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Window of opportunity

The environmental and economic benefits of specifying timber window frames

WWF-UK, July 2005
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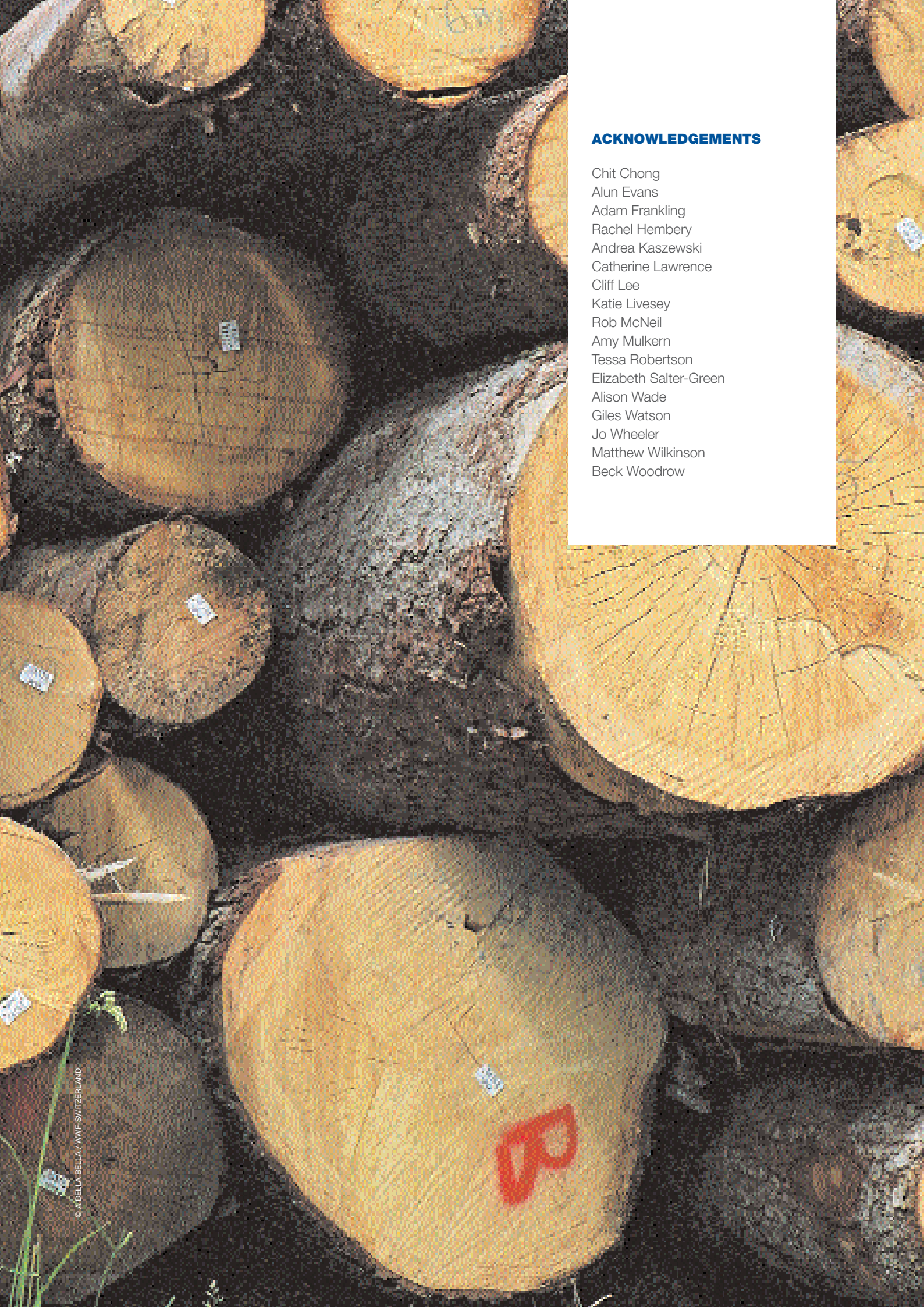

EXECUTIVE SUMMARY

The use of polyvinyl chloride (PVC) in windows has been the subject of controversial debate for decades. Opinions on its environmental impact and safety are polarised between the chemicals industry and environmental organisations. While the plastics industry claims that "PVC is as good as any material"[1], findings presented in this report justify the long-held position by WWF and other major environmental organisations that PVC is unsustainable and hazardous.

PVC is currently the material most widely used for windows across Europe. In the UK, around six million PVC windows are sold each year – twice the amount of wood windows sold. Public concern over contributing to deforestation and biodiversity loss has led to a negative image of wood. The plastics industry has largely exploited these concerns by spending millions of pounds on marketing initiatives such as the *Save a tree: use PVC* campaign of the 1990s aimed at improving the perception of plastics as a better alternative to wood.

The environmental impacts of PVC are many:

- a product that uses a non-renewable resource cannot be sustainable: oil makes up 43 per cent of the raw material required to make PVC;
- PVC windows generate 43 per cent more waste than timber windows: 82 per cent of total PVC waste goes to landfill, 15 per cent is incinerated. Only 3 per cent is recycled.
- PVC waste will rise to 6.4 million tonnes by 2020, when the capacity to recycle it will be a fifth of what will be required;
- it takes eight times more energy to manufacture a PVC window than an equivalent timber frame;
- throughout the use and disposal of the product, the overall environmental burden is significantly less for timber windows than for PVC windows; and
- hazardous chemicals are released into the environment during the incineration process of PVC.

WWF's view has always been that timber from well managed forests is a genuinely renewable resource. Specifiers who wish to ensure that they are making a sustainable or minimum impact on the environment should use timber that comes from a credibly certified source. The Forest Stewardship Council (FSC) is currently the only credible certification system recognised by WWF and other major environmental organisations.

A list of FSC certified timber window suppliers can be found in Appendix 1 at the back of this report.

In addition to the negative environmental impacts of PVC, there are many examples of research that show timber windows to be between 14 – 25 per cent less expensive than PVC windows, when considering the 'whole life' cost.

INTRODUCTION

There is an enormous amount of information on the comparable performance of PVC and timber windows. A number of independent organisations such as the Building Research Establishment have completed studies on windows made of both timber and PVC, and have concluded that timber performs better technically overall. Conversely, a number of studies carried out by the PVC industry have shown the opposite – that PVC [i] performs better than wood.

In June 2004, the European Commission published a long-awaited report aimed at settling once and for all this debate. The 325-page study, which reviewed 30 published assessments comparing the two materials, concluded: "For windows, one of the most important PVC applications, the available studies conclude that there is no "winner" in terms of a preferable material since most of the studies conclude that none of the materials has an overall advantage for the standard impact categories".[2] Interested groups were left to draw their own conclusions. It seems that enough controversy still remains to cast doubt on the environmental acceptability of PVC.

This report is written for specifiers and buyers who are in the difficult position of having to make decisions on the most economical and environmentally responsible window to specify or buy. This includes ensuring that their commitments to best-value purchasing are met.

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i PVCu (or U-PVC) is unplasticised PVC. It is this material which is mostly used for windows. Any reference to this material will be as PVC, which is a generally accepted form.

FACTS AND FIGURES

Basic information

Timber	PVC
Raw materials 79 per cent of timber windows sold in the UK are produced from softwood such as treated European redwood. Other softwoods such as Douglas fir are also sometimes used. An increasing amount of windows made from hardwoods such as oak and chestnut are also being sold. These account for 21 per cent of timber windows sold in the UK and are bought mainly because of their durability.[3] Timber is a renewable resource and is sustainable if managed responsibly.	**Raw materials** 57 per cent of PVC is made from chlorine (created by passing an electric current through salt water). The remaining 43 per cent is composed of ethylene (hydrogen and carbon, obtained from oil or gas). Reactions between chlorine and ethylene produce vinyl chloride monomer (VCM), and polymerisation of VCM produces long chains or PVC. 43 per cent of PVC is therefore made up of a non-renewable resource.
Additives Timber for windows is usually treated with: **Wood preservative** – including resins and waxes so that paint can be applied more easily and to make the frame more resistant to water. **Fungicides** – inorganic salts of boron such as disodium octaborate, or one of the azole family such as propiconazole or tebuconazole. **Carrier** – an organic solvent such as white spirit or, more commonly, water with other ingredients in a micro-emulsion, a change that reduces the release of volatile organic compounds (VOCs). **Glue** – for construction. The frames themselves are either factory- finished, or site-finished.	**Additives** Other chemicals are added to make PVC window frames: **Heat stabilisers** – to prevent decomposition, and to reduce weathering and provide light resistance: compounds of lead, barium, calcium/zinc or tin. **Lubricants** – waxes or fatty esters. **Filler** – calcium carbonate. **Impact modifiers** – acrylate rubber/chlorinated polyethylene. **Pigment** – titanium dioxide for white frames. *(See table 1 for more information on compounds in PVC windows.)*
The manufacturing process In its report, *Wood Windows-design, selection and installation,* the Timber Research and Development Association (TRADA) estimates that it takes eight times more energy to manufacture a PVC window than an equivalent timber frame.	**The manufacturing process** The compound and additive chemicals that go into making PVC tend to disperse into the environment during the production, manufacture and finishing stages, and most notably, at the end of life – inhibiting recycling. One of the most contentious areas of debate between environmentalists and PVC manufacturers is whether or not dioxins are released into the atmosphere when PVC is made, and if they are, whether or not it harms the environment. Cadmium-based stabilisers are no longer used for PVC window applications in Europe as the PVC industry has phased them out as part of the "Vinyl 2010 Voluntary Commitment", signed in March 2000. Cadmium stabilisers may be present in some older windows. The industry has pledged to phase out lead stabilisers by 2015. Both these additives are environmentally damaging.[4] There has been a return to less environmentally damaging lead salts, which are less harmful to the environment than better performing barium and cadmium systems.[5]

Table 1. Compounds in PVC windows

Materials	Function	Quantity
PVC	Polymer	81.5 per cent
Acrylate rubber	Impact modifier	6.0 per cent
TiO_2	Colorants	3.5 per cent
Lead-phosphate and stearate	Stabiliser	2.5 per cent
Limestone	Filler	5.0 per cent
Petroleum wax and fatty acid ester	Lubricant	1.5 per cent

Source: Defra, 2000

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Size of market

Around 12 million windows are sold each year in the UK,[6] nearly half of which are made from PVC[7]. Timber windows account for around 25 per cent of the market.

Timber

Wood was once the dominant material for windows in western Europe. In the UK during the 1960s, more than 95 per cent of windows were made of wood. By 1983, half of all windows were made from wood, while by 1994, PVC dominated the market and timber accounted for around 22 per cent. Since the late 1990s, however, there has been a steady growth in timber window sales year-on-year *(see diagram 1).*

In 2000, 3 million timber windows were sold in the UK. A total of 57 per cent were consumed by the public sector and 42 per cent were bought by the private sector; 86 per cent of timber windows sold were used for refurbishment purposes, and 14 per cent for new build applications.[8]

In 2003, 3.6 million timber windows were sold in the UK – with an estimated value of £360 million.[9]

Surveys conducted by the British Woodworking Federation and Michael Rigby Associates in 2004, suggest that softwood accounts for 79 per cent of timber windows sold and hardwood for 21 per cent. The surveys considered that 85 per cent of the hardwood and 83 per cent of the softwood came from a so-called "sustainable" source.[10] [ii]

The UK consumed 37 million cubic metres of timber in 2003. The construction sector accounted for 85 per cent of this total.

PVC

PVC is still the material most widely used for windows across Europe. Window profiles account for 13 per cent of all PVC used in Europe. The UK is the second largest consumer of PVC windows in Europe after Germany.[11] PVC window sales have grown virtually continuously for many years in the UK *(see diagram 2)* and 5.7 million PVC windows were sold in 2001.[12] In that year, 67 per cent of PVC windows were consumed by the private sector and 33 per cent were bought by the public sector. A total of 83 per cent of PVC windows sold were used for refurbishment purposes and 17 per cent for new build applications.[13]

The total PVC market in 2003 was valued at £4 billion, with PVC windows accounting for more than £2 billion of this value. PVC remains the dominant frame material for windows.[14]

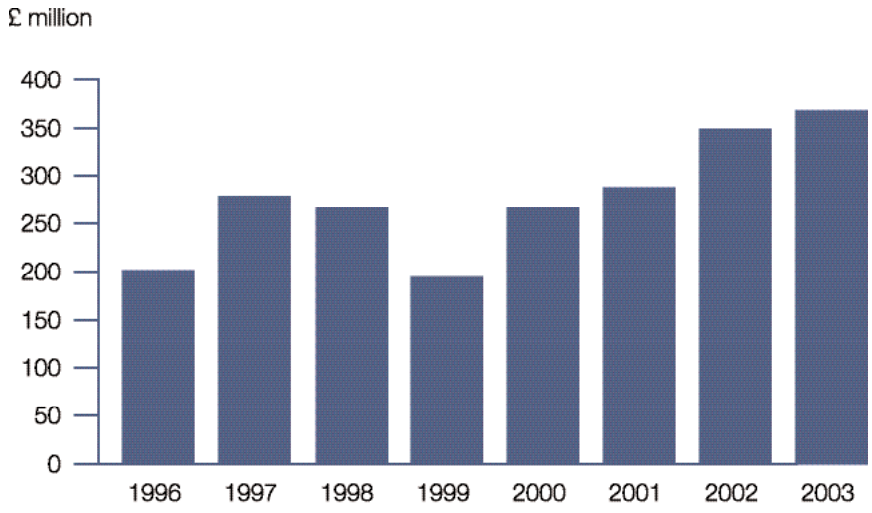
The net annual UK supply of PVC is around 790,000 tonnes (approximate value £392 million).[15]

The construction sector is the second highest user of plastics after packaging: 250,000 tonnes of polymers are used.[16] Plastics in construction are mainly used for seals, windows, doors, pipes, cables, floor coverings and insulation.[17]

In 1989, just under 100,000 tonnes of PVC compound were used for window production in the UK. In 2000, this increased to 240,000 tonnes.[18]

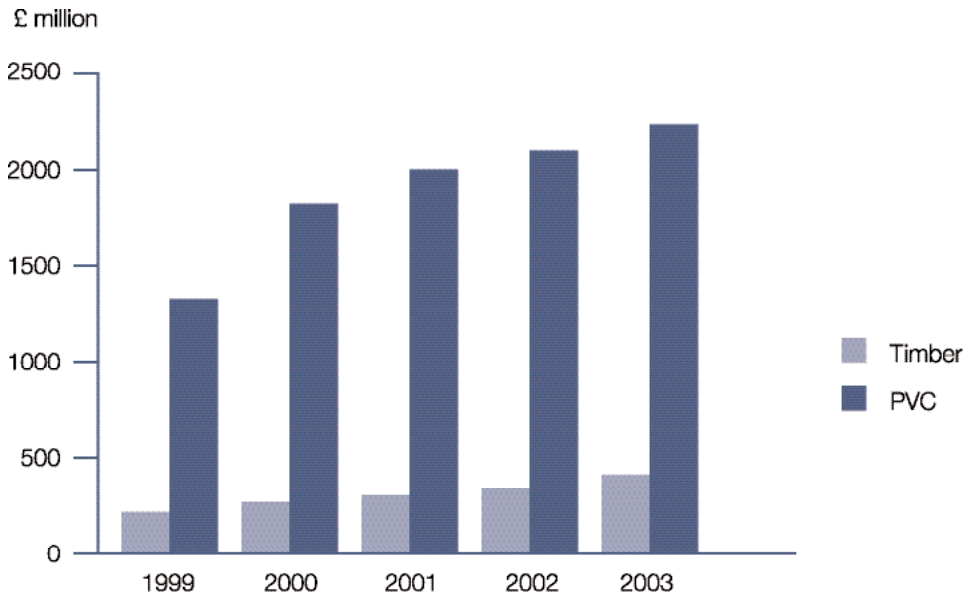
ii Many guarantees of sustainability have been proven by WWF to be false. WWF supports credible, independently certified timber from well-managed forests. Currently the Forest Stewardship Council (FSC) is the only certification system to meet WWF's criteria for responsible forest management.

Diagram 1. **Development of wood window sales in the UK 1996-2003 by value**



Source: National Statistics

Diagram 2. **PVC and wood window sales in the UK 1999-2003**



Source: Palmer Market Research / National Statistics

Timber

State of resources

Timber from well-managed forests is a genuinely renewable resource. More than 94 per cent of all timber windows sold in the UK are made from timber imported from Scandinavia (mostly Sweden).[19]

The UK is the fourth largest net importer of forest products in the world after China, Japan and the United States.[20] In 2003, the UK imported 33 million cubic metres of timber products at a cost of more than £5 billion. More than 7 million cubic metres were also taken from British forests for commercial use – most of this was FSC-certified.[21] By 2020, the Forestry Commission estimates that around 15 million cubic metres will be supplied by British forests each year.[22]

World forest cover has fallen to approximately 3.9 billion hectares (about 30 per cent of total land area) from an original 6 billion hectares at the end of the last ice age. Of what remains, 95 per cent is natural forest and 5 per cent forest plantation. Every year, the world consumes approximately 1.6 billion cubic metres of wood.[23]

The world produced a total of 390.9 million cubic metres of sawn timber (softwood and hardwood) in 2002; a total of 388.3 million cubic metres of sawn timber was consumed by the world in the same year.[24]

Many of the world's forests are felled neither sustainably nor legally – 10 per cent of the UK's annual imports of forest products are estimated to come from illegal sources. The world has 850 million hectares of degraded forest[25] and 14.6 million hectares of natural forest are destroyed each year. Timber logged illegally in Russia is arriving in the UK via processing countries such as Sweden and Finland. It is crucial that timber used in window manufacture has been certified as coming from a well-managed source, by an independent body such as the FSC.

PVC

State of resources

Oil, which makes up 43 per cent of the raw material for PVC, is a non-renewable resource. In 1993, the UK's oil reserves were estimated to last until 2023 at then current rates. The Energy White Paper published in February 2003 estimates that the UK will become a net importer of oil by around 2010. The government concluded that "moving from being largely self-sufficient to being a net importer of gas will leave the country 'vulnerable' to price increase and interruptions to supply caused by political instability or conflict".[28]

Although it is difficult to estimate the total volume of oil that goes into the manufacture of PVC windows, prices are expected to rise due to greater scarcity of oil.

In 2002, the UK's consumption of oil was 69 million tonnes[29], of which 40 million tonnes were imported.[30]

The UK government has stated that it is proactively trying to limit our dependency on fossil fuels such as oil. Under the Kyoto Protocol, the UK is obliged to reduce its greenhouse gas emissions to 12.5 per cent below 1990 levels by the year 2012. It is the government's ambition to cut these emissions by 60 per cent by around 2050, and carbon dioxide (CO_2) emissions by 20 per cent by 2010. CO_2 emissions are produced by activities such as burning fossil fuels for electricity generation.

In its Third Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) states there is now stronger and discernible evidence for human influence on the global climate and concludes that it is likely that increasing concentrations of anthropogenic greenhouse gases have contributed substantially to the observed warming over the last 50 years.

The largest CO_2 polluter is the United States, which is responsible for approximately 24 per cent of annual global emissions. The UK is currently ranking seventh. In 2003, there was actually a rise in the UK's CO_2 emissions, not a decrease. Hence, an even greater effort to reduce our dependence on fossil fuels is needed in order to meet the government's targets and to help prevent the worst impacts of climate change.

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The Forest Stewardship Council (FSC)

WWF has played a leading role in establishing the FSC, which lays down strict international standards for forest management. WWF and the FSC have common goal of promoting good forest management practice and ensuring that it is environmentally appropriate, socially beneficial and economically viable. The FSC is currently the only credible certification system recognised by WWF and other major environmental organisations such as Greenpeace, Friends of the Earth and the Woodland Trust.

The UK government's Central Point of Expertise on Timber (CPET) recently announced that FSC certification fulfils the government's own criteria for legal and sustainable timber. [26]

Today, 45 million hectares of the world's forests in 60 countries are FSC certified – more than a million in the UK alone. [27] Forest products derived from FSC certified forests are allowed to carry the FSC trademark.

A list of FSC certified window suppliers can be found in Appendix 1 at the back of this report.

For more infomation: *www.fsc-uk.info*

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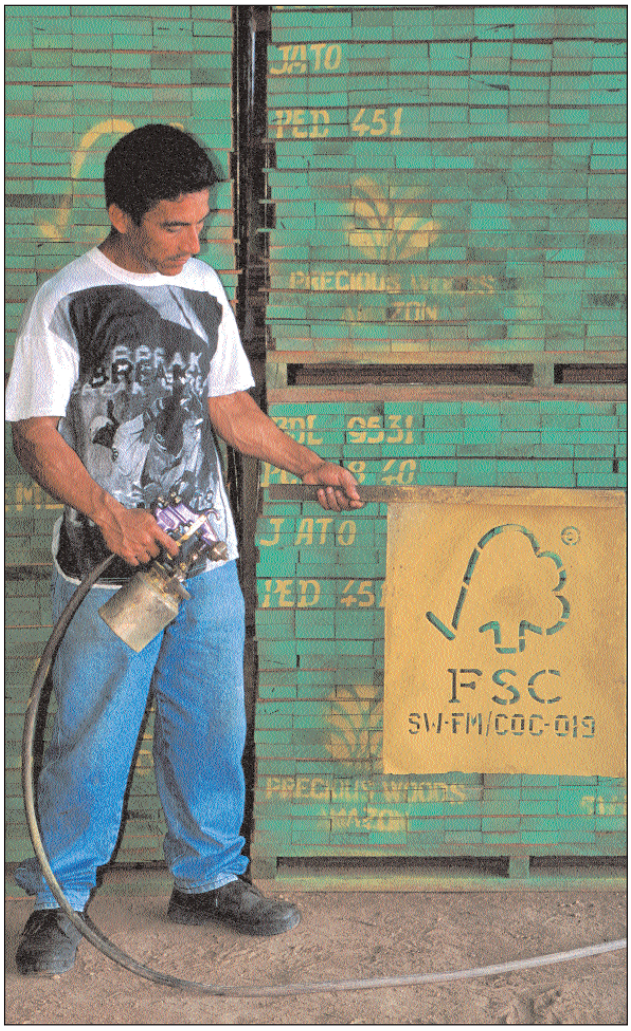
WWF-UK Forest & Trade Network

The mission of the WWF-UK Forest & Trade Network (FTN) is to improve the management of the world's production forests by using the purchasing power of UK businesses.

The WWF-UK FTN was founded as the WWF 1995 Group, with 20 member companies, in 1991. Its members' vision was to ensure that their timber and paper supplies came from well managed forests, and did not contribute to forest destruction and illegal logging practices.

Since its launch, the WWF-UK FTN has become widely recognised as a successful partnership between WWF and business – a partnership that promotes and progresses responsible management of the world's forests. The current membership of the WWF-UK FTN represents approximately 20 per cent of the total annual UK consumption of forest products by volume. It is estimated that almost 60 per cent of the material being traded by group members is FSC-certified.

Members of the WWF-UK FTN have committed themselves to tracing their timber and paper products back to the forest source. The aim of the WWF-UK FTN is to provide a framework for members to adopt a stepwise, monitored approach that enables them to identify and move away from materials coming from unknown or unacceptable sources, towards products from credibly certified forests. For more information: *www.wwf.org.uk/ftn*



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WWF's Stop Climate Chaos Campaign

WWF is calling on governments and the power sector to limit CO_2 emissions – a major cause of global warming – to help ensure the average rise in global tempretures stays well below 2°C. This is a crucial tipping point for the environment and would have devastating impacts for people and wildlife.

For more information: *www.wwf.org.uk/climatechaos*

WWF's One Million Sustainable Homes Campaign

More than half of all resources consumed globally are used in construction, and 50 per cent of energy generated across the world is used to construct, heat, light and ventilate our buildings.

In the UK we use around 37 million cubic metres of timber every year and more than 85 per cent of this is used by the construction industry, with 55 per cent used for housing. In addition to direct environmental impacts in terms of generating carbon emissions, waste and using natural resources, the way homes and communities are developed determines our lifestyle decisions and our overall impact on the environment.

At the World Summit on Sustainable Development in August 2002, WWF launched its groundbreaking campaign to bring sustainable homes, those that minimise impacts on the environment and offer social and economic benefits, from the fringes to the mainstream across the UK. WWF is working with government, industry and consumers to ensure that one million sustainable homes are developed across the UK by 2012, including refurbished as well as new homes.

For more infomation: *www.wwf.org.uk/sustainablehomes*

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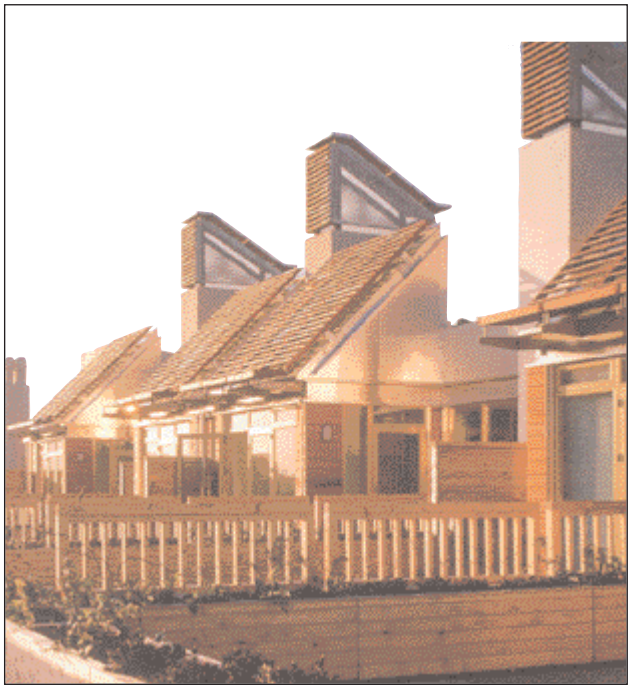

GREENWICH MILLENNIUM VILLAGE

COST OF WINDOWS

It should be noted that window costs are notoriously difficult to compare, but there are many examples of research that show timber windows to be less expensive than PVC windows.

Table 2 below shows the results of a "whole life cost" appraisal carried out by Camden Housing Capital Projects. This took into account maintenance and replacement costs and shows that high performance timber and aluminium-clad timber windows cost 23-25 per cent less than PVC over a 60-year life span.

In 2003, a consultancy working with the London Borough of Camden Council conducted research on window costs. KSC Partnerships discovered that high-performance timber windows cost on average 14 per cent less than PVC windows, when comparing an identical specification (a 1200 x 1200 profile cost £360 and £420 respectively).[31]

In 2002, the Building Research Establishment (BRE) undertook a study on cost comparison between different window profiles. The results showed that timber-framed windows are less expensive than PVC windows *(see table 3)*.[32]

Research by the Building Performance Group, also in 2002, revealed high-performance softwood timber windows to be 15 per cent less than PVC (£214 and £262 respectively).[33]

Earlier studies have shown similar findings. According to the National Housing Federation (NHF) the cost of buying, fitting and maintaining a softwood frame in 1998 was between £150 and £200 over 30 years (prices are for solvent-treated timber), whereas for PVC, one would expect to pay between £258-£274.[34] Carlisle City Council found that PVC windows were 25 per cent more expensive initially, with a negligible difference in costs over 30 years.[35] A study conducted by BRE in 2000 found that PVC windows cost between £150-£530, softwood windows between £70-£320 and hardwood windows between £130-£355.[36] The Peabody Trust, a major housing association in London, no longer specifies PVC windows for its properties.

FSC timber need not necessarily cost more than non-FSC timber. Two of the largest builders merchants and WWF-UK Forest & Trade Network members, Jewsons and Travis Perkins, do not charge a premium on any of their FSC-certified softwood timber products.

Table 2: The whole life cost over 60 years for a typical 1.5m^2 window

	Timber	PVC
Expected life	60 years	20 years
Renewal cost	£500	£420
Renewal cost over 60 years	0	£840
Maintenance cost over 60 years	£787	£460
Whole life cost over 60 years	£1,287	£1,720
Whole life cost compared to PVCu	-25 per cent	0 per cent

Source: Camden Housing Capital Projects, 2004

Table 3. Cost comparison between different window profiles

Window	Cost £/m^2	Typical replacement interval
PVC-framed window	£480-£550	25 years
Painted, preserved softwood timber-framed window	£185-£245	25 years
Hardwood timber-framed window	£300-£370	30 years

Source: BRE, 2002

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MAINTENANCE AND REPAIR

Timber

The public's perception that timber windows fail is partly because of the reputation of poorly made softwood windows installed after the Second World War. Modern high-performance timber windows are treated against rot and are pre-finished. Some have the finish guaranteed for 10 years and rot for 30 years.

Site-finished timber windows are primed with a basecoat before being used as templates for forming openings in brickwork. The wood may suffer from exposure to UV light, and some areas of the frame may only be protected by the basecoat once installed and glazed.

Factory-finished windows are more common in northern Europe than in the UK – the frames are fully protected from water and UV before installation. Up to 60 per cent of wood windows produced are now sold with full or part factory finishing and with coating performance guarantees of up to 8 years.

The British Woodworking Federation's Timber Window Accreditation Scheme requires factory applied paint finishes to be guaranteed for 8 years. According to TRADA, some manufacturers offer paint finishes that will not need repainting for 10 years.

Furthermore, quality-assured coating products with similar longevity claims are available for the millions of aged wood windows already in service. The new generation of water-borne exterior wood coatings now available are potentially extremely durable. These have a low VOC content which, together with the strong environmental credentials of timber, produces a robust argument in favour of wood windows.[37]

The major advantage of wood windows is their ability to be repaired. According to TRADA, wood windows can be "readily repaired, refinished and maintained without special components, skills or equipment".

PVC

PVC windows enjoy a reputation of being long-lasting, and of requiring little or no maintenance. The British Plastics Federation states that "PVC needs only an occasional wash and wipe". However, this claim his since been proven unrealistic: PVC windows need to be cleaned every six months or they become irreversibly discoloured by dirt.

The performance of window frame materials is summarised in *table 4* on page 15. Research shows that, on average, PVC windows tend to be disposed of after 18 years[38], a significantly shorter period than timber and aluminium windows. The London Borough of Camden Council's experience with PVC windows shows that they are "extremely difficult to repair when components are worn or damaged and often have to be replaced as a result of vandalism".[39] This experience is also shared by Manchester City Council and Guildford Borough Council.[40]

The material is also turned yellow and brittle by sunlight and can even develop hairline cracks. Once degraded in this way, PVC frames are impossible to repair.

Repairing PVC frames is not so straightforward, and requires employing a specialist and locating parts, which can be inconvenient and expensive

According to BRE, PVC degrades when exposed to weather. The weathering process can cause changes in the appearance and robustness of the window. There are technical problems in producing paints suitable for PVC. The appearance of a coloured surface layer will be affected if the surface is damaged. Dark colours become hotter than light ones in sunshine and this can influence the shape and stability of the window. Existing windows should not be repainted in a colour significantly darker than the original. To do so may induce thermal stress with which the frame and profile were not designed to cope. The titanium dioxide pigment normally used to colour white PVC retains its colour, although changes in the polymer can lead to yellowing.

Paint has been developed for redecoration of weathered PVC. The paint is water-based, and contains fungicides to prevent mould growth on the painted surface.

There are also stain-removal products for PVC.

Both timber and PVC windows incorporate fittings such as handles, locks, ventilators and glazing and weather strips, which do need to be maintained. TRADA estimates that insulated glazed panels could have a life span as low as 5-10 years, and that weather strips lose elasticity and need replacing at 5-15 year intervals.

Table 4: Performance of window frame materials (high scores denote a better performance)

Good = 3 Average = 2 Poor = 1	Embodied energy	Life years	Maintenance	Repairable	Recyclable	Disposal Hazards	Average Score
Timber	3	3	2	3	2	3	2.7
Aluminium and timber	2	3	3	2	2	3	2.5
Aluminium	1	3	3	1	3	3	2.3
Steel	2	3	2	1	3	3	2.3
Fibreglass	2	3	3	2	1	3	2.3
PVC	1	1	2	1	1	1	1.2

Source: London Borough of Camden Council, 2004

THERMAL PERFORMANCE

Windows lose more energy than other parts of buildings and often the materials they are manufactured from are less thermally efficient than available alternatives. Frame design and material strongly influence energy performance, as does the level of window glazing (i.e. double versus single). Frame materials have varying thermal properties, so it is desirable to get the most energy-efficient window from the frame that is chosen. U-value is a measure of a material's ability to conduct heat. The lower the U-value, the better the insulation. Wood windows have slightly lower U-values than PVC, although they are not differentiated in the building regulations.

Current building regulations (Part L) set the U-values for both wood and PVC windows as 2.0 W/m^{2}k (table 5).

Specifying lower U-value material means less energy consumed, lower bills and greater comfort for the end user.

Table 5.
U-values for wood-framed and PVC windows

Wood	2.0
PVC	2.0

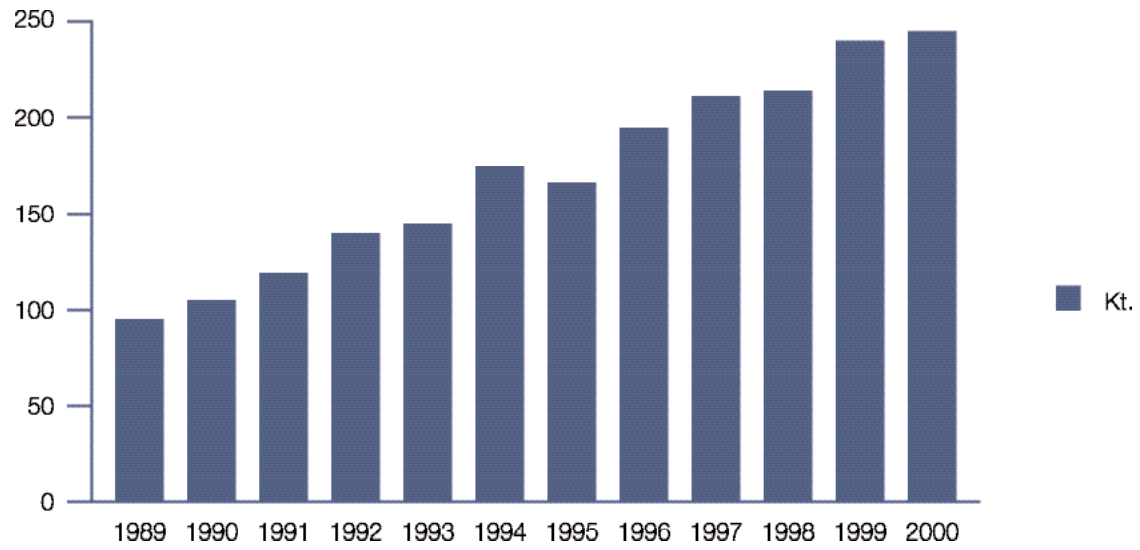
WASTE DISPOSAL AND RECYCLING

The UK construction industry is a massive consumer of timber and plastic. The industry annually requires more than 420 million tonnes of material resources, of which 360 million tonnes are incorporated into construction products – the remainder becomes waste, (420 million tonnes is equivalent to each man, woman and child in the UK annually consuming seven tonnes of resources each. That's the weight of seven family cars). Of the resources used, more than 350 million tonnes are primary materials, 43 million tonnes are recycled materials, 22 million tonnes are secondary materials (e.g. industrial by-products) and 3 million tonnes are reclaimed for reuse. To produce 360 million tonnes of construction products, the industry requires 7.8 million tonnes of fuel (oil equivalent).[41]

PVC

In 1989, just under 100,000 tonnes of PVC compound were used for window production in the UK. In 2000, the amount had increased to 240,000 tonnes *(see diagram 3)*. This gives some indication of the magnitude of the PVC waste issue.

Diagram 3. PVC used for windows – UK 1989-2000



Source: Micheal Rigby Associates, 2002

The major environmental issues regarding PVC waste are:

- the main source of atmospheric emissions is during the production of virgin PVC, followed by incineration of the PVC waste. The emissions of air pollutants associated with recycling are, in contrast, small;
- there is high demand for alkaline reagents to abate emissions of hydrogen chloride at incineration; and
- heavy metals (such as cadmium and lead) present as stabilisers in PVC are likely to be mobile in ash from an incinerator.

The European Commission published a three-year study in June 2000, which assessed the economic evaluation of PVC waste management. According to that study, around 82 per cent of total PVC waste goes to landfill, 15 per cent to incineration, and only around 3 per cent is recycled. PVC does not degrade in landfill. The report concluded that there is no safe disposal route for end of life PVC. Due to restrictions on landfill levels introduced by EU and national initiatives, incineration is expected to account for 45 per cent by 2020.

In March 2000, as part of the "Vinyl 2010 Voluntary Commitment", the European PVC industry made a specific commitment regarding the mechanical recycling of PVC windows – "to recycle at least 50 per cent of the collectable available quantity of window profiles waste by 2005". This suggests that by 2005, the industry estimates 15,000 tonnes will be recycled annually. However, the commitment has come under fire from environmentalists who point out that the targets refer to waste collected, not waste generated. In fact, the post-consumer waste of PVC in the EU is expected to increase from 3.6 million tonnes to 6.4 million tonnes by 2020.

Table 6. Types of PVC recycling

Method	Description
Mechanical recycling	High-quality recycling into similar products. The recycling of PVC waste containing heavy metals results in a dilution of these substances in a greater quantity of PVC, since it is necessary to add virgin material. At present this is not profitable. Also, there are additional costs for waste separation at the construction sites.
Down-cycling	Low-quality recycling. PVC is mixed with other plastics and materials from which further separation is either not technically feasible or too costly (e.g. from coated fabrics) and turned into substitutes for non-PVC materials. Mixed plastic waste has many additional problems – for example, difficulties in separating PVC from PET bottles. In some cases, the PVC industry has recognised this issue and contributes to this additional cost.
Feedstock recycling	This produces a hydrocarbon feedstock for the petrochemical industry or direct use of plastic waste as a reducing agent in blast furnaces. This also releases chlorine, in the form of hydrogen chloride: current facilities can accept a maximum chlorine content in the feedstock of 10 per cent.

The main methods of PVC recycling are explained in *table 6*. Present-day recycling of PVC is largely restricted to low-quality mechanical recycling into a mixed-plastics waste. The EU study in 2000 concluded that such recycling was not economically competitive, and would not have any significant effect on the amount of waste the PVC industry produced. According to a simulation undertaken by AEA Technology, assuming maximum recycling potentials of 50 per cent of waste[iii], the potential for recycling post-consumer waste is about 800,000 tonnes of PVC in 2010 and 1.2 million tonnes in 2020. This represents a recycling rate of about 18 per cent. Provided there are no limitations to the amount of PVC waste able to be collected, which seems unrealistic, this means that mechanical recycling could at best only process a maximum of one fifth of waste needing recycling.

Timber

Residue or waste is generated at all stages of the life of a piece of timber, from harvesting to end of life disposal. The DTI states that data on wood waste volumes and recycling rates are difficult to obtain and, at best, only estimates are available[42]. Obtaining information on the species of timber, or making a distinction between hardwood and softwood, in the waste stream is generally not possible. Furthermore, a study produced by the Waste Resources Action Programme (WRAP) in 2003, *Creating markets for recycled resources,* concluded that measuring waste wood is not regarded as an important business issue by the timber using industry.

However, WRAP's figures do show that more than 50 per cent of raw material does end up in the primary product *(see table 7).* The by-products, solid residues and sawdust, are normally used as feedstock for the paper or wood-based panel industries, or for fuel. The increasing domestic production of wood we have seen over the past few years indicates an increasing volume of residues produced across all sectors of the UK timber-using market.

Table 7. Wood waste from wood processing, 1997-2000 (in 000 tonnes)

		1997	1998	1999	2000
Softwood	**Log input**	3490	3570	3859	3936
	Production	1980	1995	2147	2159
	Residues	1510	1575	1712	1777
Hardwood	**Log input**	259	227	205	183
	Production	143	126	119	107
	Residues	116	101	86	76

Source: WRAP, 2002

Incineration of PVC produces harmful chemicals

One of the methods of PVC disposal – incineration – leads to the formation of dioxins, which are persistent organic pollutants (POPs). Dioxins are of great concern to WWF as they contain chlorine and are soluble in fat, mimicking the effects of hormones. Once in the environment, they build up in the food chain and are carcinogenic, mutagenic, toxic to reproduction, and are endocrine disrupting chemicals.

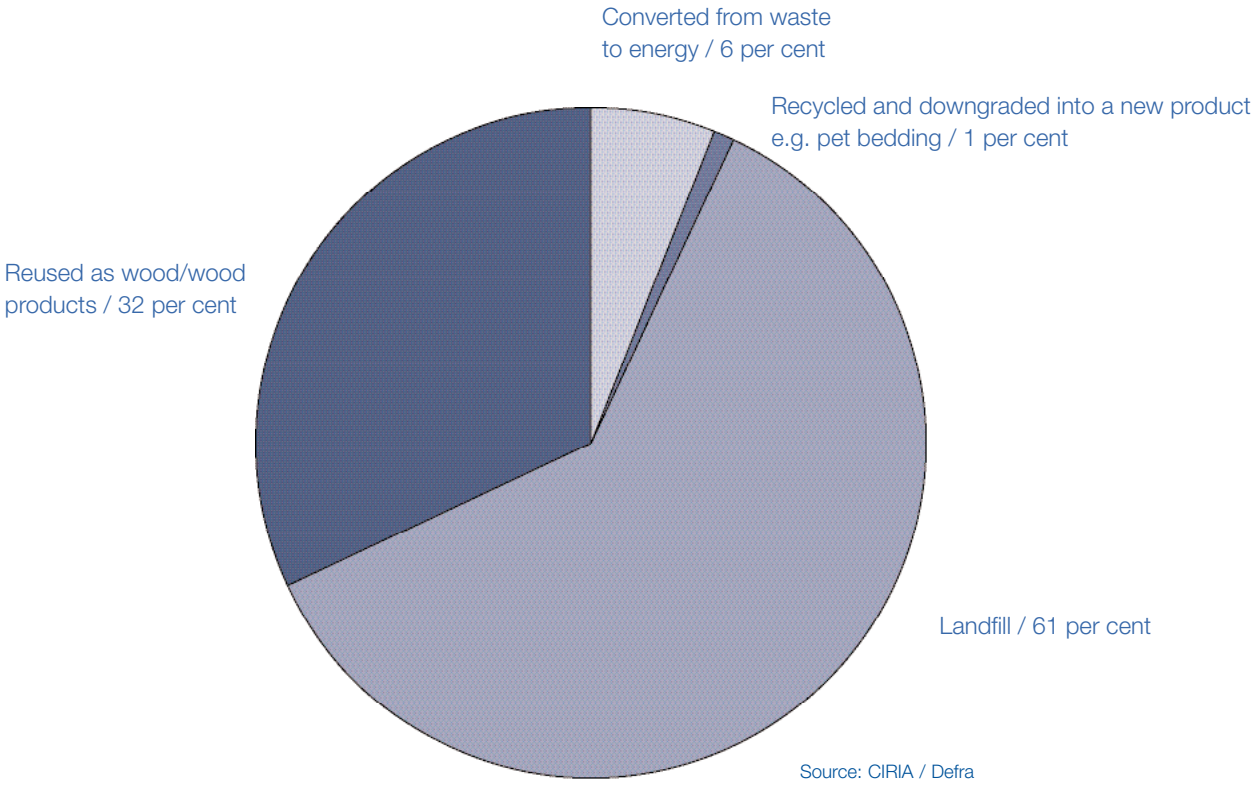
WWF is calling for hazardous man-made chemicals to be properly regulated – replaced where safer alternatives exist, or banned where necessary.

For more information: *www.panda.org/toxics*

The waste generated by the construction sector is estimated to be nearly 57 per cent of the UK total. Within this sector, the housebuilding and contracting segments account for nearly 840,000 tonnes (more than 1.5 million m^3), or 45 per cent of all UK industrial waste wood[43]. There is a market for the re-use of this timber, although supply of reclaimed timber is often sporadic, with quantity and quality being the most difficult aspects. The use of timber treatments can inhibit recycling and re-use, although modern preservatives make this much less of a problem. *Table 8* shows the treatment of wood reclaimed from demolition sources. Waste timber represents an enormous potential resource. The Construction Industry Research and Information Association (CIRIA) has produced a handbook on the use of reclaimed and recycled construction materials.

iii Representing the PVC quantities that can be recycled taking into account the technical and economic limits of PVC recycling.

Table 8. Treatment of wood reclaimed from demolition sources



Source: CIRIA / Defra

SUMMARY

Over the life cycle of these products, it is estimated that the wood window system generates 43 per cent less waste than the PVC window system owing to lower waste generation rates in both the production and end of life phases. For the PVC system, raw materials account for 77 per cent of production phase waste. The greater waste generation at the end of life is due to the lack of degradation of PVC in landfill.[44]

J BIRDSALL

LIFE CYCLE ANALYSIS

Life cycle analysis (LCA) is a tool for quantifying the inputs and outputs to a product, process or activity. The life cycle is the extraction of raw materials through to end of life management, and the results of an LCA quantify the environmental impacts of (in this case) PVC and alternatives, from manufacture to disposal.

Not surprisingly, according to the PVC industry, windows made from PVC will perform better than timber in an LCA. Likewise, according to the timber industry, timber windows will perform better than PVC in an LCA.

For the purpose of this study, three sources of data have been used for comparison. The most recent study was published in 2003 by the Food and Agriculture Organisation (FAO) of the United Nations[45]. Defra completed a study in February 2001 entitled Life Cycle Assessment of Polyvinyl Chloride and Alternatives.[46] The Building Research Establishment (BRE) also completed an environmental assessment of building materials and components in 1998. A useful table taken from BRE's environmental assessment method (BREEAM) produced in 2002 is also included.

These organisations could be said not to have a commercial interest in the findings of their studies, and their research is therefore the focus of this section. This report does not scrutinise the results of these studies, but uses them purely as examples to condense a complex issue.

1. Food and Agriculture Organisation

The FAO assessed the performance of PVC and timber windows against a range of indicators. These included global warming potential, acid rain potential, eutrophication potential and ozone creation potential. *Table 9* presents the findings:

Table 9. Performance of PVC and timber windows against a range of indicators

	Units	PVC	Wood
Global warming potential	CO_2 kg	997	906
Acidification potential	kg SO_2	4.84	2.15
Eutrophication potential	kg phoshate equivalent	0.31	0.20
Petrochemical Ozone Creation potential	kg ethene equivalent	2.71	1.64

Source: FAO, 2002

Global warming potential (given in kg CO_2 equivalent per kg of greenhouse gas): Represents how much a given mass of a chemical contributes to global warming over a given time period compared to the same mass of carbon dioxide.

Acidification potential (given in kg SO_2 equivalent per kg of emitted substance): Entry of substances into the ecosystem which contribute to "acid rain" and therefore to the acidification of the soil and water.

Eutrophication potential (given in kg phosphate equivalent): Phosphorus is a principal nutrient, but excessive quantities caused by human activities have detrimental effects on water and soil environments and their flora and fauna.

Photochemical ozone creation potential (in kg ethene [ethylene] equivalent per kg of emitted substances): This has the potential for contributing to summer smog.

MAGNET JOINERY

2. Defra

Defra examined PVC in a wide range of applications. This report concentrates on Defra's findings on window profiles and concludes that wood windows perform better than PVC windows *(see table 10).*

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Table 10. Summary of key inventory flows for window profiles

	Units	PVC	Wood
Total primary energy	MJ	9,713	9,150
Coal (in ground)	kg	10.4	3.17
Natural gas (in ground)	kg	183	178
Oil (in ground)	kg	7.83	2.20
Carbon dioxide (biomass)	g	0.00	-24,800
Carbon dioxide	g	474,000	438,000
Nitrogen oxides (NOx as NO_2)	g	1,246	1,140
Sulphur oxides (SOx as SO_2)	g	335	155
Waste (total)	kg	28.8	16.5

Source: Defra

The following bullet list details key inventory flows for wood and PVC windows:

- Primary energy – the PVC window system consumes slightly more primary energy than the wood system. The production phase for PVC consumes more primary energy than wood. However, over the use phase for both, primary energy is much the same, with PVC performing slightly better.
- Total gas consumption for both is similar through the life cycle; PVC consumes slightly more because of gas consumption in the production phase. In the use phase, PVC consumes slightly more than wood.
- Coal and oil – PVC consumes over three times more coal and oil over the life cycle than a wood window system. Consumption for PVC is mainly through production of raw materials. For wood, the main area of consumption is during the use phase, and is attributable to paint production.
- Biomass Carbon Dioxide – wood acts as a biomass CO_2 sink, consuming 32.3kg of CO2 in tree growth, and releasing 7.5kg at end of life (landfill), giving a balance of a 24.8kg biomass CO_2 uptake.
- Fossil Carbon Dioxide – PVC emits 49.4kg CO_2 (84 per cent raw material production, 16 per cent window manufacture) and wood 5.7kg (38 per cent raw material manufacture, 62 per cent window manufacture) in production.
- Total CO_2 balance – PVC emits 474kg, and the wood window 413 kg (around 15 per cent less).
- NOx – PVC emissions are around 10 per cent higher than for wood.
- SOx – PVC emissions are more than twice that of wood.
- Waste – wood generates 43 per cent less waste than PVC.

COUNTRYSIDE PROPERTIES PLC

Greenhouse effect Impact assessment values, greenhouse effect (g equivalent CO_2)	
Wood	**PVC**
457,000	487,000

The overall performance for wood is marginally better than for PVC, due to lower energy consumption during the production phase.

Air acidification Impact assessment values, greenhouse effect (g equivalent SO_x)	
Wood	**PVC**
29.60	37.70

Wood performs better than PVC, the difference being attributable to higher SOx emissions resulting from oil use in production of PVC.

Photochemical oxidant formation	
Impact assessment values, photochemical oxidant formation (g equivalent ethylene)	
Wood	**PVC**
893	383

PVC performs better than wood, because of the release by wood of VOCs during the use phase due to painting.

Depletion of non-renewable resources	
Impact assessment values, depletion of non-renewable resources (kg/year)	
Wood	**PVC**
2.73	2.95

Wood performs better here, as a result of oil consumption for PVC manufacture, and higher gas, oil and coal consumption to provide energy in the production phase. Net deforestation was not considered by Defra, as wood is considered to be fundamentally a renewable resource.

Impact of a total switch from PVC windows to wood windows in the UK

For all impact categories concerned, the environmental burden of wood windows is lower than PVC:

- Climate Change would be reduced by the equivalent effect of use of 69,446 cars in a year;
- the PVC profile system has a 2.25 times greater air acidification impact than the wood profile system owing to emissions of oxides of sulphur attributable to PVC manufacture during the production phase: air acidification would be reduced by the equivalent use of 92,656 cars in one year;
- the depletion of non-renewable resources is equivalent to the use of nearly 100,000 cars in a single year; and
- the reduction in total primary energy would be equivalent to some 25 million fewer light bulbs lit for 1,000 hours, while the reduction in waste is equivalent to the waste generated by more than 245,000 people in one year.

3. Building Research Establishment

The BRE research concluded the following:

- as a natural material requiring a minimum of industrial processing, timber windows perform best overall, being marginally better than galvanised steel, particularly if the timber is from sustainably managed sources;
- designers may be persuaded that the lower maintenance and decoration requirements of hardwoods offer a clear advantage over the higher maintenance but less expensive softwood alternative – but this must be reconciled with a greater likelihood of the material coming from non-sustainably managed sources;
- in general, windows manufactured from moderately durable or better quality timber will not require any preservative or fungicidal treatments – otherwise, factory pre-treated timber should be preferred;
- PVC windows perform less well than both timber and steel, primarily because of higher energy requirements, toxicity levels on combustion and in manufacture for their oil feedstock implications;
- it should be noted that the toxicity aspects are contested by the PVC industry, and designers are advised to take note of the industry's guidance as well as that of environmental organisations in judging this issue; and
- PVC can have excellent recycling characteristics and it may be that the problems of long-term disposal have their remedy in better recycling techniques, systems and waste-control legislation.

Environmental profile of windows

BRE's environmental assessment method (BREEAM) provides an environmental label for buildings. One of BREEAM's aims is to encourage the use of materials that have a lower impact on the environment, taking account of the full life cycle of the materials in question. *In The Green Guide to Housing Specification,* different window frame materials are assessed by their environmental impact *(see table 11).* The data at the core of *The Green Guide* is generated using a LCA approach. The scale of scoring is A, B and C, with A being the most environmentally friendly.

Table 11. Environmental profile of windows

Windows	Summary Rating	Climate Change 1	Fossil fuel depletion 2	Ozone depletion 3	Human toxicity 4	Waste disposal 5	Water extraction 6	Acid deposition 7	Ecotoxicity 8	Eutrophication 9	Summer smog 10	Minerals extraction 11	Recycled input	Recyclability	Currently recycled	Energy saved by recycling
PVC frame, double glazed	C	C	C	C	C	A	A	C	C	A	A	A	B	C	C	B
Painted and preserved softwood timber frame	A	A	A	A	A	A	A	A	A	B	C	A	C	A	B	C
Hardwood timber framed window	A	A	A	A	A	A	A	A	A	B	C	A	C	A	B	B

Source: BRE, 2002

MAGNET JOINERY

1. Global warming or greenhouse gases
2. Coal, oil or gas consumption
3. Gases that destroy the ozone layer
4. Pollutants that are toxic to humans
5. Material sent to landfill or incineration
6. Mains, surface or groundwater consumption
7. Gases that cause acid rain, etc
8. Pollutants that are toxic to the ecosystem
9. Water pollutants that promote algal blooms, etc
10. Air pollutants that cause respiratory problems
11. Metal ores, minerals and aggregates

Interpretation

PVC windows perform poorly, owing to the high intensity of the material's manufacture and a very low recycled input. Made from a renewable material requiring low energy in manufacture, softwood windows perform well but hardwood windows are superior to both softwood and PVC windows. This is mainly due to their high durability that avoids the use of preservatives and paints. As with all timber products, timber should be purchased from a well-managed and legal source. This is particularly relevant for tropical hardwood.

CONCLUSIONS

A number of general observations can be made:

- there is enough conflicting evidence to suggest that a cautionary approach to the use of PVC is taken;
- a product that uses a non-renewable resource cannot be sustainable;
- timber from well-managed forests is a genuinely renewable resource;
- there are many examples of research that show timber windows to be between 14 – 25 per cent less expensive than PVC windows, when considering the 'whole life' cost
- prices for virgin PVC are cyclical because of variations in supply and demand, and prices for the material. Therefore, as oil becomes scarcer, it is reasonable to assume that the price of PVC will rise;
- it takes eight times more energy to manufacture a PVC window than an equivalent timber frame;
- timber windows are thermally efficient, slightly more so than PVC windows;
- measures can be taken to improve the durability of timber-framed windows, including factory rather than site finishing;
- timber windows are easily repaired and maintained, PVC windows are not;
- timber windows generate 43 per cent less waste than PVC windows;
- the construction industry produces large amounts of both timber and plastic waste, but the potential to reuse timber waste is greater than the potential to reuse PVC waste;
- PVC waste will rise to 6.4 million tonnes by 2020, when the capacity to recycle it will be a fifth of what will be required; and
- throughout the use and disposal of the product, the overall environmental burden is significantly less for timber windows than for PVC windows.

REFERENCES

1 European Council of Vinyl Manufacturers (ECVM). Press release, June 2004
2 *Life Cycle Assessment of PVC and of principal competing materials.* European Commission, July 2004
3 Survey conducted by BWF and Michael Rigby Associates 2004, presented in Timber Windows, Spring 2004 edition.
4 British Plastics Federation, 2004
5 British Plastics Federation, 2004
6 US Commercial Service, October 2003
7 The Brighton Report, Michael Rigby Associates, 2002
8 *UK Market for Residential Windows and Doors.* MSI Marketing Research for Industry Ltd, 2001
9 *Product Sales and Trade - Builders Carpentry & Joinery.* National Statistics, 2004
10 BWF and Michael Rigby Associates, 2004
11 *The Brighton Report,* Michael Rigby Associates, 2002
12 *UK Market for Residential Windows and Doors.* MSI Marketing Research for Industry Ltd, 2001
13 *UK Market for Residential Windows and Doors.* MSI Marketing Research for Industry Ltd, 2001
14 Heywood Williams and Palmer Market Research, 2003: www.heywoodwilliams.com/operatingmkts.cfm
15 Defra, 2001
16 British Plastics Federation, 2004
17 British Plastics Federation, 2004
18 Michael Rigby Associates, 2002
19 British Woodworking Federation, 2004
20 *Forestry Statistics 2003* – Forestry Commission
21 WWF, 2004
22 Forestry Commission, 2000
23 WWF, 2002
24 The Food and Agriculture Organisation of the United Nations (FAO) *Yearbook of Forest Products,* July 2004
25 CIFOR, September 2004
26 *Environment Minister Elliot Morley announces move to ensure Government sourcing of legal and sustainable timber.* Defra press release, 9 November 2004
27 Forest Stewardship Council, 2004
28 *Energy White Paper*, July 2003: www.bbc.co.uk/climate/policies/uk_policy.shtml
29 DTI, 2003: www.dti.gov.uk/energy/inform/dukes/dukes2003/03main.pdf
30 *UK Energy Sector Indicators.* DTI, 2004
31 London Borough of Camden Council, 2004
32 *Green Guide to Specification* (3rd Edition), J Anderson (BRE) and D Shiers (Oxford Brookes University) with M Sinclair (Consignia). Published by Blackwell Science, January 2002.
33 Article in Building journal, 28 April 2002
34 National Housing Federation, 1998
35 Carlisle City Council, 1998
36 *The Green Guide to Housing Specification,* J Anderson and N Howard, BRE 2000.
37 *Modern coatings help win market share,* TTJ, 3 May 2003
38 Report for the PVC window industry by Michael Rigby Associates, 2002
39 *Sustainable Construction Policy and Programme for Council-Owned Housing,* London Borough of Camden Council, July 2004
40 Research for Islington Council on PVC Windows and Alternatives, April 2004
41 *The Construction Industry Mass Balance: resources, wastes and emissions,* Viridis, 2002
42 DTI, 2001
43 WRAP, 2003
44 Defra, 2000
45 *Environmental and energy balances of wood products and substitutes,* FAO, 2002
46 Defra, 2001: www.defra.gov.uk/environment/consult/pvc/05.htm