Global steel production is reliant on coal. Coal is a direct input in the production of steel – almost 70% of the steel produced today uses coal. The remainder is produced using electricity – often generated using affordable and reliable coal.

Steel is a fundamental material for modern life. The manufacture of steels ultimately delivers the goods and services that growing economies demand – healthcare, telecommunications, improved agricultural practices, better transport networks, clean water and access to reliable and affordable energy. Steel is a vital building block for development – facilitating economic growth and poverty alleviation.

In Coal & Steel, the World Coal Institute provides an overview of coal’s role in the iron and steel sector. The report looks at the demand and supply of coal and steel, the importance of steel to our daily lives, describes manufacturing processes and considers options to reduce environmental impacts, including carbon capture and storage.

Key Messages

» Metallurgical coal, also referred to as coking coal, is a vital ingredient in the steel making process. Steel is a man-made alloy of iron and carbon – carbon is found in coal.

» Coal is abundant, affordable and geographically well-distributed. Major developed and developing economies are able to utilise large indigenous coal reserves, while coal is also available from a wide variety of sources in a well-supplied worldwide market.

» Steel is essential to modern societies: food production and preparation; water collection, purification and delivery; healthcare; transport systems – cars, trains and ships; and modern communication systems all depend on steel.

» Strong population growth and rapid urbanisation is driving demand for steel – as cities develop, housing, water and electricity are urgently required and transport and communication links have to expand.

» Steel is critical in the energy sector – it is used for fuel exploration, production, electricity generation and various forms of supply infrastructure.

» Major efficiency gains have been achieved in the integrated iron and steel sector. Several innovative solutions are being developed to further reduce, manage and control emissions from the process.

» Carbon capture and storage used directly in the process, as well as at the power stations generating electricity for electric arc furnaces, could reduce sector emissions to the atmosphere to near zero.
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Steel is a universal building material due to its strength, durability, versatility and affordability.

Photo courtesy of Newscaet/Corus
Steel is a vital building block for development – it facilitates economic growth and poverty alleviation and is a major element in improving quality of life.

Coal is an essential input in the production of steel. Steel is a man-made alloy of iron and carbon – and that carbon usually comes from coal. Almost 70% of the steel produced today relies directly on metallurgical coal, also referred to as coking coal. The remainder is produced by recycling scrap steel (itself originally produced directly using coal) using electricity – often generated using affordable and reliable steam coal.

Increasing Demand for Steel

Over the last 35 years steel production worldwide has almost doubled, from less than 600 million tonnes (Mt) in 1970 to around 1.2 billion tonnes in 2006. The period 2000-2006 has seen unprecedented growth, with global figures rising over 47%.

Much of the demand for steel is being driven by the strong and rapid economic growth of China and India. In 2006, economic growth rates in those countries were 11% and 9% respectively. With a population of over 1 billion in India, and almost 1.3 billion in China, the demand for products and services has fuelled an almost insatiable demand for steel. China and India together consumed over 445Mt of steel in 2006, around 40% of total global crude steel consumption. This is set to continue as India is projected to eclipse China in population size by 2025 and the two countries will account for around 36% of the global population.

Rapid urbanisation worldwide is driving demand still further – as cities grow, housing, water and electricity are urgently required. Transport links must be expanded to meet the geographical growth of urban and peri-urban areas. The availability and reliability of modern communication systems also becomes ever more important as urban economies become more sophisticated. Around 4.9 billion people are expected to be urban-dwellers by 2030 - 60% of the world’s population. This will place huge pressure on existing infrastructure and create significant demand for housing, better transport systems, communications networks, energy, sanitation and healthcare.

Coal will continue to play a major part in the manufacture of the world’s steel for the foreseeable future. The well-supplied world market means that metallurgical coal can be delivered worldwide, facilitating the manufacture of steels which will ultimately deliver the goods and services that growing economies demand.
Molybdenum may be added in the BOF to give particular properties to the final steel. Oxygen is blown through the molten metal bath inside the BOF, causing excess carbon to be oxidised and emitted, leaving liquid steel with low carbon contents.

Some steel plants use electric arc furnaces to generate steel, where recycled material or steel scrap is melted and then reformed for further use. The recycled steel is loaded into the furnace with some iron ore, often in a partially reduced form, and high intensity electrical power is supplied to electrodes forming an arc of electricity to raise the internal temperature and melt the scrap.

In both cases some additional refining may be carried out to achieve the required steel specification, but the integrated route offers the most capability for achieving the highest quality steels, whereas the EAF route is limited in what it can produce by the quality of the scrap.

The liquid steel, whether it is produced in BOF or EAF, is then processed via rolling mills to form a variety of products from rails to bars, wires to pipes – which are then further transformed for their end-use.

See Annex for more detailed information on the steel production process.
Steel Production

Coal

Coke Oven

Pallet

Cake

Iron Ore

Limestone

Blast furnace (BF)

Hot Metal

COKE MAKING

COKING

COKE MAKING

IRON MAKING

STEEL MAKING

Basic oxygen furnace (BOF)

Electric arc furnace (EAF)

Continues Casting

Rolling/Finning
Steel is a vital material for transport systems – cars, trains, ships all utilise steel.

Photo courtesy of BHP Billiton Mitsubishi Alliance
Coking coal has particular physical properties that on heating to over 1000°C (in the absence of air) causes the coal to soften, liquefy, then resolidify into hard but porous lumps, known as ‘coke’. As a major raw material fed into the blast furnace, coking coals must be of high quality to support the charge of a blast furnace with as little degradation as possible, providing high thermal efficiency and metal reduction. Coking coals must also be low in sulphur, phosphorus and alkalis - such as sodium and potassium.

Almost all coking coal produced globally is transformed into coke in a coke oven and used in blast furnaces for the production of pig iron for the steel alloy, although some is also used in the power sector.

Coking Coal Demand & Supply
World demand for coking coal increased from 635Mt in 2005 to 706Mt in 2006. China, India, Japan, Russia and Ukraine together accounted for around 74% of total global consumption of coking coal in 2006. The largest producers of coking coal are China and Australia.
Coking Coal Trade

There is a sizeable market in coking coal, with world trade at 222Mt in 2006 – representing 27% of global hard coal trade. Coking coal exports to Asia-Pacific are estimated to have reached 132Mt in 2006. Australia remains the world’s largest coking coal exporter, accounting for around 55% of world exports in 2006, at 121Mt. The largest coking coal importers are countries with strong steel demand but lacking in domestic coking coal reserves, such as Japan, South Korea and India.

Countries with significant coking coal reserves may choose to transform the coal domestically and export the coke product. About 65% of world coke exports originate in non-OECD countries, including China, Russia and the Ukraine. Some coke is exported from OECD countries – mainly Australia, Czech Republic, Japan, Poland and the USA. Around 70% of coke is imported by major steel producers in the OECD.

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<th>Top Coking Coal Consumers – 2006e (Mt)</th>
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Source: IEA 2007

OECD is the Organisation for Economic Cooperation and Development. It is a group of 30 member countries who are committed to democratic government and the market economy.
Global steel demand increased by 9% in 2006, reaching 1.1 billion tonnes. Although most of this was from China, other countries and regions have been experiencing a resurgence in demand for steel.

In Europe, strong economic growth has fuelled recent increases in steel production and consumption. Russia has seen strong growth in steel demand, supported by the consumer boom which is spreading to cars and houses, as well as the replacement of ageing infrastructure. Previous sharp declines in North America were reversed in 2006, with the USA producing around 100Mt of steel to help meet its domestic demand.

Steel making capacity is expected to increase over coming years. In China, new capacity of 54Mt per year is expected by the end of 2008. The Middle East and Latin America are also expected to significantly increase capacity, with some 34Mt per year planned in Brazil alone.

A similar exponential growth in steel demand is expected in India - the Indian government has already planned some $350bn investments in infrastructure development during its Eleventh Five Year Plan (2007-2012).

In 2006 global steel trade was up 13% to 283Mt (excluding EU internal trade), while China became the world’s largest exporter of steel products.
Consolidation in the Iron & Steel Sector

Consolidation in the iron and steel sector is a recent trend, with several mergers within the generally fragmented industry. The largest steel company, ArcelorMittal, now accounts for around 10% of the total market. In 2006 the top five steel producers accounted for 19% of world production. Consolidation has been occurring in most regions (except China) and is likely to continue, with moves to maintain basic production near to raw materials but increasingly producing finished steel near to the major consuming markets.

### Top Steel Exporters (Mt)

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<td>EU25</td>
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<td>Ukraine</td>
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Source: ISSB  
*Estimated*

### Top Steel Importers (Mt)

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<tr>
<td>Turkey</td>
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Source: ISSB  
*Estimated*
With almost 1.3 billion people, China has the largest population in the world. Its rapid economic development is increasing demand for steel from the construction, shipbuilding, and car industries. Between 1980 and 2006, China’s GDP rose at an average rate of almost 10% annually, making it one of the top five economies in the world. China’s contribution to global economic growth is nearing that of the OECD. With 29% in 2006, it contributed more than the USA, the EU and Japan combined. With a real GDP growth rate of around 11% during 2006, China has experienced a continuous increase in the demand and use of steel.

Economic Development

Rapid urbanisation has led to massive investments in construction projects – particularly in Beijing and Shanghai but increasingly in inland cities. Infrastructure projects, electromechanical producers, ships, machines, together with preparations for the 2008 Olympic Games in Beijing, have all driven demand for steel. $38 billion is to be invested in rail construction alone in 2007 as part of an almost $190 billion investment to increase the rail network 20% by 2010 – requiring an enormous amount of steel. By 2008 Beijing is due to have 200km of underground track and Shanghai is due to expand its underground rail system from 80km to 200km by 2010.
Car consumption in China is also starting to significantly increase. In 2006, China surpassed Japan to become the world’s second largest market for new vehicles after the US. The changes in car consumption coincide with the large investment made by the Chinese government in the highway network. By the end of 2006, it had approximately 45,000km and the highway network is set to expand to 65,000km by 2010 and 120,000km by 2030.

China’s Three Gorges Dam is a major construction project and will be the largest hydroelectric power station in the world when it becomes fully operational in 2009. The reservoir is over 600km long and can hold 39.3km$^3$ of water. Steel has been a vital material, with around 463,000t of steel utilised in its construction.

**Steel Market**

In 2006, with a total production of 423Mt, China’s steel output was over three times that of the next largest producer, Japan, and accounted for 34% of global steel production. Chinese steel production in 2006 was over 18% higher than in 2005.

China surpassed Japan, Russia, the Ukraine and the EU25 to become the world’s biggest steel exporting country in 2006. With exports of 49Mt, China is exporting at the rate of almost 1Mt a week. 2006 exports were a 91% increase over the previous year. Chinese steel imports fell to 19Mt, down 30% on 2005.

**Coking Coal**

China is the world’s largest producer and consumer of coking coal, at 323Mt and 327Mt respectively. China is also the fifth largest importer of coking coal and seventh largest exporter of coking coal.

China is one of the world’s biggest coke exporters, accounting for 45% of world coke exports in 2005, at almost 13Mt.

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<th>Top Iron &amp; Steel Companies – 2006 (Mt)</th>
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<td>Baosteel</td>
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<td>Tangshan</td>
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<td>Jiangsu Shagang</td>
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<td>Wuhan</td>
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Source: IISI
Steel is involved in the entire process of water collection, purification and delivery. It is used in large infrastructure projects, smaller water tank reservoirs, pipelines, pumps and stainless steel taps.

Photo courtesy of Eric Miller/World Bank
Steel is essential to everyday life – cars, buildings, ships, bridges, houses, fridges and medical equipment are all made of steel. It is an indispensable material in almost every product we use today.

There are thousands of types of steel – each providing different characteristics due to the specific combination of elements in the alloy. Adding other elements to the hot metal provides a wide range of alloy steels, such as stainless steel. The most common is carbon steel, which is composed simply of iron and carbon.

Changing the amount of carbon in the steel affects the hardness of the alloy, enabling a variety of uses. Low-carbon steel (up to 0.35% carbon) is commonly used for drinks or food cans but can also be converted into a wide range of alloys, such as engineering steels and tool steels. Medium and high carbon steels (0.35%-over 1%) may also be used for a wide range of applications, including surgical steels. Stainless steels contain a minimum of 10% chromium, often combined with nickel, to resist corrosion.

All of these types of steel are produced using coal. The development impact these goods and services have on communities – through growing economies, raising quality of life and alleviating poverty – is therefore also reliant on coal.

Buildings & Construction
Steel is a universal building material due to its strength, durability, versatility and affordability. The superstructures of skyscrapers, bridges, high-rise apartments and commercial buildings and offices are built with steel.

Society’s need for housing is great and increasing. Around 1.1 billion people live in inadequate housing conditions in urban areas alone. Some 21 million new housing units are needed each year to meet present growth in developing countries. Steel is an ideal material to help meet this growing need – it is long-lasting, versatile, earthquake resistant and 100% recyclable.
Steel is critical in the energy sector – it is used for fuel exploration, production, electricity generation and in supply infrastructure. Mines, offshore platforms, thermal and nuclear power plants, hydroelectric dams and power plants, and renewable energy systems are all dependent on steel.

New forms of steel will enable power generation to reach higher levels of efficiency, helping in the drive to significantly reduce carbon dioxide (CO₂) emissions from the sector. Ultra-supercritical (USC) coal-fired power plant operate at higher temperatures and pressures than conventional pulverised coal plant, and can achieve operating efficiencies of greater than 45%. USC plant require specialist steels in order to withstand these conditions. These new plants are being built worldwide but continuing materials research is being undertaken to improve the steels available. Other advanced technologies such as Integrated Gasification Combined Cycle (IGCC) depend on the use of improved steel materials to achieve larger commercial capacities, matching those of the current conventional thermal power stations.

Even renewable energy systems are dependent on steel (and therefore coal) for their infrastructure needs, as well as to distribute that energy to users. Wind turbines, for example, are supported by steel towers which are typically constructed using corrosion resistant steel.

Transmission and distribution systems also rely on steel. The world’s tallest suspension tower, for example, allows power transmission lines to cross the Yangtze River in China. Each tower is 346.5m high and the project was built with 4300t of steel. The towers, completed for the East China (Jiangsu) Power Transmission Project and funded by the World Bank, form part of the 500kV transmission line project from Yan Cheng Power Station in Shanxi Provence in the north of China to Dou Shan Substation in Jiangsu Province in the south of China.

Given its role in helping to produce and distribute electricity, steel is therefore vital to economic development and alleviating poverty. There are currently 1.6 billion people without access to electricity. While energy systems themselves are not sufficient to eradicate extreme poverty, they are necessary to create the conditions for economic growth and improved social equality.

**Health, Nutrition & Housing**

The machines and equipment to grow, preserve, store and prepare food are made with steel. From agricultural machinery to refrigerators, knives to delivery trucks, each step of food growth and preparation requires steel. Steel cans have enabled preservative-free, long-term storage of food. Around 200 billion steel cans for food are produced each year, many from recycled steel.
Meeting the world’s needs for freshwater is a serious challenge. At least one in five people in the developing world lack adequate access to safe drinking water. Steel is involved in the entire process of water collection, purification and delivery. From large infrastructure projects, such as dams, to smaller water tank reservoirs, from pipelines to pumps to stainless steel taps, steel is a fundamental construction material for both potable water and sanitation – providing essential health benefits.

**Transport Systems**

Steel is also a vital material for transport systems – cars, trains and ships all utilise steel.

The safety of modern cars is provided by an internal ‘cage’ from steel. In a collision, crumple zones around this absorb the bulk of the crash energy while the specially fabricated cage will deform without breaking, reducing risks to passengers. The automobile industry helps to push innovation in the steel industry with demand for emissions reductions, stringent safety standards and affordability. For example, the body weight of a car could be reduced by 24% using new lighter steels with the same strength and safety properties, significantly reducing fuel consumption.

Ships are mainly constructed from hot rolled steel plates which are then cut to size for particular parts of the ship such as the hull, the internal framing of holds and rooms, decks, chimneys and superstructure.

**Communication**

Modern communication systems are vital for involvement in the global economy. Steel towers and masts provide hubs for mobile communications and broadcasting antenna and are among the tallest man-made structures. In Japan, the DoCoMo Telecommunications Tower on the roof of the DoCoMo Osaka Nanko building, has a maximum height of 2000m and utilises a steel design which comprises six plates suspended and skewered to a single mast supported with steel cables (below).
Viaduc de Millau, France. The largest pylon is 343 metres high, taller than the Eiffel Tower. Steel was essential to the construction of the bridge. Photo courtesy of CEVM/Foster + Partners/D. Jamme.
Carbon dioxide is formed during the chemical reactions in the production process as well as from the energy used. Major efficiency gains have been achieved in the integrated iron and steel sector over the last 50 years. State-of-the-art integrated processes are at, or very near, their thermodynamic limits. This means that while efficiency improvements can be made at older plants, there may be no further scope to directly reduce CO2 emissions from today’s best practice plants using the same approach.

Several innovative solutions are being developed to further reduce, manage and control emissions from the process, while carbon capture and storage (CCS) could reduce sector CO2 emissions to the atmosphere to near zero.

Carbon Capture & Storage
CCS is most cost-effective when applied to large, stationary sources of CO2 – such as steelworks and power stations. CSS technologies offer the possibility of reducing carbon dioxide emissions to the atmosphere to near zero without major changes to the basic industrial process of steel making. CCS would allow emissions of CO2 to be captured from the iron and steel making process and permanently stored in geological formations – preventing them from entering the atmosphere (see diagram on page 21). CCS can also be used at the power stations generating the electricity for Electric Arc Furnaces, which would have a significant impact on indirect emissions from steel production, reducing emissions over the full life cycle.

The CCS reduction potential for the iron and steel sector has been estimated to be approximately 0.5-1.5 Gigatonnes of CO2 per year.

New Processes
Further technological change and innovation can bring about a reduction in sectoral emissions. Increased use of pulverised coal injection (PCI) reduces the need for coke, avoiding emissions and efficiency losses from the coking process. New smelt reduction processes are gradually gaining market share, and the use of Direct Reduced Iron (DRI) has significantly increased during the last 30 years. In absolute terms, steel scrap use keeps growing, although its market share may be steady or even in decline.

Pulverised Coal Injection
The injection of pulverised coal into the blast furnace is an established technology, growing in use (see Annex for technical description). Significant interest has also been shown in the injection of plastic wastes into blast furnace operations as a substitute for coke and coal. Hydrogen from the plastics can be used as fuel for the process.
Direct Reduced Iron
Another steel process gaining ground is the Direct Reduced Iron-Electric Arc Furnace process. This is the most widely used alternative to the Integrated Blast Furnace-Basic Oxygen Furnace or scrap-EAF methods of steel production. Reduction of iron takes place using natural gas or coal – DRI is typically used in countries with large domestic reserves of gas or steam coal, utilising indigenous resources and therefore reducing costs associated with importing coking coal and coke making. India, for example, has limited reserves of coking coal and therefore utilises its large reserves of steam coal to reduce iron ore using DRI technology.

COREX®
COREX® is a coal-based smelting process that produces hot metal or pig iron. The output can be used by integrated mills or EAF mills. The process gasifies non-coking coal in a smelting reactor, which also produces liquid iron. The gas is fed into a shaft furnace, where it removes oxygen from iron ore lumps, pellets, or sinter; the reduced iron is then fed to the smelting reactor. Gasification of coal reduces sulphur oxide (SOx), nitrogen oxide (NOx) and particulate emissions by up to 99%, and the higher efficiency of the process reduces CO2 emissions.

FINEX®
FINEX® is an innovative process for hot metal production. Molten iron is produced directly using iron ore fines and non-coking coal rather than processing through sintering and coke making. The key technologies are fluidised bed reducing reactors for the reduction of fine ore to DRI fines and a melter gasifier for melting of DRI to hot metal. Emissions of pollutants can be significantly reduced using this process - levels of SOx and NOx will only be 8% and 4% respectively of the emissions occurring with the blast furnace process, and again greater efficiency and elimination of primary processing will dramatically reduce CO2 emissions.

The first commercial FINEX plant producing 1.5Mt of hot metal per year started operation in Posco’s Pohang works in South Korea in the first half of 2007.

Increased Steel Recycling
Steel is 100% recyclable. In 2005, over 440Mt of steel were recycled. The EAF process uses almost entirely recycled scrap, while the BOF process can also use up to 30% recycled steel. Around 43% of total world crude steel production is made from recycled steel.

The availability of steel scrap is an important concern – and a limiting factor in the application of EAF. As steel is ‘tied up’ in durable, long-lasting products, it can be many years before the steel is theoretically available for re-use. However, steel that is used today will be recovered, processed and used again, making steel the most recycled material in the world. The main sources for steel recycling today are unwanted, or discarded cars, household appliances, steel cans, as well as old buildings and structures.

The by-products from iron and steel making can also be recycled - slag, for example, can be solidified, crushed, and used in soil mix, road surfaces and cement.

Definition
Slag is a by-product of iron making, made up of molten limestone which has absorbed the impurities from the process.
ULCOS is a consortium of European steel makers with some 40 industrial organisations, research institutes and universities. The goal of ULCOS is to develop new technologies to substantially reduce CO₂ emissions in steel making.

In its first phase, the ULCOS project will evaluate a range of options to reduce CO₂ emissions by using new low-carbon technologies applied to existing plant configurations and also by considering more radical potential process routes that could become economically viable in the longer term. CSS is considered a major part of the project, necessary for a number of technology routes. Research streams include electrolysis, greater use of natural gas, hydrogen and biomass feedstocks.

The second phase (2009-on) will demonstrate promising technology options.
The two main steel production processes utilised are the Basic Oxygen Furnace and Electric Arc Furnace. Post-production processes provide the raw outputs which may then be further transformed to their final end use, such as the production of wire at this facility.

Photo courtesy of Stahl-Zentrum
Coal is essential for iron and steel production. The two main steel production processes utilised are the Basic Oxygen Furnace (BOF) and Electric Arc Furnace (EAF).

Post-production processes – casting and rolling – provide the raw outputs which may then be further transformed in manufacturing processes worldwide for their final end use.

**Raw Materials**
Steel is an alloy based primarily on iron. As iron almost always occurs as iron oxides in the earth's crust, the ores must be converted, or 'reduced' using carbon. The primary source of this carbon is coking coal.

Commercial ores usually have an iron content of at least 58%. Iron ore is mined in around 50 countries – the largest producers are Australia, Brazil and China. The seven largest producers account for about 75% of world production. Around 98% of iron ore is used in steel making.

Coking coal is converted to coke by driving off impurities to leave almost pure carbon. The physical properties of coking coal cause the coal to soften, liquefy and then resolidify into hard but porous lumps when heated in the absence of air.

**Coke Making**
The coking process consists of heating coal to around 1000-1100°C in the absence of oxygen to drive off the volatile compounds (pyrolysis). This process results in a hard porous material – coke. Coke is produced in a coke battery which is often located at or near an integrated steel mill. A coke battery is composed of many coke ovens stacked in rows into which coal is loaded.

The coking process takes place over long periods of time in the coke ovens – between 12-36 hours. Once pushed out of the oven, the hot coke is then quenched with either water or air to cool before storage or is transferred directly to the blast furnace for use in iron making.
Pulverised Coal Injection

Pulverised Coal Injection technology has been developed whereby coal is injected directly into the blast furnace. The pulverised fuel provides the process heat in the blast furnace to enable gasification of the coke. A secondary function is to provide some of the carbon for the reduction process. A wider range of coals can be used in PCI, including steam coal which has a lower carbon content than coking coal. This method has a number of advantages, including reducing overall costs and prolonging the life of existing coke batteries.

Iron Making - Blast Furnace

During the iron making process, a blast furnace is fed with the iron ore, coke and small quantities of fluxes. Air which is heated to about 1200°C is blown into the furnace through nozzles called tuyères in the lower section. The air causes the coke to gasify, producing carbon monoxide/carbon dioxide which reacts with the iron ore, as well as heat to melt the iron.

Blast furnaces have two or three tap holes and the hot metal and slag are ‘tapped’ off regularly as they accumulate in the base or hearth of the BF. The hot metal drains into a vessel known as a ladle car, which is used to transport it to the BOF plant.

Iron Making - Direct Reduction of Iron

An alternative to iron making through BF is the Direct Reduced Iron process (DRI used with EAF). The share of steel produced from DRI has increased during the past three decades and today it accounts for some 5% of global iron metal supply. Direct reduced iron is produced via an innovative iron making process. While the blast furnace is a smelter that melts everything and enables the removal of non-ferrous material such as slag, direct reduction of iron is a reduction process that does not remove this material. It must therefore use much ‘cleaner’ ore, otherwise it would be charged in the electric arc furnace and would have to be melted there. The process...
Coal & Steel involves the use of pellets of iron ore ‘fines’ to produce direct reduced iron of high quality - composed of 97% pure iron compared with the 93% for pig iron from a blast furnace.

It can then be used in combination with an Electric Arc Furnace to produce steel (DRI products are rarely used in the integrated route). The reduction process takes place using natural gas or coal - DRI is often used in countries with large domestic reserves of gas or stranded gas fields, or with significant reserves of steam coal. DRI therefore allows indigenous resources to be utilised.

Some of the biggest producers of DRI include India, Venezuela, Mexico and Iran. India, for example, has limited reserves of coking coal and therefore utilises its large reserves of steam coal to reduce iron ore using DRI technology.
Steel Making – Basic Oxygen Furnace
The most commonly applied process for steel making is the integrated steel making process via Blast Furnace-Basic Oxygen Furnace (see Figure 1 on page 24).

In the basic oxygen furnace, the iron is combined with varying amounts of steel scrap (less than 30%) and small amounts of flux. A lance is introduced in the vessel and blows 99% pure oxygen causing the temperature to rise to 1700°C. The scrap melts, impurities are oxidised, and the carbon content is reduced by 90%, resulting in liquid steel.

Other processes can follow – secondary steel making processes – where the properties of steel are determined by the addition of other elements, such as boron, chromium, molybdenum, amongst others, ensuring the exact specification can be met.

Optimal operation of the blast furnace demands the highest quality and consistent raw materials – the carbon content of coke therefore plays a crucial role in terms of its effect in the furnace and on the hot metal quality. A blast furnace fed with high quality coke requires less coke input, results in higher quality hot metal and better productivity. Overall costs may be lower, as fewer impurities in the coke mean smaller amounts of flux must be used.

Steel Making – Electric Arc Furnace
The Electric Arc Furnace process does not involve iron making through a Blast Furnace. Instead, it reuses existing steel, avoiding the need for raw materials and their processing. The furnace is charged with steel scrap, it can also include some direct reduced iron or pig iron for chemical balance.

Over the last 30 years there has been a significant increase in the use of electric arc furnaces, which now account for some 32% of total steel production (see Figure 2 on page 24).

The Electric Arc Furnace operates on the basis of an electrical charge between two electrodes providing the heat for the process. The power is supplied through the electrodes placed in the furnace, which produce an arc of electricity through the scrap steel (around 35 million watts), which raises the temperature to 1600°C, melting the scrap. Any impurities may be removed through the use of fluxes and draining off slag through the tap hole.

EAF cannot produce the wide range of steels that BF-BOF is able to because the use of scrap and DRI limits the removal of impurities at EAF plants and the quality control that can be achieved.

Electric Arc Furnaces do not use coal as a raw material, but many are reliant on the electricity generated by coal-fired power plant elsewhere in the grid.

Operations using the EAF system are often known as mini-mills, although EAF units are also common in integrated plants. They have a flexibility advantage over the BF-BOF integrated steelmaking route as the furnace can be switched on and off as desired, following market demand for products. Mini-mills are more energy efficient on site, but overall impacts need to be considered on a full life-cycle basis.
FURTHER READING

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