worldsteel ASSOCIATION

FACT SHEET

Steel industry by-products

Over the past 20 years, the steel industry's recovery rate of by-products has increased significantly. Innovative technology developments and synergies with other industries has brought the steel industry ever closer to its goal of zero-waste.

The recovery and use of steel industry by-products has contributed to a material efficiency rate of 97.3% worldwide.[1] Our goal is 100% efficient use of raw materials and zero-waste.

Recovered by-products can be reused during the steelmaking process or sold for use by other industries. This prevents landfill waste, reduces CO_2 emissions and helps preserve natural resources. The sale of these by-products is also economically sustainable. It generates revenues for steel producers and forms the base of a lucrative worldwide industry.

Steel production and by-products at a glance

There are two main ways in which steel is produced:

1. Iron ore-based steelmaking accounts for about 70% of world steel production. Iron ore is reduced to iron and then converted to steel. The main inputs are iron ore, coal, limestone and recycled (scrap) steel. The main ore-based production routes are: ironmaking via the blast furnace (BF) followed by steelmaking in the basic oxygen furnace (BOF), and ironmaking via direct reduction (DRI) followed by steelmaking in the electric arc furnace (EAF).
2. Scrap-based steel accounts for about 30% of global steel production. It is produced by recycling steel in an EAF. The main inputs are 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.

The main by-products produced during iron and crude steel production are slags (90% by mass), dusts and sludges. Process gases, for example, from the coke oven, BF or BOF are also important by-products. However, this fact sheet will mainly focus on solid by-products.

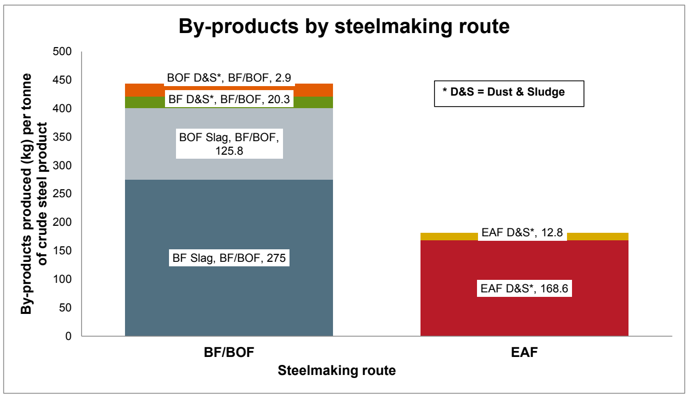

Figure 1: Main solid by-products by steelmaking routes[2]

An average value is shown for the EAF route (see Figure 1), as EAF plants often use a mix of DRI and recycled steel feeds.

On average the production of one tonne of steel results in 200 kg (EAF) to 400 kg (BF/BOF) of by-products. These include slags, dusts, sludges and other materials.

Ironmaking and steelmaking slags

More than 400 million tonnes of iron and steel slag is 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. The slags protect the liquid metal from outside oxygen and maintain temperature by forming a lid. 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-mixed concrete, concrete products, asphaltic concrete, road bases and surfaces, fill, clinker raw material, railroad ballast, roofing, mineral wool (for use as insulation) and soil conditioner.[3]
- **Granulated slag** forms sand-sized particles of glass and is primarily used to make cementitious material. Concretes incorporating granulated slag generally develop strength more slowly than concretes that contain only Portland cement – the most common type of cement – but can have better long-term strength, release less heat during hydration, have reduced permeability, and generally exhibit better resistance to chemical attack. Slag can also help bring down the cost of cement. For example, in the US it sells for 15% less than Portland cement.[4] While the use of granulated slag in cement is well established, there is still potential in many regions to increase the ratio of slag used for this purpose.
- **Pelletised or expanded slag** has a vesicular texture (like volcanic rock) and is most commonly used as a lightweight aggregate. If finely ground it also has cementitious properties. In some countries, up to 80% of the cement contains granulated BF slag.[5] Using slag prevents it going to landfill as waste, saves energy and natural resources, and significantly reduces CO_2 emissions in cement production. According to the Slag Cement Association, replacing Portland cement with slag cement in concrete can save up to 59% of the embodied CO_2 emissions and 42% of the embodied energy required to manufacture concrete and its constituent materials. However, this does not account for the CO_2 emissions associated with producing slag.

Steelmaking slag (BOF and EAF) is cooled similarly to air-cooled BF slag and is used for most of the same purposes. As the production process varies at this stage, depending on the type of steel being made, the resulting slags also have diverse chemical properties making them more difficult to use than ironmaking slags. Some of the recovered slag is used internally in the steelmaking furnace or sinter plant, while approximately 50% of the recovered slag is used externally in construction applications, primarily roads.

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 currently under development to improve lime separation. Once separated, free lime can be used as a fertiliser, in cement and concrete production, for waste water treatment, and in coastal marine blocks that encourage coral growth. Previously landfilled as useless by-products, slags are now recognised as marketable products.

The worldwide average recovery rate for slag varies from over 80% for steelmaking slag to nearly 100% for ironmaking slag. The environmental and economic benefits mean that there is still potential to increase the use of slags in many countries.

Gases, dusts and sludges

Gases from iron- and steelmaking (for example, from the coke oven, BF or BOF) once cleaned, are used internally to produce steam and electricity, reducing the demand for externally-produced electricity. Gases can be fully reused within the steel production site, and can provide up to 60% of the plant's power.[6] Alternatively, gases can be sold for power generation. They are flared only if no other option is available.

Dust and sludge are collected in the abatement equipment (filters) attached to the iron- and steelmaking processes. Sludge is produced from dust or fines in various steelmaking and rolling processes and has a high moisture content. The dust and sludge removed from the gases consist primarily of iron and can mostly 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 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 napthalene (used to make pencil pitch which in turn is used to produce electrodes for the aluminium industry, plastics and paints).[7]

Ongoing technological development

Ongoing development is taking place to further improve by-product recovery rates and, more importantly, to expand its use by improving the quality of the materials recovered.

Together with existing technologies, new developments provide environmentally and economically sustainable solutions to bring the steel industry closer to its goal of zero-waste. Public and political perception needs to be modified to extend the use of by-products to substitute quarried rock in cement under roadways or railway tracks thereby saving natural resources and reducing the environmental impact. worldsteel believes that by-products and natural resources should be able to be substituted within the same legal framework as they can both serve the same purpose. Substituting natural resources for by-products avoids duplication of energy use in the production phase.

Last updated June 2016

Footnotes

1. Sustainable Steel - Policy and Indicators 2015, worldsteel.org.
2. By-products report, worldsteel, 2009.
3. van Oss and Hendrik G., US Geological Survey Minerals Yearbook 2012, pp.69.2, 69.6.
4. van Oss and Hendrik G., US Geological Survey Minerals Yearbook 2012, p.69.3.
5. Legal Status of Slags, European Slag Association (Euroslag), pp. 2, 10, 01/2006.
6. Energy use in the steel industry report, worldsteel, 2014.
7. Reusing the by-products of the steel industry, BlueScope Steel.