7.7 Iron and steel production

7.7.1 Coverage

The sector covers iron and steel making in integrated steelworks (sinter plants, pelletization plants, coke oven plants, blast furnaces and basic oxygen furnaces including continuous and ingot casting) and electric arc furnace steelmaking. Other downstream activities like ferrous metal processing in foundries, rolling or galvanizing are dealt with within the sector "ferrous metals processing". Emissions originating from coke oven furnaces in iron and steel production are dealt with in the section coke ovens. [1]

7.7.2 Emission sources

The iron and steel industry is a highly material and energy intensive industry, in which more than half of the mass input becomes output in the form of off-gases and solid wastes/by-products. Air emissions from sinter plants dominate the overall emissions for most of the pollutants. Besides sinter plants, most relevant emissions occur in pelletization plants, coke oven plants (described in the separate section for this sector), blast furnaces, basic oxygen steelmaking and casting, and electric steelmaking and casting. [1] [2]

Sinter plants

Sinter is the product of an agglomeration process of iron-containing materials and is the source of a major part of environmental issues in integrated steel works. This product is obtained by heating a layer of crushed and mixed raw material (iron ore, coke, limestone, …) and by exhausting flue gases through this layer so that the surface melts and agglomerate is formed. Sinter plants are playing a very important role for the internal material management of integrated steel works because, under conditions, most of iron-bearing waste materials can be recycled into the sinter feed in order to utilise their iron content and consequently save raw material. The off-gas emissions from sinter strands contain pollutants such as dust, heavy metals, SO_2, HCl, HF, PAH and organochlorine components. [1] [3]

Pelletization plants

Pelletization is an alternative process to agglomerate iron-containing materials, with pellets being produced mainly at the site of the mine or its shipping port. Again, emissions to air dominate the environmental issues. [1] [9]

Coke oven plants are not subject of this part, but are dealt with in their own section.

Blast furnaces

The blast furnace remains by far the most important process to produce pig iron from iron containing materials. These are reduced using carbon and hot gas to pig iron, which later acts as a raw material for steelmaking. Due to the high input of reducing agents (coke, pulverized coal) it consumes most of the overall energy input in an integrated steelworks. [1] It produces a high volume of process gas, which needs to be cleaned before being used for internal combustion or for internal/external generation of energy.

Although the blast furnace route is the main process for iron production, several other production routes for pig iron are currently being developed. Two main types of alternative iron making are direct reduction (production of solid primary iron from iron ores and a reducing agent, e.g. natural gas) and smelting reduction (combining direct reduction in one reactor with smelting in a separate reactor, without the use of coke). COREX is a commercially successful version of a 'smelting reduction' process [4]. These techniques use coke, coal or natural gas as the reduction agent. In some of the new techniques lump ore and pellets by pulverized iron ore as the main feedstock. The solid product is called Direct Reduced Iron (DRI) and is mainly applied as feedstock in EAFs. [4] [9]

Basic oxygen steelmaking and casting
The objective of oxygen steelmaking is to reduce the carbon content and to remove the undesirable impurities still contained in the hot metal from the blast furnace. It includes the pre-treatment of hot metal, the oxidation process in the basic oxygen furnace, secondary metallurgical treatment and casting (continuous and/or ingot). In addition to hot metal, up to 25% scrap can be used as input material. Collected basic oxygen furnace (BOF) gas is cleaned and stored for subsequent use as a fuel, if economical feasible or with regard to appropriate energy management. [1] [4]

Electric steelmaking and casting
The direct smelting of iron-containing materials, mainly scrap, is usually performed in electric arc furnaces. This needs considerable amounts of electric energy and causes substantial emissions to air. The energy consumption (and the corresponding amount of CO_2 emissions) from steel production in electric arc furnaces is about one third of the energy consumption of the blast furnace / basic oxygen furnace route. The use of this 'lower CO_2 production route' is however limited by the availability of scrap and certain qualities of steel can only be achieved via the primary production route. [1]

7.7.3 BAT, Associated Emission Levels (AEL)

7.7.3.1 SO2

For **sinter plant** emissions, SO_2 can be minimised by lowering the sulphur input (use of coke breeze and iron ore with low sulphur content), emission concentrations of <500 mg SO_2/Nm³ can be achieved in this way. SO_2 emissions from sinter plants may also be reduced by dry or semi-dry adsorption systems in combination with high-efficiency dust filters (as part of a multi-pollutant control technique).
With a wet waste gas desulphurization, reduction of SO_2 emissions >98% and concentrations < 100 mg SO_2/Nm³ can be achieved. Due to the high cost wet waste gas desulphurisation should only be required in circumstances where environmental quality standards are not likely to be met [1], operational reliability (availability ratio of the equipment) is also questioned.
For **pelletization plants,** dust, SO_2 and other pollutants can be removed from induration strand waste gas either by scrubbing or semi-dry desulphurization and subsequent de-dusting (e.g. gas suspension absorber (GSA)) or by any other device with the same removal efficiency. [1]
Addition of adsorbents such as hydrated lime, calcium oxide or fly ashes with high calcium oxide content may be used to further reduce SO_2 emissions, when injected into the exhaust gas outlet before filtration. [9]

Table 1: SO_2 emission levels associated with BAT for iron and steel production

Emission Source	**BAT associated emission levels[1] mg/Nm^3 or (kg/tonne)**	**Comments**
Sinter plants [1]	< 500 (1)	500 according to BREF
Pelletization plants [1]	< 20	SO_2 as $SO_{2;}$ using system with removal efficiency >80%
Blast furnaces: cowpers (hot stoves)	< 200	Related to an oxygen content of 3% In the German IPPC implementation report from 2006 a range of 60-210 mg/m3 is reported as 5% and 95% percentiles based on half-hourly average values from continuous measurements.

[1] The BAT associated emission levels may be expected to be achieved over a substantial period of time at standard conditions and represents a typical load situation. For peak load, start up and shut down periods, as well as for operational problems of the flue gas cleaning systems, short-term peak values, which could be higher, have to be regarded.

7.7.3.2 NOX

For **sinter plants**, NO_X emissions should be minimized by, for example waste gas recirculation, waste gas denitrification using regenerative activated carbon process or selective catalytic reduction. Regenerative activated carbon and selective catalytic reduction are options for reducing NO_X emissions, but have not yet been applied in the UN-ECE region on full scale due to their high costs (currently SCR is tested in pilot plant scale at one European steel plant). [1]
For **pelletization plants** it is considered BAT to optimise plant design for recovery of sensible heat and low-NO_x emissions from all firing sections (induration strand, where applicable and drying at the grinding mills). [1] For one pelletization plant, NO_X emissions of 175 g/tonne pellet are achieved using process-integrated measures only, namely by a combination of low energy use, low nitrogen content in the fuel (coal and oil) and limiting the oxygen excess. [5]. [6]

The application of modern burners may reduce NOx emissions of to **blast furnace cowpers.**

Table 2: NO_X emission levels associated with BAT for iron and steel production

Emission Source	BAT associated emission levels[1] mg/Nm^3 or (kg/tonne)	Comments
Blast furnace (hot stoves) [1]	20-120	Related to an oxygen content of 3% In the German IPPC implementation report from 2006 a range of 20-120 mg/m^3 is reported as 5% and 95% percentiles based on half-hourly average values from continuous measurements.
Sinter plants[1] [6]	300-400 100-120[2]	Normal operation conditions SCR[3]
[1] The BAT associated emission levels may be expected to be achieved over a substantial period of time at standard conditions and represents a typical load situation. For peak load, start up and shut down periods, as well as for operational problems of the flue gas cleaning systems, short-term peak values, which could be higher, have to be regarded. [2] The emission level is based on data from Japan and Taiwan [3] Due to the high cost, waste gas denitrification is not applied except in circumstances where environmental quality standards are not likely to be met.		

7.7.3.3 Dust

Fabric filters should be used whenever possible; reducing the dust content to less than 20 mg/m^3 (hourly average). If conditions make this impossible (due to their tendency to blind and their sensitivity to fire), advanced ESPs and/or high-efficiency scrubbers may be used, reducing the dust content to 50 mg/m^3. Many applications of fabric filters can achieve much lower values. [4] [7]

Sinter plants may generate the most significant quantity of dust emissions in integrated steel mills, they arise primarily from material handling and from the agglomeration reaction on the strand.
Dust (together with PCDD/F) is furthermore the most important pollutant in sinter plants and waste gas de-dusting is considered BAT, for example by application of advanced electrostatic precipitation (moving electrode ESP, ESP pulse system, high voltage operation of ESP) or electrostatic precipitation plus fabric filter or pre-dedusting (e.g., ESP or cyclone) plus high pressure wet scrubbing system. The presence of fine dust, which mainly contains alkali and lead chlorides may limit the efficiency of ESPs.
BAT also includes to use enclosure and/or hooding, where appropriate, with emission controls, of the sinter strand operations that are potential sources of fugitive emissions, as well as to apply operating practices that minimize fugitive emissions that are not amenable to enclosure or hooding. For reducing dust emissions from material handling operations indoor or covered stockpiles, when possible, as well as a simple and linear layout for material handling should be used. Enclosed conveyer transfer points and enclosed silos to store bulk powder can further reduce emissions from bulk powder materials (fugitive emissions of coal dust are a major concern here). [1] [4] [9]

For information for **pelletization plants** see above (section SO_2).

For **blast furnace** gas treatment, an efficient de-dusting is considered BAT using dry separation techniques (e.g. deflector) for removing and reusing coarse particulate matter. Subsequently fine particulate matter is removed by means of a scrubber or a wet electrostatic precipitator or any other technique achieving the same removal efficiency. For cast house de-dusting, emissions should be minimized by covering the runners and evacuation of the emission sources (tap-holes, runners, skimmers, torpedo ladle charging points) and purification by means of fabric filtration or electrostatic precipitation. [1]

For **basic oxygen steelmaking and casting** including hot metal pre-treatment, secondary metallurgical treatment and continuous casting (including hot metal transfer processes, desulphurization and deslagging), BAT is considered to use particulate matter abatement by means of efficient evacuation and subsequent purification by means of fabric filtration or electrostatic precipitation. For basic oxygen steelmaking and casting, the use of a whirl hood for secondary dedusting aims at reducing dust emissions.
Basic oxygen furnace gas recovery and primary de-dusting is considered BAT applying suppressed combustion and dry electrostatic precipitation (in new and existing installations) or scrubbing (in existing installations). Secondary de-dusting is considered BAT applying efficient evacuation during charging and tapping with subsequent purification by means of fabric filtration or ESP or any other technique with the same removal efficiency. Efficient evacuation should also be applied during hot metal handling, deslagging of hot metal and secondary metallurgy with subsequent purification by means of fabric filtration or any other technique with the same removal efficiency. [1]

For **electric steelmaking and casting**, BAT is considered to achieve dust collection efficiencies with a combination of direct off gas extraction (4th or 2nd hole) and hood systems or dog-house and hood systems or total building evacuation of 98% (primary and secondary emissions). Waste gas de-dusting is considered BAT using well designed fabric filters achieving 5 mg dust/Nm^3 for new plants and 15 mg dust/Nm^3 for existing ones, both determined as daily mean values. [1]

Table 3: Dust emission levels associated with BAT for iron and steel production

[Comment: [9] recommends maximum dust emission levels of 50 mg/Nm³ for all operations in integrated steel mills, 20 mg/Nm³ when toxic metals are present]

Emission Source	BAT associated emission levels[1] mg/Nm3 or (kg/tonne)	Comments
Sinter Plants	< 50 [1] 10-20 [1] (0.04-0.12) [4]	Existing sinter plants equipped with advanced ESPs Application of fabric filters
Pelletization plants	10 [1] (0.04) [4]	Using a system with removal efficiency >95%
Blast furnaces: Hot stoves Blast furnaces: fugitive emissions (fully captured)	< 10 [1] (0.035-0.05) [4] (0.005-0.015) [1]	Related to an oxygen content of 3% Kg/tonne pig iron US EPA 1998 [8] reports the following shares of PM_1 in dust: Casthouse (older type): 15%; Furnace with local evacuation: 9%; Hot metal desulphurization: 2%
Basic oxygen steelmaking and casting	5-15 [1] 20-30 [1] (0.035-0.07) [4]	Fabric filters ESP US EPA 1998 [8] reports the following shares of PM_1 in dust: Charging (at source) 12%;Tapping (at source) 11%
Electric steelmaking and casting	< 5[2] [1]; (0.06)[3] [4] < 15[2] [1]; (0.12)[3] [4]	For new plants For existing plants US EPA 1998 [8] reports the following shares of PM_1 in dust for EAF: Melting and refining (carbon steel, uncontrolled): 23%

[1] The BAT associated emission levels may be expected to be achieved over a substantial period of time at standard conditions and represents a typical load situation. For peak load, start up and shut down periods, as well as for operational problems of the flue gas cleaning systems, short-term peak values, which could be higher, have to be regarded.
[2] For this value: daily mean
[3] Recommended performance indicator

In the Iron & Steel Industry BREF document, there is to emphasize that only the air emissions at EAF and the water data at Blast Furnace are expressed as daily averages when all other BAT AELs have been expressed under normal operation conditions (e.g. excluding start up and shut down periods) and design, and averaged on a substantial period of time (there is not yet any consensus reached about this definition)

7.7.3.4 VOC

Volatile organic compounds and polycyclic aromatic hydrocarbons (PAH) may be emitted from various stages in iron and steel production. These include off gases in the pelletization and sintering processes due to ~~oil~~ carbon compounds contained in the solid fuels of sinter or pelletization feed, for example from the addition of mill scale. [9]
As this sector is not considered a major emitter of VOC, no further information is given on emission levels associated with BAT.

7.7.3.5 Cross Media Effects

For all mentioned emission reduction and abatement techniques, the cross-media transfer of pollutants and the full range of environmental effects and improvements should be considered. For example additional energy consumption and increased quantities of waste or wastewater residuals may result from individual efforts for pollutant prevention, reduction, or removal.
Especially de-dusting using ESP or FF leads to an additional solid waste flow, which can be recycled into the process for some cases. If the bags in FF are precoated by injecting slaked lime, significant abatement of some acidic components (HCl, HF) can also be achieved. In combination with an injection of lignite coke or activated carbon, FF also help to reduce PCDD/PCDF emissions significantly (to below 0.1 to 0.5 ng/m3). The minimisation of dust emissions correlates with the minimisation of heavy metal emissions except for heavy metals in the gas phase like mercury. [1] [2]

7.7.4 Emerging techniques

Direct reduction and direct smelting are under development (cf. section description of production technologies) and may reduce the need for sinter plants and blast furnaces in the future.
The use of new reagents in the hot metal desulfurization process might lead to a decrease in dust emissions and a different (more useful) composition of the generated dust. The technique is under development. Several foaming techniques at pig iron pre-treatment and steel refining are already available, absorbing the dust arising from the hot metal processing. [4]
For electric arc furnaces, intermetallic bag filters combine filtering and catalytic operations and allow to reduce dust and associated pollutant emissions. [2] Additionally, a number of new furnace types have been introduced, that might be realized at industrial scale, and that show advantages with regard to heavy metals and dust emissions, e.g.:
Comelt EAF (integrated shaft scrap preheating and a complete off gas collection in each operating phase)
Contiarc furnace (waste gas and dust volumes are considerably reduced, and the gas-tight furnace enclosure captures all primary and nearly all secondary emissions)

7.7.5 Cost data for emission reductions

Source: previous of the guideline document

Characteristics of reference installation	**Control options**	**Investments[a/] [EURO]**	**Operating costs[b/] [EURO/year]**	**Abated mass flow [Mg NO_x/year]**
Iron and steel production: sinter plant				
Travelling grate sinter machine; Fuel: coke breeze; Production output: 12,000 Mg sinter/day; Operating time: 8,400 h/year	Flue gas recirculation	5,000,000	- 200,000 [e/]	2,000
	SCR	50,000,000	5,300,000	3,200

[Comment: UNECE 2006 states "Total costs of implementing FFs for one representative sinter plant are 3000 to 16000 Euro p.a."]

7.7.6 References used in chapter 7.7

[1] European Commission. 2001: "Integrated Pollution Prevention and Control (IPPC) Best Available Techniques Reference Document on the Production of Iron and Steel." http://eippcb.jrc.es/pages/FActivities.htm

[2] European Commission. 2008 Draft: "Integrated Pollution Prevention and Control (IPPC) Best Available Techniques Reference Document on the Production of Iron and Steel." http://eippcb.jrc.es/pages/FActivities.htm

[3] IIASA 2004: International Institute for Applied Systems Analysis. Interim Report IR-04-079 "Primary Emissions of Submicron and Carbonaceous Particles in Europe and the Potential for their Control".

[4] Kraus, K., S. Wenzel, G. Howland, U. Kutschera, S. Hlawiczka, A. P. Weem and C. French (2006): Assessment of technological developments: Best available techniques (BAT) and limit values. Submitted to the Task Force on Heavy Metals, UNECE Convention on Long-range Transboundary Air Pollution.

[5] The nordic council of ministers 2005: "BAT examples from the Nordic iron and steel industry" http://www.norden.org/pub/miljo/miljo/uk/TN2006509.pdf

[6] UNECE 1999. "Draft guidance documents on control techniques and economic instruments to the protocol to abate acidification, eutrophication and ground level ozone".

[7] IFC 2007. International Finance Corporation (World Bank Group): "Environmental, Health, and Safety Guidelines for Base Metal Smelting and Refining"

[8] US EPA 1998: "Compilation of air pollutant emission factors", 5th edition: EPA AP-42. United States Environmental Protection Agency.

[9] IFC 2007. International Finance Corporation (World Bank Group): "Environmental, Health, and Safety Guidelines for Integrated Steel Mills"