Category		Title
NFR	1.B.1.b	Fugitive emissions from solid fuels: solid fuel transformation
SNAP	040201 040204	Coke oven (door leakage and extinction) Solid smokeless fuel
ISIC		
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1 Overview

This source category discusses emissions from coke ovens (only fugitive emissions including emissions from charging, door and lid leaks, off-take leaks, quenching, pushing soaking, decarbonisation and solid smokeless fuel production. Emissions from combustion stacks and preheater are included in chapter 1.A.1.c 'Manufacture of solid fuels and other energy industries'), emissions from the production of solid smokeless fuel (during coal carbonisation), and emissions from transformation processes.

Coke production in general can be divided into coal handling and storage, coke oven charging, coal coking, extinction of coke and coke oven-gas purification. Combustion in coke oven furnaces is treated in chapter 1.A.1.c; the fugitive emissions from leakage and extinction are covered by this chapter. Leakage and extinction lead to emissions of all major pollutants including heavy metals and POPs.

Solid smokeless fuel has been used for a long time by householders in open fire grates in the past (Parker, 1978). Fugitive emissions during coal carbonisation for the production of solid smokeless fuel are considered to be small. Very limited information is available. It is expected that the emissions include sulphur and nitrogen oxides, VOCs (NMVOC (non-methane volatile organic compounds) as well as methane), volatile heavy metals and POPs from coal. A coal carbonisation plant can be an important source of air contamination on a local scale.

The IPCC Refinement (IPCC, 2019) introduced several new processes such as solid to solid transformation and gasification. These methods cover non-greenhouse gases and have been implemented in this guidebook. For detailed information of the coverage of emission factors as well as reference to primary literature, refer to volume 2, chapter 4.3 of the IPCC Refinement.

2 Description of sources

This section describes the coke production process as well as the production process of solid smokeless fuel.

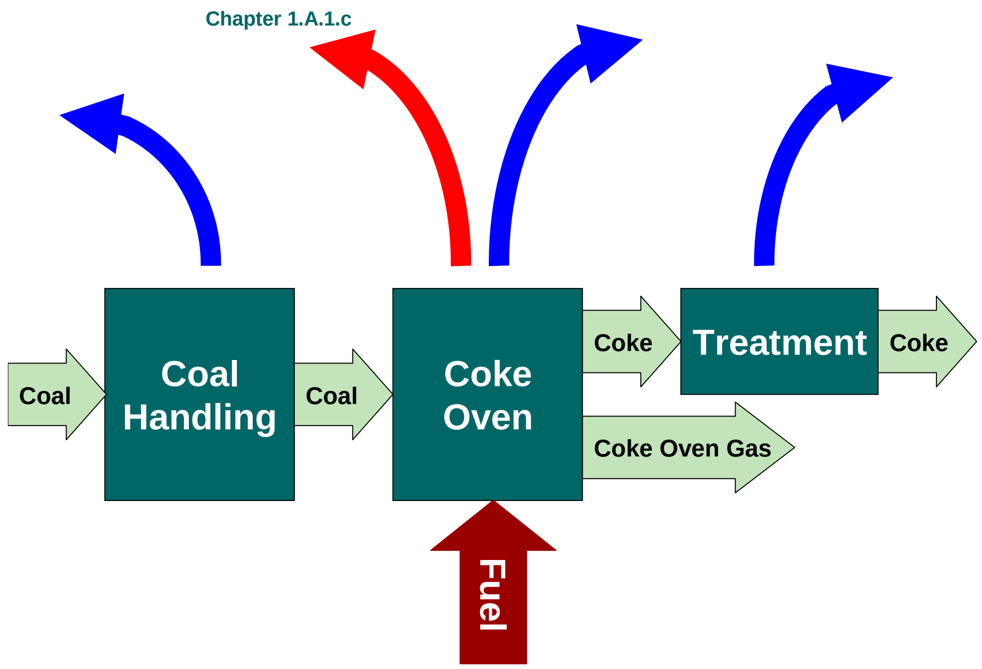
2.1 Process description

2.1.1 Coke oven

About 90 % of the coke consumed in the EU is used in pig iron production. The major part is used in blast furnaces, followed by iron foundries, non-ferrous smelters, and the chemical industry.

Figure 2-1 gives a simple process scheme, displaying the emissions from coke production.

Figure 2-1 Process scheme for coke production, the most important process within source category 1.B.1.b Solid fuel transformation; combustion emissions from the coke oven are treated in chapter 1.A.1.c



Coke and coke by-products (including coke oven gas) are produced by the pyrolysis (heating in the absence of air) of suitable grades of coal. The process also includes the processing of coke oven gas to remove tar, ammonia (usually recovered as ammonium sulphate), phenol, naphthalene, light oil, and sulphur before being used as a fuel for heating the ovens (World Bank Group, 1997).

For coke production, hard coal is crushed, mixed and sieved. The coal is transported to the coke oven, which is charged by the mixture. After heating for 14 to 36 hours at 1 150 –1 350 °C in the absence of oxygen, the coked mixture is pressed out of the coke chambers into special wagons. Subsequently, the hot coke will be extinguished.

The emissions related to coke production can be attributed to four sub-processes:

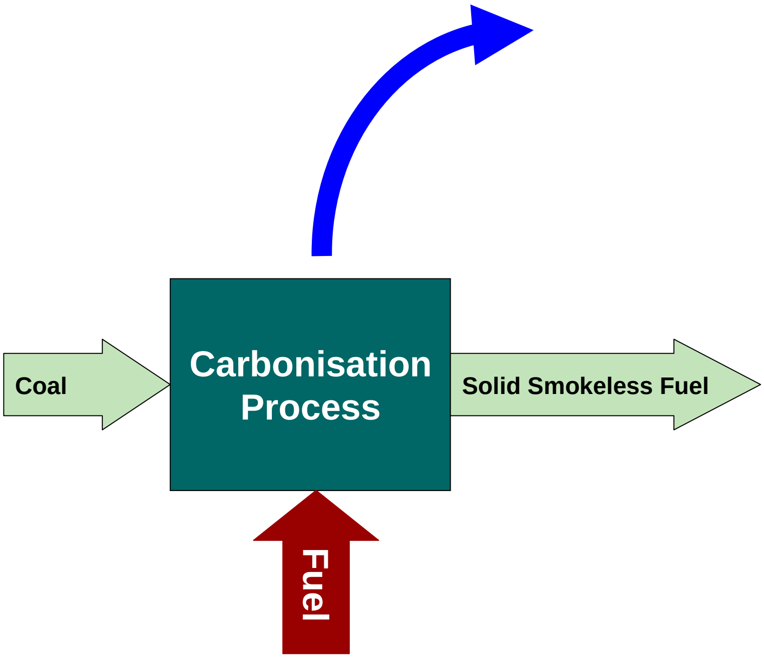
- coal handling and storage: emitting coal dust;
- coke production and extinction: emitting coal and coke dust and coke oven gas;
- coke oven gas handling and purification: emitting benzene, toluene, xylene, phenol, PAH (polycyclic aromatic hydrocarbons), H_2S, HCN and NH_3;
- combustion of coke oven gas: emitting C_xH_y, SO_2, NO_x, CO, CO_2, HF and soot.

Coke oven gas may be burned to heat the coke oven, or transferred off site (e.g. into the natural gas distribution system) and used as an energy source.

2.1.2 Solid smokeless fuel

Coal carbonisation to produce solid smokeless fuel occurs at high temperatures reaching 1 000 °C. There are three methods of coal carbonisation which differ considerably from each other. In the first method, the coal is carbonised in tubular iron retorts heated externally by the gas produced. In the second, the coal is in a large chamber and is heated by direct contact with the products of combustion of the gas made. In both cases the product reactive coke is screened to obtain sizes suitable for the open fire and for closed stoves. In the third method, the coal is carbonised by fluidization with hot gas from combustion of the coal gas made, and the relatively small particles are pressed to form briquettes (Parker, 1978). A general process scheme is given below.

Figure 2-2 Process scheme for the production of solid smokeless fuel from coal



There are also systems for making solid smokeless fuel in which only certain types of coal, for example anthracite duff, are briquetted with pitch at a suitable temperature and then carbonised.

Modern coal carbonisation plants are equipped with electrostatic precipitators that remove at least 98 % of the particulate matter from exhaust gases.

2.1.3 SOLID TO SOLID TRANSFORMATION PROCESSES

The following information has been extracted from the IPCC Refinement Volume 4 chapter 4.2.

CHARCOAL AND BIOCHAR PRODUCTION

Charcoal is produced by thermal decomposition (pyrolysis) in the absence of oxygen at high temperatures. During the process volatile compounds such as greenhouse gases, carbon monoxide and nitrogen oxides occur. Charcoal production can be poorly regulated with little or no emission control. The factors taken from the IPCC Refinement from solid to solid transformation process only covers emissions from inefficient charcoal manufacture. In industrialized countries charcoal production on large scales (in industrial plants) is often regulated, but smaller scale (domestic level) production through the use of traditional kiln technologies is normally poorly regulated.

Biochar is produced from harvested wood and applied to soils. Another rare use of biochar is making biochar briquettes for energy purposes. In retort kilns pyrolysis gases are led back to a combustion chamber and combusted internally to produce lower emissions.

2.1.4 GASIFICATION TRANSFORMATION PROCESSES

According to the IPCC Refinement Volume 4 chapter 4.2. gasification transformation processes are related to the transformation of biomass, coal or natural gas into syngas. Due to the transformation of energy systems, such conversion processes will be used more frequently. Possible emissions depend on the technologies used in the country and it is good practice to get plant specific information to estimate emissions. Based on the current state of knowledge this is mainly relevant for greenhouse gases. Tier 1 emission factors for air quality pollutants are not yet available. In the case of accessible country-specific measurement data this subcategory should be also considered.

2.2 Techniques

In the coke making process, bituminous coal is fed (usually after processing operations, which control the size and the quality of the feed) into a series of ovens. The coke oven itself is a chamber, built of heat resistant bricks, generally 0.4–0.7 m wide, 4–8 m high and 12–18 m long. A chamber has two doors, one at each end, covering almost the full cross-sectional area. In the roof, there are 3–5 charging holes and a gas outlet ('ascension pipe'). Commonly 40 to 70 chambers, alternating with heating walls, form a coke oven battery (Dutch notes on Best Available Techniques (BAT) 1997). Combustion of gases in burners in the flues between the ovens provides heat for the process. In order to improve the energy efficiency, regenerators are located right under the ovens, exchanging heat from flue gases with combustion air or fuel. Coke oven gas from the by-product recovery plant is the common fuel for under-firing the ovens at most plants, but blast furnace gas, and infrequently, natural gas may also be used (US Environmental Protection Agency (US EPA), 1985a).

The ovens are sealed and heated at high temperatures. The generation of steam, gases, and organic compounds starts immediately after charging and they are exhausted via ascension pipes into the crude gas collecting system (Dutch notes on BAT 1997). Volatile compounds are processed to recover combustible gases and other by-products. After coking, the vertical doors on each end of an oven are removed; a long ram pushes the coke from the oven into a rail quench car, which goes to a quench tower. There, large volumes of water are sprayed onto the coke mass to cool it, so that it will not continue to burn after being exposed to air. Alternatively, circulating an inert gas (nitrogen), also known as dry quenching, can cool it. Coke is screened and sent to a blast furnace or for storage.

The raw coke oven gas exits at temperatures of about 760 to 870 °C and is shock cooled by spraying recycled flushing liquor in the gooseneck. This spray cools the gas to 80 to 100 °C, precipitates tar, condenses various vapours, and serves as the carrying medium for the condensed compounds. These products are separated from the liquor in a decanter and are subsequently processed to yield tar and tar derivatives (US EPA 1985b, van Osdell et al. 1979).

The gas is then passed either to a final tar extractor or an electrostatic precipitator for additional tar removal. When the gas leaves the tar extractor, it carries 75 % of the ammonia and 95 % of the light oil originally present when leaving the oven. The ammonia is recovered either as an aqueous solution by water absorption or as ammonium sulphate salt. The gas leaving the saturator at about 60 °C is taken to final coolers or condensers, where it is typically cooled with water to approximately 24 °C. During this cooling, some naphthalene separates and is carried along with the wastewater and recovered. The remaining gas is passed into a light oil or benzene scrubber, over which is circulated a heavy petroleum fraction called wash oil or a coal-tar oil, which serves as the absorbent medium. The oil is sprayed in the top of the packed absorption tower while the gas flows up through the tower. The wash oil absorbs about 2 to 3 % of its weight of light oil, with a removal efficiency of about 95 % of the light oil vapour in the gas. The rich wash oil is passed to a counter current steam stripping column. The steam and light oil vapours pass upward from the still, through a heat exchanger to a condenser and water separator. The light oil may be sold as crude or processed to recover benzene, toluene, xylene, and solvent naphtha (US EPA 1985b, van Osdell et al. 1979).

After tar, ammonia, and light oil removal, the gas undergoes final desulphurisation (e. g. by the Claus process) at some coke plants before being used as fuel. The coke oven gas has a rather high heating value, in the order of 20 kJ/m^3 (STP). Typically, 35 to 40 % of the gas is returned to fuel the coke oven combustion system, and the remainder is used for other plant heating needs (US EPA 1985b, van Osdell et al. 1979).

Although most benzene is obtained from petroleum, some is recovered through distillation of coke oven light oil at coke by-product plants. Light oil is clear yellow-brown oil which contains coal gas components with boiling points between 0 and 200 °C (van Osdell et al. 1979). Most by-product plants recover light oil, but not all plants refine it. About 13–18 l of light oil can be produced from coke ovens producing 1 mg of furnace coke. Light oil itself contains from 60 to 85 % benzene (US EPA, 1985a; Loibl et al., 1993).

2.3 Emissions

The coke oven is a major source of fugitive emissions into the air. The coking process emits sulphur oxides (SO_x), nitrogen oxides (NO_x), volatile organic compounds (non-methane VOC and methane (CH_4)), carbon dioxide (CO_2), carbon monoxide (CO), ammonia (NH_3), particulate matter, and heavy metals. In general, emissions of nitrous oxide (N_2O) are not relevant. Coke ovens are an important source of PAH emissions (polycyclic aromatic hydrocarbons).

The components of coke oven gas (raw gas) and their concentrations are given in Table 2-1.

Table 2-1 Composition of raw coke oven gas (adapted from Winnacker, 1982)

Components of coke oven gas	Concentration [Vol.-%]
H_2	58–65
CH_4	24–29
CO	4.6–6.8
C_xH_y	2–4
CO_2	1.5–2.5

Besides these compounds, the following by-products are also components of the coke oven gas produced: tar, phenol, benzene, pyridine, ammonia, H_2S, HCN and CS_2 (carbon bisulphide) (Winnacker 1982). The by-product recovery section of a coking plant (e.g. ammonia processing, tar processing) may release significant amounts of NMVOC, CH_4, NH_3 and particulate matter (covered by SNAP code 040201).

Furthermore, continuous and discontinuous releases of emissions into the air can be distinguished (Dutch notes on BAT 1997):

Continuous emissions to air:

- emissions from storage and handling of raw materials and products,
- oven door and frame seal leakage,
- ascension pipe leakage,
- charging holes leakage,
- coke oven firing,
- vent systems in gas treatment plant,
- desulphurisation plant.

Discontinuous emissions to air:

- oven charging,
- coke pushing,
- coke cooling.

2.4 Controls

Charging:

- Dust particles from coal charging can be evacuated by the use of jumper-pipe system and steam injection into the ascension pipe or controlled by fabric filters (World Bank Group 1997).

Coking:

- Emissions decrease with the increase of the size of the ovens. Large ovens increase batch size and reduce the necessary charging and pushing, thereby reducing associated emissions. Emissions are also reduced by constant coking conditions, cleaning, and a low-leakage door construction e. g. with gas sealing (Dutch notes on BAT 1997).

Pushing:

- Emissions from coke pushing can be reduced by maintaining a sufficient coking time thus avoiding the so-called ‘green push’. Fugitive emissions can be controlled by sheds, enclosed cars or travelling hoods. It is good practice to treat captured gases in fabric filters (World Bank Group 1997).

Quenching:

- Dry quenching creates lower emissions compared to wet quenching. Gases released from the dry quenching unit can be extracted and filtered. In the case of wet quenching, measures have to be taken to prevent pollutant transfer from wastewater to the air (Dutch notes on BAT 1997).

By-product recovery:

- In the processing of light oil, tar, naphthalene, phenol, and ammonia, vapour recovery systems can be used. Tail gases from desulphurisation (Claus plant) can be returned to the coke oven gas system.

Combustion of coke oven gas:

- Flue gases from coke oven firing contain NO_x, SO_2 and particulate matter as main pollutants. SO_2 emissions depend on the degree of desulphurisation of the coke oven gas. NO_x emissions may be reduced by low-NO_x-firing techniques.

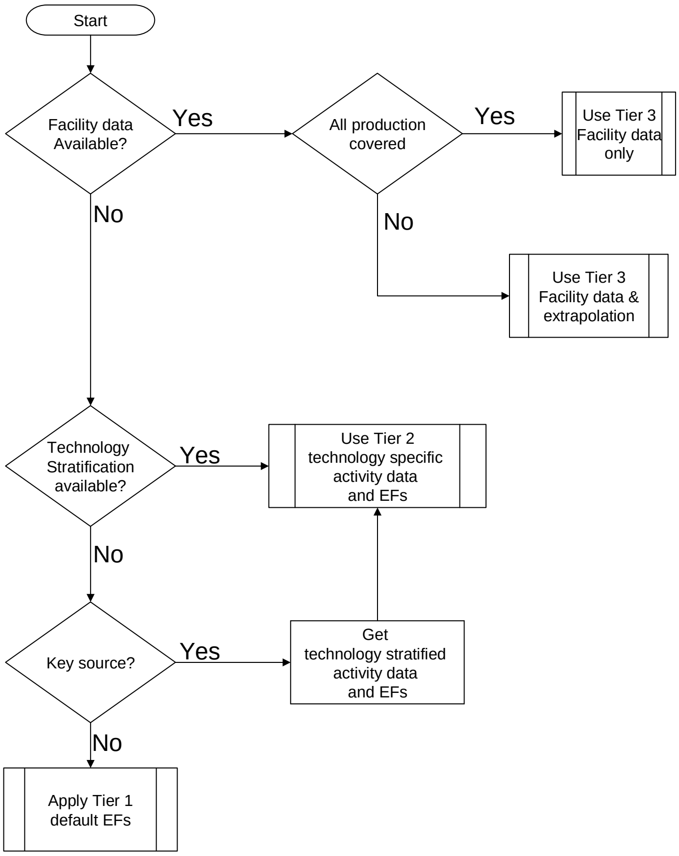
3 Methods

3.1 Choice of method

Figure 3-1 presents the procedure to select the methods for estimating emissions from solid fuel transformation. The basic idea is:

- if detailed information is available, use it;
- if the source category is a key category, a Tier 2 or better method must be applied and detailed input data must be collected. The decision tree directs the user in such cases to the Tier 2 method, since it is expected that it is easier to obtain the necessary input data for this approach than to collect facility level data needed for a Tier 3 estimate;
- the alternative of applying a Tier 3 method, using detailed process modelling, is not explicitly included in this decision tree. However, detailed modelling will always be done at facility level and results of such modelling could be seen as 'facility data' in the decision tree.

Figure 3-1 Decision tree for source category 1.B.1.b Solid fuel transformation



3.2 Tier 1 default approach

3.2.1 Algorithm

The Tier 1 approach for solid fuel transformation uses the general equation:

$$E_{pollutant} = AR_{production} \times EF_{pollutant} \quad (1)$$

where:

$E_{pollutant}$ = the emission of the specified pollutant,

$AR_{production}$ = the activity rate for the solid fuel transformation,

$EF_{pollutant}$ = the emission factor for this pollutant.

This equation is applied at the national level, using the total solid fuel transformation (usually expressed in mass of coal carbonised or mass of coke produced).

The Tier 1 emission factors assume an averaged or typical technology and abatement implementation in the country and integrate all different sub-processes within the solid fuel transformation process. In cases where specific abatement options are to be considered, a Tier 1 method is not applicable and a Tier 2 or Tier 3 approach must be used.

3.2.2 Default emission factors

This section presents the Tier 1 emission factors for solid fuel transformation. The production of coke is considered to be the most important process in this source category and is therefore used as the Tier 1 approach. In the Tier 2 approach, the production of solid smokeless fuel is also considered. Default emission factors for the main pollutants and HMs for coke production are taken from the BREF document for Iron and steel production (European Commission, 2012) and US EPA (2008). 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 table below. The default emission factor for BC[1] is taken from Kupiainen & Klimont (2004) and is based on the assumption, that $BC/PM_{2.5} = BC/PM_1$.

Default factors for charcoal and biochar production are retrieved from the IPCC Refinement Volume 4 chapter 2.3.

Default emission factors are estimated as the geometric mean of EFs from Theloke et al. 2008, Passant et al. (2002), European Commission (2012), Wenborn (1999), CITEPA (2011), Weitkamp et al. (2005), US EPA (2011) and US EPA (2008) and National Centre for Emission Management (2011).

Table 3-1 Tier 1 emission factors for source category 1.B.1.b Solid fuel transformation

Tier 1 default emission factors		
	Code	Name
NFR Source Category	1.B.1.b	Solid fuel transformation
Fuel	NA	
Not applicable		
Not estimated	PCB, HCB	

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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.

Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NOx	0.9	g/Mg coke	0.2	4.6	US EPA (2008)
CO	460	g/Mg coke	103	2110	European Commission (2012)
NMVOC	7.7	g/Mg coke	0.6	77	US EPA (2008)
SOx	0.8	g/Mg coke	0.21	3.5	European Commission (2012)
NH3	3.7	g/Mg coke	1	10	European Commission (2012)
TSP	347	g/Mg coke	75	1666	European Commission (2012)
PM10	146	g/Mg coke	31	714	European Commission (2012), Klimont et al. (2002)
PM2.5	61	g/Mg coke	13	290	European Commission (2012), Klimont et al. (2002)
BC	49	% of PM2.5	33	74	Kupiainen & Klimont (2004)
Pb	0.38	g/Mg coke	0.053	1.2	1)
Cd	0.007	g/Mg coke	0.002	0.05	1)
Hg	0.012	g/Mg coke	0.004	0.03	1)
As	0.013	g/Mg coke	0.002	0.1	1)
Cr	0.17	g/Mg coke	0.003	0.32	1)
Cu	0.048	g/Mg coke	0.007	0.09	1)
Ni	0.12	g/Mg coke	0.003	0.3	1)
Se	0.016	g/Mg coke	0.0016	0.16	1)
Zn	0.22	g/Mg coke	0.072	0.551	1)
PCDD/F	3	µg I-TEQ/Mg coke	0.3	10	UNEP (2005)
Benzo(a)pyrene	0.16	g/Mg coke	0.011	7.4	Wenborn (1999)
Benzo(b)fluoranthene	0.2	g/Mg coke	0.01	9.1	Wenborn (1999)
Benzo(k)fluoranthene	0.1	g/Mg coke	0.01	4.7	Wenborn (1999)
Indeno(1,2,3-cd)pyrene	0.07	g/Mg coke	0.01	3.4	Wenborn (1999)

1) Geometric mean value of EFs from Theloke et al. 2008, Passant et al. (2002), European Commission (2012), Wenborn (1999), CITEPA (2011), Weitkamp et al. (2005), US EPA (2001), US EPA (2008) and National Centre for Emission Management (2011)

Table 3-2 Tier 1 emission factors for source category 1.B.1.b Solid to solid transformation – charcoal production

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.B.1.b	Solid to solid transformation – charcoal production			
Fuel	charcoal				
Not applicable					
Not estimated	NMVOC, SOx, NH3, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCB, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB; TSP, PM10, PM2.5				
Pollutant	**Value**	**Unit**	**95% confidence interval 1)**		**Reference**
			Lower	**Upper**	
NOx	0.07	g/kg charcoal	0.03	0.11	IPCC Refinement 2019
CO	220	g/kg charcoal	106	337	IPCC Refinement 2019

[1]) The IPCC does not provide a range of the 95% confidence interval but minimum and maximum emission factors

Table 3-3 Tier 1 emission factors for source category 1.B.1.b Solid to solid transformation – biochar production

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.B.1.b	Solid to solid transformation – biochar production			
Fuel	biochar				
Not applicable					
Not estimated	NMVOC, SOx, NH3, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCB, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB; TSP, PM10, PM2.5				
Pollutant	**Value**	**Unit**	**95% confidence interval [1])**		**Reference**
			Lower	**Upper**	
NOx	0.4	g/kg biochar	0.1	0.7	IPCC Refinement 2019
CO	54	g/kg biochar	19	89	IPCC Refinement 2019

[1]) The IPCC does not provide a range of the 95% confidence interval but minimum and maximum emission factors

3.2.3 *Activity data*

Sources to activity data for the production of coke are standard statistics on coke production and fuel consumption (e.g. International Energy Agency, United Nations, Eurostat, International Iron and Steel Institute, etc.).

Information on the production of charcoal can be found on statistics from the FAO (https://www.fao.org/faostat/en/).

3.3 Tier 2 technology-specific approach

3.3.1 *Algorithm*

The Tier 2 approach is similar to the Tier 1 approach. To apply the 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.

The approach followed to apply a Tier 2 approach is as follows.

Stratify the solid fuel transformation in the country to model the different product and process types occurring in the national 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, for the specific technology,

$EF_{technology,pollutant}$ = the emission factor for this technology and this pollutant.

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

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

where:

$E_{pollutant}$ = the emission of the specified pollutant,

$AR_{production}$ = the activity rate for solid fuel transformation,

$EF_{pollutant}$ = the emission factor for this pollutant.

The emission factors in this approach will still include all sub-processes within the solid fuel transformation.

3.3.2 Technology-specific emission factors

This section presents the Tier 2 emission factors for emissions from solid fuel transformation. Eight separate processes are distinguished:

- Coal charging (Table 3-2)
- Door and lid leaks (Table 3-3)
- Off-take leaks (Table 3-4)
- Coke quenching (Table 3-5)
- Coke pushing (Table 3-6)
- Soaking (Table 3-7)
- Decarbonization (Table 3-8)
- Solid smokeless fuel production (Table 3-9)

Emission factors are provided in the tables below. Guidance for emissions from combustion including combustion stacks and preheaters is provided in source category 1.A.1.c.

Use of emission factors for the processes in coke oven plants provided by European Commission (2012) are preferred. When emission factors for other pollutants or processes are available in US EPA (2008), these have been included in the Tier 2 emission factor tables. European Commission (2012) includes emission levels for coke oven plants in EU Member States based on data from 2005, and the upper and lower limits reflect the different levels of abatements. Emission factors from US EPA (2008) refer to Pre-NESHAP controls unless otherwise specified in the tables, which seems to be in good agreement with the emission factor ranges in European Commission (2012), in cases where EFs are available in both sources and a comparison is possible.

Emission factors in the BREF document 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. When TSP emission factors are available in European

Commission (2012), the size distribution from US EPA (2008) has been used to estimate PM$_{10}$ and PM$_{2.5}$ emission factors.

For solid smokeless fuel production, very little information on emission factors is available. Parker (1978) indicates that the waste gases from heating a range of retorts carbonising 1 000 tonnes of coal per day would contain a quantity of sulphur dioxide of about 2.5 tonnes per day.

Table 3-4 Tier 2 emission factors for source category 1.B.1.b Solid fuel transformation, Coal charging

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.B.1.b	Solid fuel transformation			
Fuel	NA				
SNAP (if applicable)					
Technologies/Practices	Coal charging				
Region or regional conditions					
Abatement technologies	Unabated				
Not applicable					
Not estimated	NOx,BC,Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, PCDD/F, PCB, HCB				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
CO	2.7	g/Mg coke	0.1	71	European Commission (2012)
NMVOC	7.7	g/Mg coke	0.55	77	US EPA (2008)
SOx	0.1	g/Mg coke	0.01	1	European Commission (2012)
NH3	0.3	g/Mg coke	0.003	0.3	European Commission (2012)
TSP	1.7	g/Mg coke	0.3	10	European Commission (2012)
PM10	3.7	g/Mg coke	0.15	4.9	European Commission (2012), US EPA (2008)
PM2.5	2.9	g/Mg coke	0.12	3.9	European Commission (2012), US EPA (2008)

Table 3-5 Tier 2 emission factors for source category 1.B.1.b Solid fuel transformation, Door and lid leaks

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.B.1.b	Solid fuel transformation			
Fuel	NA				
SNAP (if applicable)					
Technologies/Practices	Door and lid leaks				
Region or regional conditions					
Abatement technologies	Unabated				
Not applicable					
Not estimated	NMVOC, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, PCDD/F, PCB, HCB				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NO_x	0.9	g/Mg coke	0.18	4.6	US EPA (2008)
CO	10.4	g/Mg coke	3	39	European Commission (2012)
SOx	0.7	g/Mg coke	0.2	2.5	European Commission (2012)
NH_3	0.6	g/Mg coke	0.2	1.8	European Commission (2012)
TSP	1.8	g/Mg coke	0.5	7	European Commission (2012)
PM_{10}	0.9	g/Mg coke	0.24	3.4	European Commission (2012), US EPA (2008)
$PM_{2.5}$	0.7	g/Mg coke	0.2	2.7	European Commission (2012), US EPA (2008)

Table 3-6 Tier 2 emission factors for source category 1.B.1.b Solid fuel transformation, Off-take leaks

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.B.1.b	Solid fuel transformation			
Fuel	NA				
SNAP (if applicable)					
Technologies/Practices	Off-take leaks				
Region or regional conditions					
Abatement technologies	Pre-NESHAP				
Not applicable					
Not estimated	NOx, CO, NMVOC, SOx, NH3, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCB, 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	7.7	g/Mg coke	1.9	31	US EPA (2008)

PM$_{10}$	3.8	g/Mg coke	0.9	15	US EPA (2008)
PM$_{2.5}$	3	g/Mg coke	0.7	12	US EPA (2008)

Table 3-7 Tier 2 emission factors for source category 1.B.1.b Solid fuel transformation, Coke quenching

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.B.1.b	Solid fuel transformation			
Fuel	NA				
SNAP (if applicable)					
Technologies/Practices	Coke quenching				
Region or regional conditions					
Abatement technologies	Unabated				
Not applicable					
Not estimated	NOx, NMVOC, SOx, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCB, 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**	
CO	447	g/Mg coke	100	2000	European Commission (2012)
NH$_3$	2.8	g/Mg coke	1	8	European Commission (2012)
TSP	22	g/Mg coke	10	50	European Commission (2012)
PM$_{10}$	5.1	g/Mg coke	2.3	11	European Commission (2012), US EPA (2008)
PM$_{2.5}$	4.3	g/Mg coke	1.9	10	European Commission (2012), US EPA (2008)

Table 3-8 Tier 2 emission factors for source category 1.B.1.b Solid fuel transformation, Coke pushing

Tier 2 emission factors		
	Code	Name
NFR Source Category	1.B.1.b	Solid fuel transformation
Fuel	NA	
SNAP (if applicable)		
Technologies/Practices	Coke pushing	
Region or regional conditions		
Abatement technologies	Hood and FF control	
Not applicable		
Not estimated	NOx, CO, NMVOC, SOx, NH3, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCB, 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	314	g/Mg coke	63	1568	US EPA (2008)
PM_{10}	136	g/Mg coke	27	680	US EPA (2008)
$PM_{2.5}$	52	g/Mg coke	10	260	US EPA (2008)

Table 3-9 Tier 2 emission factors for source category 1.B.1.b Solid fuel transformation, Soaking

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.B.1.b	Solid fuel transformation			
Fuel	NA				
SNAP (if applicable)					
Technologies/Practices	Soaking				
Region or regional conditions					
Abatement technologies	Unabated				
Not applicable					
Not estimated	NH3, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCB, 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**	
NO_x	0.5	g/Mg coke	0.1	3	US EPA (2008)
CO	1	g/Mg coke	0.2	5	US EPA (2008)
NMVOC	3	g/Mg coke	1	15	US EPA (2008)
SO_x	50	g/Mg coke	10	250	US EPA (2008)
TSP	8	g/Mg coke	2	40	US EPA (2008)
PM_{10}	8	g/Mg coke	2	40	US EPA (2008)
$PM_{2.5}$	8	g/Mg coke	2	40	US EPA (2008)

Table 3-10 Tier 2 emission factors for source category 1.B.1.b Solid fuel transformation, Decarbonization

Tier 2 emission factors		
	Code	Name
NFR Source Category	1.B.1.b	Solid fuel transformation
Fuel	NA	
SNAP (if applicable)		
Technologies/Practices	Decarbonization	
Region or regional conditions		
Abatement technologies	Unabated	
Not applicable		
Not estimated	NOx, NMVOC, SOx, NH3, TSP, PM_{10}, $PM_{2.5}$, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCB, 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**	
CO	15000	g/Mg coke	3000	75000	US EPA (2008)

Table 3-11 Tier 2 emission factors for source category 1.B.1.b Solid Fuel Transformation, Solid smokeless fuel

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.B.1.b	Solid fuel transformation			
Fuel	NA				
SNAP (if applicable)	040204	Solid smokeless fuel			
Technologies/Practices	Solid smokeless fuel				
Region or regional conditions					
Abatement technologies					
Not applicable					
Not estimated	NOx, CO, NMVOC, NH3, TSP, PM_{10}, $PM_{2.5}$, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCB, 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**	
SOx	2.5	kg/Mg coal carbonised	0.1	10	Parker (1978)

3.3.3 Abatement

Abatement efficiencies are estimated from emission factors for different controls included in US EPA (2008). As the emission factors in the Tier 2 tables are in good agreement with emission factors for Pre-NESHAP control in US EPA (2008), the abatement efficiencies are estimated as the improvement for a given technology related to Pre-NESHAP control.

Table 3-12 Tier 2 Abatement efficiencies for source category 1.B.1.b Solid Fuel Transformation, Coke quenching

Tier 2 Abatement efficiencies					
	Code	Name			
NFR Source Category	1.B.1.b	Solid fuel transformation			
Fuel	NA				
Technologies/Practices	Coke quenching				
Abatement technology	**Pollutant**	**Efficiency**	**95% confidence interval**		**Reference**
		Default value	**Lower**	**Upper**	
Clean water, tall tower, poor maintenance	TSP	72%	60%	80%	*US EPA (2008)*
Clean water, normal tower, proper maintenance	TSP	94%	85%	98%	*US EPA (2008)*
Dirty water, tall tower, poor maintenance	TSP	47%	35%	55%	*US EPA (2008)*

Dirty water, normal tower, proper maintenance	TSP	90%	80%	95%	*US EPA (2008)*

Table 3-13 Tier 2 Abatement efficiencies for source category 1.B.1.b Solid Fuel Transformation, Coke pushing

Tier 2 Abatement efficiencies					
	Code	Name			
NFR Source Category	1.B.1.b	Solid fuel transformation			
Fuel	NA				
Technologies/Practices	Coke pushing				
Abatement technologies	Hood and FF control				
Abatement technology	**Pollutant**	**Efficiency**	**95% confidence interval**		**Reference**
		Default value	**Lower**	**Upper**	
Hood and scrubber	TSP	17%	10%	25%	*US EPA (2008)*
Shed and FF	TSP	17%	10%	25%	*US EPA (2008)*

3.4 Tier 3 Emission modelling and use of facility data

This section provides Tier 3 information for coke production plants only. It is good practice to note again that only the fugitive emissions should be reported in this source category. It is good practice to report emissions from combustion within the coke production process in source category 1.A.1.c.

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 process;
- using 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 coke production process:

- coal handling,
- the coking process (without combustion),
- coke oven gas purification
- flaring or bypassing of coke oven gas.

For emissions of particulate matter, an even more detailed process split is available.

Facility-level data

Where facility-level emission data of sufficient quality are available (see chapter 6, Inventory management, improvement and QA/QC in part A), it is good practice to indeed use these data. There are two possibilities:

- the facility reports cover all the coke production facilities in the country;
- facility-level emission reports are not available for all coke production plants in the country.

If facility-level data are covering all coke production in the country, it is good practice to compare the implied emission factors (reported emissions divided by the national lime 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 coke 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 using extrapolation by applying:

$$E_{Total,pollutant} = \sum_{Facilities} E_{Facility,pollutant} + \left(National\ Production - \sum_{Facilities} Production_{Facility} \right) \times EF \qquad (4)$$

where

$E_{total,pollutant}$ = the total emission of a pollutant for all facilities within the source category,

$E_{facility,pollutant}$ = the emission of the pollutant as reported by a facility,

$Production_{total}$ = the production rate in the source category,

$Production_{facility}$ = the production rate in a facility,

$EF_{pollutant}$ = the emission factor for the pollutant.

Depending on the specific national circumstances and the coverage of the facility level reports as compared to the total national coke 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:

$$EF = \sum_{Facilities} E_{Facility,pollutant} \Big/ \sum_{Facilities} Production_{Facility} \qquad (5)$$

- the default Tier 2 emission factors.
- the default Tier 1 emission factor. It is only good practice to choose this option 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

To apply a Tier 3 method for process modelling, the use of AP-42 is advised. For more information on processes, abatements and emission factors, see US EPA (2008) and European Commission (2012).

3.4.3 Activity data

The detailed Tier 3 methodology needs activity statistics for each of the different sub processes. Detailed information about the local situation is necessary.

4 Data quality

4.1 Completeness

When applying a Tier 3 methodology, it is important to make sure that all relevant processes are included in the emission calculations.

4.2 Avoiding double counting with other sectors

Care should be taken not to double count emissions from this process. Emissions from the combustion in the coke production should be reported in source category 1.A.1.c.

4.3 Verification

4.3.1 Best Available Technique emission factors

Information on Best Available Technique for coke production plants is available from the reference document for Best Available Technologies in the iron and steel industry (European Commission (2012)).

Achievable emission levels associated with the use of BAT are available in this document for sub processes within the coke production.

4.4 Developing a consistent time series and recalculation

No specific issues.

4.5 Uncertainty assessment

4.5.1 Emission factor uncertainties

The uncertainty in the emission factors is estimated to be B–C. The General Guidance chapter on Uncertainties does provide information on how to quantify these quality ratings.

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

Coke oven gas	The gas formed during coking of coal
Extinction of coke	Cooling of the hot coke after removal from the coke chambers
Production of coke	Heating of coal mixtures in absence of oxygen at high temperatures

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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.