environmental Benefits

Case Study	Material	Quantity	Conventional alternative	Embodied CO_2 saving (kg CO_2 eq$^{(100\ years)}$)	Ecopoint saving	% Eco -point saving	Eco-footprint saving (ha years)	Ease	Cost	Environmental savings
1	Local oak weatherboarding	3,500m²	Preserved softwood weatherboarding	4,630	161	66		Fairly easy	Lifetime saving	Modest
			Brick cladding	204,000	2,300	95		Fairly easy	Saving	High
			uPVC cladding	503,000	3,500	97		Fairly easy	Cost premium	High
2	Reclaimed timber studwork (internal)	350m³	New softwood	63,460	380	82	174	Fairly easy	Saving	High
2	Reclaimed timber studwork (external)		New softwood	Only small quantity used				Difficult	Cost premium	High
2	Reclaimed floorboards	700m²	New softwood	2,370	14	83	6	Easy	Saving	Modest
3	FSC timber	200m³	Non-FSC timber	Environmental benefits not quantifiable				Fairly easy	Neutral	Medium
4	FSC Plywood	3,274m²	Non-FSC	Environmental benefits not quantifiable				Easy	Cost premium	Modest
5	Timber framed windows	3,671m²	uPVC framed windows	793,900	4,800	67	176[1]	Easy	Saving	High
			Aluminium framed windows	838,000	4,500	65	186[1]	Easy	Neutral	High
6	Beechblock worktop	279m²	Melamine faced worktop	107,700	462	81	24[1]	Easy	Lifetime saving	High
7	Reclaimed doors[2]	476	New FSC	5,370	36	73	48	Difficult	Cost premium	Modest
8	Reclaimed steel	98 tonnes	New steel	181,580	1,000	96	137	Fairly easy	Neutral	High
9	Reclaimed paving slabs[2]	New	1,800m²	56,549			27	Difficult	Medium	Medium
10	Pre-stressed concrete floor slabs	7,068m²	In-situ concrete	392,600	5,940	44	297	Easy	Saving	High
11	Recycled aggregate	980 tonnes	Virgin aggregate	8,840	1,170	57	2	Fairly easy	Saving	Medium
12	Recycled sand	297 tonnes	Virgin sand	1,330	320	97	1	Easy	Saving	Modest
13	Local concrete blocks	3,000 tonnes	National average	21,970	147	2	16	Easy	Neutral	Modest
14	Local bricks	1,584 tonnes	National average	10,221	68.5	1	13	Easy	Neutral	Modest
15	HCFC and HFC-free insultation	1,200m³	HCFC blown insulation	978,000			217	Easy	Neutral	High

[1] Eco-footprint saving under estimated. Limited to embodied CO_2 saving due to lack of data on other impacts

[2] Not achieved on BedZED

Conclusions

The largest saving in eco-points came from using the pre-stressed concrete floor slabs in preference to concrete cast in-situ. Pre-stressed concrete is a standard building product familiar to engineers, architects and contractors. The floors make up a significant component of the materials on the scheme (some 15% by weight). The saving comes from needing less concrete and less steel to perform the same function, thus saving in embodied energy, minerals extraction and waste disposal. The use of pre-stressed concrete in any construction application will always result in significant environmental savings compared with standard reinforced concrete.

The largest saving achieved in CO_2 emissions came from using timber window frames in preference to uPVC. This choice saved nearly 800 tonnes of CO_2 emissions (some 12.5% of the total embodied CO_2). It also brought the project a cost saving of £200,000-£400,000. The environmental impacts associated with uPVC cover most of the 12 impact areas in environmental profiling, principally climate change, acid deposition and toxic emissions to air and water.

Reclaimed steel and recycled sand achieved 96% and 97% savings relative to the conventional alternative, virtually wiping out their environmental impact. The steel was achieved cost neutrally and the recycled sand saves some £3-4/tonne compared to new.

Using beech block worktops in the kitchens in preference to melamine brought about a surprisingly large CO_2 saving, despite the relatively small quantity of this material used. This material did cost extra and was a choice by the Client based on quality and durability as well as environmental benefit. It added value to the properties.

All but two of the material choices used were achieved cost neutrally or with financial savings. The others will achieve savings in maintenance costs over the lifetime of the buildings and will recover their higher initial costs.

The environmental savings actually achieved by the case study materials reduce the total impact of the development by 20-30%. If all the case study materials in the table were achieved, environmental savings would represent some 40-45% of the total impact.

8 Local Sourcing Analysis

The table in Appendix 1 lists all the materials used to construct BedZED and where they came from. Average miles travelled have been calculated to see how well the project did in its target to source as much as possible from within a 35 mile radius.

Local sourcing is important for reducing road haulage. For heavy materials such as aggregate or bricks, weight is the limiting factor on haulage capacity for each truck. Other materials such as insulation or wind cowls are relatively light and volume during transport is what dictates the number of truck loads necessary for delivery.

In the local sourcing analysis we have therefore considered average haulage distance both by weight and by volume. Most of the heavy materials were sourced locally whilst lighter, more specialist materials came from further afield. This shows in the results where the average distance by weight is much lower than the average distance by volume.

Results:
199.1 miles by volume
65.4 miles by weight

52% of the materials (by weight) were sourced within the target 35 mile radius.

By comparison with UK average haulage figures, the same buildings using the same materials but with average sourcing distances would have the following results:

Results:
242.6 miles by volume
106.8 miles by weight

By saving a transport distance of 40.3 miles for each tonne of material used, some 120 tonnes of CO_2 emissions were saved. 10 tonnes of this was from the local bricks and 22 tonnes from the local concrete blocks. 120 tonnes amounts to some 2% of the embodied CO_2 of the BedZED buildings. This equates to 6kg / person / year, or the CO_2 burden of 10 people for 1 year.

These savings were achieved at no cost and with no additional staff time. They were a simple choice to use a local supplier.

The BedZED local sourcing policy saves an eco-footprint of 99 hectare years.

9 Total Embodied Impact Analysis

BRE have calculated the Ecopoints, embodied CO_2 and embodied energy for the whole BedZED scheme, based on all the materials used. A total breakdown of materials, quantities and sources is shown in Appendix 1. It was not practical to collect data on minor materials such as wiring, pipework or light fittings etc, so BRE have included an extra allowance for services to dwellings (plumbing, electrics, bathroom and kitchen fittings etc.) based on their experience.

	Ecopoints	Embodied Energy (GJ)	Embodied $C0_2$ (kg CO_2 eq$^{100\ years}$
Overall Development	72,020	65,700	6,389,900
Per dwelling	640	585	57,700
Per m2 (dwelling)	7.5	6.85	675
Per m2 (workspace)	7.0	6.42	600
Allowance included for services per dwelling	45	35	6,700

Benchmarks for embodied CO_2 for domestic dwellings range from 300-1,000kg/m2[1]. Volume house builders build in the range 600-800kg/m2. BedZED dwellings, at 675kg/m2, fall within that range, despite the use of high thermal mass and super-insulation. BedZED has achieved buildings that can operate carbon-neutrally for 60-120 years without introducing any additional CO_2 emissions in construction.

For offices, embodied CO_2 ranges from 500-1,100kg/m2[1]. At 600kg/m2, BedZED workspaces are in the lower half of the range and also provide carbon-neutral buildings at no additional initial cost to the environment.

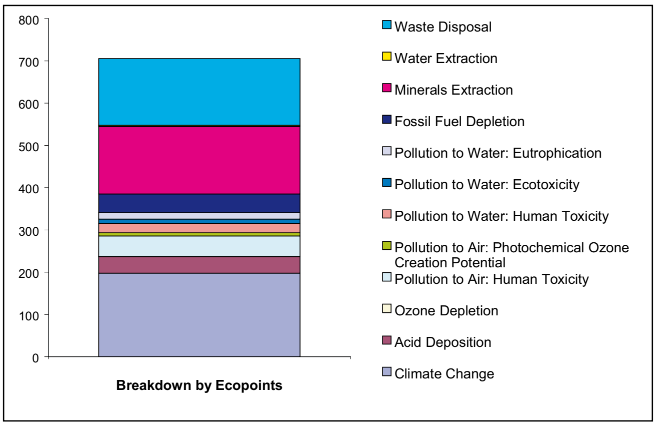
Photovoltaic panels

There is an additional embodied impact for the photovoltaic (PV) panels built into the BedZED windows and roofs. The PV's add some 12% to the embodied impact of the construction of BedZED. The panels generate 108,000 kWh of high grade solar electricity every year, saving some 52,000kg of CO_2 emissions. The environmental payback for the embodied impact of PV panels is approximately 15 years.

	Ecopoints	Embodied Energy (GJ)	Embodied $C0_2$ (kg CO_2 eq$^{100\ years}$
PVs for Overall Development	7330	9550	755,100

Environmental Profiling

The graph below shows a breakdown by environmental issue of the environmental impact of construction per BedZED dwelling, including PV's. The major issues, contributing over 75% of the impact to the development, are Climate Change, Minerals Extraction and Waste Disposal. Minerals Extraction and Waste Disposal impacts are both relatively high because of the significant amount of concrete used to achieve high thermal mass.



The Case Study materials in chapters 6 and 7 account for 30% of the development's impact. PV's account for 10%. Of the remaining 60%, a large part of the impact comes from insulation materials, mass concrete foundations, aluminium rooflights, cement screed and mortar. The materials procurement policy to source low impact, local materials where possible reduced the development's impact by a significant 20-30%.

Total Eco-footprint

The total eco-footprint of BedZED's construction materials is about 3,600 ha years. Rentalised over a 60 year design life and divided amongst the 300 residents and workers, this amounts to 0.2 ha/person. This compares with 0.22-0.25 for the average home.[2]

1 Movement for Innovation, BRE
2 Sharing Nature's Interest

10 Reclaimed Materials Summary

In total, BedZED sourced 3,404 tonnes of reclaimed and recycled materials (including 1,862 tonnes of reclaimed on-site subgrade fill). This amounts to 15% of the total materials or 7% excluding sub-grade fill. These reclaimed materials reduce BedZED's embodied CO_2 and ecopoints by 4%. They save 320ha years of eco-footprint, reducing the total eco-footprint by over 10%.

All of the measures, except reclaimed steel, resulted in cost savings to the Client or the Contractor, even after additional staff time was spent on sourcing the material. The reclaimed steel was cost neutral.

Reclaimed doors and paving slabs did not work this time within the programme constraints of this project. This was largely due to complex supply chains and a requirement for too much staff time. But from the lessons learnt on BedZED, the team believe we can double or triple the quantity of recycled/reclaimed materials in the next development.

Material	Off-the-shelf product	Achieved on BedZED	Easy	Cost implications
Reclaimed steel	x	✓	**Fairly Easy**	Neutral
Reclaimed timber for internal studwork	x	✓	**Fairly Easy**	**Saving**
Reclaimed timber for external studwork	x	x (small quantity)	**Difficult**	**Cost Premium**
Reclaimed floorboards	x	✓	**Easy**	**Saving**
Reclaimed bollards	✓	✓	**Easy**	
Recycled aggregate	✓	✓	**Fairly Easy**	**Saving**
Recycled crushed green glass sand	✓	✓	**Easy**	**Saving**
Reclaimed doors	x	x	**Difficult**	Cheaper than equal quality but more expensive than B&Q
Reclaimed paving slabs	x	x	**Difficult**	Neutral (with storage space)
Reclaimed shuttering ply	x	✓	**Easy**	**Saving**
Re-used sub-grade fill	-	✓	**Easy**	**Saving**

Recommendations

Long lead times and storage space are key to making reclaimed and recycled materials possible.

11 What you can do

1. Specify high quality timber window frames in preference to uPVC or aluminium
2. For any structural concrete, consider using a pre-stressed option
3. Introduce a local sourcing policy
4. For polystyrene based insulation, specify HCFC- and HFC-free products
5. Specify recycled aggreagtes
6. Insist on FSC certified timber
7. Look into reclaimed materials. Always build in extra lead times and, if possible, extra storage space for these.

Appendix 1

Item	Reclaimed (R) / FSC	Volume m^3	Tonnes	Origin	Road km	Componants	Source	Volume m^3	Tonnes	Component km to supplier	Total km x m^3	Total km tonnes
Concrete and aggregate												
Mass concrete		2,392.0	5,597.0	Beddington Lane	2.0	Aggregate	Beddington Lane	2,217.5	5,433.0	0.0	24,295.4	58,995.6
						Sand	Beddington Lane	1,108.6	2,716.0	0.0		
						Cement	Northfleet	554.3	1,358.0	35.2		
Ground floor hollowcore slabs		832.6	1,232.0	Derbyshire	247.0	Aggregate	Derbyshire	288.6	707.0	7.0	215,600.8	330,655.0
						Sand	Nottinghamshire	142.4	349.0	30.0		
						Cement	Staffordshire	71.0	174.0	46.0		
						Steel	Cardiff	1.6	12.0	244.0		
Upper floor hollowcore slabs		1,413.6	2,092.0	Chichester	92.8	Aggregate	Somerset	481.2	1,179.0	140.0	229,834.6	440,107.6
						Sand	Lightwater, Surrey	240.8	590.0	66.6		
						Cement	Northfleet	120.4	295.0	120.0		
						Steel	Cardiff	3.6	28.0	222.0		
Floor screed		445.2	1,334.6	Mixed on site	0.0	Sand	Lightwater, Surrey	415.1	1,017.0	44.8	23,034.8	56,432.8
						Cement	Northfleet	103.7	254.0	42.8		
Subase Type 1 – crushed limestone		221.0	420.0	S.Wales	300.0						66,300.0	126,000.0
Subase Type 1 – crushed concrete	R	57.9	110.0	Purley	7.0						405.3	770.0
Sub-base – crushed concrete	R	457.9	870.0	Mitcham	3.2						1,465.3	2,784.0
Subgrade fill	R	846.0	1,862.0	On-site							0.0	0.0
Sand		83.6	132.0	Beddington Lane	2.0						167.2	264.0
Crushed glass sand	R	174.4	279.0	Purley	7.0						1,220.8	1,953.0
Tarmac		100.0	200.0	Hayes, Middx	30.0						3,000.0	6,000.0
Precast concrete lintels –below ground		16.8	40.0	Sittingbourne, Kent	77.3						1,298.6	3,092.0
Precast concrete lintels – above ground		16.8	40.0	Leicester	182.2						3,061.0	7,288.0
Brick and blockwork												
Bricks		990.0	1,584.0	Cranleigh	45.0						44,550.0	71,280.0
Dense concrete blocks		1,490.0	3,000.0	20% Ipswich 40% Medway 40% Purfleet	73.2						109,068.0	219,600.0
Granite kerbing	R	1.2	3.0	On-site	0.0						0.0	0.0
Concrete kerbing		9.0	22.0	Derbyshire	247.0						2,223.0	5,434.0
Concrete slab paving		110.3	269.9	Derbyshire	247.0						27,244.1	66,665.3
Concrete slab paving		26.3	64.1	Sittingbourne	77.3						2.033.0	4,954.9
Porous paving		146.9	360.0	Gloucestershire	252.8						37,136.3	91,008.0
Cement mortar		600.0	1,080.0	Wimbledon	7.2	Sand	Lightwater, Surrey	377.6	925.0	39.7	22,260.7	51,721.1
						Cement	Northfleet	62.9	154.0	46.9		
Metalwork												
Structural steel	R	220.5	98.0	Brighton, Croydon and Lingfield	48.0						10,584.0	4,704.0
Link bridge beams		16.8	7.0	Sheffield	284.6						4,781.3	1,992.2
Roundback steel sections		27.0	3.6	Sheffield	284.6						7,684.2	1,024.6
Internal Steel lintels		10.0	7.5	Enfield	37.8						378.0	283.5
Steel reinforcement		1.5	12.0	Cardiff	255.9						383.9	3,070.8
External handrailing and balustrades		6.2	18.0	Croydon via Rainham	86.2	Angles, tubes and flats	midlands	6.2	17.9	200.0	1,774.4	5,121.6
						Mesh	midlands					
						Galvanising zinc	Rainham	~0.85		included on route		
Rooflights		58.2	42.0	Denmark	900.0	Aluminium frames	Germany	5.2	15.2	400.0	58,300	53,480
						Glass	Germany	9.6	24.0	400.0		

PV panels		38.9	11.7	Madrid to Germany	1,000.0						38,850.0	11,700.0
Ancon wall ties		1.0	7.4	Sheffield	284.6						284.6	2,091.8
Aluminium copings		1.8	4.9	Mitcham	3.2	Aluminium sheets	Manchester	3.4	10.0	300.0	1,025.8	3,015.6
Aluminium sills		0.1	0.2	Mitcham	3.2	Aluminium sheets	Manchester	0.2	0.5	300.0	51.3	150.8
Ventilation ductwork		324.0	1.4	Croydon	4.2						1,360.8	5.9
Ventilation outlets		12.6	0.1	Croydon	4.2						52.9	0.4
Wind cowls		3,105.0	10.0	Colchester	119.1	Fibre glass bodies	Fareham	1,656.0	1.1	201.0	729,571.5	4,237.1
						stainless steel bearings	Reighton	20.7	8.4	300.0		
						aluminium fins	Reighton	69.0	1.1	300.0		
Insulation												
Roof		1,260.0	18.9	Spain	1,500.0						1,890,000.0	28,350.0
Walls – rockwool		2,205.0	87.8	S. Wales	316.3						697,441.6	27,771.2
Floors		1,404.9	21.1	Bristol	207.0						290,814.3	4,367.7
Walls – expanded polystyrene		126.0	1.9	S.Wales	316.3						39,853.8	601.0
Acoustic insulation under screed		44.1	0.7	S. Wales	316.3						13,948.8	221.4
Carpentry and joinery												
Oak Weatherboarding	FSC	55.1	39.9	30% Croydon 70% 80km	60.0						3,307.5	2,394.0
Studwork to weatherboarding	FSC	94.5	47.3	Scotland	730.0						68,985.0	34,492.5
Support timber to sunspace facade	FSC	8.2	4.2	Scotland	730.0						5,978.7	3,066.0
Plywood	FSC	90.0	9.0	South America	10,000.0						900,000.0	90,000.0
Stair and link bridge treads		8.9	4.2	Denmark	900.0						8,010.0	3,780.0
Timber reveals to window openings		13.7	1.4	Russia	3,000.0						40,950.0	4,095.0
Internal												
Internal doors	FSC	22.0	5.5	South Africa	10,000.0						220,000.0	55,000
Other internal doors		25.0	6.25	Rugby	153.8						3,845.0	961.25
Internal door frames		19.0	10.0	Scandinavia	1,400.0						26,600.0	14,000.0
Prefabricated internal stairs		100.0	25.0	Rugby	153.8	timber	Scandinavia	52.5	26.3	1,400.0	88,880.0	40,595.0
Internal balcony floorboards	FSC	3.0	1.8	Sussex	70.0						210.0	125.0
Internal balcony joists	FSC	4.2	2.1	Scotland	730.0						3,066.0	1,533.0
Studwork to partitions	R	350.0	175.0	Dartford	43.0						15,050.0	7,525.0
Skirting and trunking		73.5	36.8	Scandinavia	1,400.0						102,900.0	51,450.0
Workspace mezzanine												
Joists	FSC	21.0	10.5	Scotland	730.0						15,330.0	7,665.0
Floorboards	R	13.7	7.4	Dartford	43.0						587.0	316.1
Birch faced ply		14.0	7.0	Russia	3,000.0						42,000	21,000
Studwork		5.5	2.8	Brazil	10,000.0						55,000	28,000
Beech block worktop		11.7	7.0	Romania	2,000.0						23,400.0	14,000.0
Timber windows and doors												
Double and triple glazed windows and doors		367.0	95.7	Denmark	900.0	Timber	Scandinavia	63.0	31.5	500.0	370,360.0	127,560.0
						Glass	Germany	21.4	64.2	400.0		
Solid doors with vision panels		10.4	2.6	Denmark	900.0	Timber	Scandinavia	10.4	2.6	500.0	14,560.0	3.640.0
Finishes												
Plasterboard		178.5	35.7	Robertsbridge	76.8						13,708.8	2,741.8
Plaster		88.7	133.0	Robertsbridge	76.8						6,812.2	10,214.4
Flooring												
Linoleum		4.7	0.2	Many componants from all over the world	5,000.0						23,500.0	1,050.0
Ceramic tiling		8.9	21.0	Poole, Dorset	184.9						1,645.6	3,882.9
Other												
Bitumastic membrane		40.0	90.0	France	500.0						20,000.0	45,000.0
Damp proof membrane		22.0	49.5	Oxford	100.0						2,200.0	4,950.0
Sedum mat		36.0	36.0	Suffolk	150.0						5,400.0	5,400.0
Rainwater tanks		260.0	3.4	S. Wales	316.3						82,238.0	1,075.4
Totals		**21,244.1 m3**	**21,815.7 tonnes**								**6,765,863.7 by volume**	**2,282,706.9 by weight**
										Average distance km	318.5	104.6
										Average distance miles	199.1	65.4

Appendix 2 - BRE Environmental Profiling

Environmental Issues

Climate change

"Global warming" is associated with problems of increased desertification, rising sea levels, climatic disturbance and spread in disease. It has been the subject of major international activity, and methods for measuring it have been presented by the Intergovernmental Panel on Climate Change (IPCC).

Gases recognised as having a "greenhouse" or global warming effect include CFCs, HCFCs, HFCs, methane and carbon dioxide. Their relative global warming potential (GWP) is calculated by comparing their global warming effect after 100 years to the simultaneous emission of the same mass of carbon dioxide.

Fossil fuel depletion

This issue reflects the depletion of the limited resource that fossil fuels represent. It is measured in terms of the primary fossil fuel energy needed for each fuel.

Ozone depletion

Ozone depleting gases cause damage to stratospheric ozone or the "ozone layer". There is great uncertainty about the combined effects of different gases in the stratosphere and all chlorinated and brominated compounds that are stable enough to reach the stratosphere can have an effect. CFCs, Halons and HCFCs are the major causes of ozone depletion. Damage to the ozone layer reduces its ability to prevent ultraviolet (UV) light entering the earth's atmosphere, increasing the amount of harmful UVB light hitting the earth's surface.

Human toxicity to air and water

The emission of some substances such as heavy metals can have impacts on human health. Assessment of toxicity has been based on tolerable concentrations in air, air quality guidelines, tolerable daily intake and acceptable daily intake for human toxicity.

Waste disposal

This issue reflects the depletion of landfill capacity, the noise, dust and odour from landfill (and other disposal) sites, the gaseous emissions and leachate pollution from incineration and landfill, the loss of resources from economic use and risk of underground fires etc.

Water extraction

This issue reflects the depletion, disruption or pollution of aquifers or disruption or pollution of rivers and their ecosystems due to over abstraction.

Acid deposition

Acidic gases such as sulphur dioxide (SO2) react with water in the atmosphere to form "acid rain", a process known as acid deposition. When this rain falls, often a considerable distance from the original source of the gas, it causes ecosystem impairment of varying degree, depending upon the nature of the landscape ecosystems. Gases that cause acid deposition include Ammonia, Hydrochloric acid, Hydrogen Fluoride, Nitrous Oxides and Sulphur Oxides.

Eutrophication (or "over-enrichment of water courses")

Nitrates and phosphates are essential for life, but in increased concentrations in water, they over-encourage the growth of algae, reducing the oxygen within the water leading to increasing mortality of aquatic fauna and flora and to loss of species dependent on low-nutrient environments. Emissions of ammonia, nitrates, nitrous oxides and phosphorous to air or water all have an impact on eutrophication.

Ecotoxicity

The emission of some substances such as heavy metals can have impacts on the ecosystem. Assessment of toxicity has been based on maximum tolerable concentrations in water for ecotoxicity.

"Low level ozone creation" (or Summer Smog)

In atmospheres containing nitrogen oxides (a common pollutant) and volatile organic compounds (VOCs), ozone creation occurs under the influence of radiation from the sun. Different VOCs, such as solvents, methane or petrol, react to form ozone at different rates. Although ozone in the upper part of the atmosphere is essential to prevent ultraviolet light entering the atmosphere, increased ozone in the lower part of the atmosphere is implicated in impacts as diverse as crop damage and increased incidence of asthma and other respiratory complaints.

Minerals extraction

This issue reflects the total quantity of mineral resource extracted. This applies to all minerals, including metal ore, and applies to both UK and overseas extraction. The extraction of minerals for building in the UK is a high profile environmental topic but the minerals themselves are not considered to be scarce. Instead, this issue is a proxy for levels of local environmental impact from mineral extraction such as dust and noise. It assumes that all mineral extractions are equally disruptive of the local environment.

Ecopoints

BRE's Ecopoints are a single score which measure environmental impact. The average UK citizen would have an impact equivalent to 100 ecopoints, and the lower the ecopoints score, the lower the environmental impact.

Ecopoints are calculated in the following manner.

First, the impact for each issue must be measured in an appropriate unit. For example, for fossil fuel depletion, the impact is measured in tonnes of oil equivalent (toe). This is known as a characterised impact.

Next, the characterised impacts are compared to the characterised impacts of a typical UK Citizen. These have been calculated by dividing the impacts of the UK by its population. This process is produces normalised impacts.

Lastly, the normalised impacts are weighted. Weighting factors for each environmental issue have been determined by BRE from an extensive research exercise that included consultation with more than seven different interest groups including environmental campaigners, local and national government and manufacturers.

The weighted normalised impacts are called Ecopoints, and they can be added to provide a total Ecopoint score for the system under examination.

The weightings and characterised impacts associated with a typical UK Citizen are provided in the table below.

Issue	% weighting	Characterised Impact associated with a typical UK citizen
Climate Change	37.8	12300 kg CO_2 eq. (100yr)
Fossil Fuel Depletion	12.0	4.09 tonnes oil eq.
Ozone Depletion	8.2	0.286 kg CFC11 eq.
Human Toxicity to Air	7.0	90.7 kg toxicity
Waste Disposal	6.1	7.19 tonnes
Water Extraction	5.4	418000 litres
Acid Deposition	5.1	58.9 kg SO2 eq.
Ecotoxicity	4.3	178000 m^3 toxicity
Eutrophication	4.3	8.01 kg PO4 eq
Photochemical Ozone Creation	3.8	32.2 kg ethene eq.
Minerals Extraction	3.5	5.04 tonnes
Human Toxicity to Water	2.6	0.0275 kg toxicity

% may not add up to 100% due to rounding

Examples

To calculate the Ecopoints for 1 tonne of mineral extraction

- **Characterised impact = 1 tonne mineral extraction**
- Characterised impact for 1 typical UK citizen = 5.04 tonnes mineral extraction
- Normalised impact = 1/5.04 = 0.198
- Weighting = 3.5%
- Ecopoints = 0.198 * 3.5 = 0.693 Ecopoints.

To calculate the Ecopoints for 1000 kg of CO_2 emission.

- Characterised impact = 1000 kg CO_2 eq
- Characterised impact for 1 typical UK citizen = 12300 kg CO_2 eq
- Normalised impact = 1000/12300 = 0.0813
- Weighting = 37.8%
- Ecopoints = 0.0813 * 37.8 = 3.07 Ecopoints

About BioRegional

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