

a guide to understanding
**the embodied impacts
of construction products**

construction products association 



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EXECUTIVE SUMMARY

- Purpose of the Guide.** The purpose of this guide is to improve understanding across the construction industry of the embodied impacts of construction products. The quest for a more sustainable and more recently a low carbon built environment, has meant that the demand for information on the impact of construction products has increased dramatically. Much attention is being given to new ways of designing and constructing buildings and whilst the focus has been on energy efficiency and capturing renewable energy, there is a growing awareness that the embodied impacts of construction products and especially embodied carbon will become increasingly important.
- What the Guide explains.** Within the construction product sector, the measurement of environmental impact is not a new activity. The guide explains how the environmental impacts of construction products are measured; what processes and schemes are already established; what information is generated; how this is used and assessed at the building level and what effect European Regulations and emerging European Standards will have.
- Construction products** are made of a variety of materials, which are manufactured into a myriad of products that combined together create buildings or infrastructure that make up the very fabric of our society. A construction product is a component of a building and not the building itself. The impact of a construction product must therefore always be considered in the context of the role it performs in a building. For example, insulation makes a building more energy efficient and that function may outweigh many times the environmental impact of its manufacture and disposal.
- Life Cycle Assessment.** All products, not just construction products, have an impact on the environment and this impact can occur at any time during the manufacture, usage or at end of life. All these stages are collectively called a life-cycle. Construction products have impacts from extraction of raw materials, processing and manufacture, maintenance and refurbishment, to eventual end of life and disposal. The measurement of this impact is called Life Cycle Assessment (LCA). There are two types of LCA for construction products: generic assessments that collate data from several manufacturers of the same type of product to create an industry average; and proprietary assessments that use information from a specific manufacturer and the LCA is specific to their product. This guide outlines the procedures that must be undertaken to implement a life cycle assessment in accordance with international standards.
- Environmental impacts.** LCA measures environmental impact across a range of issues such as impact: on air quality; on water usage and water quality; on toxicity to human life and to ecosystem functioning; on impact on global warming; as well as resource use. In the 1970s the main concern in Europe was acid rain, today it is climate change. The importance of these issues can change over time as society's concerns and priorities change. The guide provides a detailed description of the commonly assessed environmental indicators.
- Environmental Product Declarations (EPD).** The construction industry has adopted a particular approach to communicating LCA data known as an Environmental Product Declaration or EPD. This has been developed to provide environmental information from LCA studies in a common format, based on common rules known as Product Category

Rules (PCR). EPD have been used for construction products since the first environmental assessments schemes were developed in the 1990s and an ISO standard for EPD sets out the standards they should meet. EPD can only be compared when the rules of the PCR used are the same and all the relevant life cycle stages have been included. Additionally, products cannot be compared unless their functionality and use are considered at the building level within a system. The guide provides examples of what EPD look like.

- 7 **EPD Schemes across Europe.** Many European countries have developed national LCA schemes producing EPD, these include France, Germany, the Netherlands, the Scandinavian countries and the UK. The best known scheme in the UK is that developed by the Building Research Establishment (BRE) which since the mid-1990s has gathered information from UK manufacturing industry and amassed it into an environmental profiles database. This database is a major component of the BRE's Green Guide to Building Specification which is used in the government's Code for Sustainable Homes and in the BRE's environmental rating system for buildings called BREEAM.
- 8 **The European Single Market and construction products.** With the advent of the European single market for construction products, the European Commission became concerned that national EPD schemes and building level assessment schemes would represent a barrier to trade across Europe. The EU therefore sought a mandate from the EU Member States to develop European standards for the assessment of the sustainability performance of construction works and of construction products. This mandate is called CEN/TC 350. From 2010 European standards began to emerge from this process and Standard BS EN 15804 was published in February 2012 providing core rules for construction product EPD.
- 9 **European Regulations and Standards.** The Construction Products Directive of 1989 was one of the first Directives from the EU Commission to create a common framework for the regulations on buildings and construction products. It has been replaced by the Construction Products Regulation and is legally binding throughout the EU. The CPR includes requirements for the sustainable use of natural resources, the reduction of greenhouse gas emissions over the life cycle and the use of EPD for assessing and reporting the impacts of construction products. If an EU Member State wishes to regulate in these areas of sustainability it must use European standards where they exist when regulating and must withdraw national standards. This means that in the case of the CPR a Member State must use the CEN/TC 350 suite of standards.
- 10 **Assessing the impact of materials and products at the building level.** An EPD provides robust and consistent information that can be used in building level assessments and the guide elaborates on the variety of ways that this can be done. In addition a number of building level tools are emerging aimed at improving decisions at the design stage by combining embodied environmental impact data and whole life cost data (i.e. economic) and link them to BIM (Building Information Modelling) data.
- 11 **The future.** Across Europe, the various environmental rating schemes are seeking to harmonise the ways in which they assess products and buildings. Increasingly models are emerging to link embodied impacts with operational data thus enabling a better understanding of the trade-off between operational and embodied impacts and in time benchmarks for different types of buildings will emerge. All of which contributes greatly to the goal of a low carbon, more resource efficient, sustainable built environment.

The Purpose of the Guide



Lion House, built for Defra by Kier; achieved a BREEAM outstanding in use rating, the first office building in the world to do so, and was also the first in the UK to receive an EPC A+ rating

The purpose of this guide is to improve understanding across the construction industry of the embodied impacts of construction products.

The quest for a more sustainable built environment and more recently for a low carbon built environment has turned the spotlight to embodied impacts of construction products, especially embodied carbon and increasingly embodied water.

This Guide explains how to assess the environmental impact of construction products. All products, not just construction products, impact on the environment and there is increasing demand from consumers and society to know what that impact is, enabling the consumer to make informed decisions about the products they purchase. Organic food products have been labelled since the mid-1940s, fair trade products have become familiar in the coffee, chocolate and fruit markets, timber products such as garden furniture may be certified as coming from sustainably managed forests, and even fish may now be labelled as caught sustainably. More recently, major retail stores, especially the supermarkets, have begun to look at their carbon food miles and the carbon footprint of their products.

In parallel to this proliferation of consumer labels, has been the rise in Corporate Social Responsibility (CSR) reporting, with 97% of FTSE 100 companies now reporting on their CSR activities. A key element of the CSR is the carbon footprint of a companies' activities because of the major concern over the impact of climate change on human society and the natural world. Methodologies have begun to emerge to measure a carbon footprint in a standardised way; some relate to a company or organisational footprint, others to installations and others to a product. Examples include the Greenhouse Gas Protocol, the Global Reporting Initiative, or in the UK, the BSI PAS 2050 on product carbon footprinting.

The construction industry is buzzing with new thinking on how to build low carbon homes, offices, schools, hospitals and infrastructure and how to decrease the carbon impact of our existing buildings. In the UK, almost half of total carbon emissions come from day to day use of the built environment, primarily through water and space heating and numerous efforts and initiatives are therefore in progress to improve energy efficiency, capture renewable energy and use construction products with low embodied impact.

Not surprisingly the construction products sector is being asked to step up to the challenge and questions are now being asked of manufacturers about the carbon footprint of their products or the embodied water and of builders merchants for lists of sustainable products. A litany of different terms, standards – both formal and informal, methodologies, and protocols are emerging within construction, often borrowed or adopted from other sectors.

What is surprising to many though is that within the construction products sector the measurement of the impacts of construction products on the environment, including the embodied carbon and embodied water has been around for several decades, is relatively mature and much information is already available. This Guide therefore seeks to improve the knowledge and understanding of what it means to measure the environmental impact of a construction product, how it is done, what it tells us, where the data can be found, how the information can be used in the design and construction of buildings and infrastructure and what policy and regulatory initiatives will be required to use this information.

A brief history of studies examining the impact of the manufacture of a product

The first study to examine the impact of manufacturing a product was for Coca-Cola in 1969; this looked at the resources required and environmental load of different beverage containers. Since then embodied impact studies have evolved from a focus on reducing manufacturing waste and packaging, through to an examination of energy requirements especially after the 1970s Oil Crisis, on to a recognition of a broad range of impacts throughout the life of a product from its manufacture through use to disposal. This life-cycle approach has resulted in the development of Life Cycle Assessment methodologies and subsequently the development of International Standards to provide consistency in evaluation.

More recently, attention has returned to a focus on a single issue parameter rather than the broad range of impacts. This single issue is climate change and a great deal of attention has focused on measuring impact using carbon emissions or carbon footprinting.

Embodied Impact Studies - Timeline	
Year	Event
1969	First study for Coca Cola in US
1973	First Oil Crisis - OPEC oil embargo
1975	LCA type studies shift to concentrate on energy
1988	WMP and UNEP established International Panel on Climate Change
1990	First BREEAM Schemes launched
1992	Rio Summit: Framework Convention on Climate Change
1996	"Our Ecological Footprint" published
1997	Kyoto Protocol
1997	ISO 14040: LCA: Principles and Framework
1998	Green Guide to Specification 2nd Edition published and linked credits in BREEAM
1998	ISO 14041: LCA: Goal and Scope
1999	BRE Environmental Profiles Methodology and Generic Environmental Profiles published
1999	Envest Building LCA tool launched
2000	ISO 14042: LCA: Impact Assessment
2000	ISO 14043: LCA: Interpretation
2001	ISO 14020: Labels General Principles
2004	CEN/TC 350 Standardisation Mandate issued
2004	NEN 8006: Dutch PCR for construction products
2004	NF P-01-010: French PCR for construction products
2006	ISO 14025: Labels: Type 3 EPDs
2006	ISO 14040: LCA Principles and Framework updated
2006	ISO 14044: LCA: Requirements and Guidelines updated
2006	IBU PCR for construction products in Germany
2007	ISO 21930: EPDs for Construction Products
2007	UKGBC launched
2008	PAS 2050: Assessment of Greenhouse Gas emissions of goods and services
2009	LCADesign LCA tool launched in Australia
2010	CEN TR 15941: Generic Data
2010	EN 15643-1: General Framework
2010	BPIC PCR Methodology launched in Australia
2010	RICS Ska tool for Fit Out launched
2011	EN 15643-2: Environmental Framework
2011	EN 15878: Building level Calculation methods
2011	EN 15942: EPD B2B Communication Formats
2011	Construction Products Regulations
2011	PAS 2050 updated
2012	EN 15643-3: Social Framework
2012	EN 15643-4: Economic Framework
2012	EN 15804 Core Rules for the Product Category Construction products

Key environmental events

European and International Standards

Construction product focus

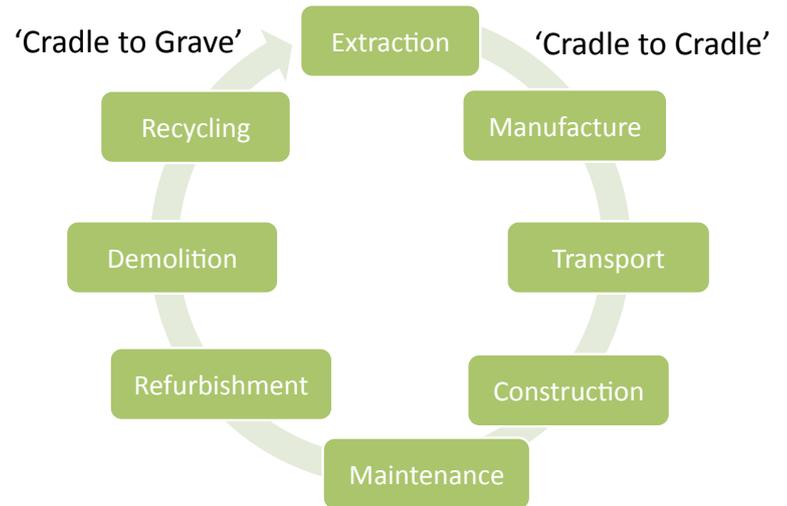
Building level focus



How does a product impact on the environment?

All products, not just construction products, have an impact on the environment. This impact can occur at any time during the manufacture, use of the product or at end of life. All these different stages are called collectively a life-cycle.

Construction products can have an environmental impact from the extraction of raw materials through processing and manufacture, maintenance and refurbishment through to eventual end of life and disposal.



Life Cycle of a construction product



How is the environmental impact of a product measured?

The measurement of the environmental impact of a product at all stages of the life cycle is called Life Cycle Assessment or LCA. LCA is thus the methodology that measures the environmental impact of a construction product, component or building.

What is Life Cycle Assessment (LCA)?

Life Cycle Assessment (LCA) is a methodology used to measure the environmental impact of a product (or a system) over a life cycle. It measures the environmental impacts from extraction of raw materials, through processing, manufacture, refurbishment to eventual end of life and disposal.



Which environmental impacts are commonly measured in an LCA?

Life Cycle Assessment is intended to report on all significant environmental impacts associated with a product or process. It therefore measures impact across a broad range of environmental issues such as impact on air quality, on water usage and water quality, on toxicity to human life and to ecosystem functioning, on impact on global warming and resource use. These issues can change and their importance increase or decrease over time as society's concerns and priorities change.

In the 1960s/1970s, the biggest environmental concern in Europe was acid rain caused by the sulphur emissions from power stations; this was followed in the 1980s by concerns over CFCs from aerosols and other sources which were associated with depletion of the protective ozone layer in the upper atmosphere. Today, in the early 21st century, the concern is about climate change believed to be caused by increasing carbon emissions caused by human activity.

The environmental impacts most commonly considered in a Life Cycle Assessment of a construction product are listed below and are examined in greater detail in a later section.

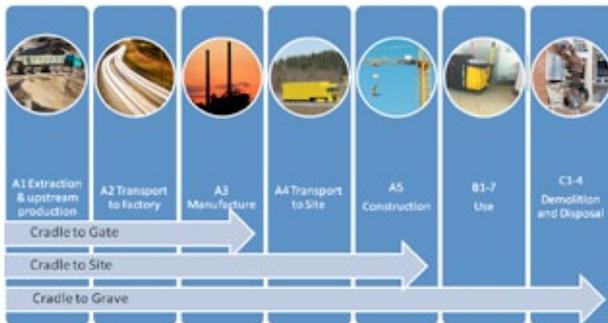
- Climate Change
- Acidification
- Eutrophication
- Stratospheric Ozone Depletion
- Photochemical Ozone Creation

Other indicators commonly provided in a LCA include:

- Renewable and Non-renewable Primary Energy
- Water consumption
- Waste for disposal
- Toxicity to ecosystems and humans
- Resource Depletion (covering variously minerals, scarce chemical elements)
- Radioactivity

The European Commission's Joint Research Centre, has a department considering life cycle assessment. The Centre has published guidance on available environmental impact assessment categories and has made recommendations on the most robust approaches for use in LCA studies. <http://lca.jrc.ec.europa.eu/lcaifohub/index.vm>

Which parts of the life cycle of a construction product are assessed in a LCA?



The scope of different LCA studies can vary, but the manufacture of the construction product will always be included (cradle to gate). Some studies will, in addition, consider the transport to, and installation of the product on a construction site, its maintenance, and the impacts of disposal (cradle to grave), but because these can vary widely depending on the location and the way that the product is used, some LCA studies do not include these later stages.

Construction products, because of their use of a wide range of raw materials and the very different forms of processing used to produce final products and the different ways that they are used, can be responsible for many environmental impacts at different stages in the life cycle. For example:

- **Extracting virgin resources:** For materials such as aggregates, raw materials extraction will be one of the principal impacts, but for more highly processed materials the production impacts are likely to dominate.
- **Manufacturing:** The impact of manufacturing can be the major environmental impact especially if large amounts of energy are required as in the production of metals or cement.
- **Packaging:** The impact of packaging is usually small though too little packaging can increase product wastage. The disposal of packaging is often a big part of its impact.
- **Transport:** Transport impacts are generally small in comparison to other life cycle impacts. Even when construction products are moved globally they are normally shipped which has a low environmental impact in comparison to road transport. The exception is for products such as aggregates and timber; which have relatively low manufacturing impacts and therefore higher relative impacts from transport, though they are still small.
- **Waste impacts:** Waste can be generated at several different stages of the life cycle - during the manufacturing process, on construction sites and during maintenance, replacement and demolition. DEFRA estimates the construction industry is responsible for over 40 million tonnes of waste generated each year¹ although the majority of this is reused, recycled or recovered.
- **Site impacts:** The IGT Final Report states that 10-15% of materials sent to a building site end up as waste – the impacts of producing these materials, that are then wasted, is a considerable impact associated with the construction site.
- **Maintenance and refurbishment:** These activities are estimated to be 45% of contractor output² (i.e. annual turnover) so a significant proportion of extraction and manufacturing impacts are likely to occur for materials used during maintenance and refurbishment projects.
- **Demolition and disposal:** Some products are unable to be reused or recycled and therefore end up as waste in landfill. Emphasis is now beginning to turn to consider end of life issues at the very start of the manufacture of a product so that it can be deconstructed and reused or recycled easily at end of life.

1 DEFRA and the Strategic Forum for Construction (2012). Quantities of CD&E waste arising and to landfill. (In preparation)

2 Strategic Forum for Construction & Carbon Trust, Construction carbon 15% target by 2012 Baseline carbon assessment for 2008

What are the key features of a LCA study?

An LCA study has a number of key features associated with it that must be included if the study is to be regarded as robust.

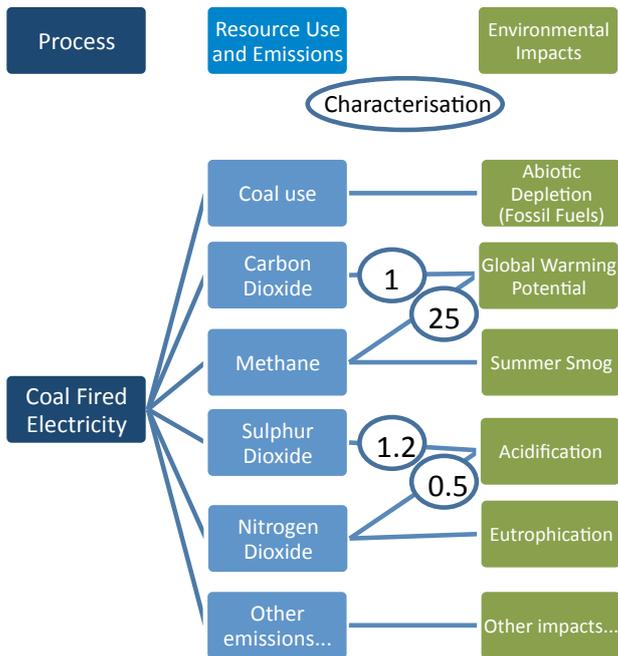
- **Goal and Scope:** These must be considered and described for any study and are an explanation of the context of the study, its boundaries and methodology and how and to whom the results are to be communicated. The following will also be covered by the Scope of the study:
 - **Transparency:** Information must be provided on the sources of data, what assumptions have been made during the study and what rules or methodology has been used.
 - **Environmental Indicators:** The range of environmental indicators assessed must be listed and justified.
 - **Life Cycle Phases:** Studies should look beyond the factory gate, to include the transport and installation of the product, its use and maintenance, and disposal at the end of life. Should there be significant differences in gate to grave processes for different products, these life cycle phases must be evaluated when product comparisons are made.
- **Impact Measurement:** Impacts must be measured for both upstream and downstream impacts. This means assessing the impacts of the inputs and energy required for the process (upstream), as well as those resulting from disposal of any wastes (downstream impacts).
- **Functionality Issues:** Studies can take into account the additional functionality of some processes or products, for example those that produce co-products or which provide more insulation than other products.
- **Comparisons:** Any comparisons between LCAs must be on the basis of common functionality, scope and methodology.
- **Compliance with standards:** All LCA standards which are made public should be critically reviewed to ISO 14044 if they make comparative assertions.

What is the process of producing a Life Cycle Assessment (LCA)?

There are five major steps required to carry out a Life Cycle Assessment. These are described below followed by more in-depth description of various aspects.

- **Goal and Scope:** The first step is to consider the goal and scope of the study and have this reviewed if the study is to be made public. Examples of different studies include product comparisons or supply chain management.
- **Data collection:** The next step is to gather primary data on the manufacture of the product. This will cover the input materials and energy used and the product's waste and emissions produced.
- **Modelling:** The next step in the Life Cycle Assessment is to build a model of the process, and link this to existing LCA data sets for the upstream and downstream processes so that a complete system model is produced. Modelling is normally done using a tool designed for the purpose which includes information for materials, energy and waste.
- **Analysis:** The final stage is analysis using the results of the modelling in the context of the goal and scope of the study.
- **Critical review:** If the study is to make public comparison then a critical review to ISO 14044 must be provided.

What are the stages involved in impact assessment?



1 kg of Carbon Dioxide and 1 kg of Methane do not cause the same amount of climate change. Methane has higher radiative forcing than CO₂ and therefore has a higher climate change impact

Inventory: The first stage is to compile the inventory for the system. This is the list of resources used and the emissions to air, water and land produced from all the processes required to manufacture the product, including the raw materials used and the energy required (upstream processes) and the disposal of wastes (downstream processes). The European Commission's Life Cycle Database has published inventory data for a wide range of materials, including some used in construction and this can be viewed at <http://lca.jrc.ec.europa.eu/lcainfohub/datasetArea.vm>.

Most LCA studies will report on the environmental impact indicators, known as Life Cycle Impact Assessment (LCIA), resulting from the Life Cycle Inventory (LCI) for the system. LCI data – the list of resources and emissions, is sometimes also provided and is the basis of LCA databases. LCI data often includes several hundred separate resource or emission data and is very difficult to use without an LCA tool to evaluate the resulting environmental impacts.

Classification: Once the inventory is compiled, the resources and emissions need to be classified in terms of what impacts they cause. For example, Carbon Dioxide emissions impact on Climate Change; Methane emissions impact on Climate Change as well as on Photochemical Ozone Creation Potential; use of Iron Ore or Fossil Fuel resources causes Abiotic Resource Depletion.

Characterisation: The relative impact of the resource use or emission for each impact category needs to be assessed and can only be done once the inventory has been compiled and classified. For each impact category, standard characterisation factors are normally used. For example, for Climate Change the standard characterisation factors are based on the Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report on Global Warming Potentials over 100 years.

Normalisation: All Life Cycle Assessment schemes will report characterised impacts. Some will also compare the impacts of a product to a common 'norm', such as to the impacts of a European Citizen, to illustrate the relative significance of a product's impacts to European activity as a whole. CML in the Netherlands provides normalisation data for a range of geographic regions and timeframes.

Weighting: In the UK, the BRE's Life Cycle Assessment scheme for construction products takes a further step and carries out an exercise to weight the different normalised impacts, i.e. decide how important impacts are relative to each other. E.g. Is climate change more important than ozone depletion? The weighting exercise enables BRE to aggregate the impacts to produce a 'BRE Ecopoint' score which is used in the BRE Green Guide to compare the overall impacts of different construction systems. Weighting is a subjective method of valuing different indicators and is outside the scope of ISO standards.

Indirect normalisation and/or weighting: Most LCA schemes do not provide normalised or weighted impacts. However such data is used in building level schemes such as DGNB in Germany and BREEAM NL to provide credits relating to the embodied impact of the building. In DGNB, the impacts are compared to reference or benchmark values, another form of Normalisation and the different impact categories have different credits available, a form of weighting. In BREEAM NL, the LCA data is converted to a 'shadow price' based on the marginal financial cost of emissions reduction, allowing the different impacts to be aggregated to a total shadow price; a system used extensively in the Netherlands for evaluating environmental impacts.

What data is created as a result of a Life Cycle Assessment (LCA)?

Two types of products can be evaluated in LCA studies; resulting in two types of LCA known as generic and manufacturer-specific or proprietary LCA:

- Generic LCAs are comprised of data gathered from several manufacturers of the same product; this information is often collected via Trade Associations. The data are compared to each other or to existing datasets as a means of verification. The datasets are combined to create an industry average, i.e. a generic LCA for that product
- Proprietary LCAs are made up of data provided by a company and the LCA is specific to that product

LCA data can be combined to create LCAs not only for building products, but also for building components, systems and whole buildings.

In the UK, the construction products sector has worked with BRE for over 15 years to produce **Generic** Environmental Profiles for most construction products, taking data from a representative sample, or for some products, from all UK producers to produce the LCA. This data is the basis of the BRE Green Guide to Specification, used in BREEAM, and available at www.bre.co.uk/greenguide

Individual manufacturers can also provide data for an LCA to produce a **Proprietary** Certified Environmental Profile and Green Guide rating, which can be seen at www.greenbooklive.com

How is LCA Information communicated?

The report resulting from an LCA study can be used internally by a manufacturer or the information promoted externally. If intended for publication it is usual for the LCA studies to be critically reviewed by an independent verifier to ensure the relevant International Standards (ISO Standards) have been followed and the study meets agreed criteria in terms of quality and approach. This is of particular importance where the information from an LCA study is used to make statements about the relevant performance of one product compared to another; in these instances it is essential that a Critical Review Panel evaluates the study and ensures that the comparison is valid and rigorous.

LCA studies can be published in full, for example, WRAP undertook an LCA of plasterboard and has published the full report³ which is nearly 300 pages. Alternatively manufacturers can draw key information from the critically reviewed report to include in marketing or technical literature, but may need to make the report available if the claims are questioned.

Concerns about the different Goal and Scope and hence methodology used for different LCA studies, the confidentiality of detailed data on manufacturing which has to be included in LCA reports and the size of the reports (which can make them unwieldy for communication) mean that the construction industry has adopted a particular approach to communicating LCA data known as an Environmental Product Declaration (an EPD).

³ http://www.wrap.org.uk/downloads/Life_Cycle_Assessment_of_Plasterboard_df15b0df.5313.pdf

What are Environmental Product Declarations (EPD)?

The singular and plural of EPD, like sheep, is the same. This was decided by the European Working Group developing standards for EPD.

The particular type of LCA, known as an Environmental Product Declaration (EPD), has been developed to provide environmental information from LCA studies in a common format, based on common rules, known as Product Category Rules (PCR). PCR for construction products have been developed in the UK, France, the Netherlands, Scandinavia, Germany and Australia amongst others.

EPD have been used for construction products since the first environmental assessment schemes were developed in the 1990s and an ISO standard for EPD, ISO 14425:2006 sets out standards they should meet.

EPD are published by a Programme Operator such as BRE Global, EPD Norge or IBU using ISO 14025 compliant PCR. EPD from a common programme can therefore be used alongside each other to make comparisons and evaluations at a building level.

European standards are drafted by one of three European Standards Organisations (CEN, CENELEC, ETSI)

The work is based on consensus; Standards are adopted after a public inquiry with the national votes (through BSI in the UK) based on corresponding weighting.

European Standards remain voluntary but their transposition into national standards and the withdrawal of diverging national standards is mandatory according to the internal rules of the European Standards Organisations

For compliant EPD, an independent verifier must be used to critically review the LCA and ensure it has followed the PCR. The verifier will see a full LCA report, known as the Background Report and the EPD, to undertake this task, but only the EPD needs to be published, so the detailed and often confidential data provided in the Background Report need not be publicly disclosed.

Construction product EPD are normally modular; so that an EPD for cement can be used with an EPD for Aggregate to produce an EPD for concrete.

The construction products industry was actively involved in the development of the International Standards for LCA and EPD.



The EPD process from InterfaceFLOR

Are Environmental Product Declarations comparable?

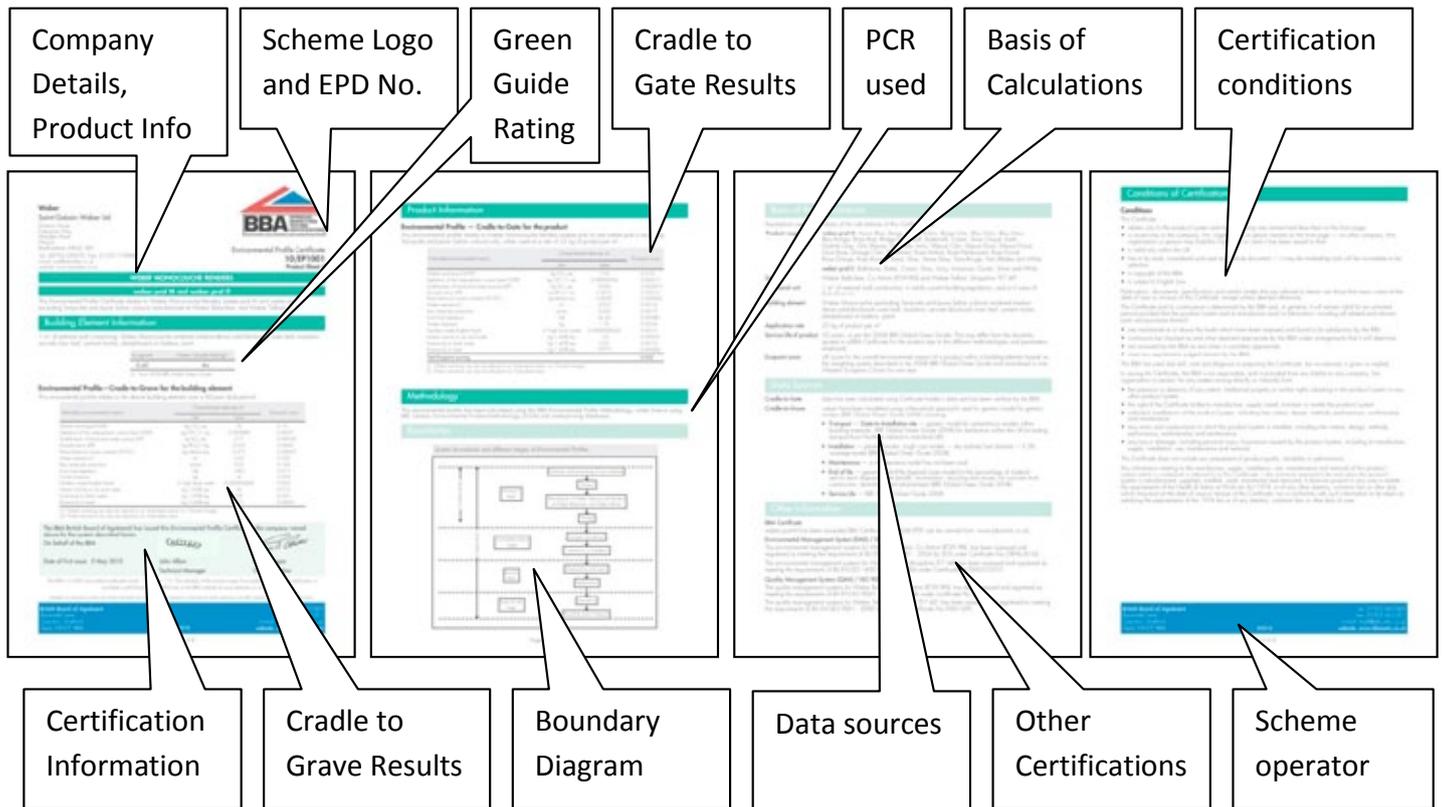
To be comparable, EPD must have the same PCR, to ensure scope, methodology, data quality and indicators are the same. In practice, because of differences in PCR, this means they must come from the same EPD program. All construction EPD Programs should comply with ISO 14040 and ISO 14044 (the International Standards for Life Cycle Assessment) and ISO 14025:2006 (the overarching standard for EPD). However, these standards still leave many aspects of the PCR and format up to the individual EPD Program, resulting in different PCRs. Some of the differences between the different EPD programs can cause considerable variation in results for the same product. This is due to differences in the underlying assumptions, boundaries and scope. At present, a manufacturer selling the same product in several different European regions cannot use a single EPD program; and may have to produce a separate EPD for each region, which can be at considerable expense.

EPD can only be compared when the same PCR have been used and all the relevant life cycle stages have been included. Additionally, products cannot be compared unless their functionality and use is considered. An EPD for 1 m³ of concrete cannot be compared with an EPD for 1 kg of structural steel section. The products must be considered within a system at the building level, providing the same functionality, for example the mass of product needed to fulfil the same structural function. The comparison must also take into account the other materials which might be needed, for example for fire proofing and the foundations to support the differing weight of the solutions and any differences in service life, maintenance and disposal for the two structural systems being compared.

What do EPD look like?

EPD can look very different, however to comply with the relevant ISO standards for EPD, common information is normally provided within the EPD. This essential data is shown by the various items highlighted for the British Board of Agreement (BBA) Environmental Product Declaration shown below.

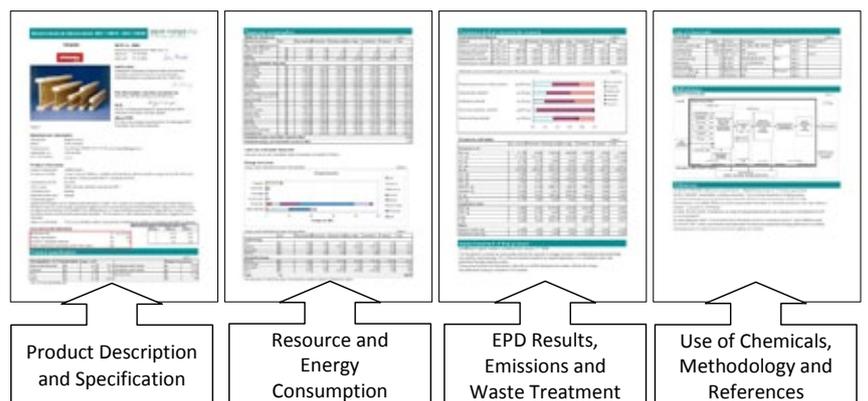
Examples of other format styles of EPD are shown below for the following schemes

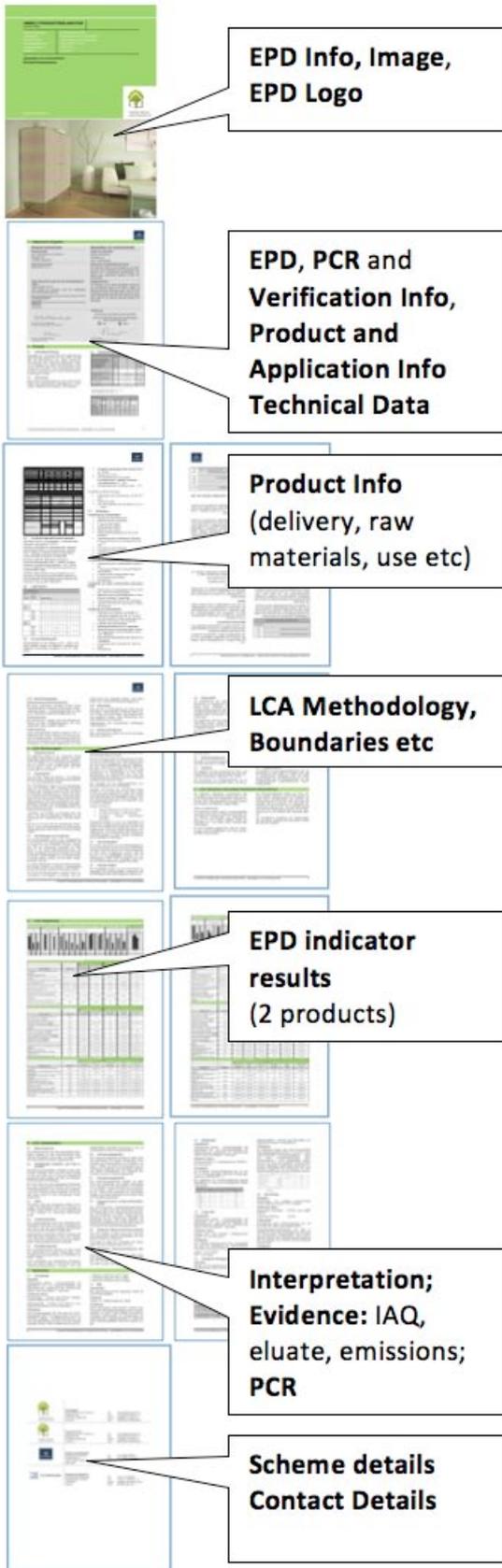


UK - BRE Environmental Profiles (2 pages) www.greenbooklive.com

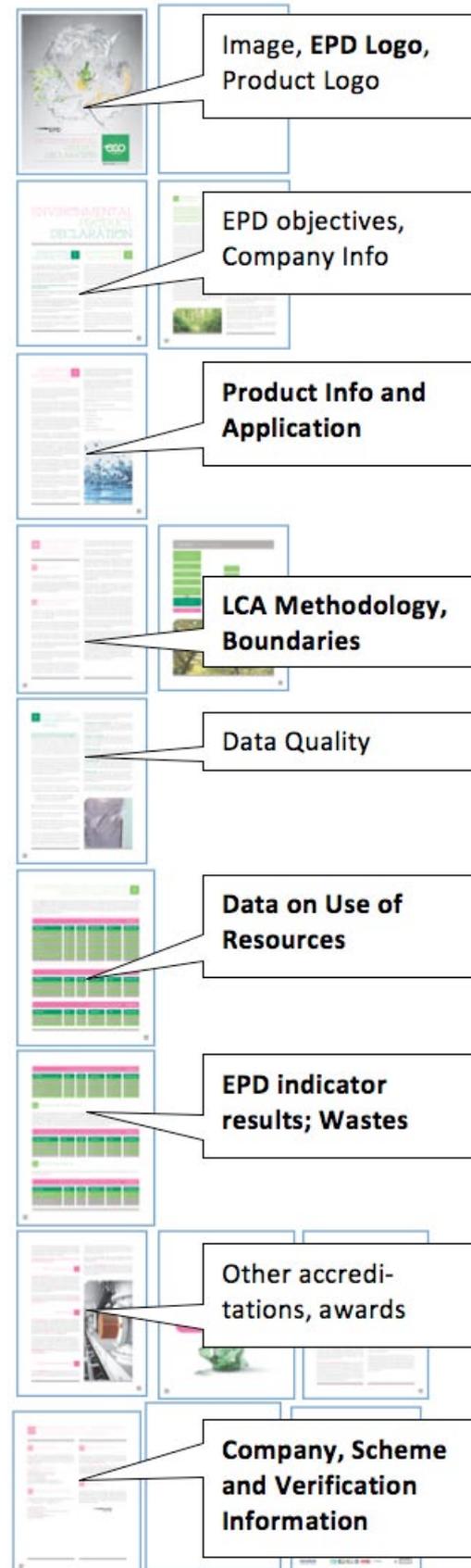


Norway – The Norwegian EPD Foundation (approx 4 pages) http://www.epd-norge.no/?lang=en_GB





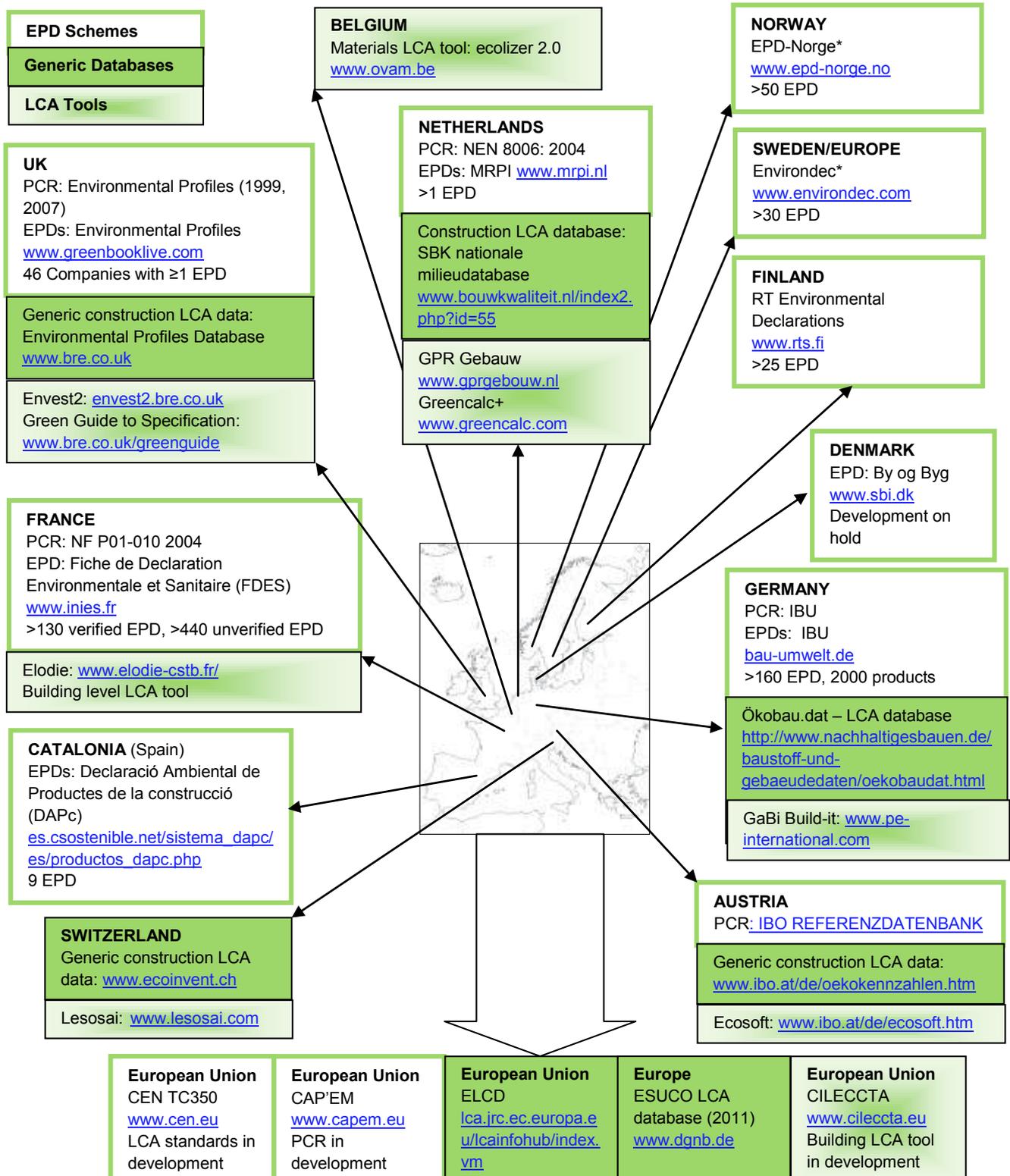
Institut Bauen und Umwelt EPD Scheme – the format for these EPDs is fixed and they always include the information shown in **bold** above.



International EPD® Scheme – the format for these EPDs is relatively fluid but they always include the information shown in **bold** above.

What Environmental Product Declaration Schemes exist for construction products in Europe?

There are a number of national LCA schemes for construction products in Europe and the map below provides links to the various national EPD schemes that exist, the Product Category Rules these schemes use and links to those EPD for construction products that have been published. Also included are the generic databases of LCA or LCI data for construction products and building level LCA tools available across Europe.



EPD numbers correct at October 2010

The table below shows some of the principal differences between the larger EPD schemes in terms of scope and methodology.

	UK	France	Germany	Sweden
Scheme	BRE Environmental Profiles	Fiche de Declaration Environnementale et Sanitaire (FDES)	IBU EPD	International EPD® system (Environdec)
Scope	Cradle to Grave, including 60 year study period	Cradle to Grave, including study period (normally 50 years)	Cradle to Site plus optionally transport use and/or End of Life (EOL) stage	Cradle to Gate plus optionally transport use and/or End of Life (EOL) stage
Declared Unit (DU) or Functional Unit (FU)	FU: product in 1 m ² building element over 60 year study period	DU: Product (e.g. m ² /kg) over study period	DU: Product (e.g. kg/m ²)	DU: Product (e.g. kg/m ²)
End of Life recycling	Allocation from primary to recycled based on primary to scrap value	System boundary at stockpile. No allocation over system boundary	EOL modelled based on impact of disposal and any recycling, plus benefits of recycling	Waste processing / recycling included until waste has a value.
Verification	BRE Global verify LCA. Manufacturer data is audited and certified by BRE/BBA	From 2012, independent third party verification by verifiers certified by AFNOR required	Independent third party verification by verifiers appointed by IBU	Independent third party verification. Manufacturer can select from a list of approved verifiers

Europe as a Single Market for construction products: the European Regulatory Framework for construction products

Construction, buildings and construction products are subject to considerable regulation.



EU Construction Products Directive (CPD)

The Construction Products Directive (CPD) of 1989 was introduced across the Member States of the European Union to create a common framework for the regulations on buildings and construction works. It was one of the early directives from the EU designed to create a single market for goods and services.

The mechanism for implementation adopted by the CPD was to set very high level requirements for works known as the Essential Requirements. It then left it to the European Committee for Standardisation (CEN) to develop standards for every construction product (through product Technical Committees) to support these Essential Requirements. More than 400 standards and 1500 test methods have been developed and adopted.

EU Construction Products Regulation (CPR)

The CPD was replaced in 2011 by the Construction Products Regulation (CPR) which was formally published in the Official Journal of the European Union on 4 April 2011. The first parts of the Regulation came into force 20 days after publication and the remaining parts enter into force on 1 July 2013. In the UK, the Sustainable Buildings Division of the Department for Communities and Local Government (DCLG) is the government lead.

Regulations are the most direct form of EU law; as soon as they come into force they are legally binding throughout every Member State of the EU, on a par with national laws. National governments do not have to take action themselves to implement EU Regulations.

One of the key new additions of the CPR is the requirements on sustainability, especially the sustainable use of natural resources (this is called Basic Works Requirement 7 (BRCW 7) and the reduction of life cycle impacts of greenhouse gases (BRCW 3). This has major repercussions; if an EU Member State wishes to regulate in these areas of sustainability it will have to do so using European standards and in particular the standards under development by CEN Technical Committee CEN/TC 350.

It is important to understand that all Member States, including the UK, have to use these standards and cannot regulate using national standards if European standards exist.

The CPR also includes the requirement that EPD be used to assess the impact of a product.

CEN/TC 350

Development of horizontal standardised methods for the assessment of the integrated environmental performance of buildings

From 2000, the European Commission began to be concerned that the plethora of national schemes for assessing the environmental impact of buildings and construction products across Europe could begin to create technical barriers to trade and interrupt the single market within the European Union. It was to reduce these potential barriers to trade and to provide consistent and integrated evaluation of impact at the building level, that the EU Member States agreed to ask the European Committee for Standardization (CEN - essentially all the national standards bodies within Europe) to develop a horizontal (i.e. applicable to all products and building types) approach to the measurement of embodied and operational environmental impacts of construction products and whole buildings across the entire life cycle. Subsequently, the scope of the standards being developed has been extended to include economic performance and social performance of buildings.

The European Commission mandated the development of these new European Standards in 2004, known as mandate M/350 and the standards are being developed by the European Standards Technical Committee set up to do this called CEN/TC 350. This Committee began its work in 2005 and divided the work into six task and working groups:

- [CEN/TC 350/ Task Group Framework](#)
- [CEN/TC/WG1 Environmental Performance Assessment of Buildings](#)
- [CEN/TC/WG2 Building Life Cycle description](#)
- [CEN/TC/WG3 Product Level \(EPD, communication formats\)](#)
- [CEN/TC/WG4 Economic Performance Assessment of Buildings](#)
- [CEN/TC/WG5 Social Performance Assessment of Buildings](#)

The work of CEN/TC 350 is mirrored in each EU Member State by a national committee. In the UK, the mirror group is the British Standards Institution BSI Committee B/558. This meets regularly to discuss the outputs of the various CEN/TC 350 work groups (as well as other construction sustainability issues involving standards). The Committee's role is to comment on the draft documents issued by CEN/TC 350 and to decide the UK voting strategy for each document; it aims to reach consensus on responses to proposals.

The importance of European Standards is that EU Member States, including the UK, have to use European Standards where they exist when regulating and National Standards must be withdrawn if they are in conflict with European Standards. So if the UK decides to regulate on measuring the sustainability of buildings and construction products then the UK will have to use the CEN/TC 350 standards. National standards for construction products such as for durability have been replaced over the past decade by European standards and it is expected that this will also happen on sustainability issues.

A significant proportion of the UK construction products industry is formed of European and global companies so European standards or indeed International standards are more practical and relevant than national schemes.

How do Environmental Product Declarations (EPD) contribute to sustainable construction?



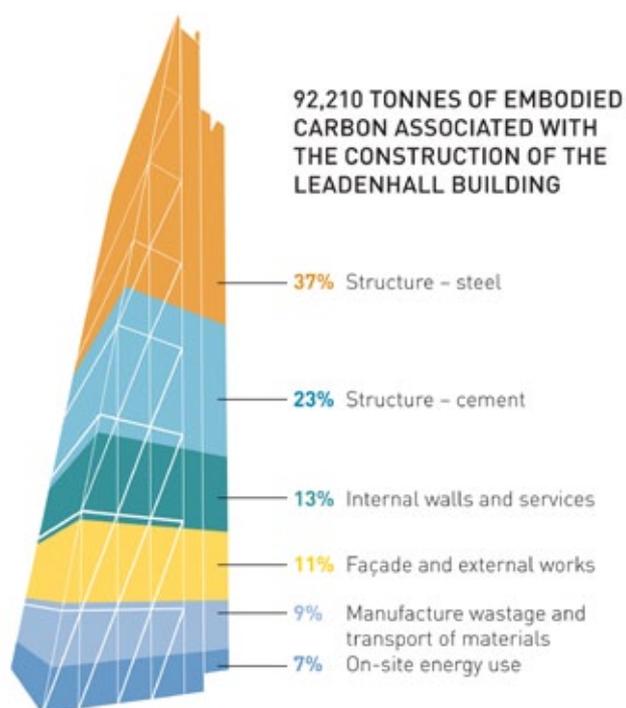
The process of Life Cycle Assessment to create Environmental Product Declarations provides a standardised way to collect data, assess impact, communicate the information and review the environmental performance of construction products. However products are components of a building and not the end product themselves, so how can the embodied impact data included within an EPD be utilised to deliver a more sustainable built environment?

EPD are provided by the manufacturing industry for the communication of credible information about the environmental performance of building products (whether generic or manufacturer specific) in a variety of situations, such as:

- Performance per individual unit (e.g. per m^3 of ready mix concrete, per kg of cement, per m^2 of plasterboard), the unit is defined based on the way the material is sold or delivered
- Performance based on the function of the product as installed (e.g. per unit of thermal resistance for insulation, or per linear metre of beam with a given span and loading)
- Performance at a building level, over the full life cycle, taking into account functionality as above



Environmental Product Declarations can be used in a variety of ways by different parts of the construction supply chain:



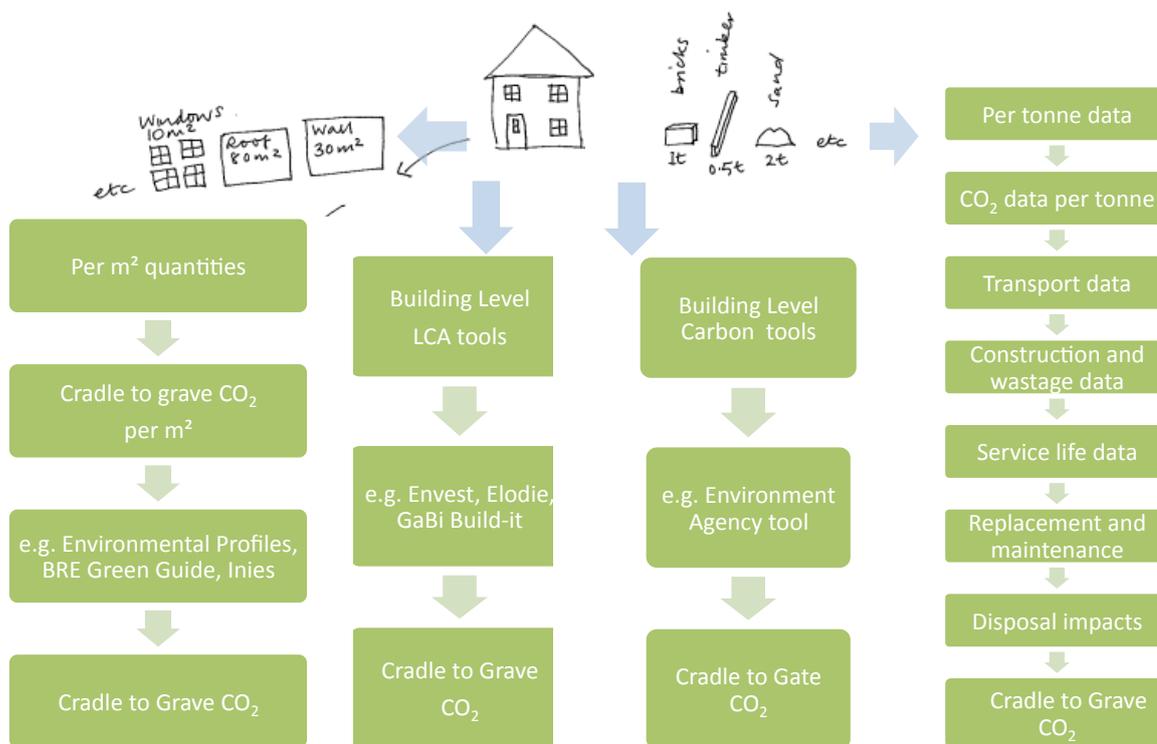
British Land have commissioned a series of studies, including for the Leadenhall Building shown above, to improve understanding of carbon emissions throughout the life cycle of a building and the role of embodied energy in construction materials

- **Construction Product Manufacturers: Product Designers:** The process of obtaining an EPD can give a manufacturer a good understanding of the causes and types of impact associated with their product and where in the product supply chain their major life cycle impact hotspots occur. This provides a strong basis for improving the design of the product to reduce the life cycle impacts and optimise environmental performance in the building; this is often referred to as ecodesign.
- **Construction Product Manufacturers: Marketing:** EPD enable manufacturers to communicate credible product and company environmental performance in a transparent way and enable manufacturers to substantiate marketing claims and comparisons against similar products. EPD can also be used to show how the impact of a product has been reduced over time.
- **Construction Product Manufacturers: Supply Chain:** EPD normally use generic data for the input materials, energy and waste processing associated with the manufacture of construction products. However the supply chain can also collect and provide specific data for these processes which can be used to more accurately represent the impact of products. EPD verification can cover the specific information provided by the supply chain as well as the product manufacturer to ensure the robustness of this approach.
- **Procurement:** EPD can be used as source information in the procurement and purchase of products. They provide buyers with the confidence of knowing that the environmental performance of a specific product has been reviewed and validated by an independent party with expertise in LCA. Having EPD does not mean that a product has lower environmental impact than others, but provides the information to evaluate products.
- **Specification:** Specifiers can include information provided in EPD in their performance specifications to ensure that products used in the building meet the required environmental performance.
- **End Users:** An EPD enables consistent and robust comparisons to be made between products at the building level. It allows end users to make informed choices using a standardised, comprehensive and verified set of information.
- **Client Groups:** Many client bodies wish to calculate the embodied carbon of their developments and information included in an EPD can help them to do this. Along with other environmental indicators, EPD provide verified credible embodied carbon or greenhouse gas data for construction products (the carbon footprint) which is information about the product's impact on climate change and can be used in building level embodied carbon assessments. This means the EPD provides the greenhouse gas emissions or embodied carbon associated with that construction product. EPD can also include data on recycled content for example.
- **Planning and Regulation:** In the UK, Brighton & Hove City Council is the first council in the UK to require an embodied carbon assessment of developments as part of its planning permission process.

Assessing the impact of materials at the building level

As the operational impacts (primarily heating, cooling, ventilation and lighting) of buildings decrease through regulation of new build and retrofit of the existing stock, then the impact of the materials used to construct the buildings (the embodied impacts) becomes more important.

Until recently, there has been little focus on these embodied impacts but interest is growing with a range of approaches being developed. With all approaches, the intention is first to quantify the impact, and then to provide information so that users can identify areas with the greatest potential for reduction and to evaluate reduction strategies. An EPD provides one mechanism to do that, by providing robust and consistent information that can be used to quantify the embodied impacts of a building over its life cycle.



How to count carbon

The diagram shows several approaches to measuring the environmental impact associated with materials at the building level. Some approaches only measure carbon (CO₂ or greenhouse gases (CO₂e)) whilst others measure a wider range of embodied impact indicators provided within EPD and LCA databases. The approaches also cover different scopes, eg cradle to gate, or cradle to site, or cradle to grave.

The simplest approach combines the measured areas of different element specifications, and their impact. For example, data on carbon impact can be obtained from a variety of sources such as the BRE Green Guide (which provides cradle to grave embodied greenhouse gas emissions (CO₂e) data per m² for each element), pricing handbooks such as Hutchins UK Blackbook (cradle to gate embodied carbon data) or from relevant EPD sources such as inies (FR) which provide impact per m². This approach means the cradle to gate or cradle to grave impact can be calculated for both embodied CO₂e, or embodied CO₂, or a range of LCIA indicators (as provided in EPD).

An alternate approach is to consider the mass of individual materials, and environmental data provided on this basis. Measurement of individual materials on a mass basis can be undertaken by converting quantitative data from Bills of Quantities to tonnes, and this can then be linked with data per tonne of product. Databases such as the Inventory of Carbon and Energy (Bath University) or LCIA databases such as the German National construction LCIA database, ökobau LCA databases such as GaBi or ecoinvent can be used for this purpose. These models can be adapted by the user to calculate transport, wastage and site impacts and to consider the service life of materials and their end-of-life.

Building level LCA tools

In addition, purpose-built tools exist which will provide cradle to gate embodied impact information (including embodied carbon) using input data on the mass of materials used; an example is the UK Environment Agency tool focussing on infrastructure. EcoQuantum in the Netherlands, or GaBi Build-it in Germany, use similar input data by mass to provide cradle to grave LCA data for a building.

Other building level LCA tools exist such as Envest in the UK or Elodie in France. They require varying levels of information about the building but allow the user to design the building within the tool from a palette of materials, specifications or EPD.

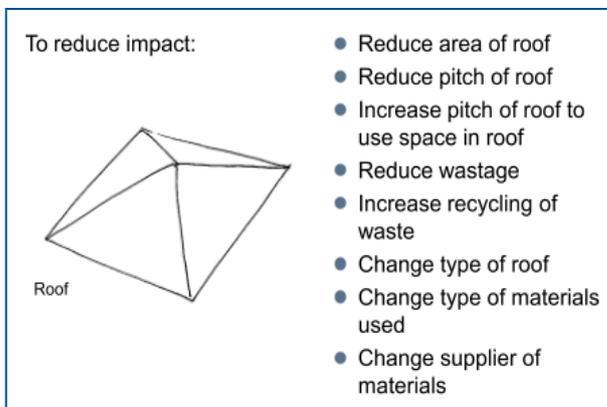
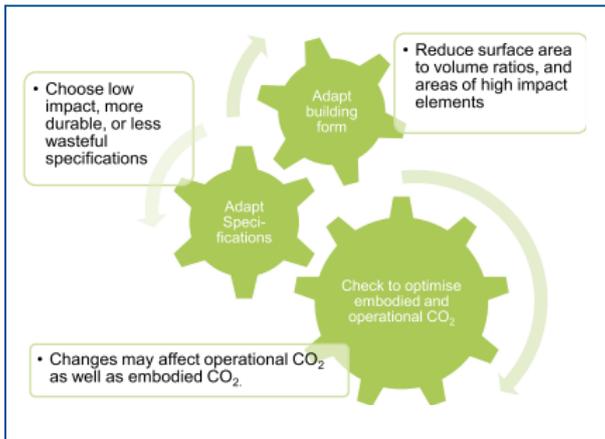
There are also a number of tools which link to CAD (Computer Aided Design) models, for example Sustainable Building Specifier (Germany) and LCADesign (Australia). These building level LCA tools all provide cradle to grave assessments, though based on national models of product and building service life and end-of-life.

There are two tools under development which will help reduce the burden of embodied impact modelling by linking Building Information Models (BIM) directly to Life Cycle Assessment data for construction materials. Both tools are also expected to provide parallel assessment of building whole life costs (i.e. economic costs). One of the tools is being developed by a UK consortium funded by the UK Technology Strategy Board and should be available in 2012. The other tool is being developed by a European Consortium within the European Commission's 7th Framework Programme's and will be available in 2013.

To date (2012), very few of these approaches integrate the operational impact of the building alongside the embodied impact, but in the near future it is important that the synergies between the embodied and operational impacts are considered in tandem.

The links between building products and building operational performance are many – the choice and placing of construction products can affect thermal mass, U value, air tightness, daylighting and acoustics amongst other measures. Additionally, choices for the building fabric can affect foundation design and building footprint. Holistic design and assessment at the building level is therefore necessary to optimise the benefits of improvements, ensuring trade-offs between operational performance and the embodied performance of different elements are fully considered. Focus should not only be on the choice of materials once the building form has been designed, but also on the affect that the building design has and whether other forms could minimise overall impacts (see diagram above).

The example demonstrates some aspects to consider which may serve to reduce the embodied impacts of a roof. Awareness of the embodied impacts of the construction products used in the building of a roof enables the effective quantification of the benefits that such alterations will have. Therefore, by knowing the embodied impacts arising along the supply chain, any building can be made more sustainable not only through improvements to the supply chain, but also via more efficient and sustainable building design.



Benchmarks for Building Types

Benchmarks can provide a guide to the normal impact expected for a given building type such as dwellings, schools, offices. At present, there are no publicly recognised benchmarks of embodied impact for the UK construction industry, although a number of consultancies and clients have their own in-house databases using a variety of scopes and methodologies. Research is therefore required into impacts for a significant range of buildings. This has been recognised as a significant issue in the government's Innovation and Growth Team report on Low Carbon Construction, and it is hoped that over time, robust benchmarks with good background information will become available.

One difficulty is the plethora of different approaches to measuring embodied impact which means that it is very difficult to make comparisons between buildings with any certainty. An overview of the types of variation in scope are shown in the table below, and should be considered before making any comparisons of building level data or using benchmarks.

Aspect	Options
Scope	Cradle to Gate? Cradle to Grave? Transport Included? Site Waste Included?
Building Life	50, 60 or 100 year lifespan (or other)
Reporting	CEN/TC 350 indicators, BRE Ecopoints, Embodied Carbon (ECO ₂), Embodied Greenhouse Gases (ECO ₂ e)
Elements included	Key Building Elements (Floors, Roof, External Walls, Windows, Internal Walls); Building Services (lighting, heating, cooling, ventilation, small power, fire, water etc), Structure (Foundations, Superstructure), Fitout elements (floor finishes, ceilings, doors, internal finishes, external shading) Building operation
Data sources	Inventory of Carbon and Energy, EPD, LCA databases...
Replacement based on service life	Probabilistic? Deterministic? The same reference case used as basis for service life assesment e.g. Urban, well maintained or rural, average maintenance

How are the embodied impacts of materials treated in building level environmental rating schemes?

Building level environmental rating schemes such as BREEAM and LEED have been developed to evaluate the environmental performance of buildings as a whole, taking into account a whole range of environmental (and some social and economic) issues, including those related to choice of materials. The result of these assessments is an overall score which defines the environmental performance of the building. These methodologies are used to demonstrate and inspire environmental practice and design and to a greater or lesser extent can also help reduce running costs and provide a better internal environment.

The treatment of materials in building level rating schemes can vary from tick box checklists through to whole building LCA. All consider the environmental impact of construction products and materials but as the approach used varies so widely the results could at best be incomparable and in some cases contradictory.

The different approaches used in the most influential building level schemes are illustrated below. The first overview is of the emerging CEN/TC 350 standards for building level assessment which have been mandated by the European Commission to provide a harmonised approach for building level assessment across Europe and are likely to become highly influential in the future.

CEN/TC 350 – Assessing the sustainable performance of buildings and construction products - Building Level Assessment

Following a mandate by the European Commission, CEN Technical Committee 350 has developed the following building level standards covering environmental impacts:

- EN 15643-1:2010 Sustainability of construction works - Sustainability assessment of buildings - Part 1: General framework,
- EN 15643-2:2011 Sustainability of construction works - Assessment of buildings - Part 2: Framework for the assessment of environmental performance
- EN 15978:2011 Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method

These standards provide guidance on implementing consistent evaluation of building level environmental impacts, both embodied and operational, for all types of buildings across Europe. The standards use a life cycle assessment approach to evaluate a common set of environmental indicators over a series of defined life cycle stages. Impacts from materials used in the building fabric, structure, services and fitout will be included, as will maintenance, repair, refurbishment, and demolition, with the impacts of disposal and the benefits of any resulting reuse, recycling or energy recovery. Impacts from operational energy use are also included in the same matrix, so this will emphasise that the carbon emissions from materials use and building operation are really indistinguishable.

The intention is that where possible, measures such as waste reduction or changing air conditioning refrigerants for example, are considered through their impact on the building using realistic scenarios rather than through a series of separate credits which may not take into account the effect these measures actually have for a specific building.

The standards only cover the measurement, calculation and reporting of life cycle impacts of buildings. They do not cover any further evaluation undertaken within building level schemes – so if schemes align with CEN/TC 350 they will still be able to weight individual impacts and life cycle stages as they wish.

The BRE Environmental Assessment Method (BREEAM) – United Kingdom

Developed in 1990 and now widely used in the UK and internationally, one of the key aims of BREEAM is to encourage the use of construction materials with lower embodied impacts. BREEAM uses the Green Guide to Specification as the basis for scoring the embodied impacts of construction materials. The Green Guide was developed by BRE to provide guidance to designers and specifiers on choosing the most environmentally friendly building constructions. By translating LCA data for generic and certified products into an A+ to E rating system for building elements such as walls and roofs, it is easy to use the guide to select solutions with low embodied impacts for any construction project. 12% of the BREEAM score for a building relates to the credits achieved in the materials section, half of which are based on the Green Guide ratings for the construction solutions used. Other material credits in BREEAM relate to the responsible sourcing of construction products, the reuse of existing facades and structures and the use of recycled aggregates. BREEAM 2011 includes the opportunity for products with any independently verified EPD to increase the credit for a building element in BREEAM 2011 using a new credit uplift. The uplift is dependent on the impact of the products within the element (so if the product is responsible for 60% of the impact of the specification it will have more uplift than if it was only responsible for 20%; the existing Green Guide rating of the element used (A+ and A rated specifications get the most uplift) and the scope of the EPD, with cradle to grave EPD gaining the most uplift. However, it should be noted that the uplift does not take any account of the impacts described in the EPD, just the fact that the EPD is available.

BREEAM published a statement in November 2011 explaining their approach to CEN/TC 350, describing how they intend to continue using the Green Guide to evaluate building materials within BREEAM. This approach differs from CEN/TC 350, as although Green Guide ratings are LCA based, they deal with typical, rather than specific constructions, and do not cover the building foundations, the core superstructure, building services or some of the fitout (doors or ceilings for example). BREEAM also considers the embodied impacts and operational impacts (from energy use) completely separately, with the balance of credits unrelated to the underlying impacts. In future, BREEAM will provide an LCA tool, IMPACT based on the CEN/TC 350 methodology, for use in BREEAM, which may overcome some of these difficulties.

Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB) - Germany

Founded in 2007, the DGNB (or German Sustainable Building Council) provides Gold, Silver or Bronze awards for buildings reflecting environmental, economic and social characteristics. The environmental impact of the building is weighted at 22.5% of the overall score, the same as the social and economic impact and technical quality. Unlike BREEAM, the certification system uses a building level LCA, including the operation of the building, to evaluate both building materials (structure, fabric, building services and fitout) and operational energy use. Credits are achieved by comparing overall impact to reference and target impacts per m² per annum for seven environmental impact categories, with 14% of DGNB credits available in total. The scheme therefore considers the trade-offs between embodied and operational impacts using a consistent impact and weighting methodology, broadly in line with the European CEN/TC 350 suite of standards.

Leadership in Energy and Environmental Design (LEED) – United States

Developed by the US Green Building Council in 2000, the LEED certification system seeks to improve the way the construction industry addresses sustainability. One of the potential shortcomings observed within the LEED system has been its lack of a life cycle assessment approach to quantify the embodied impacts of construction materials. The checklist approach used by LEED to assess materials by means of targeting high levels of recycled content, renewable content and local sourcing can oversimplify and lead to uncertain outcomes. However, LEED has begun to test the use of two life cycle assessment based pilot credits, which may become standard in future LEED versions. The first uses a tool “EcoCalculator” to assess the key elements of the building (like BREEAM) and compare them to a benchmark result (the average of the element options included in the tool). The incorporation of life cycle assessment should ensure that the embodied impacts of construction products are more fully and accurately taken into account as part of the scoring process. A second Pilot Credit relates to the provision of EPD or LCA studies, thus encouraging manufacturers to become more aware of the impacts of their supply chains and to reduce the embodied impacts of their products. Credits are available if more than 10% by value of the non-structural materials used in the building have generic or manufacturer LCA or EPD, with increasing credit being given for specific data, peer reviewed LCAs and the greatest credit being given to independently verified EPD thus recognising the consistency and robustness of this type of LCA data. It should be noted that this, like the BREEAM credit uplift, does not take any account of the actual impacts described in the EPD, but just the fact that an EPD has been produced.

Embodied Impact Categories

The following data sheets provide a more detailed description of the environmental impact categories measured in a Life Cycle Assessment.

The data sheets have a standard format and provide an understanding of why the impact is considered important, how it is measured, what the metric of measurement is; what alternate names might it be known as and how widely the impact category is used.

Embodied Carbon

Acidification

Eutrophication

Stratospheric Ozone Depletion

Photochemical Ozone Creation

Abiotic Depletion: Elements and Energy

Raw Material Use / Mineral Extraction

Toxicity

Land Use

Embodied Water

Embodied Carbon

Also known as: Carbon Footprint, Climate Change, Global Warming, or Global Warming Potential, Embedded Carbon, ECO₂.

WHAT IS EMBODIED CARBON?

Embodied carbon is the Carbon Dioxide (CO₂) or greenhouse gas (GHG) emissions associated with the manufacture and use of a product or service. For construction products this means the CO₂ or GHG emission associated with extraction, manufacturing, transporting, installing, maintaining and disposing of construction materials and products.

The majority of embodied carbon for a construction product is CO₂ emitted from the use of fossil fuels in extraction and manufacturing of construction materials and as a result of process emissions from manufacturing.

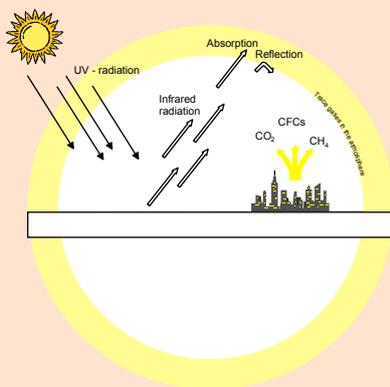
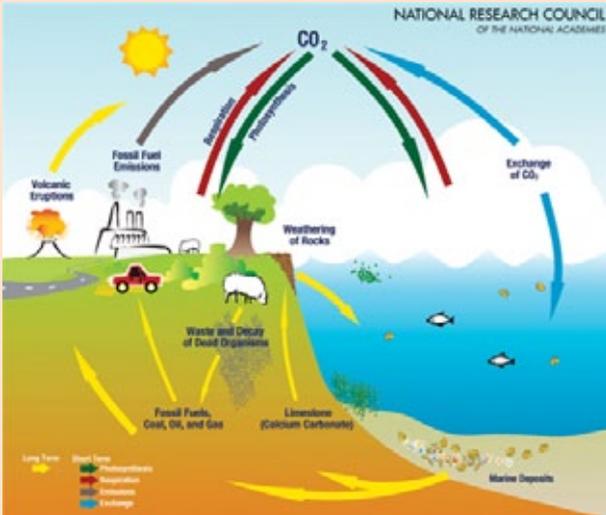
WHY IS IT IMPORTANT?

The potential threat of climate change has caused concern globally, with many initiatives aimed at reducing the carbon emissions resulting from human activities. The built environment is a significant contributor to total GHG emissions with estimates of 38% and 48% attributable to buildings. In the UK, government targets⁴ in the Climate Change Act⁵ are to reduce GHG emissions by 34% by 2020 and by 80% by 2050; these will be unachievable without a significant reduction in the carbon performance of new and existing buildings. This has led to the government's plans to make all new homes "zero carbon" by 2016 and all new non-domestic properties to be zero carbon by 2019⁶. These measures, along with incentive schemes such as the Renewable Heat Incentive and Feed-in Tariffs for renewable energy are all designed to deliver a low carbon economy and will all have a bearing on the manner in which the construction industry will operate in the coming years.

But these measures only impact on the operational carbon. Close to 50 million tonnes of GHGs are produced as a result of manufacturing, transporting, installing and disposing of construction products and materials used in the UK (including imported products)⁷ – this is equivalent to nearly 8% of the UK's GHG emissions. As emissions are reduced from our use of buildings, these emissions become more important, and there will be an increasing focus to measure and reduce embodied carbon in the future.

EMBODIED VERSUS OPERATIONAL CARBON

There are two types of GHG emissions associated with buildings: the embodied carbon of the products that make up the building and the operational carbon which is the energy consumption associated with general day to day use of the building, primarily through water and space heating. Together they make up the total carbon footprint of the building.



Global Warming

4 www.decc.gov.uk/en/content/cms/emissions/carbon_budgets/carbon_budgets.aspx
5 www.theccc.org.uk/home
6 www.communities.gov.uk/publications/planningandbuilding/zero-carbon-definition
7 www.bis.gov.uk/assets/biscore/business-sectors/docs/e/10-1316-estimating-co2-emissions-supporting-low-carbon-igt-report

Table 1: Relationship between environmental and economic terminology

	CAPEX (Capital Expenditure)	OPEX (Operational Expenditure)
Embodied Impacts	Construction, Refurbishment, Demolition	Maintenance, Repair
Operational Impacts		Heating, Lighting, Cooling, Equipment, Security

The operational carbon is generally the largest contribution to GHG emissions in existing buildings, with around 75-90% attributable to the operational carbon. About 10-25% of the carbon from existing buildings is attributable to the embodied carbon of the building fabric.

In the future as new buildings become much more energy efficient and electricity production from renewable and low carbon sources such as solar, wind or nuclear increases, the proportion of embodied carbon to operational carbon will change and increase.

HOW IS EMBODIED CARBON MEASURED?

Embodied carbon is usually expressed in units of carbon dioxide. However, the term "carbon" is often used as a catch-all term and can mean either:

- Carbon dioxide (CO₂) alone
- A basket of greenhouse gases (GHGs), as used in the Kyoto Protocol⁸ [carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur hexafluoride (SF₆)].

Increasingly, the importance attached to covering all GHGs means that the number of studies/publications that report CO₂ alone is decreasing. Instead, the global warming potential (GWP) of GHG emissions is generally reported, expressed in units of carbon dioxide equivalent (CO₂e), taking account of the different impact of GHGs (see below).

Some studies of embodied carbon consider only the embodied emissions in the manufacturing supply chain (extraction, manufacturing, transport), i.e. "cradle-to-gate" studies. Other studies include transport to site and installation (cradle to site) and others also include the disposal of the product at the end of life, taking account of any landfill or incineration and the benefits of recycling and reuse ("cradle to grave" or "cradle to cradle" studies).

EMBODIED CARBON AND GLOBAL WARMING POTENTIAL

Not all Greenhouse Gases are alike. While CO₂ is the most ubiquitous GHG, there are a number of other gases which contribute to climate change in the same way as CO₂ by trapping heat in the atmosphere - in scientific terms this is known as radiative forcing. The effect of different gases is reported using global warming potential (GWP). GWP is a relative measure of the amount of CO₂ which would need to be released to have the same radiative forcing effect as a release of 1 kg of the GHG over a particular time period.

8 http://unfccc.int/kyoto_protocol/items/3145.php

There are two types of GHG emissions associated with buildings: the embodied carbon of the products that make up the building and the operational carbon which is the energy consumption associated with general day to day use of the building, primarily through water and space heating. Together they make up the total carbon footprint of the building.

Table 2: GWP for Common Greenhouse Gases from IPCC⁹

Greenhouse Gas (GHG)	GWP – 100 year timeframe (kg CO ₂ e)
Carbon dioxide (CO ₂)	1
Methane (CH ₄)	25
Nitrous oxide (N ₂ O)	298
Sulphur hexafluoride (SF ₆)	22800
Perfluorobutane	8860
HFC 134a (tetrafluoroethane)	1430

GWP is therefore a way of quantifying the potential impact on climate change of a particular gas, normalised to the GWP of CO₂. Methane is a common GHG and has a GWP 25 times greater than CO₂ over 100 years. The most common time period over which GWP is measured is 100 years (GWPI00), however other time horizons such as 20 or 500 years are also used for measurement. As molecules have different lifetimes in the atmosphere, the GWP20 or GWP500 of a gas is likely to be different to that of GWPI00, with the exception of the reference gas CO₂ which always has a GWP of 1. The GWPI00 for common GHGs are shown in Table 2: GWP for Common Greenhouse Gases from IPCC.

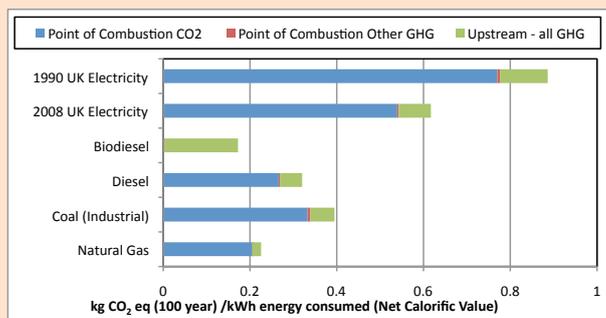
SOURCES OF EMBODIED CARBON

The majority of embodied carbon associated with construction products arises directly from the use of energy – for example from burning fossil fuels in power stations, boilers, furnaces, kilns and engines. But other sources are process emissions such as the release of CO₂ from the calcination of limestone in cement manufacture or the release of HFC blowing agents during manufacturing of some insulation foams. However, carbon emissions also occur before energy is used, for example during the extraction of fossil fuels or uranium, their transport and processing, and from distribution losses such as gas leaks (natural gas is predominantly methane) – these are known as upstream emissions and are analogous to the “Scope 3” emissions from the supply chain in corporate GHG reporting. Greenhouse gas emissions from UK energy consumption (from DEFRA Emissions Factors, 2010) shows the relative impact of emissions of CO₂ and other GHGs at the point of combustion (eg. the power station for electricity, the vehicle for diesel, the boiler for fuels) and from upstream GHGs.

Another source of embodied carbon is the emission of GHGs during the disposal of construction products. All disposal processes (recycling, energy recovery, incineration or landfill) are likely to result in some emissions from transport or reprocessing, but the main concern is with materials which can release carbon during disposal processes, such as biomass or plastics. At present in the UK, incineration and energy recovery are not as common a disposal option as they are elsewhere in Europe, but both approaches result in CO₂ emissions.

The behaviour of biomass such as timber in landfill is still the subject of ongoing research, with some studies suggesting most timber will stay intact, whilst others estimate a significant proportion will decay to produce a mix of CO₂ and methane (which has 25 times the global warming potential of CO₂), with varying degrees of collection for flaring or energy recovery. The treatment of biomass in disposal needs to be considered alongside the treatment of carbon which is taken from the atmosphere by biomass as it grows. This “biogenic” or “sequestered” carbon can be considered as a negative emission of CO₂ and has benefits as the carbon stays locked up in products until disposal, when it may be released back into the atmosphere. More detail on approaches to biogenic carbon are provided in the on Table on page 36.

9 IPCC, IPCC Fourth Assessment Report: Climate Change 2007, Section 2.10.2. www.ipcc.ch/publications_and_data/ar4/wgl/en/ch2s2-10-2.html



Greenhouse gas emissions from UK energy consumption (from DEFRA Emissions Factors, 2010)

THE RANGE OF METHODS AND STANDARDS FOR MEASURING A PRODUCT'S EMBODIED CARBON

Life Cycle Assessment (LCA)

Life Cycle Assessment (LCA) – the technique to assess the environmental impacts associated with a product or service over its full life cycle – is one of the original methods used to provide embodied carbon data. ISO standards ISO 14040:2006¹⁰ and ISO 14044:2006¹¹ have been developed to broadly define LCA studies. All studies will follow a pattern of defining the goal and scope of the study, gathering data for the system being considered, creating an LCA model and evaluating the environmental impacts of the system. According to the ISO Standards, LCA studies used to make public comparisons between different products need to be critically reviewed by LCA experts to ensure that the results have been interpreted and communicated correctly and without misleading readers.

GHG emissions are one of the standard indicators normally assessed within both LCA and EPD, so LCA studies and more specifically construction product EPD can be used to provide Embodied Carbon data. Depending on the scheme, the relevant indicator for Embodied Carbon may be called Climate Change, Global Warming, or Global Warming Potential.

Environmental Product Declarations (EPD)

Environmental Product Declarations are standardised documents used to communicate the environmental performance of a particular product based on LCA. EPD are freely available from a number of construction schemes in Europe and elsewhere and cover a very wide range of construction products, with many being for specific manufacturer's products, although trade association EPD are also available. National EPD schemes include BRE's Certified Environmental Profiles¹² within the UK, FDES using the French Standard, NF P01-010 presented in the Inies database¹³ in France, IBU¹⁴ in Germany and EPD Norge¹⁵ in Norway.

GHG emissions are one of the standard indicators normally assessed within both LCA and EPD, so LCA studies and more specifically construction product EPD can be used to provide Embodied Carbon data. Depending on the scheme, the relevant indicator for Embodied Carbon may be called Climate Change, Global Warming, or Global Warming Potential.

EPD in general are covered by the ISO 14025:2006 standard which defines how EPD need Product Category Rules (PCR) to ensure products are assessed consistently. The construction industry has also developed ISO 21930:2007¹⁶ to specifically define how construction products should develop PCR and use EPD. ISO 21930:2007 sets out how LCA should be used to consistently determine the environmental impacts associated with a construction product, taking into account the way construction products are combined to produce buildings – the real product which we need to assess, and how EPD can be used to make comparisons by taking into account the use of the products at the building level.

CEN/TC 350

Although the EPD schemes listed above are largely compliant with the ISO standards, they still have flexibility within the standards to use very different approaches to measurement, assessment, verification and reporting. Difficulties in using EPD outside the relevant country mean that the European Commission has initiated a process to develop harmonised standards within Europe for building level assessment of construction products, known as CEN/TC 350¹⁷.

10 ISO 14040:2006 Environmental management -- Life cycle assessment -- Principles and framework

11 ISO 14044:2006 Environmental management -- Life cycle assessment -- Requirements and guidelines

12 www.greenbooklive.com

13 www.inies.fr/IniesConsultation.aspx

14 <http://bau-umwelt.de/hp481/Environmental-Product-Declarations-EPD.htm>

15 www.epd-norge.no

16 ISO 21930:2007 Sustainability in building construction -- Environmental declaration of building products

17 www.cen.eu/CEN/sectors/sectors/construction/sustainableconstruction/Pages/cen_tc350.aspx

Once the CEN/TC 350 environmental standards are in place in early 2012, manufacturers should only need to undertake one LCA study to obtain the relevant TC 350 compliant Cradle to Gate EPD for their product, irrespective of where it is being used in Europe. Due to differences in transport, construction practice, maintenance, exposure (and resulting service life) and disposal methods in different countries however, it is likely that different cradle to grave EPD will have to be produced for products in different European regions to account for the resulting differences in environmental impact over the building life (in addition to the need to translate all EPD to local languages).

Carbon Footprint

A carbon footprint for a construction product is analogous to its embodied carbon. In the UK, the Carbon Trust, the British Standards Institution (BSI), and DEFRA developed PAS 2050:2008¹⁸ as a standard method to calculate the carbon footprint of products and services. However, this was developed primarily with consumer products in mind and the assessment method was not really geared towards such long life products as construction products incorporated in buildings, this was particularly relevant in the way that PAS 2050 looked at recycling and the sequestration of carbon in bio-based products. A revision of PAS 2050 in mid-2011¹⁹ has updated the methodology and now offers an option to use PCR such as CEN/TC 350 as a route to compliance with PAS 2050:2011.

HOW CAN EMBODIED CARBON BE MEASURED FOR BUILDINGS

At its simplest, the embodied carbon of a building can be calculated in much the same way as building costs were calculated historically – a Bill of Quantities is linked to the embodied carbon per quantity, and the total for the building can be calculated. Now that Bills of Quantities are used more rarely, quantifying the materials used in the building and linking to environmental data is not so straightforward. However a number of building level tools are now in existence, such as Envest2²⁰ produced by BRE, and research is ongoing worldwide to link CAD models for designers with environmental data for materials. In the UK, the research funding body the Technology Strategy Board (TSB) is funding a research programme²¹ aiming to produce a range of building level assessment tools for the UK market, many of which will provide embodied carbon data in some form.

18 www.bsigroup.com/Standards-and-Publications/How-we-can-help-you/Professional-Standards-Service/PAS-2050

19 www.bsigroup.com/upload/Standards%20&%20Publications/Environment/PAS%202050%202011%20Summary%20of%20changes%20Web.pdf

20 www.bre.co.uk/envest

21 www.innovateuk.org/content/press-release/designing-tomorrows-greener-buildings-.ashx

CONSIDERATIONS WHEN MEASURING EMBODIED CARBON AT THE BUILDING LEVEL

There are two main aspects to consider when measuring embodied carbon - the first is the use of consistent data for construction product embodied carbon (i.e. relevance and quality), and the second is the scope of the study (i.e. what to cover and in what detail). Key pointers that will ensure quality or affect the scope of studies measuring the embodied carbon of construction projects are listed below:

- **Cradle to gate data** is most commonly available at product level. Using data at this level will ignore any differences over the life of the building, for example between two windows which may have different lifetimes in the building or maintenance requirements such as painting.
- **The impacts of transport** are most important for those materials with relatively low impact, like aggregates and timber, where it can have as much impact as the material itself. For more processed materials, transport impacts are less significant, especially recognising shipping is an extremely efficient means of trans-continental transport.
- **Considering site wastage** from construction is also relevant, particularly when comparing prefabricated construction which should have little waste on site, and other solutions which might have wastage rates of over 10%.
- **Taking into account disposal at end of life** is a key decision for biomass, as is considering biogenic carbon locked up into products such as timber which is associated with this choice.
- **Recycling material at end of life** obviously provides a benefit, as does using recycled material in the first place. Different approaches to this benefit are in place across Europe. The French consider only the impacts associated with manufacture of the material as used, known as the "recycled content" or 100:0 approach, whilst the metals industry favour a substitution, or 0:100 approach, with recycled material at end of life substituting for primary production from virgin materials. This approach has been adopted by CEN/TC 350. Another approach used by BRE in their Environmental Profiles is to give credit for recycling based on the relative value of scrap to primary material and PAS 2050:2011 allows both the 100:0 or 0:100 approach. The methodology used to calculate such aspects should be consistent for all materials throughout the building level study and clearly documented.
- **Using consistent data** is important to ensure that the results are meaningful, and can be used over time for benchmarking or identifying successful strategies for reducing embodied carbon. Comparing data with different units, for example, measures that are just CO₂ or that include all GHGs can cause differences of between 5 and 10% at a building level. Most Environmental Product Declarations (EPD) only allow comparison or aggregation of EPD from the same scheme or using the identical product category rules.
- **The level of detail** for the study is also relevant. Some studies are based on a full bill of quantities and may include foundations, external works, staircases, building services equipment, doors, skirting board and gutters for example. Others might focus on only the main elements – walls, roof, floors and windows – potentially less than half the total embodied carbon for a typical house²². As building elements are interdependent it is important that all key aspects of the building are assessed, together with the impact of the building in use, to ensure the optimum solution is considered when reducing operational and embodied carbon. This is particularly relevant if designing out building services for example or using additional materials to produce a zero carbon solution.

22 Anderson J, Housing and Global Warming: the impact of housing construction and domestic space heating on the emission of greenhouse gases, MSc Thesis, University of East London, 1998.

DATA SOURCES FOR EMBODIED CARBON

Embodied carbon data for construction products can be provided as a single indicator, or as one of a number of environmental indicators including for instance resource use or toxicity and measured using life cycle assessment (LCA).

BRE

In the UK, the construction products sector; the trade associations and companies, have worked with the Building Research Establishment (BRE) since the mid-1990s to develop a database of Life Cycle Assessment (LCA) data for construction materials consumed in the UK. This means that trade associations have gathered basic information from their company members and have submitted this raw data (called Life Cycle Inventory data) to BRE. This database includes information on embodied carbon using CO₂e (identified by BRE as “climate change”), for a broad range of construction materials. This database includes information on all stages of the life cycle, including disposal, and has been developed using a consistent methodology²³, based on data provided by industry and checked and evaluated by BRE.

This database is one of the underlying datasets that sits behind the BRE Global's **Green Guide to Specification**, which provides embodied carbon data for each of the 1200 construction specifications (roofs, internal walls, etc) included in the published Green Guide 4th edition²⁴. The embodied carbon data is provided as total GHGs on a per m² basis over a 60 year study period including replacements and disposal.

From October 2010, this embodied carbon data has been available free of charge online at www.bre.co.uk/greenguide, and covers nearly 2000 building specifications. This information will enable calculation of the embodied carbon of a whole building by linking the areas of key element constructions (floors, walls, roofs, windows) with the embodied carbon per m².

Whilst such a method offers the simplest, consistent approach to obtaining embodied carbon data for a building, detailed design analysis would not be entirely possible using this method as inclusion of elements such as columns, structural cores and building services would need to be covered in a different way.

University of Bath

Cradle to Gate embodied carbon data is also available from the **Inventory of Carbon and Energy (ICE) Database**²⁵ developed by the University of Bath. The ICE Embodied Carbon data is based on their review of freely available embodied carbon data and provides their best estimate of embodied carbon (Cradle to Gate, CO₂ and CO₂e) for most UK consumed construction materials. The data is available through a BSRIA publication²⁶, which also includes case studies and guidance on treatment of the end of life for materials.

The UK Government Departments of Energy and Climate Change (DECC), as well as the Department of the Environment (DEFRA) provide GHG emission factors from the disposal of a range of materials including timber, plastics, textiles, metals and inert materials in landfill, recycling, composting and energy from waste²⁷.

23 BRE Environmental Profiles Methodology, draft methodology published 2008 available from www.bre.co.uk/greenguide and original methodology from 1999.

24 www.brebookshop.com

25 www.bath.ac.uk/mech-eng/ser/embodied/

26 Hammond, G. & Jones, C., 2011. “Embodied Carbon - the Inventory of Carbon and Energy (ICE).” BSRIA, Bracknell, UK.

27 2010 Guidelines to DEFRA/DECCs GHG Conversion Factors for Company Reporting, Annex 9

Europe

National databases of generic construction product life cycle impact data are also available such as the German **ökobau.dat**²⁸ or Dutch **Nationale Milieudatabase (NMD)**²⁹ although these are not in English and mainly describe national production.

Life Cycle Inventory data is a list of all the resources and emissions associated with a product or service developed during LCA studies. The **European Life Cycle Database (ELCD) Core Database Version II**³⁰ is a free database providing Life Cycle Inventory Data which covers some construction materials. To convert this data to provide embodied carbon information, all GHG emissions must be identified and considered along with their Global Warming Potential – a process most easily undertaken within an LCA tool which is the intended use for the ECLD, but possible using a spreadsheet.

There are two databases of construction LCI data which can be purchased. These are the **ecoinvent**³¹ database developed by the Swiss Government, which also provides data for a wide range of chemicals and other materials, and the **GaBi construction database**³². ecoinvent can be purchased as a standalone database, or can be used within several LCA tools, GaBi must be used within the GaBi LCA tool.

Other sources of data for embodied carbon include results from **carbon footprinting studies**, life cycle assessment studies (**LCA**) and Environmental Product Declarations (**EPD**) which have already been outlined above.

28 www.nachhaltigesbauen.de/baustoff-und-gebaeuedaten/oekobaodat.html

29 www.milieudatabase.nl/index.php?id=inzage

30 <http://lca.jrc.ec.europa.eu/lcaifohub/datasetArea.vm>

31 www.ecoinvent.org

32 <http://documentation.gabi-software.com/XIVConstructionMaterials.html>

SPECIAL CASE:

Standards and Protocols: Overview of Biomass and Biogenic Carbon and Recycling Methodologies

The treatment of carbon sequestered within biomass and its release from disposal processes at the end of life is one of the principle differences between the various schemes for considering the embodied carbon or LCA of products. The table below shows the principal differences in the treatment of biomass/ biogenic carbon and recycling between some of the most widely used European standards and schemes. ³³³⁴³⁵

Scheme	Methodology
Greenhouse Gas Protocol Product Accounting & Reporting Standard ³³	<p>Land use Changes: Changes associated with direct land use within 20 years or harvest cycle (whichever is longer) are included.</p> <p>Emissions from crop production, fertilisers etc: included.</p> <p>Soil carbon changes: included where due to land use change and practices.</p> <p>Biogenic carbon uptake: included based on mass of biogenic carbon within product.</p> <p>Biogenic carbon stored in product: Carbon which is not released to atmosphere within the 100 year assessment period can be considered as stored carbon.</p> <p>Biogenic carbon released from disposal: Included.</p> <p>Closed loop recycling: Closed loop approximation method/recyclability substitution approach/0:100 method/ end of life approach used (these methods are different names for the same approach which assumes recycled material displaces virgin production). However the 100:0 (recycled content) approach can also be used but the choice must be justified.</p> <p>Open loop recycling and energy recovery from EOL disposal (eg incineration with energy recovery, energy recovery from landfill gas collection): Impacts associated with open loop recycling and energy recovery go to process using recycled content/recovered energy.</p> <p>Offsetting: not included.</p>
CEN/TC 350: EN15804 Core Rules for the Product Category construction products ³⁴	<p>As GHG Protocol but:</p> <p>Land use Changes: not specified.</p> <p>Soil carbon changes: not specified.</p> <p>Biogenic carbon released from disposal: Included in Module C for all disposal processes.</p> <p>Biogenic carbon released from recycling or energy recovery: Included in Module C until waste reaches end-of-waste state. Module D can show the net benefits of recycling and energy recovery, eg a credit based on recycling/recovery process and avoided impacts of virgin production.</p> <p>Recycling: 0:100 (substitution) approach is used. Benefits of recycling beyond the system boundary shown in Module D.</p>
PAS 2050: 2011 ³⁵	<p>As GHG Protocol but:</p> <p>Biogenic carbon uptake: not included for food and animal feed products. Included for all other products, including food packaging</p> <p>Recycling: 0:100 or 100:0 approaches can be chosen.</p>

33 www.ghgprotocol.org/standards/product-standard

34 BS EN 15804:2012 <http://shop.bsigroup.com/en/ProductDetail/?id=00000000030259256>

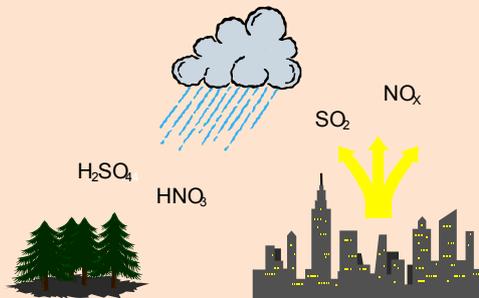
35 www.bsigroup.com/upload/Standards%20&%20Publications/Energy/PAS2050.pdf

Acidification (AP)

(Also known as: Acidification; Acidification for Soil and Water, Acidifying Pollution, Aquatic Acidification)

WHAT IS ACIDIFICATION POTENTIAL AND WHY IS IT IMPORTANT?

Acidic gases such as sulphur dioxide (SO_2) react with water in the atmosphere to form "acid rain", a process known as acid deposition. When this rain falls, often a considerable distance from the original source of the gas, it causes ecosystem damage of varying degrees, depending upon the nature of the landscape ecosystems.



Acidification (Kreissig, 1999)

Notable examples of the damage caused by acidification occurred in the pine forests of Scandinavia and Eastern Europe as a result of the use of coal and oil in the UK. Starting from the 1970s, awareness of acid rain increased, leading to the Sulphur Emissions Reduction Protocol, and legislation to reduce other air pollutants. The main gases that cause acid deposition are nitrogen oxides (NO_x) and sulphur oxides (SO_x); ammonia and hydrogen fluoride also cause acidification but to a much lesser extent. SO_x and NO_x are commonly emitted as a result of combustion of fossil fuels, particularly from coal and oil fired power generation and diesel vehicles or in manufacturing processes using coal, all of which have relevance to the construction industry.

HOW IS ACIDIFICATION POTENTIAL MEASURED?

Acidification potential is measured using the ability of a substance to release H^+ ions, which is the cause of acidification, or it can be measured relative to an equivalent release of SO_2 . The most common measure of a liquid's acidity, pH, is measured by the presence of H_3O^+ which is formed through the combination of water and H^+ ions. As with climate change, the total acidification potential of an emitted substance is calculated based on the quantity of a substance multiplied by its acidification potential characterisation factor:

HOW WIDELY USED IS IT?

Acidification potential is one of the most widely used indicators. It features in most indicator sets and is a mandatory indicator in many reporting frameworks/standards. Organisations and standards using acidification potential include:

CEN/TC 350 (EU)	DAPc (Catalonia)
BRE (UK)	Environdec (International)
IBU (DE)	FDES (FR)
NEN 8006: 2004 (NL)	TRACI (US)
EPD-Norge (NOR)	Ecoindicator99 (Swiss)

Eutrophication (EP)

(Also known as: Eutrophication; Nutrification)

WHAT IS EUTROPHICATION POTENTIAL AND WHY IS IT IMPORTANT?

Nitrates and phosphates are essential for life, but increased concentrations in water can encourage excessive growth of algae and reduce the oxygen within the water. Eutrophication can therefore be classified as the over-enrichment of water courses. Its occurrence can lead to damage of ecosystems, increasing mortality of aquatic fauna and flora and to loss of species dependent on low-nutrient environments. This leads to an overall reduction in the biodiversity of these environments and has knock-on effects on non-aquatic animals and humans who rely on these ecosystems.

Common sources of emissions that cause eutrophication include leaching/runoff from agriculture where nitrogen/phosphorous based fertilisers are used, pollution from sewers/poorly-managed drainage systems and atmospheric nitrogen pollution as a result of burning fossil fuels. In the construction industry, uncontrolled runoff from construction sites, lack of maintenance of drainage/sewage systems and the intensive production of products/fuels from agricultural products could all contribute to eutrophication.

HOW IS EUTROPHICATION POTENTIAL MEASURED?

Eutrophication is measured using the reference unit of kg nitrogen or phosphate equivalents. As such it is a measure of the extent to which a substance in the water causes the proliferation of algae, with nitrogen or phosphate as the reference substance. The major contributors to eutrophication are nitrogen compounds, such as nitrates, ammonia, nitric acid and phosphoric compounds including phosphates and phosphoric acid.

The characterisation factors used by CML for Eutrophication potential are based on the work of Heijungs.

HOW WIDELY USED IS IT?

Eutrophication potential is one of the most commonly reported impact categories. Organisations and standards that use eutrophication potential include:

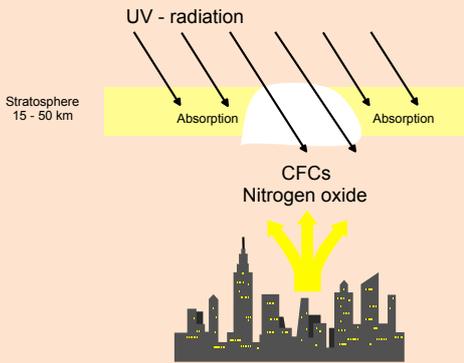
CML Baseline 2002 (NL/Global)	Environdec (SWE)
CEN/TC 350 (EU)	EPD-Norge (NOR)
BRE (UK)	FDES (FR)
NEN 8006: 2004 (NL)	DAPc (Catalonia)



Eutrophication (Kreissig, 1999)

Stratospheric Ozone Depletion (ODP)

(Also known as: Ozone Degradation Potential; Ozone Depletion Potential; Depletion of the Ozone Layer)



Ozone Depletion (Kreissig, 1999)

WHAT IS OZONE DEPLETION POTENTIAL AND WHY IS IT IMPORTANT?

Ozone-depleting gases cause damage to stratospheric ozone or the “ozone layer” by releasing free radical molecules which breakdown ozone (O_3). Damage to the ozone layer reduces its ability to prevent ultraviolet (UV) light entering the earth’s atmosphere, increasing the amount of carcinogenic UVB light hitting the earth’s surface. This in turn results in health problems in humans such as skin cancer or cataracts and sun related damage to animals and crops. The major ozone depleting gases are CFCs, HCFCs and halons. Growing concern in the 1980s led to world-wide efforts to curb the destruction of the ozone layer; culminating in the Montreal protocol which banned many of the most potent ozone depleting gases.

Common sources of these gases are refrigerants and blowing agents. In the construction materials industry, steps have been taken to replace ozone depleting insulating foam blowing agents with non-ozone depleting gases such as HFCs. These, however, often have high Global Warming Potentials (see Embodied Carbon section).

HOW IS OZONE DEPLETION POTENTIAL MEASURED?

Ozone depletion potential is expressed as the global loss of ozone due to a substance compared to the global loss of ozone due to the reference substance CFC-11. This gives ODP a reference unit of kg chlorofluorocarbon-11 (CFC-11) equivalent. The characterisation model has been developed by the World Meteorological Organisation (WMO) and defines the ozone depletion potential of different gases.

HOW WIDELY USED IS IT?

Ozone Depletion Potential is a very commonly reported impact category and features in many standard and initiatives. Organisations/standards that use ODP as an impact category include:

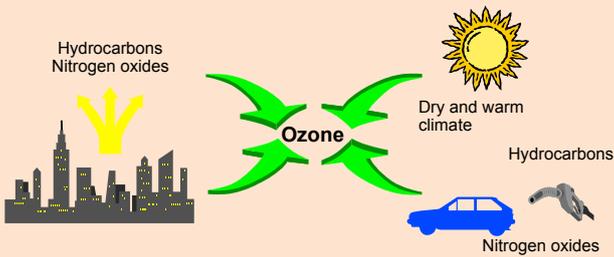
CML Baseline 2002 (NL/Global)	FDES (FR)
CEN/TC 350 (EU)	NEN 8006: 2004 (NL)
BRE (UK)	DAPc (Catalonia)

Photochemical Ozone Creation (POCP)

(Also known as: Photochemical Oxidant Formation; Smog; Summer Smog)

WHAT IS PHOTOCHEMICAL OZONE CREATION POTENTIAL AND WHY IS IT IMPORTANT?

In atmospheres containing nitrogen oxides (NO_x), a common pollutant and volatile organic compounds (VOCs), ozone and other air pollutants can be created in the presence of sunlight. Although ozone is critical in the high atmosphere to protect against ultraviolet (UV) radiation, low level ozone is implicated in impacts as diverse as crop damage and increased incidence of asthma and other respiratory complaints. The most common manifestation of the effects of high levels of POCP-contributing gases is in the summer smogs seen over large cities such as Los Angeles or Beijing. The principal source of NO_x emissions is fuel combustion while VOCs are commonly emitted from solvents, which are heavily used in paints and coatings. Both of these are highly relevant to the construction industry. As the effects of photochemical ozone vary greatly depending on the geography, climate and other characteristics of an area, companies in the construction industry should be especially mindful of POCP as an impact category in heavily urbanised areas and areas with existing air pollution problems.



POCP (Kreissig, 1999)

HOW IS POCP MEASURED?

The POCP impact category is a measure of the relative ability of a substance to produce ozone in the presence of NO_x and sunlight. POCP is expressed using the reference unit, kg NMVOC or kg ethene equivalent. Characterisation factors for POCP have been developed using the United Nations Economic Commission for Europe (UNECE) trajectory model.

HOW WIDELY USED IS IT?

Photochemical Ozone Creation Potential is a very commonly reported impact category and features in many standard and initiatives. Organisations/standards that use POCP as an impact category include:

CML Baseline 2002 (NL/Global)	NEN 8006: 2004 (NL)
CEN/TC 350 (EU)	Environdec (SWE)
BRE (UK)	DAPc (Catalonia)
FDES (FR)	

Abiotic Depletion (ADP)

Abiotic Depletion – Elements

Abiotic Depletion – Energy

(Also known as: Abiotic Depletion of Raw Materials; Abiotic Depletion Potential; Depletion of Abiotic Resources; Fossil Fuel Depletion [Abiotic Depletion – Energy only])

WHAT IS ABIOTIC DEPLETION AND WHY IS IT IMPORTANT?

Abiotic depletion indicators aim to capture the decreasing availability of non-renewable resources as a result of their extraction and underlying scarcity. As implied in the titles above, there are several different versions of abiotic depletion covering either all non-renewable resources or more particular resources such as scarce elements/ores or non-renewable fuels.

As pressure on resources increases in the coming century, the construction industry, which consumes significant quantities of resources, including metals and fossil fuels will come under more pressure financially and in legislation to manage its consumption. ADP can be a useful indicator of progress in managing resource consumption. A brief summary of the differences between the different abiotic depletion categories is given below.

Abiotic Depletion (All/Raw Materials): This impact category indicator is related to extraction of both scarce elements and fossil fuels but has been superseded by a breakdown of the impact category into two separate indicators for elements and fossil fuels.

Abiotic Depletion (Elements): This impact category indicator is related to extraction of scarce elements (and their ores).

Abiotic Depletion (Energy/Fossil Fuels): This impact category indicator is related to the use of fossil fuels as fuel or feedstock.

HOW IS ABIOTIC DEPLETION MEASURED?

The Abiotic Depletion Potential (ADP) is determined for each extraction of elements based on the remaining reserves and rate of extraction.

The ADP is based on the equation $\text{Production}/\text{Ultimate Reserve}^2$ which is compared to the reference case, Antimony (Sb). Different measures use the economic or ultimate reserve within the earth's crust. This gives abiotic depletion units of kg Sb equivalent.

Fossil Fuels were originally measured in the same way, but since 2010 have been calculated slightly differently. CML uses an absolute measure based on the energy content of the fossil fuel. This does not take into account the relative scarcity of different fossil fuels as fossil fuels are largely transferable resources, but in reality these only vary by 17% between coal (the most common) and gas (the most scarce).

HOW WIDELY USED IS IT?

Abiotic Depletion is slightly less common than indicators such as GWP, Acidification Potential, POCP or ODP. However, growing awareness of resource consumption in the construction industry has seen larger numbers of standards/EPD schemes etc reporting abiotic depletion. Some organisations/standards using an ADP indicator are shown alongside.

Abiotic Depletion (All/Raw Materials)	CEN/TC 350 (EU)
CML Baseline 2002 (NL/Global)	BRE (UK)
FDES (FR)	Abiotic Depletion (Elements)
DAPc (Catalonia)*	CML Baseline 2010 (NL/Global)
Abiotic Depletion (Energy/Fossil Fuels)	CEN/TC 350 (EU)
CML Baseline 2010 (NL/Global)	

Raw Material Use/Mineral Extraction

(Also known as: Total Material Requirement; Resource Extraction; Primary resource consumption)

WHY IS RAW MATERIAL USE/RESOURCE EXTRACTION IMPORTANT?

'Raw material use' takes account of the use of all renewable and non-renewable resources while 'Mineral extraction' accounts for all virgin mineral material consumed in a process/product/project e.g. the extraction of aggregates, metal ores and minerals.

These indicator categories generally trace resources back to the initial extraction of raw materials and include all consumption of resources up to factory gate/ completion of the project (i.e. cradle to gate). These indicator categories differ from abiotic depletion categories as they simply relate the total resource use and do not account for the relative scarcity of resources. In addition, raw material use indicators take account of renewable resources, so cover biotic as well as abiotic resources.

As with abiotic depletion indicators, raw material/mineral extraction are of significance to the construction industry due to the quantities of material involved in the production of construction products. Raw material use can be presented as an inventory list of materials required, giving more detailed information about the resources consumed than an aggregated indicator:

HOW IS RAW MATERIAL/RESOURCE USE MEASURED?

Raw material use can be measured as an absolute value in terms of mass of material used or can be displayed as an inventory list of the resources consumed. Environdec EPD require that raw material use be reported but allow both a 'total stock resources' or a complete inventory of renewable and non-renewable resources. Raw material use can also be subdivided into sub-categories covering minerals, biomass/biotic resources and fossil fuels.

The mineral extraction indicator used by the BRE is based on the Total Material Requirement (TMR) indicators used by the European Union and developed by the Wuppertal Institute, based on earlier work for the World Resources Institute. However the indicators covering fossil fuel, biomass (mainly agricultural product) and soil erosion (only covered for agriculture, not forestry) are not included. The category is measured in tonnes of mineral extracted.

HOW WIDELY USED IS IT?

A raw material or mineral extraction-style indicator is a common feature of EPD and other environmental assessments. However, construction companies undertaking such studies should be aware of differences in the reporting requirements of different organisations. Some organisations/standards using resource consumption/mineral extraction indicators are shown below:

BRE (UK)	Environdec (SWE)
RT (Finland)	CEN TC 350 (EU)
EPD-Norge (NOR)	ILCD (Global)

Toxicity

(Includes: Human Toxicity; Aquatic Ecotoxicity; Fresh Water Aquatic Ecotoxicity; Terrestrial Ecotoxicity; Marine Ecotoxicity)

WHAT IS TOXICITY AND WHY IS IT IMPORTANT?

Toxicity indicators aim to quantify the degree to which a particular substance causes damage to living organisms. There are a number of different indicators which indicate toxicity to different groups of organisms in different ecosystems. Assessments of toxicity are based on guidelines for tolerable concentrations in air and water; tolerable daily intake and acceptable daily intake for human toxicity. Substances that generally have the highest impacts in toxicity categories include heavy metals such as mercury or chromium and aromatic hydrocarbons (substances with a benzene ring). It should be noted that indoor air quality and its effect on human health is not covered by this category, but they are sometimes accounted for in a separate "Indoor air quality" category.

Issues relating to toxicity generate much debate in the construction industry and beyond. Designers should carefully review the material supplier's guidance and note any relevant regulations, codes and standards appropriate to different materials. They should also consider the context and application within which the materials are to be used to ensure that industry-specific regulations/standards are adhered to. Many of the chemicals used in society have not undergone a risk assessment and assessment techniques are still developing, something that manufacturers of construction products should also be aware of.

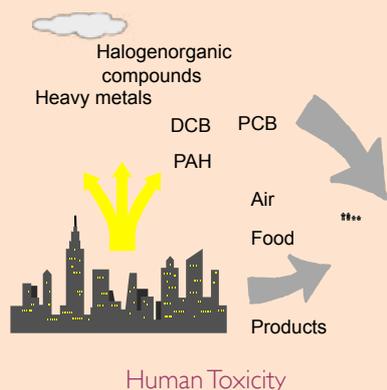
HOW IS TOXICITY MEASURED?

Toxicity Potentials are commonly calculated using the Uniform System for the Evaluation of Substances (USES-LCA), which is based on EUSES, the EU's toxicity model. This provides a method for describing fate, exposure and the effects of toxic substances on the environment. As the toxicological effect of a substance varies depending on the ecosystem or group of organisms exposed to it, Toxicity Potentials are different across the various toxicity impact categories. Characterisation factors for toxicity potentials are expressed using the reference unit, kg 1,4-dichlorobenzene (1,4-DB) equivalent (also sometimes written as kg DCB eq.).

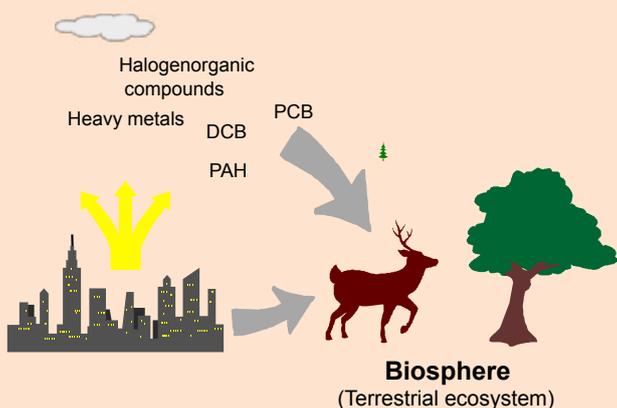
HOW WIDELY USED IS IT?

As toxicity methodologies are still evolving and, as stated above, are still the source of much debate, toxicity is less widely reported than indicators such as GWP, Acidification Potential, POCP or ODP. Organisations/standards that use toxicity indicators include:

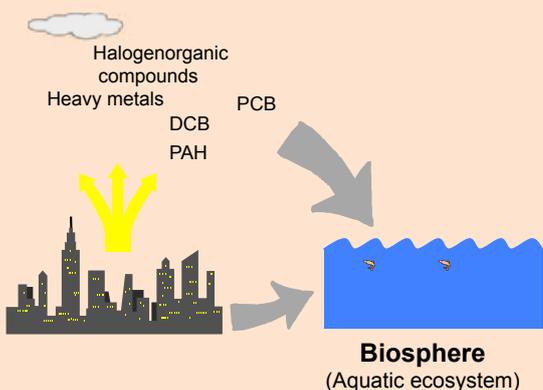
CML Baseline 2002 (NL/Global)	FDES (France)
BRE (UK)	Appeldoorn Declaration REACH



Human Toxicity



Terrestrial Toxicity



Aquatic Toxicity

Land Use

(Also known as: Land Use Change; Land Use Evolution; Land Quality Change)

WHY IS LAND USE AND LAND USE CHANGE IMPORTANT?

The way that land is used and the way that land use changes over time has significant implications on ecosystems, landscapes and the environment. Changes in the qualities of the soil in terms of nutrient content, pH, soil depth (i.e. due to erosion) or water filtration have knock-on effects on biodiversity, food production and land values. Therefore, land use is a true sustainability issue as it covers social, economic and environmental issues.

Land use indicators, however, are still in their infancy and no single established standard has emerged. While the effects of many indicators are acknowledged to be regional, the effect of land use change can change over very small distances complicating the quantification of land use. Similarly, loss of biodiversity, an important measure of the effect of land use change, is hard to quantify effectively - "Species Richness" a common biodiversity indicator takes no account of the abundance of different species, however, any attempt to categorise species as more important than others are likely to be very controversial.

Land use change is highly relevant to the construction industry as most construction projects will result in direct land use change. In addition construction products/projects consume significant quantities of products from mining and quarrying, which represent some of the most dramatic examples of land use change. As a result, land use indicators are likely to become relevant to construction companies in the near future, as efforts to standardise methodologies and incorporate land use into current assessment methods bear fruit.

HOW IS LAND USE CHANGE MEASURED?

Land use indicators generally fall into two categories: those that capture the occupation/type of land use and those that capture changes in land quality.

The first category is usually measured as type of land use over a given time (e.g. industrial, forestry, mining, agriculture) or the change with time of the distribution of land uses for a given area. These measures will have units that express the area occupied by a particular type or percentage/area changes for a land use type.

The second type of indicators (land quality) generally take the form of a suite of sub-indicators of soil quality or biodiversity. Indicators in this category include: diversity/density of vegetation cover; thickness of topsoil, erosion resistance, nutrient richness (biotic production), soil filtration ability, groundwater indicators, species richness and species diversity.

HOW WIDELY USED IS IT?

Given the complexities outlined above, land use remains a relatively uncommon indicator in construction product assessments/initiatives. Where land use is included, simple, but less detailed, 'occupation' or 'land use type' indicators are used.

ILCD (Global)

BPIC Aus LCI (AUS)

Embodied Water

Associated Terms: Water consumption, Net Fresh Water consumption, Water Balance, Water Accounting, Water Footprint

WHAT IS EMBODIED WATER AND WHY IS IT IMPORTANT?

Fresh water resources are coming under increasing pressure from population growth, rising per capita water use, urbanisation and increased industrial activity and the effects of climate change.

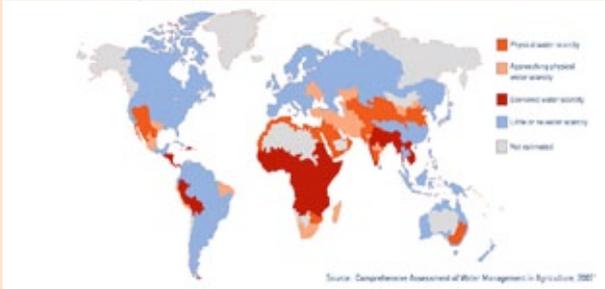
Embodied Water begins to consider the effect of man's activities on water, for example in reducing availability.

In parallel with carbon management and reporting, water reporting is emerging as a headline indicator on a corporate and product level. Effective water reporting creates an indispensable instrument to meaningfully inform business decision making and drive performance improvements on the multiple levels of strategic, corporate and product business opportunities. However, there are many ways in which water can be reported.

Before the current widespread interest in water footprinting, the construction industry, through the various EPD schemes across Europe, developed a concept of embodied water associated with construction products.

Traditionally embodied water refers to the cumulative quantity of water used to produce a product through the supply chain, as originally proposed by Allan in 1993³⁶, although there are still various different interpretations.

As the impacts of water use have very different implications depending on where and how it is used, an aggregated measure of total water used (e.g. as embodied water quantified in m³) does not provide a truly meaningful indicator for environmental assessments and profiles of products such as those for construction, which are sourced from many different geographical regions and in the case of timber, consume water over long time periods. [For example: The 140 litres of water required to produce one cup of coffee³⁷ might be of no harm to water resources if the main requirement for water was from cultivation occurring mainly in humid areas with high rainfall, but it could be damaging if it were mainly from demand in more arid areas.]



Global water scarcity map (FAO 2007)

³⁶ Allan, J.A., 1993. Fortunately there are substitutes for water otherwise our hydropolitical futures would be impossible. ODA, Priorities for Water Resources Allocation and Management. ODA, London, pp. 13–26.

³⁷ www.waterfootprint.org/?page=files/CoffeeTea

HOW IS EMBODIED WATER MEASURED?

Until recently, there has been little consistency in measurement of embodied water, or the use of terms such as water accounting, water footprinting, water use or water consumption. Work is now underway to standardise these activities.

Within the construction industry, most existing measures used in EPD consider water use, taking into consideration water which is moved from one state or location to another, but ignoring water which is returned to its original source, such as river water which is extracted for cooling but then returned to the same river. However there are differences, for example, in terms of how they treat water taken from a river and returned to the sewer, water used to generate hydroelectricity, or ground water returned to surface water. EPD may also report water related impacts addressing the effects of water pollutants, for example eutrophication and toxicity.

- **Water Use.** This is the amount of water withdrawn for use in a system.
- **Fresh Water Consumption.** This is the amount of water withdrawn from ground- or surface water that does not return to the water catchment area from which it was withdrawn – examples might be because of evaporation, return to another catchment or incorporation in a product..
- **Water Accounting.** Water accounting is generally understood as an umbrella term denoting both the measurement, management, and reporting of water use and wastewater discharge, and the identification and assessment of water-related business risks and impacts.
- **Water Footprinting .** The development of the international water footprinting standard, ISO 14046, currently suggests 3 types of water footprints:
 - **Water availability footprint** – a measure of water consumption also taking into account the underlying scarcity (and sometimes quality) of the water consumed.
 - **Water Footprint Profile** – a group of water related indicators, covering, for example water availability, eutrophication, toxicity etc. provided to give an overall picture of the water-related impacts.
 - **Weighted Water Footprint** – a single score indicator derived from the indicators within a Water Footprint Profile.

In contrast, the water footprint from the Water Footprint Network (WFN) represents a scheme classifying different water types (including water consumption) purely on the accounting level, i.e. inventory level. As such, it does not include any assessment of related environmental impacts within the water footprint definition, although this type of assessment can be undertaken using the output of a WFN Water Footprint. The WFN defines surface and groundwater use as blue water use and rainwater use as green water. Water pollution is termed grey water and expressed as the theoretical dilution volume with which polluted water should be diluted to reach regulatory emission limits.

WHAT METHODS AND TOOLS ARE AVAILABLE?

Methods

The developing **ISO 14046 Water Footprint standard** which is currently in its second working draft version builds on the ISO 14000 family of life cycle standards. The ISO 14046 draft specifies requirements and guidelines to assess and report the water footprints of products and processes as well as organisations, and is based on the requirements of LCA. In contrast to the WFN water footprint definition, the ISO Standard will go beyond just determining the water inventory by also evaluating the environmental relevance of each water inventory flow as part of the water footprint. The publication of the standard is expected in 2013.

Tools

To facilitate an adequate and robust accounting of water use and consumption in the construction sector, only a few databases are currently available. The GaBi and ecoinvent life cycle databases, for instance, both provide data on water use in the production of a multitude of building and construction materials and processes. These data differentiate various water resource types including among others lake, river, ground, sea and rain water.

Environmental Product Declarations and Developing Standards

While most established EPD schemes already consider water use, none currently meets the developing approach of ISO 14046, which specifically quantifies the net water consumption in addition to total water input. A comparison of these EPD schemes's treatment of water with the ISO 14046 requirements as outlined in the second working draft is contained in the primary document, along with the approach of the CEN/TC 350 Standard, EN 15804.

References and links

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- UNEP & SETAC LC Initiative, Communication of Life Cycle information in the building and energy sectors, 2008
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- BIS, Low Carbon Construction IGT Final Report, 2010:
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- BIS, government response to IGT Final Report
www.bis.gov.uk/assets/biscore/business-sectors/docs/111-976-low-carbon-construction-action-plan.pdf
- BRE Environmental Profiles Methodology (free)
www.bre.co.uk/greenguide/page.jsp?id=2081
- RICS: Redefining Zero (free)
www.rics.org/site/scripts/download_info.aspx?fileID=6878
- WRAP Low Carbon Procurement
- IStructE, A short guide to embodied carbon in building structures:
<http://shop.istructe.org/a-short-guide-to-embodied-carbon-in-building-structures.html>

Tools

- Environmental Profiles are available at www.greenbooklive.com where their LCIA and Green Guide ratings can also be viewed.
- Environment Agency Carbon Calculator for Construction
- Invest2
<http://invest2.bre.co.uk/>
- GaBi Build-IT (German)
- Elodie www.elodie-cstb.fr/ (French)
- LISA (Australian) www.lisa.au.com
- LCADesign (Australian) www.ecquate.com/
- The Technology Strategy Board Low Impact Buildings “Design and Decision Tools” call is funding 12 projects, many of which will calculate embodied CO₂
- EU funding CILECCTA project linking LCA, LCC and BIM



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