Stainless Steel and CO_2

Facts and Scientific Observations

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Just like any other industry, the Stainless Steel Industry faces the obligation to control its CO_2 emissions. The purpose of this document is to clarify what they are and where they come from. In order to do this, we quantify CO_2 emission released from 1) the extraction and preparation of raw materials, 2) the electricity consumption within the steel industry and 3) the use of fuel on industrial site. Finally, this study allows us to identify the main sources of CO_2 and to better understand the role of Stainless Steel industry in the CO_2 emissions.

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I. General facts

Stainless Steel (SS) is an alloy with applications ranging from household cutlery to reactor tanks for the chemical industry. Stainless Steel's resistance to corrosion and staining, low maintenance and relatively low cost make it an ideal base material for many uses. Indeed, these mechanical properties promote the use of Stainless Steel in buildings or public works such as railways, subways, tunnels and bridges. Besides, storage tanks and tankers used to transport food are often made of Stainless Steel, due to its mechanical behaviour and bacteriological neutrality. This also influences its use in commercial kitchens and food processing plants, as it can be steam cleaned, sterilized, and does not need painting or application of other surface finishes (ISSF, 2009).

There are basically two ways to produce Stainless Steel: from ore based virgin raw material and from recycled material. The first one uses blast furnaces (BF), working with coal and ore, and the second one uses electric arc furnaces (EAF), working with scrap and electricity. The EAF route, which is extremely efficient, is the main process used to make Stainless Steels. In fact, more than 60 % of all new Stainless Steel is made up with electric arc furnace (ISSF, 2009).

Stainless Steel is well-known as one of the highest recyclable materials. Depending on the type of steel, depending on the location and on the availability of the scrap, production from scrap can be economically advantageous. In general, the recycling system for Stainless Steel works extremely well and requires no subsidies. It is estimated that at least 70% of Stainless Steels are recycled at the end of their life (Table 1). For this industry, scrap has a high intrinsic value. The only limitation is obvious: scrap is not always available, especially in emerging countries. Also, the long lasting value of Stainless Steel restricts the availability of scrap. For instance, when Stainless Steel is used in buildings, it remains there for many years and cannot be recycled before the building is destroyed.

Over the last eight years, the world production of Stainless Steel has been as follows:

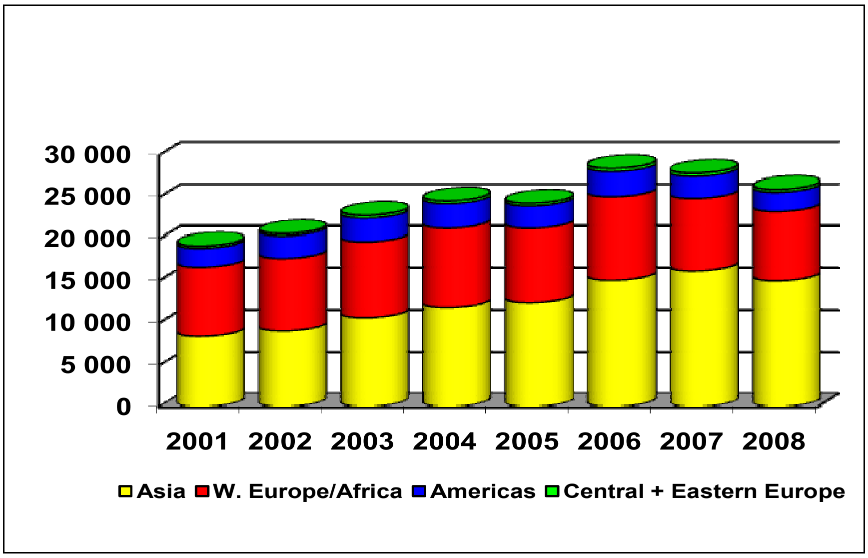

Figure 1: Crude Steel Production (1000 metric tons)
Source: International Stainless Steel Forum (2009)

As we can see from Figure 1, steel production tends to increase over the years: the world production increased from 20 millions of tons to 25 millions of tons in only eight years. In fact, the growth in the use of Stainless Steel has been the highest of any material in the world (ISSF, 2009). Stainless Steel qualities such as recyclability, reuse, long life, low maintenance and product safety might explain this growth.

II. Stainless steel life cycle

Yale University (2009) describes the stainless steel life cycle by identifying the four main life stages of this material:

- The production process which includes the entire SS making process from crude production to finished flat and long SS products for use in manufacturing;
- The fabrication and manufacturing process where the finished SS is used in different end use sectors to produce final goods;
- The use phase in which final goods are employed by the end user where they remain for the lifetime of any given product;
- The recycling and waste management process where final products, once they reach their end of life, are either recycled or disposed of its landfills.

The generic stainless steel cycle is presented below:

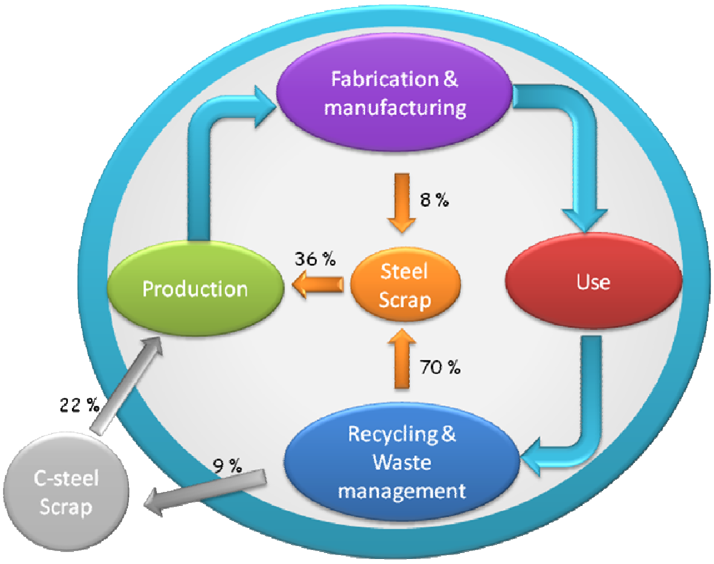

Figure 2: The world Stainless Steel cycle for 2005
Source: Yale/ISSF Stainless Steel Project (2009)

As we can see from Figure 2, these processes are interconnected through the generation and use of scrap. According to this study, raw material content represents only 45-50% of material used to produce Stainless Steel.

The research carried by Yale University (2009) provides as well the key estimates about the life cycle of Stainless Steel for its main five application sectors:

Main application sectors	Use of finished SS in manufacturing	Average lifetime (in years)	To Land fill	Collected for recycling	
				total	As SS
Building	16 %	50	8 %	92 %	95 %
Transportation	21 %	18	13 %	87 %	85 %
Industrial Machinery	31 %	20	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	16 %	78 %	71 %

Table 1: Life cycle of Stainless Steel in main application sectors

Source: Yale Study 2009

III. The CO_2 emissions

Over the last decades, carbon dioxide emission is becoming a growing concern in society. As a consequence, we see the set up of a new environmental policy in order to control and measure CO_2 emissions. In this context, the Stainless Steel industry, just like any other industry, must also quantify and communicate about its releasing emissions. Recent sustainability studies conducted by ISSF (2005, 2007) show, however, that the emissions from the production and use of Stainless Steels remain minimal.

In fact, Stainless Steel environmental profile depends directly on the production method and on the amount of scrap used. According to Johnson J. (2006), the energy requirements to produce one ton of Stainless Steel may vary between 79 GJ, using 100 % of raw materials, to only 26 GJ with 100% of scrap. As a consequence, the emission of CO_2 associated to the virgin-based production is much higher than the recycling-based production. In particular, 5.3 tons of CO_2 are emitted to produce one ton of SS using only raw materials, but 1.6 tons of CO_2 with recycling materials. Current global operations are based on a mixed production route, where primary energy requirements to produce one ton of Stainless Steel, and consequently CO_2 releases, are intermediate.

In order to clearly quantify the current releasing emissions related to its production, we will identify the CO_2 emissions from:

- the part connected with the extraction and preparation of ores and ferroalloys production, including the electricity needed for it;
- the part connected with the electricity production needed for Stainless Steel production;
- the part which is due to the local Stainless Steel industrial processes (thus belongs to the Stainless Steel industry).

We first start with the CO_2 emissions related to the extraction and preparation of ores and ferroalloys.

A. CO_2 emissions connected with the production of ore and ferroalloys

This part includes CO_2 emissions due to mining extractions and processes associated with the production of primary chromium, nickel and iron. The electricity required for mining and ferroalloy production is also included.

To produce Stainless Steel, we mainly require Stainless Steel scrap, carbon steel scrap and ferro-alloys such as ferro-Ni and ferro-Cr. According to ISSF Scrap Survey (2008), 31.5 % of contents come from Stainless Steel scrap, 18.8 % from carbon steel scrap and 49.7 % from raw materials. The CO_2 emissions connected to the extraction of each material are shown in Table 2:

Raw materials (CO_2 ton/ton)	*Element content (%)*
8,6762	*32 - Ni in Ferro Ni*
5,9872	*56,5 -Cr in Ferro Cr*
1,395	*100 - Fe in C-steel scrap*

Table 2: CO_2 emissions from raw materials to produce SS
Source: International Stainless Steel Forum (ISSF)

If Stainless Steel were to be produced solely from virgin material, CO_2 releases associated to ferroalloys production would be 5 tons per ton of SS. However, CO_2 emissions decrease with the increasing rates of stainless scrap. In average, 40 % of stainless scrap (Scrap Survey ISSF, 2008) is used to produce one ton of Stainless Steel. As a consequence, carbon dioxide emissions are cut by 40 %, releasing less than 3 tons per ton of SS (LCI/LCA study, 2008).

We now turn to the CO_2 emissions connected with the electricity needed in the production of Stainless Steel.

B. CO_2 emissions connected with electricity production of Stainless Steel

CO_2 emissions in electricity generation result from the combustion of gas and coal and from nuclear and hydraulic sources. The amount of CO_2 emitted depends on the type of electricity used. Here is the CO_2 emission factor by type of electricity plant:

Nature of electricity	Grams of CO_2 per MJ	Tons of CO_2 per ton of SS
Hydraulic	1,11	0,04
Nuclear	1,67	0,06
Combined cycle	118,61	4,27
Natural Gas	245,28	8,83
Fuel	247,5	8,91
Coal	271,67	9,78

Table 3: CO_2 emissions by different type of electricity plant
Source: "International Energy Agency" (IEA)

Electricity generation data and fuel consumption rates, provided by IEA, were used to calculate the efficiency of electricity generation. In average, 177.6 grams of CO_2 are released to produce one MJ of electricity. In other words, the amount of CO_2 related to this activity is evaluated to 0.65 tons of CO_2 per ton of SS.

Finally, we present CO_2 emissions due to the Stainless Steel industrial production itself.

C. *Direct Production emissions*

This part includes CO_2 emission from the use of fuels on industrial site.

According to the PE International (2009), the amount of CO_2 coming from the Stainless Steel production itself varies between 0.49 and 0.28 tons of CO_2 depending on the type of product manufactured. International Stainless Steel Forum measures are quite similar, the average CO_2 emissions are evaluated to 0,36 tons /ton SS.

IV. The role of Steel Industry in CO_2 emissions

The following figure shows the share of CO_2 emissions between the three actors: production of raw materials, electricity and direct production:

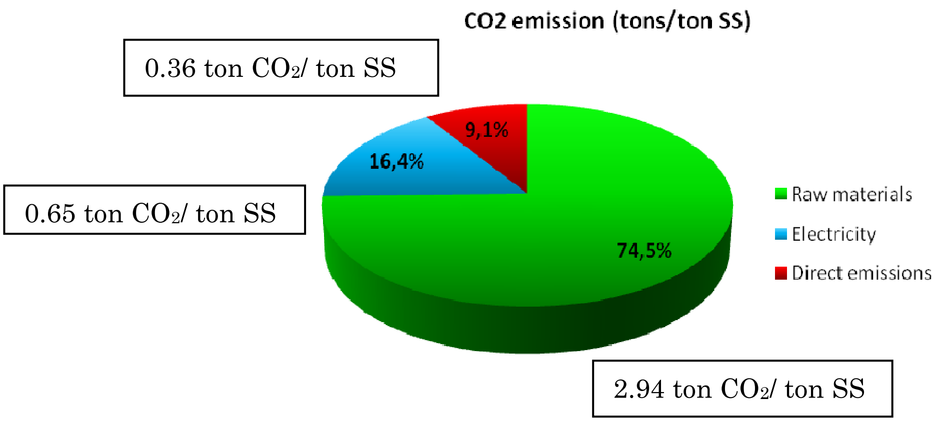

Figure 3 : Distribution of CO2 emissions
Source: Data provided by ISSF, estimated by SCM

We see that most of the CO_2 emissions do not come from the industrial process itself, but from the ore preparation. In particular, 90.9 % of the CO_2 emission comes from upstream sources while only 9.1 % from the Stainless Steel site itself.

Annex: Summary Results

Steel composition	
% raw materials	49,7%
% carbon scrap	18,8%
% stainless scrap	31,5%
Production method	
% Blast Furnace	11%
% Electric Arc Furnace	62%
% Mixed route	27%
Raw materials	
ton FeCr / ton SS	0,19
ton FeNi/ ton SS	0,17
ton C-steel/ ton SS	0,24
Emissions	
CO_2 emissions from raw materials (ton CO_2/ton SS)	2,94
CO_2 emissions from electricity and steam (ton/ton SS)	0,65
CO_2 direct emissions (ton/ton SS)	0,36
Total emissions	
Total CO_2 emissions (ton / ton SS)	3,95

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

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