

Appendix 6



SUSTAINABLE STEEL

At the core of a green economy



CONTENTS

Message from the Chairman and Director General	3
The steel industry at a glance	4
How we use steel	6
Steel at the core of our economy	8
Steel's endless life cycle	12
Industry focus: environment	16
Industry focus: safety, training and community	22
Steel: meeting societies' needs sustainably	26
What governments and policymakers can do to help	36
End notes	37

MESSAGE FROM THE CHAIRMAN AND DIRECTOR GENERAL

Steel is at the core of a green economy, in which economic growth and environmental responsibility work hand in hand.

The steel industry believes that sustainable development must meet the needs of the present without compromising the ability of future generations to meet their own needs. Within this, a green economy delivers prosperity for all nations, wealthy and poor alike, while preserving and enhancing the planet's resources.

Steel is essential to the technologies and solutions that meet society's everyday needs – now and in the future. Steel is central to our current transport systems, infrastructure, housing, manufacturing, agriculture, water and energy supply. It is also critical to the sectors and technologies that will enable and drive a green economy.

Renewable energy, resource-efficient and energy-efficient buildings and low carbon transport, infrastructure for fuel efficient and clean energy vehicles and recycling facilities – all of these things depend on steel.

In addition, many of the challenges posed by population growth, urbanisation, poverty reduction and mitigation of natural disasters can best be met by steel.

Steel's two key components are iron – one of Earth's most abundant elements – and recycled steel. Once steel is produced it becomes a permanent resource because it is 100% recyclable without loss of quality and has a potentially endless life cycle. Its combination of strength, recyclability, availability, versatility and affordability makes steel unique.

While the steel industry is energy and carbon-intensive, significant progress has been made to reduce steelmaking impacts. Research and development investment is ongoing. Steel's versatility and recyclability have also brought about countless

innovative steel applications that, when seen from a product life cycle perspective, provide savings that neutralise and often far outweigh the initial material production impacts.

Steel's durability also allows for the reuse of countless products, which is enhanced through proper design. This saves natural resources.

In this report, we will share with you:

- how steel enables economic growth and will enable a green economy that meets society's needs in a sustainable way
- innovative steel solutions that maximise energy and emission savings over product life cycles while maintaining affordability and the highest safety standards
- the progress the steel industry has made over the past 20 years in its environmental and safety performance
- action being taken by the industry to ensure continued improvement
- what government and policymakers can do to help us to strengthen steel's contribution to a green economy.

We recognise that continued engagement and collaboration with our stakeholders are essential as we strive to fulfill our vision of a sustainable steel industry in a sustainable world. We welcome your ideas and feedback.

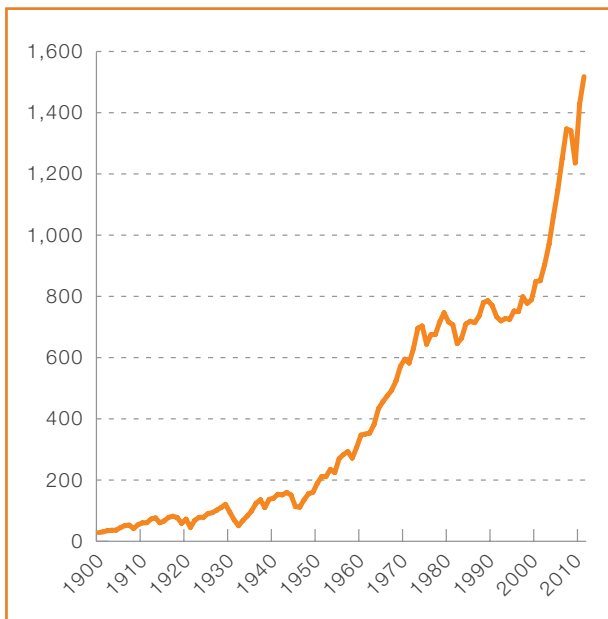
Dr Xiaogang Zhang

worldsteel Chairman and
President, Anshan Iron & Steel Group Corporation

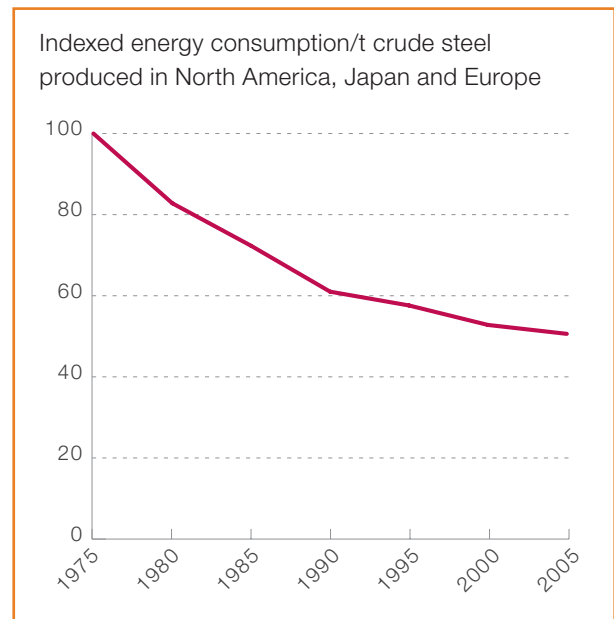
Dr Edwin Basson

Director General
worldsteel

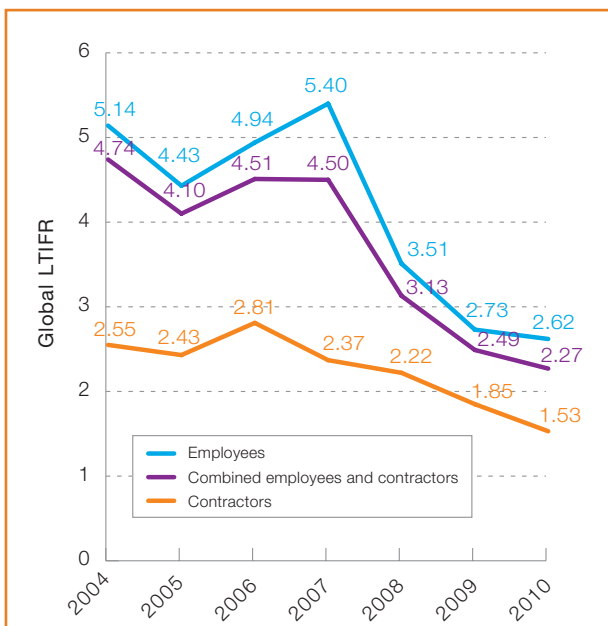
World crude steel production, 1900-2011 (Mt)



Energy use



Lost-time injury frequency rate (LTIFR)



Global steel use

215 kg

of steel was used per capita in 2011, worldwide.

CO₂ emissions

1.8 t CO₂/t crude steel

based on route-specific CO₂ intensities for three steel production routes: basic oxygen furnace, electric arc furnace and open hearth furnace; and weighted based on the production share of each route.

Employees

More than 2 million

people are employed by the steel industry directly.

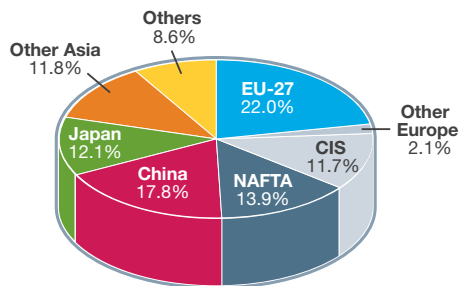
THE STEEL INDUSTRY AT A GLANCE

Major steel-producing and steel-using countries

2001

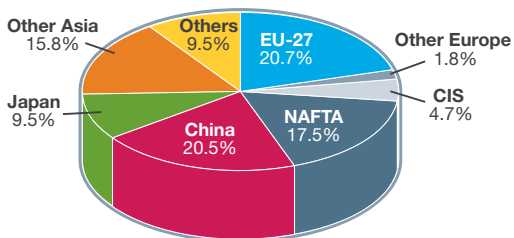
Production:

World total: 851 million tonnes crude steel



Use (finished steel products):

World total: 769 million tonnes crude steel



Environmental management system certification

89%

of steel industry employees and contractors work in EMS-registered production facilities (EMAS or ISO 14001).

Steel recycling

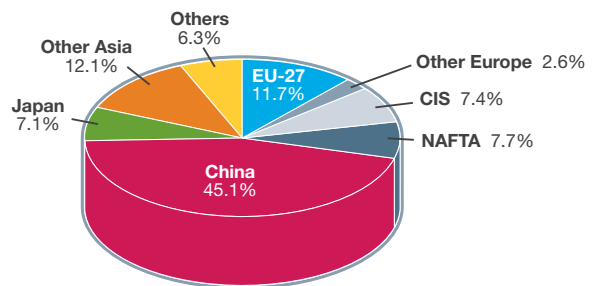
Over 22 billion tonnes

of steel has been recycled worldwide since 1900 owing to steel's 100% recyclability.

2011

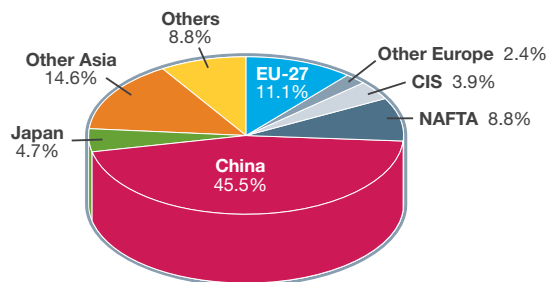
Production:

World total: 1,518 million tonnes crude steel



Use (finished steel products):

World total: 1,371 million tonnes crude steel



Material efficiency

98%

of the raw materials used to make crude steel are converted to products and by-products. The industry's goal is zero waste.

Investment in new processes and products

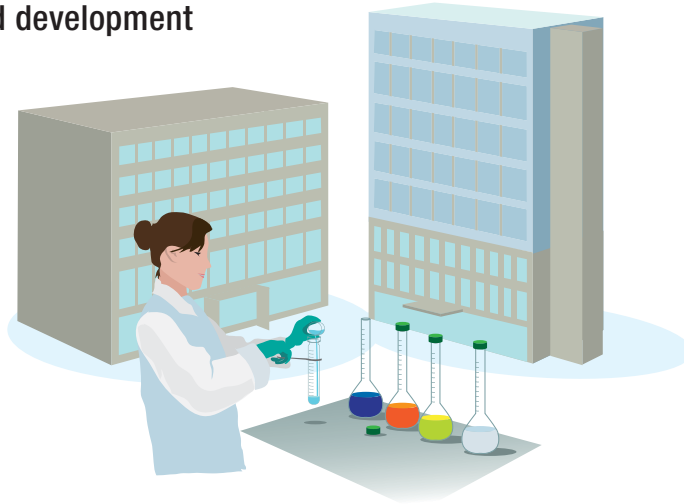
8.8%

of revenue. Includes investment in R&D and capital expenditure.

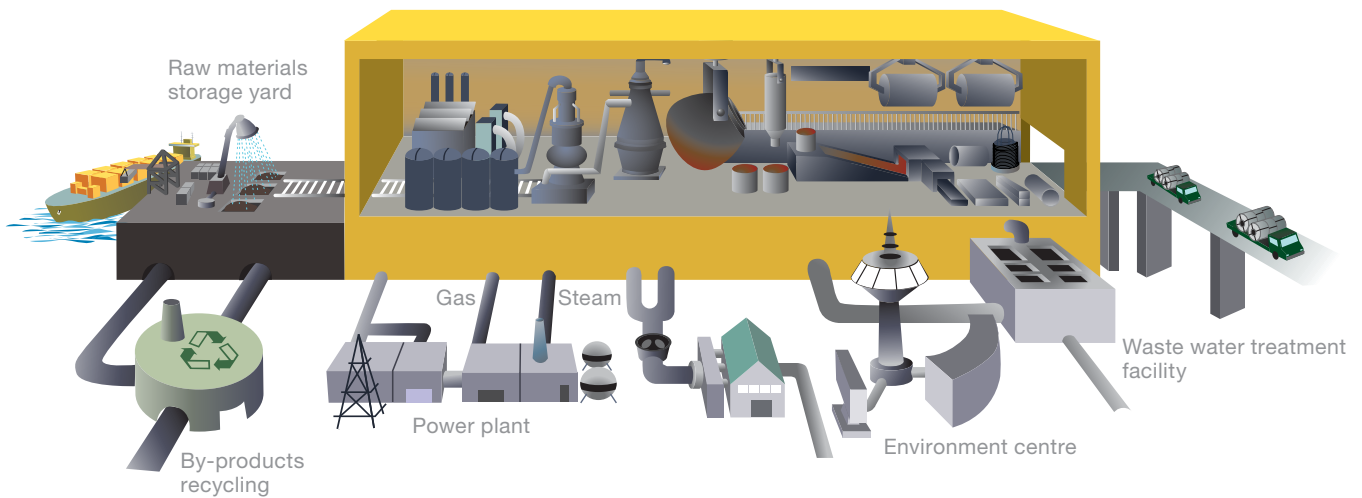
HOW WE USE STEEL

Use by sector in 2011

Research and development

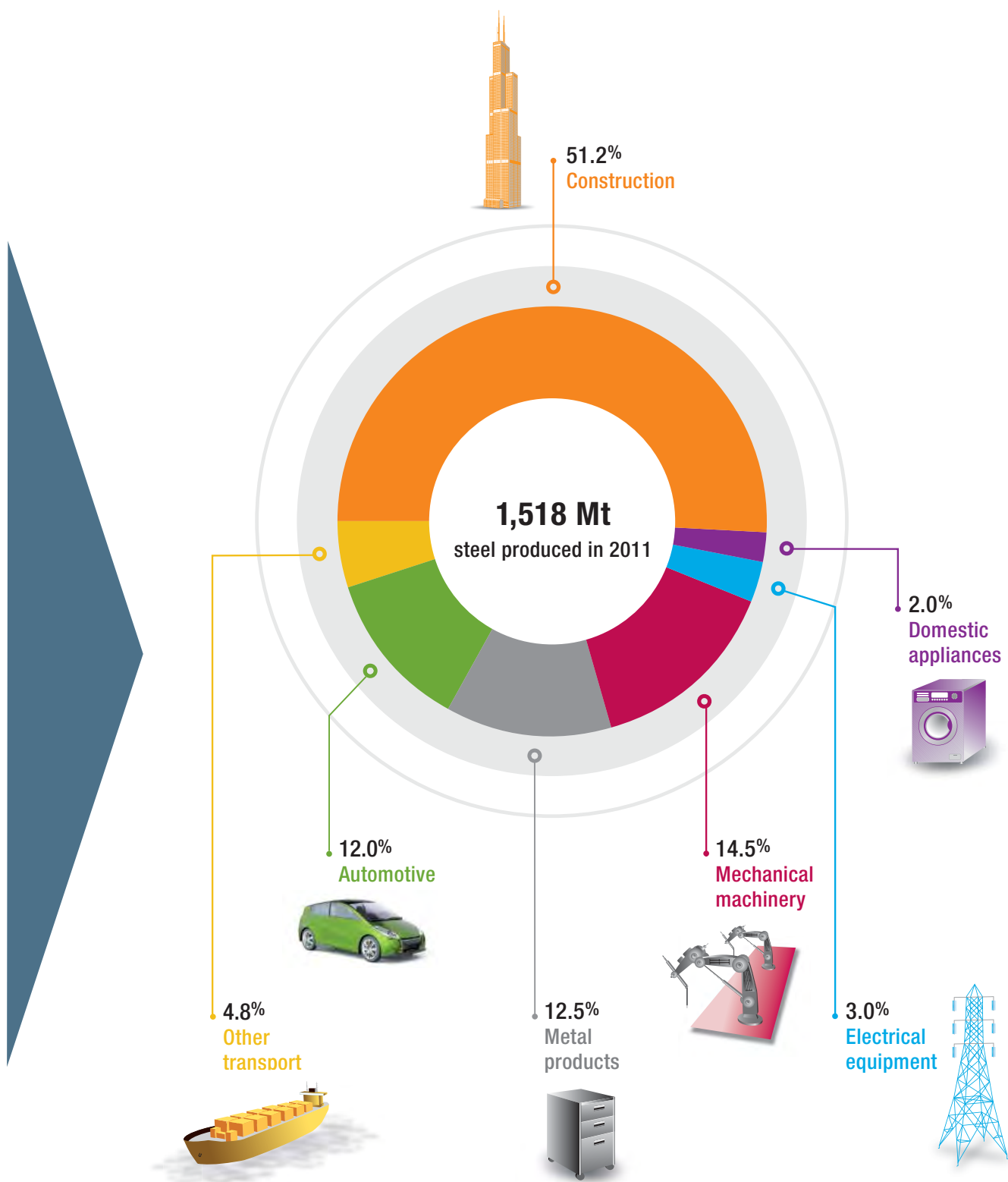


Steelmaking facility



Steel is everywhere in our lives





Steel enables economic growth

Steel has enabled our modern way of life. It has helped lift societies out of poverty, spurring economic growth, and continues to do so around the world today.

Iron, steel's precursor, fueled the industrial revolution starting in 1750, enabling manufacturing equipment in factories and rail transport. Modern steelmaking was developed 150 years ago with the invention of the Bessemer process allowing for the affordable mass-production of steel (an iron alloy). This set off a second industrial revolution, and sustained economic growth.

Today, steel is one of the most common materials in the world. We rely on it for our housing, transport, food and water supply, energy production, tools and healthcare. Nearly everything around us is either made of steel or manufactured by equipment made of steel.

Steel is inextricably linked with economic growth and prosperity, as shown in Figure 1. This figure estimates stocks of steel per person, based on their current wealth (GDP per person), and suggests that as a person's income increases they build up their stock of steel, which then tends to reach a plateau.

Table 1 (see p. 9) demonstrates that steel stocks range from 0.1 tonnes per person for the poorest nations to over 13 tonnes per person for Japan, with the world average at around 2.7 tonnes per person.

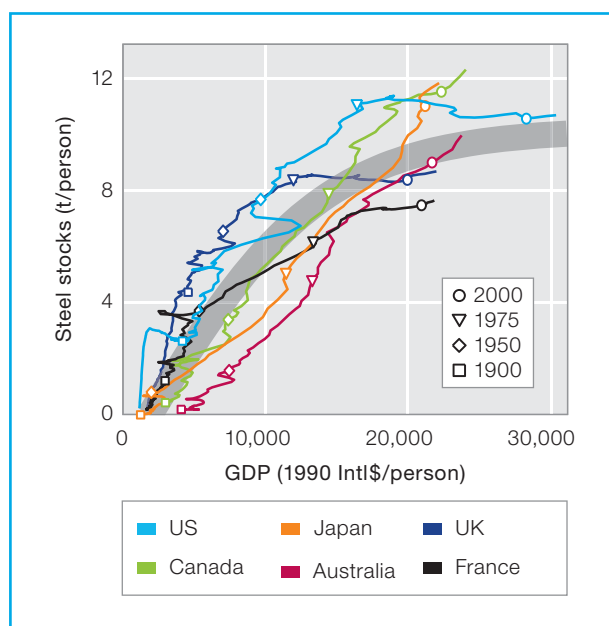
Figure 2 demonstrates typical distribution of steel use in developed countries.

Developing societies require steel to build new roads, railway lines, buildings and bridges. They also need it to lay new pipelines for gas, water and sanitation and to build factories and machinery.

Once basic infrastructure needs are met and GDP continues to rise, the demand for consumer goods such as washing machines and refrigerators increases, as does the need for mobility via trains, buses and automobiles – all of which require steel for their production and related infrastructure (stations and fueling). Urbanisation is also enabled by steel – e.g. allowing for high-rise buildings.

As suggested in Figure 1, steel stocks per person, or the demand for steel in developed societies tends to plateau as a certain level of wealth is reached and the need for new infrastructure and buildings are satisfied. Per capita demand tends to remain high in areas with high industrial production, contributing to sustained economic growth.

Figure 1: Steel stocks in-use vs GDP for different countries¹



STEEL AT THE CORE OF OUR ECONOMY

Figure 2: Typical steel use in developed countries²

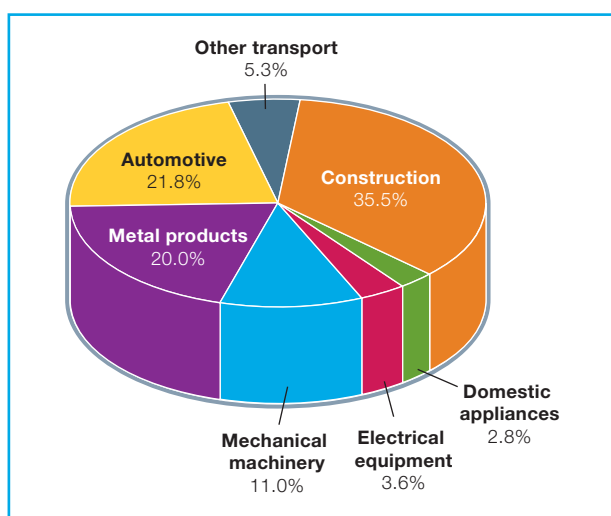
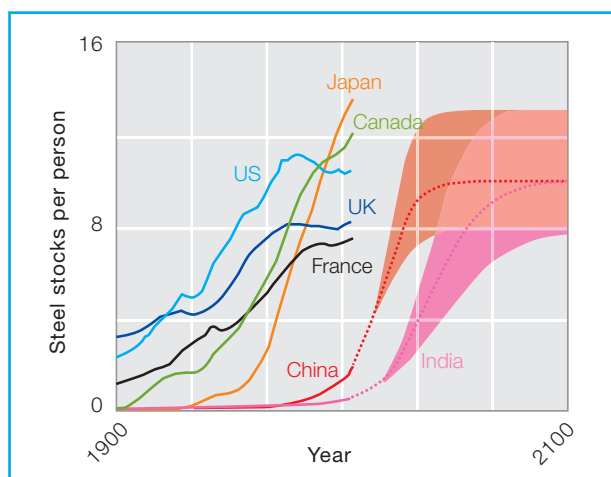


Figure 3: Past and forecast steel stocks in China and India³



For example, steel demand is high in South Korea due to the country's high level of steel exports in steel-containing goods such as ships and cars. It is also high in Japan because of shipbuilding, engineering and automotive – it remains a big net exporter of automotive vehicles. Steel is also required in both of these highly urbanised countries for high-rise buildings that are earthquake resistant.

Table 1: Steel stocks in-use for selected countries, 2005¹

Country	Steel stocks (tonnes/person)
Argentina	4.1
Australia	9.8
Bangladesh	0.1
Brazil	3.1
Canada	12.1
China	2.2
Congo, DRC	0.1
Egypt	1.1
Ethiopia	0.1
France	7.5
Germany	9.0
India	0.4
Indonesia	0.3
Japan	13.6
Mexico	4.8
Nigeria	0.1
Pakistan	0.1
Philippines	0.1
Russia	4.6
South Africa	3.0
South Korea	7.9
Spain	8.7
Thailand	2.2
Turkey	4.2
United Kingdom	8.5
United States	10.5
Vietnam	0.1
World average	2.7

Steel is unique and ever-evolving

Steel's two key components are iron, one of Earth's most abundant elements, and recycled steel. Once steel is produced it becomes a permanently available resource because it is 100% recyclable and has a potentially infinite life cycle. This infinite recyclability without loss of properties, combined with its strength, versatility, availability and affordability make steel unique.

There are thousands of different types of steel, designed to meet the specific needs of end users. Many products in use today were developed over the past 10 years.

Steels are alloys based on iron. Depending on the desired properties – such as strength, ductility, and stiffness – a multitude of other elements can be present in small amounts.

The variety of steels is not only defined by chemical composition, but also by a variety of microstructures on a nano and sub-nano scale. This leads to an impressive range of achievable properties and ensures that there is much scope to continue developing new, innovative, lightweight and high-strength steels.

Stock levels for steel in China and India in particular are expected to grow significantly by 2050 – as shown in Figure 3 – to meet their growing need for buildings, infrastructure and transport in a sustainable way. There will also be strong growth in steel production in other areas of the world where steel will be vital in raising the material and social welfare of developing societies.

Steel will continue to be needed in both developed and developing countries in advanced and new applications that support sustainable development and thereby, a green economy.

Steel supports the green economy

We have many challenges to overcome as a global society. We are faced with resource shortages, water and land stress, environmental degradation and climate change. There are also many needs to be met – from poverty eradication to mitigation of natural disasters. The challenges are magnified by a population set to grow from the present 7 to 9 billion by 2050, accompanied by rapid urbanisation. It is clear that things cannot go on as they have, and that we must transition to a green economy in which economic growth and environmental and social responsibility work hand in hand.

The steel industry believes that sustainable development must meet the needs of the present without compromising the ability of future generations to meet their own needs. Within this, a green economy delivers prosperity for all nations, wealthy and poor alike, while preserving and enhancing the planet's resources.

The transition to a green economy is already underway⁴ and presents countless opportunities for positive change.

Steel has an essential role to play in this transition and in sustaining a green economy.

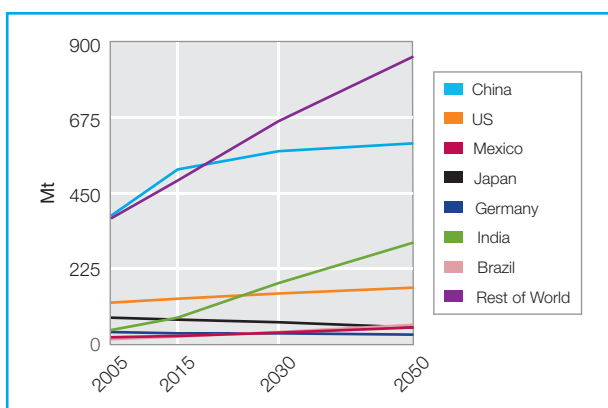
Steel is critical to the sectors and technologies that will enable and drive a green economy. Renewable energy (see p. 33), resource and energy efficient buildings (see p. 27), low-carbon transport (see p. 31), infrastructure for fuel efficient and clean energy vehicles (see p. 31) and recycling facilities all depend on steel. These sectors will also provide employment opportunities, as does the steel sector itself.

The steel industry employs more than 2 million people directly around the world, with a further 2 million contractors and 4 million in supporting industries. Considering steel's position as the key

product supplier to industries such as automotive, construction, transport, power and machine goods, the steel industry is at the source of employment for many more millions of people.

Global steel use has grown more than seven-fold since 1950. By 2050, steel use is projected to increase by 1.5 times that of present levels, to meet the needs of our growing global population. Figure 4 shows a forecast of steel consumption by region.

Figure 4: Past and forecast steel consumption⁵



In addition to providing employment and steel products that will enable a green economy, the steel industry is also working to make improvements in its own sustainability performance.

Our efforts are focused on:

- further reducing the environmental footprint of steelmaking (see p. 16)
- ensuring world-class safety performance (see p. 22)
- supporting the application of steel in products that reduce life cycle CO₂ emissions, such as AHSS in vehicles (see p. 31)
- promoting life-cycle thinking and intelligent product design to allow for dematerialisation and expanded reuse (see p. 14, 29)
- further improving end-of-life steel product recovery and recycling rates (see p. 13).

Steel solutions in a green economy: wind turbines

Steel is a key material in providing solutions for clean energy delivery. It is essential to wind power generation. Every part of a wind turbine depends on iron and steel. Onshore wind turbines require an average of 180 tonnes of steel per MW, while offshore wind turbines require an average of 450 tonnes of steel per MW.⁶

Wind could provide a quarter of the world's electricity by 2050 if current growth rates continue – requiring an additional 1,000,000 onshore and 100,000 offshore turbines.⁷ Steel will be essential not only in building these turbines, but also in the transmission and distribution of the electricity produced and in supporting applications.

Over 20 years, a 3 MW wind turbine can deliver 80 times more energy than was used in its production and maintenance.⁸

At the end of its life the wind turbine can be remanufactured for reuse, extending the useful life of the turbine (see p. 15), and eventually recycled. Steel is 100% recyclable without loss of properties.



<http://worldsteel.org/publications/bookshop>

Steel production

Globally, steel is produced via two main routes: the blast furnace-basic oxygen furnace (BF-BOF) route and electric arc furnace (EAF) route, which are shown in Figure 6. Variations and combinations of production routes also exist.

The key difference between the routes is the type of raw materials they consume. For the BF-BOF route these are predominantly iron ore, coal, and recycled steel, while the EAF route produces steel using mainly recycled steel and electricity. Depending on the plant configuration and availability of recycled steel, other sources of metallic iron such as direct-reduced iron (DRI) or hot metal can also be used in the EAF route (see p. 18 for raw material inputs by route.)

About 70% of steel is produced using the BF-BOF route. First, iron ores are reduced to iron, also called hot metal or pig iron. Then the iron is converted to steel in the BOF. After casting and rolling, the steel is delivered as coil, plate, sections or bars.

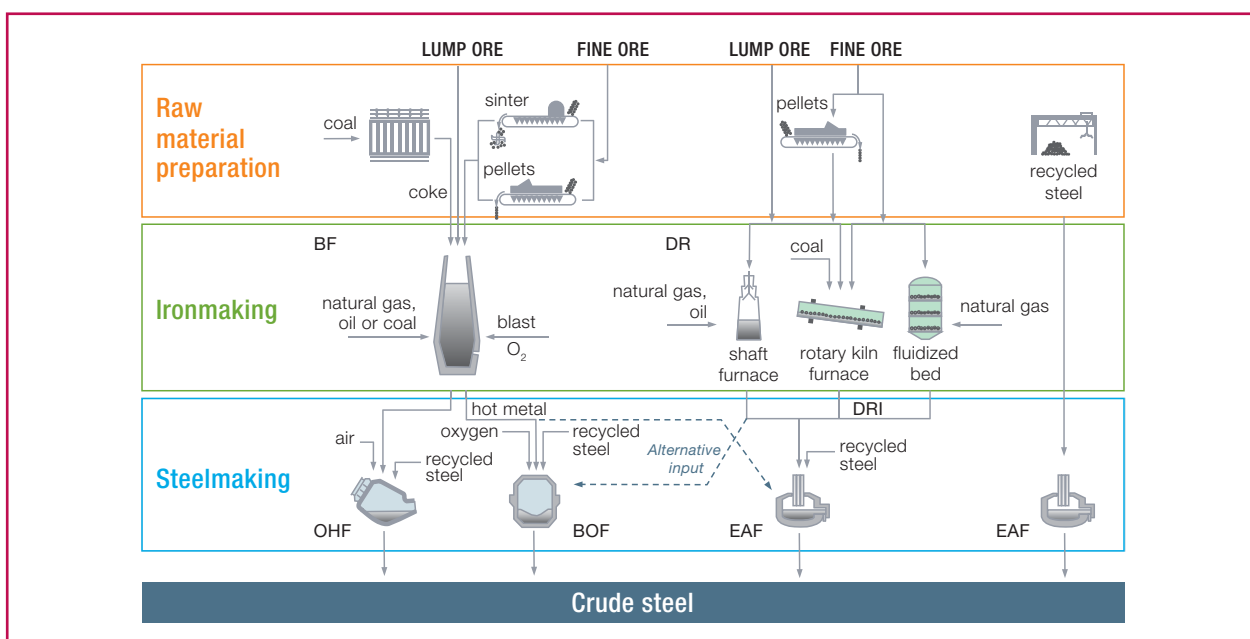
Steel made in an EAF uses electricity to melt recycled steel. Additives, such as alloys, are used to adjust to the desired chemical composition. Electrical energy can be supplemented with oxygen injected into the EAF. Downstream process stages, such as casting, reheating and rolling, are similar to those found in the BF-BOF route. About 29% of steel is produced via the EAF route.

Another steelmaking technology, the open hearth furnace (OHF), makes up about 1% of global steel production. The OHF process is very energy intensive and is in decline owing to its environmental and economic disadvantages. Only four furnaces of this type are known to be in operation.

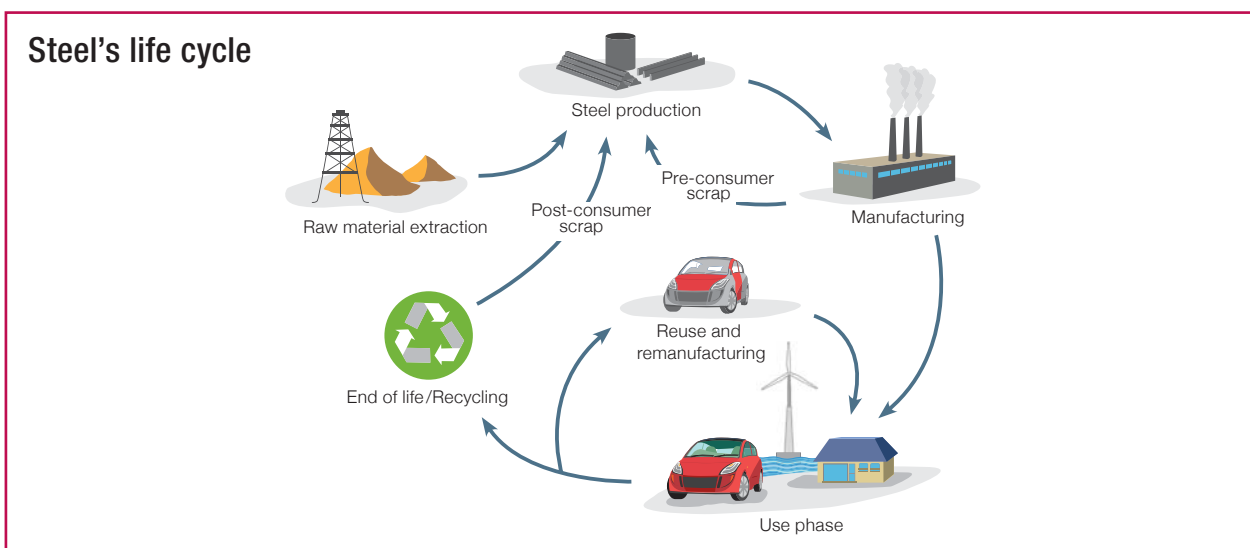
Most steel products remain in use for decades before they can be recycled. Therefore, there is not enough recycled steel to meet growing demand using the EAF steelmaking method alone. Demand is met through a combined use of the BF-BOF and EAF production methods.

All of these production methods can use recycled steel scrap as an input. Most new steel contains recycled steel.

Figure 6: Steel production routes



STEEL'S ENDLESS LIFE CYCLE



Steel recycling

Steel is 100% recyclable, which means it can be reprocessed into the same material of the same quality again and again. Also, it is easily recovered by magnetic separation.

Once steel is produced, its life cycle is potentially endless, making it a permanent resource for society – as long as it is recovered at the end of each product life cycle.

Recycling is especially important in a green economy because it conserves valuable resources and prevents useful materials going to landfill sites as waste. There are two main sources of recycled steel, also called steel scrap: excess material from steel production and downstream manufacturing (pre-consumer scrap), and steel at the end of a product's life (post-consumer scrap).

100% of scrap from steel production and downstream processing is collected and recycled directly into steel production. Post-consumer scrap has to be collected and prepared (for example by shredding and baling). Because of the high value of steel scrap, there are also economic incentives that help to maintain high recycling levels.

Post-consumer steel product recovery rates vary across regions and sectors. A recent worldsteel review of these rates for various sectors is shown in Table 2. Recovery rates differ from recycling rates. For example, while about 85% of automobiles are recovered for recycling, nearly 100% of the steel in these recovered vehicles is recycled, thanks to steel's magnetic properties and the ease of magnetic separation.

In addition to steel industry efforts, there are also joint activities with other metal industries, research institutes and academia to identify losses throughout the life cycle and see how they can be minimised to further improve steel recycling rates.⁹

Steel is the most recycled industrial material in the world, with over 500 Mt recycled annually, including pre- and post-consumer scrap.

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.

Table 2: Post-consumer steel product recovery rates by sector

Sector	Recovery rate 2007 (%)	Recovery rate 2050 (%)	Life cycle in years
Construction	85	90	40-70
Automotive	85	90	7-15
Machinery	90	95	10-20
Electrical and domestic appliances	50	65	4-10
Weighted global average	83	90	N/A

- Rail track is regularly reused by swapping over the left and right rails on a track. When no longer suitable for main-line use, rails can be tested for cracks and then reused on secondary lines with lower traffic. They can also be recapped or redesigned to extend their useful life.⁵
- Ships can be dismantled and steel parts can be re-rolled for reuse as rebar for construction. Steel shipping containers can also be reused and converted into buildings.¹⁰
- Older wind turbines in more mature markets that are replaced with newer, more powerful ones can be shipped to other locations for reuse.¹¹ Remanufacturing the used wind turbine extends the life of the wind turbine even further.

Reuse and remanufacturing

Steel product reuse

Steel's durability enables many products to be reused. This extends the product life cycle and therefore conserves resources. Design is critical in saving resources and enhancing product reuse. Consequently, many steel companies and steel product manufacturers are increasingly designing products for reuse.

Reuse is the best form of recycling as little or no additional energy is required for reprocessing.

For example:

- Steel construction components – roofing and wall elements, structural beams – are reused and increasingly being designed for reuse (see p. 28, 29).
- Steel barrels, or drums, have a typical life of six months. If they are used 10 times, however, that lifespan can be extended to five years.
- Automotive steel parts that are undamaged from vehicles that have reached the end of their useful lives are sold by car dismantlers as spare parts for vehicles still in use.

Increased reuse of products will play an important role in sustaining a green economy.

In the future, manufacturers of steel products may also have an important role to play as certifiers of used steel products before they go to market, ensuring the integrity and safety of the product.⁵

Governments could support increased reuse by:

- providing clear guidelines on certification for product reuse
- supporting voluntary codes and standards on product durability within industrial sectors, and
- raising consumer awareness about the benefits of reuse.⁵

Steel product remanufacturing

Remanufacturing is the process of restoring durable used products to like-new condition.¹² It involves the disassembly of a product, during which each component is thoroughly cleaned, examined for damage, and either reconditioned to original equipment manufacturer specifications or replaced with a new part. The product is then reassembled and tested to ensure proper operation.

It differs from recycling in that the value added during original fabrication, including labour, energy, and equipment expenditures, is conserved. This added value is lost in recycling, which reduces the product to its material components and requires additional labour, energy, and machinery. Remanufacturing also differs from repairing, which is a process limited to making the product operational as opposed to thoroughly restoring it.¹³

Remanufacturing extends the overall product life cycle and saves valuable resources. Many steel products lend themselves to remanufacturing, taking advantage of the durability of the steel components. Although mostly invisible to consumers, remanufacturing is already commonplace and will likely become more widespread in a green economy. It offers products that are not only greener, but also less expensive for consumers.

A wide range of steel products is already remanufactured. This includes machine tools, electrical motors, automatic transmissions, office furniture, domestic appliances, car engines and wind turbines.

Engine remanufacturing

A life cycle assessment study shows that remanufactured engines can be produced with up to 83% less energy than the energy needed to produce a new engine (see Figure 7), and emitting up to 87% less carbon dioxide. Consumers can also save up to 53% on cost over a new engine with the purchase of a remanufactured engine. In the study, the iron and steel components made up about 78% of the mass of the modeled engine.¹⁴

Wind turbine remanufacturing

Steel is essential to wind power generation, as every part of the turbine depends on iron and steel (see p. 11). Wind turbines have an average lifetime of 20 to 30 years. Wind farms in mature markets tend to be 'repowered' to increase capacity – a process in which

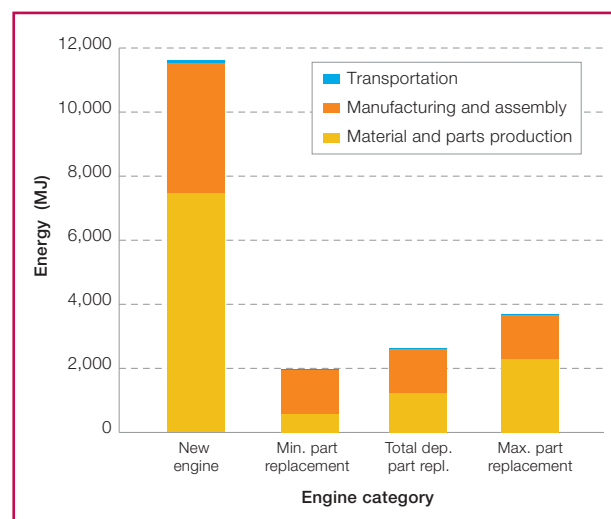
the older turbines are replaced by fewer, newer, more powerful turbines. In Germany, for example, 116 wind turbines with a total rated capacity of 56 MW were dismantled and replaced by 80 turbines with a total rated capacity of 183 MW in 2010.¹⁵

The older turbines can be remanufactured for use on other sites requiring less capacity or in newer markets, thereby extending their useful life.¹¹ If properly remanufactured, the wind turbine can last another 20 years.¹⁶

Remanufacturing also provides the option of keeping the same wind turbines on site. Some remanufacturers even offer on-site service – reducing service time and cost¹⁷ (which can be less than half the cost of a new one¹⁶) – and full warranties on the remanufactured turbines.^{18, 19}

Wind turbine remanufacturers also offer the market sizes no longer provided by the world's major manufacturers²⁰ or individual wind turbine parts with the same warranty as new parts that are up to 25% less expensive.²¹

Figure 7: Total life cycle energy consumption for new and remanufactured engines¹⁴



Working to make steel even more sustainable

Reducing steel's environmental footprint

Steel manufacturing has a variety of impacts on the environment. The main impacts come from the use of energy and raw materials, which result in emissions such as carbon dioxide (CO₂), sulphur oxides (SO_x), nitrogen oxides (NO_x), dust to air as well as water usage and associated emissions.

Measures taken by steel companies to minimise and reduce steel's environmental footprint are described in this section. This section also describes many ongoing joint industry efforts.

A global life cycle inventory database to assess steel's footprint and create more eco-efficient products

worldsteel has been collecting life cycle inventory data from its members since 1995. The data consist of 'cradle-to-gate' environmental inputs and outputs including

- resource use (raw materials, energy and water)
- emissions to land, air and water

for various steel products (for example, 1 kg of hot rolled coil produced) and is available on a global or regional basis. The data can also include the benefits associated with recycling the steel at the end of a product's life.

This data can be used to perform life cycle assessment (LCA) studies on steel-containing products, based on an internationally standardised methodology (ISO 14040 series). LCA studies help to fully understand the environmental impact of a product by providing a full picture of where environmental burdens occur along the product life cycle including production, use and end-of-life (recycling or disposal).

LCA studies enable informed material selection decisions and more eco-efficient products by identifying potential areas to reduce the product's environmental footprint.

Environmental management systems

An EMS helps an organisation to monitor and improve its environmental performance and to increase its operating efficiency.

According to worldsteel's sustainability statistics, in 2010 approximately 89% of steel industry employees and contractors worked in EMS-registered production facilities (EMAS or ISO 14001 certification), up from 85% in 2004.

Water management

Proper water management is part of an effective EMS. It also plays a critical role in the viability of steel plants, especially in regions of water scarcity. Water issues and how they are managed at specific plants vary greatly due to local aspects such as water availability, water quality, plant configuration and legislation.

The steel industry uses saltwater, brackish water and freshwater. Water is used mainly for once-through cooling – over 81% in relation to total intake.²² In general, sea water is the preferred option for this process due to availability and costs and it is returned directly to the source with no tampering in quality at all. In much smaller volumes, water is found throughout the steelmaking process for cooling or heat transfer of heat processing equipment. Water is also required for descaling, dust scrubbers and other processes.

A recent worldsteel member survey showed that average consumption and discharge for integrated steel plants are 28.6 m³/tonne steel and 25.3 m³/tonne of steel, respectively. For the EAF route the

INDUSTRY FOCUS: ENVIRONMENT

average is 28.1 m³/tonne steel for consumption and 26.5 m³/tonne of steel. Water consumption and discharge are close to each other and few losses occur in the process, indicating an overall efficient use of water. In most cases water loss is caused by evaporation.²²

Using advanced technologies, steel plants in areas of water scarcity are able to recycle and reuse around 98% of their water.

Air quality

A key aspect of steel industry environmental protection is to minimise emissions to the air. Emission sources are mapped and monitored. Process improvements can then be identified and implemented with the goal of reducing emissions.

Control mechanisms to reduce emissions can include²³:

- baghouse/filtration systems
- chemical treatment
- thermal oxidation
- scrubber systems
- dust suppression.

worldsteel leads working groups covering various aspects of air quality to facilitate improvements and the spread of best practice throughout the industry.

Case study Responsible Steel

In Australia, the Steel Stewardship Forum is developing a credible and independently verifiable steel certification scheme, called Responsible Steel. Its aim is to minimise impact and improve performance throughout the steel value chain, from mining to scrap recovery.

In a transparent and accountable manner, Responsible Steel would:

- ensure responsible ethical, social and environmental practices throughout the value chain
- enable industry to demonstrate openness, responsibility and improvements
- reinforce and promote consumer and stakeholder confidence in products containing steel
- set operational excellence goals, driving better performance within industry
- enable selection of suppliers and materials throughout the supply chain based on their sustainable performance in addition to technical performance
- reduce reputational risks.

Responsible Steel is expected to be up and running by 2017.



Steel Stewardship Forum
Responsiblesteel

Responsible resource management

Raw material and energy efficiency

The steel industry is highly efficient in its use of raw materials with the technology available today. Key contributing factors to efficiency include high material efficiency rates, co-product use and recycling and steel recycling (see previous chapter).

Key raw materials needed in steelmaking include iron ore, coal, limestone and recycled steel. Inputs for the two main steel production routes (see p. 12) are described below.

The integrated (BF-BOF) route typically uses 1,400 kg of iron ore, 800 kg of coal, 300 kg of limestone, and 120 kg of recycled steel to produce 1,000 kg of crude steel.

The electric arc furnace (EAF) route typically uses 880 kg of recycled steel, 16 kg of coal and 64 kg of limestone to produce 1,000 kg of crude steel.

Detailed inputs and outputs are included in worldsteel LCI data for steel products (see p. 16).

worldsteel members report that 98% of the raw materials used to make crude steel are converted to products and by-products, meaning that very little waste goes to landfill.²⁴ The industry's goal is zero waste.

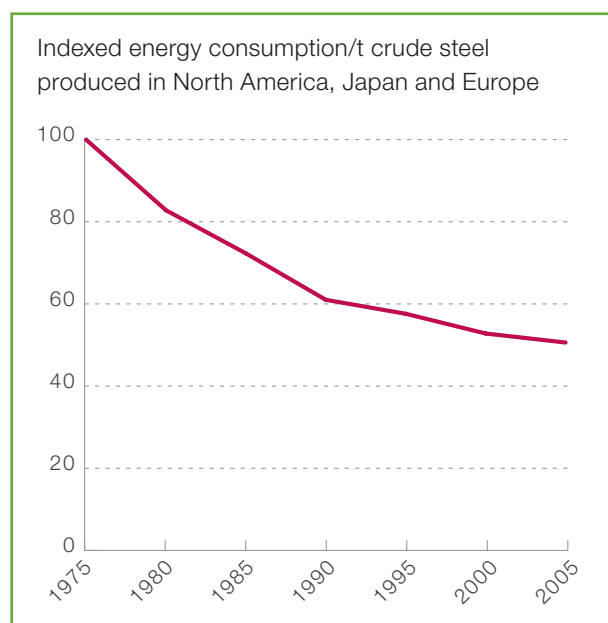
The efficient use of energy has always been one of the steel industry's key priorities. Cost is a key incentive for this, considering that energy purchases account for 20-40% in basic steel production.^{25, 26}

One worldsteel study estimates that steel companies have cut their energy consumption per tonne of steel produced by 50% over the past 35 years (see Figure 8).

While existing production technologies are already very efficient, every steel company is at a different point of maturity and development. There are still potential improvements to be made through:

- Technology transfer – continued sharing and implementation of best practice.²⁵
- Optimisation of operations and controls – including less electricity to power motor drive systems (MDSs). MDSs are needed in pumps, fans, forming and machining, handling equipment and compressors – and estimated to use 19% of primary energy in making steel products – including downstream manufacturing.⁵

Figure 8: Energy use in steelmaking⁴⁷



Co-product use and recycling

Recovered co-products (a term used interchangeably with by-products), can be recycled during the steelmaking process or sold for use by other industries. Use of co-products supports the sustainability of the steel industry. It prevents landfill waste, reduces CO₂ emissions and helps preserve natural resources. The sale of co-products is also economically sustainable. It generates revenues for steel producers and forms the base of a lucrative worldwide industry.

Some companies report a co-products utilisation and recycling rate as high as 99%.²⁷

The main co-products from iron and crude steel production are slags, process gases, dusts and sludges²⁸. More than 400 million tonnes of iron and steel slags are produced each year. Slags are a mixture of silica, calcium oxide, magnesium oxide, and aluminium and iron oxides. During smelting, slagging agents and fluxes (mainly limestone or dolomite and silica sand) are added to the blast furnace or steelmaking furnace to remove impurities from the iron ore, steel scrap and other ferrous feeds. As the slags are lighter than the liquid metal, they float and can be easily removed.

There are three main types of marketed ironmaking or BF slags, categorised by how they are cooled: air-cooled, granulated, and pelletised (or expanded).

Air-cooled slag is hard and dense and is especially suitable for use as construction aggregate. It is also used in ready-mix concrete, road bases and surfaces, roofing and mineral wool (for use as insulation).²⁹

Granulated slag forms sand-sized particles of glass and is primarily used to make cementitious material.

Slag can also help bring down the cost of cement.

For example, in the US it sells for 20-25% less than Portland cement.²⁹

Slags are recognised as marketable products. The worldwide average recovery rate for slag varies from over 80% for steelmaking slag to nearly 100% for ironmaking slag. There is still much potential to increase the recovery and use of slags in many countries, especially for environmental and economic benefits.

One of the main barriers to using some steelmaking slags is their high content of free lime, which is not ideal for construction applications. Various technologies are under development to improve lime separation. Once separated, free lime can be used as fertiliser, in cement and concrete production, for waste water treatment, and in coastal marine blocks that encourage coral growth.

Gases from ironmaking and steelmaking, once cleaned, are used internally, reducing the demand for externally-produced electricity. Coke oven gas contains about 55% hydrogen and may prove an important hydrogen source in the future.²⁵ It can be fully used within the steelmaking plant, and can provide up to 40% of the plant's power.³⁰

The dust and sludge removed from the gases consist primarily of iron and can be used again in steelmaking. Iron oxides that cannot be recycled internally can be sold to other industries for various applications, from Portland cement to electric motor cores.

The EAF route may create zinc oxides that can be collected and sold as a raw material. In the BF-BOF route, cleaning the coke oven gas creates valuable raw materials for other industries including ammonium sulphate (fertiliser), BTX (benzene, toluene and xylene – used to make plastic products), and tar and naphthalene (used to make pencil pitch which in turn is used to produce electrodes for the aluminium industry, plastics and paints).³⁰

Investment in low-carbon steelmaking breakthrough technologies

CO₂ emissions in the steel industry

According to the Intergovernmental Panel on Climate Change (IPCC), to keep the worldwide temperature increase below 2.4°C, global CO₂ emissions have to be significantly reduced by 2050.³¹

The greenhouse gas of most relevance to the world steel industry is carbon dioxide (CO₂), as it makes up approximately 93% of all steel industry greenhouse gas emissions.³² CO₂ emissions vary by production route. On average, 1.8 tonnes of carbon dioxide are emitted for every tonne of steel produced.³³ The iron and steel industry accounts for approximately 6.7% of total global CO₂ emissions.³⁴

Steel use is projected to increase by 1.5 times by 2050 from present levels (see p. 11), hence, CO₂ emissions could increase by the same amount. However, recognising that climate change is a key priority, the industry is determined to take action to significantly reduce its emissions.

CO₂ generated by the steel industry results mostly from the chemical interaction between coal and coke (carbon) and iron ore in a blast furnace. This process is called ore reduction and produces hot metal which is then converted to steel. There is no large-scale commercially available substitute for carbon in steelmaking.

Technological advancements over the past 25 years have enabled substantial reductions in CO₂ emissions from steel production. These advancements include:

- energy efficiency in the steelmaking process
- improved steel recycling rates
- increased recycling and utilisation of co-products from steelmaking
- extensive process automation for precise control of steelmaking processes.

Modern steel production processes are now very close to their theoretical minimum CO₂ intensity per tonne of steel output. While further medium-term improvements will be made through technology transfer and spread of best practice, to make a significant difference in CO₂ intensity in the long term, new low-carbon breakthrough steelmaking technology is required (see next page).

Climate Action programme

In line with its priority to reduce CO₂ emissions and to set a baseline to benchmark improvements, the industry established a CO₂ data collection programme in 2008. It is open to all steel-producing companies in the world.

The measurement framework covers all key points that influence CO₂ emissions and energy use.³⁵ worldsteel analyses the data and prepares a report for the participating companies. The report enables a company to see how each of its plants compares to others worldwide.

The database now holds CO₂ and energy intensity data for 30% of global steel production capacity.

The Climate Action programme, which was started in 2009, recognises participating steel producers.

Low-carbon steelmaking breakthrough technologies

In 2003, worldsteel launched a CO₂ breakthrough coordination programme to exchange information about carbon-lean steel production technologies.

Research and investment is taking place in:

- the EU (ultra-low CO₂ steelmaking, or ULCOS, supported by 10 EU companies and miners)
- Japan (Course 50, Japanese Iron and Steel Federation)
- the US (the American Iron and Steel Institute)
- Canada (the Canadian Steel Producers Association)
- South America (ArcelorMittal Brazil)
- South Korea (POSCO)
- China (Baosteel) and Taiwan, China (China Steel)
- Australia (BlueScope Steel/One Steel and CSIRO coordination).

Investment levels in the various programmes vary, with the highest to date being in the EU's ULCOS I (US\$95 million) and ULCOS II (more than US\$630 million) programmes. Japan's Course 50 programme is fully government funded and cost US\$126 million for step 1 (2008-2012) and US\$189 million for step 2 (2013-2017). In total, about US\$1 billion has been invested in these R&D projects to date.

The programmes have identified the most promising steelmaking technologies that potentially reduce CO₂ emissions by more than 50%. Research is now focused on feasibility at various levels of production, from laboratory work to pilot plant development, demonstrators and eventually commercial implementation.

A significant amount of CO₂ will still be produced if carbon is used as the reducing agent for iron ore. One technique for dealing with the gas is to capture it and store it. Carbon capture and storage (CCS) requires technical solutions for cleaning the gas and transporting it through pipes into storage sites. Storage options include saline aquifers and, marginally, exhausted gas fields. Coal-based ironmaking technologies associated with CCS are the most likely candidates for development.

Technologies of the future

ULCOS-BF process – top gas recycling in combination with CCS

Blast furnace top gas recycling relies on separation of the top gas so that the useful components can be recycled into the furnace as a reducing agent. The CO₂ is captured and stored. This is the most promising process concept in the middle term, with a demonstrator planned to come on stream with full CCS in a few years' time.

ULCOWIN: Alkaline electrolysis of iron ore

Electrolysis is commonly used to produce metals other than steel and requires large amounts of electricity. The process would depend on a CO₂-lean electricity source such as hydro or nuclear power.

ULCOLYSIS and MOE: Molten oxide electrolysis

Molten oxide electrolysis works by passing an electric current through molten slag fed with iron oxide. The iron oxide breaks down into liquid iron and oxygen gas. No carbon dioxide is produced. Process emissions are further reduced with a CO₂-lean electricity source.

ULCOS Smelting reduction (Hlsarna) in combination with CCS

Hlsarna, combines a melting cyclone for ore melting and a liquid-bath smelter vessel for final ore reduction and hot metal production. It produces fairly pure CO₂, which can be captured allowing for major CO₂ reductions. Construction of the Hlsarna pilot plant was completed in 2011 and hot commissioning began the same year at IJmuiden in the Netherlands at an 8 tonne/hour scale.

Hydrogen flash smelting

Iron is reduced from iron ore at high temperatures (above 1,300°C) and with very short reaction times. No CO₂ is emitted but producing hydrogen requires large amounts of CO₂-lean electricity. This process can also be operated on low CO₂ fuels like natural gas.

Prioritising safety, investing in our people

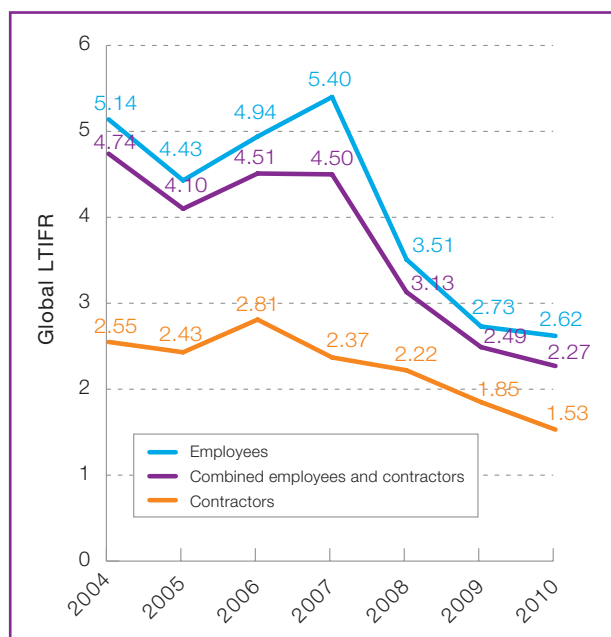
Employee safety and health

A safe and healthy working environment for all employees is the number one priority for every worldsteel member. worldsteel's policy is to help all our members achieve an accident-free workplace.

This is supported through:

- use of industry safety and health principles
- sharing experience and good practice – through seminars, workshops and development of an alert network to share serious incidents
- annual reporting on safety performance – up to 87 member organisations in 2010 from 46 in 2005
- safety and health excellence recognition programme – showcasing member initiatives and projects.

Figure 9: Lost time injury frequency rate³⁶



There is no area, process or type of work that cannot be accident-free. worldsteel member companies are committed to eliminating accidents and injuries from the industry and significant improvements have been achieved over recent years, as shown in Figure 9.

Some businesses have gone without any lost time injuries or fatalities for many years. These companies know that such performance requires excellence in all aspects of their operations. This excellence also produces superior business performance. The most successful steel companies are also the safest.

worldsteel safety and health principles

worldsteel published guidelines to help companies implement six principles for improved safety performance. Adopting these principles at the highest level, member companies demonstrate their commitment to an injury-free and healthy workplace.

The six fundamental principles are:

- All injuries and work-related illnesses can and must be prevented.
- Management is responsible and accountable for safety and health performance.
- Employee engagement and training is essential.
- Working safely is a condition of employment.
- Excellence in safety and health supports excellent business results.
- Safety and health must be integrated into all business management processes.

Sharing experience and good practice

In 1999, worldsteel developed Accident-Free Steel, a programme that brought together safety specialists and line managers from worldsteel member companies. This initiative continues today. Senior safety and health managers regularly meet to discuss ways to improve safety and health performance.

INDUSTRY FOCUS: SAFETY, TRAINING AND COMMUNITY

Employee development and training

An interesting outcome of worldsteel's project on yield improvement was that good yields are obtained with good people, much more than with good equipment. This emphasises the importance of employee development, training, communication and knowledge management.

To succeed in a technologically-driven environment, the steel industry must continue to offer opportunities to develop the knowledge and skills of its people. New methods of training, such as self-directed learning and online courses, show that the industry considers training a priority.

Some companies have set up close associations with academic institutions to provide specialised training to employees. Others run their own centres. For example, TenarisUniversity and ArcelorMittal University are corporate universities that offer training to thousands of their employees, customers and suppliers.

Promoting industry knowledge

Steel companies around the world face a shortage of talent in metallurgy, materials science, physics, chemistry, engineering and mathematics.

Recognising this trend, the industry has introduced many initiatives to attract, develop and retain talented people as well as improve the industry's image. One such initiative is steeluniversity.org.

steeluniversity.org is a free online initiative developed by worldsteel. With financial and technical support from worldsteel member companies, it provides interactive e-learning resources on steel technologies.

The resources are intended for use by undergraduate students, their teachers, lecturers and professors and also by employees and their trainers in steel companies. Students from over 400 universities worldwide train their skills using steeluniversity.org and many universities have included the simulations into their course work. More than 100 steel companies use steeluniversity.org and 50 of them have made it part of their training programmes.

The steeluniversity Challenge

Every year worldsteel runs a virtual steelmaking challenge. Participants compete against other teams and individuals in a 24-hour worldwide competition. The steeluniversity Challenge is a unique competition for metallurgists from universities and steelmakers from around the world.

In 2012, a team from Shougang Qiangang in China won in the category for young steel industry employees. A team from Universidade Federal do Ceara in Brazil won in the student category.



Building mutual respect between our industry and our communities

Contributing to communities worldwide

Steel companies around the world seek to foster mutual respect between themselves and their local communities. They bring value to the local economy by providing jobs and taxes, but also through numerous social initiatives. These vary from one region to another, and depend on the local culture. They include:

- investing in community education, culture and the arts
- company sponsorship and employee participation in volunteer programmes
- providing housing and healthcare services
- engaging in dialogue to better understand and respond to community concerns and priorities.

Case study

Part of local communities

Every ArcelorMittal operation across the world is part of its local community. ArcelorMittal engages with communities to contribute to their social and economic development.

ArcelorMittal contributes to economic development by providing jobs, building local infrastructure and creating opportunities for local businesses to supply their operations. For example, in Liberia, the company's mining project is one of the biggest foreign investments since the civil war.

ArcelorMittal's contribution is not limited to economic development. The company also works with regional communities on local health and education projects. In Liberia, the ArcelorMittal Foundation has renovated two hospitals. These facilities are open to employees, their families and the wider community.

In 2011, around 12,000 people received care in these hospitals.



Case study

Developing talent and empowering rural women

A secure source of income through employment helps improve rural women's social and economic status, standards of living, self-confidence and courage to face their many challenges.

The IT industry in India has taken the lead in providing value added services to its customers. Business process outsourcing (BPO) has rapidly evolved. However, these opportunities it provides have largely been for youth in the cities and not available to rural areas, due to infrastructural limitations.

JSW Steel recognised the potential of the BPO sector for various applications and the vast opportunities that it can provide for empowering women in the villages surrounding its operations.

A training centre was set up to train rural women who had completed their higher secondary education. The women were also provided with transport and a stipend for six months. J-Soft, a software subsidiary of JSW Steel set up the necessary communication facilities for the BPO business in Vidyanagar, next to the steel plant. J-Soft identifies projects and supervises the BPO operations.

As a result, more than 1,000 women have been trained. Currently, 150 women are involved as business associates. With their experience, many have subsequently found jobs in JSW steel and other companies in the area. Also, providing skills-based employment opportunities reduces migration to other areas. This helps to provide skilled human resources to the new industries coming up in the Vijayanagar industrial complex.



Buildings and infrastructure

Society's need for housing is great and growing. According to the UN, 1.6 billion people live in inadequate housing around the world today and an estimated 100 million are homeless: 20 to 40 million in urban areas and about 60 million in rural areas.³⁷

The global population is set to grow by another 2 billion people by 2050, accompanied by rapid urbanisation. Especially in BRIC countries, the need for non-residential buildings (schools, offices, shops and manufacturing facilities) and related infrastructure will also continue to grow.

As the need for buildings and infrastructure continues to grow worldwide, reducing structures' consumption of natural resources, and associated emissions, is crucial for future sustainability. While buildings currently account for about 20% of global greenhouse gas emissions, they also present many opportunities for reducing emissions and mitigating climate change.^{38, 39}

Steel enables construction and provides sustainable building solutions

Steel enables construction by providing equipment such as cranes, drills and bulldozers, scaffolding, reusable and portable shelters at construction sites.

Steel is also an ideal material to help meet society's growing needs for buildings and infrastructure in a sustainable way. Not only is it affordable and readily available, its intrinsic properties, such as its strength, versatility, durability and 100% recyclability allow for improved environmental performance across the entire life cycle of buildings.

Steelmakers around the world are increasingly offering intelligent steel construction solutions that enable energy-efficient and

low-carbon-neutral buildings. These solutions are highly material efficient and recyclable.

They reduce the environmental impacts over the structures' life cycle and help to extend their life span through design for disassembly and reuse.

These steel solutions not only improve the environmental performance of buildings, they also provide other benefits such as affordability and faster, safer and less noisy construction.

From construction to use, reuse and eventual decommissioning at end-of-life – benefits associated with steel building solutions are described by life cycle phase below.

Construction

Freedom of design, dematerialisation and material efficiency

Its stiffness allows steel to span greater distances and provides more design freedom than other materials. Steel's superior strength-to-weight ratio makes it possible for the structure to bear high loads using less material. Therefore, less material is needed to make a quality structure, and smaller foundations are required. Steel is also lightweight compared to many other building materials used for the same purpose, which can result in dematerialisation. For example, 1 kg of steel is sufficient to clad almost nine times the area of 1 kg of roof tiles.⁴⁰ This also means that more flat steel can be transported in each load than many other materials used for the same purpose. Less material use and less transportation can also lower overall building costs.

As steel building components can be cut to precise specifications or prefabricated off-site, on-site waste is minimised. Any waste can be directly recycled in the steelmaking process.

STEEL: MEETING SOCIETIES' NEEDS SUSTAINABLY

How steel is used in buildings and infrastructure

More than half of the steel produced worldwide goes into steel buildings and infrastructure. The possibilities for using steel in buildings and infrastructure are limitless. The most common applications are listed below.⁴²

For buildings

- **Structural sections:** these provide a strong, stiff frame for the building and make up 25% of the steel use in buildings.
- **Reinforcing bars:** these add tensile strength and stiffness to concrete and make up 44% of steel use in buildings. Steel is used because it binds well to concrete, has a similar thermal expansion coefficient and is strong and relatively cost-effective. Reinforced concrete is also used to provide deep foundations and basements and is currently the world's primary building material.
- **Sheet products:** 31% is in sheet products such as roofing, purlins, internal walls, ceilings, cladding, and insulating panels for exterior walls.
- **Non-structural steel:** steel is also found in many non-structural applications in buildings, such as heating and cooling equipment and interior ducting. Internal fixtures and fittings such as rails, shelving and stairs are also made of steel.

For infrastructure

- **Transport networks:** steel is required for bridges, tunnels, rail track and in constructing buildings such as fueling stations, train stations, ports and airports. About 60% of steel use in this application is as rebar and the rest is sections, plates and rail track.
- **Utilities (fuel, water, power):** over 50% of the steel used for this application is in underground pipelines to distribute water to and from housing, and to distribute gas. The rest is mainly rebar for power stations and pumping houses.

Safer, faster and affordable construction

Industry surveys consistently demonstrate that steel is the safest construction material.⁴¹ Components are prefabricated offsite in a safe, controlled factory environment. From here they are delivered to site and erected by a small number of skilled personnel. There is minimal requirement for on-site cutting or adjustment, and no need for the time-consuming and potentially hazardous shuttering and handling operations associated with other construction materials.

Steel construction speeds up the development process and reduces overall construction costs. Shorter construction periods also reduce disruption and result in less disturbance to the local community around the site. Steel is relatively clean and quiet to erect, and requires few site deliveries.

Use, maintenance and reuse

Resource efficient, passive buildings and low-carbon or carbon-neutral technologies

In the use phase of a building, steel products can help improve energy efficiency and thermal comfort, and reduce energy and water demand. Steel products also offer solutions and technologies that make passive, low-carbon and carbon-neutral structures possible.

Large internal volumes made possible with steel structures allow for 'one-room-thick' designs. These are buildings that have windows and/or doors on both sides of the room, which allows for good cross-ventilation and can help maintain thermal comfort and indoor air quality with less need for mechanical air-conditioning. If oriented correctly, such buildings can also be effective designs for maximising passive solar heating: large areas of glass allow the sun to warm the building during colder months. Good light penetration also reduces the need for artificial

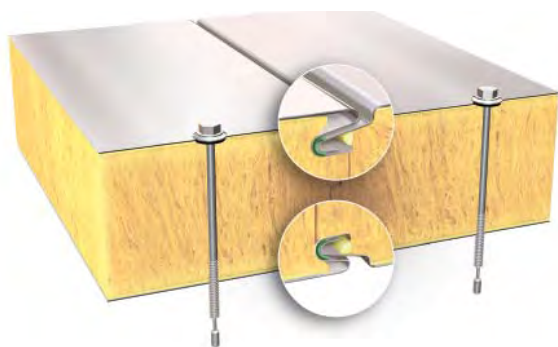
lighting, which further reduces energy consumption. However, windows must be shaded from the sun during summer months to avoid increasing the need for air-conditioning.⁴⁰

In warmer climates, light coloured steel roofs and walls can be used to reflect energy away from buildings, thereby reducing energy demand for internal cooling. In cool climates, where there is minimal need for summertime cooling, dark roofs and walls can be used to absorb solar energy, thereby reducing annual energy demand for heating.⁴⁰

Steel insulating exterior wall panels (such as Ruukki's, pictured below) can also improve use-phase energy efficiency of buildings.⁴³ Because the panels provide excellent air-tightness, they help to minimise energy use and related costs during the use phase of the building and thereby contribute to savings of up to 30% in maintenance costs. These wall panels are fully reusable and recyclable.

Steel products require minimal maintenance, which results in less resource use compared to alternative materials that require more frequent replacement.

Rainwater can be harvested from roofs and stored in tanks, which helps to reduce the consumption of mains supply water for irrigation, toilet flushing and so on. This also helps control stormwater flow rates. There are steel water tanks, coated with food-grade polymer, that are designed for rainwater harvesting.⁴⁰



Ruukki Energy Sandwich Panel

Safer, more durable buildings

Steel offers the highest strength-to-weight ratio of any building material. Because of its strength and durability, steel structures can be designed to withstand natural disasters. Steel is also impervious to attacks from termites or fungi, does not rot or split and is highly fire resistant.

With appropriate surface treatment when necessary, it can be weatherproof, corrosion resistant and immune to the harmful effects of UV rays, ensuring a very long service life without degradation.⁴⁴

Long product life cycles and adaptability for reuse of buildings

Steel's strength and durability allow for long product life cycles. For example, buildings made with steel last 40 to 100 years, or longer with proper maintenance.

Steel-framed buildings are easily adaptable if the configuration of the building needs to change. The ability of steel to bridge long spans means that steel buildings contain large open-plan spaces which are easily reconfigured with partition walls. The steel frame itself can be adapted, with parts added or taken away, and its light weight means that extra floors can often be added without overloading existing foundations.⁴¹

Steel also facilitates the conversion of obsolete buildings, such as warehouses or train stations into modern living or working spaces, extending their useful life, saving resources and costs. CO₂ emissions savings from building reuse are estimated at 1 to 1.5 kg CO₂/kg steel.⁵

Steel-framed structures can be taken apart and rebuilt without noisy and dusty demolition. This is better for the environment and for the local community.

End-of-life

Component reuse and 100% recyclability

Steel products have long lifespans and can be used to create adaptable spaces or to add volume to extend the life of existing buildings. Eventually, however, most buildings will be decommissioned. Reusing or recycling building components is key to the sustainability of a structure's end-of-life, as it is the most economical and ecological solution.

Steel roofing, cladding, purlins, walling and structural beams are increasingly designed for disassembly and reuse (see case studies). Although reinforcing steel is currently recycled rather than reused, there is potential for reuse by assembling buildings from modular reinforced concrete elements, such as standard floor slabs.⁵

Steel is also 100% recyclable, without loss of quality. Therefore, if recovered at the end of each use phase, the life cycle of steel is endless. It can also be easily recovered with magnets.

At 85%, global recovery rates for steel construction applications are relatively high (see p. 14). However, there is potential for improvement. For example, current recovery rates from demolition sites in the UK are 99% for structural steelwork and 94% for all steel construction products – figures that far exceed those for any other construction material.⁴¹ With continued and improved design for disassembly, reuse and recovery rates will continue to increase.

Did you know?

New **high-strength lightweight steel** is dramatically changing the market. In 1937, **83,000 tonnes of steel** was used to build the **Golden Gate Bridge** in San Francisco. Today, only **half** of that would be needed.⁴⁵

Case studies

Energy-efficient designs for disassembly, reuse and recycling

BlueScope Steel makes products that can be used in designs for disassembly and reuse. These are components of a building, or entire buildings, that are designed with the intention of reuse rather than demolition. For example, the MacArthur Centre for Sustainable Living in Australia was designed for disassembly using reusable and renewable materials.⁴⁶

The design incorporates whole sheets of steel for the roofing and much of the walling to maximise opportunities for those sheets to be used again in future. When the steel is no longer needed, it can be recycled.



Dematerialisation

BlueScope Steel has successfully developed high-strength steel products, so that the same function is achieved using fewer raw materials. This is known as dematerialisation. For example, roofing that was once manufactured at 0.55 mm thick, is today made from high-strength Colorbond steel 0.42 mm thick – a reduction of 24%.

Steel framing is another example of design innovation that maintains functionality with less material use. Some house framing that used to be 1.20 mm thick is only 0.6 mm thick today – a saving of 50%.

Transport

Mobility is essential to our modern way of life. The efficient transport of goods has become key to our ever more globalised economy. Freight has almost doubled over the past 30 years.³⁹

Energy use in the transport sector almost doubled between 1970 and 2000 and is still growing strongly at just under 2% a year. The sector accounts for 20% of total global primary energy use and contributes 13% of greenhouse gas emissions.³⁹ There are, however, many opportunities for improvement. These include a shift of transport modes, more intense use of current transport modes, improved efficiency, and change of drive trains.

Steel provides strong, safe and sustainable transport solutions

Steel facilitates our mobility and the transport of goods. Whether in the form of bicycles, motorcycles, cars, buses, trains, ships or planes – or in the transport networks that support them – steel is essential to every mode of transport.

Steel is well-suited to transport applications because it is durable, strong (providing safety in the case of collision), lightweight, UV-resistant, affordable, and 100% recyclable. Innovations in design and the development of new high-strength steels have also played a key role in improving the efficiency of many of these transport modes, especially automobiles – with the potential to reduce their life cycle greenhouse gas emissions by nearly 70% (see case study).

Steel provides a vital security margin in case of collision because of its remarkable ability to deform and harden simultaneously. At higher impact velocities, the strength of steel increases without the risk of breakage often associated with other materials.

Steel's strength and durability enables long product life spans and the reuse or remanufacture of components such as rail track, engines, automotive parts, shipping containers and rail cars (see p. 14).

And because steel is 100% recyclable without loss of quality, and easily separated from other materials with magnets, the steel used in transport modes and infrastructure networks can be easily recovered and recycled at end-of-life. For example, vehicles have a recovery rate of about 85% globally (see p. 14), and nearly 100% of the steel in the vehicle can be recycled due to ease of magnetic separation.



FutureSteelVehicle

Case study

FutureSteelVehicle

FutureSteelVehicle (FSV) is a programme of WorldAutoSteel, the automotive group of the World Steel Association. It is part of a body of research that represents nearly US\$80 million in steel industry investment.

The FSV:

1. Achieves 35% body structure mass savings compared to an average vehicle.
2. Uses 97% high-strength (HSS) and Advanced High-Strength Steel (AHSS).
The FSV programme brings more advanced steel and steel technologies to its portfolio, including more than 20 new AHSS grades, representing materials expected to be commercially available by 2020.
3. Reduces total life cycle greenhouse gas emissions by nearly 70%. Evaluating vehicle performance during the use phase only does not properly assess vehicle emissions impact. The total life cycle must be taken into account. AHSS is the only material to achieve reductions in all life cycle phases. AHSS combined with an electrified powertrain reduces total life cycle greenhouse gas emissions by 56% to 70% compared to an average vehicle.
4. FSV enables five-star safety ratings.
5. Dramatic mass and emissions reductions are achieved at no cost penalty over current steel body structures. The FSV with a battery electric powertrain can be manufactured and assembled for an estimated US\$1,115.

How steel is used in transport

Nearly 17% of steel produced worldwide is used to meet society's transport needs. It is also essential to the related infrastructure: roads, bridges, ports, stations and airports. Some major applications today include:⁴²

- **For cars and light trucks**
An average car contains 960 kg of steel and iron. 34% is in the body structure, panels, doors and trunk closures for high-strength and energy absorption in case of a crash. 23% is in the drive train, consisting of cast iron for the engine block and machinable carbon steel for the wear resistant gears. 12% is in the suspension, using rolled high-strength steel strip. The remainder is found in the wheels, tyres, fuel tank, steering and breaking systems.
- **For ships and shipping containers**
Steel for the ship hull is rolled mild steel. These are strong and dimensionally consistent plates that are welded together. Shipping containers are also made of steel.
- **For trains and rail cars**
Steel makes up 20-25% by mass of high speed trains.⁴⁸ The main steel components of these trains are bogies (structure underneath the trains including wheels, axels, bearings and motors). Freight or goods wagons are made almost entirely of steel.
- **For aeroplanes**
Steel is required for the landing gear.
- **For infrastructure**
Transport networks: steel is used in bridges, tunnels, rail track, and in constructing buildings such as fueling stations, train stations, ports and airports. About 60% of steel use in infrastructure is rebar. The rest is sections and rail track.

Energy

Energy is essential for development. About 1.6 billion people have no access to electricity and about 2.4 billion rely on traditional fuels (wood, agricultural waste, cow dung) for cooking and heating.³⁹

Giving everyone access will require strong growth in energy supply. Improving the well-being of people in developing countries, the expected economic growth in industrialised countries, and projected population growth, will likely lead to a 50% increase in world energy demand by 2030.⁴⁹

Steel is essential to energy production and distribution

Steel is critical for supplying the world with energy. Whether based on fossil fuels, nuclear technology or renewables, steel is indispensable in producing and distributing this energy. Steel also has an important role to play in improving the efficiency of these energy sources and many steel applications – such as cars (see p. 30) and buildings (see p. 26).

Innovative steel solutions contribute to improved efficiency

Below are a few examples of how steel is being used to improve the efficiency of energy production.

Transformers: Transformers step down the voltage from power stations to household voltage. The magnetic core of transformers is made of steel. As a result of continual development and increased application of new electrical steel grades, the energy loss in modern transformers can be reduced by 35% compared to conventional ones.⁵⁰

Wind towers: Steel provides the strength for taller, more efficient wind turbines.⁵¹

Fossil fuel power plants:⁵⁰

- High temperature-resistant steels have made efficiency in steam power plants possible and have the potential to be developed and employed even further.
- Combined heat and power (CHP) allows waste heat in power plants to be used for power generation as heat energy, increasing the overall efficiency of fossil fuel power plants. The waste heat is transported exclusively in steel pipes.

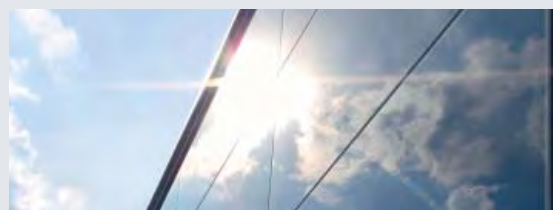
Case study

A fully-integrated solar panel façade

Ruukki has developed a photovoltaic system that is fully integrated into a building's façade. The solar power system does not depend on the sun's warmth, only its radiation. The power generated is used to meet the building's own needs and can be fed into the electricity grid.

In the façade of an average-sized office building in Finland, Ruukki's solar panel façade can produce 18,000 kWh of electricity a year. This is enough to meet the annual needs of a medium-sized, electrically heated family home. Output and capacity can easily be increased.

The system is based on modular solar power or PV panels, which have been made from glazed PV modules, and Ruukki's steel rainscreen panel system. The PV modules are based on copper indium gallium diselenide (CIGS) thin-film technology, a commonly used technology in solar cells. Installation is quick and easy.



Steel's role in energy production and distribution

Steel is indispensable for energy production and distribution.

Nuclear and fossil fuel based energy:

- mining equipment
- offshore oil platforms
- equipment for oil and gas extraction and production
- natural gas and oil pipelines and storage tanks
- power plants.

For the production and distribution of electricity:

- transformers (magnetic steel core)
- generators and electric motors
- power distribution pylons and steel-reinforced cables.

For energy transport and distribution:

- ships, trucks and trains used to transport fuel
- transport networks: steel is required for bridges, tunnels, rail track, and in constructing buildings such as fueling stations, train stations, ports and airports.

Steel is also used in all areas of renewable energy.

- **Biomass:** steel is used extensively in agriculture (see p. 35).
- **Solar:** steel plays a key role in converting solar energy into electricity or hot water. It is used as a base for solar thermal-panels and in pumps, tanks and heat exchangers.⁵²
- **Wave and tidal:** a steel pile is the main component of a tidal turbine in tidal energy systems. Steel is also used to fabricate wave energy devices. The steel used is formulated to withstand the challenges of the marine environment.
- **Hydroelectric:** steel is needed to reinforce concrete dams.
- **Wind:** steel is the main material used in onshore and off-shore wind turbines. Almost every component of a wind turbine is made of steel, from the foundation, to the tower, gears and casings (see p. 11).

Did you know?

No generator, transformer or electric motor could be operated without **electrical steels** needed to transform electrical power into usable energy. Electrical steels are iron-silicon alloys tailored to produce **specific magnetic properties**.

Wherever electrical energy is generated, electrical steels are needed. This core material is used throughout the **entire energy value chain**: from power generation (generators), transmission and distribution (transformers) to the consumption (electric motors and appliances) of electrical energy in the electrical components industry.

Food and water

Global demand for food, feed and fibre are expected to double by 2050 as the world's population grows to around 9 billion.⁵³ Population growth, coupled with further industrialisation and urbanisation, will result in increased demand for water.

Freshwater withdrawals have tripled over the last 50 years and the demand continues to increase by 64 billion cubic meters a year.⁵⁴ Current needs are also still going unmet, with more than one out of six people lacking access to safe drinking water, or 1.1 billion people.⁵⁵ There is great potential to improve supply through better management of our water resources.

Steel is integral to food and water supply

Steel is needed for growing, storing and delivering our food. It is also needed in water collection, storage, purification and distribution.

Steel also provides solutions that help to improve water management and reduce losses. For example, in many cities more than 40% of the total water supply is lost during distribution. Tokyo has adopted corrugated stainless steel pipes for 90% of its extensive network of underground potable water pipes, eliminated leakages and lowering costs.⁵⁶

Steel cans – preserving food safely and sustainably

Almost 200 billion cans of food are produced each year. Compared to other food preservation methods, steel cans save energy because refrigeration and freezing is not needed. They are also tamper-resistant and protect food and drink from moisture, oxygen and light – helping to preserve the nutritional value of its contents without the need for additives.

Steel cans are 100% recyclable and have an average global recycling rate of 68%.⁵⁷ There is also potential to make steel cans reusable and lighter by altering designs and canning processes.⁵

Did you know?

Globally, about **7.2 million tonnes of steel** packaging is recycled each year. This saves **11 million tonnes of CO₂ equivalents** which would have come from new steel production. This saving is equivalent to taking approximately **280,000 cars** off the road. **Each can recycled saves about twice its weight in CO₂.**⁵⁷

Steel's role in food and water supply

For food

- **agriculture:** farming tools and equipment, silos, equipment to feed and shelter livestock, pipes and irrigation systems, water tanks
- **distribution:** ships and shipping containers, rail, trucks, planes and related infrastructure such as bridges, tunnels, rail track, fueling stations, train stations, ports and airports
- **preservation and storage:** food cans, refrigerators
- **preparation:** appliances such as stoves, ovens and microwaves, and utensils.

For water

- **collection:** pumps, pipes, well-drilling equipment (see p. 27 – Utilities)
- **storage and distribution:** pumps, pipes, tanks, buckets (see p. 27 – Utilities)
- **purification and recycling:** equipment and tanks for waste water treatment plants and desalination plants (see case study).

Case study

Making freshwater more readily available

Outokumpu develops solutions for desalination with duplex stainless steel, making the process more affordable and freshwater more readily available.

Water infrastructure represents a large share of public spending, especially in areas where freshwater is in short supply. Desalination – turning seawater into consumable and drinkable water – is the preferred solution for supplying water for many arid regions. Stainless steel provides solutions for the desalination industry, ensuring long-lasting, maintenance-free equipment.

Owing to its high strength, duplex stainless steel allows for dematerialisation of desalination systems through reductions in plate thickness and, consequently, in weight. Reduced weight also reduces plant investment costs and results in raw material and energy savings related to production, transport, and welding. Duplex desalination technology is used worldwide.



WHAT GOVERNMENTS AND POLICYMAKERS CAN DO TO HELP

Improve the life cycle performance of steel and steel products

Cooperation with other stakeholders, especially government and legislators, is of key importance in enabling the steel industry to improve. Below is an outline of some ways in which governments and policymakers can facilitate improvements in steel's life cycle performance that will help our industry to fulfill its vision and sustainable development commitments,⁵⁸ and benefit society as a whole.

Climate change

Governments that are signatories to the UN Framework Convention on Climate Change are negotiating commitments to GHG emissions after 2012.

worldsteel's key message to governments is that all steel-producing countries need to be involved in setting commitments and timetables for future actions.

The responsibility lies with governments to set a framework and policies for positive action on climate change that has an equal impact on steel and other industries. Equally, an approach that has similar impact in different countries and regions is vital. The right approach will avoid cost differences in different countries. Cost differences increase the serious problem of carbon leakage and will not reduce global GHG emissions.

Policies to add a tax or a price on carbon emissions, assist technology transfer, Clean Development Mechanism projects or other financial incentives should not distort fair competition in the industry.

Governments must support research and development of breakthrough technologies. The major expenditure required cannot come from industry alone. Government funding needs to be available in terms of primary research and in the more significant sums for pilot plants, to prove the technical and economic feasibility of new technologies. Already, major governmental support for breakthrough technologies on carbon reduction is in place in the EU and Japan.

Incorporate life cycle thinking into legislation

It is critical that life cycle thinking is incorporated into legislation. For example, vehicle emissions regulations need to shift from a tailpipe emissions basis to a full life cycle basis. Life cycle assessment (LCA) considers emissions from all aspects of a vehicle's life, from material production to end-of-life-recycling, as well as the actual use phase, and should play an important role in current regulations in discussion around the world.

When vehicle emissions assessment is focused solely on emissions produced during the driving phase (tailpipe), this encourages the use of lighter weight alternative materials that are often more energy intensive or greenhouse gas-intensive to produce. However, this may have the unintended consequence of increasing greenhouse gas emissions during the vehicle's total life cycle.

Legislation that focuses only on one part of a product's life cycle may have the unintended consequence of shifting environmental problems from one part of the product's life cycle to another.

END NOTES

1. Müller, D. B., Wang, T. and Duval, B., 2011. Patterns of iron use in societal evolution, *Environmental Science and Technology*, 45(1) pp. 182-188.
2. worldsteel estimate, 2011.
3. Wang, Tao, 2011. Unpublished work.
4. United Nations Environment Programme (UNEP), *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication*, 2011.
5. Allwood J.M., Cullen J.M., et al., 2012. *Sustainable Materials: with both eyes open*, UIT Cambridge, England.
6. worldsteel estimate based on 2011 analysis, for onshore wind turbines: 50 tonnes/MW for nacelle and rotor, 100 tonnes/MW for tower, and 30 tonnes/MW for foundation; and for offshore wind turbines: 50 tonnes/MW for nacelle and rotor, 100 tonnes/MW for tower, and 300 tonnes/MW for foundation.
7. The Energy Report, 100% renewable energy by 2050. WWF in collaboration with Ecofys and the Office for Metropolitan Architecture (OMA) and with support from www.eneco.eu, 2011, www.panda.org/energyreport.
8. Danish Wind Industry Association, www.windpower.org.
9. Metals for Buildings: Essential & fully recyclable, 2011, www.metalsforbuildings.eu.
10. <http://inhabitat.com>.
11. The market for used wind turbines has been growing steadily since 2003, with wind farms from Denmark, the Netherlands and Germany mostly being shipped to the Balkans and Eastern Europe. Source (accessed April 2012): www.windea.org/technology/ch02/en/2_4_3.html.
12. Lund, R. 1984. Remanufacturing: The experience of the United States and implications for developing countries. World Bank technical paper, ISSN 0253-7494, no. 31. Integrated resource recovery series 2. Washington, DC: World Bank and United Nations Development Program, The International Bank for Reconstruction and Development.
13. Lund, R. 1993. Remanufacturing. In *The American edge: Leveraging manufacturing's hidden assets*, edited by J. Klein and J. Miller. New York: McGraw-Hill.
14. Smith, V.M. and G.A. Keoleian. "The Value of Remanufactured Engines: Life Cycle Environmental and Economic Perspectives." *Journal of Industrial Ecology* (2004) 8(1/2): 193-221.
15. Wind Industry in Germany, German Wind Energy Association (BWE), 2011.
16. <http://green.blogs.nytimes.com/2009/01/26/old-turbines-get-a-second-wind-through-remanufacturing>, accessed: April 2012.
17. www.windpowerinnovationsinc.com, accessed: April 2012.
18. www.fescodirect.com, accessed: April 2012.
19. www.repoweringsolutions.com, accessed: April 2012.
20. www.halus.com, accessed: April 2012.
21. www.trwaftermarket.com, accessed: April 2012.
22. worldsteel, *Water Management in the Steel Industry*, 2011.
23. BlueScope steel, CSE Report 2011, <http://csereport2011.bluescopesteel.com/environment/air.html>.
24. Sustainability indicators, worldsteel.org.
25. "The State-of-the-Art Clean Technologies (SOACT) for Steelmaking Handbook, 2nd Edition" Asia Pacific Partnership for Clean Development and Climate, 2010.
26. "Saving One Barrel of Oil per Ton (SOBOT)." American Iron and Steel Institute, 2005.
27. Nippon Steel Sustainability Report, 2011.
28. Sludge is a muddy by-product recovered during the treatment of waste water or sewage water. See worldsteel by-products fact sheet, worldsteel.org.

29. van Oss and Hendrik G., "Iron and Steel, Slag [Advanced Release]: 2007 Minerals Yearbook", US Geological Survey, 2007.
30. "Reusing the By-products of the Steel Industry", BlueScope Steel, www.bluescopesteel.com/go/about-bluescope-steel/student-information/reusing-the-by-products, accessed January 2010.
31. IPCC, Fourth Assessment Report, Climate Change 2007.
32. worldsteel LCA Methodology report, 2011.
33. Calculated using route-specific CO₂ intensities for three steel production routes: basic oxygen furnace, electric arc furnace and open hearth furnace. It is a weighted average based on the production share of each route.
34. Steel industry CO₂ emissions were 2.6 billion tonnes in 2010, global CO₂ emissions from all sources was 38.7 billion tonnes in 2010 (IEA 2010 "CO₂ emission from Fuel Combustion").
35. See worldsteel.org for details on the measurement framework.
36. worldsteel safety survey data, 2011 update.
37. Miloon Kothari, UN Press Briefing by Special Rapporteur on the Right to Adequate Housing, November, 2005.
38. IPCC Fourth Assessment Report, Working Group III, ch 1.
39. Metz, B., Controlling Climate Change, 2010, Cambridge University Press.
40. BlueScope Steel, Steel in Sustainable Buildings, Technical Bulletin No. 8, version 2, 2010.
41. TataSteelEurope, Sustainable steel construction.
42. Percentages listed below are based on 2008 data. Source: Allwood J.M., Cullen J.M., et al., 2012, Sustainable Materials: with both eyes open, p.31-38. UIT Cambridge, England.
43. Ruukki, Energy sandwich panels for external walls, www.ruukki.com, accessed May 2012.
44. Metals for Buildings: Essential & fully recyclable, 2011, www.metalsforbulidings.eu.
45. For more information on steel use in bridges, see the worldsteel case study on bridges at worldsteel.org.
46. BlueScope Steel, Sustainability: Recycling, Technical Bulletin No. 4, Vers. 1, June 2009.
47. worldsteel estimate based on data from national and regional associations.
48. e-mail 26 April, 2012, Siemens AG, Rail Systems Division, Communications.
49. IEA, World Energy Outlook 2008.
50. Boston Consulting Group and German Steel Federation, Steel's CO₂ balance, A Contribution to Climate Protection, 2010.
51. worldsteel, Steel solutions in a green economy: Wind turbines, 2012.
52. 'Stainless steel in solar energy use.' International Stainless Steel Forum (ISSF), 2008.
53. www.fao.org/wsfs/forum2050/wsfs-forum/en.
54. www.worldometers.info/water.
55. www.worldwatercouncil.org.
56. Cutler, P., Nickel Institute, Stainless steels and drinking water around the world, 2003.
57. worldsteel, Environmental case study: steel food cans, 2011.
58. Sustainable development policy, worldsteel.org.

worldsteel represents approximately 170 steel producers (including 17 of the world's 20 largest steel companies), national and regional steel industry associations, and steel research institutes. worldsteel members represent around 85% of world steel production. worldsteel acts as the focal point for the steel industry, providing global leadership on all major strategic issues affecting the industry, particularly focusing on economic, environmental and social sustainability.

worldsteel members are committed to a vision where steel is valued as a major foundation of a sustainable world. This is achieved by a financially sound industry that takes leadership in environmental, social and economic sustainability.

In 2002, the global steel industry worked together to establish a policy on sustainable development. This built on a set of principles established in 1972 and a statement of principles issued in 1992. Our Sustainable Development Charter, based on this policy, was signed by 66 member companies in 2012.



World Steel Association

Rue Colonel Bourg 120
B-1140 Brussels
Belgium

T: +32 (0) 2 702 89 00
F: +32 (0) 2 702 88 99
E: steel@worldsteel.org

C413 Office Building
Beijing Lufthansa Center
50 Liangmaqiao Road
Chaoyang District
Beijing 100125
China

T: +86 10 6464 6733
F: +86 10 6464 6744
E: china@worldsteel.org



worldsteel.org