Stainless steel and CO_2:

Facts and scientific observations

ISSF

INTERNATIONAL STAINLESS STEEL FORUM

Stainless steel and CO_2: Facts and scientific observations

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Like any other industry, stainless steel aims to reduce its CO_2 emissions. The purpose of this document is to clarify what those emissions are and where they originate. In order to achieve these objectives, we have quantified the CO_2 emitted from the following three sources:

1. From the extraction and preparation of ores and production of ferro-alloys , including the electricity needed for these processes
2. From electricity consumed within the stainless steel industry
3. From the production process at stainless steel sites.

This study enables us to identify the main sources of CO_2 from the production of stainless steel and to better understand the stainless steel industry's contribution to carbon dioxide emissions from cradle to gate of the manufacturing sites.

General facts

Stainless is the term used to describe a remarkable and extremely versatile family of metals that contain a minimum of 10.5% chromium. Chromium is essential to achieve the metal's "stainless" properties. Other alloying elements (such as nickel, molybdenum and copper) provide a wide range of mechanical and physical properties.

Stainless steel has applications that range from household cutlery to reactor tanks for the chemical industry. Stainless steel's resistance to corrosion and staining, coupled with its low maintenance and 100% recyclability make it an ideal base material for many applications. Indeed, its mechanical properties promote the use of stainless steel in buildings and public works such as railways, subways, tunnels and bridges. Food storage tanks and transport vehicles are often made of stainless steel because it is easy to clean and has excellent hygienic properties. This leads to the use of stainless steel in commercial kitchens and food processing plants, as it can be steam cleaned, sterilised, and does not need any additional surface treatment (ISSF, 2009).

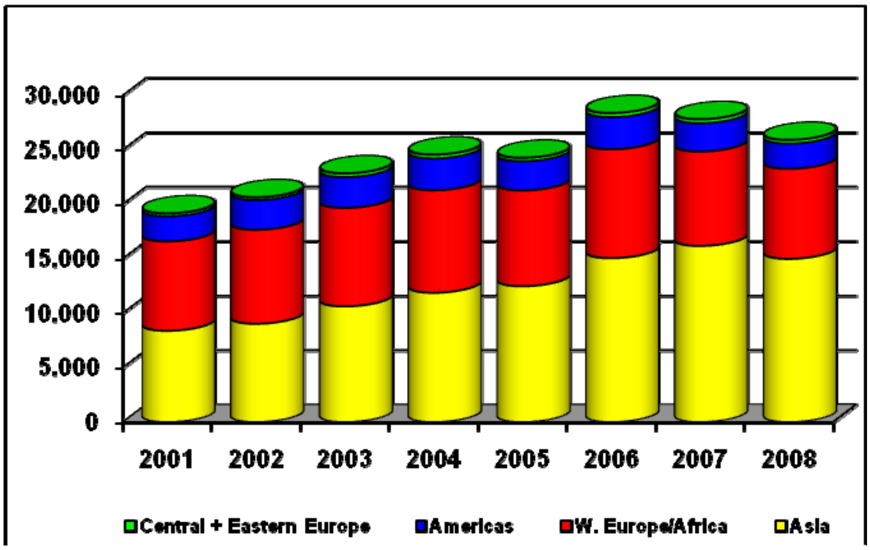
There are basically two ways to produce stainless steel: from ore-based primary raw material; or from recycled material. The first method uses a blast furnace (BF) and its main inputs are coal and ore. The second method utilises an electric arc furnace (EAF) and its main inputs are scrap steel and electricity. The EAF route is the main process used to make stainless steel. In fact, more than 80% (estimated) of all new stainless steel is made using the EAF method (ISSF, 2009).

For the stainless steel industry, scrap has a high intrinsic value. The only limitation is the availability of scrap, especially in emerging countries. The durability of stainless steel restricts the availability of scrap. For example, when stainless steel is used in buildings, it remains there for many years and cannot be reused before the building is dismantled.

Stainless steel is 100% recyclable and has one of the highest recycling rates of any material. It is estimated that at least 70% of stainless steels are recycled at the end of their life (see Table 1). Depending on the type, location and availability of stainless steel scrap, production via the EAF route can be economically advantageous. In addition, the recycling system for stainless steel is very efficient and requires no subsidies.

Over the past eight years the world has produced more than 190 million metric tons of stainless steel (see Figure 1). World production increased from less than 20 million tons to over 25 millions of tons in just eight years. The growth in the use of stainless steel has been the highest of any material in the world (ISSF, 2009). Stainless steel's properties, such as its 100% recyclability, reusability, durability, low maintenance and product safety, might explain this growth.

Figure 1: Crude stainless steel production, 2001-2008 in '000 metric tons



(Source: ISSF, 2009)

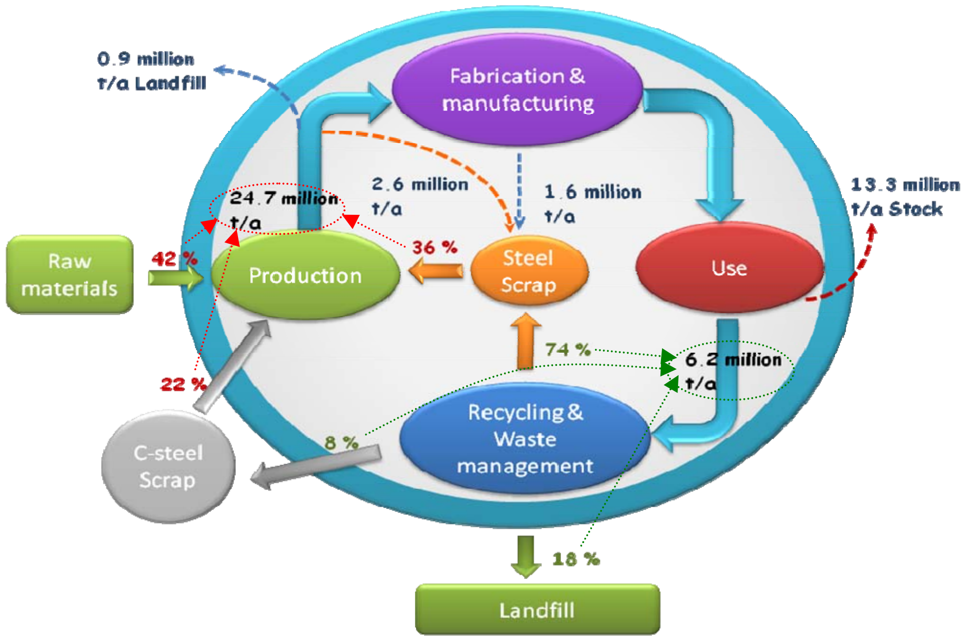
Stainless steel life-cycle

Yale University (2009) describes the stainless steel life-cycle by identifying the material's four main life-stages:

1. The production process which includes the entire stainless steel making process from crude production to finished flat and long products for use in manufacturing.
2. The fabrication and manufacturing process where the finished stainless steel is used in different end use sectors to produce final goods.
3. The use phase in which final goods are employed by the end user, and where the stainless steel remains for the lifetime of a given product.
4. The recycling and collection process where end-of-life products are either recycled or disposed of in landfill.

The generic life cycle of stainless steel is illustrated in Figure 2. The data shown in the figure relates to the movements of raw materials, end use products, recycled and waste stainless in 2005.

Figure 2: Life cycle of stainless steel, 2005.



(Source: Yale University/ISSF Stainless Steel Project, 2009)

Figure 2 shows that the flow of stainless steel is connected by the generation and use of scrap. According to the Yale study, around 60% of the materials to produce stainless steel are scrap (stainless steel and carbon steel scrap) and raw materials make up less than 45% of the material used to produce stainless steel. The research carried by Yale University (2009) also provides key estimates of the life cycle of stainless steel products in six main application sectors (see Table 1).

Table 1: Life cycle of stainless steel in main application sectors

Main application sectors	Use of finished SS in manufacturing	Average life (in years)	To landfill	Collected for recycling	
				Total	As stainless steel
Building	16%	50	8%	92%	95%
Transportation	21%	14	13%	87%	85%
Industrial machinery	31%	25	8%	92%	95%
Household appliances	6%	15	18%	82%	95%
Electronics	6%	-	40%	60%	95%
Metal goods	20%	15	40%	60%	80%
Total	100%	22	18%	82%	90%

(Source: Yale University/ISSF Stainless Steel Project, 2009)

CO_2 emissions

Over the last few decades, carbon dioxide emissions have become a major concern in society. As a consequence, new environmental policies have been established to control and measure CO_2 emissions. The stainless steel industry, just like any other industry, quantifies and communicates its emissions performance. Recent sustainability studies conducted by ISSF (in 2005 and 2007) show that emissions from the production and use of stainless steel are minimal.

In order to clearly quantify the CO_2 emissions during the production of stainless steel, we will identify the CO_2 emissions from:

- The extraction and preparation of ores and the production of ferro-alloys, including the electricity needed for these processes.
- The electricity production needed to produce stainless steel.
- The production processes at stainless steel sites

CO_2 emissions from the production of ore and ferro-alloys

This part of the stainless steel production process includes CO_2 emissions from raw material extraction and processes associated with the production of primary chromium and nickel, and carbon steel scrap. The electricity required for mining and ferro-alloy production is also included.

The main ingredients required to produce stainless steel are stainless steel scrap, carbon steel scrap and ferro-alloys such as ferro-nickel, ferro-chromium and ferro-molybdenum. The CO_2 emissions connected to the extraction of each material are shown in Table 2.

Table 2: CO_2 emissions from raw materials needed to produce stainless steel

Raw materials (CO_2 ton/ton)	Element content
8.7	32% Ni in ferro-Ni
6.0	56.5% Cr in ferro-Cr
8.5	67% Mo in ferro-Mo
1.4	100% Fe in carbon steel scrap

(Source: Ferronickel LCA data in 2003 revised from data year 2000 by Nickel Institute, LCI of primary Ferrochrome production in 2007 by ICDA, 2005 data from IMOA, CO_2 scrap value for LCI study of the World Steel Association 2000)

If stainless steel was to be produced solely from raw materials, the CO_2 emissions from the production of ferro-alloys would be 4.2 tons per ton of stainless steel. However, CO_2 emissions decrease as the amount of stainless scrap is increased.

On average, around 36 % of stainless steel scrap (ISSF Scrap Survey, 2008) is used to produce one ton of stainless steel. As a consequence, carbon dioxide emissions are **2.8 tons** per tons of stainless steel.

Due to the high recycling rate of stainless steel this represents a 33% reduction of CO_2 emissions (estimated by ISSF, 2009)

CO_2 emissions connected to the electricity required to produce stainless steel at the plant

The calculations in this section quantify the emissions produced during the upstream generation of the electricity that is used at the stainless steel site. Carbon dioxide emissions in electricity generation result from the combustion of gas and coal, as well as from nuclear and hydraulic sources of electricity. The amount of CO_2 emitted depends on the type of electricity used. Table 3 shows the CO_2 emitted by each type of electricity plant per mega joule of electricity generated.

Table 3: CO_2 emissions by type of electricity generation plant

Source of electricity	Grams of CO_2 per MJ
Hydraulic	1.11
Nuclear	1.67
Combined cycle	118.61
Natural gas	245.28
Fuel oil	247.50
Coal	271.67

(Source: International Energy Agency)

Electricity generation data and fuel consumption rates, provided by the International Energy Agency (IEA), were used to calculate the efficiency of electricity generation plants in different parts of the world.

Table 4: Electricity CO_2 emissions by country

	Europe	USA	China	Japan	World
CO_2 emissions (grams of CO_2/MJ)	145.7	189.1	228.9	175.4	177.6

(Source: SCM estimation from data provided by the IEA and EDF [French energy supplier])

Table 4 shows that the amount of CO_2 released differs greatly by country. On average, 177.6 grams of CO_2 are released to produce one MJ of electricity.

ISSF estimates that 3,700 MJ of electricity are required to produce one ton of stainless steel at the stainless steel plant. In Europe, where 30% of electricity comes from nuclear plants, 0.54 tons of CO_2 are released per ton of stainless steel produced. In China, where nuclear sources only represent 2% of electricity production, 0.85 tons of CO_2 are released per ton of stainless. Therefore, the amount of CO_2 emissions connected to the electricity required to produce stainless steel at the stainless steel plant has been calculated to be **0.65 tons** of CO_2 per ton of stainless steel.

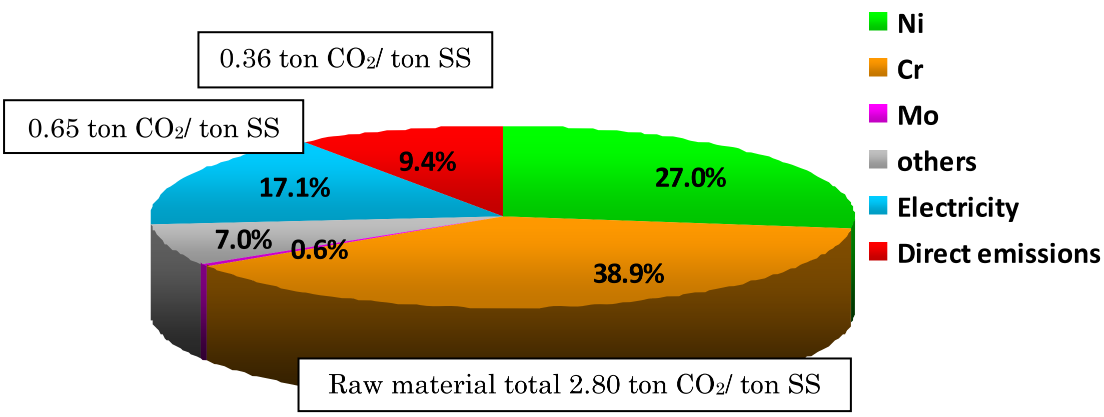
Direct production emissions

According to PE International (2009), the amount of CO_2 emitted during the production of stainless at the steel plant varies between 0.49 and 0.28 tons per ton of stainless. This includes CO_2 emissions from the use of fuel on the site where the stainless is produced. The exact volume depends on the type of product manufactured. ISSF measurements show similar values. ISSF calculates that average CO_2 emissions are **0.36 tons/ton** stainless steel.

The role of the stainless steel industry in CO_2 emissions

Figure 3 shows the share of CO_2 emissions between the three parts of the stainless steel production process: production of raw materials (Ni, Cr, Mo and others); electricity; and direct production.

Figure 3: Distribution of CO_2 emissions



(Source: Data provided by ISSF, estimates calculated by SCM)

From Figure 3 above, it is obvious that ore preparation and upstream activities offer the greatest potential to reduce CO_2 emissions.

Annex: Summary of results

Steel composition

% raw materials	42%
% carbon steel scrap	22%
% stainless scrap	36%

Production method

Blast furnace (BF)	11%
Electric arc furnace (EAF)	62%
Mixed route (BF and EAF)	27%

Source: Data provided by ISSF 2008, estimated by SCM

Emissions

Emissions from raw materials (ton CO_2/ton stainless steel)	2.80
Emissions from electricity and steam (ton CO_2/ton stainless steel)	0.65
Direct emissions (ton CO_2/ton stainless steel)	0.36

Total emissions

Total CO_2 emissions (ton CO_2/ton stainless steel)	3.81

Source: Data provided by ISSF (2007, 2009), estimates by SCM

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