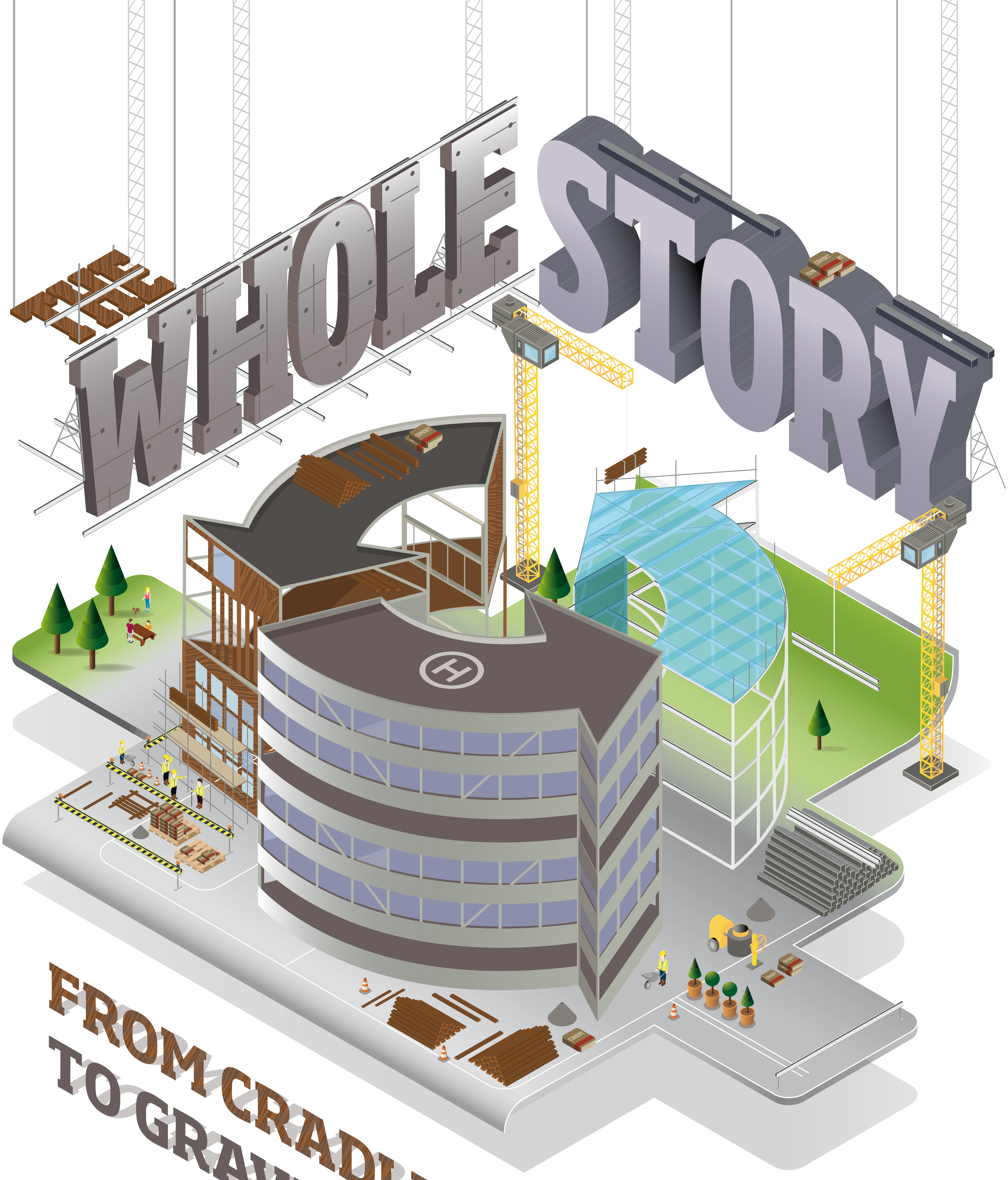
THE WHOLE STORY



FROM CRADLE TO GRAVE

IN ASSOCIATION WITH

TATA STEEL

BCSA

Waste not, want not

You could be forgiven for picking up this supplement and thinking: "I've got enough to worry about with the economy the way it is, I can't deal with this sustainability stuff right now". But the fact you're reading this suggests that you, like me, believe that it's not a binary choice between economy and environment, and that sustainable business – and indeed a sustainable built environment – will be central to our recovery, growth and future prosperity.

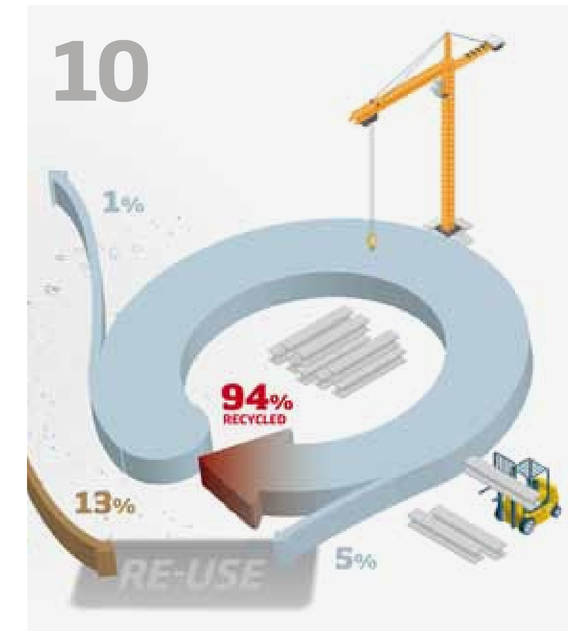
The topic of this supplement – whole lifecycle assessment – although it sounds like a bit of techie jargon, is really at the heart of this challenge. Of course, the energy used in operating our homes and buildings is a big issue, but sustainability is much broader and goes much deeper than this. Whole lifecycle assessment is an attempt to take into account the true cost and impact of the materials we use, from sourcing to end of life, or preferably re-use and renewal - so-called "cradle-to-cradle".

This isn't particularly new thinking – and resource efficiency is not a recent phenomenon. Arguably we're only just recapturing a previous attitude to "waste not, want not" that had been the dominant paradigm for centuries.

But the case for moving away from our current consumption-based economy towards a new, green economy that values the scarcity of natural resources has never been stronger. Rapid fluctuations in fossil fuel prices, changing climate and growing environmental pressures, markets still constrained by the global financial crisis and increasing demand for ever-depleting resources, are forcing us to look closely at the way we do things.

Businesses that flourish in the future will do so not because they have the best CSR programmes or green PR campaigns, but because they have made resource efficiency – the challenge of doing more with less – a core business strategy and are creating lasting value from more sustainable business practices. This supplement is full of examples of good practice, which must become the norm, not the exception, if we are to begin to meet the needs of billions of people trying to live off the interest of one planet rather than using up all of its capital in one or two generations.

Paul King, chief executive, UK Green Building Council ❑



THE BIGGER PICTURE

WHY THE FUTURE MATTERS

Enlightened clients are starting to ask difficult questions about whole-life impacts such as embodied carbon and recyclable components

It's something that – instinctively – we all know is true. This focus on creating "low carbon" buildings in operation is a serious case of tunnel vision. The impacts of constructing that building, with all its materials and components sourced from around the world, and the fate of the rubble at the end of its life are conveniently ignored.

But it's not embodied carbon emissions or resource depletion that are keeping the property company directors awake at night. What concerns them is risk: is your portfolio worth what you think it is?

"Anything that's a risk to the future value of a property will concentrate people's minds," says David Telford, who heads up Hurley Palmer Flatt's sustainability division. "What chiefly concerns property fund managers is that there is a potential for a tipping point: at some point a building just won't be leasable if it is not sustainable."

And while many property owners just read "energy efficient" for sustainable, the most forward looking are realising that they need to take a much more strategic view of what brings value to a building: its planned length of service, flexibility of space, ability to refresh and refurbish and – eventually – how precious commodities such as copper will be reclaimed. And in response, consultants and designers are starting to measure whole-life impacts such as embodied carbon (see box, below) and creating measurement tools, databases and benchmarks.

> "CONSULTANTS AND DESIGNERS ARE STARTING TO MEASURE WHOLE-LIFE IMPACTS SUCH AS EMBODIED CARBON"

"There is some clever thinking going on as this debate moves out of universities and into the hands of practitioners," says Chris Trott, partner and sustainability engineer at Foster + Partners. "It's probably the big portfolio owners such as education authorities, NHS Trusts and large commercial portfolios that are starting to ask the right questions."

This approach is still very much in its infancy, though, says Trott: "The big property companies know how to look after their buildings once they have got them, but the briefing part of it and the feeding back in a structured way is still relatively immature.

"There are a select few who are interested in looking at the impacts and benefits over the whole lifecycle, from extraction right through to end-of-life," says Kristian Steele, senior consultant at Arup Materials. "Many people are just trying to get their heads round it.

"There are clients who are interested in showcase buildings where they are trying to understand what lifecycle assessment (LCA) means and learn from the process so that they can deal with it in a better way as their knowledge progresses. Much of the useful work at the moment is around education and understanding as opposed to specific change of design decision."

The big debate

One of the big areas of debate is whether embodied impacts should take into account what happens to a material at the end of a building's life. If something can be re-used or recycled, then much of the carbon spent in producing that product in the first place has been saved – which is taken into account in a cradle-to-grave assessment.

It is, of course, easier to look only at what happens to a product up to the point it leaves the manufacturer; a so-called cradle-to-gate lifecycle assessment. The benefit of this is that these processes are defined and don't change, whereas what happens once a product leaves the factory gate varies from project to project. However, the downside is that this approach can misinform decisions.

"The trouble with the cradle-to-gate metric is that you may draw the wrong conclusions if studying the embodied carbon of the initial construction phase only," says James Fiske, head of the Economic Research Unit at Mott MacDonald. "We therefore strongly recommend that the industry adopts a cradle-to-grave approach to studying embodied carbon, linking this at the same time to the calculation of emissions over the life, caused by energy consumption or even carbon absorption in some cases." Measurement of carbon and cost should be linked, says Fiske, to save different construction teams measuring these items separately.

Mott MacDonald's approach is to use a cradle-to-gate measure for embodied carbon and model what is done to a material or component during and after its life separately, combining them to give a cradle-to-grave insight. "The maintenance, replacements, transportation, disposal and recycling processes should be modelled individually in order to improve accuracy, as you can only evaluate what you are doing at one point in time with any accuracy," says Fiske. He goes on to say that if the material is from a recycled source then the cradle-to-gate metric should reflect the recycling process, rather than the impact of producing something from a virgin material.

"Thinking of the full lifecycle is always the preferable approach," says Steele. "Cradle-to-gate is a useful way to get started but as you become more familiar and capable, you can do cradle-to-grave type calculations."

Steele and other LCA practitioners advocate looking at every phase of a building's life – materials extraction and manufacture, transportation and construction, operation and

▶

WHEN IS EMBODIED CARBON NOT EMBODIED CARBON?

Embodied carbon is the amount of CO_2 emitted during a product's entire lifecycle, including raw material extraction, transport, manufacture, assembly, installation, maintenance, disassembly or demolition and decomposition. However, people often use the term "embodied carbon" to refer to emissions during the earliest phases of a product's life only.

Manufacturers can provide data on the carbon that has been embodied up to the point it leaves the factory, so-called cradle-to-gate embodied carbon. What happens next may vary depending on product but those future effects are locked in as soon as the product is used. Because the cradle-to-gate figures are easy to get hold of – Bath University's Inventory of Carbon and Energy (ICE) lists embodied impact only to the end of the manufacturing process – these are often the only ones considered. However, the embodied carbon during later parts of a product's lifecycle can be significant: for example, if materials for small projects are transported from a long way away or if a component needs to be replaced, repaired or maintained many times during a building's life.

Similarly, other embodied impacts – such as greenhouse gas emissions, water use or land use – can also be considerable in later phases such as disposal and recycling. And while the current political focus is on carbon, these other impacts will be considered equally important in the future.

KRISTIAN STEELE

"If I were looking at the issues I would identify as important, I would look at the embodied impacts of your asset. But you also want your asset to be healthy and safe, be responsibly sourced and you should also strive to ensure it demonstrates good resource efficiency. These are all aspects which should be looked at on a lifecycle basis. We might say that if things last longer, they are better. But that does not mean they should not also demonstrate the qualities which would enable them to be recycled or, even better, for components or materials to be re-used."

Kristian Steele is a senior consultant at Arup Materials

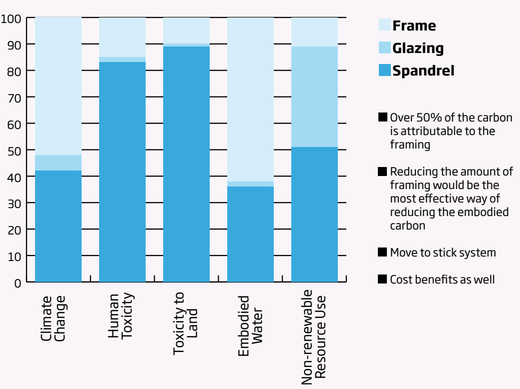
INTRODUCTION

GUY'S HOSPITAL

Lifecycle assessment (LCA) studies can really come into their own on refurbishment projects, when whole-life carbon can be considered alongside cost to help inform decisions.

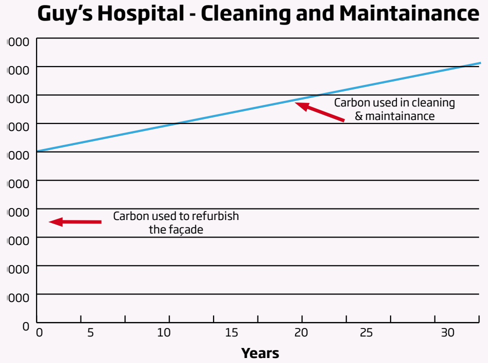
Working for the Guy's and St Thomas' NHS Foundation Trust, replacing failing cladding on Guy's Hospital, Arup was able to use simple lifecycle tools to compare six different cladding systems.

Guy's Hospital - Impact Reduction



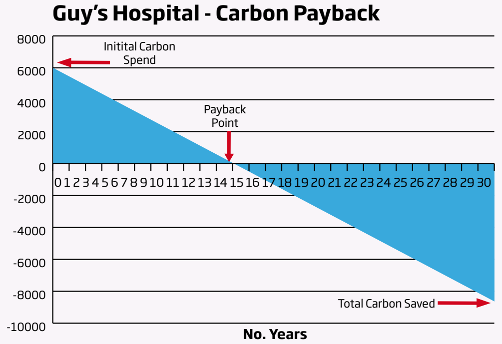
Arup senior consultant Kristian Steele looked at a broad range of impacts for the cladding systems, although he says that clients will almost always focus on carbon.

Guy's Hospital - Cleaning and Maintainance



Arup built simple models using LCA to show carbon in use. These models are not readily available but are vital to help clients and designers make whole-life decisions.

Guy's Hospital - Carbon Payback



LCA also allowed Arup to work out when the carbon spend would be paid back by the operational carbon improvements, a measure that was used in planning.

"THE MARKET WILL LEAD DESIGN FOR DISMANTLING AND RE-USE ON HIGH-VALUE ITEMS"

▶ maintenance, dismantling and re-use or disposal – in order to pinpoint where the biggest impacts are and therefore where the biggest improvements can be made.

Trailblazers

While full LCA studies that consider the cradle-to-grave impacts for whole buildings are rare, and may be carried out after a building has been designed as a data gathering exercise, designers are starting to use LCA-related information to help make decisions on material and product selection. Foster + Partners, for example, is adding LCA data into its materials database so that architects will automatically have the information when they are researching specifications.

In refurbishment, LCA can be a very useful tool. Steele analysed the replacement of damaged facade on Guy's Hospital to work out that the carbon spent on the new rainscreen would be paid back by the energy saved within 12.5 years (left).

LCA can also be used as a weapon against building control departments, reports one consultant who did not want to be named. Sometimes it doesn't make sense to insulate and upgrade a building to current Part L standards when you are spending more carbon than you save.

While LCA considers a wide range of environmental impacts through a product or component's life, inevitably the focus is on carbon. "Climate change is the defining environmental issue of our time," says Steele. So in the UK, much of the work being done by clients in this area focuses on a building's carbon footprint: embodied, operational and end-of-life.

There are a few trailblazers. In the Middle East, the developers of Masdar City are making serious attempts to consider the impacts of a building over its entire lifecycle – including re-use and recycling (see page 8). Foster + Partners used their LCA-informed materials database when comparing and selecting materials for the buildings and public spaces.

Closer to home, the ODA has made great strides. Many of the main venues – the aquatics centre, the Olympic stadium and the water polo arena – have temporary elements designed so they can be dismantled and possibly re-used and the park also features the largest ever temporary steel framed building, the basketball and handball arena.

In the utilities sector, Water regulator Ofwat has forced water and sewage companies to consider whole life rather than just operational carbon. The result for companies such as Anglian Water (see box, right) is a new approach to procuring components and systems, taking into account embodied and operational carbon alongside cost.

In private sector client briefs, mentions of LCAs or whole-life carbon are conspicuous by their absence. "The private sector remains interested in one thing: getting the lowest capital cost – with a few notable exceptions," says Rob Lambe, who heads up Willmott Dixon's sustainability consultancy Re-Thinking. "There's a bit of debate about energy efficiency but it is having little impact in terms of actual decision-making. Apart from one current scheme that is out to tender, the WWF HQ, we haven't experienced any serious attempt at accounting for whole-life carbon in bids issued."

Considering only capital costs leads to decisions being based on a partial picture, says Lambe, a fact that is recognised in the Treasury's Green Book, which says all procurement decisions should be based on whole-life cost rather than capital cost. Lambe thinks we should go one step further to also consider environmental impact over the entire lifecycle: "Overall, we should be addressing whole-life value, which is a combination of environmental impact, including carbon, embodied and in use, costs , including capex and opex, functionality and ability to meet performance requirements."

Another potential trial ground for whole-life carbon thinking is the new ecotowns. However, the planning policy statement issued by the government in relation to ecotowns does not list whole-life carbon as a consideration.

At the ecotown in north-west Bicester, housing association A2Dominion, which is part of P3Eco, a newly formed eco-development company responsible for the town, is going some way towards that goal. Contractors Willmott Dixon and Hill Partnerships have been targeted with reducing the embodied carbon by 40% compared with a standard new-build house. "[This] would be the sort of order of magnitude that would take us towards the low carbon footprint that we want," says Nicole Lazarus, sustainability consultant to A2Dominion.

Re-use and recycling have been key concerns for the ODA on the Olympic park. The aquatics centre, pictured, the Olympic stadium and the water polo arena all have temporary elements designed so they can be dismantled and re-used

Market forces or regulation

Chris Trott sees market forces rather than legislation as the strongest driver for clients towards lifecycle thinking. "High-value artefacts and items are much more likely to be readily planned for their whole lifecycle because they have a residual value after their first life," he says. "Part of the secret to effectively designing buildings is to design components and assemblies where items of high value can be separated and recycled."

Designers who don't consider end-of-life in their designs risk locking in commodities that would have brought value further down the line. "The market will lead design for dismantling and re-use on these high-value items, providing designers rise to the challenge," says Trott. "The design and professional fraternities have a role to play too. It's not so much about inventing new things, it's about how you go through the process of design." (see page 14). This is already happening to some degree, reports Telford: on datacentres. These buildings have relatively short lives – seven to eight years – before refitting. But the copper used for the busbars is extremely valuable. "We have started discussions with some of the manufacturers who want to rent rather than sell the busbars," says Telford.

Liz Green, senior sustainability consultant at Mott MacDonald, thinks that LCA should become mandatory. "In the UK it is still not being seen or enforced as policy," she says. "That does need to change."

Craig Jones, a senior associate at Sustain, agrees: "We need regulation or legislation," he says, "Or a mainstream gold standard that includes embodied or whole-life carbon. We need a harder driver."

Trott is less sure: "Legislation is the minimum bar to entry: it often affects so many people that the bar is not set very high. Where the legislation might be successful is requiring assessments to be made, with the information being reported into government or other bodies."

Ultimately both market forces and legislation will drive us towards a more whole-life perspective on carbon and other impacts. Firms such as Arup, Foster + Partners, Mott MacDonald and Deloitte, which recently bought DCarbon8, are smart enough to realise that there is commercial advantage to be had in building up the expertise, tools and data now. ❑

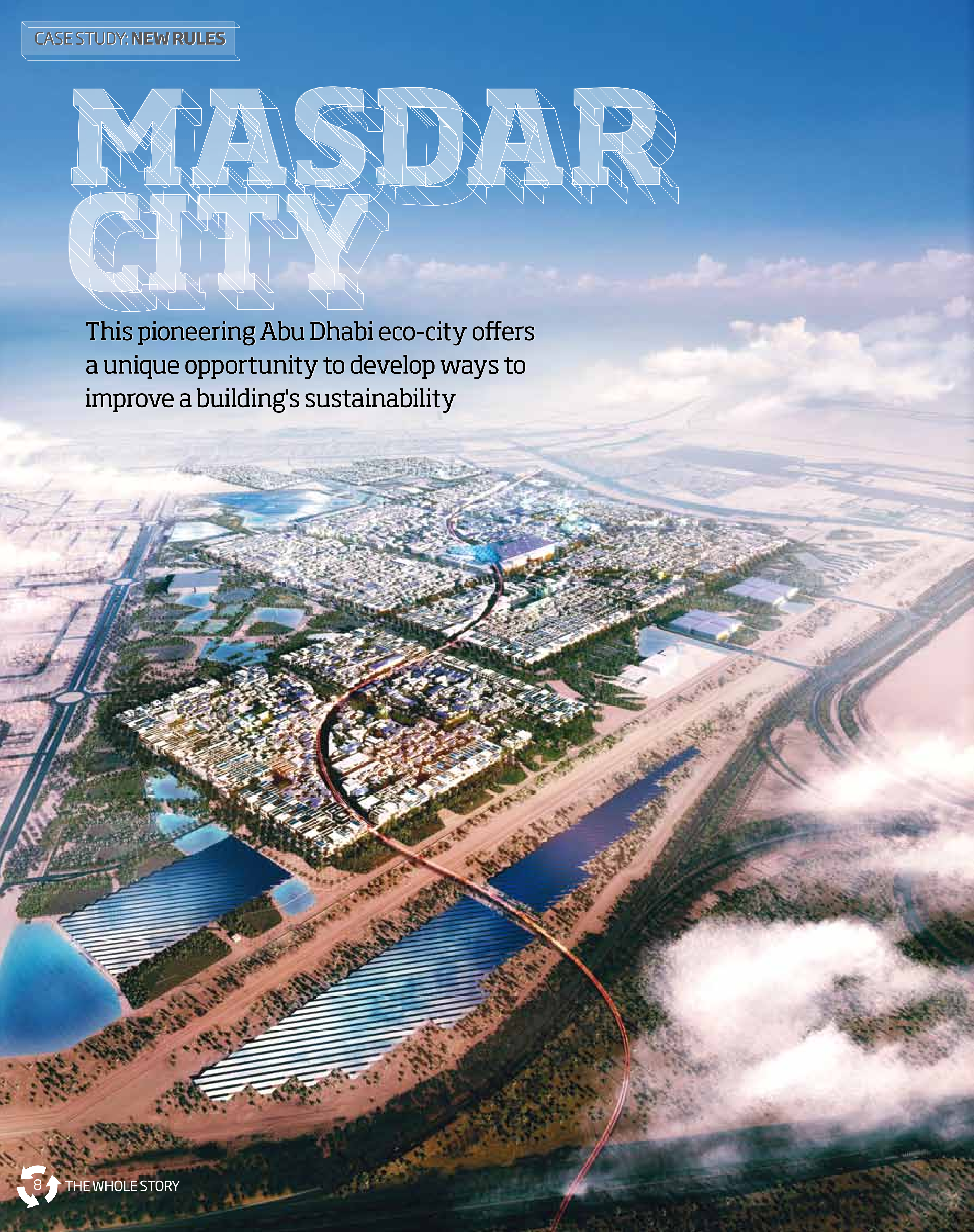
CASE STUDY: ANGLIAN WATER

In response to Ofwat's climate change policy, Anglian Water is taking whole-life carbon as well as cost into account.

Working with its integrated design-build delivery provider @one Alliance, the water firm is developing a catalogue of products that give both cost and carbon savings. Embodied and operational carbon are calculated with a specially developed Carbon Modeller and the goal is to halve embodied carbon by 2015 compared with similar assets built in 2010.

Innovative systems developed by the team include creating a curved trench for structured plastic water pipes using a special shaped bucket. This reduces the amount of bedding and surround material required, cutting costs by 38% and reducing embodied carbon 50%. So far 60 products have been developed with 150 more identified.

@one Alliance includes Anglian Water Services, Balfour Beatty Utility Solutions, Barhale, Black & Veatch, Grontmij, MWH, and Skanska Aker Solutions, and is supported by Mott MacDonald.



MASDAR CITY

This pioneering Abu Dhabi eco-city offers a unique opportunity to develop ways to improve a building's sustainability

CASE STUDY: NEW RULES

If you wanted to challenge decision-making on sustainable development, Abu Dhabi might be the place. In a country where fresh water is created in desalination plants and materials must be transported from afar, competing environmental pressures could not be more evident.

Masdar City aims to find a way through these issues. Its ambition is to be the world's first carbon neutral, zero-waste city powered by renewable energy.

Developer Masdar, a wholly owned subsidiary of the Abu Dhabi government's Mubadala Development Company, is pushing the boundaries across a range of sustainability targets. In doing so, it will make new discoveries and set standards that the rest of the world will follow. Among its goals is reducing the embodied carbon of construction materials, including the use of recyclable and recycled materials.

"The country itself does not have very much in the way of building resources. They recognise that the ability to recycle, design for dismantling and embodied carbon are important," says David Telford, director of Hurley Palmer Flatt's energy and sustainability division, who worked on the concept design for the Sprinter Building in the Swiss Village in Masdar. On site in January next year and due to be completed in early 2013, the Sprinter Building is one of the first to go up in Masdar City and will house the Swiss embassy.

Designed by Foster + Partners, Masdar is based on a traditional idea of compact cities: high density but not high rise. Construction started officially in February 2008 and the heart of this research-based city, the Masdar Institute, is already built.

Once complete, the city will be home to about 40,000 people, with 50,000 commuting in. A light rapid transit system will take workers into the city and – unusually for this part of the world – Masdar has been designed with green pedestrian streets to tempt people to walk.

As a sustainable city, Masdar is being designed so its buildings can renew themselves as the city changes and develops over the years. For the Sprinter Building, future lives beyond its first use as an office had to be considered in its design. "It had to be very flexible so that it could accommodate lots of different uses over its life," says Telford. "The main structure remains the same while the internal layout changes."

The next step is to plan for those parts of the building that will be replaced. "It's thinking about the bits that would need to be renewed and designing them for recycling," says Telford. For example, the design team looked at the chilled beams to examine whether the valuable commodities within them could be easily separated and recycled. "We looked at the steel, aluminium and copper – how they were joined together and whether you can get those materials back."

Major plant must also be designed for ease of replacement and pipes and wires must be sized to take into account different loadings and requirements in the building's future lives. "If the internal layout of the building changes, would the basic infrastructure be able to be adapted and used?" says Telford.

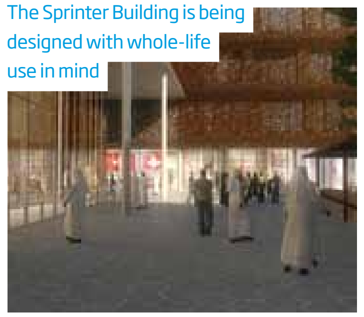
The design team also had a whole range of sustainability targets to hit with their concept design. Economically, the building had to be high efficiency, achieving a net to gross of over 75%; specifications had to use local suppliers where possible; embodied carbon had to be reduced by 30%, operational energy and carbon by 50%, operational water by 30% and recyclable and recycled materials used where possible.

"THE ABILITY TO RECYCLE, DESIGN FOR DISMANTLING AND EMBODIED CARBON ARE IMPORTANT"

"It had to be a multi-disciplinary approach," says Telford who set the M&E design and sustainability strategy. So at a very early stage the designers – Swiss architect BGP who provided the concept design, local delivery designers A+Dyer, and Hurley Palmer Flatt – looked at different options to find the best fit. "There were two or three concepts and we all did a little bit on each and rated them against what each of us was trying to achieve and got the best compromise. And at the same time we did a quick cost assessment."

On this project, the client was not necessarily looking for lowest cost. "The client was interested in the shape of the curves: for example, how much extra cost would it be to get an extra amount of carbon reduction," says Telford.

Telford recognised the challenges of competing environmental targets, so developed an analysis tool to help find the optimum solutions. The first step in using the tool is to take all the environmental parameters and work with the client to weight them according to mandatory targets, strong desires and good-to-haves. Different scenarios can then be run through the tool, with a score indicating how close to the client's values that solution has reached.



The Sprinter Building is being designed with whole-life use in mind

Telford based the tool on environmental, economic, social and cultural sustainability, the four pillars of Estidama, Abu Dhabi's sustainable building framework. But the tool can be adapted to meet the values and requirements of any client.

Like every building in Masdar, the information from the Sprinter Building will be fed into the city's databases and tools to help inform future phases of development.

To help designers and specifiers, Masdar has set up a specialist portal called The Future Build, which is effectively a directory of "green" materials and products from the United Arab Emirates. Any product on the database must first be independently assessed to make sure that it lives up to its billing, with benefits listed that are relevant to Masdar's 15 environmental criteria.

The plan is that professionals will begin to use the portal on other projects in Abu Dhabi and the United Arab Emirates – and ultimately that it will be useful to built environment professionals around the world. ❑

The Masdar Institue building in Masdar City

THE FACTS

BEHIND THE FIGURES

Before you start comparing the impacts of different materials over their lifecycles, there are a few things you need to know ...

It's not rocket science. If you want to compare the embodied impacts of different structural materials, just look up the impact figures per kg, multiply by the weight of that material and hey presto! There's your answer.

If only it were that simple.

While nobody is claiming that lifecycle assessment is on a par with rocket science, there are certainly a few knotty issues to tackle before designers and engineers can make informed comparisons between materials. Ignore them, and you're only looking at a partial picture.

In the table opposite, you will find background information and explanations to help people to understand what they are reading when they look through tables of data such as Bath University's Inventory of Carbon and Energy (ICE). And on pages 12 and 13 you will find illustrations that show what proportions of our main structural materials are currently re-used, recycled or sent to landfill.

If you need a quick briefing on what lifecycle assessment is all about, turn to page 16 for our Beginner's Guide.

WHAT'S IN A LIFECYCLE?

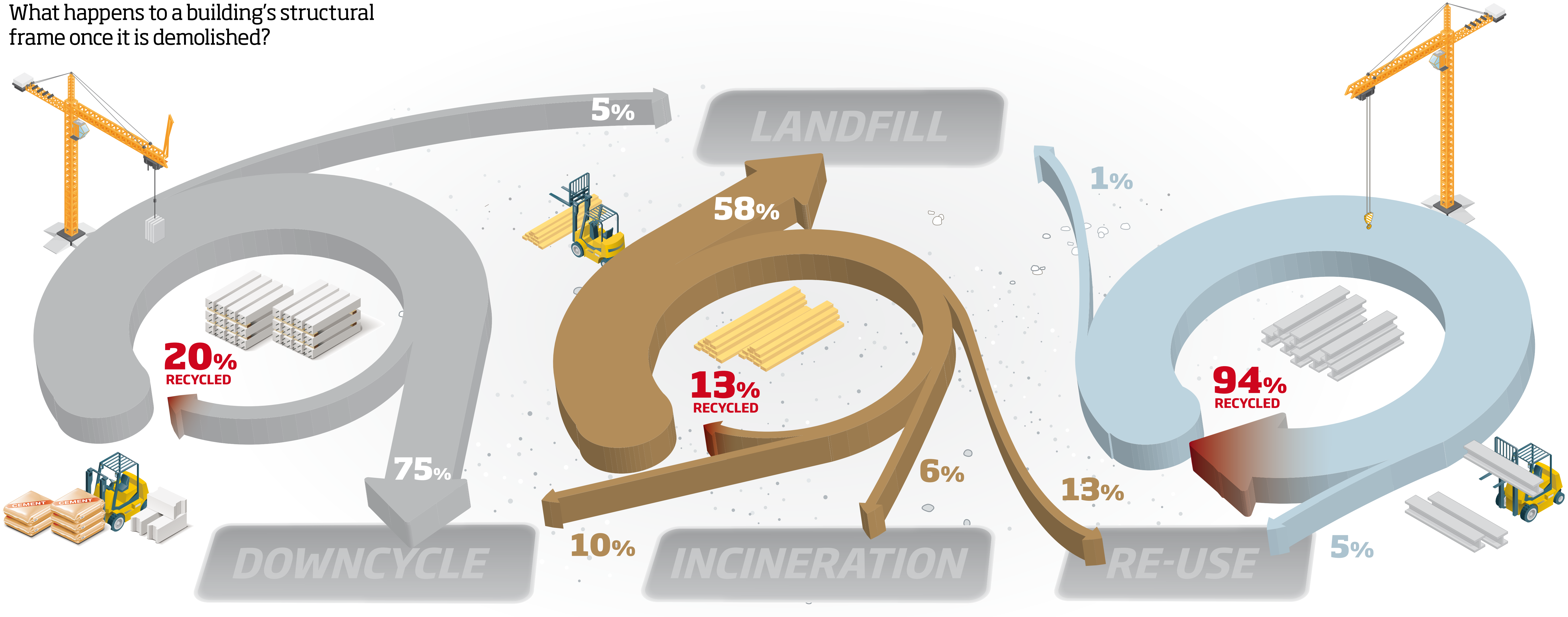
How approaches and assumptions vary between the materials

	STEEL	TIMBER	CONCRETE
CARBON FOOTPRINT ISSUES			
Quality of data	The general quality of data is good. Steelmakers have a high profile and have responded to pressure to make full and comprehensive studies of their impacts.	The quality of data is variable, something which both the industry and the government admits. Huge variations in results can be calculated depending on the assumptions made and no common agreements exist to assist in this.	The general quality of data is good. The choice of mix can have a significant bearing on the carbon intensity.
Methods of analysis	The steel industry, along with most metals producers, favour the use of a cradle-to-grave approach, which recognises the benefits of future recycling.	Timber manufacturers tend to use a cradle-to-gate approach, which stops when the material leaves the factory gate. Sequestration – the ability of the timber to store carbon over its lifetime – is usually assumed to occur.	Concrete manufacturers tend to adopt a cradle-to-gate approach with no consideration of end of life. Within the UK, an assumption is made that the rebar in reinforced concrete is made from 100% recycled steel.
What are the values using these methods?	On the basis of a cradle-to-grave approach, taking into account the benefits of future recycling, the steel industry uses figures between 0.76kgCO_2/kg for structural sections and 1.35kgCO_2/kg for galvanised strip.	The Inventory of Carbon and Energy (ICE) database is cradle-to-gate and takes no account of end-of-life issues. It admits the difficulty in calculating the burdens of timber but calculates those of glulam to be 0.84kgCO_2e/kg of timber.	The ICE database contains a figure of 0.163kgCO_2e/kg for C40 concrete. Reinforcement burdens add 0.43kg CO_2/kg of steel to this figure, according to Concrete Centre data. This assumes all rebar is sourced in the UK.
What are the values using a cradle-to-grave approach?	As above. On the basis of a cradle-to-grave approach, taking into account the benefits of future recycling, the steel industry uses figures of between 0.76kgCO_2/kg and 1.35kgCO_2/kg of steel, depending on the product.	On the basis of published TRADA data on end-of-life outcomes for timber in the UK, the carbon intensity of glulam is 1.1kgCO_2/kg.	Based on recycling and landfill data from the government, a figure of 0.153kgCO_2e/kg is used for C40 concrete. To this must be added the burdens of reinforcement. The World Steel Association calculated this as 0.82kgCO_2/kg of steel
Other issues	Steel manufactured from iron ore produces a by-product called blast furnace slag. Because it is classed as a by-product, LCA rules state that the manufacturer can take credit for subsequent use. A credit for this is included in the figures for steel mentioned above.	The benefits of timber in construction are based on assumptions that the timber is sustainably sourced. Care needs to be taken to ensure that this is so. If not, the carbon burdens of timber will increase considerably.	Blast furnace slag, a by-product of steel making, is widely used as a cement replacement. Concrete manufacturers take credit for this. However, this is contentious as the steel manufacturers also lay claim to these credits. This issue has yet to be resolved.
END-OF-LIFE OUTCOMES			
Recycling	Steel scrap has a high value and has an efficient collection and capture infrastructure. Globally, it is estimated that 80% of steel scrap is captured. In the UK, 94% is captured from construction demolition and, for heavy framing products, 99% is captured or re-used.	The BRE Green Guide estimates that 23% of timber from demolition sites is recycled. In 2008, TRADA estimated that approximately 10% of timber waste was used to make chipboard, suggesting 13% is recycled to its original or equivalent use.	Approximately 20% of aggregate from demolition sites is thought to be recycled. However, the cement, that part of the concrete that accounts for up to 75% of CO_2 production, is lost permanently.
Re-use	A study carried out in 2003 estimated that 13% of structural sections are re-used. This is thought to be high and the actual figure is probably between 5-10%. Sections re-use mainly occurs in the agricultural sector.	Most re-used structural timber is in the form of beams, joists and studwork. Salvaged timber is sometimes re-milled and sold to consumers in the form of timber flooring, beams and decking. Little information is available on the percentage of timber re-used in this way.	Structural concrete does not generally lend itself to re-use, mainly due to its continuous nature and the subsequent difficulties in separating components. There is some scope to re-use precast components.
Landfill	The amount of steel that ends up in landfill from building demolition is a function of the ease of recovery. It is greatest for reinforcing bar, estimated at 6%, and least for rolled sections, where a nominal 1% loss is assumed.	The BRE Green Guide estimates that 58% of timber from building demolition ends up in landfill, which may be due to the difficulty in separating timber with value from contaminated timber. A 2008 TRADA publication puts the figure at 80%.	Increases in landfill tax have resulted in great strides in reducing the concrete going to landfill in recent years. Construction waste remains a problem, however, and is currently the target of a project to reduce by 50% the amount ending up in landfill by 2012.
Downcycling	Steel scrap is manufactured into products with the same value as the original material. Downcycling does not take place.	A great deal of timber waste is cycled back into products of lower value and utility. TRADA has estimated that over 1 million tonnes of wood waste goes into the manufacture of chipboard.	Most concrete from demolition sites is used as hard core and fill where it replaces aggregate, which is otherwise won from gravel or rock. Cement, which accounts for most of the CO_2 production, is lost in demolition.
Incineration	Not applicable.	About 6% is incinerated at end of life. Energy recovery is restricted by lack of infrastructure.	Not applicable.

THE FACTS

END-OF-LIFE SCENARIOS

What happens to a building's structural frame once it is demolished?



CONCRETE

The great majority of concrete from demolition sites is crushed and used as sub-base or fill. This is downcycling rather than recycling, ie a secondary use which is not of the same value as the first.

Aggregates from demolition may be re-used in concrete production but its use is restricted both by rules governing maximum percentages allowed and also by supply, since the amount of aggregate that can be recovered for this purpose is limited. Where aggregates are re-used in concrete, new cement, the source of most of the CO_2 emitted in concrete production, is still needed. The Concrete Centre is the source of the downcycling figure, with the other figures estimated using various sources.

TIMBER

Definitive information on what happens to timber waste following building demolition is difficult to find. Recent publications from TRADA indicate that up to 80% of timber waste in the UK goes to landfill. The information presented here is from the BRE Green Guide.

The downcycling figure is an estimate based on published information on how much timber is diverted from the waste stream for the manufacture of chipboard.

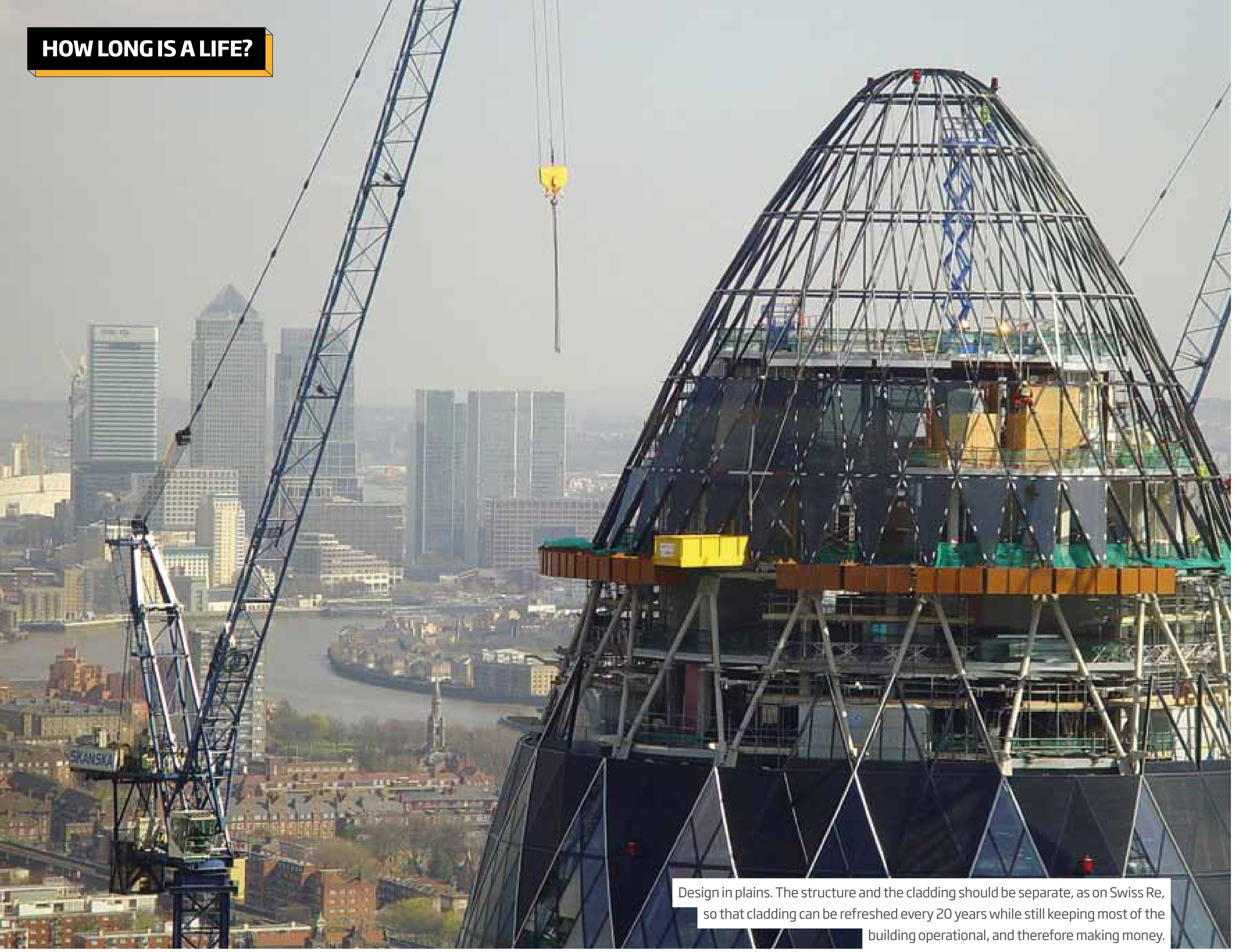
Problems with contamination in the waste stream in particular restrict opportunities to divert waste for re-use and recycling.

STEEL

Steel benefits from having a high intrinsic value supported by a well developed and efficient scrap collection infrastructure. It can be recycled at end of life to form products that are of the same, or higher, standard and quality as the original material and most steel components are large and easily captured.

Capture rates vary depending on the ease of extraction from the demolition site but are always above 90% and average 94% for all steel components. For sections, it is 99%.

These rates can be found in Material flow analysis of the UK steel construction sector, J. Ley, 2001.



Design in plains. The structure and the cladding should be separate, as on Swiss Re, so that cladding can be refreshed every 20 years while still keeping most of the building operational, and therefore making money.

DESIGN FOR LIFE

Designers should think not only about getting a building up, but also when and how its elements will be retired, says Foster + Partners sustainability expert Chris Trott

HOW LONG IS A LIFE?

"WE ARE LIVING IN A SEVERELY RESOURCE CONSTRAINED WORLD"

Chris Trott does not believe in designing buildings that last. Well, not unless you really need them to. "What I am not arguing for is long life," says the Foster + Partners partner and sustainability engineer, "but for a good long think about the life of a building and then actually planning for the life you have agreed on."

For most clients, this will require a paradigm shift in thinking, says Trott: "Clients need to be more analytical about where their values lie. Do they want a building that will last for 150 years? Or will they only need it for 20 years because things are moving quickly? You might refit two or three times in that time. After that, take the building down and recycle the site."

For inspiration, Trott suggests that designers should look to the worlds of sport and entertainment. "If you follow Formula One, everywhere they go, they take their own pavilion building for their entertainment with them. They can disassemble a whole building. A lot can be learned from technology transfer from other sectors."

For designers, this approach also requires fresh thinking. Trott guesses that in the UK only a handful of buildings are being designed for decommissioning at the end of their life, in contrast with countries in central continental Europe and Scandinavia.

"In Switzerland, designers have nine phases of service briefing, the ninth being deconstruction or decommissioning," says Trott. "There is a requirement for there to be a plan on how buildings will be deconstructed and taken out of use."

Green thinking and design in these countries has advanced faster than in the UK due to necessity, suggests Trott: "They have been energy resource poor, so energy tends to be a lot more expensive. That affects buildings' costs and the costs of their materials, so they have had to think about issues in the green debate a lot earlier than us." Trott thinks it would be sensible if the planning process in the UK took this approach too: "We live in a severely resource constrained world. We are running out of natural resources with the conventional once-through model.

"Probably now one of our greatest resources is waste. We have to take the view that waste is a resource to be re-used – whether newspaper, a tin can or a piece of a building. We are probably now starting to approach the point where the majority of natural resources are already in the things we use. Eventually we will run out. A planning system that supports re-use would be a good move."

Before planning comes the brief: the first step in deciding on a suitable life for a building is to draw out what a client's values are, says Trott: "We would have a dialogue to establish what is important for them. It's about us explaining the opportunities and them reacting to which of these they think they value."

It is not just the building's life which must be decided at this stage, but the life of its components too. If leases on offices get shorter for example, the available cycle-time for refurbishment will be shorter and the elements that need to be replaced or refreshed should aim to have lives which coincide with the lease lengths. "If somebody is saying we are moving to a 15-year lease, then components would legitimately be reviewed in the same cycle and that would feed into the design process. Conversely, if you are working to a 25-year lease, what do you do with components that have to come out after 15 years?"

Once this sort of brief has been set, it's a case of designing your building so that the bits that do need to be replaced can be easily disassembled and changed. And crucially, this should be possible while the building – or most of it – remains in operation.

"Foundations are pretty much there for life, as are the structural frame and structural floor systems," says Trott. "Cladding systems might be replaced after 20 years. That is perfectly legitimate and should be thought about from the beginning so they can be demounted and recycled.

"I have personally been involved with an existing building where the cladding could not be taken off because it was a structural cladding system and the building would have fallen down. The building was a complete construction site in order to bring it back into use. What you need is an ongoing asset with income coming in as the work happens."

Similarly, M&E systems should be easy to replace. "Quite a lot of things tend to go into modular plant rooms and risers. It's entirely legitimate to expect these things to come out in the same way that they came in – with a little bit of thought," he says.

In the new order of design for disassembly, connections and fasteners take on a new importance. "Don't mix things up if possible," advises Trott. "And where they do come together, think how they will come apart. Things that don't work so well for dismantling are composites and things that need lots of glue."

A few commodities – such as copper – are already valuable enough to warrant design that allows for easy extraction when a building is refreshed or dismantled. As more resources are depleted, this rule will apply more widely.

"With high value things, the market will lead, providing designers rise to the challenge," says Trott. "It's about recognising which elements people would recover value from, and not sinking that asset forever." That challenge is to design today to meet requirements of the future. Otherwise clients will miss out now.

CHRIS TROTT

PIC: URBAN LAND INSTITUTE

"One of our greatest resources is waste. We have to take the view that waste is a resource to be reused – whether it's a tin can or piece of a building"

Chris Trott is a sustainability engineer and partner at Foster + Partners

BEGINNER'S GUIDE TO LIFECYCLE ASSESSMENT

The best way to judge the environmental credentials of products and materials is to look at the impact they will have from the cradle to the grave

What is lifecycle assessment?
Lifecycle assessment (LCA) is a way of assessing the environmental impacts of all stages in a product's life from extraction of raw material through processing, manufacture, transport, construction, maintenance and disposal or recycling.

Where did it come from?
Some say Coca Cola was the first company to do LCAs in 1969, but it wasn't until the mid-eighties and early-nineties that it really took off. The Society of Environmental Toxicology and Chemistry (SETAC) coined the phrase "lifecycle assessment" in 1990 and in 1997/1998, ISO produced a series of standards which were updated in 2006.

What environmental impacts do LCAs consider?
These can include global warming, ozone depletion, acidification, eutrophication, smog, heavy metals, carcinogenic substances, waste, respiratory effects, ionising radiation, ecotoxic substances, land use and raw materials.

How do you do one?
This is what ISO 14040 says you need to do when carrying out a LCA study:
1. Define the goal and scope – understanding the aims of the study and setting boundaries.
2. Carry out a lifecycle inventory (LCI) analysis – mapping flows of water, energy and raw materials from nature and the releases to nature.
3. Do a lifecycle impact assessment – look at the materials and emissions in the LCI, decide how you will look at environmental impacts (eg all ozone depleting gases) and work out how much each set of emissions contributes to each of the impacts. There are many methods for assessment.
4. Interpret the results – within the scope of the study and the methodology used. This stage should also identify areas for improvement.

Is it all about carbon?
As carbon dioxide is emitted by fossil fuelled power stations to generate energy for the grid, carbon has become the currency of energy efficiency. CO_2 is accepted as a major cause of global warming, but it is not the only greenhouse gas. Timber, which many people consider truly sustainable since it takes in CO_2 while growing, decays to form methane, which is 21 times more potent than CO_2 as a greenhouse gas, according to Defra/DECC. Decay is one of the possibilities for timber at the end of its life and a full lifecycle analysis should consider to what extent that is likely to happen.

"CRADLE-TO-GRAVE LCA HELPS TARGET THE PHASES WHERE MOST IMPROVEMENT COULD BE MADE"

What's the difference between cradle-to-grave and cradle-to-gate LCAs?
Cradle-to-grave assessments cover the whole lifecycle from extraction to disposal and end of life.

Cradle-to-gate assessments are a partial LCA, which stops at the factory gate, ie before the finished product has been transported anywhere.

What are the benefits of using cradle-to-grave LCAs?
Cradle-to-grave LCAs provide a comprehensive analysis of the resources used and the substances emitted through a product's whole lifecycle. This allows decisions to be based on a true assessment of a product's impact, and also means that manufacturers or users of a product can target the phases in a product's lifecycle where the most significant improvements could be made.

Cradle-to-gate LCAs only provide a partial picture. Decisions made based on these alone ignore impacts during transport, construction, maintenance, disposal and recycling and could mean materials or products with a worse overall impact on the environment are selected.

Cradle-to-gate calculations can even lead to nonsensical results. For example, materials that are responsible for taking in carbon – or sequestration – are given a negative emissions value. So in theory, the more of that material you use, the more environmentally friendly the building becomes.

Why are cradle-to-gate LCAs more common than cradle-to-grave LCAs?
The simple answer is that it is easier to consider impacts only as far as the factory gates. Many manufacturers provide cradle-to-gate LCA information and databases such as Bath University's Inventory of Carbon and Energy (ICE) (see box, above right) contain data to the gate only.❏

CRAIG JONES

"Cradle-to-gate figures give you an idea of what it takes to make a product. It very much depends on what happens to that product as to what its cradle-to-grave impact will be."

Dr Craig Jones is one of the authors of the Inventory of Carbon and Energy (ICE), which he developed with Professor Geoffrey Hammond while at Bath University. He is now a senior associate at carbon reduction consultancy Sustain.

Jones started working on the ICE at the end of 2004, and within about nine months the first version of the database was ready. His university homepage made reference to the database and soon he started to receive a few emails.

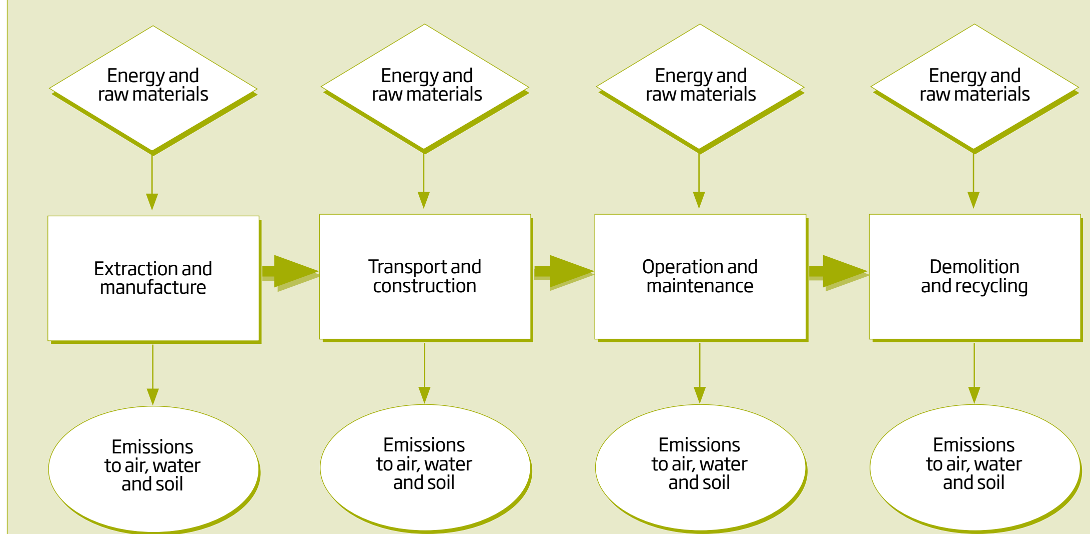
The steady stream of emails grew and now there is an automated distribution system. To date 12,000 people have downloaded the ICE. "It still surprises Professor Hammond and myself how widely it has been picked up," says Jones.

The challenges in building the database were the variability of results and the different methods used by different sectors to calculate embodied carbon and energy, although the available data has improved over the years, he says. "The new EU assessment method which is coming out soon will help with compatibility," comments Jones.

When he first started developing the database, Jones attempted a cradle-to-site version but it soon became apparent that this didn't work because it was difficult to make assumptions which could apply to all cases. "Cradle-to-gate figures give you an idea of what it takes to make a product," he says. "It very much depends on what happens to that product as to what its cradle-to-grave impact will be.

"There is a risk people will take the ICE data as is when new to the subject, but as they work more in this area, they understand that full lifecycle assessment is not just cradle-to-gate but cradle-to-grave."

WHAT'S CONSIDERED IN AN LCA?



CLEAR FOOTPRINTS

Only considering embodied impacts as far as end of construction can seriously distort the answers, as the Target Zero study shows

The Target Zero school study building was based on the Christ the King Centre for Learning, Knowsley, Merseyside

It's a question that some people don't want you to ask: why can you get such different answers if you look at embodied carbon over the whole life of a building, rather than just up to the point where the materials in that building leave the factory?

For the answer, we can turn to Target Zero: a detailed study into the carbon footprints of five building types – schools, offices, supermarkets, warehouses and mixed use. Sponsored by the BCSA and Tata Steel, the study looked into the operational carbon of five actual buildings, considering how they could be adapted to reach zero carbon in operation. It also worked out the embodied carbon for each building – carbon emitted in the manufacture, transport, construction, and end-of-life phases – and considered the impact of changing frame materials.

The aim of the research, led by lifecycle assessment (LCA) expert Nick Avery, principal researcher in Tata Steel's environment group, was to develop a better understanding of how the different elements and life phases of a building contribute to its carbon footprint. While the main study looked at operational carbon, Avery's remit was to consider the beginning and end of the story.

"Informed decision-making should really consider the full lifecycle," says Avery, who sits on technical committee CEN/TC350 which is developing European standards for LCAs in construction. "We should also find out what's going to happen at end of life, when a building is demolished or dismantled, because trying to live sustainably means trying to save resources for future generations. It's about being forward-looking and not just considering what's happening now."

The Target Zero study took five actual buildings and used an LCA model to calculate the whole life or cradle-to-grave embodied carbon of the main structure, looking at phases from materials extraction through to demolition and recycling. Engineers at Aecom then redesigned the buildings to consider the same structures with concrete, steel and where appropriate, timber frames, to compare the embodied carbon results.

Using bills of quantities produced by Cyril Sweett, Avery and his team then fed the information into an LCA model developed in-house by Tata Steel: CLEAR (Construction Life-Cycle Environmental Assessment Resource). The buildings were split down into different elements: foundations, bearing structure, roof and so on. "You need to break it down to give meaningful results," says Avery. "If you grouped them all together, you would not know where the most significant impacts were."

Best practice for LCA is to use current data for information such as wastage and recycling rates says Avery. "If you don't use current data, you are really opening a can of worms: you can justify anything based on a future scenario. You have to take current manufacturing impacts and current end of life performance now and say: 'This is what the current snapshot looks like'."

Sourcing some of the data needed for the model took time. "We did quite a lot of work to try and define wastage rates on the construction site," says Avery. "We then had to factor in additional material required to cover the wastage." Wherever possible they used published data, much of it from WRAP.

The CLEAR model, which has been independently reviewed by Arup to ISO 14040 and 14044, takes into account recycling at end of life, which some tools don't. The fact that 99% of scrap steel is melted down and used again, gives a significant benefit to the environment: the demolished building is effectively producing steel, which will take less energy to re-melt than an equivalent tonnage of virgin material, argues Avery. Similarly, where concrete is crushed and used for aggregate, some benefits should be taken into account.

"We are trying to account for the value of that material, trying to define what that value is," says Avery. "Using a limited cradle-to-gate LCA analysis, the benefit of recycling is ignored and therefore considered no better than sending waste to landfill."

"IGNORING END OF LIFE, YOU'RE SAYING RECYCLING AND REUSE IS NO BETTER THAN LANDFILLING"

WHAT IS TARGET ZERO?

Target Zero is a free resource for clients and designers to help with the early stages of decision-making. It considers five different building types – schools, offices, warehouses, supermarkets and mixed use – and spells out the most cost-effective routes towards achieving zero carbon in operation, considering low and zero carbon technology.

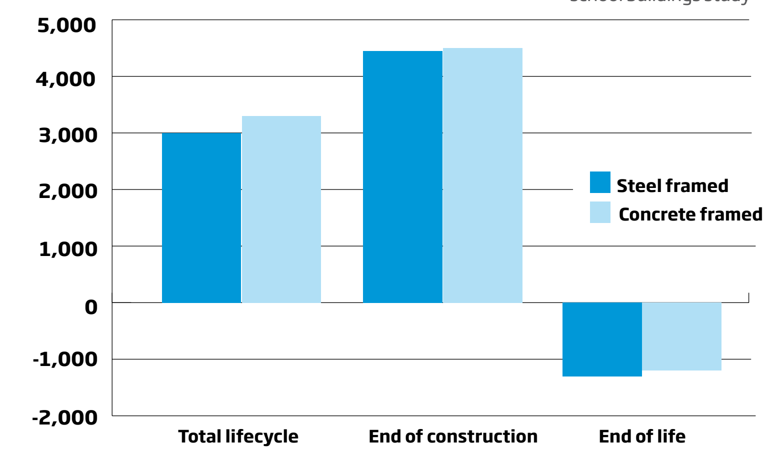
The study also looks at the most cost-effective routes to achieving the highest BREEAM ratings and considers the impact of different framing materials on the carbon footprint of a building, looking at the whole lifecycle from material extraction right through to demolition and recycling.

Go to: **www.targetzero.info**

TARGET ZERO

Emissions by lifecycle phase (tCO₂e), showing how end-of-life impacts change the answers

Source: Target Zero school buildings study



The most surprising finding for Avery was the large proportion of embodied carbon tied up in the buildings' foundations and floor slabs. "If you want to reduce the carbon footprint of your building, you should focus on your foundation and floor slabs," says Avery. "It's really down to the amount of concrete used. Reducing that somehow would yield great improvements."

What the findings also clearly highlight is that using cradle-to-gate LCAs, where only the embodied carbon tied up in the materials by the end of manufacture is counted, can lead to very different answers. Look at the school study building (see graph, above). At the end of construction the concrete and steel options look comparable, but taking into account end of life considerations the steel frame is clearly ahead.

Timber, too, can tell a very different story when its full lifecycle is considered, says Avery. Some people consider only the first part of timber's lifecycle and so think of it as carbon negative because it absorbs carbon as it is growing – but this carbon will eventually be returned to the atmosphere by burning or rotting.

Another complication is that currently up to 80% of timber goes to landfill in the UK and produces methane, some of which will be captured and some of which won't. "It's a complicated area and there's no agreed method of dealing with it," says Avery. "The conclusion we came to on Target Zero is that timber emissions are highly uncertain."

These are all issues which must be addressed. Unless we really don't care about what happens beyond the next 20 years, our choice of materials should be informed by the impacts or benefits when a building is dismantled or demolished. One of the best ways to counter the effects of global population growth and resource consumption is to maximise the reuse and recycling of materials with minimal loss in function, says Avery. "You really should be taking into account what happens to the material at end of life, whether it's beneficial to the planet or not," says Avery. "If you ignore it, what you are saying is it does not really matter to the planet whether it will be re-used, recycled or landfilled."

See page 23 for cradle-to-grave embodied carbon figures for the materials considered in the Target Zero study.

CASE STUDY: **EMBODIED CARBON**

Steps towards sustainability

Brighton and Hove council now requires embodied carbon data for all new build housing applications. Sustainability officer Francesca Iliffe tells us why

From July this year, any planning applications for new build housing in Brighton and Hove must provide embodied carbon information as part of the application process. While other councils' local planning policies say that embodied impacts should be considered, Brighton and Hove is the first to make such a calculation a mandatory part of the planning process

"This is really important for us," says sustainability officer Francesca Iliffe. "As part of our duty to deliver sustainable development, we understand that some of the biggest impacts are around carbon emissions. All of the focus is on Part L, which seeks to reduce in-use carbon emissions, but a significant proportion of emissions come from embodied carbon in materials."

Brighton and Hove council worked with local enviromental consultant Phlorum to produce a simple tool that estimates the embodied carbon of the materials and products being used, up to the end of the manufacturing phase, using a few basic pieces of information about the house. The tool is free to use and has been designed to take no more than 10 minutes to fill out.

"We worked with Phlorum to really simplify this. We did not want it to be onerous," says Iliffe. "To do a full lifecycle assessment for the building and get really accurate data would more than likely involve using consultants. This tool is based on accurate data, but provides an estimate."

At the moment, Brighton and Hove's only requirement is for applicants to submit their partial embodied carbon figures: there are no targets set and no suggestion yet that planning decisions will be based on the results.

Although the tool considers only cradle-to-gate carbon, Iliife hopes that introducing it will be a step towards considering whole-life impacts: "It is certainly our aspiration at Brighton and Hove that there be a cradle-to-grave approach and that these issues be considered as early as possible by local architects and developers. Our intention with the tool is to signal that the council sees embedded carbon as a significant impact of development and to initiate a basic measurement of what comes through the planning system.

"We are aware that there will be inaccuracies but this tool will provide more information than we have ever had before and is a first attempt at quantifying carbon impacts in a way we have not tried before."

AN ARCHITECT'S VIEW

Mark Pellant is a partner in Hove practice Koru Architects. He has experience of building houses with low embodied carbon. His house and studio at Lloyds Road in Hove (pictured) was completed last year and has about half the embodied carbon of a traditional brick and block house.

Pellant is supportive of Brighton and Hove's move to record the embodied energy of new build housing at planning stage, but questions whether it will have any impact on the materials architects choose.

"You have to have the will and desire to reduce the embodied energy or the environmental impact or to improve the environment for the occupants," he says. "The checklist is a good idea, but how do you encourage the use of these materials? Inevitably people will go for the cheapest option."

Clients are not asking for low embodied carbon materials, says Pellant. But some are looking for natural materials for health reasons, to avoid offgassing, and these tend to be low in embodied carbon, he says.

Francesca Iliffe

Mark Pellant's house and studio in Hove has about half the embodied carbon of a traditional brick and block house

Initially, the council will be using the information to build up a database. Its online sustainability checklist, which was introduced in electronic form in 2008, allows the council to store a wide range of relevant information, and its latest version also includes a free tool for estimating operational carbon, which will allow for comparisons between cradle-to-gate embodied and in-use emissions.

The 2011 checklist contains 15 headings under which applicants must submit information, although not all are mandatory for every development. They range from CO_2 to water, food growing to parking, with the embodied carbon calculation coming under a heading of materials.

"We can get really fantastic data about the sustainability of development as it comes through the planning process," Iliffe says. "All planning authorities have a duty to deliver sustainable development. But if you aren't measuring it, how do you know if you are delivering it?"

Brighton and Hove council has always been ambitious about its sustainable development goals. Its adopted local plan policy says: "Planning permissions will be granted for proposals which demonstrate a high standard of efficiency in the use of energy, water and materials".

In 2008 it introduced a supplementary planning document on sustainable building design, which called for zero carbon emissions in use, a standard that was revoked as a "recession busting measure".

As well as helping to inform some of the council's future decisions about sustainability, Iliffe hopes that the tool will help educate local architects, planning agents and consultants about embodied carbon. "Architects and planning agents can try different options then see what will reduce their embodied carbon footprint."

The requirement to calculate embodied energy is limited to new build residential – conversions and commercial buildings would require a more complex tool – so Brighton and Hove's picture will be incomplete.

The other limitation is that the tool measures only the carbon emitted to make a product, not that produced during transportation, installation, maintenance or dismantling. "We looked at cradle-to-grave but that was an extra level of complexity," says Iliffe, who adds that Phlorum's tool, from which Brighton's version was developed, does have this ability.

To date there have been 16 planning applications that have included the embodied carbon data, but many more people have been online to try the tool out.

It is too early to say what impact – if any – the embodied carbon measurement tool will have. Outside interest so far has come from academic institutions, rather than other local authorities.

Will other local authorities follow suit? Perhaps not imminently. But embodied impacts are moving up the local government agenda and when more mainstream political policy does turn to embodied carbon, Brighton and Hove will be ahead of the game. ■

INTERVIEW

'We're on the cusp of a major change'

The steel sector is committed to helping the construction industry assess the environmental performance of materials in an accurate and meaningful way. Alan Todd, director of market development at the British Constructional Steelwork Association (BCSA), explains why

Over the past decade, the drive to reduce the environmental impact of construction has resulted in some of the most exciting innovations and dramatic changes that our industry has ever seen. And as all parts of the industry's supply chains work increasingly to targets and requirements set by construction clients and by the government, the means of measuring and assessing environmental performance is developing and improving too.

There is little doubt that lifecycle assessment (LCA) is the most sophisticated, useful environmental measurement approach developed to date. LCA is not a new concept for construction, but it is becoming increasingly refined to make the results as useful and accurate as possible. Standards that are being developed, such as CEN/TC350 in the UK and Europe, show the importance of carrying out an LCA assessment correctly.

By studying the environmental aspects and potential impacts from raw material extraction to manufacture, use and disposal, a whole LCA provides data for each point in a material's life. It is the most complete way to assess environmental impact, and enables true comparisons to be made between the environmental impacts of materials and building approaches.

However there are currently some areas of confusion and uncertainty associated with the whole LCA approach: the term "LCA" is applied at times to cradle-to-gate assessments, which do not include data for a material in use or at the end of life. Assessments that are limited to just some of the elements of a material's lifecycle can only give part of the picture, and pose a risk that important sustainability decisions may be made with the best intentions but without the longer term environmental impacts – which can be both positive and negative – being taken into account.

Both cradle-to-gate and whole-life cradle-to-grave assessments rely on a number of assumptions in their underlying methodology. However, as the cradle-to-grave approach is, by definition, founded on the correct principle of considering the full lifecycle, it should surely be treated as a more accurate assessment than any approach that excludes key parts of a material's lifecycle.

Whole LCA are beginning to feature more and more in the media as well as in the requirements of clients and project teams at the leading edge of our industry – it is the way that the sustainability of our built environment will be measured in the future. But before we reach the point where it is our standard system of evaluation, there are some obstacles that we will need to work on together to overcome.

> "ASSESSMENTS LIMITED TO JUST SOME PARTS OF A MATERIAL'S LIFECYCLE CAN ONLY GIVE PART OF THE PICTURE"

Primarily, the information about what happens to major construction materials at the end of their useful life must be made more widely available. Without this, the journey to proper whole lifecycle cradle-to-grave assessments becoming the standard across the industry will be very challenging.

The limited information that is needed for a cradle-to-gate assessment is more readily available, so this type of assessment is currently easier to carry out. There is a danger that this approach will be accepted by some practitioners as "good enough". Should this become an attitude that prevails, the construction industry's considerable efforts to reduce its environmental impact will be less effective.

The question for organisations and individuals who truly believe in the sustainability agenda, is what can we do to facilitate the process of change? The BCSA and Tata Steel are committed to making data available that will facilitate cradle-to-grave assessments of steel solutions but practitioners must have access to comparable data for all the major construction materials. This supplement provides cradle-to-grave emission figures for steel and other materials, along with the assumptions that we believe are reasonable for their end-of-life treatment.

We'd welcome views and input from other organisations – please contact John Dowling (BCSA sustainability manager) at cradletograve@steelconstruction.org if you are interested in getting involved and playing your part in construction's journey towards cradle-to-grave whole lifecycle assessment. We're on the cusp of a major change and this is an opportunity to help shape that change. ■

Cradle-to-grave embodied carbon of materials

Below is a table showing the full lifecycle (cradle-to-grave) embodied carbon of some common construction materials. These values were generated for the Target Zero low-carbon building study (see pages 18-19) using recognised information sources. They are presented as an appendix within the Target Zero guidance documents. See www.targetzero.info

MATERIAL	DATA SOURCE	END OF LIFE ASSUMPTION	SOURCE	TOTAL LIFECYCLE CO_2 EMISSIONS (tCO_{2e}/t)
Fabricated steel sections	Worldsteel (2002)	99% closed loop recycling, 1% landfill	MFA of the UK steel construction sector [1]	1.009
Steel purlins	Worldsteel (2002)	99% closed loop recycling, 1% landfill	MFA of the UK steel construction sector [1]	1.317
Organic coated steel	Worldsteel (2002)	94% closed loop recycling, 6% landfill	MFA of the UK steel construction sector 1	1.693
Steel reinforcement	Worldsteel (2002)	92% recycling, 8% landfill	MFA of the UK steel construction sector [1]	0.820
Concrete (C25)	GaBi LCI database 2006 -PE International	77% open loop recycling, 23% landfill	Department for Communities and Local Government[2]	0.132
Concrete (C30/37)	GaBi LCI database 2006 -PE International	77% open loop recycling, 23% landfill	Department for Communities and Local Government[2]	0.139
Concrete (C40)	GaBi LCI database 2006 -PE International	77% open loop recycling, 23% landfill	Department for Communities and Local Government[2]	0.153
Glulam	GaBi LCI database 2006 -PE International	16% recycling, 4% incineration, 80% landfill	TRADA[3]	1.1
Plywood[5]	GaBi LCI database 2006 -PE International	16% recycling, 4 % incineration, 80% landfill	TRADA[3]	1.05
Plasterboard	GaBi LCI database 2006 -PE International	20% recycling, 80% landfill	WRAP[4]	0.145
Aggregate	GaBi LCI database 2006 -PE International	50% recycling, 50% landfill	Department for Communities and Local Government[2(a)]	0.005
Tarmac	GaBi LCI database 2006 -PE International	77% recycling, 23% landfill	Department for Communities and Local Government[2]	0.020

1 Material flow analysis of the UK steel construction sector, J. Ley, 2001
2 Survey of Arisings and Use of Alternatives to Primary Aggregates in England, 2005 Construction, Demolition and Excavation Waste, www.communities.gov.uk/publications/planningandbuilding/surveyconstruction2005
[a] Adjusted for material left in ground at end of life.
3 TRADA Technology wood information sheet 2/3 Sheet 59 'Recovering and minimising wood waste', revised June 2008.
4 WRAP Net Waste Tool Reference Guide v 1.0, 2008 (good practice rates).
5 Data excludes CO_2 uptake or CO_2 emissions from biomass.

"The future is not completely beyond our control. It is the work of our own hands."

Robert F Kennedy (1925-1968)

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