

# **SKILLS Project - SUSTAINABILITY**



# **Sustainability**



## **FOREWORD**

This publication is ...

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## **SUMMARY**

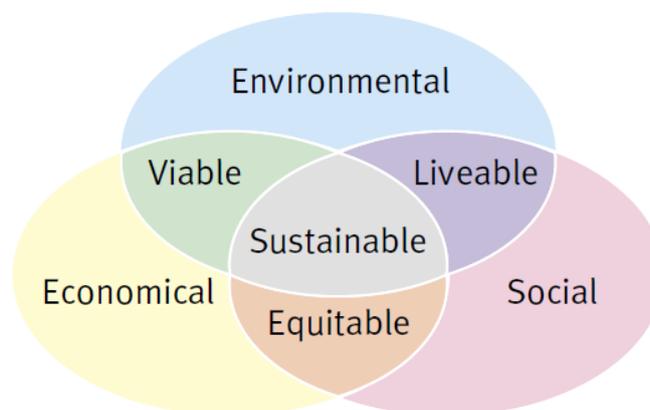
For centuries, steel has demonstrated all its advantages as a construction material for use in famous buildings in the world, but steel is not only a material that delivers technical prowess. It has so many qualities that simply make it the preferred material of architects, especially for multi-storey buildings. This publication has been drafted by architects for architects. It provides information on the material and on the industrial components. It gives the bases of good practice in order to achieve maximum benefit in using steel, in terms of structural behaviour of steel frames, the building envelope, acoustic and thermal performances and sustainable construction

# 1 SUSTAINABILITY IN CONSTRUCTION

The preoccupations of the sustainable development are of particular concern for the construction sector, which is responsible for 25% of greenhouse gas emissions and for 40% of the primary energy consumption. They constitute a major stake for all the involved professionals.

## 1.1 Introduction to sustainability

General principles are established according to three main considerations: ecological, economical and socio-cultural, although all the methods for determining their impact have not been agreed on an international scale.



**Figure 1.1 three constituent parts of sustainable development: the 'triple bottom line'**

During the whole life cycle of a construction, the sustainability of buildings concerns a range of topics related to choice of materials, construction process, occupation and end of life. Those items may be expressed in terms of specific criteria, such as:

- Efficient use of materials,
- reduction of primary energy use (and CO<sub>2</sub> emissions),
- waste minimization,
- pollution,
- other global impacts, coupled with more social issues related to reduction of transport,
- Improvements in quality of life, well-being and biodiversity.

## 1.2 Steel, overview of the material

It is a question today of designing and of realizing creative projects which integrate values and new techniques. Steel is the mainspring in our quest to improve the quality of our buildings and their impact on our living environment

### 1.2.1 Strengths of steel for construction

The excellent weight-resistance ratio of the material offers incomparable constructive and architectural possibilities. This performance opens the way to the reducing the weight in buildings, using thin walled structures in the façade. These features offer a large amount of space with light and vast possibilities for architectural integration.

The range of qualities opens the architectural choices and allows the optimized selection of the processes, the materials and the methods of construction, especially by considering the global life of the building to be realized up to its demolition.

For the envelope, the metallic construction is generally designed with an external thermal insulation; walls are built from industrialized systems, metallic or not (glass, wood, concrete, terra-cotta, plaster, etc.), which offer a lot of solutions for each project.

The association of steel with other materials offers many efficient solutions for thermal and acoustic insulation.

### 1.2.2 Environmental aspects of steel

Steel is an excellent solution for conserving raw materials, thanks to its capability to be infinitely recycled without losing its own properties.

Today, the production of steel in Europe consists of 50% recycled metal, reducing the need for ore; for certain products intended for construction, this rate can reach up to 98%. This re-use of the material is in particular made possible by its magnetic properties facilitating the sorting.

For 25 years, the control of energy and the reduction of CO<sub>2</sub> emissions during production have led to vast improvements in developing new steel materials and taking into account life cycle of materials and products. The European steel industry has substantially contributed to the energy efficiency and the reduction in CO<sub>2</sub> emissions.

Between 1970 and 2005, the European steel industry reduced CO<sub>2</sub> emissions by 60%; between 1990 and 2005, this reduction was 21% (Eurofer). In the same period, crude steel production increased by 11.5% (Worldsteel for EU15).

Other solutions are already underway to improve these results.

Steel is a neutral material which emits no polluting substance or element that is harmful to the environment or health, even under the influence of corrosion.

Galvanizing and painting (carried out in the factory) are corrosion protection systems that guarantee the durability of steel up to 25 years.

Maintenance of steel is limited to regular follow-up and periodic painting

For buildings there are several environmental initiatives across Europe. These approaches can be quantitative or qualitative, using variable criteria. However, some subjects are common, but with different treatments, for which steel solutions bring firm answers.

*The harmonious integration of the building with its surrounding environment*

The choice of a steel frame for a building project allows the designer a large freedom of shape and the flexibility to adapt work to the constraints of the site.

Used for façades or roofing, steel products offer the architect a range of textures, geometries and colors to respond to the most sensitive and the varied of contemporary sites, whether a historical city centre or in the countryside.

*Lightness of the structures and the flexibility of spaces*

A frame made with columns and beams is typical in steel buildings. Without load-bearing walls, the construction is lighter; the impacts on the foundations and the ground are lesser.

It is also easier to remodel internal spaces according to the changes of use.

A structure with connected components is an efficient solution for vertical extensions as well as in the renovation of an existing building.

*Less on-site problems*

Steel products and associated elements are industrially made, of high precision. They are delivered with accurate dimensions for on-site assembly. Due to the higher level of pre-fabrication, implicit in steel-intensive constructions systems, speed of construction is increased.

The construction site is transformed, with reduced deliveries, precise and appropriate assembly, less storage and no waste.

*Maintenance*

Steel solutions provide durability and facilitate cleaning and replacement of components.

Services (fluids, ducts, etc) are generally placed in the ceiling void. The maintenance and the possible reconfiguration of the services are then facilitated, especially in the presence of cellular beams. This flexibility allows the different levels to be completely refitted.

At the end of life, the demolition consists of a clean dismantling, for a complete recovery of materials.

*Re-use of steel profiles*

In Western Europe, a study has shown that about 11% of profiles in the construction sector are directly reused after demolition, without remolding.

*Creating a safe and comfortable internal space*

All combinations of wall components can be accommodated.

Steel solutions in combination with additional products contribute to the excellent sound insulation through the ‘mass-spring-mass’ principle.

For thermal comfort, steel allows the design of ‘evolved’ façades, adapted to the various climatic conditions:

- Double-skin façades, implementation of a layer of ventilated air,
- Fixed or mobile solar control mechanisms

*Integration of alternative technologies on steel buildings*

Alternative Energy Technologies (AET) are integrated into building design for a wide range of reasons but typically the primary motivators are green aspirations and planning restraints such as 'Grenelle', which will require a certain percentage of a building's energy consumption to be provided by additional benefits from using AET, including renewable energy. AET provide environmental benefits over the use of standard energy supply. Moreover, they have a very low impact on steel buildings. The main concerns for AETs implantation are:

- Plant Room: The location of the plant room and spatial restrictions can impact on the viability of specific technologies
- Shading: the shape of the new building may restrict the location of solar PV panels.

Roof Orientation: The orientation and the shape of the roof can be a limitation on energy output, for either solar hot water collectors or photovoltaic panels.

Reliability: If an unproven technology is used then it may not be reliable and so the desired carbon savings cannot be made.

## 2 FOCUS ON STEEL ADVANTAGES FOR SUSTAINABLE CONSTRUCTION

Since the 2<sup>nd</sup> of July 2013, the new construction products regulation (305/2011/EC) introduces a new basic requirement for construction works, number seven, dealing with 'sustainable use of natural resources'.

It means the construction works must be designed, built and demolished in such a way that the use of natural resources is sustainable and in particular ensure the following:

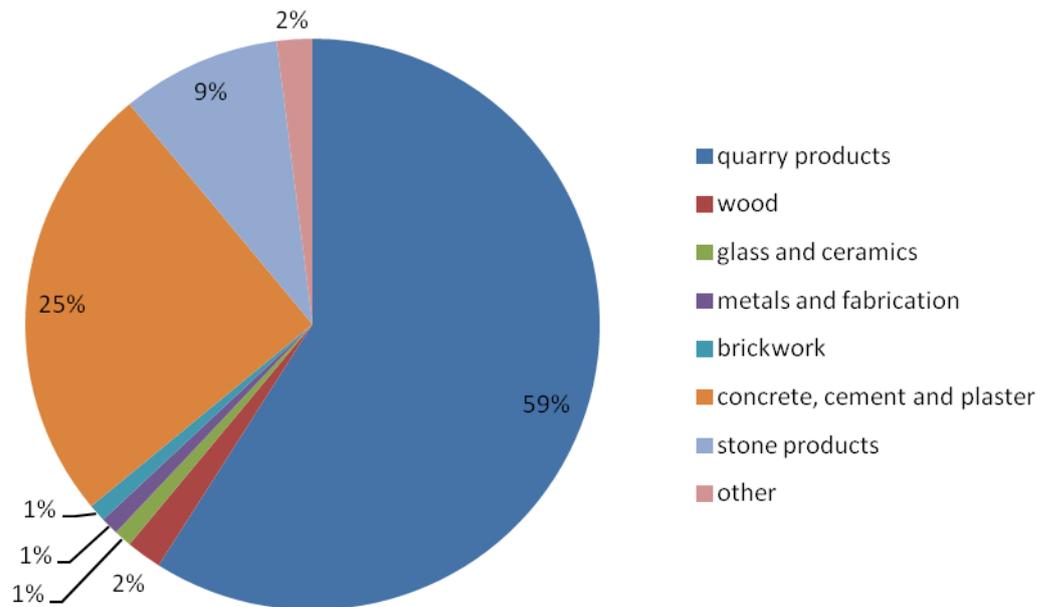
- a) reuse or recyclability of the construction works, their materials and parts after demolition;
- b) durability of the construction works;
- c) use of environmentally compatible raw and secondary materials in the construction works

This chapter is focusing on information about steel that giving part of answers.

### 2.1 Material and resources

Construction is one of the major users of materials and resources. That is why it is important to minimise their use and to maximise their recycled content. All steel production has a high recycled content from scrap.

- Construction industry uses 3.5 tons of materials per person per year (average cross Europe),
- The recycled content is more than 50 % for all type of steel products and can attempt more than 90% for construction's component, such as sections,
- In low-rise buildings, a typical steel framed weighs approximately 1/6 of that of a concrete structure,
- In multi-storey buildings,, the weight of a primary steel structure (composite floor) is only 50% of that of a reinforced concrete structure and floor slab.
- All steel components can be recycled or re-used which reduces primary material resources



**Figure 2.1** Materials use in all aspects of construction, including production and civil engineering (refer to CIRIA report, UK)

Concerning sustainable construction, it is common to read values for the best known indicators as primary energy or global warming potential linked with a given tonne of product. It is standard practice to express the carbon dioxide emissions associated with material production on a per tonne basis (as shown in the table 2.1).

**Table 2.1** typical values of primary energy and CO2 for crude steel

	Plate	Sections	Tubes	Hot-dip galvanized	Purlins & rails
CO2 (tonnes per tonne of steel)	0.919	0.762	0.857	1.35	1.1
Energy (GJ per tonne of steel)	17.37	13.12	15.42	21.63	19.38

*Worldsteel values provided by TataSteel,*

This may give the impression that steel has higher impacts than other construction products. However, steel has a higher strength-to-weight ratio than most other structural materials meaning that one tonne of steel goes much further. As a result, the CO<sub>2</sub> emissions associated with any steel building will be lower.

Steel buildings are sufficiently lightweight that they can be constructed on poor ground and former ‘brownfield’ sites.

## 2.2 Waste

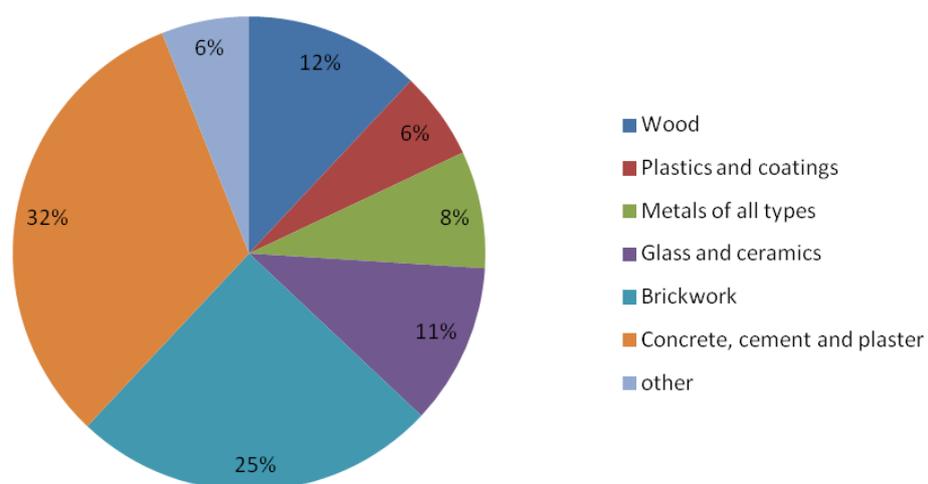
Waste in the unusable parts of the manufacture and construction process end refers to both recyclable and non-recyclable materials and products.

Since the 31th march of 2011, a Council Regulation (2011/333/EC) establish criteria determining when iron and steel scrap shall cease to be waste, under Directive 2008/98/EC of the European Parliament and of the Council, upon transfer from the producer to another holder. Some conditions have to be fulfilled, especially if they meet the technical requirements of the metal producing industry, comply with existing legislation and standards applicable to products and do not lead to overall adverse environmental or human health impacts.

Steel construction minimises waste in manufacture and on site, and all steel can be re-used or recycled at the end of the building's life.

- Construction industry produces 0.5 tons of waste per person per year (excluding quarry waste),
- 98 % of steel from demolition projects end 100 % of scrap steel in factory production is recycled,
- The quality of steel is not reduced by the recycling process,
- Pre-fabrication of building components means that waste on site is greatly reduced.

Globally, the construction industry produces 20 % of all the waste produced across the EU – amounting 180 millions of tons p.a., and a high proportion of this is sent to landfill. The approximate breakdown of wastage in materials in construction is illustrated below. The largest proportion of wastages is in cement products (32 %) and brickwork (25 %).



**Figure 2.2 Waste produced from construction materials (excluding quarry products)**

Across Europe, an average of 10% of all materials used on construction sites are wasted and over 60 % of this waste is sent to landfill, as the opportunities

for recycling on site and often limited. Waste includes off-cuts of boards, cut bricks, damaged components, packaging, etc.

**Table 2.2 Wastage rates of materials on construction sites**

	Wastage rate	Proportion sent to landfill
Timber formwork to concrete	13%	45%
Concrete	10%	50%
Cement-fiber roofing	10%	100%
Insulation boards	10%	90%
Timber flooring	7,5 - 10%	45%
Mineral wool	8%	100%
Plasterboard	7,5 - 10%	90%
Softwood	10%	45%
Plaster	5 - 10%	90%
Brick and blockwork	5%	50%
Tiles for roofing	5%	70%
Glass	5%	65%
Reinforcement	5%	5%
Light steel framework	2,5	Negligible
<b>Average wastage of materials</b>	<b>10 - 13%</b>	<b>60% estimated</b>

Data from Building Research Establishment, UK

Steel wastage is effectively eliminated by the efficient use of materials in factory production, and all steel off-cuts and drill are sent for re-cycling back into new steel components.

## 2.3 Transport

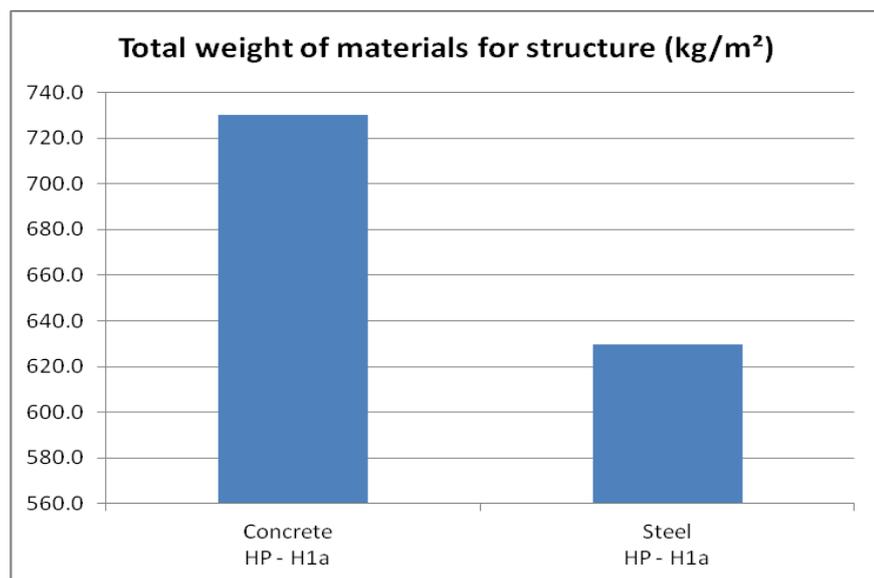
Transport of materials and personnel to construction sites is responsible for 10 % of all vehicle movements across the EU, and 40 % of the energy used in construction is related to the transport of materials and products. Steel construction can reduced these impacts, as follows:

- Steel is pre-fabricated into frames and modules that are transported as completed components on building site,
- Deliveries to site can be timed to suit local traffic conditions and thus not increase local congestion,
- Fewer workers on site means fewer journeys to site and car parking locally,

- Transport of pre-fabricated components is reduced by over 70 % relative to materials in block-brick or concrete construction,
- Minimal transport of waste to landfill sites is achieved by off-site construction

The pre-fabricated nature of steel construction means that deliveries of relatively large components can be made ‘just-in-time’ to suit local traffic conditions, rather than requiring many smaller deliveries of materials.

It is estimated that the total vehicle movements related to highly pre-fabricated steel construction are reduced by up to 70 % relative to site-intensive concrete or masonry construction, which potentially reduces embodied energy due to transport by the same proportion.



**Figure 2.3 Example of comparison of weight between structural solutions - concrete vs steel for a current office building**

Sustainability is also linked to the proximity of the transport infrastructure and availability of public transport systems. Steel construction leads to more flexible use buildings which can be designed to promote a ‘live-to-work’ environment.

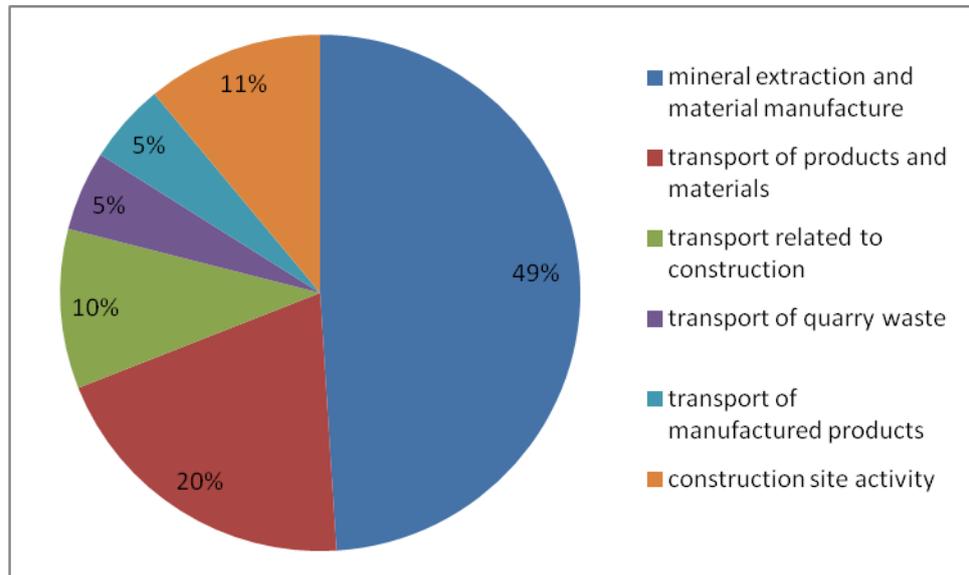
## 2.4 Energy

The most effective way of reducing energy consumption in buildings is by reducing operational energy by good energy efficient design and facilities management.

- Housing is responsible for 27 % of the EU’s total energy consumption and a typical house produces 1.5 tonnes of carbon per year (as CO<sub>2</sub>),
- Steel frames can be designed to be highly insulating with U values as low as 0.15 W/m<sup>2</sup>.K although 0.25 W/m<sup>2</sup>.K is more typical,

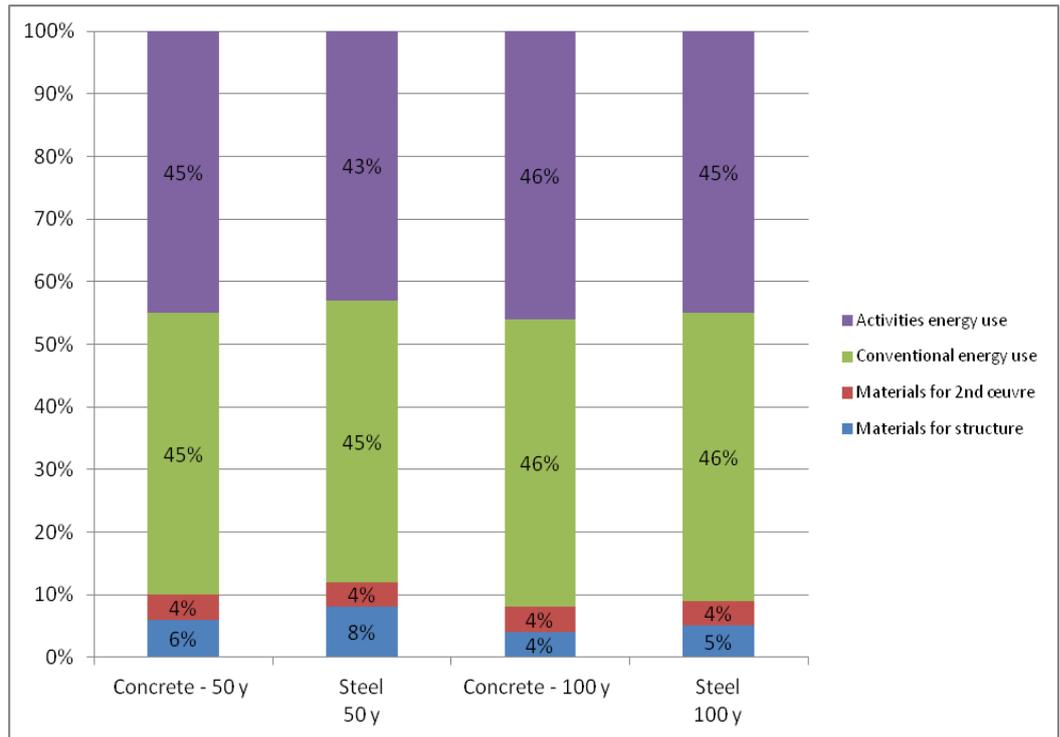
- Air-tightness is much better in highly insulated steel framed buildings than in traditional buildings,
- The heating and ventilation systems can then be chosen for optimal energy behavior,
- Renewable energy systems, such as photovoltaic, can be introduced easily, only depending on the building shape.

11% of energy used in various construction activities is related to on-site construction, in comparison to 40 % on transportation and 49 % on minerals extraction and manufacture. Steel construction requires of course less on-site energy and transport of components to site is particularly optimised.



**Figure 2.4 Energy used in the construction sector by activity**

Life cycle studies show that over 50 year design life of a typical residential building, the operational energy (due to heating, lighting, etc) is 7 to 10 times higher than the embodied energy of a structural material. Therefore, it is more important to design to minimize energy used and energy lost through the building envelope.



**Figure 2.5 Comparison of primary energy consumption for main items, according to two life durations: 50 or 100 years**

Concerning the example represented in figure 2.5, envelop of building was designed to attempt requirements of thermal regulation (RT2005), as a low-consumption building. Those impacts distribution on the global scope shows clearly that energy consumptions of life in work represent more than 80 % of the total primary energy consumption.

The European Directive on ‘energy performance of buildings’ (2010/31/UE) confirms requirements related to national regulations in each European country for the aim of reducing primary energy use and CO<sub>2</sub> production by 20% (relative to 1990 figures) in 2020. Locally implemented, the improvement of thermal insulation and air-tightness control are the main ways of change. Thus, steel facades and roofs can be designed to be highly insulated and air-tight and reduce primary energy demand by up to 70 % relative to traditional buildings.

Renewable energy systems can be introduced to potentially create ‘zero energy’ buildings that achieve energy balance with respect to external energy demand.

## 2.5 Minimising pollution

The reduction of pollution in construction, in use and in dismantling operations is dependent on careful selection of materials and processes, such as the use of pre-fabricated ‘dry’ steel construction technologies.



From several years, the steel construction industry has effectively eliminated the risk of pollution in manufacture and in on-site processes.

- Steel is an inert material which does not deteriorate in internal environments,
- Pre-fabricated steel components are produced in factory-controlled conditions using energy saving and pollution-reducing technologies,
- Thanks to the ‘dry’ construction system, pollution on site is eliminated,
- Transport pollution is minimised by fewer deliveries and daily worker travel to the building site,
- Steel is not combustible and does not produce fumes in fire.

Steel construction has minimal impact on construction site, because manufactured components are delivered ‘just-in-time’ when required.

Water is used by steel producers to cool components during the process: all this water is re-cycled and re-used.

Waste materials, such as blast-furnace slag, are further refined to be used as a cement replacement or road sub-base.

## 2.6 Performance and quality

Steel construction is high quality with good performance characteristics in comparison to use of traditional materials.

Performance and quality are dependent on the longevity and aesthetics of the completed building, and on the nature of the building process.

- Longer spans can be achieved leading to more adaptable space for current and future use,
- No cracking or long term movement due to shrinkage occurs, leading to fewer maintenance problems,
- Steel has a long life and is robust to damage,
- Performing acoustic insulation of floors and walls is available,
- High levels of thermal insulation are achievable, leading to reduced heating costs,

In terms of construction technology:

- Steel is manufactured to guaranteed high strength properties and is accurate in its geometry and on site construction,
- Construction programmes using steel technology are reduced by 30 to 70 % compared to traditional building, leading to earlier return on the investment and reduced site costs,
- Connections and attachments can be simple and easy to reach, thus foreseeing future adaptations and extensions.

For equivalent loads, steel components of frame are quite smaller than of traditional materials, directly offering raw materials reduction.

About aesthetics, building forms can be designed in very wide and free range, thanks to the different shapes and types of steel components. Often using highly pre-fabricated elements, many solutions are provided for balconies, penthouses, walkways and other attachments.

## 2.7 Durability

The quality of a construction is also reflected by the conservation of its functions during the life cycle, which first consequence is the durability for steel components.

Durability means duration of use of the building, that it must be set by the client, according to the environment conditions.

It is essential to adapt the degree of protection to the conditions in which the steel construction elements are installed. There are two main forms of protection:

- Painting,
- Galvanizing

**Table 2.3** typical values for galvanizing of 1 kg of steel to EN ISO 1461

CRITERIA	Traditional Brick/block construction
Gross energy	3.4 – 5.3 MJ
Global warming potential	0.1 – 0.33 kg CO2 equivalent

*Based on a review of existing LCA studies. Values excluding steel burdens and recycling credits.*

In each way of protection, the principle is the formation of protective layer. It is important to note that the steel frame buildings do not generally suffer major damage as a result of atmospheric corrosion. Moreover corrosion is not an issue for internal steelwork.

## 2.8 Health and well-being

Flexibility, efficiency and functionality for spaces are provided by steel framed buildings, which prove beneficial in industrial and retail buildings as well as office buildings.

Because, people spend an average of 90 % of their lives in buildings in EU, health and well-being are crucial points.

- Functional and adaptable spaces is provided, leading to a ‘live-work-play’ environment,
- Steel framed buildings with high levels of thermal insulation are comfortable and pleasant places in which to live and work,
- Acoustic insulation, even high level of performance, could be suited with steel technologies and well-associated materials,

In terms of construction technology:

- Noise, dust and pollution are dramatically reduced on the building site which benefits neighbouring properties.

By the year 2020, the indoor air quality is one of main stake; steel as inert material provide an answer to this new issue.

## 2.9 Social issues

Steel construction contributes to an improved built environment and to a better standard of a ‘live-work-play’ place by the design of more functional buildings that are adaptable to future demands.

Social issues of sustainability relate to broader aspects of how people interact with buildings, and the cultural legacy of the built environment, as well as sustainability of employment and skills levels.

- High quality and long-life buildings are achieved which improves comfort and user satisfaction,
- Flexibility in use is important in many office and public buildings,
- ‘mixed-use’ steel framed buildings provide public space at ground floor level and may be combined with below-ground parking.

In terms of construction technology:

- Steel fabricating and installation processes are very safe in comparison to site-based operations.

In terms of the manufacture:

- Productivity and working conditions are greatly improved in the factory and on the construction site relative to traditional building,
- Jobs are ‘highly skilled’ and require training and qualifications. Excellent job opportunities are maintained,
- Pressure on landfill sites due to wastage of materials is dramatically reduced.

## 2.10 Practice of sustainability with steel

According to new Construction Products Regulation, Environmental Product Declarations should be used when available for the assessment of the sustainable use of resources and of the impact of construction works on the environment.

### 2.10.1 Environmental product declaration

An Environmental Product Declaration (EPD) is now a widely developed approach for construction products. Based on EN 15804, the overall goal of an EPD is to provide relevant, verified and comparable information to meet various customer and market needs.

Using life cycle assessments, the steel industry has already provided several EPD for generic products as well as branded systems. The energy and lighting consumption during service life exceeds the embodied energy in the structure.

### 2.10.2 Environmental performance of buildings

The EN 15978 European Standard specifies the calculation method, based on Life Cycle Assessment (LCA) and other quantified environmental information, to assess the environmental performance of a building, and gives the means for the reporting and communication of the outcome of the assessment. This text describes the system boundary, the list of indicators and, for the calculations, gives procedures and requirements for the required data.

Globally for a construction product as well as a building, the life cycle includes a series of major stages, composed of sequences (as shown in figure 2.6):

- Product stage (A1 to A3),
- Construction process stage (A4 and A5 steps)
- Use stage (B1 to B7 )
- End of life stage (C1 to C4)

The D module is dealing with ‘benefits and loads beyond the system boundary’, that means re-use or recycling potential: one of the great advantages of steel!

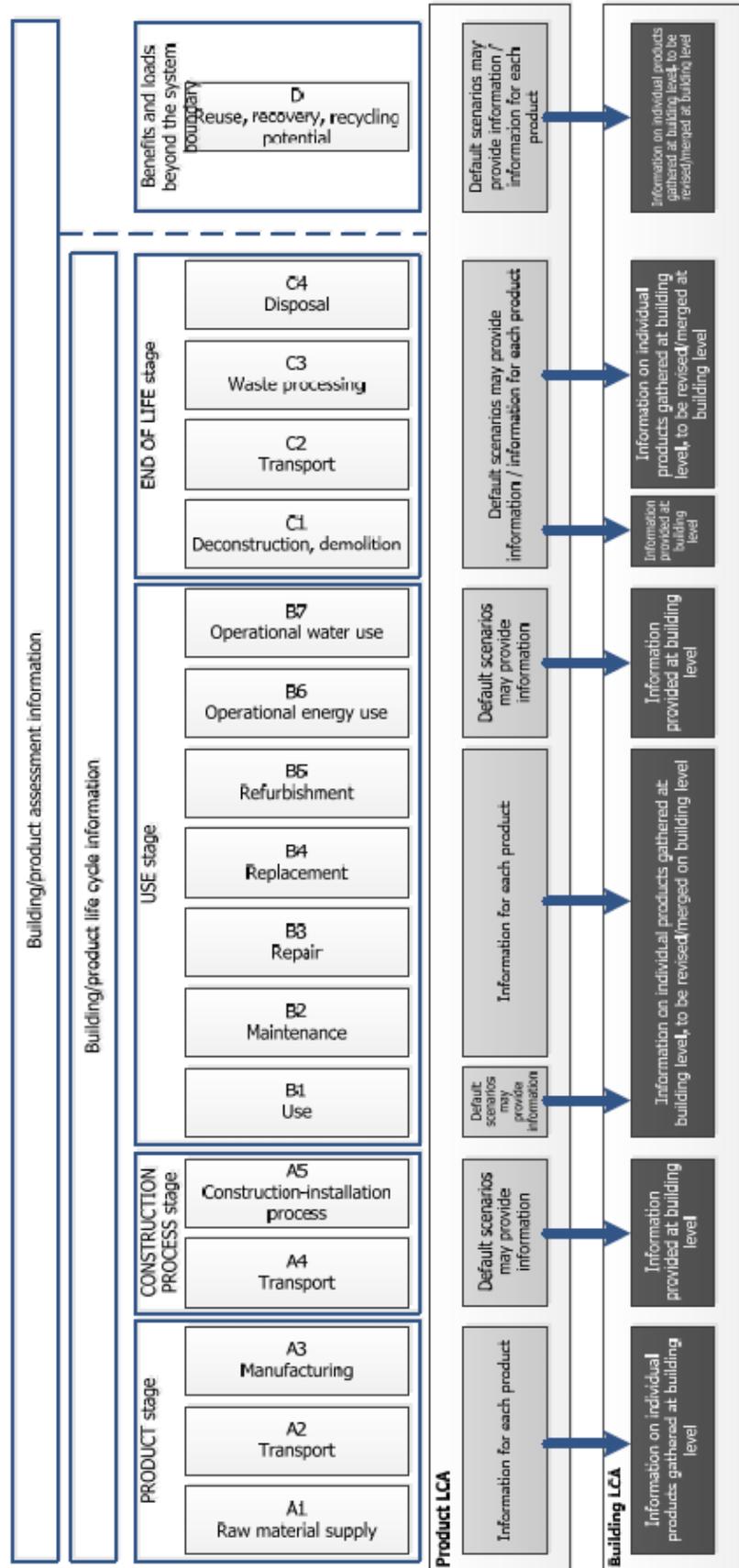
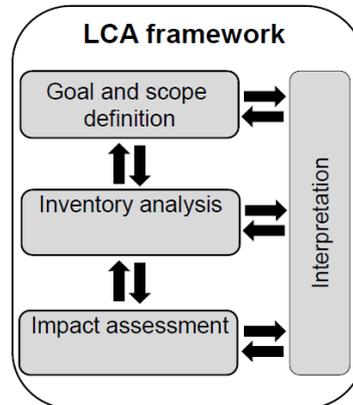


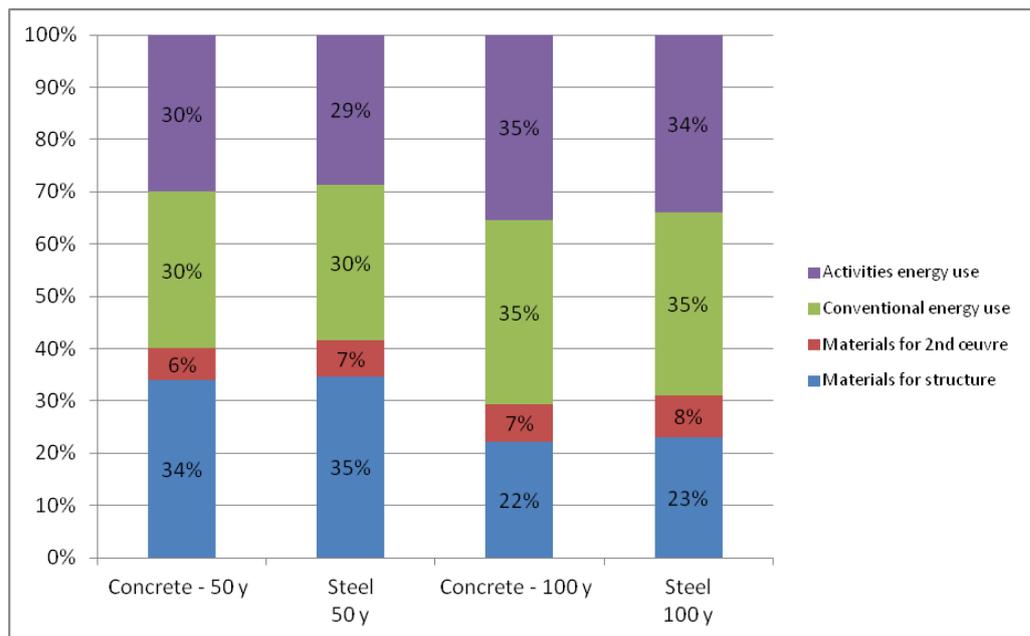
Figure 2.6 Relation between product LCA and building LCA along the life cycle modules, based on EN 15804 and EN 15978

### 2.10.3 Life cycle assessment studies of buildings

The use of previous information leads to LCA study. This type of approach follows general rules of ISO 14040 and ISO 14044, which define following phases and framework:



One of the direct applications is often to compare two buildings or part of them. The next example is extracted of an assessment that focuses on environmental impacts related to frame.



**Figure 2.7 Comparison of global warming potential (CO2 impacts) contributions for two types of frame, considering two life durations: 50 or 100 years**

At the end, various environmental certification approaches have been developed, such as BREEAM in UK, LEED in the USA, DGNB in Germany or HQE in France, which provide a rating system to assess the impact of a project in terms of sustainability. At the heart each of these systems is the calculation of consumption and operational processes.

Target audiences are property managers, portfolio owners, facility managers and tenants. But also architects, designers and some users want to consider the impact that construction materials and products have on the environment.

Across Europe, more than 5 700 certified buildings are listed in 2012 (source GreenBuilding) for those four methods. Existing for several years, many examples made of steel have been well rated in all sectors: residential, commercial, industrial or public.

#### **2.10.4 Social and economical impacts**

A recent European standard (EN 15643) is dealing with sustainable assessment of buildings, especially focus on social and economical impacts. Since 2012, each of those items has their own standard that defines the framework for the assessment of performances.

### 3 Key drivers for steel construction

Typical key factors, which influence the use of steel in construction and are linked with sustainability approach, may be classified under the headings of:

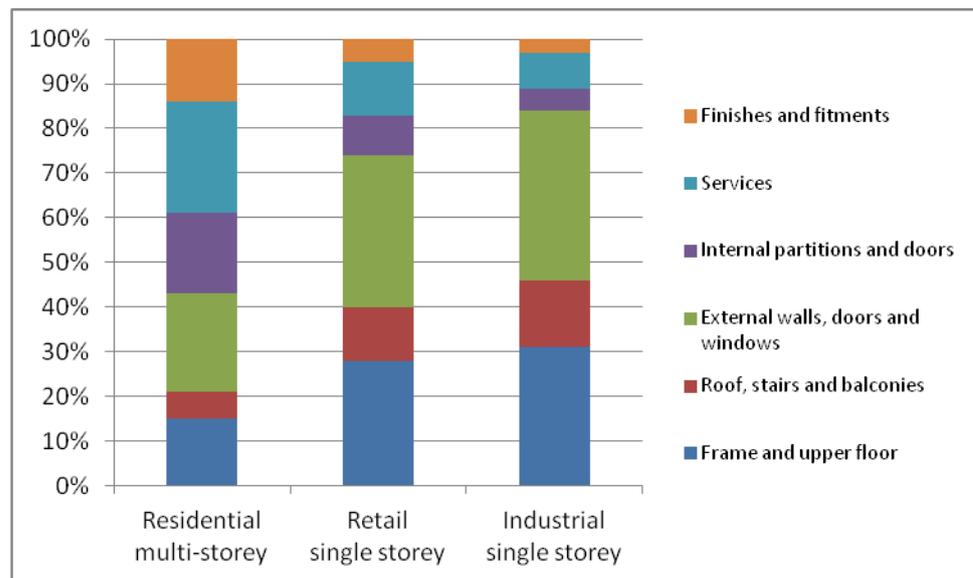
#### COST

Cost of construction is related to use of materials, labour, specialist components, equipment and machinery, and design time.

Steel construction achieves higher levels of productivity and therefore labour costs could be optimised both in the factory and on the construction site in comparison to masonry or concrete construction.

Speed of construction and safety are increased by the higher levels of pre-fabrication implicit in steel-intensive construction systems.

The cost of the steel framework is typically only 12-15 % of the as-built cost for a residential building, and therefore it is the influence of the choice of structure on the other building parts and on the speed of installation, which are dominant contributory factors in achieving savings in the construction process.



**Figure 3.1 Breakdown of construction costs for different types of typical steel-framed buildings**

Life cycle costs also recognise that the operational costs are 100 times more than the construction costs over a 50 year life. So, it is operational benefits in use which are the main target.

#### QUALITY

Quality is related to performance, reliability and design elegance, which are more difficult to assess than economic-related factors. Initial requirements expressed by the client and type of use for the project are also decisive elements to satisfy users of the building, which also means ‘quality’.

However, contractor's costs due to minor repairs, such as cracking and shrinkage caused by drying out of materials, are essentially eliminated using dry construction technologies in steel, leading potentially to savings 1 or 2% in construction cost.

Steel is a high quality material product to exacting standards, and components are dimensionally accurate when manufactured and installed.

Flexibility in the use of a building over its life affects its asset value, which is an important aspect of a client's investment plan.

Steel often means architectural quality: it can be achieved by a variety of facade treatments and building shapes, including flexibility in internal space planning, which can be provided easily by longer spanning steel technologies.

Modular and pre-fabricated elements also improve quality thanks to high precision and tolerance control. Services and expensive components can be installed and pre-tested remote from the construction site.

## TIME

Time is clearly related to speed of construction, as the faster the construction process, the greater the potential savings cost due to:

- Fixed site costs on the facilities and management,
- Interest costs due to borrowing,
- Early income from rental or business use,
- Less disruption to the users (particularly in building extensions).

Steel construction methods of all types are highly pre-fabricated and are installed rapidly on site, leading to time-related benefits. Several studies present various findings on the benefits of different forms of construction with various levels of pre-fabrication.

One of them from National Audit Office in table 3.1 is dealing with housing. Types of construction investigated were planar panels, 'hybrid' panels and modular construction and fully modular construction, which were compared to traditional construction. The key results of the report, in terms of the important time and cost-related factors in pre-fabricated systems, are presented in table 3.1.

**Table 3.1 comparison of key time and cost factors in systems with various levels of pre-fabrication**

<b>CRITERIA</b>	<b>Traditional Brick/block construction</b>	<b>Panel construction</b>	<b>Panel and modular construction</b>	<b>Fully modular construction</b>
Total construction period	100 %	75 %	70 %	40 %
Time to create weather-tight envelope	100 %	55 %	50%	20 %
On-site labour requirement	100 %	80 %	70%	25 %
Total cost on-site materials	65 %	55 %	45%	15 %
Total cost in on-site labour	35 %	25 %	20 %	10 %
Total cost of off-site manufacture	0 %	20 %	35 %	75 %

*Source: National Audit office, UK, 2004*

For steel-framed construction, the key indicator is the time to create a weather-tight envelope, which can reduce to 20 % of the time required for traditional brick-block construction. The overall construction period can be also reduced, but, in any case, steel construction with high level of pre-fabrication requires a different organization of the time project than a traditional way of building with a new allocation of time between design and construction.

## REFERENCES

### Main regulations and standards:

Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011

ISO 14040 Environmental management –Life cycle assessment –Principles and framework.

ISO 14044 Environmental management –Life cycle assessment –Requirements and guidelines

ISO 14025 - Environmental labels and declarations - Type III environmental declarations - Principles and procedures

EN 15804 Sustainability of construction works –Environmental product declarations –Core rules for the product category of construction products.

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