

# Stainless Steel and CO<sub>2</sub>: Facts and Scientific Observations





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## Introduction

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Like any other industry, the stainless steel industry aims to reduce its CO<sub>2</sub> 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<sub>2</sub> emitted from the following three sources:

1. CO<sub>2</sub> emissions directly from operations that are owned or controlled by the reporting companies. This is known as Scope 1 emissions.
2. CO<sub>2</sub> emissions from the generation of purchased or acquired electricity, steam, heating or cooling energy consumed by the reporting companies. This is known as Scope 2 emissions.
3. All indirect CO<sub>2</sub> emissions that occur in the upstream value chains of the reporting companies. This is known as Scope 3 emissions.

This study enables us to identify the main sources of CO<sub>2</sub> 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.

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, 2018).

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 85% 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 nineteen years the world has produced approximately 620 million metric tons of stainless steel (ISSF, 2021). World production increased from less than 20 million tons to over 50 millions of tons in sixteen years (see [Figure 1](#)). The growth in the use of stainless steel has been the highest of any material in the world (ISSF, 2021). Stainless steel's properties, such as its 100% recyclability, reusability, durability, low maintenance and product safety, might explain this growth.

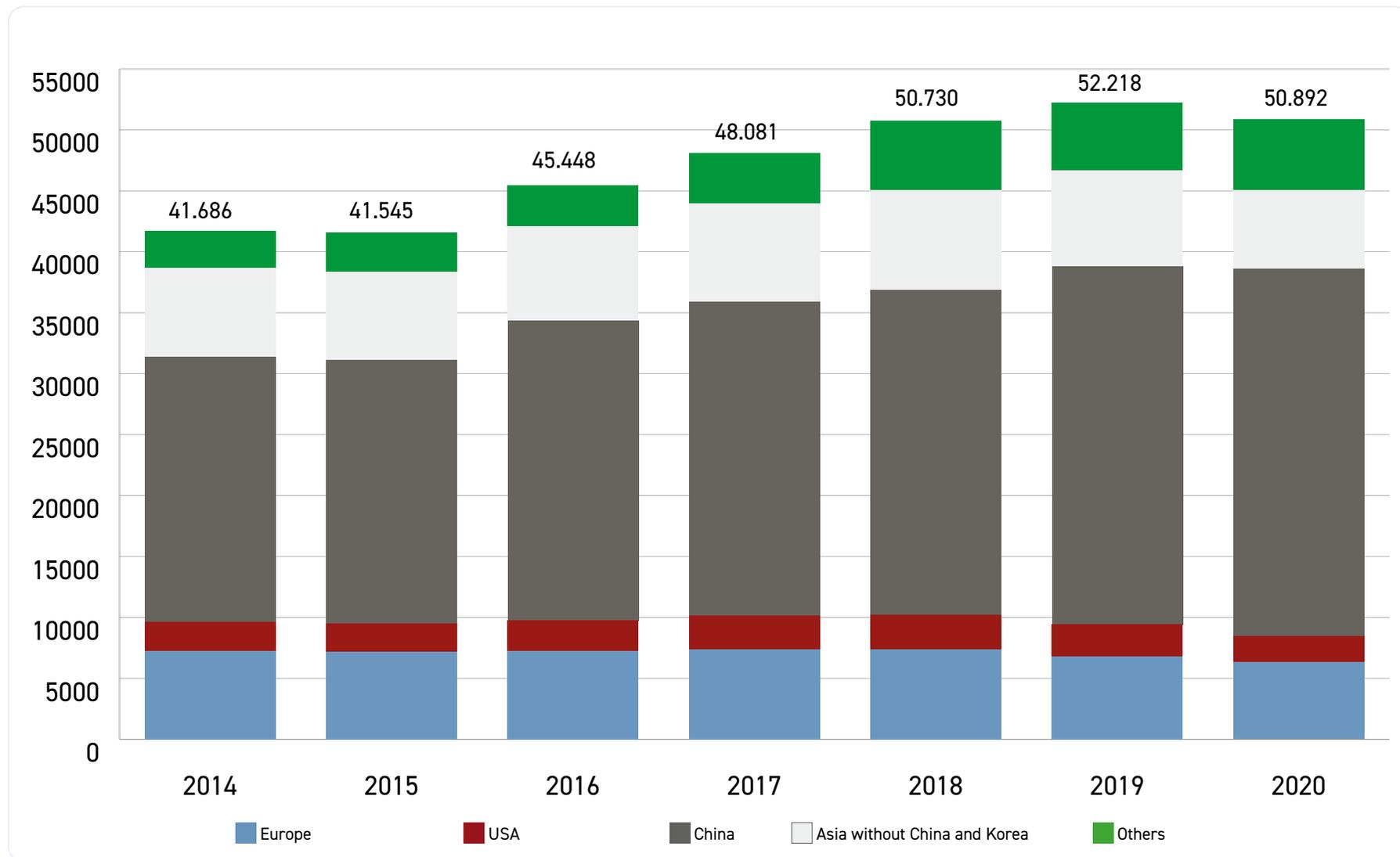


Figure 1 Stainless melt shop production (slab/ingot equivalent) by region in 1,000 metric tonnes  
 Others: Brazil, Russia, S. Africa, S. Korea, Indonesia  
 Source: ISSF, 2021

## 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 2015.

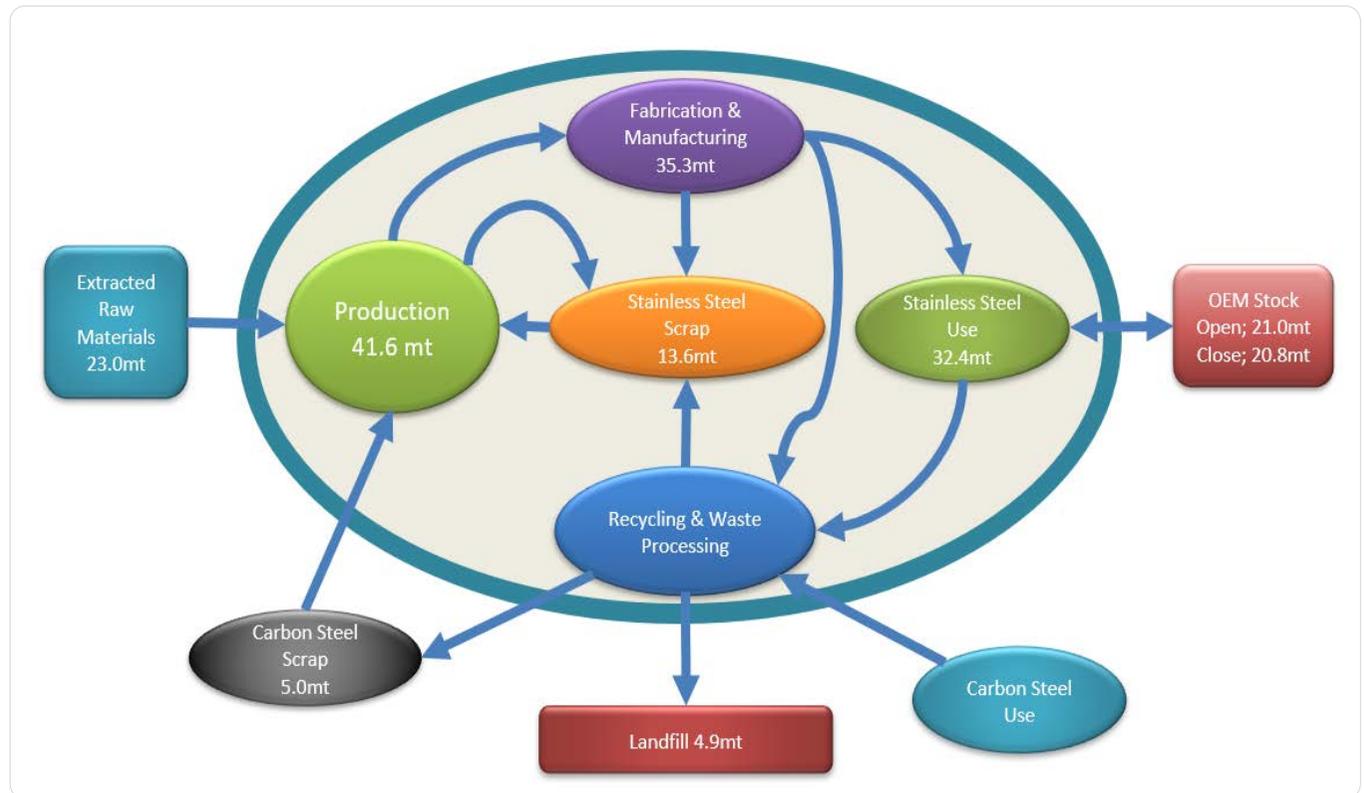


Figure 2 Life cycle of stainless steel for the year 2015. (Source: Yale University/ISSF Stainless Steel Project, 2019)

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).



## Life Cycle of Stainless Steels in Main Application Sectors

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%
Transportation (others)					
Industrial Machinery	25	8%	95%	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, 2019



## CO<sub>2</sub> 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<sub>2</sub> 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 2018) show that emissions from the production and use of stainless steel are minimal.

In order to clearly quantify the CO<sub>2</sub> emissions during the production of stainless steel, we will identify the CO<sub>2</sub> emissions from Scope 1, scope 2 and scope 3 as previously defined (see introduction).

## CO<sub>2</sub> emissions from the production of ore and ferro-alloys (scope 3 emissions)

This part of the stainless steel production process includes CO<sub>2</sub> 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.

Raw materials (CO <sub>2</sub> ton/ton)	Element content	CO <sub>2</sub> per ton of stainless steel produced
8.7	29% Ni in ferro-Ni	0.26 tons
6.0	56.5% Cr in ferro-Cr	0.84 tons
8.5	67% Mo in ferro-Mo	0.05 tons
1.62	100% Fe in carbon steel scrap	

Table 2 CO<sub>2</sub> emissions from raw materials needed to produce stainless steel

Source: Ferronickel LCA data in 2014 data based 2011 by Nickel Institute, LCI of primary Ferrochrome production in 2007 by ICDA, 2005 data from IMOA, CO<sub>2</sub> scrap value for LCI study of the World Steel Association 2019)

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<sub>2</sub> 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<sub>2</sub> emissions from the production of ferro-alloys would be 4.2 tons / ton of stainless steel. However, CO<sub>2</sub> emissions decrease as the amount of stainless scrap is increased.

On average, over 75 % of stainless steel scrap (ISSF, 2020) is used to produce one ton of stainless steel. As a consequence, carbon dioxide emissions are 2.23 tons / ton of stainless steel.

Due to the high recycling rate of stainless steel this represents a 48% reduction of CO<sub>2</sub> emissions (estimated by ISSF, 2021).

## CO<sub>2</sub> emissions connected to the electricity required to produce stainless steel at the plant (scope 2 emissions)

ISSF calculates that the amount of CO<sub>2</sub> emissions connected to the electricity required to produce stainless steel at the stainless steel plant were 0.47 tons / ton of stainless steel from the data based on 2019.

## Direct production emissions (scope 1 emissions)

According to PE International (2009), the amount of CO<sub>2</sub> emitted during the production of stainless at the steel plant varies between 0.28 and 0.49 tons / ton of stainless. This includes CO<sub>2</sub> 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<sub>2</sub> emissions are 0.34 tons / ton stainless steel.

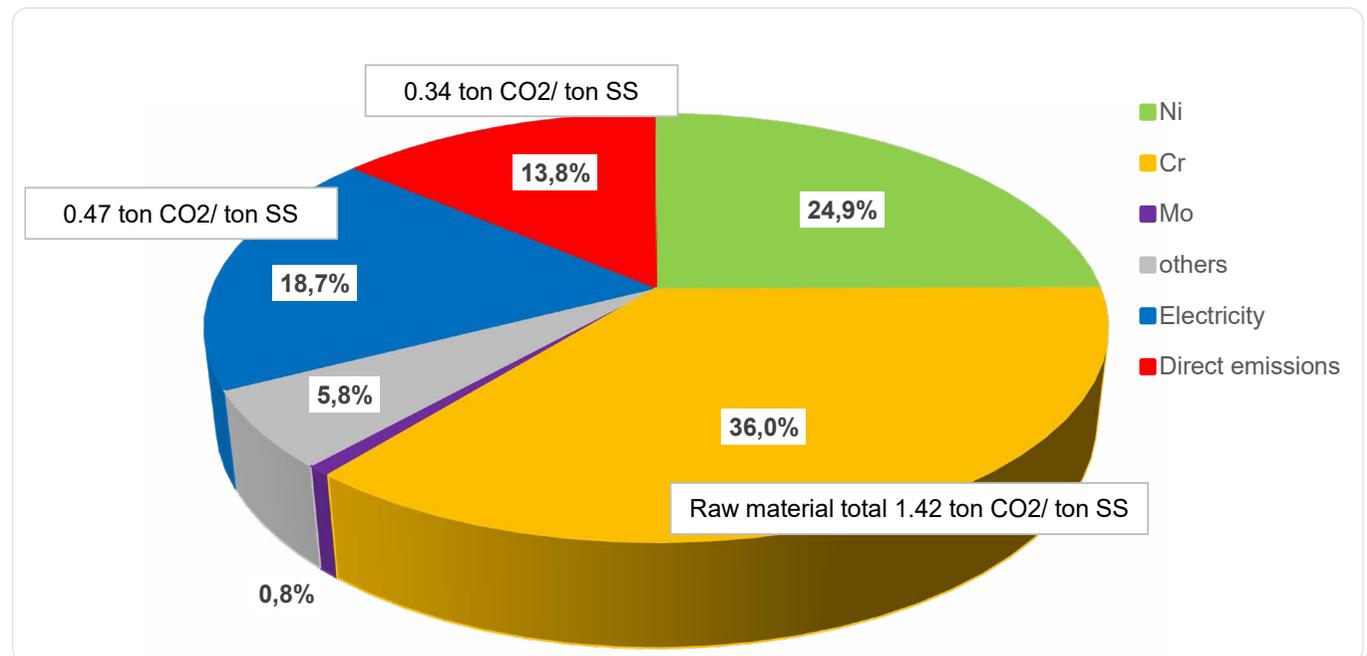


Figure 3 *Distribution of CO<sub>2</sub> emissions*  
Source: 2019 Data provided by ISSF, 2021

## The role of the stainless steel industry in CO<sub>2</sub> emissions

Figure 3 shows the share of CO<sub>2</sub> emissions between the three parts of the stainless steel production process: production of raw materials (Ni, Cr, Mo and others); electricity; and direct production.

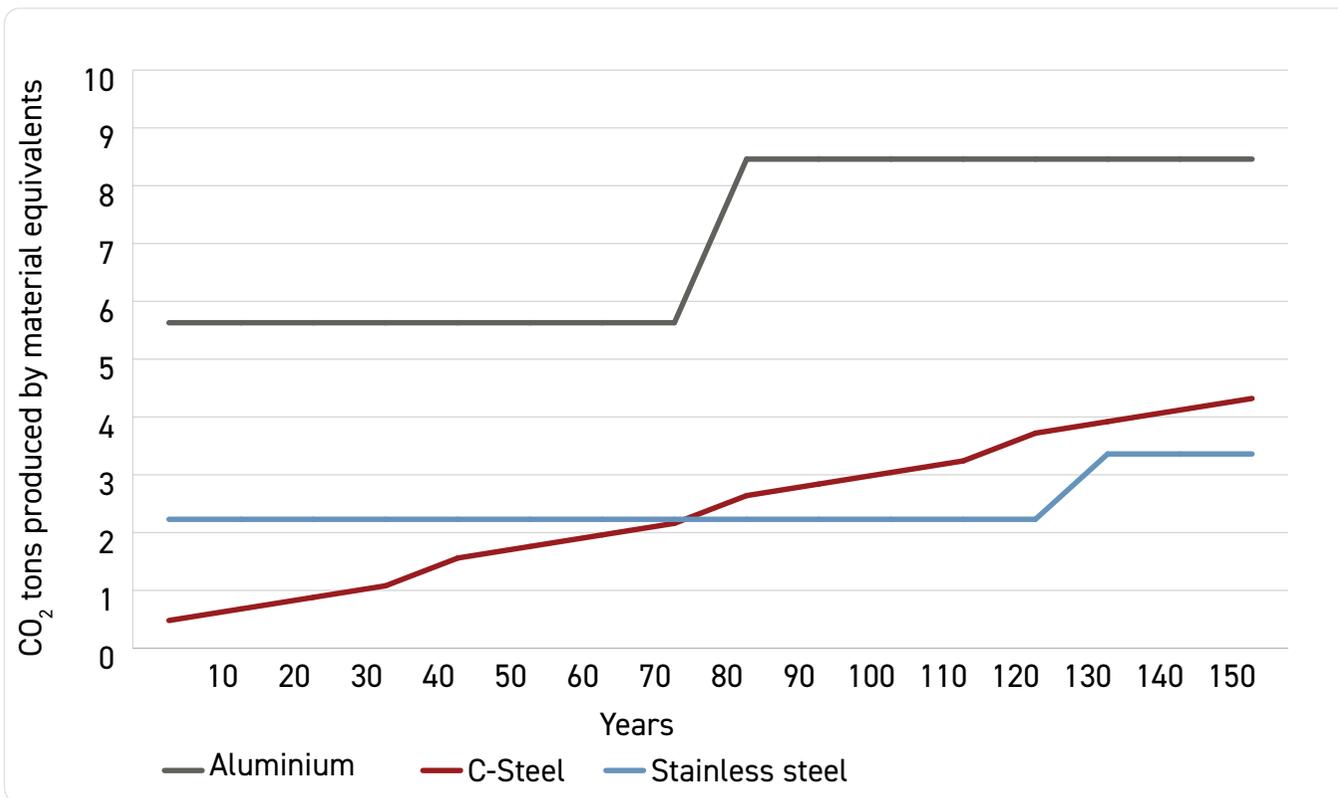


Figure 4 CO<sub>2</sub> production emissions for alloys in structures over 150 years of operational life

## CO<sub>2</sub> production emissions for alloys in structures over 150 years of operational life

Figure 4 shows the CO<sub>2</sub> production emissions for stainless steel, carbon steel and aluminium.

The data is CO<sub>2</sub> tons emitted per ton of material produced (Scope 1 + Scope 2 + Scope 3). The carbon steel emissions increase every 10 years due to regular maintenance needed to suppress corrosion. Stainless steel and Aluminium emissions do not increase as their passive films prevent the need for regular maintenance. The lifetime of stainless steels in-service beyond 110 years are not known. An assumption that stainless needs partial replacement after around 125 years has been included for prudence. The CO<sub>2</sub> emissions data and associated recycling credits are industry supplied figures. The Aluminium data has been adjusted downwards to reflect the fact that the density of Aluminium is about one third that of carbon steel and stainless steels.



## Annex: Summary of results

% raw materials	25%
% carbon steel scrap	24%
% stainless scrap	51%

Table 5 *Steel composition*  
Source: 2019 Data provided by ISSF (2021)

Blast furnace (BF)	10%
Electric Arc Furnace (EAF)	62%
Mixed route (BF and EAF)	28%

Table 6 *Production method*  
Data provided by ISSF (2016)

Scope 1 emissions	0.34
Scope 2 emissions	0.47
Scope 3 emissions	1.42
<b>Total CO<sub>2</sub> emissions (ton CO<sub>2</sub>)/ton stainless steel)</b>	<b>2.23</b>

Table 7 *Total emissions*  
2019 Data provided by ISSF (2021)



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**[worldstainless.org](http://worldstainless.org)**