Category		Title
NFR	2.C.1	Iron and steel production
SNAP	0402	Processes in iron and steel industries and collieries
	040202	Blast furnace charging
	040203	Pig iron tapping
	040205	Open hearth furnace steel plant
	040206	Basic oxygen furnace steel plant
	040207	Electric furnace steel plant
	040208	Rolling mills
	040209	Sinter and pelletizing plants (except combustion)
	040210	Other
ISIC	2710	Manufacture of basic iron and steel
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Contents

1 Overview

The iron and steel industry is a highly material and energy-intensive industry. More than half of the mass input becomes outputs in the form of off-gases and solid wastes or by-products. The emissions from sinter plants dominate the overall emissions for most of the pollutants. The contribution of this sector to the total emissions to air in the EU is considerable for a number of pollutants, especially for some heavy metals and polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/F).

The iron and steel industry broadly consists of:

- primary facilities that produce both iron and steel;
- secondary steel making facilities;
- iron production facilities;
- offsite production of metallurgical coke.

Part of the processes in iron and steel production are combustion (mainly during sintering). The emissions from sintering process originating from combustion are addressed in chapter 1.A.2.a. Emissions from metallurgical coke production are not addressed in the present chapter but rather in chapter 1.B.1.b.

2 Description of sources

2.1 Process description

Figure 2.1 illustrates the main processes for iron and steel production: metallurgical coke production, sinter production, pellet production, iron ore processing, iron making, steel making, steel casting and very often combustion of blast furnace and coke oven gases for other purposes.

The main processes may occur at what is referred to as an 'integrated' facility and typically include blast furnaces, and basic oxygen steel making furnaces (BOFs), or in some cases open hearth furnaces (OHFs). It is also common for parts of the production to be offsite under the responsibility of another operator such as an offsite coke production facility.

Figure 2.1   Illustration of the main processes in the iron and steel industry; at the far left are the inputs for the integrated process, the far right displays the outputs. The figure is adapted from IPCC (2006) (COG = coke oven gas).
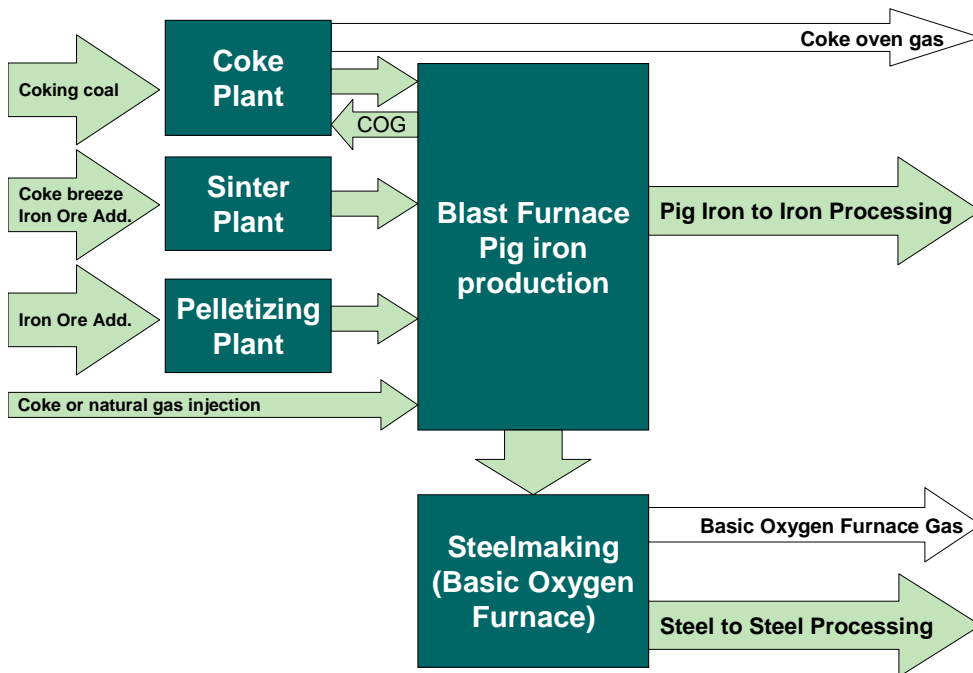
In some countries, there are coke production facilities that are not linked to iron and steel production (i.e., 'offsite'). The present chapter provides guidance for estimating emissions of air pollutants from all coke production to ensure consistency and completeness. It is good practice for countries to estimate emissions from onsite and offsite coke production separately under higher tiers as the by-products of onsite coke production (i.e. coke oven gas, coke breeze etc.) are often used during the production of iron and steel.

Primary and secondary steel making

Steel production can occur at integrated facilities from iron ore, or at secondary facilities, which produce steel mainly from recycled steel scrap. Integrated facilities typically include blast furnaces, and basic oxygen steel making furnaces (BOFs), or in some cases open hearth furnaces (OHFs). Raw steel is produced using a basic oxygen furnace from pig iron produced by the blast furnace and then processed into finished steel products. Pig iron may also be processed directly into iron products. Secondary steel making most often occurs in electric arc furnaces (EAFs). In 2003, BOFs accounted for approximately 63 % of world steel production and EAFs approximately accounted for 33 %; OHF production accounted for the remaining 4 % but is today declining.

Iron production

Iron production can occur onsite at integrated facilities or at separate offsite facilities as discussed above under 'Primary and secondary steel making'. In addition to iron production using a blast furnace, iron can be produced through a direct reduction process. Direct reduction involves the reduction of iron ore to metallic iron in the solid state at process temperatures less than 1000 °C.

Metallurgical coke production

Metallurgical coke production is considered to be an energy use of fossil fuel and as a result it is good practice to report emissions from this activity under source category 1.B.1.b (within the Energy sector). The methodologies are presented here, however, because the activity data used to estimate emissions from energy and non-energy in integrated iron and steel production have significant overlap. All fuel consumed in the present source category not allocated as inputs to the coke oven, sinter plants, pelletisation plants and blast furnace are regarded as fuel combustion, which is dealt with and reported in the Energy sector (1.A).

2.1.1   Metallurgical coke production

Metallurgical coke is primarily used in the blast furnace to make iron. Coke is also used in other metallurgical processes, such as the manufacture of cast iron, ferroalloys, lead and zinc, and in kilns to make lime and magnesium. Metallurgical coke is the solid product obtained from the carbonisation of coal, principally coking coal, at high temperature. It is low in moisture content and volatile matter. Coking coal refers to bituminous coal with a quality that allows the production of a coke suitable to support a blast furnace charge. Its gross calorific value is greater than 23 865 kJ/kg (5 700 kcal/kg) on an ash-free but moist basis. Coke oven gas is a by-product of the manufacture of metallurgical coke for the production of iron and steel. Figure 2.2 illustrates the coke production process.

Figure 2.2   Process scheme of the coke production process. It is good practice to report emissions from the coke oven process in source category 1.B.1.b.
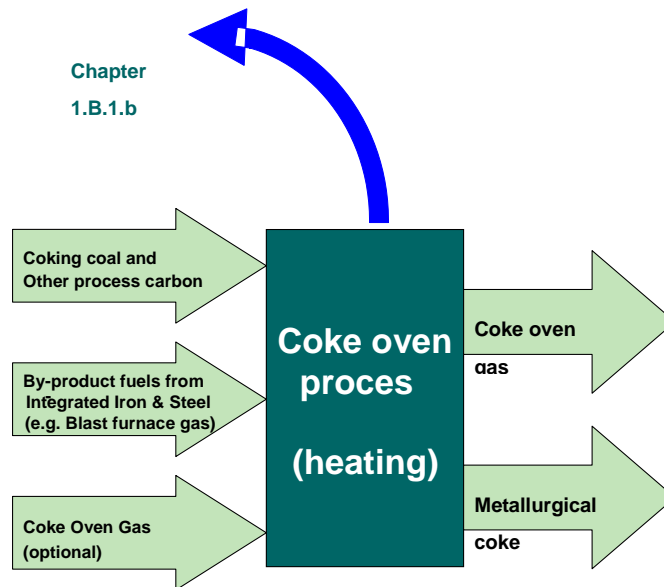

Note that coke oven gas may be burned for energy recovery within the coke plant or may be transferred onsite in an integrated iron and steel plant and used for in sinter production or iron production processes. Coke oven gas may also be transferred off site (e.g., into the natural gas distribution system) and used as an energy source. The combustion of coke in blast furnaces during the iron and steel-making process produces blast furnace gas which may then be recovered and transferred from the iron and steel mill to the onsite coke plant and burned within the coke ovens or used in sinter production.

2.1.2   Sinter and pellet production

This subsection only addresses travelling grate sintering, which is by far the most important technique for iron ore sintering. The discontinuous pan sintering process and the rotary kiln process are now used at very few plants and are not discussed here. In addition, other agglomeration processes like pelletisation, briquetting and nodulisation are not considered here.

Iron ore and other iron-containing materials may be agglomerated in sinter plants at integrated iron and steel plants prior to introduction into the blast furnace. Feedstock to sinter plants may include fine iron ores, additives (e.g., lime or olivine), and iron-bearing recycled materials from downstream iron and steel making processes (e.g., dust from blast furnace gas cleaning). Coke breeze (small-grade oven coke with particle sizes of <5 mm) is the most commonly used process material in sinter plants. The coke breeze may be produced from the onsite coke ovens in integrated iron and steel plants or may be purchased from offsite coke producers. Blast furnace gas or coke oven gas produced onsite during integrated iron and steel production may be used in sinter plants. Operation of sinter plants produces emissions of air pollutants like nitrogen oxides (NO_x), sulphur oxides (SO_x) and non-methane volatile organic compounds (NMVOCs) from the combustion activities. Off gas from sinter production also contains NMVOCs. Figure 2.3 illustrates the sinter production process.

Figure 2.3 **Process scheme of the sinter production process. The red arrow represents combustion emissions (see source category 1.A.2.b); the blue arrow represents process emissions (reported in this source category).**
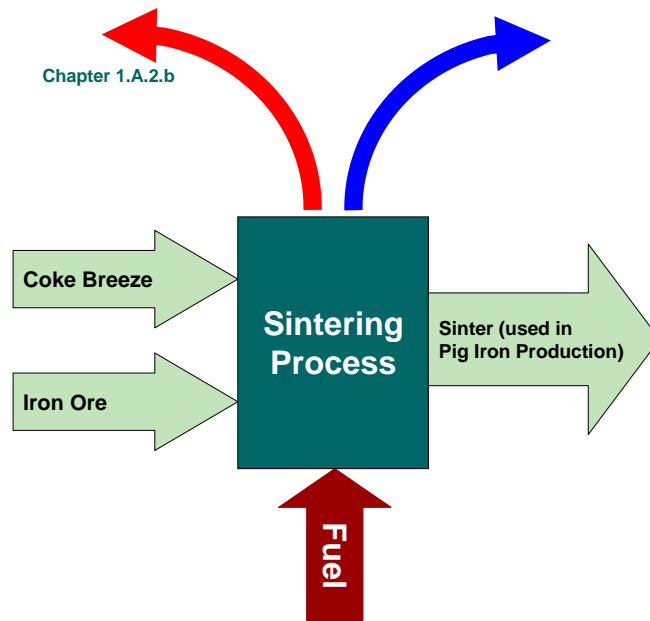

Pellets are formed from iron-containing raw materials (i.e., fine ore and additives) into 9–16 mm spheres in a very high temperature process. The process includes grinding, drying, balling, and thermal treatment of the raw materials. Pelletisation plants are principally located at iron mines or at shipping ports but can also be located onsite as part of an integrated iron and steel facility. Natural gas or coal may be used as fuel for pelletisation plants; for pelletisation plants located onsite at an integrated iron and steel facility, coke oven gas may be used as a fuel. Energy consumption for the process and the associated emissions will depend in part on the quality of the iron ore and other raw materials used in the process, and also upon the heating values of fuels used.

2.1.3 Iron making

The production of iron, more specifically the use of carbon to convert iron ore to iron is a major source of carbon monoxide (CO), carbon dioxide (CO_2) and NMVOCs. Figure 2.4 describes the iron-making process and associated sources of emissions. Carbon is supplied to the blast furnace mainly in the form of coke produced from metallurgical grade coking coal (but can also be in the form of charcoal made from wood or other forms of carbon.). Carbon serves a dual purpose in the iron making process, primarily as a reducing agent to convert iron oxides to iron but also as an energy source to provide heat when carbon and oxygen react exothermically. Blast furnace gas is produced during the combustion of coke in blast furnaces. It is typically recovered and used as a fuel partly within the plant and partly in other steel industry processes or in power stations equipped to burn it. Blast furnace gas may also be recovered and transferred from the iron and steel mill to the onsite coke plant and burned for energy within the coke ovens. Blast furnace gas may also be transferred offsite and used as an energy source both within the furnace and when blast furnace gas is combusted to heat blast air. Oxygen steel furnace gas is obtained as a by-product of the production of steel in a basic oxygen furnace (BOF) and is recovered on leaving the furnace. All carbon used in blast furnaces should be considered process-related industrial process and produce use (IPPU) emissions.

Figure 2.4   **Scheme of the iron making process. The red arrow represents combustion emissions (reported in source category 1.A.2.b); the blue arrow represents process emissions (reported in the present source category).**
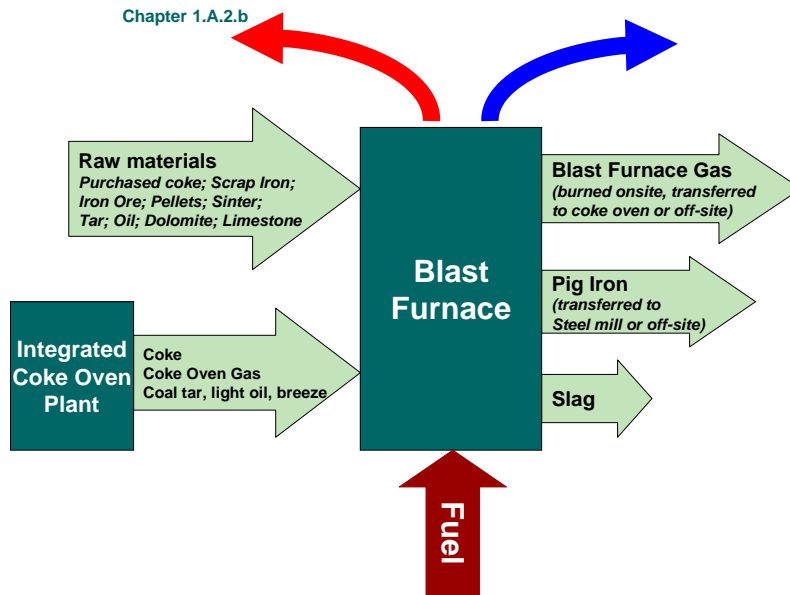
Additionally, iron can be produced through a direct reduction process. Direct reduction involves the reduction of iron ore to metallic iron in the solid state at process temperatures less than 1000 °C. A solid product referred to as direct reduced iron (DRI) is produced by the direct reduction process. DRI has a carbon content of <2 %. DRI is normally used as a replacement for scrap metal in the electric arc furnace steel making route but may also be used as a feedstock for blast furnace iron making. DRI may also be melted into briquettes, referred to as hot briquetted iron (HBI), when the product has to be stored or transported.

2.1.4   Steel making

Steel production can occur at integrated facilities from iron ore, or at secondary facilities, which produce steel mainly from recycled steel scrap. Integrated facilities typically include blast furnaces and basic oxygen steel making furnaces (BOFs), or in some cases open hearth furnaces (OHFs). Raw steel is produced using a basic oxygen furnace from pig iron produced by the blast furnace and then processed into finished steel products. Pig iron may also be processed directly into iron products. Secondary steel making most often occurs in electric arc furnaces (EAFs). In 2003, BOFs accounted for approximately 63 % of world steel production and EAFs approximately accounted for 33 %; OHF production accounted for the remaining 4 % but is today declining.

Steel production in a BOF begins by charging the vessel with 70–90 % molten iron and 10–30 % steel scrap. High purity oxygen then combines with the carbon in the iron to create an exothermic reaction that melts the charge while lowering the carbon content. Iron from the blast furnace usually contains 3–4 % carbon, which must be reduced to less than 1 %, refined and alloyed to produce the desired grade of steel.

Steel production in an EAF typically occurs by charging 100 % recycled steel scrap, which is melted using electrical energy imparted to the charge through carbon electrodes and then refined and

alloyed to produce the desired grade of steel. Although EAFs may be located in integrated plants, typically they are stand-alone operations because of their fundamental reliance on scrap and not iron as a raw material. Since the EAF process is mainly one of melting scrap and not reducing oxides, carbon's role is not as dominant as it is in the blast furnace/BOF process. It is good practice to consider all carbon used in EAFs and other steel making processes as process-related IPPU emissions. A simple scheme of the steel making process is given in Figure 2.5, showing the inputs, outputs and associated emissions with the steel making process.

Figure 2.5   General process scheme for steel making, applicable to the three types of furnaces. Emissions are reported in the present source category.
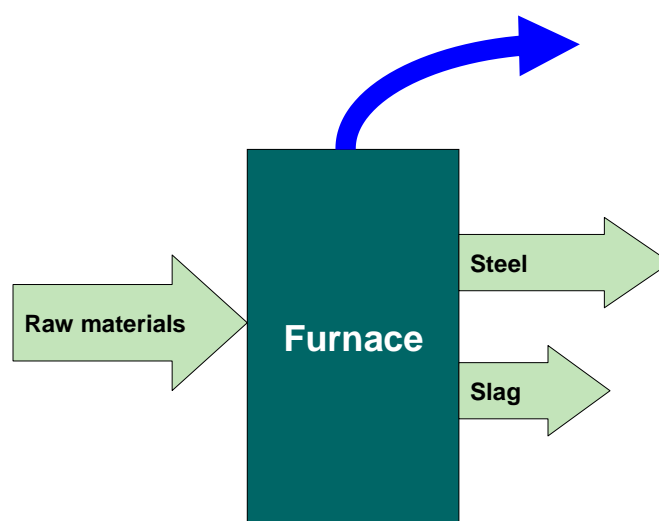
After the steel making process, casting products (ingots, slabs, billets or blooms) are subsequently processed in rolling mills and product finishing lines in order to prepare them for market.

2.2   Techniques

2.2.1   Coke plant

The process of making coke can be divided into several steps (European Commission, 2001; 2012):

- Coal handling, consisting of:
  - o   discharge of coal from ships or trains onto a transportation system or for storage, during which wind may cause coal dust emissions;
  - o   coal storage in large coal stocking areas, where wind may cause coal dust emissions;
  - o   coal transport by conveyor, transfer points outside buildings and road transportation;
  - o   coal preparation: bed blending, bunker blending and crushing, leading to dust emissions;
  - o   charging of the coal tower with possible dust emissions;
  - o   charging of the charging car with possible dust emissions.
- Coke oven battery operations, which dominate the emissions from a coke oven plant. This process consists of various elements, as follows.

- o Coal charging, where pulverised coal (mainly coking coal) is charged through the charging holes. The flow of coal must be kept under control; the aim is to achieve charging with reduced emissions ("smokeless charging").
- o Heating and firing of the chambers. Heating flues with nozzles for fuel supply are used to fuel the individual coke oven chambers. This process generally uses clean coke oven gas as a fuel but blast furnace gas can be used as well. To improve the process efficiency, regenerators exchange heat from flue gases with combustion air or blast furnace gas. If the heating walls are not completely gas tight, coke oven gas will reach flue gas and be emitted via the stack.
- o Coking. This carbonisation process starts right after the coal charging. The process takes around 14–24 hours to complete. Emissions may occur through holes, wall cracks and via heating gases. Crude coke oven gas (COG) is released as a by-product in this process.
- o Coke pushing and quenching. After the coke is fully carbonised, it is pushed out of the oven and quenched. Generally a quenching car is used to transport the hot coke to a quenching tower.
- o Coke handling and screening. After quenching, the coke is stored in stock piles from which it is transported. Finally, the coke is crushed and screened. Smaller coke (<20 mm) is mainly used for the sinter process (described in subsection 2.1.2 of the present chapter); the larger fraction (20–70 mm) is used in the blast furnace (described in subsection 2.1.4).
- Collection and treatment of coke oven gas. COG is treated before being used as a fuel, because the raw gas contains valuable products. The treatment process consists of five steps:
- o cooling of the crude oven gas by a primary cooler and an electrostatic precipitator, causing part of the COG and present water vapour to condense;
- o tar recovery from the condensate by a tar/water separator;
- o desulphurisation of the coke oven gas, using either wet oxidation or absorption and stripping of H2S;
- o recovery of ammonia from the coke oven gas as well as the condensate;
- o recovery of light oil (mainly benzene, toluene and xylene) from coke oven gas.
- Coke oven water flows are generated during the coking process and coke oven gas cleaning. Water vapour originates from various sources: coal moisture, chemical water formed during the coking process and steam or ammonia liquor. Most of the water vapour is condensed by the primary cooler and electrostatic precipitator. Water from the tar/water separator contains high concentrations of ammonia and is lead to the ammonia liquor storage tank. The NH_3 concentration is decreased before discharging the water to a wastewater treatment, because the recovered NH_3 is valuable as an energy source and its potential damage to ecosystems.

2.2.2 Sinter and pelletising production

The sintering process is used for several primary metal production processes, each having a different design. During sintering, fine-grained, smeltable ores, in particular iron ore, are agglomerated into compact lumps by heating nearly to the melting or softening point. Melting tends to occur at the grain boundaries leading to a caking of the material.

Before the sintering, the various substances are first mixed and, if desired, granulated. The iron ores are agglomerated on conveyor sinter installations, the conveyor belts consist of a large number of wagons. These wagons that have been linked up as an endless conveyor belt which can be as big as 4 m in width and 100 m in length. The fine ore to be sintered is moistened and fed on to the circulating grid together with coke breeze and additives such as limestone, quick lime, olivine or dolomite. Burners above a heat-resistant grate belt heat the material to the required temperature

(1100–1200 °C). This causes the fuel in the mixture to be ignited. The combustion then is self supporting and provides sufficient heat, 1300–1480 °C, to cause surface melting and agglomeration of the mix. The carbon burns with the aid of the air sucked through the grid into the mixture, resulting in the flame front being moved through the sintering bed. On the underside of the sinter strand a series of windboxes is situated that draw combusted air down through the material bed into a common duct, leading to gas cleaning devices (US EPA, 1994). The sintering processes are completed once the flame front has passed through the entire mixed layer and all fuel has been burnt.

The fused sinter is discarded at the end of the sinter strand, where it is crushed and screened. Undersize sinter is recycled to the mixing mill and goes back to the strand. The remaining sinter product is cooled in open air or in a circular cooler with water sprays or mechanical fans. The cooled sinter is crushed and screened for a final time, then the fines are recycled, and the product is sent to the blast furnaces to be charged (US EPA, 1994).

The most common types of sinter coolers used include circular or straight line moving beds, quiescent beds, or shafts. Air or water is used as the cooling medium in these coolers, with air being prevalent in newer plants and water being dominant in older plants (Kelly, 1983; GCA Corporation, 1981).

Technical data which are typical for the plants operating in western Europe are listed in Table 2.1.

Table 2.1   Range of technical parameters of European sinter plants.

Parameter	Range	Ref.
width [m]	2.5–4.5	Bothe (1993)
area [m²]	50–400 (ᵃ)	Bothe (1993)
specific flue gas flows [m³/t sinter]	1800–2000	Rentz *et al*. (1997)
flue gas flows [million m³/h]	up to 1.5	Bothe (1993)
height of sinter layer	ca. 250–650 mm	Theobald (1995)
coke input [kg/tonne sinter]	38–55	

(ᵃ)   Some small installations are reported to be in operation in Poland, another one in Germany (sintering of iron containing return and filter materials).

The sinter plant plays a central role in an integrated iron and steel works for making use of production residues which would have to be disposed otherwise. Slags from steel production, filter dusts of diverse flue gas cleaning systems (including those applied to the sinter plant itself) and various iron-containing materials from residue treatment are recycled in the sinter plant. Recycling may lead to an enrichment of relevant compounds, particularly heavy metals. Some residue materials like roll mill scale may be contaminated with organic compounds (oils), being precursors for polycyclic aromatic hydrocarbons (PAH) and PCDD/F formation. An example of input material composition is shown in Table 2.2 below.

Table 2.2   **Example of input material to a sinter plant. The percentages relate to dry mixture.**

Material	Percentage (%)
Hematite	81.3
Magnetite	2.7
Returns	7.9
Pellet abrasions	2.2
Blast furnace dust	0.3
Steel work dust	0.6
Roll scale	1.3
Limestone	9.4
Olivine	3.5
Coke breeze	5

Chlorine compounds can enter into the sinter installation by means of the additive coke slack as well as by the ore from its natural chloride contents. Furthermore, returned materials such as certain filter particles, scale and sludges from waste water treatment, which are added to the materials to be sintered, can also increase the chlorine content of the substances used. This is reflected in the waste gases from sinter installations which contain inorganic gaseous chlorine compounds.

An alternative process is pelletisation, where no combustion is necessary.

By 2010 a new technology called 'converted blast furnace' or 'melting-reduction technology' is expected to be operational. For this process sintering, pelletisation and coke input will no longer be necessary (Annema *et al*., 1992).

2.2.3   Pig iron production by blast furnace

A blast furnace is a closed system into which iron bearing materials (iron ore lump, sinter and/ore pellets), additives (slag formers such as limestone) and reducing agents (coke) are continuously fed from the top of the furnace shaft through a charging system.

A hot air blast, enriched with oxygen coal powder, oil, natural gas and in a few cases plastics as a fuel, is injected on the tuyère level providing a counter-current of reducing gases. The air blast reacts with the reducing agents to produce mainly CO, which in turn reduces iron oxides to metal iron. The liquid iron is collected in the hearth along with the slag and both are cast on a regular basis. The liquid iron is transported in torpedo vessels to the steel plant and the slag is processed to produce aggregate, granulate or pellet for road construction and cement manufacture. The blast furnace gas is collected at the top of the furnace. It is treated and distributed around the works to be used as a fuel for heating or for electricity production.

The processed iron ore contains a large content of hematite (Fe_2O_3) and small amounts of magnetite (Fe_3O_4). In the blast furnace, these components are reduced, producing iron oxide (FeO). Finally, the iron charge melts and liquid hot metal and slag are collected. The reducing carbons react to form CO and CO_2.

As the blast furnace burden (mixture of iron bearing materials and additives) moves down, its temperature increases, thus facilitating oxide reduction reactions and slag formation. The burden undergoes a series of composition changes as this happens.

- The iron oxide in the burden becomes increasingly reduced (forming sponge iron and finally molten pig iron).
- The oxygen from the iron ore reacts with the coke or the carbon monoxide, thus forming carbon monoxide or carbon dioxide, which is collected at the top.
- The gangue components combine with the fluxes to form slag. This slag is a complex mix of silicates of a lower density than the molten iron.
- The coke primarily serves as a reducing agent but also as a fuel. Together with other fuels, it leaves the furnace as carbon monoxide, carbon dioxide or carbon in the pig iron.
- Any hydrogen present also acts as a reducing agent by reacting with oxygen to form water.

The main operations in the production of pig iron are as follows.

- Charging of raw materials. The burden (including iron bearing) and coke are charged into the top of the furnace. A scaled charging system isolates the gas from atmosphere, since the operating pressure of the blast furnace exceeds atmospheric pressure.
- Generation of hot blast. This is provided by hot stoves (blast furnace cowpers). A hot blast is needed to transfer heat to the solid burden in order to raise the temperature for the reaction and also helps to provide the oxygen for coke gasification and transport the gas that reduces iron oxides, on contact with the burden. The blast is heated by burning gases until 1100–1500 °C, after which cold ambient air is heated to form the hot blast, which is fed to the blast furnace. In each blast furnace, three or four hot stoves are necessary.
- Blast furnace. Raw materials enter at the top, while products are tapped at the bottom (hearth). Solid burden moves downwards, meeting a rising stream of reducing gases. Blast furnace gas is collected at the top of the furnace for treatment. The blast furnace can be divided into six temperature zones, including:
  - the top: charging of the burden and evacuation of blast furnace gas;
  - the shaft: heat transfer from the hot blast furnace gas to the solid burden;
  - the belly: further reduction of iron oxide, start of coke reaction;
  - the bosh: coke reactions continue, iron melts and shag is formed;
  - the tuyères: hot blast introduced in the furnace by up to 42 tuyères, located around the upper perimeter of the hearth and fed by a large pipe, circling the furnace at the height of the bosh (oxides are completely reduced at this stage);
  - the hearth: collecting of the molten pig iron and slag.
- Direct injection of reducing agents. Most modern installations inject reducing agents into the furnace at the tuyère level, replacing the coke in the top charge. This enables the operator to optimise the use of reducing agents. Other advantages are the increased output and a reduction in the coke-making requirements.
- Casting. The blast furnace is periodically cast to remove the molten pig iron and slag from the hearth. Pig iron and slag are mostly tapped together and subsequently separated at the skimmer in the cast house. The molten pig iron is then poured into ladles, while slag flows in runners to a granulation plant, slag ladles or an open pit.
- Slag processing. The slag can be put to a variety of processes, including material for road building, concrete aggregate, thermal insulation and as a cement replacement. Three processes are currently in operation to treat blast furnace slag.

- o Slag granulation process. The molten slag is poured through a high-pressure water spray in a granulation head. After granulation, the slag/water slurry is transported to a drainage system, a vertical filtering hopper or a rotating de-watering drum.
- o Slag pit process. This process involves pouring thin layers of molten slag directly into slag pits adjacent to the furnaces. The pits are alternately filled and excavated, and lump slag is broken up and crushed for use as coarse aggregate. Lump slag is a desirable raw material for road construction.
- o Slag pelletising process. The molten slag is spread in a layer on a plate, acting as a deflector. The sheet of slag is sheared by controlled water jets, which initiate the swelling and cooling of the slag. The slag is then projected centrifugally into the air on a rotating drum to complete the blowing-up and cooling.

The blast furnace process is the most energy-consuming process unit in iron and steel production. The gross total energy input is 18.67 GJ/Mg pig iron. Top gas pressure recovery can be used for electricity generation, this will generate up to 5.5 GJ/Mg pig iron (European Commission, 2001).

2.2.4   Steel making

Open hearth furnace steel plant

This process covers the production of steel in an air furnace fired with gas or fuel oil. The basic metallic charge consists of pig iron and scrap. Ferroalloys, deoxidizers and ore are also used as charge.

Slag generation depends on limestone, lime, fluorite and bauxite used in the process. The composition of charge and the properties of added compounds influence the steel quality as well as the quality and quantity of air pollutants generated in the process. Fuel gas and air necessary in the process are heated up in the regenerator to a temperature of 1100 °C and then led to the working space of furnace, after which combustion the furnace gases reach a temperature of 1 700–1 800 °C and heat the charge in the oxidising atmosphere.

Basic oxygen furnace plant

Carbon accounts for 4–4.5 % of the weight of pig iron. In its solid state pig iron is hard and brittle, and rolling or forging is impossible. This can only be done by lowering the carbon content to 1 % or (in many cases) even lower (European Commission, 2001). This is the steel production process.

The first step in the conversion of iron steel is the removal of carbon. This is feasible thanks to the strong attraction between carbon and oxygen. In the blast furnace process, the carbon released from the coke breaks the iron/oxygen bond in the ore by binding itself to CO and CO_2. In the steel making process, the opposite occurs, the oxygen causing the carbon to leave the iron. It disappears from the converter in the form of carbon monoxide gas.

The oxygen-blown steel making process takes place in a pear-shaped vessel called a converter. This has a refractory lining and is mounted in such a manner that it can be tilted. Inside iron is turned into steel by blowing almost pure oxygen on to the surface of the molten metal, causing undesirable substances to be combusted. The refining process can be enhanced, where necessary, by 'bottom stirring' with argon gas by porous bricks in the bottom lining in certain phases of the process. This produces a more intensive circulation of the molten steel and an improved reaction between the gas and the molten metal. The oxidation (combustion) of the various elements which escape from the bath is accompanied by the release of a great deal of heat. In many cases steel scrap is added at a

rate of 10–20 % to cool the metal. The gas, which is rich in carbon monoxide, is removed and used as a fuel.

A complete cycle consists of the following phases: charging scrap and molten iron, blowing, sampling and temperature recording, and tapping. In a modern steelwork, 300 tonnes of steel are produced in a 30 minute cycle.

At the end of the refining process the ladle filled with molten steel is conveyed to the continuous casting machine. Continuous casting, in which billets or slabs are cast direct from molten metal, replaces the traditional method of pouring molten steel into moulds to produce ingots which, when solidified, are reheated and rolled into slabs or billets. Continuous casting not only saves time and energy, but also improves the quality of the steel and increases the yield.

Electric furnace steel plant

In an electric arc furnace non-alloyed and low-alloyed steel is produced from polluted scrap. The scrap is mainly produced by shredding cars and does not have a constant quality. Through carbon electrodes electricity is added to the scrap in the furnace, thus raising the temperature to 1700 °C. Lime, anthracite and pig-iron are then added. Depending on the desired quality of the steel, chromium, manganese, molybdenum or vanadium compounds can be added. A batch process is used. Each cycle consists of the same steps: charging of scrap, preheating, refining with addition of other material and tapping.

Emissions are produced during each step of a cycle. Several abatement techniques are used to reduce the dust emissions. The interior of the furnace is covered with fire-resistant coating.

Rolling mills

Long products such as sections and concrete reinforcing rods can be produced by hot rolling steel ingots. The huge reduction in thickness is accompanied by changes in structure and recrystallization, leading to a material with a very fine crystal structure. This is necessary for strength and deformability. This procedure is part of the traditional method of pouring molten steel into moulds to produce ingots which, when solidified, are reheated into slabs or billets, often using coke oven gas as the reheating agent. This method has in many cases been replaced by continuous casting.

However, it is impossible to achieve these large degrees of re-rolling with continuously cast billets and this applies also to the continuously cast strip. This problem can be solved by mounting conductive coils round the casting apertures. The electromagnetic stirring of the still molten core of the billet produces a very fine, homogeneous structure without segregation. This makes it possible to accept a lower degree of rolling without loss of quality.

The continuous cast slabs are transported to the hot strip mill without waiting for them to cool and rolled immediately. The hot rolling of steel slabs has long been used as a 'flattering process'. This term does not, however, apply to modern hot strip mills. By a subtle combination of chemical composition, reheating, deformation rate, speed of cooling after hot rolling and strip temperature during coiling, a variety of steel grades can be produced, ranging from high strength steel alloys to ultra-low carbon, super-deformable steel. In principle, it is even feasible to carry out heat treatment during hot rolling. This is achieved by cooling the strip rapidly to 200–300 °C after the last stage of deformation, producing a dual phase microstructure which ensures a unique combination of high strength and high deformability.

The hot slabs are prepared for rolling by heating in walking-beam furnaces to rolling temperature (about 1200 °C). The roughing mill train consists of five stands placed in tandem, where the slabs are rolled to achieve both the desired width and thickness. In a seven stands finishing train, the product takes on the desired dimensions and shape and flatness of the strip are largely determined. As it passes over the run-out table, the strip is cooled to the desired temperature using water, after which it is coiled.

There are limits to the purposes for which thin sheet produced from hot rolling mills can be used. Besides the fact that the requirements in terms of surface quality cannot be met by hot rolling material, however carefully it is rolled, the thickness can be a physical problem. Therefore much of the hot-rolled strip is destined for further reduction of the thickness in cold rolling reduction mills.

As a first step it is put through the pickling line to remove the mill-scale. Immediately after pickling the necessary lubricant is applied by electrostatic machines. After cold reduction, which greatly improves the strength of the material, it is annealed to restore the desired deformability. This process is now largely carried out in continuous furnaces but batch annealing is also used. Gradual heating and cooling results in recrystallization of the steel, restoring its deforming properties. During this process, which takes several days, nitrogen or hydrogen is passed through the furnace to prevent oxidation of the steel.

After annealing, the material is passed through the tempering mill and coiled for further processing.

2.3 Emissions

2.3.1 Sinter Plants

Of the eight CORINAIR standard gaseous compounds, all except ammonia are known to be emitted by sinter plants. The emissions described below are a result of the combustion and industrial processes.

- SO_2 emissions mostly originate from sulphur contained by the coke used as fuel. Actual emissions may be further dependent on the basicity of the mixture. With calcium oxide (CaO) dominated mixtures SO_2 production is decreased by increasing basicity. From magnesium oxide (MgO) dominated mixtures about 97 % of the sulphur content is converted to SO_2. The major fraction of the total SO_2 emission is generated in the hot part of the sinter belt (near the end) (Rentz *et al*., 1997).

- NO_x are mainly emitted as NO due to rapid down cooling of the flue gases. NO_x emissions originate from nitrogen contained in coke (c. 80 %) and iron ore (c. 20 %) (Rentz *et al.*, 1997).

- Raw materials contain heavy metals (HM). Dust emissions are generally associated with BC and HM emission. The EF for BC[1] relates to the emission of $PM_{2.5}$. During the sintering process some of the HM may be volatilised or converted into volatile compounds (e.g. chlorides) and can therefore be found in the flue gas. This mainly concerns zinc (Zn), lead (Pb), and cadmium (Cd). Arsenic (As) is emitted in gaseous form as As_2O_3, passing the dry gas cleaning facilities, which are usually operated at 120 °C. Since these volatile compounds form or adsorb fine particles, which are removed by the gas cleaning facilities, they may be accumulated during the sinter return cycle. Moreover, fine particles passing the filters may have a much higher content of these metals than the raw gas dust or the sinter mixture (Rentz *et al*., 1997).

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[1] For the purposes of this guidance, BC emission factors are assumed to equal those for elemental carbon (EC). For further information please refer to Chapter 1.A.1 Energy Industries.

- Polycyclic organic material (POM), e.g. PAH and PCDD/F, may be formed from chlorine and precursor compounds like oily additives. Potentially, POM emissions may be released from the sinter machine wind box, from the sinter machine discharge point and from sinter product processing operations (i.e. crushing, screening, and cooling). Because of the high temperatures used in sintering operations, it is probable that sinter plant POM emissions are in both gaseous and particulate matter forms (Kelly, 1983; Siebert *et al.*, 1978).

- Emissions of fluorides (sintering of ores recovered in Sweden) and hydrochloric acid (use of seawater moistening or coke treatment) have been observed (Bothe, 1993).

At a sinter plant, emissions may occur as ('direct') stack emissions and to a minor degree as fugitive ('indirect') emissions during all process steps mentioned above.

- Ambient air is sucked by several wind boxes through the mixture to support the combustion process on the sinter belt. After passage of the belt the flue gases are collected, de-dusted and released through the main stack.

- The main process steps (like coke crushing, raw material handling, belt charging and discharging, sintering) are usually done within encapsulated or semi-encapsulated housings. The housings may be equipped with suction hoods connected via flue gas cleaning devices to the main stack or to separate stacks. Thus, there may be more than one stack emission point at a given sinter plant.

- Fugitive dust emissions may arise during handling and transportation of the raw materials and of the cooled sinter as well as during maintenance and accidental interruptions of the cyclones or filters. More important, due to the strong thermal convection in the sinter hall, fugitive emissions through leakages in the roof are likely to occur particularly at the end of the sinter belt.

The European Blast Furnace Committee survey of the operational data for sinter plants (1996) reveals that sinter plants use 1125–1920 MJ/t sinter of thermal energy (solid fuels including flue dust and ignition fuel), with an average consumption of 1480 MJ/t sinter. These are 39.5–67 kg coke breeze equivalents/t sinter, with an average of 52 kg coke breeze equivalents/t sinter. Total electrical consumption is in the ranges 68–176 MJ/t sinter, with an average of 105 MJ/t sinter. There is only a slight difference in fuel consumption between low basicity sinter (< 1.7 CaO/SiO_2) and higher basicity sinter (≥ 1.7 CaO/SiO_2) (European Commission, 2001).

2.3.2 *Blast furnace for pig iron production*

The main emissions from the blast furnace charging are carbon monoxide, carbon dioxide, hydrogen and hydrogen sulphide. The charging of the smelters produces a certain amount of dust during a short period of time. For the Commonwealth of Independent States (CIS) countries, a dust content of 400 g/m^3 in the exhaust gas from the inter-cone space of the vapour lock is reported (Kakareka *et al.*, 1998). It is rather coarse dust, with a particle size bigger than 10 microns. Although the dust contains heavy metals from the ore and the coke, the dust itself is rather inert due to the extensive pre-treatment activities like pelletising and sintering. In addition emissions may arise from conveying operations.

Dust emissions also arise from the boring of the tap and the filling of the trough, mainly from the contact between the hot metal and slag and ambient oxygen. Also dust emissions occur after the skimmer but to a lesser extent than in the first part of the route. This dust contains BC and some heavy metals. The particle size of the dust during the boring is mainly below 10 microns, however, BC is often related to the emission of $PM_{2.5}$. The size of the particles from emissions from the roof is usually about 50 % bigger than 10 microns.

The heating of the transport trough after coating gives volatile decomposition products, which are also emitted by the heating of the plugging material. Decomposition products from tar are polycyclic aromatic hydrocarbons (PAH) and benzene containing aromatics. The exact benzene content is not available. In principle the same products are produced by the heating of coal. The amount of coal used is however so small that these emissions can be neglected.

2.3.3 Steel making furnaces

Open hearth furnace

The process emissions of the open hearth furnace consist of particulates and heavy metals. Also main pollutants such as NO_x, CO and SO_x are emitted but these are considered to originate mainly from the combustion activities and therefore addressed in chapter 1.A.2.a.

In an open hearth furnace, dust generation depends on three basic processes: combustion, mechanical impact of furnace atmosphere and charge, and the chemical processes. The flow of gases in the furnace working chamber results in entrainment of fine particles of charge in the initial process of heating and in the refining process. The chemical processes taking place in fluid metal actively increase dust generation in the furnace gases. Especially in the process of intensive refining, rising CO bubbles throw particles to the surface of the melt which are then entrained by furnace gases, thereby increasing the dust load. Introduction of ore materials into the furnace as well as of dolomite and limestone affects slag generation and results also in an increase in furnace gas dust generation. Moreover, a considerable increase of furnace gas dust generation is observed during oxygen application for intensification of combustion and refining processes.

The concentration of dust in furnace gas heating changes during the process. Moreover, the concentration in individual periods depends on a whole range of factors, of which the following are the most important:

- type of charge material;
- type of process used;
- technical condition of the furnace;
- type of fuel;
- application of oxygen during the melting and refining processes.

The amount and temperature of furnace gases depends also on many factors including: furnace capacity, type of fuel, type of roof lining, furnace construction (stationary or tilting), type of heads and technical condition of a furnace. The SO_2 content in furnace gas is relatively low, even in the case of using residual oil as a fuel.

Basic oxygen furnace

For a blast oxygen furnace, the primary dust abatement produces, in addition to CO and CO_2, mainly dust emissions. When the converter is provided with a fire resistant coating, this coating has to be preheated, producing PAH containing aromatic hydrocarbons. The amount of PAH is usually below the detection limit of the measuring technique. The dust contains a small amount of BC and heavy metals. The secondary dust abatement produces dust with higher heavy metal content than the primary dust. The same applies to the unabated dust emissions from ventilation through the roof. The main part of the dust emissions consists of particles with a size smaller than 10 microns. For the dust emitted through the roof this is more than 50 %.

Fuel is consumed to preheat and dry the converters after relining and repair. This thermal energy consumption totals approximately 0.051 GJ/Mg steel. Electricity consumption is estimated at 23 kWh/Mg steel or 0.08 GJ/Mg steel. This figure includes the production of oxygen and the operation of the converters. The process gas from the converter contains large amounts of CO and is hot. When the energy from the BOF gas is recovered (waste heat recovery and/or BOF gas recovery), the basic oxygen furnace becomes a net producer of energy. In a modern plant, energy recovery can be as high as 0.7 GJ/Mg steel (European Commission, 2001).

Electric arc furnace

In an electric arc furnace plant, besides carbon monoxide and carbon dioxide, dust is the main emission. Sixty percent of the dust particles are smaller than ten microns. Because polluted scrap is used, the dust contains heavy metals such as lead and zinc. Also copper, chromium, nickel, arsenic, cadmium, and mercury (Hg) are present. Small amounts of BC, hexachlorobenzene, dioxins and furans are also emitted. The emission of BC is related to the emission of $PM_{2.5}$. Emissions of PAH depend on the coating material used, e.g. in the Netherlands PAH are not emitted, because tar-free materials are used for the coating.

The total energy input for this process is between 2 300 and 2 700 MJ per Mg of steel produced, of which 1 250–1 800 MJ/Mg is from electricity. The oxygen demand is 24–47 m^3/Mg steel (European Commission, 2001).

Rolling mills

Hot-rolling of slabs and non-flat products (billets) produces hydrocarbon emissions from lubricating oils. Preheating of material and annealing after rolling results in emissions of nitrogen oxides and carbon monoxide. When volatile halogenated organic (VHO) gas is used some sulphur dioxide will also be emitted. Pickling before cold rolling produces emissions of hydrochloric acid. Cold rolling gives emissions of hydrocarbons and decomposition products of lubricant oil. Gradual heating and cooling gives emissions of nitrogen oxides and carbon monoxide. Protection gas contains polycyclic aromatic hydrocarbons.

In general, it can be said that emissions from rolling mills are small compared to the other emissions from the (integrated) steel plant. Therefore, rolling mills will not be considered as a separate source in the Tier 1 and Tier 2 emission factors. Some information is available in the Tier 3 section.

2.3.4   *Particulate matter (PM)*

Measurements of emissions of particulate matter from the sources listed above may use techniques which give filterable, condensible or total PM. A number of factors influence the measurement and determination of primary PM emissions from activities such as iron and steel production. The quantity of PM determined in an emission measurement depends to a large extent on the measurement conditions. This is particularly true of activities involving high temperature and semi-volatile emission components – in such instances the PM emission may be partitioned between a solid/aerosol phase and material which is gaseous at the sampling point but which can condense in the atmosphere. The proportion of filterable and condensable material will vary depending on the temperature of the flue gases and in sampling equipment.

A range of filterable PM measurement methods are applied around the world typically with filter temperatures of 70-160°C (the temperature is set by the test method). Condensable fractions can be determined directly by recovering condensed material from chilled impinger systems

downstream of a filter – note that this is condensation without dilution and can require additional processing to remove sampling artefacts. A common approach for total PM includes dilution where sampled flue or exhaust gases are mixed with ambient air (either using a dilution tunnel or dilution sampling systems) which collect the filterable and condensable components on a filter at lower temperatures (but depending on the method this can be 15-52°C).

Tier 1 and Tier 2 PM emission factors have been reviewed to identify if the data represent filterable or total (filterable and condensable) PM. The review identifies whether the PM emission factors (for TSP, PM_{10} and $PM_{2.5}$) represent total PM, filterable PM or whether the basis of the emission factor cannot be determined (see individual emission factor tables).

Note that PM emission factors in the Guidebook represent primary emissions from the activities and not formation of secondary aerosol from chemical reaction in the atmosphere after release.

2.4 Controls

2.4.1 Sinter plants

Limited information is available about specific control measures for gaseous emissions. A desulphurisation facility is operated at a German plant (Lüngen and Theobald, 1991). Measures for SO_2 and NO_x reduction are known from plants operated in Japan (Bothe, 1993).

Abatement measures are directed to dust emissions. In principle, reduction of dust emission also leads to reduction of emissions for those compounds being bound to particulates. Sinter strand windbox emissions are commonly controlled by cyclone cleaners followed by a dry or wet electrostatic precipitator (ESP), high pressure drop wet scrubber, or baghouse. Crusher and hot screen emissions are usually controlled by hooding and a baghouse or scrubber. Usually horizontal dry electrostatic precipitators are used. However, less efficient mechanical dust removal devices (e.g cyclone batteries) might be installed in old sinter plants if only protection of the blower wheel rather than environmental protection is intended. Some sinter plants located in CIS countries are reported to have only this low standard abatement technology, others are equipped with wet venturi washers (Kakareka, 2008).

Since POM has been identified as a relevant source of dioxins and furans some sinter plants have been equipped with special abatement technologies (e.g. the 'airfine system' in Austria or injection of activated charcoal or open hearth coke in conjunction with a fabric filter) or optimised dust removal facilities, such as 'MEEP', which is ESP with a rotating electrode (Theobald, 1995).

2.4.2 Blast furnace for pig iron production

To reduce the escape of the basic materials during charging, a vapour lock is installed on the top of the smelter. The lock is charged after pressure equalisation. Different constructions for this lock are in use. The sealed charging system can be a bell charging system or one without a bell. In addition, the evacuation of gas at the top of the furnace and connection to the blast furnace gas treatment system can be used to control emissions (European Commission, 2001).

The trough, the skimmer and the transport runners are usually covered. Dust and decomposition products are removed, and pass fabric filters before emission into air. The part not captured passes through the roof. This emission is not abated. The total amount escaping through the roof is about 40 % of the total emission.

From the decomposition products of tar and coal only the condensable part of the PAH emissions is captured by the fabric filters.

2.4.3 Steel making furnaces

In the case of purifying furnace gases from open-hearth furnaces the effectiveness of dust removal units should not be lower than 99 %. That is why wet scrubbers, electrostatic precipitators or fabric filters are used for furnace gas dust removal. The wet scrubbers were the earliest to be applied for furnace gas dust removal from open hearth furnaces. They usually consist of two elements: dust coagulator and basic dust removal unit. The dust removal systems most often used in the case of open hearth furnaces are electrostatic precipitators. Their efficiency is very high and usually exceeds 99 %. Only in a few cases lower efficiencies (i.e. 94–98 %) are observed. However, obsolete equipment reduces cleaning efficiency to about 85 %.

For flue gas cleaning at double-bath furnaces both wet and dry cleaning systems are applied. Dry systems are more widely used where gases are cooled and cleaned first in the waste heat boiler and in the scrubber and then in an electrostatic precipitator (Kakareka *et al*., 1998). Recently, fabric filters have been applied to the purification of furnace gas from open hearth furnaces. They allow an efficiency of 99 % or even higher, regardless of the dust contents in furnace gas. Nonetheless, they require an especially precise design and proper selection of technical parameters.

For a basic oxygen furnace, primary dust abatement consists of a vapour cooler for separation of coarse dust and a washer for fine dust abatement. The secondary dust abatement is usually a fabric filter.

In an electric arc furnace, reduction of the emissions can be achieved by technological process changes as well as by abatement equipment. Varying the operating conditions or the design of the furnace may lead to a reduction in the amount of dust produced. Use of an 'after burner' reduces the amount of CO emitted. Use of equipment to capture the emitted particles, e.g. fabric filter or electrostatic precipitators (ESP), reduces the amount of dust emitted. Fugitive emissions can be reduced by placing the furnace in a doghouse (a 'hall') and using abatement equipment to clean the effluent from the doghouse. Table 2.3 lists the overall efficiency of several abatement technologies.

Table 2.3   **Abatement technologies and their efficiencies for complete electric furnace steel plants (assuming good housekeeping).**

Abatement technology	Efficiency ([a]) (%)
Fabric filter	95
Electrostatic precipitators (ESP)	>95
Doghouse, suction hood and fabric filter	>99.5
Fibrous filter and post-combustion	>95

([a])   With abatement for PM (and for most HM, but not for As and Hg)

In rolling mills, hydrochloric acid from pickling is removed by a washing tower. Hydrocarbon vapours from rolling are captured by lamella filters. Production gas containing PAHs can be burned in afterburners.

3 Methods

3.1   Choice of method

In Figure 3.1, a procedure is presented to select the methods for estimating process emissions from an integrated steel plant. This decision tree is applicable to all processes in this sector. The basic idea of the decision tree is as follows.

- If detailed information is available, use it as much as possible.

- If the source category is a key category, a Tier 2 or Tier 3 method must be used for estimating the emissions. This condition is met by the decision tree in Figure 3.1. Also, in the case of specific abatement options, a Tier 1 method is not enough and a Tier 2 or Tier 3 method must be used.

- A Tier 3 method basically consists of two possibilities: the use of detailed process modelling or the use of facility level data.

Figure 3.1   Decision tree for source category 2.C.1 Iron and steel production.
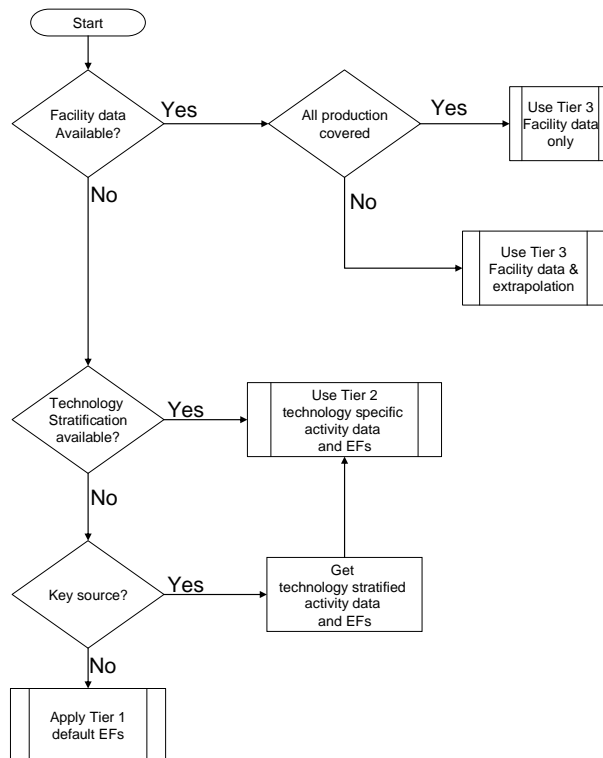
3.2   Tier 1 default approach

3.2.1   Algorithm

The Tier 1 approach for process emissions from an integrated steel plant uses the general equation:

$$E_{pollutant} = AR_{production} \times EF_{pollutant} \tag{1}$$

where:

$E_{pollutant}$	=	the emission of the specified pollutant
$AR_{production}$	=	the activity rate for the iron and steel production
$EF_{pollutant}$	=	the emission factor for this pollutant

This equation is applied at the national level, using annual national total production. Information on the production of steel, suitable for estimating emissions using the simpler estimation methodology (Tier 1 and 2), is widely available from United Nations statistical yearbooks or national statistics.

The Tier 1 emission factors assume an averaged or typical technology and abatement implementation in the country and integrate all different sub-processes occurring in an integrated steel production facility. This includes:

- steel production;
- pig iron production;
- sinter production.

In cases where these sub-processes are not together in one facility, the Tier 1 method cannot be used and it is good practice to use a Tier 2 method. In the Tier 2 approach, these sub-processes are treated individually, where also specific technologies are taken into account.

Furthermore, in the Tier 1 approach, it is assumed that NO_x, SO_x and CO emissions are originating mainly from combustion activities. These emissions are accounted for in source category 1.A.2.a.

In cases where specific abatement options are to be taken into account a Tier 1 method is not applicable and a Tier 2 or Tier 3 approach must be used.

3.2.2 Default emission factors

The Tier 1 approach needs emission factors for all relevant pollutants in an integrated steel plant (which includes sinter or pellet production, pig iron production and steel production). The emission factors cover all the activities occurring within the facility and are expressed per mass of liquid steel that is shipped off the facility. The emission factors provided in Table 3.1 below have been derived from all available materials, taking into account the results of an assessment of emission factors included in previous versions of the Guidebook and the newer information from the Best Available Techniques Reference (BREF) document on the iron and steel industry (European Commission, 2001). To obtain the Tier 1 emission factors for an integrated steel facility, the following conversion ratios have been assumed (European Commission, 2001):

- for every kg pig iron produced, 1.16 kg sinter is used;
- for every kg steel produced, 0.94 kg pig iron is used.

Information from the BREF document has been used wherever available, but the information in this document is not sufficient to complete the Tier 1 default emission factor table. Additional information has been taken from the 'Estimation of willingness-to-pay to reduce risks of exposure to heavy metals and cost-benefit analysis for reducing heavy metals occurrence in Europe' (ESPREME) study (Theloke *et al*., 2008) that included emissions from EU-27, Albania, Belarus, Croatia, Iceland, Macedonia, Moldova, Norway, the European part of Russia, Serbia and Montenegro,

Switzerland, and Ukraine, from the Coordinated European Particulate Matter Emission Inventory Programme (CEPMEIP) study (Visschedijk et al., 2004) and from a former version of the Guidebook (Guidebook, 2006) where no other data were available. The emission factor for BC from iron and steel production is obtained from US EPA, SPECIATE database version 4.3 (US EPA, 2011). The EF for BC relates to the emission of $PM_{2.5}$. For the purposes of this guidance, BC emission factors are assumed to equal those for elemental carbon (EC). For further information please refer to Chapter 1.A.1 Energy Industries.

Table 3.1   Tier 1 emission factors for source category 2.C.1 Iron and steel production.

Tier 1 default emission factors					
	Code	Name			
NFR source category	2.C.1	Iron and steel production			
Fuel	NA				
Not applicable					
Not estimated	NO_x, CO, SO_x, NH_3, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
NMVOC	150	g/Mg steel	55	440	European Commission (2001)
TSP	300	g/Mg steel	90	1 300	European Commission (2001)
PM_{10}	180	g/Mg steel	60	700	Visschedijk et al. (2004) applied on TSP
$PM_{2.5}$	140	g/Mg steel	40	500	Visschedijk et al. (2004) applied on TSP
BC	0.36	% of $PM_{2.5}$	0.18	0.72	US EPA (2011, file no.: 91153)
Pb	4.6	g/Mg steel	0.5	46	European Commission (2001), Theloke et al. (2008)
Cd	0.02	g/Mg steel	0.003	0.1	European Commission (2001), Theloke et al. (2008)
Hg	0.1	g/Mg steel	0.02	0.5	European Commission (2001), Theloke et al. (2008)
As	0.4	g/Mg steel	0.08	2	Theloke et al. (2008)
Cr	4.5	g/Mg steel	0.5	45	European Commission (2001), Theloke et al. (2008)
Cu	0.07	g/Mg steel	0.01	0.3	European Commission (2001), Theloke et al. (2008)
Ni	0.14	g/Mg steel	0.1	1.1	European Commission (2001), Theloke et al. (2008)
Se	0.02	g/Mg steel	0.002	0.2	Guidebook (2006)
Zn	4	g/Mg steel	0.4	43	European Commission (2001), Guidebook (2006)
PCB	2.5	mg/Mg steel	0.01	5.0	European Commission (2012)
PCDD/F	3.0	µg I-TEQ/Mg steel	0.04	6.0	European Commission (2012)
Total 4 PAHs	0.48	g/Mg steel	0.009	0.97	European Commission (2012)
HCB	0.03	mg/Mg steel	0.003	0.3	Guidebook (2006)

Note:
These PM factors represent filterable PM emissions only (excluding any condensable fraction (European Commission, 2001)).

3.2.3 Activity data

Information on the production of sinter, pig iron and steel, suitable for estimating emissions using the simpler estimation methodology (Tier 1) is widely available from United Nations statistical yearbooks or national statistics.

Further guidance is also provided by the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006), volume 3 on Industrial Processes and Product Use (IPPU), subsection 4.2.2.4, 'Choice of activity data'.

3.3   Tier 2 technology-specific approach

3.3.1   Algorithm

To apply the Tier 2 approach in the iron and steel industry, the integrated steel works discussed in the Tier 1 section is split into three separate processes (or four, depending on whether pig iron production is split in two or treated as a whole):

- sinter production (or pelletisation);
- pig iron production, including:
  - o   blast furnace charging;
  - o   pig iron tapping;
- steel making.

This section provides 'default' emission factors, to be used for separate sinter, pig iron or steel plants, when the used technology is unknown.

Furthermore, this section provides the different techniques found in pig iron production and steel production, in a similar approach. To use the technology-specific Tier 2 approach, both the activity data and the emission factors need to be stratified according to the different techniques that may occur in the country. In the iron and steel industry, three different techniques are distinguished for the production of steel (the last process in the integrated steel works facility), in decreasing order of importance:

- basic oxygen furnace;
- electric arc furnace;
- open hearth furnace

To apply a Tier 2 approach to the various processes in the iron and steel industry, the approach could be as follows:

Stratify the iron and steel production in the country to model the different product and process types occurring in the national iron and steel industry into the inventory by;

- defining the production using each of the separate product and/or process types (together called 'technologies' in the formulae below) separately; and
- applying technology specific emission factors for each process type:

$$E_{pollutant} = \sum_{technologies} AR_{production,technology} \times EF_{technology,pollutant} \qquad (2)$$

where:

$AR_{production,technology}$	=	the production rate within the source category, using this specific technology
$EF_{technology,pollutant}$	=	the emission factor for this technology and this pollutant

When applying the Tier 2 approach, it is good practice to make this technology stratification for each of the processes (sintering, pig iron production and steel making) individually. To calculate the total emissions for this source category, emissions from sintering, pig iron production and steel making can simply be added up.

A country where only one technology is implemented will result in a penetration factor of 100 % and the algorithm reduces to:

$$E_{pollutant} = AR_{production} \times EF_{technology,pollutant} \qquad (3)$$

where:

$E_{pollutant}$	=	the emission of the specified pollutant
$AR_{production}$	=	the relevant activity rate for the process
$EF_{pollutant}$	=	the emission factor for this pollutant

In this case, the emission factors will still include all sub-processes within either the sintering, pig iron production or steel making.

3.3.2 Technology-specific emission factors

Applying a Tier 2 approach for the process emissions from sinter, iron and steel production, technology specific emission factors are needed. These are provided in this section. A so-called BREF document (European Commission, 2001; 2012) for this industry is available at http://eippcb.jrc.es/reference/. In section 4.3.1 emission factors derived from the emission limit values (ELVs) as defined in the BREF document are provided for comparison.

Emission factors in the BREF documents are mostly given in ranges. The range is interpreted as the 95 % confidence interval, while the geometric mean of this range is chosen as the value for the emission factor in the tables below.

This subsection provides process emission factors for the different technologies in the different processes in iron and steel production, as summarized in subsection 3.3.1 of the present source category.

This subsection is somewhat different from the Tier 2 sections in other chapters. The Tier 2 emission factors are given for the different processes that have been previously identified within the iron and steel industry.

The emission factors are taken from various sources, in decreasing order of preference:

- BREF document on the iron and steel industry;
- an ESPREME study for heavy metal emission factors (Theloke *et al*., 2008) and a CEPMEIP study for particulate emission factors (Visschedijk et al., 2004);
- an older version of the Guidebook;
- expert judgement.

For the production of pig iron and steel making, technology-specific emission factors are also given below. The Tier 2 emission factors also include the transport of hot iron within the facility.

Note also that there appear to be some inconsistencies between data obtained from the BREF documents on particulates and the heavy metals emission factors from the ESPREME project

(Theloke et al, 2008). This may lead to some inconsistencies between certain Tier 1 and Tier 2 emission factors, or between the relative emission rates for different pollutants across different technologies.

For the purposes of this guidance, BC emission factors are assumed to equal those for elemental carbon (EC). For further information please refer to Chapter 1.A.1 Energy Industries.

Sinter or pellets production

Typical technologies

The tables below provide the default emission factors that may be used to estimate the emissions from sinter and pellet production. These emission factors are applicable to a 'typical' sinter plant and pelletising plant of which the specific technology is unknown.

Emissions from NO_x, SO_2 and CO are assumed to be mainly due to the combustion of fuels; guidance on estimating these emissions is provided in chapter 1.A.2.a. All other emissions are estimated in the present chapter.

Table 3.2   Tier 2 emission factors for source category 2.C.1 Iron and steel production, sinter production.

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.1	Iron and steel production			
Fuel	NA				
SNAP (if applicable)	040209 Sinter and pelletizing plant (except comb. 030301)				
Technologies/Practices	Sinter production				
Region or regional conditions					
Abatement technologies					
Not applicable					
Not estimated	NO_x, CO, SO_x, NH_3, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
NMVOC	138	g/Mg sinter	50	400	European Commission (2001)
TSP	200	g/Mg sinter	160	260	European Commission (2001)
PM_{10}	100	g/Mg sinter	80	130	Visschedijk et al. (2004) applied on TSP
$PM_{2.5}$	80	g/Mg sinter	70	110	Visschedijk et al. (2004) applied on TSP
BC	0.17	% of $PM_{2.5}$	0.09	0.34	US EPA (2011, file no.: 91139)
Pb	3.5	g/Mg sinter	1.8	5.4	Theloke et al. (2008)
Cd	0.004	g/Mg sinter	0.002	0.005	Theloke et al. (2008)
Hg	0.049	g/Mg sinter	0.016	0.15	European Commission (2001)
As	0.018	g/Mg sinter	0.0089	0.027	Theloke et al. (2008)
Cr	0.016	g/Mg sinter	0.005	0.05	European Commission (2001)
Cu	0.033	g/Mg sinter	0.007	0.16	European Commission (2001)
Ni	0.09	g/Mg sinter	0.05	0.16	Theloke et al. (2008)
Se	0.02	g/Mg sinter	0.002	0.2	Guidebook (2006)
Zn	0.06	g/Mg sinter	0.002	**1.8**	European Commission (2001)
PCB	0.09	mg/Mg sinter	0.025	0.18	European Commission (2012)
PCDD/F	8.0	µg l-TEQ/Mg sinter	0.2	16	European Commission (2012)
Total 4 PAHs	0.30	g/Mg sinter	0,0002	0.59	European Commission (2012)
HCB	0.03	mg/Mg sinter	0.003	0.3	Guidebook (2006)

Note:
These PM factors represent filterable PM emissions only (excluding any condensable fraction (European Commission, 2001)).

Table 3.3   Tier 2 emission factors for source category 2.C.1 Iron and steel production, pellet production.

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.1	Iron and steel production			
Fuel	NA				
SNAP (if applicable)	040209 Sinter and pelletizing plant (except comb. 030301)				
Technologies/Practices	Pellet production				
Region or regional conditions					
Abatement technologies					
Not applicable					
Not estimated	NO_x, CO, SO_x, NH_3, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
NMVOC	14	g/Mg pellet	5	40	European Commission (2001)
TSP	50	g/Mg pellet	20	130	European Commission (2001)
PM_{10}	25	g/Mg pellet	10	70	Visschedijk et al. (2004) applied on TSP
$PM_{2.5}$	20	g/Mg pellet	8	50	Visschedijk et al. (2004) applied on TSP
BC	0.17	% of $PM_{2.5}$	0.09	0.34	US EPA (2011, file no.: 91139)
Pb	20	g/Mg pellet	3	130	European Commission (2001)
Cd	0.1	g/Mg pellet	0.02	0.4	European Commission (2001)
Hg	0.2	g/Mg pellet	0.1	0.4	European Commission (2001)
As	0.018	g/Mg pellet	0.0089	0.027	Theloke et al. (2008)
Cr	2.1	g/Mg pellet	1	4.4	European Commission (2001)
Cu	3.6	g/Mg pellet	1.7	7.5	European Commission (2001)
Ni	11	g/Mg pellet	5	25	European Commission (2001)
Se	0.02	g/Mg pellet	0.002	0.2	Guidebook (2006)
Zn	16	g/Mg pellet	2.4	110	European Commission (2001)
PCB	0.09	mg/Mg pellet	0.025	0.18	European Commission (2012)
PCDD/F	0.10	µg I-TEQ/Mg pellet	0.008	0.20	European Commission (2012)
Total 4 PAHs	0.0009	g/Mg pellet	0,0007	0.0011	European Commission (2012)
HCB	0.03	mg/Mg pellet	0.003	0.3	Guidebook (2006)

Note:
These PM factors represent filterable PM emissions only (excluding any condensable fraction (European Commission, 2001)).

Specific technologies

Tables 3.4–3.7 below provide technology-specific emission factors within the sintering process. Data are taken from the ESPREME study. For pollutants not considered in ESPREME, emission factors from Table 3.2 have been used to complete the tables.

Table 3.4 **Tier 2 emission factors for source category 2.C.1 Iron and steel production, sinter production, controlled by wet flue gas desulfurization (WFGD).**

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.1	Iron and steel production			
Fuel	NA				
SNAP (if applicable)	040209 Sinter and pelletizing plant (except comb. 030301)				
Technologies/Practices	Sinter production				
Region or regional conditions					
Abatement technologies	wFGD (state-of-the-art)				
Not applicable					
Not estimated	NO_x, CO, SO_x, NH_3, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
NMVOC	138	g/Mg sinter	50	400	European Commission (2001)
TSP	200	g/Mg sinter	160	260	European Commission (2001)
PM_{10}	100	g/Mg sinter	80	130	Visschedijk et al. (2004) applied on TSP
$PM_{2.5}$	80	g/Mg sinter	70	110	Visschedijk et al. (2004) applied on TSP
BC	0.17	% of $PM_{2.5}$	0.09	0.34	US EPA (2011, file no.: 91139)
Pb	0.99	g/Mg sinter	0.5	1.5	Theloke et al. (2008)
Cd	0.0011	g/Mg sinter	0.0005	0.0015	Theloke et al. (2008)
Hg	0.018	g/Mg sinter	0.012	0.036	Theloke et al. (2008)
As	0.005	g/Mg sinter	0.0025	0.0075	Theloke et al. (2008)
Cr	0.13	g/Mg sinter	0.05	0.2	Theloke et al. (2008)
Cu	0.03	g/Mg sinter	0.007	0.2	European Commission (2001)
Ni	0.025	g/Mg sinter	0.015	0.045	Theloke et al. (2008)
Se	0.02	g/Mg sinter	0.002	0.2	Guidebook (2006)
Zn	0.06	g/Mg sinter	0.002	1.8	European Commission (2001)
PCB	0.09	mg/Mg sinter	0.025	0.18	European Commission (2012)
PCDD/F	8.0	µg I-TEQ/Mg sinter	0.2	16	European Commission (2012)
Total 4 PAHs	0.30	g/Mg sinter	0,0002	0.59	European Commission (2012)
HCB	0.03	mg/Mg sinter	0.003	0.3	Guidebook (2006)

Note:
These PM factors represent filterable PM emissions only (excluding any condensable fraction (European Commission, 2001)).

Table 3.5 **Tier 2 emission factors for source category 2.C.1 Iron and steel production, sinter production, controlled by carbon injection and fabric filter.**

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.1	Iron and steel production			
Fuel	NA				
SNAP (if applicable)	040209 Sinter and pelletizing plant (except comb. 030301)				
Technologies/Practices	Sinter production				
Region or regional conditions					
Abatement technologies	Virgin activated carbon injection (SIC) & fabric filter				
Not applicable					
Not estimated	NO$_x$, CO, SO$_x$, NH$_3$, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
NMVOC	138	g/Mg sinter	50	400	European Commission (2001)
TSP	200	g/Mg sinter	160	260	European Commission (2001)
PM$_{10}$	100	g/Mg sinter	80	130	Visschedijk et al. (2004) applied on TSP
PM$_{2.5}$	80	g/Mg sinter	70	110	Visschedijk et al. (2004) applied on TSP
BC	0.17	% of PM$_{2.5}$	0.09	0.34	US EPA (2011, file no.: 91139)
Pb	5.9	g/Mg sinter	3	9	Theloke et al. (2008)
Cd	0.0066	g/Mg sinter	0.003	0.009	Theloke et al. (2008)
Hg	0.006	g/Mg sinter	0.004	0.012	Theloke et al. (2008)
As	0.03	g/Mg sinter	0.015	0.045	Theloke et al. (2008)
Cr	0.78	g/Mg sinter	0.4	2	Theloke et al. (2008)
Cu	0.03	g/Mg sinter	0.007	0.2	European Commission (2001)
Ni	0.15	g/Mg sinter	0.09	0.27	Theloke et al. (2008)
Se	0.02	g/Mg sinter	0.002	0.2	Guidebook (2006)
Zn	0.06	g/Mg sinter	0.002	1.8	European Commission (2001)
PCB	0.09	mg/Mg sinter	0.025	0.18	European Commission (2012)
PCDD/F	8.0	µg I-TEQ/Mg sinter	0.2	16	European Commission (2012)
Total 4 PAHs	0.30	g/Mg sinter	0,0002	0.59	European Commission (2012)
HCB	0.03	mg/Mg sinter	0.003	0.3	Guidebook (2006)

Note:
These PM factors represent filterable PM emissions only (excluding any condensable fraction (European Commission, 2001)).

Table 3.6   Tier 2 emission factors for source category 2.C.1 Iron and steel production, sinter production, controlled by simultaneous control of SO2, NOx and Hg (SICs).

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.1	Iron and steel production			
Fuel	NA				
SNAP (if applicable)	040209 Sinter and pelletizing plant (except comb. 030301)				
Technologies/Practices	Sinter production				
Region or regional conditions					
Abatement technologies	Simultaneous control of SO_2, NO_x and Hg (SICs)				
Not applicable					
Not estimated	NO_x, CO, SO_x, NH_3, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
NMVOC	138	g/Mg sinter	50	400	European Commission (2001)
TSP	200	g/Mg sinter	160	260	European Commission (2001)
PM_{10}	100	g/Mg sinter	80	130	Visschedijk et al. (2004) applied on TSP
$PM_{2.5}$	80	g/Mg sinter	70	110	Visschedijk et al. (2004) applied on TSP
BC	0.17	% of $PM_{2.5}$	0.09	0.34	US EPA (2011, file no.: 91139)
Pb	12	g/Mg sinter	6	18	Theloke et al. (2008)
Cd	0.013	g/Mg sinter	0.006	0.018	Theloke et al. (2008)
Hg	0	g/Mg sinter	0	0	Theloke et al. (2008)
As	0.06	g/Mg sinter	0.03	0.09	Theloke et al. (2008)
Cr	1.6	g/Mg sinter	1	3	Theloke et al. (2008)
Cu	0.03	g/Mg sinter	0.007	0.2	European Commission (2001)
Ni	0.3	g/Mg sinter	0.18	0.54	Theloke et al. (2008)
Se	0.02	g/Mg sinter	0.002	0.2	Guidebook (2006)
Zn	0.06	g/Mg sinter	0.002	1.8	European Commission (2001)
PCB	0.09	mg/Mg sinter	0.025	0.18	European Commission (2012)
PCDD/F	8.0	µg I-TEQ/Mg sinter	0.2	16	European Commission (2012)
Total 4 PAHs	0.30	g/Mg sinter	0,0002	0.59	European Commission (2012)
HCB	0.03	mg/Mg sinter	0.003	0.3	Guidebook (2006)

Note:
These PM factors represent filterable PM emissions only (excluding any condensable fraction (European Commission, 2001)).

Table 3.7   Tier 2 emission factors for source category 2.C.1 Iron and steel production, sinter production, controlled by dry ESP.

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.1	Iron and steel production			
Fuel	NA				
SNAP (if applicable)	040209 Sinter and pelletizing plant (except comb. 030301)				
Technologies/Practices	Sinter production				
Region or regional conditions					
Abatement technologies	Dry ESP				
Not applicable					
Not estimated	NO$_x$, CO, SO$_x$, NH$_3$, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
NMVOC	138	g/Mg sinter	50	400	European Commission (2001)
TSP	200	g/Mg sinter	160	260	European Commission (2001)
PM$_{10}$	100	g/Mg sinter	80	130	Visschedijk et al. (2004) applied on TSP
PM$_{2.5}$	80	g/Mg sinter	70	110	Visschedijk et al. (2004) applied on TSP
BC	0.17	% of PM$_{2.5}$	0.09	0.34	US EPA (2011, file no.: 91139)
Pb	0.0099	g/Mg sinter	0.005	0.015	Theloke et al. (2008)
Cd	0.000011	g/Mg sinter	0.000005	0.000015	Theloke et al. (2008)
Hg	0.009	g/Mg sinter	0.006	0.018	Theloke et al. (2008)
As	0.00005	g/Mg sinter	0.000025	0.000075	Theloke et al. (2008)
Cr	0.0013	g/Mg sinter	0.0005	0.002	Theloke et al. (2008)
Cu	0.03	g/Mg sinter	0.007	0.2	European Commission (2001)
Ni	0.00025	g/Mg sinter	0.00015	0.00045	Theloke et al. (2008)
Se	0.02	g/Mg sinter	0.002	0.2	Guidebook (2006)
Zn	0.06	g/Mg sinter	0.002	1.8	European Commission (2001)
PCB	0.09	mg/Mg sinter	0.025	0.18	European Commission (2012)
PCDD/F	8.0	µg I-TEQ/Mg sinter	0.2	16	European Commission (2012)
Total 4 PAHs	0.30	g/Mg sinter	0,0002	0.59	European Commission (2012)
HCB	0.03	mg/Mg sinter	0.003	0.3	Guidebook (2006)

Note:
These PM factors represent filterable PM emissions only (excluding any condensable fraction (European Commission, 2001)).

Pig iron production

Typical technologies

Table 3.8 provides emission factors for pig iron production, for the whole process from the charging of the blast furnace until the tapping of pig iron.

All emissions of NO_x, SO_x and CO are assumed to originate from the combustion activities in the blast furnace; these emissions are included in source category 1.A.2.a. The emission factors assume a 'moderate' level of abatement (see Table 3.24).

Table 3.8   Tier 2 emission factors for source category 2.C.1 Iron and steel production, pig iron production.

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.1	Iron and steel production			
Fuel	NA				
SNAP (if applicable)	040202 Blast furnace charging				
Technologies/Practices					
Region or regional conditions					
Abatement technologies					
Not applicable					
Not estimated	NO_x, CO, NMVOC, SO_x, NH_3, Cd, As, Ni, Se, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
TSP	50	g/Mg pig iron	160	260	European Commission (2001)
PM_{10}	40	g/Mg pig iron	80	130	Visschedijk et al. (2004) applied on TSP
$PM_{2.5}$	25	g/Mg pig iron	70	110	Visschedijk et al. (2004) applied on TSP
BC	2.4	% of $PM_{2.5}$	0.09	0.34	Kupiainen & Klimont (2004)
Pb	0.0006	g/Mg pig iron	0.0003	0.0009	Theloke et al. (2008)
Hg	0.0001	g/Mg pig iron	0.00007	0.0002	Theloke et al. (2008)
Cr	0.0003	g/Mg pig iron	0.00015	0.0005	Theloke et al. (2008)
Cu	0.015	g/Mg pig iron	0.0015	0.15	Guidebook (2006)
Zn	0.073	g/Mg pig iron	0.0073	0.73	Guidebook (2006)
PCB	2.5	mg/Mg pig iron	0.01	5.0	European Commission (2012)
PCDD/F	0.002	µg I-TEQ/Mg pig iron	0.001	0.004	European Commission (2001)
Total 4 PAHs	2.5	g/Mg pig iron	0.25	25	Guidebook (2006)

Note:
These PM factors represent filterable PM emissions only (excluding any condensable fraction (European Commission, 2001)).

Specific technologies

Tables 3.9–3.11 provide technology-specific emission factors within the pig iron production process. All data are taken from ESPREME results, all other (relevant) pollutants not considered in the ESPREME study are grouped as 'not estimated' (NE).

Table 3.9   Tier 2 emission factors for source category 2.C.1 Iron and steel production, pig iron production, heat recovery.

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.1	Iron and steel production			
Fuel	NA				
SNAP (if applicable)	040202 Blast furnace charging				
Technologies/Practices					
Region or regional conditions					
Abatement technologies	Heat recovery				
Not applicable					
Not estimated	NO$_x$, CO, NMVOC, SO$_x$, NH$_3$, Ni, Se, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
TSP	50	g/Mg pig iron	160	260	European Commission (2001)
PM$_{10}$	40	g/Mg pig iron	80	130	Visschedijk et al. (2004) applied on TSP
PM$_{2.5}$	25	g/Mg pig iron	70	110	Visschedijk et al. (2004) applied on TSP
BC	2.4	% of PM$_{2.5}$	0.09	0.34	Kupiainen & Klimont (2004)
Pb	0.0114	g/Mg pig iron	0.0057	0.017	Theloke et al. (2008)
Cd	0.000018	g/Mg pig iron	0.0000095	0.000029	Theloke et al. (2008)
Hg	0.00019	g/Mg pig iron	0.000095	0.00029	Theloke et al. (2008)
As	0.00057	g/Mg pig iron	0.00029	0.00086	Theloke et al. (2008)
Cr	0.0057	g/Mg pig iron	0.0029	0.0086	Theloke et al. (2008)
Cu	0.015	g/Mg pig iron	0.0015	0.15	Guidebook (2006)
Zn	0.073	g/Mg pig iron	0.0073	0.73	Guidebook (2006)
PCB	2.5	mg/Mg pig iron	0.01	5.0	European Commission (2012)
PCDD/F	0.002	µg I-TEQ/Mg pig iron	0.001	0.004	European Commission (2001)
Total 4 PAHs	2.5	g/Mg pig iron	0.25	25	Guidebook (2006)

Note:
These PM factors represent filterable PM emissions only (excluding any condensable fraction (European Commission, 2001)).

Table 3.10   Tier 2 emission factors for source category 2.C.1 Iron and steel production, pig iron production, abated by dry ESP.

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.1	Iron and steel production			
Fuel	NA				
SNAP (if applicable)	040202 Blast furnace charging				
Technologies/Practices					
Region or regional conditions					
Abatement technologies	Dry ESP				
Not applicable					
Not estimated	NO_x, CO, NMVOC, SO_x, NH_3, Ni, Se, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
TSP	50	g/Mg pig iron	160	260	European Commission (2001)
PM_{10}	40	g/Mg pig iron	80	130	Visschedijk et al. (2004) applied on TSP
$PM_{2.5}$	25	g/Mg pig iron	70	110	Visschedijk et al. (2004) applied on TSP
BC	2.4	% of $PM_{2.5}$	0.09	0.34	Kupiainen & Klimont (2004)
Pb	0.000006	g/Mg pig iron	0.000003	0.000009	Theloke et al. (2008)
Cd	1.0E-8	g/Mg pig iron	5.0E-9	1.5E-8	Theloke et al. (2008)
Hg	0.000056	g/Mg pig iron	0.000028	0.000084	Theloke et al. (2008)
As	0.0000003	g/Mg pig iron	1.5E-7	4.5E-7	Theloke et al. (2008)
Cr	0.000003	g/Mg pig iron	0.0000015	0.000006	Theloke et al. (2008)
Cu	0.015	g/Mg pig iron	0.0015	0.15	Guidebook (2006)
Zn	0.073	g/Mg pig iron	0.0073	0.73	Guidebook (2006)
PCB	2.5	mg/Mg pig iron	0.01	5.0	European Commission (2012)
PCDD/F	0.002	µg I-TEQ/Mg pig iron	0.001	0.004	European Commission (2001)
Total 4 PAHs	2.5	g/Mg pig iron	0.25	25	Guidebook (2006)

Note:
These PM factors represent filterable PM emissions only (excluding any condensable fraction (European Commission, 2001)).

Table 3.11   Tier 2 emission factors for source category 2.C.1 Iron and steel production, pig iron production, abated by fabric filter.

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.1	Iron and steel production			
Fuel	NA				
SNAP (if applicable)	040202 Blast furnace charging				
Technologies/Practices					
Region or regional conditions					
Abatement technologies	Fabric filter with medium efficiency				
Not applicable					
Not estimated	NO_x, CO, NMVOC, SO_x, NH_3, Ni, Se, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
TSP	50	g/Mg pig iron	160	260	European Commission (2001)
PM_{10}	40	g/Mg pig iron	80	130	Visschedijk et al. (2004) applied on TSP
$PM_{2.5}$	25	g/Mg pig iron	70	110	Visschedijk et al. (2004) applied on TSP
BC	2.4	% of $PM_{2.5}$	0.09	0.34	Kupiainen & Klimont (2004)
Pb	0.00049	g/Mg pig iron	0.00024	0.00073	Theloke et al. (2008)
Cd	8.1E-7	g/Mg pig iron	4.1E-7	1.2E-6	Theloke et al. (2008)
Hg	0.00019	g/Mg pig iron	0.000095	0.00029	Theloke et al. (2008)
As	0.000024	g/Mg pig iron	0.000012	0.000037	Theloke et al. (2008)
Cr	0.00024	g/Mg pig iron	0.00012	0.00037	Theloke et al. (2008)
Cu	0.015	g/Mg pig iron	0.0015	0.15	Guidebook (2006)
Zn	0.073	g/Mg pig iron	0.0073	0.73	Guidebook (2006)
PCB	2.5	mg/Mg pig iron	0.01	5.0	European Commission (2012)
PCDD/F	0.002	µg I-TEQ/Mg pig iron	0.001	0.004	European Commission (2001)
Total 4 PAHs	2.5	g/Mg pig iron	0.25	25	Guidebook (2006)

Note:
These PM factors represent filterable PM emissions only (excluding any condensable fraction (European Commission, 2001)).

Table 3.12   Tier 2 emission factors for source category 2.C.1 Iron and steel production, pig iron production, abated by wSV (medium).

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.1	Iron and steel production			
Fuel	NA				
SNAP (if applicable)	040202 Blast furnace charging				
Technologies/Practices					
Region or regional conditions					
Abatement technologies	wSV (medium)				
Not applicable					
Not estimated	NO$_x$, CO, NMVOC, SO$_x$, NH$_3$, Ni, Se, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
TSP	50	g/Mg pig iron	160	260	European Commission (2001)
PM$_{10}$	40	g/Mg pig iron	80	130	Visschedijk et al. (2004) applied on TSP
PM$_{2.5}$	25	g/Mg pig iron	70	110	Visschedijk et al. (2004) applied on TSP
BC	2.4	% of PM$_{2.5}$	0.09	0.34	Kupiainen & Klimont (2004)
Pb	0.00072	g/Mg pig iron	0.00036	0.0011	Theloke et al. (2008)
Cd	0.0000012	g/Mg pig iron	0.0000006	0.0000018	Theloke et al. (2008)
Hg	0.00018	g/Mg pig iron	0.000092	0.00028	Theloke et al. (2008)
As	0.000036	g/Mg pig iron	0.000018	0.000054	Theloke et al. (2008)
Cr	0.00036	g/Mg pig iron	0.00018	0.00054	Theloke et al. (2008)
Cu	0.015	g/Mg pig iron	0.0015	0.15	Guidebook (2006)
Zn	0.073	g/Mg pig iron	0.0073	0.73	Guidebook (2006)
PCB	2.5	mg/Mg pig iron	0.01	5.0	European Commission (2012)
PCDD/F	0.002	µg I-TEQ/Mg pig iron	0.001	0.004	European Commission (2001)
Total 4 PAHs	2.5	g/Mg pig iron	0.25	25	Guidebook (2006)

Note:
These PM factors represent filterable PM emissions only (excluding any condensable fraction (European Commission, 2001)).

Steel production

Typical technologies

This subsection provides Tier 2 emission factors for steel making, for three different technologies used in steel plants. If the technology is unknown, the emission factors for a basic oxygen plant can be used as the default Tier 2 emission factors for steel making. Within Europe, most steel making facilities are basic oxygen furnaces (European Commission, 2001).

Open hearth furnace steel plant

Table 3.13 provides the Tier 2 emission factors for an open hearth furnace steel plant. Emission factors are derived from an assessment of all available emission factors in the earlier version of the Guidebook. These come from various sources and weighted averages have been calculated in order to get a complete picture covering both uncontrolled and controlled facilities.

Emissions of NO$_x$, SO$_x$ and CO from the open hearth furnace are assumed to originate from the combustion activities in the blast furnace. It is good practice to report these emissions in source

category 1.A.2.a. See table 3-6 of chapter 1.A.2 Combustion in Manufacturing Industries and Construction to find the appropriate combustion emission factors.

Table 3.13   Tier 2 emission factors for source category 2.C.1 Iron and steel production, steel making, open hearth furnace.

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.1	Iron and steel production			
Fuel	NA				
SNAP (if applicable)	040205 Open hearth furnace steel plant				
Technologies/Practices					
Region or regional conditions					
Abatement technologies					
Not applicable					
Not estimated	NO$_x$, CO, NMVOC, SO$_x$, NH$_3$, Ni, Se, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
NMVOC	20	g/Mg steel	10	40	Fudala (1993)
TSP	1 000	g/Mg steel	100	11 000	US EPA /1986)
PM$_{10}$	800	g/Mg steel	70	8 800	US EPA /1986)
PM$_{2.5}$	600	g/Mg steel	50	6 300	US EPA /1986)
BC	2.4	% of PM$_{2.5}$	0.09	0.34	Kupiainen & Klimont (2004)
Pb	300	g/Mg steel	200	500	Theloke et al. (2008)
Cd	0.8	g/Mg steel	0.5	1.5	Theloke et al. (2008)
As	30	g/Mg steel	20	50	Theloke et al. (2008)
Cr	2.3	g/Mg steel	1.5	3.8	Theloke et al. (2008)
Cu	0.3	g/Mg steel	0.003	7.8	Wessely (1983), Kakareka (1998)
Ni	10	g/Mg steel	8	15	Theloke et al. (2008)
Zn	8.1	g/Mg steel	0.52	150	Wessely (1983), Kakareka (1998)
PCDD/F	0.067	µg I-TEQ/Mg steel	0.043	0.094	European Commission (2012)
Total 4 PAHs	0.01	g/Mg steel	0.005	0.02	European Commission (2012)

Note:
These PM factors represent filterable PM emissions only (excluding any condensable fraction (European Commission, 2001)).

Basic oxygen furnace steel plant

For the basic oxygen furnace, Table 3.14 provides the appropriate emission factors for heavy metals and for particulates. For particulates, emission factors refer to a conventional installation of average age, with primary dust removal by ESP, wet scrubbing and limited capturing of secondary dust emissions. Emission factors when using other abatement technologies can be calculated using the abatement efficiencies provided in Table 3.27.

Table 3.14   Tier 2 emission factors for source category 2.C.1 Iron and steel production, steel making, basic oxygen furnace.

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.1	Iron and steel production			
Fuel	NA				
SNAP (if applicable)	040206 Basic oxygen furnace steel plant				
Technologies/Practices					
Region or regional conditions					
Abatement technologies					
Not applicable					
Not estimated	NMVOC, SO$_2$, NH$_3$, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
NO$_x$	10	g/Mg steel	5	20	European Commission (2001)
CO	3.5	kg/Mg steel	1.5	8	European Commission (2001)
TSP	35	g/Mg steel	15	80	European Commission (2001)
PM$_{10}$	32	g/Mg steel	14	76	Visschedijk et al. (2004) applied on TSP
PM$_{2.5}$	28	g/Mg steel	12	72	Visschedijk et al. (2004) applied on TSP
BC	*0.36*	*% of PM$_{2.5}$*	*0.18*	*0.72*	*US EPA (2011, file no.: 91153)*
Pb	4	g/Mg steel	2.7	6.7	Theloke et al. (2008)
Cd	0.067	g/Mg steel	0.053	0.08	Theloke et al. (2008)
Hg	0.0014	g/Mg steel	0.0007	0.0021	Theloke et al. (2008)
As	0.4	g/Mg steel	0.27	0.53	Theloke et al. (2008)
Cr	2.3	g/Mg steel	1.5	3.1	Theloke et al. (2008)
Cu	0.02	g/Mg steel	0.01	0.04	European Commission (2001)
Ni	0.13	g/Mg steel	0.067	0.67	Theloke et al. (2008)
Se	0.003	g/Mg steel	0.0003	0.03	Guidebook (2006)
Zn	4	g/Mg steel	0.4	40	Guidebook (2006)
PCB	2.5	mg/Mg steel	0.01	5.0	European Commission (2012)
PCDD/F	0.69	µg I-TEQ/Mg steel	0.043	0.94	European Commission (2012)
Total 4 PAHs	0.010	g/Mg steel	0.005	0.020	European Commission (2012)

Note:
These PM factors represent filterable PM emissions only (excluding any condensable fraction (European Commission, 2001)).

Electric furnace steel plant

The default emission factors for use with an electric arc furnace are provided in Table 3.15.

Table 3.15   Tier 2 emission factors for source category 2.C.1 Iron and steel production, steel making, electric arc furnace steel plant.

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.1	Iron and steel production			
Fuel	NA				
SNAP (if applicable)	040207 Electric furnace steel plant				
Technologies/Practices					
Region or regional conditions					
Abatement technologies					
Not applicable					
Not estimated	NH₃, Se, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
NO_x	130	g/Mg steel	120	140	European Commission (2001)
CO	1.7	kg/Mg steel	0.74	3.9	European Commission (2001)
NMVOC	46	g/Mg steel	16	130	European Commission (2001)
SO_2	60	g/Mg steel	24	130	European Commission (2001)
TSP	30	g/Mg steel	1	780	European Commission (2001)
PM_{10}	24	g/Mg steel	1	620	Kakareka (2008) applied on TSP
$PM_{2.5}$	21	g/Mg steel	1	550	Kakareka (2008) applied on TSP
BC	0.36	% of $PM_{2.5}$	0.18	0.72	US EPA (2011, file no.: 91153)
Pb	2.6	g/Mg steel	1.1	4.4	Theloke et al. (2008)
Cd	0.2	g/Mg steel	0.15	0.29	Theloke et al. (2008)
Hg	0.05	g/Mg steel	0.038	0.057	Theloke et al. (2008)
As	0.015	g/Mg steel	0.007	0.02	Theloke et al. (2008)
Cr	0.1	g/Mg steel	0.008	2.5	European Commission (2001)
Cu	0.02	g/Mg steel	0.001	0.46	European Commission (2001)
Ni	0.7	g/Mg steel	0.2	1.1	Theloke et al. (2008)
Zn	3.6	g/Mg steel	0.3	46	European Commission (2001)
PCB	2.5	mg/Mg steel	0.01	5.0	European Commission (2012)
PCDD/F	3	µg I-TEQ/Mg steel	0.04	6	European Commission (2012)
Total 4 PAHs	0.48	g/Mg steel	0.009	0.97	European Commission (2012)

Note:
These PM factors represent filterable PM emissions only (excluding any condensable fraction (European Commission, 2001)).

Specific technologies

This section provides technology-specific emission factors within the steel making process. Data are mainly taken from the ESPREME dataset (Theloke *et al*., 2008). Pollutants not provided from ESPREME are added to these tables using the typical technology tables above.

Table 3.16   Tier 2 emission factors for source category 2.C.1 Iron and steel production, steel making, basic oxygen furnace, abated by dry ESP.

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.1	Iron and steel production			
Fuel	NA				
SNAP (if applicable)	040206 Basic oxygen furnace steel plant				
Technologies/Practices					
Region or regional conditions					
Abatement technologies	Dry ESP				
Not applicable					
Not estimated	NO$_x$, CO, NMVOC, SO$_x$, NH$_3$, Se, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
TSP	30	g/Mg steel	1	780	European Commission (2001)
PM$_{10}$	24	g/Mg steel	1	620	Kakareka (2008) applied on TSP
PM$_{2.5}$	21	g/Mg steel	1	550	Kakareka (2008) applied on TSP
BC	0.36	% of PM$_{2.5}$	0.18	0.72	US EPA (2011, file no.: 91153)
Pb	0.015	g/Mg steel	0.01	0.025	Theloke et al. (2008)
Cd	0.00025	g/Mg steel	0.0002	0.0003	Theloke et al. (2008)
Hg	0.0006	g/Mg steel	0.0003	0.0009	Theloke et al. (2008)
As	0.0015	g/Mg steel	0.001	0.002	Theloke et al. (2008)
Cr	0.0013	g/Mg steel	0.0005	0.002	Theloke et al. (2008)
Cu	0.02	g/Mg steel	0.001	0.46	European Commission (2001)
Ni	0.0005	g/Mg steel	0.00025	0.0025	Theloke et al. (2008)
Zn	0.023	g/Mg steel	0.015	0.038	US EPA (2011, file no.: 2830510) applied on Pb
PCB	2.5	mg/Mg steel	0.01	5.0	European Commission (2012)
PCDD/F	0.69	µg I-TEQ/Mg steel	0.043	0.94	European Commission (2012)
Total 4 PAHs	0.10	g/Mg steel	0.05	0.20	European Commission (2012)

Note:
These PM factors represent filterable PM emissions only (excluding any condensable fraction (European Commission, 2001)).

Table 3.17 Tier 2 emission factors for source category 2.C.1 Iron and steel production, steel making, basic oxygen furnace, abated by wSV (medium).

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.1	Iron and steel production			
Fuel	NA				
SNAP (if applicable)	040206 Basic oxygen furnace steel plant				
Technologies/Practices					
Region or regional conditions					
Abatement technologies	wSV (medium)				
Not applicable					
Not estimated	NO$_x$, CO, NMVOC, SO$_x$, NH$_3$, Se, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
TSP	30	g/Mg steel	1	780	European Commission (2001)
PM$_{10}$	24	g/Mg steel	1	620	Kakareka (2008) applied on TSP
PM$_{2.5}$	21	g/Mg steel	1	550	Kakareka (2008) applied on TSP
BC	0.36	% of PM$_{2.5}$	0.18	0.72	US EPA (2011, file no.: 91153)
Pb	1.8	g/Mg steel	1.2	3	Theloke et al. (2008)
Cd	0.03	g/Mg steel	0.024	0.036	Theloke et al. (2008)
Hg	0.0018	g/Mg steel	0.00092	0.0028	Theloke et al. (2008)
As	0.18	g/Mg steel	0.12	0.24	Theloke et al. (2008)
Cr	0.16	g/Mg steel	0.1	0.4	Theloke et al. (2008)
Cu	0.02	g/Mg steel	0.001	0.46	European Commission (2001)
Ni	0.06	g/Mg steel	0.03	0.3	Theloke et al. (2008)
Zn	2.7	g/Mg steel	1.8	4.5	US EPA (2011, file no.: 2830510) applied on Pb
PCB	2.5	mg/Mg steel	0.01	5.0	European Commission (2012)
PCDD/F	0.69	µg I-TEQ/Mg steel	0.043	0.94	European Commission (2012)
Total 4 PAHs	0.10	g/Mg steel	0.05	0.20	European Commission (2012)

Note:
These PM factors represent filterable PM emissions only (excluding any condensable fraction (European Commission, 2001)).

Table 3.18   Tier 2 emission factors for source category 2.C.1 Iron and steel production, steel making, electric arc furnace, abated by dry ESP.

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.1	Iron and steel production			
Fuel	NA				
SNAP (if applicable)	040207 Electric furnace steel plant				
Technologies/Practices					
Region or regional conditions					
Abatement technologies	Dry ESP				
Not applicable					
Not estimated	NH₃, Se, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
NO_x	130	g/Mg steel	120	140	European Commission (2001)
CO	1.7	kg/Mg steel	0.74	3.9	European Commission (2001)
NMVOC	46	g/Mg steel	16	130	European Commission (2001)
SO_2	60	g/Mg steel	24	130	European Commission (2001)
TSP	30	g/Mg steel	1	780	European Commission (2001)
PM_{10}	24	g/Mg steel	1	620	Kakareka (2008) applied on TSP
$PM_{2.5}$	21	g/Mg steel	1	550	Kakareka (2008) applied on TSP
BC	0.36	% of $PM_{2.5}$	0.18	0.72	US EPA (2011, file no.: 91153)
Pb	0.018	g/Mg steel	0.0075	0.03	Theloke et al. (2008)
Cd	0.0015	g/Mg steel	0.001	0.002	Theloke et al. (2008)
Hg	0.024	g/Mg steel	0.018	0.027	Theloke et al. (2008)
As	0.0001	g/Mg steel	0.00005	0.00015	Theloke et al. (2008)
Cr	0.0013	g/Mg steel	0.0005	0.002	Theloke et al. (2008)
Cu	0.02	g/Mg steel	0.001	0.46	European Commission (2001)
Ni	0.005	g/Mg steel	0.0015	0.0075	Theloke et al. (2008)
Zn	0.027	g/Mg steel	0.011	0.045	US EPA (2011, file no.: 2830510) applied on Pb
PCB	2.5	mg/Mg steel	0.01	5.0	European Commission (2012)
PCDD/F	3.0	µg I-TEQ/Mg steel	0.04	6.0	European Commission (2012)
Total 4 PAHs	0.48	g/Mg steel	0.009	0.97	European Commission (2012)

Note:
These PM factors represent filterable PM emissions only (excluding any condensable fraction (European Commission, 2001)).

Table 3.19   Tier 2 emission factors for source category 2.C.1 Iron and steel production, steel making, electric arc furnace, abated by fabric filter.

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.1	Iron and steel production			
Fuel	NA				
SNAP (if applicable)	040207 Electric furnace steel plant				
Technologies/Practices					
Region or regional conditions					
Abatement technologies	Fabric filter (optimized)				
Not applicable					
Not estimated	NH₃, Se, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
NO_x	130	g/Mg steel	120	140	European Commission (2001)
CO	1.7	kg/Mg steel	0.74	3.9	European Commission (2001)
NMVOC	46	g/Mg steel	16	130	European Commission (2001)
SO_2	60	g/Mg steel	24	130	European Commission (2001)
TSP	30	g/Mg steel	1	780	European Commission (2001)
PM_{10}	24	g/Mg steel	1	620	Kakareka (2008) applied on TSP
$PM_{2.5}$	21	g/Mg steel	1	550	Kakareka (2008) applied on TSP
BC	0.36	% of $PM_{2.5}$	0.18	0.72	US EPA (2011, file no.: 91153)
Pb	1.5	g/Mg steel	0.6	2.4	Theloke et al. (2008)
Cd	0.12	g/Mg steel	0.081	0.16	Theloke et al. (2008)
Hg	0.076	g/Mg steel	0.057	0.086	Theloke et al. (2008)
As	0.0081	g/Mg steel	0.004	0.012	Theloke et al. (2008)
Cr	0.105	g/Mg steel	0.05	0.2	European Commission (2001)
Cu	0.02	g/Mg steel	0.001	0.46	European Commission (2001)
Ni	0.41	g/Mg steel	0.12	0.6	Theloke et al. (2008)
Zn	2.3	g/Mg steel	0.9	3.6	US EPA (2011, file no.: 2830510) applied on Pb
PCB	2.5	mg/Mg steel	0.01	5.0	European Commission (2012)
PCDD/F	3.0	µg I-TEQ/Mg steel	0.04	6.0	European Commission (2012)
Total 4 PAHs	0.48	g/Mg steel	0.009	0.97	European Commission (2012)

Note:
These PM factors represent filterable PM emissions only (excluding any condensable fraction (European Commission, 2001)).

Table 3.20 **Tier 2 emission factors for source category 2.C.1 Iron and steel production, steel making, electric arc furnace, abated by fabric filter.**

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.1	Iron and steel production			
Fuel	NA				
SNAP (if applicable)	040207 Electric furnace steel plant				
Technologies/Practices					
Region or regional conditions					
Abatement technologies	Fabric filter (retrofitted)				
Not applicable					
Not estimated	NH₃, Se, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
NO_x	130	g/Mg steel	120	140	European Commission (2001)
CO	1.7	kg/Mg steel	0.74	3.9	European Commission (2001)
NMVOC	46	g/Mg steel	16	130	European Commission (2001)
SO_2	60	g/Mg steel	24	130	European Commission (2001)
TSP	30	g/Mg steel	1	780	European Commission (2001)
PM_{10}	24	g/Mg steel	1	620	Kakareka (2008) applied on TSP
$PM_{2.5}$	21	g/Mg steel	1	550	Kakareka (2008) applied on TSP
BC	0.36	% of $PM_{2.5}$	0.18	0.72	US EPA (2011, file no.: 91153)
Pb	0.18	g/Mg steel	0.075	0.3	Theloke et al. (2008)
Cd	0.015	g/Mg steel	0.01	0.02	Theloke et al. (2008)
Hg	0.0016	g/Mg steel	0.0012	0.0018	Theloke et al. (2008)
As	0.001	g/Mg steel	0.0005	0.0015	Theloke et al. (2008)
Cr	0.013	g/Mg steel	0.005	0.02	European Commission (2001)
Cu	0.02	g/Mg steel	0.001	0.46	European Commission (2001)
Ni	0.05	g/Mg steel	0.015	0.075	Theloke et al. (2008)
Zn	0.27	g/Mg steel	0.11	0.45	US EPA (2011, file no.: 2830510) applied on Pb
PCB	2.5	mg/Mg steel	0.01	5.0	European Commission (2012)
PCDD/F	3.0	µg I-TEQ/Mg steel	0.04	6.0	European Commission (2012)
Total 4 PAHs	0.48	g/Mg steel	0.009	0.97	European Commission (2012)

Note:
These PM factors represent filterable PM emissions only (excluding any condensable fraction (European Commission, 2001)).

Rolling mills

This subsection presents two Tier 2 tables for hot and cold rolling mills.

Table 3.21   Tier 2 emission factors for source category 2.C.1 Iron and steel production, rolling mills, cold rolling mills.

Tier 2 emission factor					
	Code	Name			
NFR Source Category	2.C.1	Iron and steel production			
Fuel	NA				
SNAP (if applicable)	040208	Rolling mills			
Technologies/practicies	Cold rolling mills				
Region or regional conditions					
Abatement technologies					
Not applicable	HCH, PCB				
Not estimated	NOx, CO, NMVOC, SOx, NH3, PM10, PM2.5, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
TSP	96	g/Mg steel	30	300	European Commission (2001)

Note:
These PM factors represent filterable PM emissions only (excluding any condensable fraction (European Commission, 2001)).

Table 3.22   Tier 2 emission factors for source category 2.C.1 Iron and steel production, rolling mills, hot rolling mills.

Tier 2 emission factor					
	Code	Name			
NFR Source Category	2.C.1	Iron and steel production			
Fuel	NA				
SNAP (if applicable)	040208	Rolling mills			
Technologies/practicies	Hot rolling mills				
Region or regional conditions					
Abatement technologies					
Not applicable	HCH, PCB				
Not estimated	NOx, CO, SOx, NH3, PM10, PM2.5, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB, Total 4 PAHs				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	

NMVOC	7	g/Mg steel	2	20	European Commission (2001)
TSP	9	g/Mg steel	2	40	European Commission (2001)

Note:

These PM factors represent filterable PM emissions only (excluding any condensable fraction (European Commission, 2001)).

3.3.3 Abatement

A number of add-on technologies exist that are aimed at reducing the emissions of specific pollutants. The resulting emission can be calculated by replacing the technology specific emission factor with an abated emission factor as given in the formula:

$$EF_{technology\,abated} = \eta_{abatement} \times EF_{technology\,unabated} \tag{4}$$

This section presents default abatement efficiencies for a number of abatement options, applicable in this sector.

Sinter production

Table 3.23 shows abatement efficiencies for sinter plants. The abatement efficiencies for particulates are taken from the CEPMEIP study (Visschedijk *et al*., 2004). The efficiencies are calculated with respect to the 'older' plant, with only (multi-)cyclones installed. Emission factors for the conventional installation with ESP are provided in the Tier 2 estimate for sinter plants in Table 3.2. Abatement efficiencies for PCDD/F are taken from an earlier version of the Guidebook.

Table 3.23   Abatement efficiencies (η_{abatement}) for source category 2.C.1 Iron and steel production, sinter production.

Abatement technology	Pollutant	Efficiency	95% confidence interval		Reference
		Default value	Lower	Upper	
Moderate control of fugitive sources	particle > 10μm	70%	40%	85%	Visschedijk (2004)
	10μm > particle > 2.5μm	63%	25%	81%	Visschedijk (2004)
	2.5μm > particle	50%	0%	75%	Visschedijk (2004)
Effective control of fugitive sources	particle > 10μm	90%	80%	95%	Visschedijk (2004)
	10μm > particle > 2.5μm	88%	75%	94%	Visschedijk (2004)
	2.5μm > particle	80%	60%	90%	Visschedijk (2004)
"MEEP" moving ESP	PCDD/F	75%	25%	92%	EMEP/EEA (2006)
Injection of adsorbent	PCDD/F	92%	75%	97%	EMEP/EEA (2006)

Pig iron production

This section presents abatement efficiencies for the production of pig iron. For particulates, CEPMEIP emission factors were presented in Table 3.8 for the charging of the blast furnace and the tapping of pig iron together. In Table 3.24 below, abatement efficiencies are presented applicable to these emission factors.

Table 3.24 **Abatement efficiencies (η_{abatement}) for source category 2.C.1 Iron and steel production, pig iron production**

Tier 2 abatement efficiency					
	Code	Name			
NFR Source Category	2.C.1	Iron and steel production			
Fuel	NA				
SNAP (if applicable)	040202 040203	Blast furnace charging Pig iron tapping			
Abatement technology	**Pollutant**	**Efficiency** **Default value**	**95% confidence interval** **Lower**	**Upper**	**Reference**
Conventional plant (installation with average age; conventional de dusting, ESP, wet scrubber; some fugitives capturing	particle > 10µm	88%	76%	94%	Visschedijk (2004)
	10µm > particle > 2.5µm	81%	62%	90%	Visschedijk (2004)
	2.5µm > particle	76%	52%	88%	Visschedijk (2004)
Modern plant (BAT): high efficiency ESP or equivalent to control primary sourcers; fabric filters for fugitive emissions	particle > 10µm	98%	94%	99%	Visschedijk (2004)
	10µm > particle > 2.5µm	96%	81%	99%	Visschedijk (2004)
	2.5µm > particle	93%	64%	98%	Visschedijk (2004)

Blast furnace charging

Table 3.25 provides abatement efficiencies for heavy metals from the charging of the blast furnace. The particulate abatement efficiencies are calculated with respect to a plant with older technology (only multi-cyclones) using CEPMEIP data (Visschedijk *et al*., 2004).
Heavy metal abatement efficiencies are based on Kakareka *et al*. (1998) and calculated with respect to the unabated plants.

Table 3.25 **Abatement efficiencies (η_{abatement}) for source category 2.C.1 Iron and steel production, pig iron production, blast furnace charging**

Tier 2 abatement efficiency					
	Code	Name			
NFR Source Category	2.C.1	Iron and steel production			
Fuel	NA				
SNAP (if applicable)	040202 040203	Blast furnace charging Pig iron tapping			
Abatement technology	**Pollutant**	**Efficiency** **Default value**	**95% confidence interval** **Lower**	**Upper**	**Reference**
Venturi scrubber or ESP	Cd	96%	91%	98%	Kakareka (1998)
	Pb	95%	93%	98%	Kakareka (1998)
	Zn	95%	90%	98%	Kakareka (1998)
	Ni	94%	88%	97%	Kakareka (1998)
Includes dust suppression systems such as pressuce equalisation	Cd	99.6%	98%	100%	Kakareka (1998)
	Pb	99.6%	98%	100%	Kakareka (1998)
	Zn	99.7%	98%	100%	Kakareka (1998)
	Ni	99.6%	98%	100%	Kakareka (1998)

Steel making

This section presents abatement efficiencies for open hearth furnace and basic oxygen furnace steel plants. For the electric arc furnace, no abatement efficiencies are available.

Open hearth furnace

Abatement efficiencies are available for an open hearth furnace steel plant, when using an electrostatic precipitator. Efficiencies are calculated with respect to the uncontrolled emission factors.

Table 3.26   Abatement efficiencies ($\eta_{abatement}$) for source category 2.C.1 Iron and steel production, steel making, open hearth furnace

Tier 2 abatement efficiency						
	Code	Name				
NFR Source Category	2.C.1	Iron and steel production				
Fuel	NA					
SNAP (if applicable)	040205	Open heart furnace steel plant				
Abatement technology	**Pollutant**	**Efficiency**	**95% confidence interval**		**Reference**	
		Default value	**Lower**	**Upper**		
Electrostatic precipitator	particle > 10µm	99%	87%	100%	US EPA (1986)	
	10µm > particle > 2.5µm	99%	92%	100%	US EPA (1986)	
	2.5µm > particle	99%	92%	100%	US EPA (1986)	

Basic oxygen furnace

Abatement efficiencies are available from CEPMEIP data. Efficiencies are calculated with respect to an 'older' plant, with primary dust removal by scrubber with removal efficiency of around 97 % and limited capturing of secondary dust emissions.

Table 3.27   Abatement efficiencies ($\eta_{abatement}$) for source category 2.C.1 Iron and steel production, basic oxygen furnace steel plant

Tier 2 abatement efficiency						
	Code	Name				
NFR Source Category	2.C.1	Iron and steel production				
Fuel	NA					
SNAP (if applicable)	040206	Basic oxygen furnace steel plant				
Abatement technology	**Pollutant**	**Efficiency**	**95% confidence interval**		**Reference**	
		Default value	**Lower**	**Upper**		
Conventional plant (installation with average age; conventional de dusting, ESP, wet scrubber; some fugitives capturing	particle > 10µm	42%	0%	71%	Visschedijk et al. (2004)	
	10µm > particle > 2.5µm	42%	0%	71%	Visschedijk et al. (2004)	
	2.5µm > particle	42%	0%	71%	Visschedijk et al. (2004)	
Modern plant (BAT): high efficiency ESP or equivalent to control primary sourcers; fabric filters for fugitive emissions	particle > 10µm	80%	0%	96%	Visschedijk et al. (2004)	
	10µm > particle > 2.5µm	79%	0%	96%	Visschedijk et al. (2004)	
	2.5µm > particle	78%	0%	96%	Visschedijk et al. (2004)	

3.3.4 *Activity data*

Information on the production of sinter, pig iron and steel suitable for estimating emissions using the simpler estimation methodology (Tier 1) is widely available from United Nations statistical yearbooks or national statistics.

For sinter plants, standard international compilations of production statistics are available from:

• EUROSTAT – Brussels (Iron and Steel, Yearly statistics, Theme 4, Series C)

• International Iron and Steel Institute, Brussels

• Wirtschaftsvereinigung Stahl, Düsseldorf, Germany (Statistical yearbook from the Iron and Steel Industry)

• National statistics yearbooks

Further guidance is also provided by the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006), volume 3 on Industrial Processes and Product Use (IPPU), chapter 4.2.2.4, 'Choice of activity data'.

3.4 Tier 3 emission modelling and use of facility data

3.4.1 *Algorithm*

There are two different methods to apply emission estimation methods that go beyond the technology specific approach described above:

• detailed modelling of the processes described with the integrated iron and steel works;

• facility level emission reports.

Detailed process modelling

A Tier 3 emission estimate using process details will make separate estimates for the consecutive steps in the processes of sintering, iron making and steel making.

Facility level data

Where facility level emission data of sufficient quality (see the guidance chapter on QA/QC in Part A of the Guidebook) are available, it is good practice to use these data. There are two possibilities:

• facility reports cover all steel production in the country;

• facility level emission reports are not available for all integrated steel plants in the country.

If facility level data are covering all steel production in the country, it is good practice to compare the implied emission factors (reported emissions divided by the national steel production) with the default emission factor values or technology-specific emission factors. If the implied emission factors are outside the 95 % confidence intervals for the values given below, it is good practice to explain the reasons for this in the inventory report

If the total annual steel production in the country is not included in the total of the facility reports, it is good practice to estimate the missing part of the national total emissions from the source category, using extrapolation by applying:

$$E_{Total, pollutant} = \sum_{Facilities} E_{Facility, pollutant} + \left(National\ Production - \sum_{Facilities} Production_{Facility} \right) \times EF \quad (5)$$

Depending on the specific national circumstances and the coverage of the facility level reports as compared to the total national steel production, it is good practice to choose the emission factor (*EF*) in this equation from the following possibilities, in decreasing order of preference:

* technology specific emission factors, based on knowledge of the types of technologies implemented at the facilities where facility level emission reports are not available;

* the implied emission factor derived from the available emission reports:

$$EF = \frac{\sum_{Facilities} E_{Facility, pollutant}}{\sum_{Facilities} Production_{Facility}} \qquad (6)$$

* the default Tier 1 emission factor — this option should only be chosen if the facility level emission reports cover more than 90 % of the total national production.

3.4.2 Tier 3 emission modelling and use of facility data

Integrated steel plants are major industrial facilities and emission data for individual plants might be available through a pollutant release and transfer registry (PRTR) or another emission reporting scheme. When the quality of such data is assured by a well-developed quality assurance/quality control (QA/QC) system and the emission reports have been verified by an independent auditing scheme, it is good practice to use such data. If extrapolation is needed to cover all steel production in the country either the implied emission factors for the facilities that did report, or the emission factors as provided in the Tier 1 or Tier 2 approach could be used.

3.4.3 Activity data

Since PRTR generally do not report activity data, such data in relation to the reported facility level emissions are sometimes difficult to find. A possible source of facility level activity might be the registries of emission trading systems.

In many countries national statistics offices collect production data at the facility level but these are in many cases confidential. However, in several countries, national statistics offices are part of the national emission inventory systems and the extrapolation, if needed, could be performed at the statistics office, ensuring that confidentiality of production data is maintained.

4 Data quality

4.1   Completeness

Care should be taken to include all emissions. Emissions reported as 'included elsewhere' (IE) in this source category, should be reported in the combustion source category (chapter 1.A.2.a). It is good practice to check that this is indeed the case!

4.2   Avoiding double counting with other sectors

Care should be taken not to double count emissions. Emissions reported in this source category, should not be reported in the combustion source category (chapter 1.A.2.a) or be reported as IE. It is good practice to check that this is indeed the case!

4.3 Verification

4.3.1 Best Available Technique emission factors

This section discusses the Best Available Technique emission factors in the iron and steel industry. For processes within the industry, e.g. sintering, pelletising, pig iron production and steel making, the EU BREF document for the iron and steel industry (European Commission, 2001) gives typical emission ranges associated with using such techniques. These values are not given in this document because of the strong technology and abatement dependency of the emission levels. Also, these values are only given for some pollutants. Please refer to the BREF document (European Commission, 2001) for specific information.

4.4 Developing a consistent time series and recalculation

No specific issues.

4.5 Uncertainty assessment

No specific issues.

4.5.1 Emission factor uncertainties

No specific issues.

4.5.2 Activity data uncertainties

No specific issues.

4.6 Inventory quality assurance/quality control (QA/QC)

No specific issues

4.7 Gridding

No specific issues

4.8 Reporting and documentation

No specific issues

5 Glossary

Coating material	Fire-resistant material covering the interior of the furnace. The coating is repaired from time to time and removed after a limited number of cycles. The coating material used can contain tar but tar-free material is available.
Continuous casting	Slabs or non-flat products (billets) are cast directly from molten metal. Continuous casting not only saves time and energy but also improves the quality of the steel and increases the yield. Moreover, the process is more controllable. At the end of the refining process the ladle filled with molten steel is conveyed to the continuous casting machine. From a ladle mounted above the caster, the molten steel enters the tundish, whence it flows into the moulds. If necessary, certain alloying

	elements which become unstable when exposed to oxygen in the atmosphere, or which act only for a brief period, can be added at the last minute by introducing cored wire into the mould.
Deoxidizers	Substances used for removing oxygen from molten metals
Direct emissions	Stack emissions (i.e. Ducted gas flow), excludes fugitive emissions
Electric arc furnace	A furnace equipped with carbon electrodes between which a high voltage is applied. The resulting electric arc melts the scrap.
Iron run	Connection between the skimmer and the tilting runner.
Möller mixture	The complete package of basic materials for one smelter charge. A charge consists of a number of carriage loadings that are emptied into the smelter according to a specified scheme.
Pig iron	Crude iron obtained directly from the blast furnace and cast in moulds
Pressure equalisation	The equalisation of pressure in the vapour locks at the blast furnace top with atmospheric pressure.
Primary dust removal	Oxygen blowing with a vertical converter
Refractory lining	Fire-resistant coating of the converter. The coating contains tar.
Refractory material	Material used for closing a tap hole. The refractory material generally contains in coal and tar.
Runner coating	Fire resistant material used for coating the runners. This product also contains coal and tar.
Scrap method	Re-use of metals as raw material for the process.
Secondary dust removal	Oxygen blowing with a tilted converter during loading and tapping.
Skimmer	Tunnel shaped construction where the heavier pig iron is separated from the lighter slag floating on the iron.
Tilting runner	A bridge on the end of the iron runner where the mixers can be filled and exchanged. The mixer is a container placed on a railroad carriage used for transport to, for instance, the steel factory (basic oxygen furnace).
Trough	Covered guide between the oven and the skimmer.
Unabated emissions	Emissions from roof ventilation with a tilted converter with no secondary dust removal
VHO gas	Smelter gas enriched with coke oven gas with a varying composition. Both products contain small amounts of hydrogen sulphide, left over from cleaning processes.

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7 Point of enquiry

Enquiries concerning this chapter should be directed to the relevant leader(s) of the Task Force on Emission Inventories and Projection's expert panel on Combustion and Industry. Please refer to the TFEIP website (www.tfeip-secretariat.org) for the contact details of the current expert panel leaders.