worldsteel
ASSOCIATION

# STEEL IN THE CIRCULAR ECONOMY

## A life cycle perspective

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Cover image: Steel staircase, office building, Prague, Czech Republic

Design: double-id.com

# FOREWORD

We live in a rapidly changing world with finite resources. At the same time, improvements in standards of living and eradication of poverty, combined with global population growth, exert pressure on our ecosystems.

As steel is everywhere in our lives and is at the heart of our sustainable future, our industry is an integral part of the global circular economy. The circular economy promotes zero waste, reduces the amount of materials used, and encourages the reuse and recycling of materials, all fundamental advantages of using steel. This offers a markedly different approach and outcome to the "take, make, consume and dispose" economic model the world has been used to.

This publication focuses on the importance of a life cycle approach in delivering true sustainability. It highlights for legislators and industry decision makers the importance of analysing the entire life cycle of a product before making legislative or manufacturing material decisions.

Too many legislative bodies around the world still enact regulations which only affect the "use phase" of a product's life, for example water and energy consumption for washing machines, energy consumption for a fridge or $CO_2$ emissions whilst driving a vehicle. This focus on the "use phase" can lead to more expensive alternative lower density materials being employed but which typically have a higher environmental burden when the whole life cycle is considered.

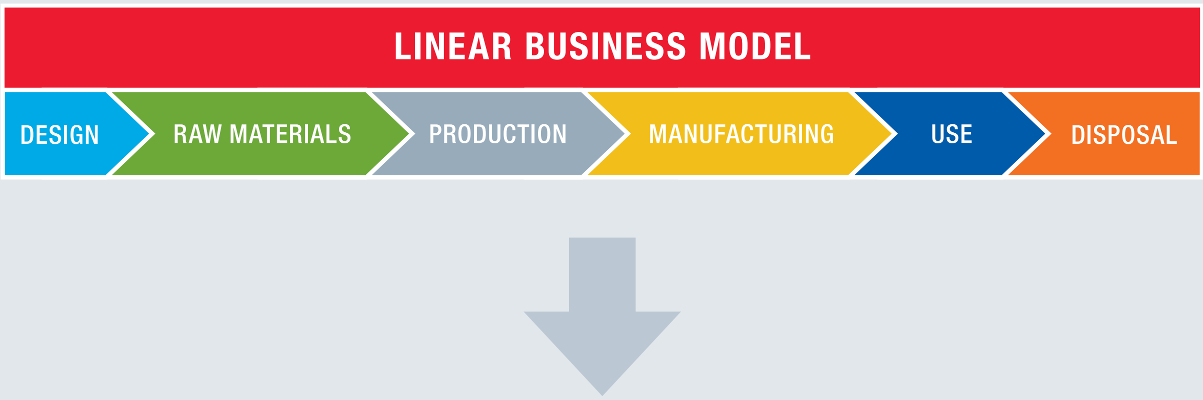
This use phase limitation cannot continue. Life cycle thinking must become a key requirement for all manufacturing decisions.

Dr Edwin Basson
Director General
World Steel Association

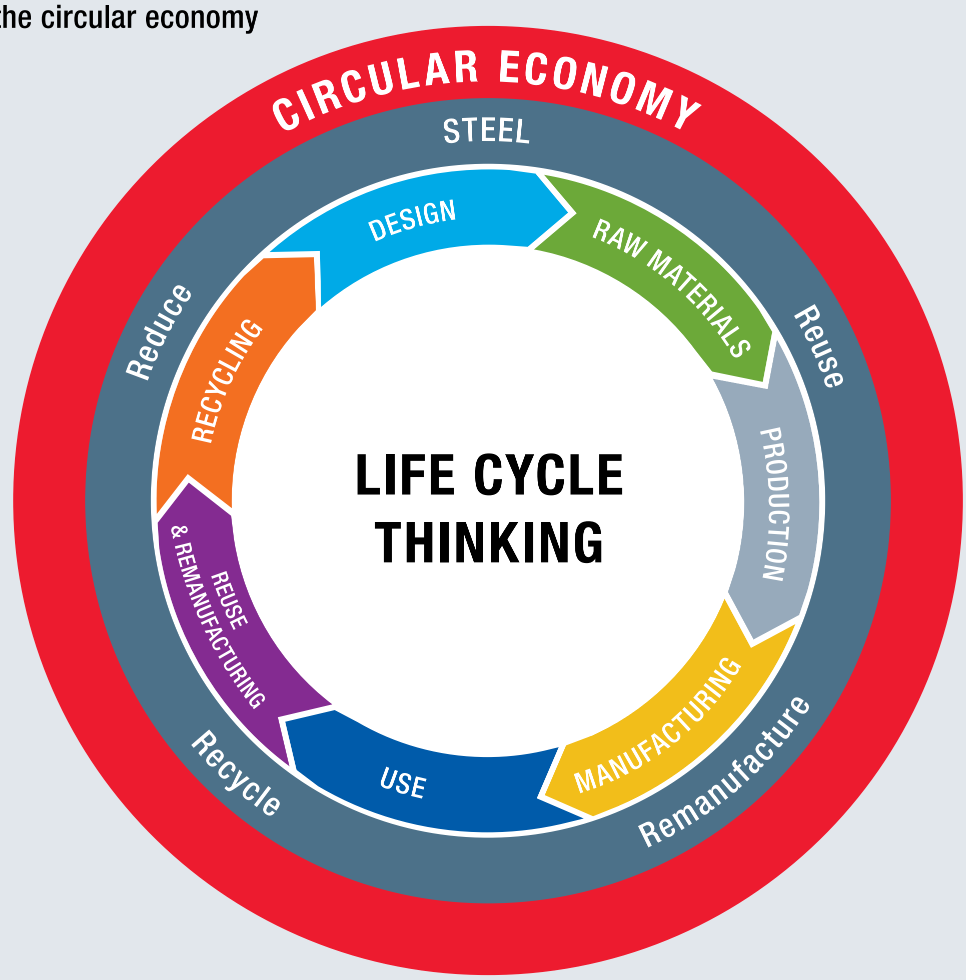
We would like to dedicate this publication to the memory of Jean-Sébastien Thomas (ArcelorMittal) who very sadly died recently. Jean-Sébastien was Chairman of the worldsteel LCA Expert Group for the last three years and was a committed and enthusiastic driving force behind our life cycle activities. Much of his passion and knowledge is incorporated in this publication.

For more information about the technical terms used in this brochure, please see the Glossary, page 29.

Linear business model




Steel in the circular economy



# THE CIRCULAR ECONOMY

"The steel industry is an integral part of the circular economy model. The circular economy promotes zero waste, reuse of materials and recycling. It offers a markedly different approach and outcome to the 'take, make, consume and dispose' economic model currently in use."

— Dr Edwin Basson,
Director General
worldsteel

The circular economy is a move from linear business models, in which products are manufactured from raw materials and then discarded at the end of their useful lives, to circular business models where intelligent design leads to products or their parts being repaired, reused, returned and recycled.[1] A circular economy aims to rebuild capital, whether it is financial, manufacturing, human, social or natural. This approach enhances the flow of goods and services.[2]

The concept of the circular economy drives optimal resource efficiency. It makes sure that resources are efficiently allocated to products and services in such a way as to maximise the economic well-being of everyone. In addition, products need to be designed to be durable, easy to repair and, ultimately, to be recycled. The cost of reusing, repairing or remanufacturing products has to be competitive to encourage these practices. Simply replacing a product with a new one should no longer be the norm.

A circular economy ensures that value is maintained within a product when it reaches the end of its useful life while at the same time reducing or eliminating waste. This idea is fundamental to the triple-bottom-line concept of sustainability, which focuses on the interplay between environmental, social and economic factors. Without a life cycle approach, it is impossible to have a genuine circular economy.

In a well-structured circular economy, the steel industry has significant competitive advantages over competing materials. Four keywords define these advantages:

- REDUCE: Reducing the weight of products, and therefore the amount of material used, is key to the circular economy. Through investments in research, technology and good planning, steelmakers have over the past 50 years drastically reduced the amount of raw materials and energy required to make steel. In addition, the steel industry is actively promoting and developing the use of high-strength and advanced high-strength steel grades in many applications. These grades contribute to the lightweighting of applications, from wind turbines to construction panels and automobiles, as less steel is needed to provide the same strength and functionality.
- REUSE: Because of its durability, steel can be reused or repurposed in many ways, with or without remanufacturing. This already occurs with automotive components, buildings, train rails and many other applications. Reuse of steel is not limited to its original application; repurposing dates back to ancient times (turning swords into ploughshares). Reuse occurs in sectors where it is technically possible without reducing safety, mechanical properties and/or warranties. Rates of reuse will increase as eco-design, design for reuse and recycling, and resource efficiency become more commonplace.
- REMANUFACTURE: Many steel products, such as automotive engines and wind turbines, can be remanufactured for reuse to take advantage of the durability of steel components. Remanufacturing restores durable used products to like-new condition.[3] It differs from repair, which is a process limited to making the product operational, as opposed to thorough disassembly and restoration with the possible inclusion of new parts.[4]
- RECYCLE: Recycling has been carried out in the steel industry since steel was first made. Steel is 100% recyclable and can be recycled over and over again to create new steel products in a closed material loop. Recycled steel maintains the inherent properties of the original steel. The magnetic property of steel ensures easy and affordable recovery for recycling from almost any waste stream while the high value of steel scrap guarantees the economic viability of recycling. Today, steel is the most recycled material in the world. Over 650 Mt of steel are recycled annually[5], including pre- and post-consumer scrap.

The steel industry continues to further integrate these advantages into its operations in order to highlight the benefits of steel to those people making decisions on material choices. Co-operation from the whole production chain is necessary to ensure that reused or remanufactured products have the same properties as new steels.

Steel is 100% recyclable and can be recycled over and over again to create new steel products in a closed-material loop. Recycled steel maintains the inherent properties of the original steel.

Every product we buy has a life cycle. Whether it is a food can, a car, or a washing machine, every product is manufactured, used, and then can be reused, recycled or disposed of at the end of its useful life. Steel that enters the waste stream can be easily separated and collected from other materials for recycling, by the use of magnets.

Life Cycle Thinking (LCT) is a term that is used to describe the holistic thinking that is needed to solve society's problems sustainably. Life cycle thinking requires us to consider the raw materials used, energy consumption, waste and emissions of a product across each phase of its life. This starts with design and ends at the point where the product reaches the end of its useful life. A well-designed, steel-containing product will already anticipate the reuse or recycling of its components at the end-of-life.

Only by calculating the resources and energy used, and the waste and emissions produced at every stage along this journey can we define the true environmental impact of a product. This also enables us to identify where its long-term environmental sustainability can be improved. For example, the small increase in energy consumption or the addition of alloying elements required to produce high-strength steels is compensated many times over when you consider the life cycle of the product. Using these high-strength steels means that products can be lighter[6] and therefore often save energy during the use phase of their life, for example, when applied to the automotive sector. Over the entire life cycle of the product, less energy is used.

There is another reason why life cycle thinking is very important. By knowing the actual impact of each stage of a product's life, we can make the best decisions on what materials we should use.

For example, in addition to high-strength steels, low density materials such as aluminium, carbon fibre or plastics are sometimes used to make applications lighter. However, manufacturing low density materials can involve a much more expensive or environmentally damaging production process. At the end of the product's life, these materials may need to be sent to landfill because there is no economical way to recycle or reuse the material. Alternatively, they can be downcycled to a lower grade product. It is important that this information is known before key material decisions are made. The whole life cycle, from raw material extraction through to end-of-life recycling or disposal has to be considered.

### PACKAGING › Reducing thickness of steel for packaging has positive environmental impact over its life cycle

The technology used to manufacture the drawn wall ironing (DI) tinplate used in two-piece steel food and beverage cans is very sophisticated. Since Baosteel first developed DI steel in 1998, its thickness has been reduced from 0.280 to 0.225mm. The thinner DI tinplate is widely used in the beverage packaging industry.

Reducing material thickness requires additional rolling of the steel, which slightly increases the energy consumption of the reheating furnace and the rollers. However, reducing the thickness of DI tinplate brings benefits. Less steel is required and the production rate of finished cans is greatly improved. Transport impacts are also reduced. This decreases emissions and energy consumption.

The life cycle environmental benefits of the thinner DI material were quantified in an LCA of two-piece steel cans made by the Baoyi Can Making Co. Ltd. Reducing the thickness of the steel from 0.280 to 0.225 mm has decreased the weight of the material used as well as reduced the $CO_2$ emissions of two-piece steel cans by 14.5% over their life cycle.

*Source: Baosteel*

## The life cycle assessment (LCA) approach

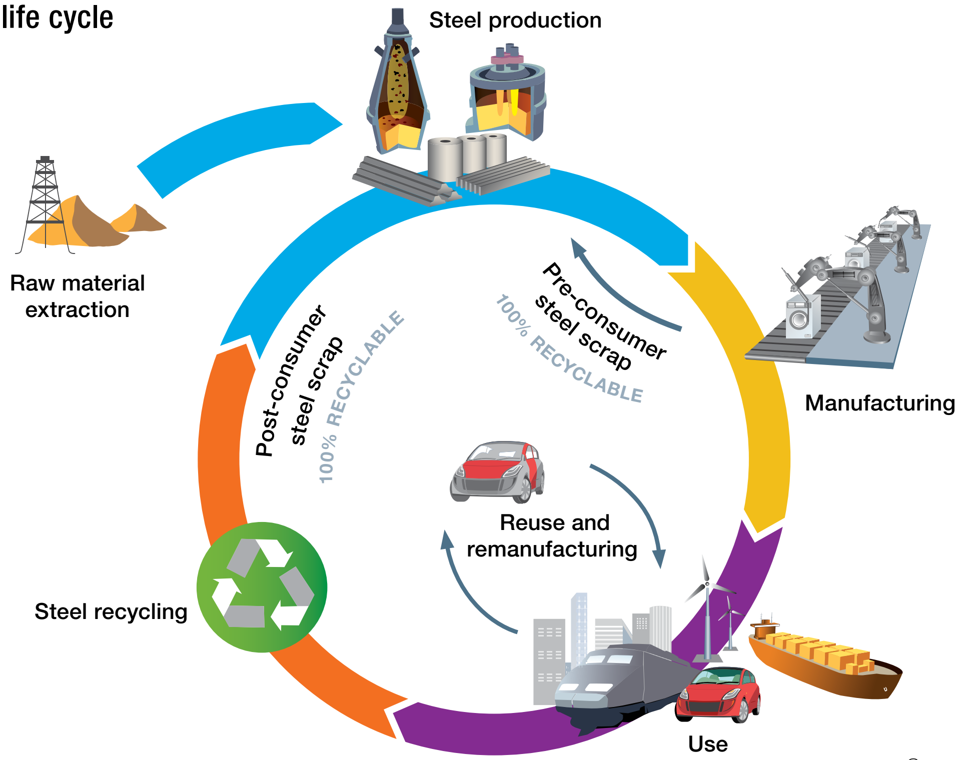
Life cycle assessment (LCA) is a tool that enables us to measure the holistic environmental impact or performance of a product at each stage in its life cycle. It provides a measure which can be used to compare the environmental sustainability of similar products and services which have the same function.

LCA considers the potential impacts from all stages of the material's life cycle including manufacture, product use and end-of-life stages. This is referred to as the cradle-to-grave approach. When the material is fully recycled back into the same material, with no loss in quality, as is the case for steel, this can be referred to as the cradle-to-cradle approach.

LCA generally comprises four stages:

1. **Goal and scope definition:** Identify the purpose of the study and its boundaries.
2. **Life cycle inventory (LCI):** Data collection and calculation to create an inventory (a list of inputs and outputs) of the materials, energy and emissions related to the product being studied.
3. **Life cycle impact assessment (LCIA):** Quantify the potential environmental impacts based on the life cycle inventory of a specific product or system. One of the most commonly referred to impacts is the global warming potential (GWP) which defines greenhouse gas emissions expressed in terms of $CO_2$-equivalents.
4. **Interpretation:** Identify the significant environmental issues, make conclusions and recommendations.

### Steel's life cycle




*Source: worldsteel*

The quality and relevance of LCI/LCA results, and the extent to which they can be applied and interpreted, depend on the methodology used. The International Organisation for Standardisation (ISO) has developed standards which provide guidance on methodological choices and set down rules for transparency and reporting. The relevant ISO standards on LCA are covered in:

- ISO 14040: 2006 - Environmental management - Life cycle assessment - Principles and framework
- ISO 14044: 2006 - Environmental management - Life cycle assessment - Requirements and guidelines

These standards form the basis of a number of other standards which focus on specific issues related to LCA. Some examples include:

- Technical Specification ISO TS 14067: 2013 - carbon footprints
- ISO 14046: 2014 - water footprints
- ISO 14025: 2006 - environmental labels and declarations
- ISO 21930: 2007 - sustainability in building construction (currently being updated)
- GHG Protocol (WRI/WBCSD)

Product Category Rules (PCRs) are becoming increasingly important as these are documents that define the rules and requirements for Environmental Product Declarations (EPDs) of a specified product category. Following ISO 14025: 2006 (Type III environmental labels and declarations), PCRs are vital to ensure transparency and comparability between different EPDs based on the same PCR.

## Durability of steel

A circular economy promotes long product lives. The longer a product lasts the less raw materials will need to be sourced. Product durability contributes to reducing the depletion of raw materials.

By 2050, an estimated 9 billion people will inhabit the Earth. Steel is an enabler of the sustainable development needed to meet the needs of these people.

In theory, all new steel could be made from recycled steel. However, this is not practically feasible due to the long life of steel products, given steel's strength and durability. Around 75% of steel products ever made are still in use today.[7] Buildings and other structures made from steel can last from 40 to 100 years and longer if proper maintenance is carried out. For example:

- In 1883, New York's Brooklyn Bridge became the world's first steel bridge to carry traffic. Over 130 years later it still carries over 120,000 vehicles a day.
- Completed in 1891, the Basilica of San Sebastien in the Philippines capital, Manila, remains the only pre-fabricated steel church in Asia. Sections were manufactured in Belgium and shipped to the Philippines where the church was assembled.
- The iconic Sydney Harbour Bridge has been carrying road and rail traffic since it opened in 1932. The bridge contains over 53,000 tonnes of steel waiting to be recycled.

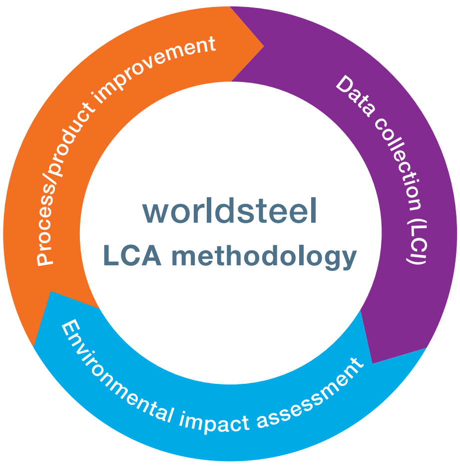
**None of these structures are scheduled to be replaced in the foreseeable future.**

Steel's durability is one of the key properties that make it a sustainable material. Not only does steel ensure long product life, it also allows the reuse of countless products, from paper clips to rail and automotive components (see Reuse and remanufacturing on page 18).

*Sydney Harbour Bridge*

There are many different grades of steel ranging from mild conventional steels to high-strength steels, advanced high-strength steels and specialty steels such as stainless. Each grade of steel has properties designed for its specific application.

## worldsteel's LCA methodology and life cycle inventory (LCI) database




The methodology worldsteel uses to calculate the LCI of steel products is documented in the association's Life Cycle Assessment (LCA) methodology report, 2011. The methodology is aligned to international standards for the calculation of LCA (ISO 14040: 2006 and ISO 14044: 2006). The methodology has been peer-reviewed by an external panel at each update. Both the methodology and the database are updated regularly to keep them current and relevant to the market.

worldsteel has been collecting life cycle inventory (LCI) data from its global membership since 1995. Two updates of worldsteel's global LCI database were made in 2001 and 2010 and it is being updated again in 2015. The LCI data is available to worldsteel member companies and third-parties. The full database is maintained by worldsteel.

The data enables academics, architects, government bodies, steel customers and other interested parties to undertake LCA studies of steel-containing products. Anyone wishing to undertake such a study can obtain global and regional LCI data for 15 steel products by completing the request form available on worldsteel.org. The data can be used across all market sectors (for example, automotive, building, packaging, energy, electronic appliances). By collecting data from different regions, worldsteel can identify and encourage the use of best practices amongst its global membership.

worldsteel's LCI data covers the raw material and production phases (cradle-to-gate) of the steel life cycle. This data includes environmental inputs and outputs such as resource use (raw materials, energy and water) and emissions to land, air and water from each process within the steelworks. These processes include cokemaking, steel production, final processing of steel products, and other necessary processes such as boilers, power plants and waste water treatment.

worldsteel also provides a detailed methodology to consider the benefits obtained by recycling steel from products that have reached the end of their useful life (see appendix 10 of the methodology report). This data is also available from worldsteel, based on specific end-of-life recycling rates of the product. By recycling steel, less primary raw materials are needed. Recycling accounts for significant energy and raw material savings: over 1,400 kg of iron ore, 740 kg of coal, and 120 kg of limestone are saved for every tonne of steel scrap made into new steel.

Using this product-specific LCI data on a global or regional basis, the environmental impact, or LCA, can be calculated for a final product, from cradle to grave.

**Also at worldsteel.org:**

- LCA methodology report 2011
- LCI data request form for 15 steel products

> "At first glance, materials that weigh less or, more precisely, have a lower density than steel, such as aluminium, carbon fibre, magnesium and plastics may appear to be interesting alternatives. However, when the total life cycle of a material is taken into account, steel remains competitive, owing to its strength, durability, recyclability, versatility and cost"
>
> — Prof. Jean-Pierre Birat,
> Secretary General
> European Steel Technology Platform

## AUTOMOTIVE › Life cycle thinking leads to intelligent automotive material choices

The global transportation industry is a significant contributor to greenhouse gas emissions and accounts for about 23% of all man-made $CO_2$ emissions. Regulators are addressing this challenge by setting progressive limits on automotive emissions, fuel economy standards or a combination of both.

Many of the existing regulations began as metrics to reduce oil consumption and focused on extending the number of kilometres/litre (miles/gallon) a vehicle could travel. This approach has been extended into the regulations which now limit GHG emissions from vehicles.

The steel industry believes that this approach needs an urgent review. Extending the fuel economy metric to meet objectives to reduce emissions is resulting in unintended consequences.

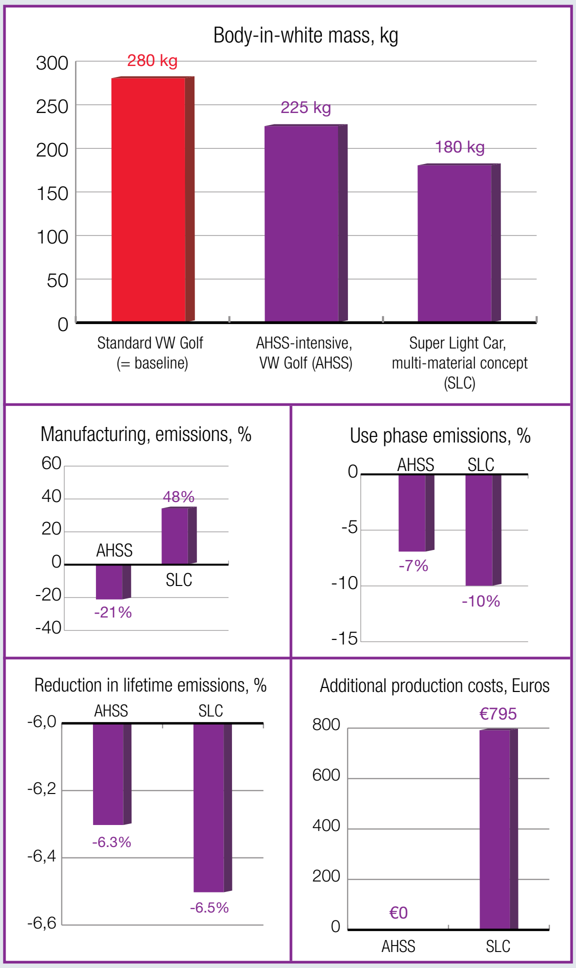
Low-density alternative materials are being used to reduce vehicle mass. These materials may achieve lighter overall vehicle weights, with corresponding reductions in fuel consumption and use phase emissions. However, the production of these low-density materials is typically more energy and GHG intensive, and emissions during vehicle production are likely to increase significantly. These materials are often not able to be recycled and need to be sent to landfill. Numerous LCA studies show how this can lead to higher emissions over the entire life cycle of the vehicle as well as increased production costs.

A study of the **Toyota Venza** compared the life cycle emissions of two body structures: one dominated by high-strength steels and the other using a magnesium/aluminium structure which is 104 kilograms lighter. Carried out by the independent University of California at Davis, the study found that, while emissions during the use phase decreased by 6% in the magnesium/aluminium vehicle, emissions during the entire life cycle increased by 7% compared to the high-strength steel design.

The **Super Light Car** (SLC), a European multi-material project, achieved a 36% reduction in the weight of the body-in-white compared to the baseline vehicle, a standard VW Golf. Emissions during the driving phase of the SLC's life were reduced by 10%, and by 6.5% over its entire life cycle compared to the baseline vehicle. However, during the production phase, emissions were 44% higher and costs were significantly increased - **up to €795 per vehicle.** By contrast, a VW Golf manufactured from advanced high-strength steels (AHSS) would lead to a 6.3% reduction in emissions over the vehicle's entire life. This is just 0.2% lower than the SLC vehicle. During the manufacturing phase of the AHSS vehicle, emissions are reduced by 21% at no extra cost.

The use of LCA gives a much more accurate picture of the environmental impact of the vehicles that we drive. It is for this reason that worldsteel and steelmakers agree that life cycle thinking should play a role in future regulations, but further research is needed on how this can be implemented.

**Comparison of $CO_2$ emissions of standard VW Golf against AHSS-intensive Golf and multi-material* Super Light Car (SLC)**




*Materials used in SLC: 53% aluminium, 36% steel, 7% magnesium and 4% plastic.*

*Source: WorldAutoSteel*

# SUSTAINABILITY AND LIFE CYCLE ASSESSMENT

## Life cycle thinking:
## Key to every aspect of sustainability


In 2012, 66 members of worldsteel signed the worldsteel Sustainable Development Charter[8] which commits them to improving the social, economic and environmental performance of their companies. By signing the Charter, worldsteel's members agreed to operate their businesses in a financially sustainable way, supply steel products and solutions that satisfy customer needs and provide value, optimise the eco-efficiency of steels throughout their life cycle, and foster the well-being of employees and communities.

The Charter represents a definitive commitment by the global steel industry to embrace life cycle thinking and all three pillars of sustainability (economic, social and environment).

The steel industry is one of the few industries to monitor and report its sustainability performance at the global level, since the first sustainability report was published in 2004. This has enabled the steel industry to benchmark its performance and to enhance transparency. Most companies also report on their sustainability performance individually.

In terms of **environmental sustainability**, changes at every phase in the steel production process over the past 50 years have resulted in significant improvements in the resource and energy efficiency in the production of steel, including a 60% drop in energy consumption per tonne of steel produced.[9] The environmental benefits related to steel's durability, allowing for long product lifetimes and reuse, and its recyclability are also crucial factors that make steel a sustainable material.

**Social sustainability** is achieved if the manufacture, use and end-of-life processes for a given product are respectful of the human being and ensure that future generations can enjoy the same lifestyle we do today. This involves protecting the health and safety of the people who make or use a product, managing resources for future generations, and ensuring that social issues such as inequality and poverty are addressed.

**Economic sustainability** requires businesses to make ethical profits which are used to ensure the long-term viability of their enterprises. In turn, this creates sustainable employment which has a positive impact on the well-being of people and communities.

More than two million people are directly employed by the steel industry with a further two million contractors on site. Indirectly, many millions more have jobs with upstream suppliers and in the downstream industries that rely on steel. In turn, these people and businesses contribute to their own communities through taxes and by providing further employment.[10]

**While LCA is typically applied to environmental sustainability, an 'integrated life cycle approach' can also be used to measure the social LCA and economic impact (life cycle costing, LCC) of products. Keeping all three in balance is key if we are to make sustainable products.**

**It is important to note that social and economic factors are as critical as environmental factors if we are to create industries and societies which are truly sustainable.**

### Also at worldsteel.org:

- Sustainable steel: Policy and indicators 2014
- Safety and health section


Source: Severstal

"Steel is the most recycled material in the world. As more steel scrap becomes available, the steel industry will close the loop in the circular economy and will further reduce its need for raw materials"

— Dr Paul Brooks,
Chairman, Environment Committee, worldsteel
and Group Director, Environment, Tata Steel

## LCA by life cycle phase

Every product goes through a series of phases during its lifetime (see page 4 and 8). The first is **design** where the product is defined. This stage should consider the sustainable use of the product as well as including provisions for the sustainable reuse and recycling of the product once its use phase comes to an end.

The next phase is **raw material selection**, followed by **manufacturing**, **use**, **reuse** (which may include **remanufacture**) and then **recycling**. At the end of the process, the recycled material is transformed into a new product and the cycle begins again.

## Raw materials and steel production

Key raw materials needed in steelmaking include iron ore, coal, limestone and steel scrap (or recycled steel). With the exception of steel scrap, the ingredients for steelmaking are still relatively abundant. Steel scrap is in short supply globally, largely due to the long service life of steel in infrastructure. However, the steel industry recycles as much steel scrap as possible that becomes available.

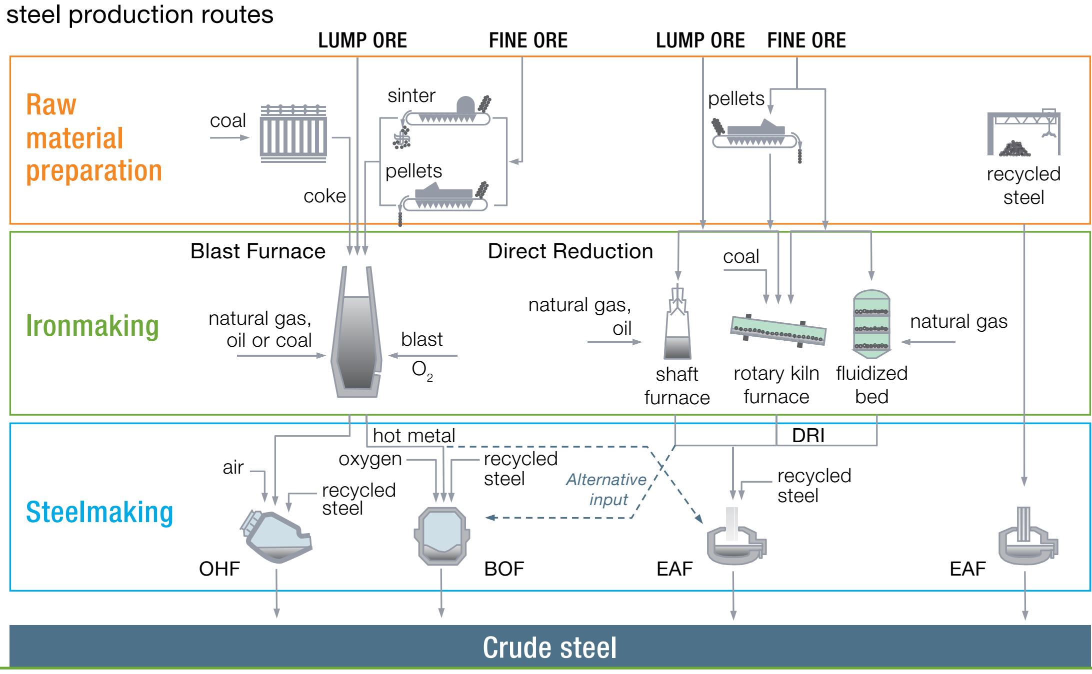
Steel is made through one of two main production routes:

- **The blast furnace or integrated route:** based on the blast furnace (BF) and basic oxygen furnace (BOF). To produce 1,000 kg of crude steel, the main inputs are (approximately) 1,400 kg of iron ore, 800 kg of coal, 300 kg of limestone, and 120 kg of steel scrap.[11] About 70% of the world's steel is produced via this process.[12]
- **The electric arc furnace (EAF) route:** Primary raw materials are steel scrap and/or direct reduced iron (DRI) or hot metal and electricity. To produce 1,000 kg of crude steel, the EAF route uses (on average) 880 kg of steel scrap, 300 kg of iron, 16 kg of coal and 64 kg of limestone. The EAF route can also be charged with 100% steel scrap. About 30% of the world's steel is produced via the EAF process.[12]

Another steelmaking technology, the open hearth furnace (OHF), makes up about 1% of global steel production and is in decline owing to its environmental and economic disadvantages.

The blast furnace route always uses some scrap (can be up to 35%). An EAF can be charged with 100%

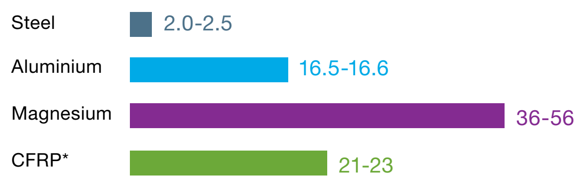
The steel production routes



steel scrap but can use no scrap when it is charged with 100% DRI. There is not enough end-of-life steel available to produce all new steel from recycled sources.

The steel industry has dramatically reduced its energy consumption over the past half century.[9] Members of worldsteel are collectively and individually exploring the development of new breakthrough technologies which may make it possible to reduce the energy consumption and $CO_2$ emissions of the steelmaking process further. Steel producers are also working to reduce the impact of $CO_2$ emissions through the use of carbon capture and storage technologies. This complements the continual steps they are taking to reduce other emissions such as dust, $NO_x$ and $SO_x$ from the steelmaking processes.[13]

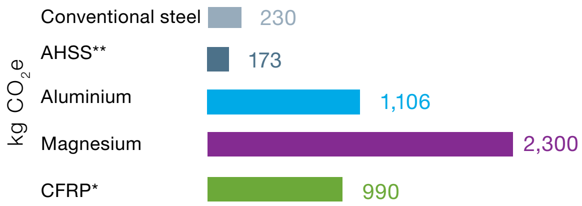
Average GHG emissions during global material production
(In kg $CO_2$e/kg of material) including finishing[14]




*Note: 1kg of steel is not equal to 1kg of another material. Functional units also need to be compared (see table below for more details on estimated functional units).*

Functional units
Material production GHG emissions comparison for a typical automotive part

| | Mid-Range $CO_2$e | Estimated Part Weight (kg) |
|---|---|---|
| Conventional steel | 2.3 | 100 |
| AHSS** | 2.3 | 75 |
| Aluminium | 16.5 | 67 |
| Magnesium | 46.0 | 50 |
| CFRP* | 22.0 | 45 |




**CFRP: Carbon Fibre Reinforced Plastic*
***AHSS: Advanced High-Strength Steel*

## Markets for by-products

In addition to reducing their demand for raw materials, steelmakers have become more effective at reducing waste and finding markets for the by-products produced in the steelmaking process. This helps to significantly reduce waste from steel's life cycle. Today, approximately 96% of the raw materials used to make crude steel are converted into steel products or by-products.[15] The aim is to increase this to 100%.

The industry has made significant efforts to find new markets and applications for its by-products which include slags, process gases (coke oven, blast furnace and basic oxygen furnace gases), tar and benzene. Slag, one of the steel industry's major by-products, is now widely used in the cement industry. This reduces the environmental burden of cement production. According to the Slag Cement Association, replacing Portland cement with slag cement in concrete can save up to 59% of the embodied $CO_2$ emissions and 42% of the embodied energy required to manufacture concrete and its constituent materials.[16] However, this does not account for the $CO_2$ emissions associated with producing slag. Slag has other applications as a crop fertiliser (it is rich in phosphate, silicate, magnesium, lime, manganese and iron) and as an aggregate in road building.

## Manufacturing and use

During the manufacturing phase, intermediate steel products (for example, hot rolled coil) are transformed into steel-containing products such as automobiles. One of the key benefits of steel is that it can be designed to meet the specific strength, durability, and end-of-life recycling requirements of almost any application. Steel makes up nearly 60% (by mass) of North American vehicles, and 50% in the rest of the world.[17] Using advanced high-strength steels (AHSS) makes it possible to design lighter, optimised vehicles which enhance safety, improve fuel economy and reduce lifetime greenhouse gas emissions.

Ongoing research is producing new steels that are even stronger and lighter than those available today. Wind tower turbines, vital for producing clean wind energy, are already 50% lighter than they were a decade ago.[18] For a 70-metre tower, that translates into a 200 tonne reduction in $CO_2$ emissions.[18] With their higher strength-to-weight ratio, the newer steels can be used to manufacture tower sections of up to 30-metres. This reduces emissions during transport and assembly.

Higher grade steels are also being developed for construction. They enable the construction of larger and taller buildings in a more efficient way and produce the lowest possible amount of waste. The use of higher grade steels is expected to reduce the quantity of steel used in construction. Transportation costs are also reduced thanks to the thinner, and therefore lighter, steel components. They also shorten the time needed for processing at plants and on-site construction, largely due to a reduction in the number of welds required. Using these steels, it is possible to reduce the number of columns in building structures and make them thinner. This results in larger areas and provides opportunities for better design and use of space. Higher grade steels enable structures to be developed which incorporate dissipation mechanisms to absorb the majority of the seismic energy generated by an earthquake.[19]

## WIND ENERGY › Using LCA to calculate energy payback for wind turbines

Based in Denmark, Vestas is a global manufacturer of wind turbines. Since 1999, the company has been using LCA to develop energy-efficient products and production methods as well as mitigating the environmental impact of its wind turbines over their entire lifetime.

A cradle-to-grave LCA study has enabled Vestas to calculate the energy payback of its V112, 3.3-megawatt (V112-3.3 MW) wind power plant. The calculation takes into account the energy required to manufacture, operate, service and dispose of the plant.

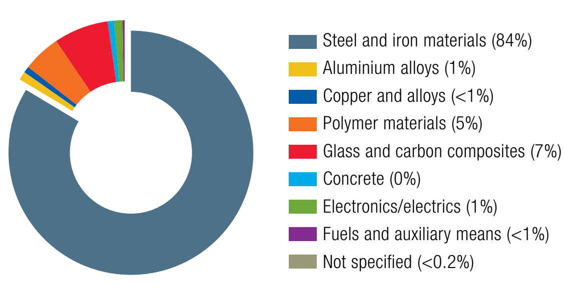
The calculation shows that the energy required to produce a V112-3.3 MW wind turbine will be paid back 37 times over the turbine's life in medium wind conditions. When 1 kWh is invested in a wind energy turbine, 37 kWh of energy is generated in return.

Vestas' use of LCA has enabled them to demonstrate that the environmental impact associated with production of a wind turbine is minimal over its average 20-year life cycle.

A significant reason for this is the high level of steel and iron used in the V112-3.3 MW wind turbine (up to 84% of the total weight). At the end of the turbine's useful life, all of this steel and iron can be recycled into new steel products with the same, or improved, properties.

At least 83% of the V112-3.3 MW turbine is recycled. The components contributing to its recyclability include metal parts which are primarily manufactured from steel and iron. Overall, around 86% of the V112-3.3 MW turbine is made from metals (see diagramme for materials breakdown). The benefits of recycling the steel from the turbine at the end of its life lead to a reduction of 15% in the global warming potential (GWP) and a 10% improved energy payback.

### Materials breakdown




*Source: Vestas*[20]

## Reuse and remanufacturing

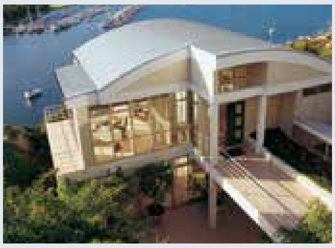
By designing steel products for reuse or remanufacturing, even more resources can be conserved. Reuse is advantageous as little or no energy is required for reprocessing. Steel's durability ensures many products can be partially or fully reused at the end of their life. This can extend the life cycle of the steel product significantly. However, initial design based on life cycle thinking is critical if reuse is to succeed.

The construction industry has been one of the first to embrace the reuse of steel components such as structural beams, roofing and wall elements. Increasingly these elements are being designed for reuse. Although reinforcing steel is currently recycled rather than being reused, opportunities exist to create modular reinforced concrete elements such as standard floor slabs.[21]

Reuse through repurposing involves a specially designed collection and reprocessing system to make the product fit for a new application. The amount of energy and resources required for reuse applications can be significantly lower than producing a new application from raw materials. For example, steel plates used to build ships can be re-rolled and used in the construction of new vessels. The only input is the energy required to reheat, re-roll and transport the steel.[21]

Remanufacturing restores durable, used products to like-new condition[3]. It involves the disassembly of a product, during which each component is

### SPECIAL STEELS › LCA shows new COLORBOND® steel reduces environmental impact over its life cycle



BlueScope has successfully used LCA to verify the reduced cradle-to-grave environmental impact of its latest version of COLORBOND® steel. COLORBOND®, a pre-painted aluminium, zinc and magnesium coated steel, is a high-volume building product which is extensively utilised in Australia's residential, commercial and industrial markets.

BlueScope is committed to using LCA as a tool to measure the impact of new production techniques and product designs over their entire life. As LCA measures a broad range of categories, it gives confidence that benefits gained in one area aren't simply shifted to another area that is not being measured.

BlueScope has invested over AUD$100 million in the development of Activate™ technology which provides a superior substrate for the latest evolution of COLORBOND® steel. Developed in conjunction with Nippon Steel & Sumitomo Metals Corporation, Activate™ enables metal resources to be conserved without compromising corrosion performance. This is achieved primarily through the addition of magnesium to the 55% aluminium-zinc alloy coating and leads to a considerable reduction in the metallic coating mass of new COLORBOND® steel.

While this outcome is impressive, a change in formulation can also have unpredictable environmental consequences. BlueScope commissioned an independent comparative LCA of the old and new generations of COLORBOND® steel products. In the case study, the COLORBOND® steel was used as roofing for 1,000 square metres of commercial/industrial space.

The LCA results show that the latest version of COLORBOND® steel sustainably outperforms its predecessor consistently in 18 categories covering air, water, land and human health. The LCA concluded that the reduction in environmental impact was the result of innovation in the formulation of the metallic coating. This results in an increased lifespan for COLORBOND® steel while using fewer metal resources.

*Source: BlueScope Steel[22]*

thoroughly cleaned, examined for damage, and either reconditioned to original equipment manufacturing (OEM) specifications or replaced with a new part. The product is then reassembled and tested to ensure proper operation. This process differs from repair, which is limited to making the product operational as opposed to thorough restoration. A wide range of steel products are already remanufactured. They include machine tools, electrical motors, automatic transmissions, office furniture, domestic appliances, car engines and wind turbines.

Steel also facilitates its own longevity. Steel-framed buildings can be easily adapted if the configuration of the structure needs to be changed. The building can be taken apart and rebuilt with minimal disruption to local communities and the environment. Strong, durable exterior steel structures can accommodate multiple internal reconfigurations to suit changing needs. Warehouses or industrial buildings made with steel can be easily converted into modern living or working spaces. This extends the useful life of the building (and the life of the steel it contains) to save resources and reduce costs.[21]

## Recycling

Steel is 100% recyclable without loss of its inherent material properties and is the most recycled material in the world. Approximately 650 million tonnes[23] of pre- and post-consumer scrap are recycled annually, leading to significant savings in energy and raw material use. All scrap from steel production and downstream processing (often referred to as pre-consumer scrap) is collected and recycled directly in the steel production process. The recycled content of any steel product can range from 5 to 100%.

More than 23 billion tonnes[24] of scrap have been recycled since steel production began. Using magnetic separation, the steel scrap from post-consumer products can be easily retrieved from almost any waste stream. A worldsteel review showed that recovery rates for different sectors range from 50% for small electrical and domestic appliances, up to more than 90% for machinery. Levels of up to 98%[24] for structural steel in commercial and industrial buildings are achieved.

Large, heavy structural steel components require planning for end-of-life management. However, with steel scrap having value, the incentive to recover and recycle these components is high and more cost-effective than paying for them to be placed in landfill sites. It is important to note the difference between recovery and recycling rates. While more than 85%[13] of vehicles are recovered globally, nearly 100% of the steel in these recovered automobiles is recycled.

**Recycling ensures that the value of the raw materials invested in steelmaking lasts far beyond the end of a steel product's life, and that the steel remains a permanent resource for society.**

When raw materials become more scarce and costly, the price of steel will increase. As the price of scrap steel is linked to that of the primary material, the incentive to recover steel will continue to increase in the future. As steel production is still increasing, and because the majority of steel remains in use in buildings, bridges and other products for many years, the proportion of steel produced from steel scrap remains limited. Availability will increase in the future as there is a large amount of steel still in use.

Around 75% of steel products ever made are still in use today.

The use of the term 'recycling' should be clarified. All types of steel can be recycled back into new steel of various grades, keeping its inherent material properties. Thus, steel scrap from lower value steel products can also be converted into high value steels by using appropriate processing and metallurgy. For other materials this is not typically possible; indeed the quality of recycled material is often downgraded or downcycled, as in the case of concrete, wood and aluminium.[25, 26]

Recycling is important in the circular economy as it conserves valuable resources. In addition to steel industry efforts to increase recovery rates, there are also initiatives, in conjunction with other metal industries and research institutes, to identify losses throughout product life cycles. The goal is to minimise these losses and further improve the recycling rate of steel and other materials.

"When it comes to product life cycles, steel has undeniable advantages compared to all other materials, and this is a huge opportunity for the entire industry. However, there are currently considerable regional differences when it comes to approaches, regulations, and criteria, and it would give the industry greater impact if these were harmonised."

— Dr Wolfgang Eder, Chairman, worldsteel and CEO, voestalpine

There is a great deal of legislation in place to ensure that the environmental impact of products, manufacturing, and waste is minimised. However, this legislation typically focuses on one aspect of a product's life - usually the use phase.

When assessing the sustainability of the steel industry, regulations focus on production emissions. As a result, the steel industry is considered to be one of the biggest $CO_2$ emitters due to the sheer amount of steel produced: 1.6 billion tonnes annually. Taking a life cycle approach, which also considers the benefits of steel products in use, changes this perspective.

A number of different initiatives to promote life cycle thinking are being undertaken around the world across most market sectors. Voluntary schemes, such as building or product rating schemes, focus on a range of areas. Some concentrate solely on the use phase or single indicators such as embodied energy or carbon. These single indicator measures can result in a less sustainable outcome or unintended consequences, because they do not take into account the full lifetime of the product or multiple environmental impacts.

## Regional and global initiatives

Several regional and global life cycle based initiatives have been developed over the past 10 to 15 years of which some have been taken into account in legislation. However, a number of these initiatives remain at an early stage and need further developing. Below we highlight a few examples of regional and global initiatives supporting the circular economy.

Launched in 2002, the **Life Cycle Initiative**[27] is a partnership between the United Nations Environment Programme (UNEP) and the Society for Environmental Toxicology and Chemistry (SETAC). This initiative aims to put life cycle thinking into practice. Phase III of the project, which will run from 2012 to 2016, aims to enable the global use of credible life cycle knowledge in order to create more sustainable societies. With its global approach and UN backing, the partnership influences governments around the world to include life cycle thinking in new environmental, social and economic legislation.

One of the latest initiatives from the European Union is the **Product Environmental Footprint (PEF) standard**.[28] A PEF aims to measure the environmental performance of a product throughout its lifetime. Some steel companies are actively participating in the current pilot phase of the initiative and are testing the applicability of the standard for steel products. While PEF is an EU scheme, the intention of the European Commission is that once implemented, it should be applied to every product sold in the European market.

### EXCELLENCE IN LIFE CYCLE ASSESSMENT

› **Steelie Award**

Every year, during its annual conference in October, worldsteel hosts the Steelie Awards to recognise the contributions and achievements of companies and individuals in seven categories including technology, education and environment – all areas that are vital for the industry to remain sustainable. The Excellence in LCA award recognises companies that have played a key role in establishing and guiding the work of worldsteel in LCA demonstrating their commitment to the ethical and pro-active use of LCA and shaping the debate in the public and policy-making arenas. Member nominations are called for by worldsteel and judged by an external expert panel.

Winners of the Excellence in LCA Steelie Award

**2014: Tata Steel in Europe** for the use of LCA to demonstrate the benefits of steel in bridge designs versus alternative materials (page 23)

**2013: BlueScope Steel** for improving environmental sustainability of its product range: Next generation ZINCALUME® steel AM125 and COLORBOND® steel AM100 (page 18)

**2012: Baosteel** for their overall LCA activities

**2011: ArcelorMittal** for their overall LCA activities

**2010: Tata Steel in Europe** for their overall LCA activities

Steel is used to make bridges, railway tracks, skyscrapers, wind turbines, stadiums, washing machines, cars and computers. Most of the products that surround us are made of steel or produced by a tool or machine made of steel.

The Australian Life Cycle Assessment Society (ALCAS) and the Life Cycle Association of New Zealand (LCANZ) have joined together to create the **Australasian Environmental Product Declaration (EPD) Programme** which was launched in September 2014. It is a move which is designed to increase the use of EPDs in the region.[29]

In North America, the **American Center for Life Cycle Assessment (ACLCA)** is seeking to build capacity and knowledge of environmental LCA among industry, government and NGOs. ACLCA is the professional society for LCA in North America and, among other things, hosts an annual international conference dedicated to a wide range of LCA topics. These include emerging issues, advances in data collection and methodologies, policy applications, and case studies.

In China, the Ministry of Industry and Information Technology launched an initiative on eco-design in the automotive and home appliance sectors during 2013. The **Chinese Eco-design Initiative** aims to draft the eco-design manual for several key products including cars. Most car manufacturers in China, and some raw materials suppliers, have participated in the pilot project of this initiative. In the long term, the eco-design initiative will launch an authentication system for eco-designed products. Products which meet the criteria will have priority over non-complying products in the Chinese government's procurement catalogue.

# Market sector initiatives

## Construction

The global construction industry has established a number of standards which are driving the adoption of life cycle thinking in new buildings and renovations. These standards recognise the sustainability performance of a building across a range of criteria including energy use. Developers and building managers use the ranking to demonstrate the sustainability of their construction projects to clients and regulators.

Credits are awarded for the use of construction products that have a low environmental impact and are responsibly or locally sourced. One of steel's major benefits in these schemes is that it contributes to use phase energy efficiency and it can be completely recycled or reused at the end of the building's life.

The **Building Research Establishment Environmental Assessment Method (BREEAM)** is

### UTILITY POLES › Steel versus wood for poles

In 2013, the American Iron and Steel Institute (AISI) commissioned an LCA study into the life cycle costs of timber and galvanised steel utility poles in North America. The study covered the production, installation, maintenance and disposal of utility poles over a 40-year timeframe.

The assessment covered typical LCA criteria such as emissions to air and water, as well as addressing concerns such as the ecological impact of steel and wooden poles on various species of fauna.

Of the 35 indicators assessed, a clear majority showed steel poles had a significantly lower impact than those made of wood. For several of these, the steel pole advantage was 100% or greater. Some key findings from the study included:

- Steel poles produce lower levels of emissions associated with climate change over 40-years. Existing forest management practices result in a 20 to 30% loss of carbon storage.
- Endangered and threatened species are less disrupted if steel poles are utilised. Up to 90 species of fauna are affected by the harvesting and production of wooden poles.
- Steel poles generate less waste as all steel can be recycled into new products. At the end of their service life, wooden poles are typically landfilled, but can also be burnt or reused. As wooden poles are treated with chromate copper arsenate, their disposal in landfill can be detrimental to human health and the environment.

*Source: American Iron and Steel Institute*[30] widely used in Europe for buildings and large-scale developments, but has also been adopted in other regions. The most common standard in North America is the US Green Building Council's **Leadership in Energy and Environmental Design (LEED)** Program. Like BREEAM, building projects must meet pre-set criteria to earn points in order to achieve certification. Version 4 of LEED for building design and construction, released in November 2013, incorporates new credits for whole building LCAs, EPDs and product transparency documents (such as health product declarations or HPDs). LEED is expanding globally with just under 25,000 projects certified in over 250 countries.[31]

The Green Building Council of Australia launched the next generation of their **Green-Star® Design** and **As Built tool** in October 2014. The tool now includes a credit for the LCA of buildings and rewards the use of EPDs.[32]

The adoption of these standards has led many steelmakers to create EPDs for their own construction products. Typically an EPD presents LCA results covering each step of the product's life from raw material sourcing to its eventual disposal. However, cradle-to-gate EPDs are also being developed. There are various international standards available for companies to follow including:

- ISO 14025: 2006 - environmental labels and declarations
- ISO 14040 and 14044: 2006 - LCA methodology
- EN 15804: 2012 - European Norm describing core rules for construction products
- ISO 21930: 2007 - sustainability in building construction (currently being updated)

## BRIDGES › Independent research demonstrates steel has lowest life cycle impact

Government authorities are increasingly using sustainability criteria when choosing materials for infrastructure projects. In the Netherlands, an LCA study of different materials used in bridge construction was conducted by environmental consultancy Beco on behalf of the Dutch Department of Infrastructure. The study was supervised by a steering committee including experts in construction and sustainability from the Dutch government, BAM Infra and environmental consultant NIBE and then reviewed.

Two common types of bridge were analysed:

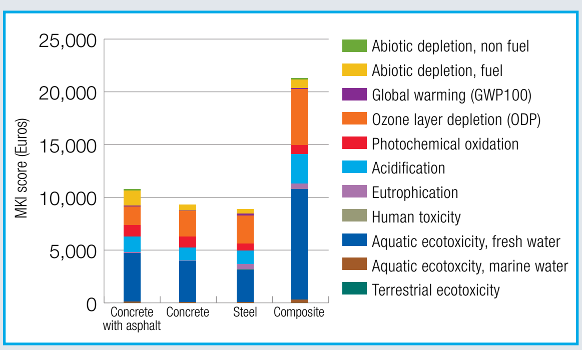
- Bicycle bridge with a span of 14 metres
- General traffic bridge with a span of 24 metres.

To determine the environmental impact of the bridges, the Harmonised SBK Environmental Assessment Method for Buildings and Civil Engineering works was used. This method is based on standards including BS 80065 and ISO 14040/44. The Dutch Environmental Database (SBK) formed the data source of the study.

The results are expressed as an Environmental Indicator (MKI) score which weighs several environmental effects. The higher the MKI, the larger the environmental impact of the project. The study found that steel had significant advantages in the following areas:

- **Recyclability:** while steel can be recycled and reused, without loss of quality, materials such as wood and plastic are typically burned at the end of their life, while concrete is downcycled to create low-value products such as gravel.
- **Lightweight:** Steel bridges are four to eight times lighter than those built from concrete. Even bridges made from plastic, which is typically regarded as a lightweight material, have the same weight as the steel bridge design. The resulting reduction in the foundation construction would also provide an additional advantage for steel.
- **Environmental impact:** Due to its low weight and good recycling properties, the steel road bridge has the lowest MKI score. Compared to plastic, the environmental footprint of a steel bridge is approximately 60% lower.

MKI score for road bridges shows steel has the lowest impact over the life cycle of the bridge




*Source: Tata Steel in Europe*[33]

Each of the existing standards includes LCA and/or EPD provisions, and addresses the operational energy of the building as well as the embedded energy and emissions of the building materials used. These initiatives aim to create a comprehensive framework so that different regions can implement and adopt green building regulations and codes, and to provide incentives for voluntary leadership programmes such as LEED.

## Automotive

Current environmental regulations tend to concentrate on the use phase of a product's life. One example of this is the US Environmental Protection Agency's Corporate Average Fuel Economy (CAFE) Standards. The CAFE standards focus on the use phase by requiring car manufacturers to achieve a fleet-wide average fuel economy of 54.5 miles per gallon (5.14 litres/100 km) by 2025.

Although the standard aims to reduce the use phase environmental impact of vehicles, it can lead to an increase in the impact of the other phases of the vehicle's life cycle. For example, an increase in emissions from the production of alternative, low-density materials or a lack of recyclability of these alternative materials. This could potentially lead to increased landfilling.

Cars utilising battery electric powertrains are another example. While reducing tailpipe or exhaust emissions, these cars can have high levels of emissions during production of the battery, typically utilise non-renewable energy during the use phase, and their batteries are difficult to recycle at end-of-life.

Several worldsteel members have been developing new grades of innovative high-strength steels allowing auto components to be made thinner and lighter without sacrificing safety. These new steels can achieve weight reductions of up to 25% compared to conventional steels.[34] WorldAutoSteel, the automotive group of worldsteel, has undertaken projects worth more than €70 million to research and develop ways to apply these advanced steels to create more efficient, lightweight vehicle designs.

Many automakers are already using LCA as a tool to reduce the environmental impacts of their products. For example:

- In 2002, Honda implemented LCA Data and Management Systems and regards LCA as a 'vital tool for environmental impact assessment'.
- Toyota actively carries out LCA studies in the development stage of new technology. It has made the decision not to use carbon fibre in its designs because of the high level of GHG emissions released during its production. These emissions outweigh the GHG savings achieved by reducing the mass of the vehicle.
- Volkswagen and Mercedes use LCA for environmental product design and issue environmental certificates in accordance with the relevant ISO-standards.
- Ford routinely uses LCA and has begun to require carbon footprint data from its suppliers.
- Nissan's 2010 green initiative incorporates LCA in the design of all new models.

Although there are many hurdles to cross before LCA can be used as a basis for vehicle regulations, governments around the globe are considering future implementation. In its mid-term review in March 2014, of current legislation, the European Commission stated: "Policy action should be taken to guide manufacturers towards optimal solutions taking account of, in particular, greenhouse gas emissions associated with the generation of energy supplied to vehicles such as electricity and alternative fuels, and to ensure that those upstream emissions do not erode the benefits related to the improved operational energy use of vehicles."

Life cycle based environmental regulation is in its infancy and not without significant challenges. Nevertheless, the potential life cycle based regulation of automotive GHG emissions provides a unique opportunity to align regulatory practice with the latest thinking on environmental product policy. It provides an opportunity for a new era of enlightened and successful environmental legislation. The steel industry has been working with governments as a knowledge resource to help address methodological issues and other factors. The goal is that future regulations should take life cycle thinking into account.

"Construction, automotive and packaging are examples of just three market sectors where life cycle thinking is starting to be incorporated into regulations. However, a global rethink of regulations in all market sectors across every region is required in order to ensure that the true environmental impact of products is assessed correctly and consistently."

— Clare Broadbent,
Head of Product Sustainability
worldsteel

## Packaging

In Europe, many studies have been carried out to gain accurate and up-to-date LCI data on different packaging materials. These studies have resulted in a life cycle inventory, a list of inputs and outputs associated with each type of packaging.

This LCI data was utilised at the European level in 2013 when the European Commission introduced the **Single Market for Green Products initiative**, which includes the PEF standard. The initiative aims to create a common life cycle assessment methodology which can be used to calculate the environmental footprint of 'green' products which are marketed across the EU. Without the initiative, a company wishing to market its product as 'green' in multiple EU countries would need to apply the different national schemes in force in each separate market. This methodology is the third EU instrument which aims to improve the sustainability of products. The other two are the **Eco-label** and the **Eco-design Directive**.

APEAL (the Association of European Producers of Steel for Packaging) continually updates the life cycle inventory for tinplate which can be accessed from the **European Reference Life Cycle Database (ELCD)**.

### TRANSPORT › Environmental savings with high-strength steel in trailers

Logistics is a key element in forestry. In Sweden, a large proportion of timber is transported by truck. It is important to produce more efficient vehicles so that transport costs and carbon dioxide emissions can be reduced.

An LCA study was carried out to analyse the potential environmental savings by upgrading the strength of the steel in the chassis of the trailer. The goal was to reduce the curb-weight of the truck, crane and trailer.

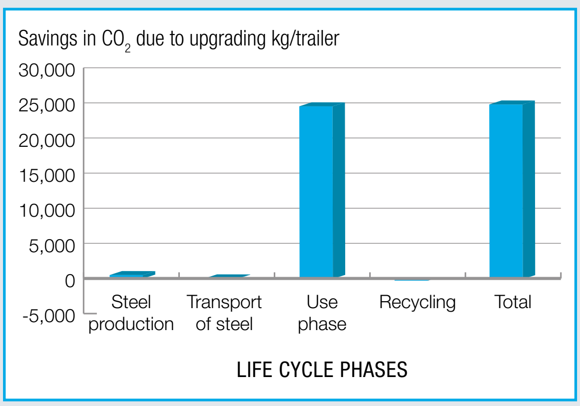
By upgrading the longitudinal beams in the trailer from conventional rolled profiles (S310) to welded beams made from Domex 700, the trailer weight was reduced by 350 kg in space weight. Changes in design and weight savings in other parts of the chassis led to a further 150 kg drop in weight. Additional weight reductions can be achieved by replacing other parts of the trailer with high-strength steel (HSS).

The LCA is based on a vehicle which travels an average of 175,000 km/year and has an average lifetime of seven years. It is assumed that 50% of the distance is driven with an empty trailer. The reductions in $CO_2$ emissions over the different stages of the trailer's life are shown in the figure on the right.

In addition to savings in carbon dioxide, the upgrade saves 100 megawatt hours of non-renewable energy resources. Costs are also reduced due to lower fuel consumption: the lifetime saving was calculated to be €12,300/vehicle (based on a fuel price of €1.5/litre).

*Trailer using high-strength steel from SSAB*

**$CO_2$ emission savings by applying light-weight, high-strength steel (EcoSteel software)**




*Source: Jernkontoret*[35]

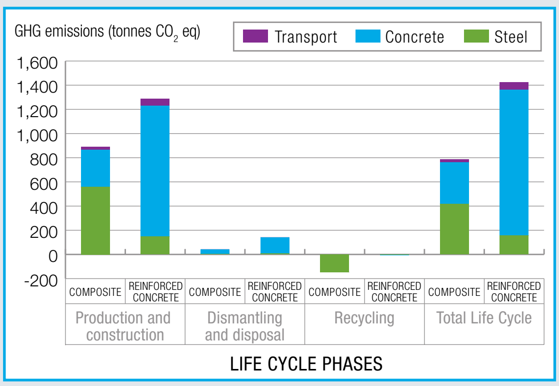
## OFFICE BUILDINGS › LCA in the eco-design of office building

To compare the global warming potential (GWP) of a composite steel-concrete building with one composed of 100% reinforced concrete, ArcelorMittal undertook a peer-reviewed LCA study of two buildings which had the same dimensions and number of floors.

The study was carried out by the BIO Intelligence Service and peer-reviewed in accordance with ISO 14040. Results have been confirmed by ArcelorMittal's AMECO software. This free software (http://sections.arcelormittal.com) enables users to assess the life cycle environmental impact of composite buildings and bridge structures.

In terms of $CO_2$ impact, the results show the benefits of the eco-optimised composite steel-concrete structure. While the concrete in both buildings can be crushed and reused in applications such as road construction, the steel building contains less concrete. If the reuse and recycling of the steel is taken into account, the GWP of the composite steel-concrete building is up to 82% lower.

### Comparison between composite (steel-concrete) solution and 100% reinforced concrete solution

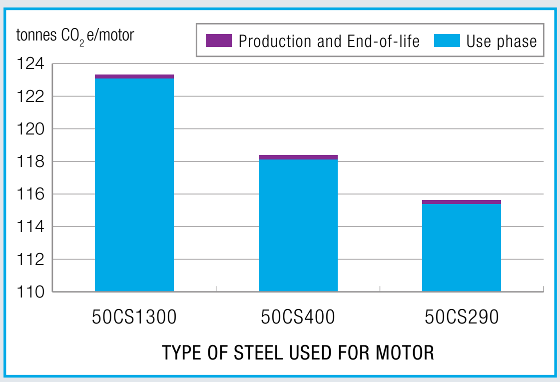



*Source: ArcelorMittal[36]*

## MOTORS › Improving electrical steels for AC motors

China Steel Corporation (CSC) and the Tatung Motor Co. have undertaken an LCA of Tatung's three-horsepower electric motors, in co-operation with the Industrial Technology Research Institute (ITRI) and the Metal Industries Research Development Centre (MIRDC). Two Product Category Rule (PCR) documents for steel products and alternating current (AC) motors were developed in this study and verified against the ISO 14025 standard.

The LCA enabled CSC to quantify the reduced greenhouse gas emissions over the life cycle of its advanced electrical steels. The results demonstrated significant improvements in motor efficiency when the advanced electrical steels (50CS290 and 50CS400) were utilised. Replacing the least advanced steel (50CS1300) with the most advanced (50CS290) leads to a 2.9% increase in efficiency. Shaft lifetime increases to 20,230 hours, an increase of 24.5%. Both benefits will significantly reduce emissions over the life cycle of the motor if the most advanced steel is used.




*Source: China Steel Corporation*

## BUILDINGS › LCA proves zero carbon steel buildings are a reality

Globally, the construction sector faces an unprecedented challenge to significantly reduce the greenhouse gas emissions generated by the built environment. However, there has been a lack of reliable data to inform the technical decisions required to meet this challenge.

Completed in 2012, the £1 million Target Zero project demonstrated that net zero carbon buildings in the UK are achievable in steel. The project was led by a consortium of leading sustainable construction organisations in the UK.[37] The project demonstrated how to meet anticipated future building regulations whilst achieving the highest sustainability ratings for buildings. This was possible through assessing cost, embodied carbon, operational energy efficiency, associated carbon emissions and cost effective carbon reduction technologies.

The study analysed five non-domestic building types including a secondary school and considered an existing steel-framed building and alternative structural options.

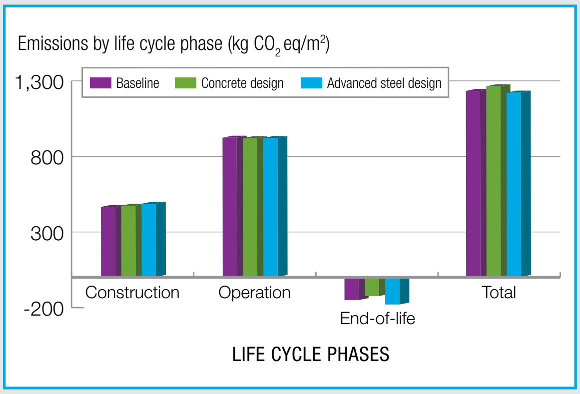
Tata Steel used CLEAR, its in-house construction LCA tool, to assess the carbon embodied in the materials and the erection/demolition processes. This, combined with the operational emissions from the building's use, including quantification of the benefits of reuse, recycling and recovery of materials at end-of-life, allows a full life cycle approach to be taken.

The embodied carbon emissions for the three structural options considered for the school building, prior to carbon reduction technologies such as photovoltaics, being applied, are shown in the figure below. The results from CLEAR showed that advanced steel solutions (Option 2) offer competitive embodied and whole-of-life carbon performance compared to alternative solutions.

The three structural options were as follows: a baseline design using steel and concrete, a concrete based design and an advanced steel design.

Similar results were found for the other four building types studied. One of the key findings was the important contribution recycling materials, at the end of the building's life, makes to reducing their environmental impact.

### Life cycle results for the three structural school building options




*Source: Tata Steel in Europe*[38]

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37. The consortium of leading construction organisations included BCSA, AECOM, Sweett Group, the SCI and Tata Steel.
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| avoided burden | A methodology that credits a system for producing a co-product (for example, scrap) that can be used to displace primary production of a material, thus avoiding the environmental burden of primary production. |
| BREEAM | Building Research Establishment Environmental Assessment Method. Method used to assess the sustainability of buildings which is widely used in Europe and other regions. |
| $CO_2$ equivalent | The concentration of a greenhouse gas (GHG) that would absorb the same level of infrared radiation as a given concentration of $CO_2$. Unit of measuring global warming potential. |
| cradle-to-cradle | A life cycle approach where the material is fully recycled back into the same material, with no loss in quality. |
| cradle-to-gate | A study in which the impacts are assessed from raw material extraction up to the point where the product leaves the factory gate. |
| cradle-to-grave | A study which includes all life cycle phases from raw material extraction up to the point where the product is disposed of as waste or recovered and recycled. |
| downcycling | The process of reusing or recycling materials to create a product of lower quality or value than the original. |
| EN 15804: 2012 | European Norm 15804. Provides core rules for construction products. |
| end-of-life | Defines the end of the useful life of a product when it is ready to be disposed of or recycled. End-of-life scrap results from the treatment of a product at the end of its useful life. Also referred to as post-consumer scrap. |
| environmental product declaration (EPD) | A comprehensive disclosure of a product's environmental impacts based on a life cycle assessment (LCA). |
| EPD | See environmental product declaration. |
| function | Defines the purpose of what is being studied in an LCA, in reference to a functional unit.<br><br>For steel, the functional unit covers the production of one kilogram of a steel product to the point it leaves the factory gate. |
| GHG | See greenhouse gas. |
| GHG Protocol | The Greenhouse Gas (GHG) Protocol is the most widely used international accounting tool for government and business leaders to understand, quantify, and manage greenhouse gas emissions. The GHG Protocol, a decade-long partnership between the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), is working with businesses, governments, and environmental groups around the world to build a new generation of credible and effective programmes to mitigate climate change. |
| Global Warming Potential (GWP) | The ability of different greenhouse gases to trap heat in the atmosphere relative to carbon dioxide expressed as kg $CO_2$-equivalents. |
| greenhouse gas (GHG) | A gas in the atmosphere which contributes to the greenhouse effect by absorbing infrared radiation. The principal greenhouse gases are:<br>• Carbon dioxide ($CO_2$)<br>• Fluorinated gases<br>• Methane ($CH_4$)<br>• Nitrous oxide ($N_2O$) |
| HPDs | Health product declaration: a report listing the health effects associated with the materials content of a building product. |
| Integrated life cycle assessment | A tool for the systematic evaluation of overall sustainability aspects (environmental, social (social LCA), economic (LCC)) of a product or service system through all stages of its life cycle. |
| ISO 14025: 2006 | International standard covering the principles and procedures for Type III environmental labels and declarations. |
| ISO 14040: 2006 | International standard covering LCA principles and framework. |

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| ISO 14044: 2006 | International standard covering requirements and guidelines for LCA. |
| ISO 14046: 2014 | International standard for measuring the water footprint of products. |
| ISO TS 14067: 2013 | International technical specification for calculating the carbon footprint of products. |
| LCA | See life cycle assessment. |
| LCC | See life cycle costing. |
| LCI | See life cycle inventory. |
| LCIA | See life cycle impact assessment. |
| LEED | Leadership in Energy and Environmental Design - Version 4. Most common method for assessing the sustainability of buildings in North America and other regions. |
| Life cycle assessment (LCA) | A tool for the systematic evaluation of the environmental aspects of a product or service system through all stages of its life cycle. |
| Life cycle costing (LCC) | A tool that evaluates the costs of a product throughout its life cycle. |
| Life cycle impact assessment (LCIA) | An analysis of data to evaluate the contributions of the inputs and outputs identified in the LCI to various environmental impact categories. For examples of impact categories, see worldsteel's LCA methodology report 2011 (page 12). |
| Life cycle inventory (LCI) | The results obtained from quantifying the energy and raw material requirements, atmospheric emissions, waterborne emissions, solid wastes, and other releases for the entire life cycle of a product, process, or activity. That is, a list of the inputs and outputs. |
| OEM | Original equipment manufacturer. |
| PCR | See product category rule. |
| post-consumer scrap | See end-of-life scrap. |
| product category rule (PCR) | A set of specific rules, requirements and guidelines for developing Type III environmental declarations (EPDs) for one or more product categories. Based on ISO 14025: 2006. |
| prompt scrap | Scrap resulting from steelmaking, forming, or part manufacturing processes. Also known as pre-consumer scrap and includes manufacturing scrap. |
| Recycling | A resource recovery method involving the collection and treatment of a previously used product for use as the same material in the manufacture of a new product. |
| Remanufacturing | Remanufacturing restores durable used products to like-new condition. It differs from repair, which is a process limited to making the product operational. |
| SETAC | Society for Environmental Toxicology and Chemistry. Co-founders of the Life Cycle Initiative. |
| triple bottom line | Measuring the extent to which enterprises are able to act in a sustainable way gave rise to the concept of the triple bottom line. Its use has expanded traditional accounting techniques to include performance on social and environmental impacts and is today widely used as a measure of the sustainability of an enterprise. The aim is to show that positive financial results can be achieved, without a negative impact on the environment or society around the enterprise. |
| UNEP | United Nations Environment Programme. Co-founders of the Life Cycle Initiative. |

The World Steel Association (worldsteel) is one of the largest and most dynamic industry associations in the world. worldsteel represents approximately 170 steel producers (including 9 of the world's 10 largest steel companies), national and regional steel industry associations, and steel research institutes. worldsteel members represent around 85% of world steel production.

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