Energy Efficiency and CO₂ Reduction in the Iron and Steel Industry

In brief

The iron and steel industry is one of the biggest industrial emitters of CO₂, accounting for between 4% and 7% of anthropogenic CO₂ emissions globally. In the past 40 years there has been a 50% reduction in energy consumption in the industry in Europe. This has mainly been due to the increased use of recycled scrap iron, from a 20% share in the 1970’s to around 40% today, while the manufacture of iron from iron ore has declined. However, a complete shift to recycling is limited by the availability and quality of scrap.

The technology

There are two main routes to produce steel. The integrated route is based on the production of iron from iron ore, while the recycling route uses scrap iron as the main iron-bearing raw material in electric arc furnaces. In both cases, the energy consumed comes from fuel (mainly coal and coke) and electricity. The recycling route consumes much less energy (about 80%) than the integrated route.

The integrated route – used for about 70% of production globally – relies on the use of coke ovens, sinter plants, blast furnaces (BF) and Basic Oxygen Furnace (BOF) converters. The fuels used are fully exploited, first for their chemical reaction potential (during which they are converted into process gases) and then for their energy potential, by capturing, cleaning and combusting these process gases in production processes and to generate heat and electricity. However, the increased energy efficiency that comes with the re-use of process gases – so-called cascadic fuel use – does not reduce overall energy consumption, in terms of the primary fuels used for the chemical reactions.

Ongoing research

Alternatives to the two main production routes include direct-reduced iron technology and smelting reduction (which, like the blast furnace, produces hot metal). The advantage of these technologies compared with the integrated route is that the raw materials do not need to be treated (‘beneficiated’), e.g. by sintering and making coke, and that they can adjust well to low-grade raw materials. On the other hand, more primary fuels are needed, especially natural gas for direct reduced iron technology and coal for smelting reduction.

20-25% savings in CO₂ emissions in the smelting reduction process can be achieved if the additional coal is transformed into process gases, which are then captured and used to produce heat and electricity. At present in the EU-27, only one plant uses direct-reduced iron technology (in Germany), while none of the eight operational facilities for smelting reduction in the world are in Europe.

There is potential for reducing direct CO₂ emissions by about 27Mt per year by applying best practice, including the retrofitting of
existing equipment. This potential however relies strongly on a substitution of local raw materials with increased imports of best performance raw materials from outside the EU (especially ores and coal).

The industry’s flagship ULCOS programme (Ultra–Low Carbon dioxide (CO₂) Steel-making), supported by the European Commission and involving a consortium of 48 leading players in industry and research, aims to reduce the CO₂ emissions of today’s best routes by at least 50%. The first phase of ULCOS had a budget of EUR 75 million.

As a result of the first phase of ULCOS, four main processes have been earmarked for further development. The top gas recycling blast furnace is based on the separation of the off-gases so that the useful components can be recycled back into the furnace and used as a reducing agent. Meanwhile, oxygen is injected into the furnace instead of preheated air to facilitate CO₂ capture and storage (CCS). The timeline to complete the demonstration programme is about 10 years, allowing further market rollout after 2020.


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Fact file

**Key performance indicators**

- Currently, 45% of steel is produced and used in mainland China.
- By 2020 the annual consumption of steel in the wind energy industry could amount to 5.2 Mt, in order to achieve the projected 220 GW of wind energy and 4.5 Mt by 2030 to achieve the projected 350 GW of wind power.

**Production and consumption of iron and steel**

- The production of crude steel in the EU in 2011 was 177.2 Mt, representing 11.7% of the total world production (1514 Mt of crude steel), compared to 22.0% ten years earlier (in 2001), even though production was higher.
- In 2009, with the financial crisis, steel production in Europe dropped by 30% compared to the previous three years.
- From 2001–2011, Chinese steel production grew more than fourfold (from 151.5 Mt to 648 Mt of crude steel).
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**Greenhouse gas emissions and savings**

- GHG emissions from the iron and steel industry between 2005 and 2008 on average amounted to 252.5 Mt of CO₂ equivalent.
- In Europe, about 80% of CO₂ emissions from the ‘integrated route’ originate from waste gases. These waste gases are used within the same industry to produce about 80% of its electricity needs.
- During the period 2005 to 2008, direct emissions from the integrated route were on average 2.3 tCO₂/t of rolled products and 0.21 tCO₂/t of rolled products for the recycling route.

**Employment**

- In the EU-27, about 360,000 people were directly employed in the sector in 2013.

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**If the body structures of all cars produced worldwide were made of Advanced High-Strength Steel instead of conventional steel, 156 Mt CO₂ eq would be avoided.**
The Hisarna technology combines preheating of coal and partial pyrolysis in a reactor, a melting cyclone for ore melting and a smelter vessel for final ore reduction and iron production. Market rollout is scheduled for 2030. The ULCORED (advanced Direct Reduction with CCS) involves the direct reduction of iron ore by a reducing gas produced from natural gas. The reduced iron is in a solid state and will need an electric arc furnace to melt the iron. An experimental pilot plant is planned in Sweden, with market rollout foreseen for 2030. The other two experimental processes, known as ULCOWIN and ULCOSYS, are electrolysis processes to be tested on a laboratory scale.

In thermal power plants, the development of new steel grades will increase temperature and pressure and will contribute to the improvement of energy efficiency. In advanced supercritical plants with steam conditions up to 600 ºC and 30 MPa, net efficiencies between 46 and 49% could be reached whereas older pulsed coal plants, with subcritical steam parameters, operate with efficiencies between 32-40%. Each percentage point efficiency increase is equivalent to a 2.5% reduction in tonnes of CO₂ emitted.

The development of new grades (light-weight alloys) for the automotive industry can decrease steel consumption (energy consumption) and at the same time improve the efficiency of the final products – lighter cars will be more efficient.

The industry

The production of crude steel in the EU in 2011 was 177.2 Mt, representing about 11.7% of total world production (1 514 Mt of crude steel), compared to a 22.0% share ten years earlier, in 2001, even though production was slightly higher then (187.2 Mt). The main difference is that Chinese production has grown more than fourfold over this period.

The growth of iron and steel production in the EU-27 is estimated at about 0.7% per year up to 2050. The increase in the production would be covered mainly by an increase in the recycling route. Production from the integrated route is expected to stay around its current values. Indeed, the world steel industry has an overcapacity of 542 Mt out of an expected global capacity of 2 172 Mt by 2014.

Barriers

Further increases in the recycling rate beyond the 60% in 2030 will be hampered by the availability of scrap. Such high recycling rates will increase the impurities and reduce overall steel quality. Recycling is associated with high emissions of heavy metals and organic pollutants due to the impurities of scrap.

Meanwhile, the thermochemical efficiency of current blast furnaces is almost opti-
mal. As CO₂ emissions are linked to the chemical reaction for the reduction of iron ore, there can be no significant decrease in CO₂ emissions without the development of breakthrough technologies, as proposed by ULCOS.

The industry is also facing a social challenge due to the increasing average age of its workforce: more that 20% will retire from 2005 to 2015 and close to 30% during the following 10 years. The industry will therefore need to attract, educate and secure more qualified people.

**Needs**

There is a clear need to support the ULCOS research effort with a high share of public funds, and to encourage the deployment of these breakthrough technologies.

One important synergy in the quest to curb prospective CO₂ emissions through the ULCOS project is by sharing innovation initiatives within the power sector or with other (energy-intensive) manufacturing industries that could launch Carbon Capture and Storage (CCS) initiatives (e.g. the cement industry). No CCS projects were awarded in the first call for proposals under the EC’s New Entrants’ Reserve (NER 300) funding programme. But the EUR 275 million set aside for CCS projects is still available for the second phase of the programme.

Not all the European operators are performing as well as they could, so there is still potential to save energy by bringing them up to the level of the best performers.

**Installed capacity**

The EU-27 is the second leading manufacturer of iron and steel products in the world, China being the largest. The main EU steel producers are Germany, Italy, France, Spain, UK, Belgium and Poland. The USA is the main importer and the EU, Japan, Russia and Ukraine are the main steel exporting countries.

In 2011, total EU crude steel production was 177.2 Mt, accounting for 11.7% of world steel output.