ISSF
INTERNATIONAL STAINLESS STEEL FORUM

Stainless Steel and CO_2: Facts and Scientific Observations

Contents

Introduction

15 June 2015

Like any other industry, the stainless steel industry 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. The extraction and preparation of ores and production of ferro-alloys, including the electricity needed for these processes
2. Electricity consumed within the stainless steel industry
3. 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 steel 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 80% 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 fourteen years the world has produced approximately 400 million metric tons of stainless steel (see Figure 1). World production increased from less than 20 million tons to over 40 millions of tons in fourteen years. The growth in the use of stainless steel has been the highest of any material in the world (ISSF, 2015). Stainless steel's properties, such as its 100% recyclability,

reusability, durability, low maintenance and product safety, might explain this growth.

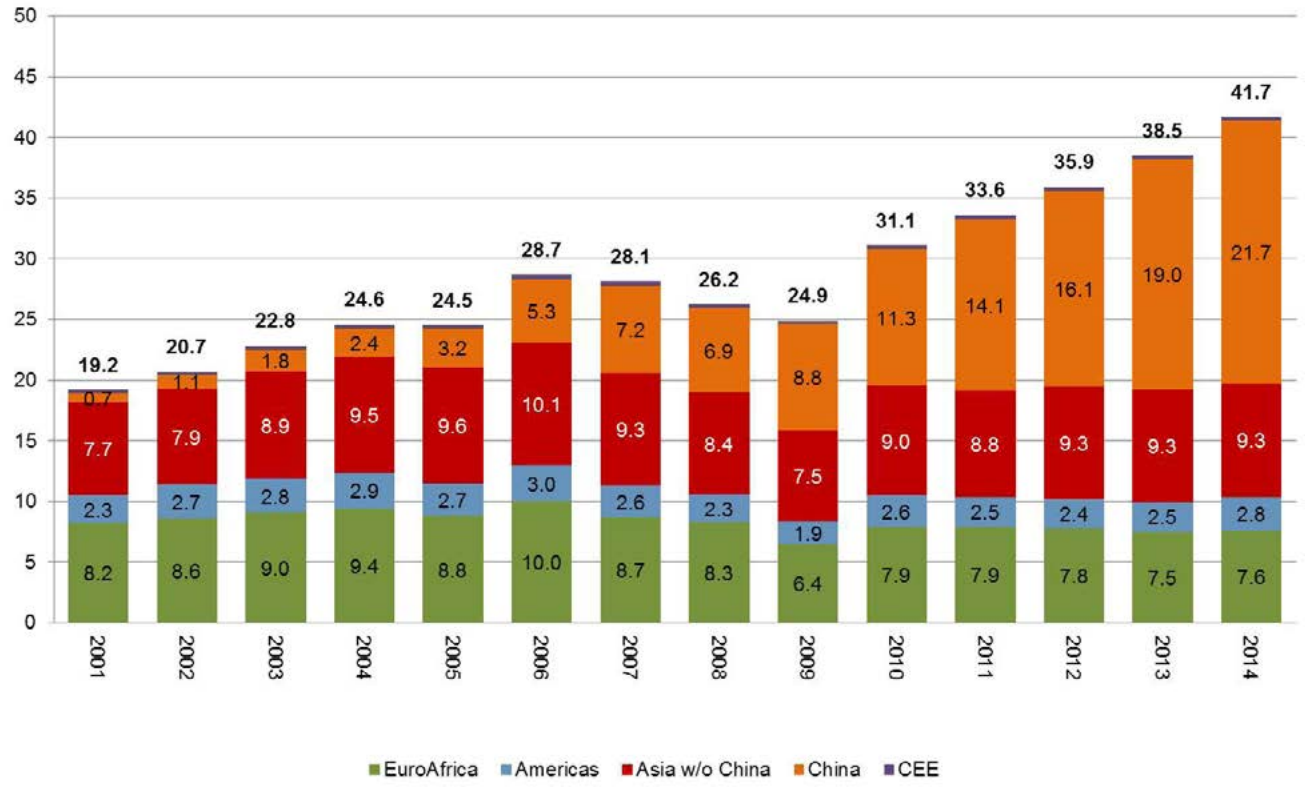

Figure 1 *Stainless steel meltshop production, 2001-2014 in 1 million metric tons*
Source: ISSF, 2015

Stainless steel life-cycle

Yale University (2013) 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 2010.

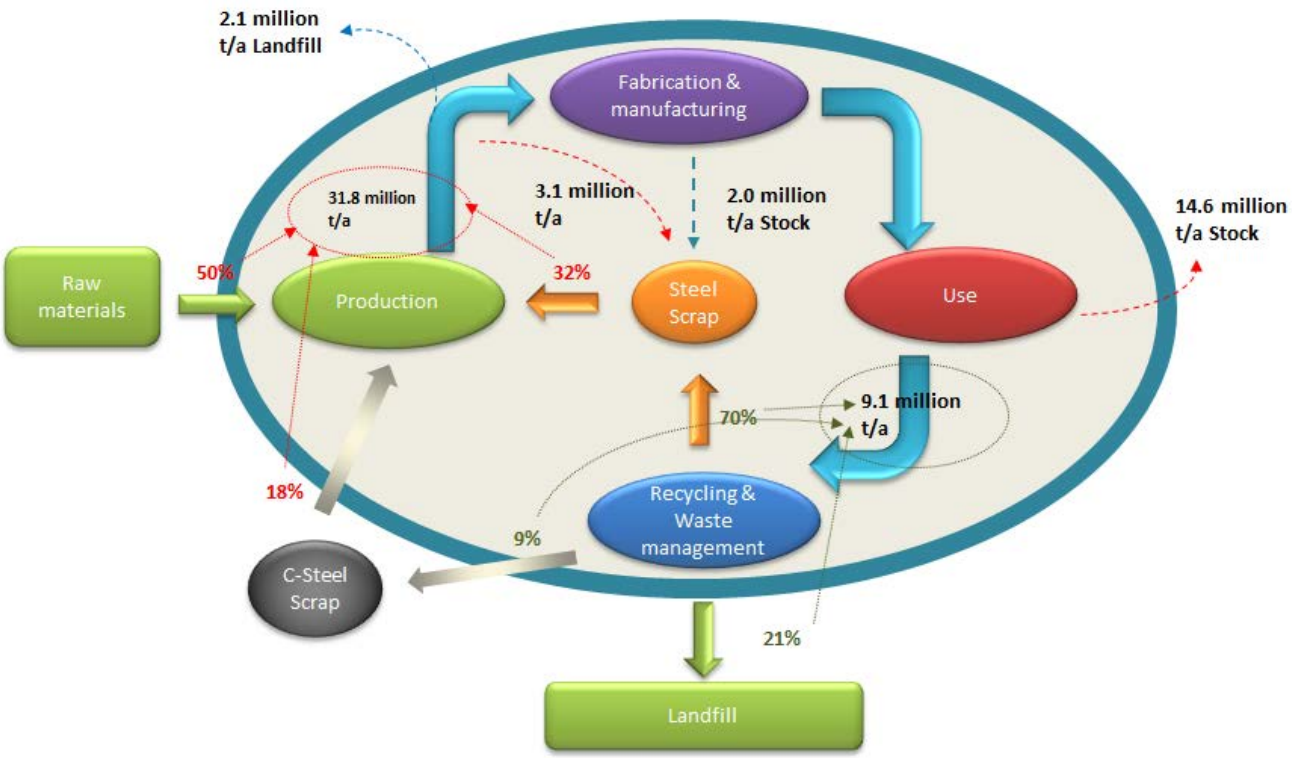

Figure 2 *Life cycle of stainless steel for the year 2010. (Source: Yale University/ISSF Stainless Steel Project, 2013)*

Figure 2 shows that the flow of stainless steel is connected by the generation and use of scrap. According to the Yale study, around 50% of the materials to produce stainless steel are scrap (stainless steel and carbon steel scrap) and raw materials make up around 50% of the material used to produce stainless steel. The research carried by Yale University (2013) also provides key estimates of the life cycle of stainless steel products in six main application sectors (see Table 1)

End Use Sector	Average lifetime (in years)	To landfill	Collected for recycling		
			Total	As stainless steel	As carbon steel
Building and infrastructure	50	8%	92%	95%	5%
Transportation (passenger cars)	14	13%	87%	85%	15%
Transportations (others)	30				
Industrial Machinery	25	8%	92%	95%	5%
Household Appliances and Electronics	15	30%	70%	95%	5%
Metal Goods	15	40%	60%	80%	20%

Table 1 *Life cycle of stainless steel in main application sectors*
Source: Yale University/ISSF Stainless Steel Project, 2013

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 (between 2007 and 2013) 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.

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 / ton of stainless steel. However, CO_2 emissions decrease as the amount of stainless scrap is increased.

On average, around 50 % of stainless steel scrap (ISSF, 2013) is used to produce one ton of stainless steel. As a consequence, carbon dioxide emissions are less than 2.0 tons / ton of stainless steel.

Raw materials (CO_2 ton/ton)	Element content
8.7	29% 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

Table 2 *CO2 emissions from raw materials needed to produce stainless steel*
Source: Ferronickel LCA data in 2014 data based 2011 by Nickel Institute, LCI of primary Ferro chrome production in 2007 by ICDA, 2005 data from IMOA, CO2 scrap value for LCI study of the World Steel Association 2000)

Due to the high recycling rate of stainless steel this represents a 52% reduction of CO_2 emissions (estimated by ISSF, 2013)

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

ISSF calculates that the amount of CO_2 emissions connected to the electricity required to produce stainless steel at the stainless steel plant were 0.54 tons / ton of stainless steel from the data collection in 2013.

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 0.28 and 0.49 tons / ton of stainless. This includes CO_2 emissions from the use of fuel. The exact volume depends on the type of product manufactured. ISSF measurements show similar values. ISSF calculates that average CO_2 emissions are 0.44 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.

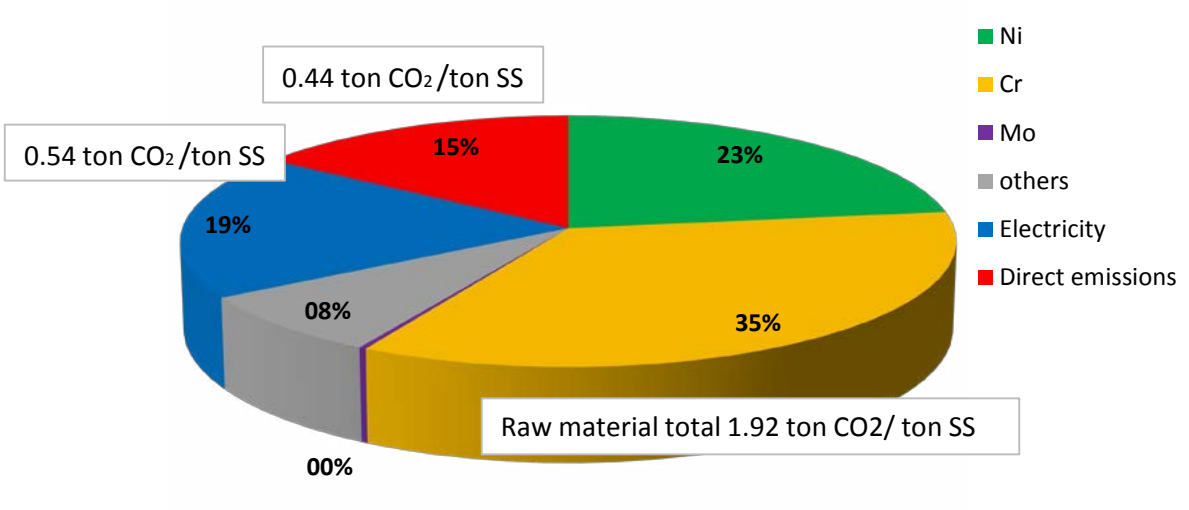

Figure 3 *Distribution of CO_2 emissions*
Source: 2013 Data provided by ISSF, 2015

Annex: Summary of results

% raw materials	22%
% carbon steel scrap	28%
% stainless scrap	50%

Table 4 *Steel composition*
Source: 2013 Data provided by ISSF (2015)

Blast furnace (BF)	10%
Electric Arc Furnace (EAF)	65%
Mixed route (BF and EAF)	25%

Table 5 *Production method*
Data provided by ISSF (2014)

Emissions from raw materials (ton CO_2/ton stainless steel)	1.92
Emissions from electricity and steam (ton CO_2/ton stainless steel)	0.54
Direct emissions (ton CO_2)/ton stainless steel)	0.44
Total CO_2 emissions (ton CO_2)/ton stainless steel)	**2.90**

Table 6 *Total emissions*
2013 Data provided by ISSF (2015)

References and sources

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About ISSF

The International Stainless Steel Forum (ISSF) is a non-profit research and development organisation which was founded in 1996 and which serves as the focal point for the international stainless steel industry.

Who are the members?

ISSF has two categories of membership: company members and affiliated members. Company members are producers of stainless steel (integrated mills and rerollers). Affiliated members are national or regional stainless steel industry associations. ISSF now has 65 members in 25 countries. Collectively they produce 80% of all stainless steel.

Vision

Stainless steel provides sustainable solutions for everyday life.

More information

For more information about ISSF, please consult our website worldstainless.org.

For more information about stainless steel and sustainability, please consult the sustainablestainless.org website.

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