

SNAP CODE: 040207

SOURCE ACTIVITY TITLE: PROCESSES IN IRON & STEEL INDUSTRIES & COLLIERIES
Electric Furnace Steel Plant

NOSE CODE: 105.12.07

NFR CODE: 2 C 1

1 ACTIVITIES INCLUDED

The electric steel furnace is a part of the production process for primary iron and steel. Figure 1.1 in the Introduction of the Guidebook shows a flow sheet of an integrated iron and steel plant. The block where scrap is added, is where the electric furnace is situated. The figures 5.3 and 5.4 in the Guidebook Introduction show a more detailed picture of an electric furnace.

2 CONTRIBUTION TO TOTAL EMISSIONS

Electric furnaces contribute substantially to the total emission of particulates (PM), cadmium, chromium, zinc, hexachlorobenzene and dioxins and furans (see Tables 2.1-2.3).

Table 2.1: Contribution to total emissions of the CORINAIR90 inventory (28 countries)

Source-activity	SNAP-code	Contribution to total emissions [%]							
		SO ₂	NO _x	NMVOC	CH ₄	CO	CO ₂	N ₂ O	NH ₃
Electric Furnace Steel Plant	040207	0	0.1	0	-	0.6	-	-	-

0 = emissions are reported, but the exact value is below the rounding limit (0.1 per cent)

- = no emissions are reported

Table 2.2: Contribution to total heavy metal (HM) emissions of the OSPARCOM-HELCOM-UNECE Emission Inventory (38 countries; Berdowski et al; ref. 17)

Source-activity	SNAP-code	Contribution to total emissions [%]								
		dust ¹	Cd	Hg	Pb	As	Cr	Cu	Ni	Zn
Electric Furnace Steel Plant	040207	9	7	2	2	1	28	1	1	16

¹⁾ contribution of total iron and steel industry to total European (excluding the former U.S.S.R.) PM₁₀ emission (ref. 18)

0 = emissions are reported, but the exact value is below the rounding limit (0.5 per cent)

- = no emissions are reported

Table 2.3: Contribution to total POP emissions of the OSPARCOM-HELCOM-UNECE Emission Inventory (38 countries; Berdowski et al.; ref. 17)

Source-activity	SNAP-code	Contribution to total emissions [%]	
		Hexachlorobenzene	Dioxins/Furans
Electric Furnace Steel Plant	040207	3	3

0 = emissions are reported, but the exact value is below the rounding limit (0.5 per cent)

Electric furnace steel plant are unlikely to be a significant source of sulphurhexafluoride (SF₆), hydrofluorocarbons (HFCs) or perfluorocarbons (PFCs), (ETC/AEM-CITEPA-RISOE 1997; ref. 19).

3 GENERAL

3.1 Description

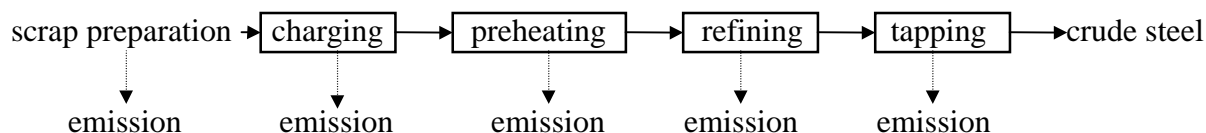
In an electric arc furnace non-alloyed, and low-alloyed steel is produced from polluted scrap. The scrap is mainly produced by shredding cars and does not have a constant quality.

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. The process is a batch process. Each cycle consists of the same steps: charging of scrap, preheating, refining with addition of other material and tapping (see figure 3.1).

Emissions are produced during each step of a cycle. Several abatement techniques are used to reduce the dust emissions (see Section 3.5).

The interior of the furnace is covered with fire-resistant coating.

Figure 3.1. The steps in a production cycle of an electric arc furnace.



3.2 Definitions

Electric arc furnace: A furnace equipped with carbon electrodes between which a high voltage is applied. The resulting electric arc melts the scrap.

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.

3.3 Techniques

The techniques used are extensively described in literature.

3.4 Emissions

Besides carbon monoxide and carbon dioxide, dust is the main emission. Sixty percent of the dust particles are smaller than ten micron. Because polluted scrap is used, the dust contains heavy metals such as lead and zinc. Also copper, chromium, nickel, arsenic, cadmium, and mercury are present.

Small amounts of hexachlorobenzene and dioxins and furans are also emitted. 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.

3.5 Controls

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 3.1 lists the overall efficiency of several abatement technologies.

Table 3.1. Abatement technologies and their efficiencies for complete electric furnace steel plants (assuming good housekeeping).

Abatement technology	efficiency (%)
fabric filter	95% ¹
electrostatic precipitators (ESP)	>95% ¹
doghouse, suction hood and fabric filter	>99.5% ¹
fibrous filter and post-combustion	>95% ¹

¹) abatement for PM (and for most HM, but not for As and Hg)

4 SIMPLER METHODOLOGY

A simpler method would be based on multiplying an overall emission factor (related to secondary steel production) with production statistics of secondary steel. However, owing to the variations in composition of the ore and the scrap, no general applicable information can be given. At this stage no breakdown of emission factor depending on ore and/or scrap composition is available.

5 DETAILED METHODOLOGY

Extensive measurements in a local situation will provide better information. Another way of estimating the emissions is using a mass balance. A third way is by estimating the emissions for each step of a production cycle.

6 RELEVANT STATISTICS

The electric energy comes from an external power plant. For preheating of the scrap natural gas (heat content 31.65 MJ/m³) is used. The amount used is about 3 - 7 m³ per ton scrap.

Simpler methodology

The production statistics needed is the total secondary steel production of the country and a way to distribute this production over the plants (e.g. capacity per plant).

Detailed methodologies

Needed for: method 1 - Per plant measurements

method 2 - All flows going in and out of each plant

method 3 - The amount of product in each step of the production cycle

For the third methodology some information is presented in the tables.

7 POINT SOURCE CRITERIA

All electric (arc) furnace plants should be considered as point sources.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

From the smelters in the Netherlands about 2,800 ton dust a year is captured. The dust production can be calculated to be about 11.6 kg/ton steel. The abated dust emission is about 0.64 kg/ton steel produced (abatement efficiency 95%). From this figure emission factors for heavy metals have been calculated.

Table 8.1. Emission factors for (in)direct greenhouse gases plus SO_x from electric arc furnaces.

Plant type	Compound	Emission factor g/Mg	Data Quality	Abatement type	Abatement efficiency	Fuel type	country or region	Ref.
us ⁷	SO _x	350	D	unknown	unknown	unknown	USA	15
stack, cs ⁶	SO _x	350	D	unknown	unknown	unknown	unknown	15
us ⁷	SO ₂	28-350 ¹	D	unknown	unknown	unknown	unknown	15
us ⁷	SO ₂	130	D	unknown	unknown	unknown	Switzerland	5
us ⁷	SO ₂	130	D	unknown	unknown	unknown	Netherlands	3
us ⁷	NO _x	200	D	unknown	unknown	unknown	unknown	15
stack, cs ⁶	NO _x	50	D	unknown	unknown	unknown	unknown	15
us ⁷	NO _x	80-820 ²	D	unknown	unknown	unknown	unknown	15
us ⁷	NO _x	220	D	unknown	unknown	unknown	Switzerland	5
us ⁷	NO _x	470	D	unknown	unknown	unknown	Netherlands	3
us ⁷	NM VOC	90	D	unknown	unknown	unknown	unknown	15
us ⁷	NM VOC	170	D	unknown	unknown	unknown	unknown	15
us ⁷	NM VOC	33-180 ³	D	unknown	unknown	unknown	unknown	15
us ⁷	NM VOC	80	D	unknown	unknown	unknown	Switzerland	5
charging, us ⁷	VOC	0.5	D	unknown	unknown	unknown	unknown	15
tapping, us ⁷	VOC	1	D	unknown	unknown	unknown	unknown	15
stack, cs ⁶	VOC	175	D	unknown	unknown	unknown	unknown	15
us ⁷	VOC	58	D	unknown	unknown	unknown	Netherlands	3
us ⁷	CH ₄	10	D	unknown	unknown	unknown	unknown	15
us ⁷	CH ₄	10	D	unknown	unknown	unknown	unknown	15
us ⁷	CO	10000	D	unknown	unknown	unknown	unknown	15
carbon steel	CO	9000	D	unknown	unknown	unknown	unknown	15
us ⁷	CO	1000-11500 ⁴	D	unknown	unknown	unknown	unknown	15
us ⁷	CO	1000	D	unknown	unknown	unknown	Switzerland	5
us ⁷	CO	1500	D	unknown	unknown	unknown	Netherlands	3
us ⁷	CO ₂	150000-220000	D	unknown	unknown	unknown	Denmark	6
us ⁷	CO ₂	2000-100000 ⁵	D	unknown	unknown	unknown	unknown	15
us ⁷	CO ₂	100000	D	unknown	unknown	unknown	Switzerland	5
us ⁷	CO ₂	1400000	D	unknown	unknown	unknown	Netherlands	3
us ⁷	N ₂ O	5	D	unknown	unknown	unknown	unknown	15

¹⁾ suggested value: 130 g/Mg

²⁾ suggested value: 200 g/Mg

³⁾ suggested value: 90 g/Mg

⁴⁾ suggested value: 10000 g/Mg

⁵⁾ suggested value: 50000 g/Mg

⁶⁾ cs is carbon steel

⁷⁾ us is unknown type of steel

Table 8.2. Emission factors for heavy metals from electric arc furnaces.

Plant type	Compound	Emission factor g/Mg	Data Quality	Abatement type	Abatement efficiency	Fuel type	country or region	Ref.
ccs ¹	As	0.1	E	unknown	unknown	unknown	Netherlands	1
ccs ¹	Cd	0.25	E	unknown	unknown	unknown	Netherlands	1
ccs ¹	Cr	1	E	unknown	unknown	unknown	Netherlands	1
ccs ¹	Cu	0.8	E	unknown	unknown	unknown	Netherlands	1
ccs ¹	Hg	0.15 ¹	E	unknown	unknown	unknown	Netherlands	1
ccs ¹	Ni	0.25	E	unknown	unknown	unknown	Netherlands	1
ccs ¹	Pb	14	E	unknown	unknown	unknown	Netherlands	1
ccs ¹	Se	0.05	E	unknown	unknown	unknown	Netherlands	1
ccs ¹	Zn	50	E	unknown	unknown	unknown	Netherlands	1
ss ²	As	0.015	E	unknown	unknown	unknown	Netherlands	1
ss ²	Cd	0.07	E	unknown	unknown	unknown	Netherlands	1
ss ²	Cr	15	E	unknown	unknown	unknown	Netherlands	1
ss ²	Cu	0.5	E	unknown	unknown	unknown	Netherlands	1
ss ²	Hg	0.15 ¹	E	unknown	unknown	unknown	Netherlands	1
ss ²	Ni	5	E	unknown	unknown	unknown	Netherlands	1
ss ²	Pb	2.5	E	unknown	unknown	unknown	Netherlands	1
ss ²	Se	0.05 ¹	E	unknown	unknown	unknown	Netherlands	1
ss ²	Zn	6	E	unknown	unknown	unknown	Netherlands	1
us ³	As	0.048	E	uncontrolled	0%	unknown	Netherlands	3
us ³	As	0.002	E	fabric filter	95%	unknown	Netherlands	3
us ³	Cd	0.086	E	uncontrolled	0%	unknown	Netherlands	3
us ³	Cd	0.004	D	fabric filter	95%	unknown	Netherlands	3
us ³	Cd	0.39	E	unknown	unknown	unknown	} United	12
us ³	Cd	0.22	E	unknown	unknown	unknown	} Kingdom	12
us ³	Cd	0.23	D	unknown	91%	unknown	Switzerland	5
us ³	Cr	0.61	E	uncontrolled	0%	unknown	Netherlands	3
us ³	Cr	0.03	D	fabric filter	95%	unknown	Netherlands	3
us ³	Cr	0.12 - 7.9	E	unknown	unknown	unknown	Poland	4
us ³	Cu	0.55	E	uncontrolled	0%	unknown	Netherlands	3
us ³	Cu	0.03	D	fabric filter	95%	unknown	Netherlands	3
us ³	Cu	0.05 - 3.1	E	unknown	unknown	unknown	Poland	4
us ³	Hg	0.0048	E	uncontrolled	0%	unknown	Netherlands	3
us ³	Hg	0.0002	E	fabric filter	95%	unknown	Netherlands	3
us ³	Hg	1	E	unknown	unknown	unknown	Switzerland	5
us ³	Ni	0.086	E	uncontrolled	0%	unknown	Netherlands	3
us ³	Ni	0.004	D	fabric filter	95%	unknown	Netherlands	3
us ³	Pb	18	E	uncontrolled	0%	unknown	Netherlands	3
us ³	Pb	1	D	fabric filter	95%	unknown	Netherlands	3
us ³	Pb	0.08 - 5.5	E	unknown	unknown	unknown	Poland	4
us ³	Pb	21	E	unknown	unknown	unknown	} United	12
us ³	Pb	12	E	unknown	unknown	unknown	} Kingdom	12
us ³	Pb	31	D	unknown	91%	unknown	Switzerland	5
us ³	Zn	190	E	uncontrolled	0%	unknown	Netherlands	3
us ³	Zn	11	D	fabric filter	95%	unknown	Netherlands	3
us ³	Zn	0.37 - 24	E	unknown	unknown	unknown	Poland	4
us ³	Zn	94	D	unknown	91%	unknown	Switzerland	5

¹⁾ ccs is carbon & construction steel

²⁾ ss is stainless steel

³⁾ us is unknown type of steel

Table 8.3. Emission factors for dust from electric arc furnaces.

Plant type	Compound	Emission factor g/Mg	Data Quality	Abatement type	Abatement efficiency	Fuel type	country or region	Ref.
charging, us ⁴	dust	100 - 300	E	unknown	unknown	unknown	France	11
tapping, us ⁴	dust	60 - 130	E	unknown	unknown	unknown	France	11
ccs ¹	dust	60 - 200	E	unknown	unknown	unknown	Sweden	2
stack, cs ²	dust	25000	E	unknown	unknown	unknown	unknown	15
ss ³	dust	30 - 900	E	unknown	unknown	unknown	Sweden	2
us ⁴	dust	120 - 150	D	filter	unknown	unknown	Denmark	6
us ⁴	dust	6000 - 20000	E	unknown	unknown	unknown	France	11
us ⁴	dust	11000 - 23000	E	uncontrolled	unknown	unknown	Germany	9
us ⁴	dust	610	E	uncontrolled	0%	unknown	Netherlands	3
us ⁴	dust	30	D	fabric filter	95%	unknown	Netherlands	3
us ⁴	dust	1300	D	unknown	91%	unknown	Switzerland	5

¹⁾ ccs is carbon & construction steel

²⁾ cs is carbon steel

³⁾ ss is stainless steel

⁴⁾ us is unknown type of steel

Table 8.4. Emission factors for dioxins and furans and benzo(a)pyrene from electric arc furnaces.

Plant type	Compound	Emission factor µg I-TEQ/Mg	Data Quality	Abatement type	Abatement efficiency	Fuel type	country or region	Ref.
us ¹	dioxins/fur.	5 ⁴	E	unknown	unknown	unknown	Belgium	13
us ¹	dioxins/fur.	6	E	unknown	unknown	unknown	France	7
us ¹	dioxins/fur.	0.15 - 1.8	C	fabric filter	unknown	unknown	Germany	13
us ¹	dioxins/fur.	0.068 - 0.23	C	ESP	unknown	unknown	Germany	13
us ¹	dioxins/fur.	2	E	semi-abated	unknown	unknown	Netherlands	16
us ¹	dioxins/fur.	20	E	semi-abated	unknown	PVC cont.	Netherlands	16
us ¹	dioxins/fur.	0.7	E	unknown	unknown	no Cl ₂	} United	13
us ¹	dioxins/fur.	10	E	unknown	unknown	high Cl ₂	} Kingdom	13
us ¹	dioxins/fur.	0.2 - 8.6 ²	E	unknown	unknown	unknown	Sweden	13
us ¹	dioxins/fur.	11	E	unknown	unknown	unknown	Switzerland	5,13
us ¹	B(a)p ³	17 ³	E	unknown	unknown	unknown	Czech Rep.	8

¹⁾ unknown type of steel

²⁾ ng NTEQ/Mg

³⁾ B(a)p (benzo(a)pyrene) in mg/Mg

⁴⁾ value based on data from Sweden and the Netherlands; the range is 0.1 - 50 µg I-TEQ/Mg

9 SPECIES PROFILES

Comparison of species profiles with local information about ore and scrap compositions might be useful for verification purposes. However, no generalised information is available. See Table A.2 in Annex A for an example of dust composition.

10 UNCERTAINTY ESTIMATES

The uncertainty differs per compound. It varies between a factor of 1.5 and 3.5.

Since most material is on Western European countries, it can only be applied to Southern and Central and Eastern European countries when no better information is available.

11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

The weakest aspect of the methodology is the lack of measurements in relation to the type of steel produced, the composition of the scrap/ore used in the furnace and the abatement.

For the simpler methodology a formula to calculate an emission factor based on ore/scrap composition used, steel type produced and abatement used would be very useful. Ideally the formula would be in this form:

$E.F. = \hat{a} \cdot [x]_{in} \cdot f_x \cdot PM \cdot \zeta_x$ with \hat{a} is an enrichment factor, $[x]_{in}$ is concentration of metal x in ore/scrap, f_x is a factor depending on concentration of metal x in steel produced, PM is the amount of particulates emitted and ζ_x is the abatement efficiency for compound x.

Not enough information is available to breakdown the emission factors for the total production cycle to emission factors for each step of a production cycle.

12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

The basic steel plants are to be regarded as point sources.

13 TEMPORAL DISAGGREGATION CRITERIA

Although the electric arc furnace is a discontinuous process, the smelter operation as such is a continuous process. The plant is operating 24 hours a day and 7 days a week.

14 ADDITIONAL COMMENTS

No additional comments

15 SUPPLEMENTARY DOCUMENTS

US Environmental Protection Agency, Compilation of air pollutant emission factors AP-42

16 VERIFICATION PROCEDURE

Verification of heavy metal emissions by comparing the profile of the emissions with ore and scrap compositions could be used as a verification method. A mass balance over the complete plant (one of the detailed methods) can be used as verification method.

17 REFERENCES

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18 BIBLIOGRAPHY

No additions to the general literature about iron and steel production.

19 RELEASE VERSION, DATE AND SOURCE

Version : 3.3

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Original and
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20 POINT OF ENQUIRY

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ANNEX A: CONCENTRATION DATA FOR COMPOUNDS IN FLUE GASES AND DUST

Table A.1. Compound concentration in the flue gas of electric arc furnaces.

Plant type	Compound	Concentration mg/m3	Data Quality	Abatement type	Abatement efficiency	Fuel type	country or region	Ref.
us ³	SO ₂	5 - 50	D	unknown	unknown	unknown	France	11
us ³	NO _x	50	D	unknown	unknown	unknown	France	11
us ³	dust	0.08	D	filter	unknown	unknown	Denmark	6
us ³	dust	500 - 15000	E	uncontrolled	unknown	unknown	Germany	
us ³	dust	0.7 - 13.5	D	}	97.4%	unknown	Germany	9
us ³	As	-	-	}	-	unknown	Germany	9
us ³	Cd	<0.001 - 0.015	C	} doghouse &	>92.5%	unknown	Germany	9
us ³	Cr	<0.001 - 0.008	C	} spark arrester	>98.4%	unknown	Germany	9
us ³	Ni	<0.001 - 0.003	C	} & bag &	>90%	unknown	Germany	9
us ³	Pb	0.04 - 0.7	C	} pocket filters	>93.6%	unknown	Germany	9
us ³	Zn	0.23 - 0.7	C	}	>98.5%	unknown	Germany	9
us ³	dust	2	C	)	99.9	unknown	Germany	9
us ³	As	<0.001	C	)	>95	unknown	Germany	9
us ³	Cd	<0.002	C	) doghouse &	>99.8	unknown	Germany	9
us ³	Cr	<0.002	C	) suction hood &	>99.9	unknown	Germany	9
us ³	Ni	<0.001	C	) fabric filter	>99.6	unknown	Germany	9
us ³	Pb	0.08	C	)	99.9	unknown	Germany	9
us ³	Zn	0.8	C	)	99.9	unknown	Germany	9
us ³	dioxins/fur.	0.016 - 0.26 ¹	C	fabric filter	unknown	unknown	Germany	13,14
us ³	dioxins/fur.	0.010 - 0.040 ¹	C	ESP	unknown	unknown	Germany	13,14
us ³	dioxins/fur.	2.3 ¹	D	fibrous filter	unknown	unknown	Luxembourg	13
us ³	dioxins/fur.	0.77 ¹	D	fibrous filter & post-combustion	unknown	unknown	Luxembourg	13
us ³	dioxins/fur.	0.04 ¹	E	unknown	unknown	unknown	Netherlands	13
us ³	dioxins/fur.	0.1 - 1 ²	E	unknown	unknown	unknown	Sweden	13

¹) ng I-TEQ/m³

²) ng NTEQ/m³

³) unknown type of steel

Table A.2. Concentration of heavy metals in dust (in wt.%).

	Cd	Cr	Cu	Ni	Pb	Zn	Country	Ref.
Low alloy steel	0.1	0.14 - 0.6	0.4	0.1	6.1-7.0	17 - 31	France	11
Stainless steel	0.03	13.7	0.3	3.8	1.9	1.9	France	11
Steel	0.017	unknown	unknown	unknown	2.3	7.0	Switzerland	5
Steel	0.02 - 0.1	unknown	unknown	unknown	1.3-3.7	unknown	UK	10

Table A.3. Concentration of dioxins/furans in filter dust.

Plant type	Compound	Emis. Factor µg I-TEQ/Mg filter dust	Data Quality	Abatement type	Abatement efficiency	Fuel type	country or region	Ref.
us ²	dioxins/fur.	1000 ¹	E	unknown	unknown	unknown	Sweden	13
us ²	dioxins/fur.	150	E	unknown	unknown	unknown	Netherlands	13
us ²	dioxins/fur.	74 - 1500	D	unknown	unknown	unknown	Germany	13

¹) ng NTEQ/Mg filter dust

²) unknown type of steel.