Stainless Steels and CO_2; Industry Emissions and Related Data

Contents

Introduction

January 2022

Like any other major industry, the stainless steels industry endeavours to reduce its operational CO_2 emissions on an ongoing basis.

It should however be noted that within the stainless steels industry there are essentially two production systems, namely;

1. The scrap-based production system in which the bulk of used raw materials are end-of-life stainless steels and/or similar alloy materials that are recycled to produce new stainless steels. This production system is aligned to geographical locations where the availability of end-of-life materials and scrap is high.
2. The Nickel Pig Iron (NPI) production system in which the bulk of the Nickel units required for stainless steel production is not derived from stainless steel scrap, but from extracted Nickel ores which are converted into NPI. This production system is aligned to geographical locations where the availability of stainless steel scrap is low.

There is currently insufficient available end-of-life stainless steel scrap in all regions of the world to permit only scrap-based production to exist. This situation is likely to remain true for several decades to come.

The purpose of this document therefore is to clarify what emissions exist and where they originate from and in order to achieve these objectives, we have quantified the CO_2 emissions from the following three sources.

a. Scope 1 Emissions which covers direct emissions from business-owned or business-controlled emission sources.
b. Scope 2 Emissions which covers indirect emissions from the generation of purchased electricity, steam, heating and cooling consumed by the reporting company.
c. Scope 3 Emissions which are associated with the extraction, preparation and transport of ores and the subsequent production and transport of ferro-alloys including the electricity needed for these processes.

    Special Note; There is no data currently available from stainless steel producers for the emissions associated with the extraction of Nickel ore and the subsequent production of Nickel Pig Iron (NPI). This situation is due to current country-specific legally-imposed disclosure restrictions. However, some of this data is available from industry research groups and as such, this data has been used to provide some ‘indicative guidance numbers’ later in this brochure.

These above-described three sources allow us to provide a cradle to gate view of the stainless steel industry's CO_2 emissions.

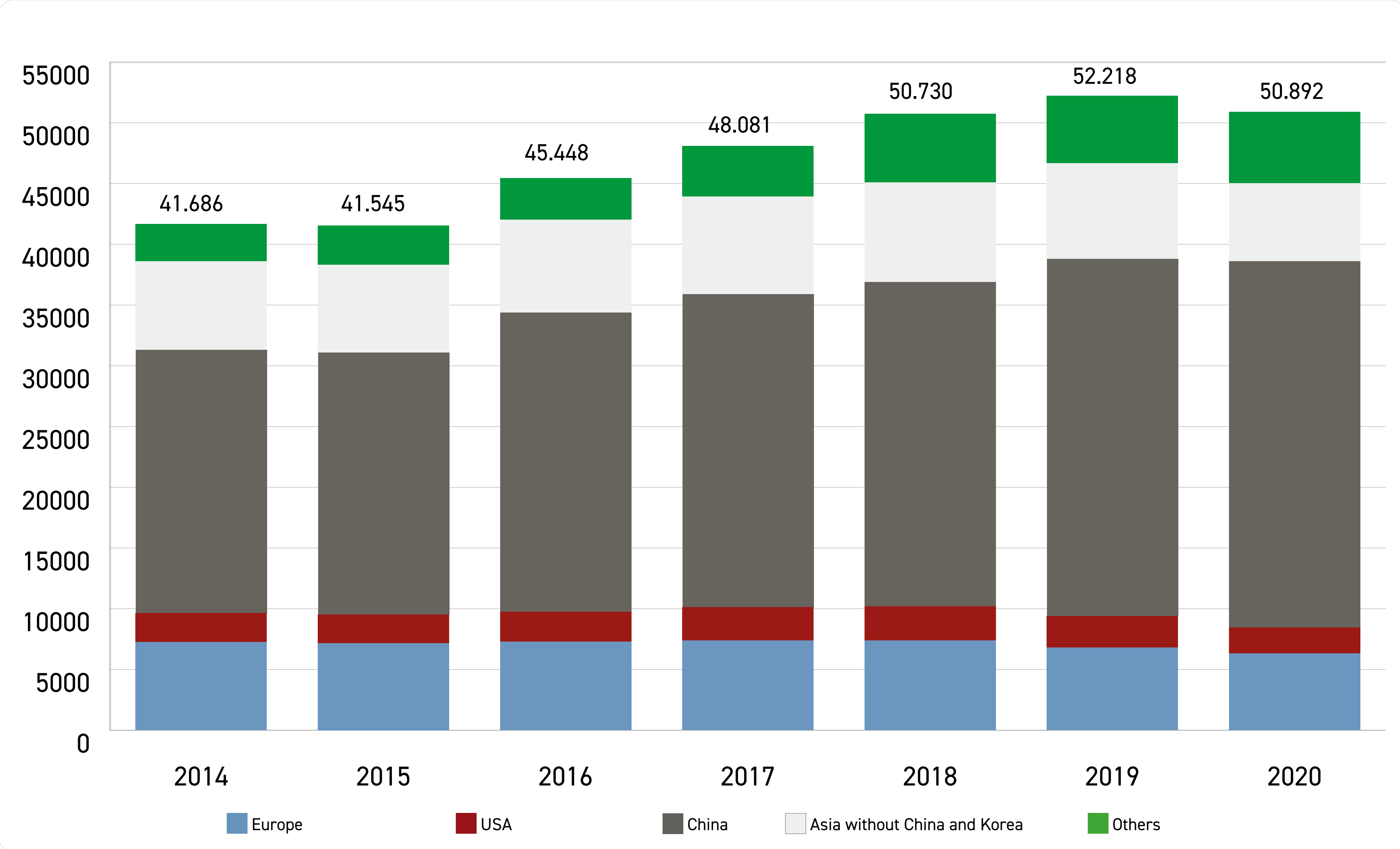
General facts

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.

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.

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 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 20 years the world has produced approximately 670 million metric tons of stainless steel (ISSF, 2021). World production increased from 19 million tons to over 50 millions of tons over the same time period. (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 partly explain this amazing consumption growth.

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

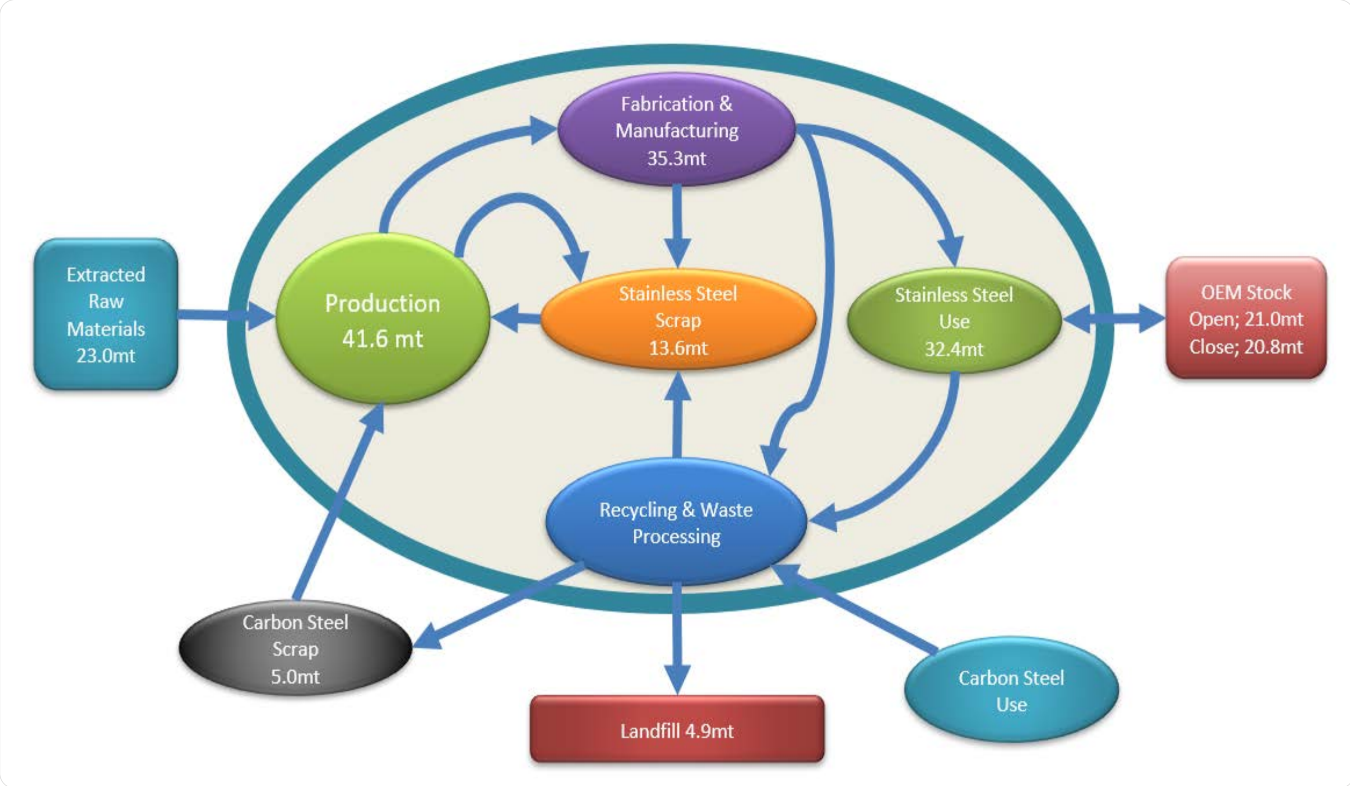


Figure 2 shows that the flow of stainless steel is connected by the generation and use of scrap. According to the Yale study, around 50% of the materials to produce stainless steel are scrap (stainless steel and carbon steel scrap) and raw materials make up around 50% of the material used to produce stainless steel. The research carried by Yale University (2019) 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)	30				
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_2 Emissions

Over the last few decades, carbon dioxide emissions have been recognized as a major concern in our society. As a direct consequence, new environmental policies have been established to control and measure CO_2 emissions. The stainless steels industry, just like any other industry, quantifies and communicates its CO_2 emissions performance.

Recent sustainability studies conducted by the ISSF (between 2007 and 2018) show that emissions from the production and use of stainless steels are generally low. However, and in order to clearly quantify the CO_2 emissions during the production of stainless steel, we will identify the CO_2 emissions from the categories previously defined as Scope 1, Scope 2 and Scope 3.

It is important to remind our readers that the presented emissions data is highly representative of the scrap-based (recycled content) producers. The calculated data for Nickel Pig Iron (NPI) based producers is for indicative guidance only.

Scope 1 Emissions

The current scrap-based producer average is 0.39 tonnes of CO_2 per tonne of stainless steel produced. 80% of the producer results sit (normally distributed) in the range 0.20 to 0.60 tonnes of CO_2 per tonne of stainless steel produced.

Scope 2 Emissions

The current scrap-based producer average is 0.49 tonnes of CO_2 per tonne of stainless steel produced. 93% of the producer results sit (normally distributed) in the range 0.30 to 0.70 tonnes of CO_2 per tonne of stainless steel produced.

Scope 3 Emissions

Scope 3 emissions cannot be defined in the same manner. We currently know that there is a linear relationship between the amount of recycled content (scrap stainless steel and low alloy steels) charged and the magnitude of Scope 3 emissions. The higher the recycled content the lower the Scope 3 emissions.

Furthermore, the available data only covers recycled content (also known as the scrap mix) between 40% scrap and 90% scrap. The most common range of recycled content is between 50% and 85% scrap which yields the following Scope 3 emission levels.

- 50% scrap; 2.45 tonnes of CO_2 per tonne of stainless steel produced
- 75% scrap; 1.59 tonnes of CO_2 per tonne of stainless steel produced
- 85% scrap; 1.25 tonnes of CO_2 per tonne of stainless steel produced

The linear relationship is not predicted to continue below a recycled content of 40% because this represents the region where NPI-based production becomes more commonplace. NPI production produces emissions in the average range (specified by geographical source) of 60 to 85 tonnes of CO2 per tonne of Nickel produced. This means that if NPI is used to make an 8% Nickel containing stainless steel, the increase in Scope 3 emissions (when compared to a 40% scrap mix) associated with this route will typically be between 4.0 and 6.0 tonnes of CO2 per tonne of stainless steel produced.

NB; For comparative purposes, a 40% scrap mix with zero NPI delivers a Scope 3 emissions level of 2.80 tonnes of CO2 per tonne of stainless steel produced.

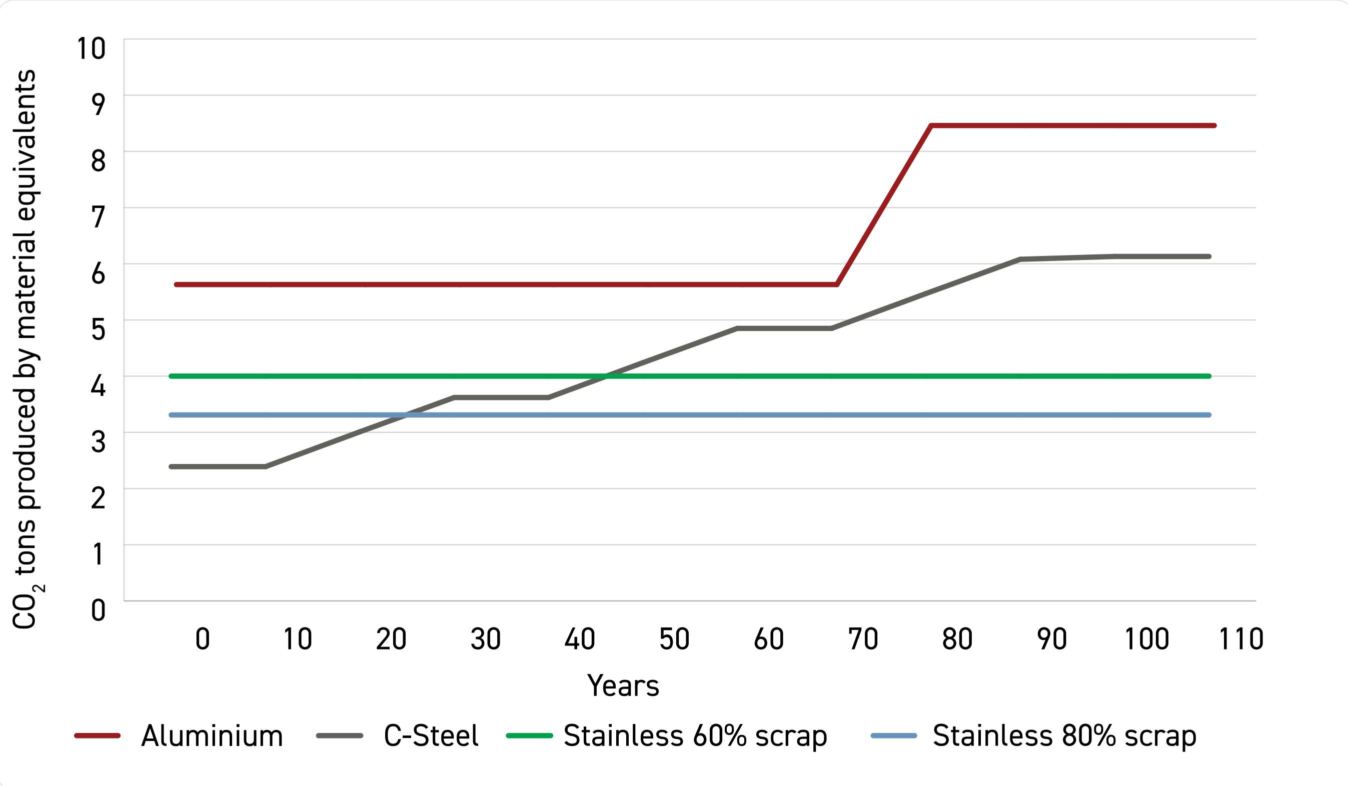
The summary table of emissions is shown in table 2.

Table 2 *Stainless Steel Average Production Emissions by Recycled Content*
The calculated data is intended to provide indicative guidance numbers only. Within the calculated data the Scope 1 and Scope 2 emissions have not been adjusted, as this data is currently not disclosed.

Scrap %	NPI %	Scope 1	Scope 2	Scope 3	Total	Comments
90%		0.39	0.49	1.07	1.95	ISSF Member data
80%		0.39	0.49	1.42	2.30	ISSF Member data
70%		0.39	0.49	1.76	2.64	ISSF Member data
60%		0.39	0.49	2.11	2.99	ISSF Member data
50%		0.39	0.49	2.45	3.33	ISSF Member data
40%	30%	0.39	0.49	5.24	6.12	Calculated data
30%	35%	0.39	0.49	5.99	6.87	Calculated data
20%	41%	0.39	0.49	6.83	7.71	Calculated data

BACK

Figure 3 *CO_2 production emissions for alloys in structures over 110 years of operational life*
The data was calculated from material and processing emissions data available from the International Stainless Steel Forum, the World Steel Association and the Organisation for Economic Co-operation and Development (OECD).



CO_2 production emissions for alloys in structures over 110 years of operational life

Figure 3 shows the CO_2 production and maintenance emissions for stainless steels, carbon steel and aluminium. Two different types of produced stainless steel have been included, namely Stainless 1 which is produced with an 80% recycle content and Stainless 2 which is produced with a 60% recycled content.

The data comprises CO_2 tons emitted per ton of material produced (Scope 1 + Scope 2 + Scope 3) plus any CO_2 emissions associated with regular maintenance needs. The carbon steel emissions increase every 10 years due to regular maintenance needed to supress 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 yet known as the industry is currently 108 years old.

The CO_2 emissions data and associated included 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

Scope 1 emissions		0.39
Scope 2 emissions		0.49
Scope 3 emissions	85% scrap	1.25
	75% scrap	1.59
	50% scrap	2.45
	30% scrap	5.99*
Total CO_2 emissions (ton CO_2)/ton stainless steel)	85% scrap	**2.13**
	75% scrap	**2.47**
	50% scrap	**3.33**
	30% scrap	**6.87***

Table 4 *Total emissions*
2019 Data provided by ISSF (2021)
** calculated data*

References and sources

1. Hiroyuki Fujii, Toshiyuki Nagaiwa, Haruhiko Kusuno and Staffan Malm, How to quantify the environmental profile of stainless steel. Paper presented by ISSF at the SETAC North America 26th Annual Meeting, November 2005.
2. Julia Pflieger and Harald Florin, Life Cycle Inventory on Stainless Steel Production in the EU. PE International, 2009.
3. Pascal Payet-Gaspard, Stainless Steel: Sustainability and Growth. Presentation at the CRU Conference, November 2009.
4. Barbara Reck and T.E. Graedel, Comprehensive Multilevel Cycles for Stainless Steel in 2010 Final Report to the International Stainless Steel Forum (ISSF) and Team Stainless, Yale University, 2013
5. Barbara Reck, Marine Chambon, Seiji Hashimoto and T.E. Graedel, Global Stainless Steel Cycle Exemplifies China's Rise to Metal Dominance
6. LCI/LCA Study: The development of the life cycle inventory. PE International, 2008.
7. Scrap Survey. ISSF, 2008.
8. What Makes Stainless Steel a Sustainable Material? ISSF, 2009.
9. Jeremiah Johnson, B.K. Reck, T. Wang and T.E. Graedel, The energy benefit of stainless steel recycling. Energy Policy, Vol. 36, Issue 1, pp 181-192, 2008.
10. Worldsteel Studies: Application of the Worldsteel LCI Data to Recycling Scenarios. World Steel Association, 2008.
11. Accounting for steel recycling in Life Cycle Assessment studies. World Steel Association, 2009.
12. ISSF Stainless Steel in Figures 2021
13. NPI production emissions calculated from data supplied by Skarn Associates / Macquarie 2021
14. Organisation for Economic Co-operation and Development (OECD).

worldstainless.org