Climate Impact of Metal-Casting

2023-024

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Summary

The Swedish Foundry Association has made a third updated version of the background report of the carbon footprint indicator which was first presented in 2011 and later updated in 2016 and 2020.

The purpose of this work has been to analyze the electricity situation in 21 foundry-producing countries, including Sweden, and to describe the amount of CO_2 emissions that the national electricity mix gives rise to.

The Swedish Environmental Research Institute, IVL has, on the behalf of the Swedish Foundry Association, produced a report with general data on carbon dioxide emissions from electricity consumption from 21 countries.

Based on the background data, presented by IVL, and certain assumption, calculations have been made for a number of different metals. These have been made in the same way as in previous background reports; report numbers 2011-009, 2016-003 and 2020-001. The results are an indication that there are climate-related differences depending on which country the cast components are manufactured in. In essence, it is the countries' electricity mix that affect the outcome, where Sweden is very well ahead since electricity from hydro and nuclear power produces low emissions of greenhouse gases in the operating phase.

However, these results should not be seen as a reason to discontinue the ongoing work on energy efficiency in Swedish foundries. If the foundry industry in other countries or individual foundries work to improve their processes and the Swedish foundries do not, there is a risk that the Swedish foundries will lose competitiveness, both economically and environmentally.

One final notion is that this tool is based on the energy mix used in each country for metal melting. Therefore, actual results may vary for a specific foundry.

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List of Annexes

1 Origins of this report

The Swedish Foundry Association has conducted a third update of the background report that serves as the foundation for the climate indicator, which was initially developed in 2011 and subsequently updated, first in 2016 and then again in 2020. Based on this report, the climate indicator will also be updated.

2 Introduction

The production of castings is an energy-intensive process, with the highest energy consumption occurring primarily in the melting facilities. In Sweden, the majority of the energy used in the melting process comes from electricity.

The climate impact of metal casting arises from various sources, including the production of electricity purchased for melting the metal and emissions generated during the transportation of castings from the foundry to the customer. In this report, electricity purchased for melting the metal will be the area of study.

3 Purpose and objective

The goal is to analyze the electricity situation of 21 countries, including Sweden, and describe the amount of CO_2e (carbon dioxide equivalents) emissions generated by each country's electricity mix.

CO_2e stands for carbon dioxide equivalents. There are several different gases, apart from carbon dioxide, that can impact the climate. Since these gases can have slightly different climate impacts, they are converted into how much carbon dioxide they are equivalent to, and these are expressed as carbon dioxide equivalents.

4 Production of background data

At the request of the Swedish Foundry Association, IVL Swedish Environmental Research Institute has compiled indicative and general data on the carbon dioxide emitted as a result of electricity generation in 21 countries.

Countries covered by the study are Brazil, China, Czech Republic, Denmark, Finland, France, Germany, Great Britain, India, Italy, Japan, Mexico, Netherlands, Norway, Poland, Slovenia, South Africa, Spain, Sweden, Turkey, and USA.

The IVL report is attached in Annex 1.

4.1 Data on the energy mix of the various countries

Data for the share of fossil fuels in the electricity mix of different countries have been obtained from *Our World in Data*. The collected data is for the year 2022.

4.2 Data on electricity

Regarding electricity consumption, IVL has primarily utilized two different sources for its data collection: the EcoInvent lifecycle database of the Swiss Centre for Life Cycle Inventories, and Thinkstep’s lifecycle database GaBi Professional Database.

- **EcoInvent, version 3.9.1**
  The data concerns CO_2e (carbon dioxide equivalents) emissions from the entire life cycle of medium voltage in the electricity grid for each respective country. The calculations are based on data from 2019, which is the latest available statistics in the database.

- **GaBi Professional Database, version 2023.2**
  The data relates to CO_2e (carbon dioxide equivalents) emissions from the entire life cycle of medium voltage in the electricity grid for each respective country. The calculations are based on data from 2019, which is the latest available statistics in the database.

The data sources display a number of differences. Choice of source is discussed further under the following chapter.

5 Choice of data sources for calculations

IVL has developed two data sources for electricity production, which show some differences.

5.1 Choice of data for calculating emissions from electricity generation

According to IVL's report, both GaBi and EcoInvent are considered highly credible and generally produce good data. EcoInvent tends to yield slightly higher results compared to GaBi Professional, but the exact reasons for this are not clear from IVL's report. EcoInvent's results are often perceived as relatively high compared to other data sources, but that does not necessarily mean they are more inaccurate. EcoInvent has a broader international distribution and is likely interpreted as more credible for that reason.

EcoInvent was used for the previous version of this report, and based on the above reasoning, it was chosen as the source for further calculations.

A comparison between data from EcoInvent and GaBi for iron melting alone is shown in Figure 2. It is evident that there are differences between these databases, but the relationship between different countries remains unaffected. An exception to this is the data for Brazil, where GaBi reports significantly higher values than EcoInvent. However, no explanation for this difference is provided.

Data for emissions from electricity production were missing for Turkey in previous versions of the climate indicator. This is no longer the case as there are now reported data in both EcoInvent and GaBi. Based on the data published by Our World in Data regarding the share of fossil fuels in various countries' electricity mixes, it can be noted that Turkey's fossil fuel share is close to that of China, as shown in Figure 1[1]. However, the reason Turkey's climate impact is considerably lower despite this is that Turkey primarily uses gas as an energy source and not coal.

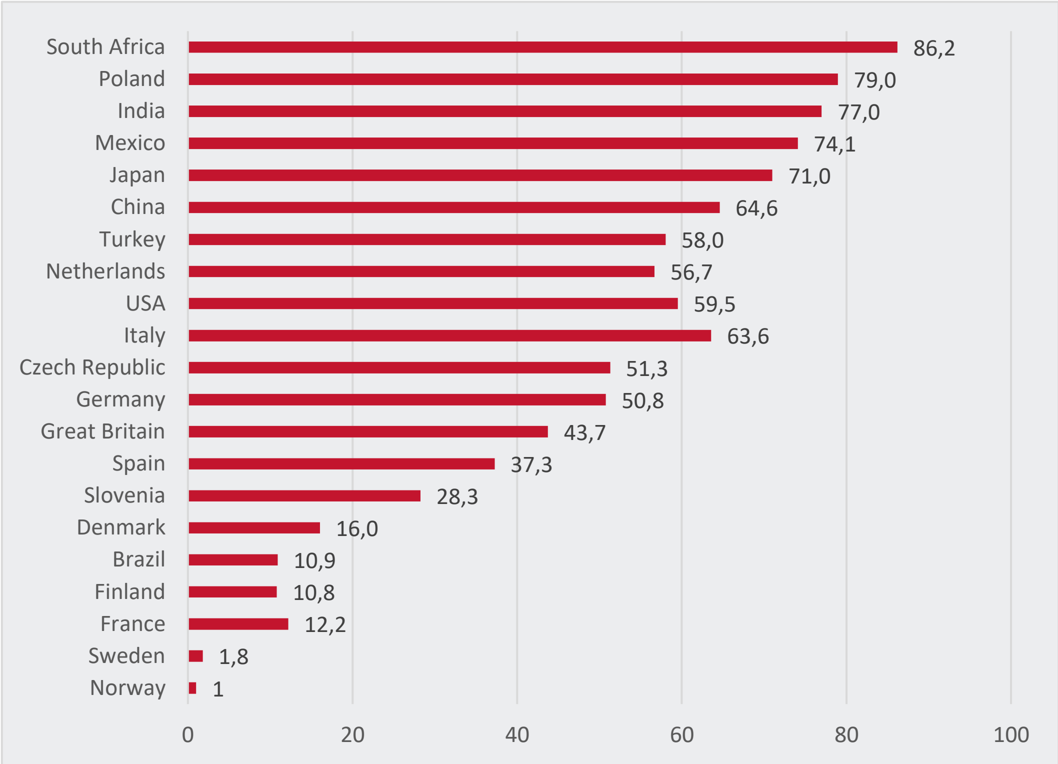


Figure 1: The share of fossil fuels in various countries' electricity mixes (2022), expressed as a percentage. Source: [Our World in Data.]()

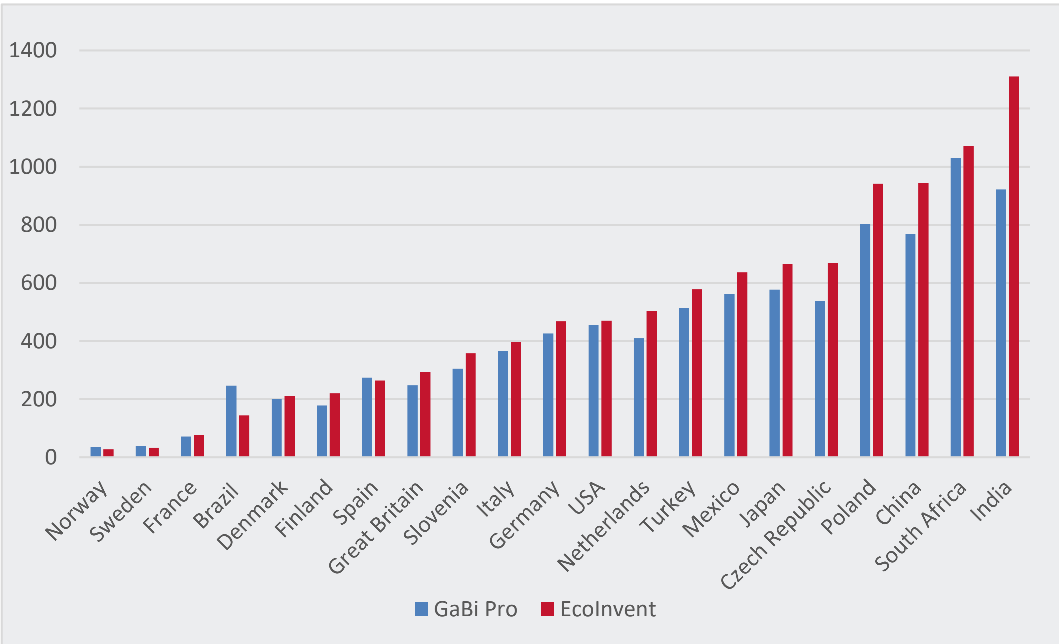


Figure 2: Climate-impacting emissions per kWh from electricity production. Data applies to the year 2019 for both EcoInvent and GaBi Professional.

6 Assumptions of which the calculations are based

The total energy requirement to manufacture one tonne of cast products of a specific metal depends on a number of different production-related factors. A metal-specific indicator will therefore be extremely unreliable, and presumably the most suitable approach in future versions would be to specify some form of statistical dispersion based on this.

To describe in detail the actual climate impact of cast products production, one would have to use a specific foundry/cast product from a country and compare it with a corresponding foundry/part from another country. It has not been possible to undertake this within the parameters of this report. This is mainly due to the lack of public data produced in the same way in the different countries but is also down to the fact that it was not within the remit of the project that such detailed findings be produced from comparable foundries in the various countries.

To be able to provide an indicative picture of the differences in climate impact due to cast products manufactured in different countries, we have therefore made a few simplifications and assumptions.

The restrictive parameter we have employed is that we only considered the amount of electrical energy that must be applied to a furnace in order to smelt the amount of metal required to produce one tonne of cast products, including a typical loss due to e.g., remelting. Generally, this means that the climate impact that is obtained represents a part of the total impact the production of one tonne of cast products generates. Table 1 specifies the amount of electricity used to smelt one tonne of metal and an average yield. It might be of help to explain where these figures came from:

Some were obtained from the so-called BREF (Best Available Techniques reference document) for the foundry industry dating from 2005 [2]. This document contains actual values for different foundries, expressed as a range. Based on this range, a value was chosen that does not need to be the same as the median value. Exactly which value is to be used is difficult to determine, as there is a lot of variation between different foundries, and some have progressed further in their work on energy-efficiencies. It may also be the case that some of the BREF document was produced before 2005. But because of the lack of any more recent values, the decision has been made to use the same figures as for the old report to be able to make a comparison.

Some values have been taken from Theoretical/Best Practice Energy Use In Metalcasting Operations, U.S. Department of Energy dating from 2004 [3]. These figures are entirely theoretical and cannot therefore be compared directly with those stated in BREF. To still be able to use them, they have been multiplied by 1.65 to obtain an approximate figure for energy applied to a furnace to smelt one tonne of metal. Equally, the figure of 1.65 is not a precise one. It can vary for different types of foundries and is perhaps somewhat on the high side for foundries involved in pressure die-casting. However, given that there are no precise new figures, the same values as in the previous report have been used, which makes it easier to compare the reports.

If a country's foundries are engaged in streamlining their foundry processes to make them more energy-efficient, this will be reflected in the actual consumption and the cost to the customer. By the same token, however, it is never reflected in the data presented in the climate indicator.

Table 1. Direct use of electricity for melting (theoretical value) of a tonne of metal and assumed exchange.

Metal	Average yield %	Electricity consumption for melting 1 tonne of metal, kWh
Iron	80	700*1
Steel (Induction)	60	740*2
Steel (Arc)	60	550*1
Aluminum	70	530*1
Bronze	55	227*3
Brass	50	293*3
Zinc	30	120*3
Magnesium	55	518*3

*1 Integrated Pollution Prevention and Control. Reference Document on Best Available Techniques in the Smitheries and Foundries Industry, May 2005

*2 BBC Inductive schmeltzen

*3 Theoretical/Best Practice Energy Use In Metalcasting Operation. U.S. Department of Energy. The theoretical values have been multiplied by a factor of 1.65 to obtain a estimate of the amount of energy supplied to the oven to melt one tonne of metal.

7 Differences compared to the previous study

IVL has pointed out some differences in its report compared to the previous study regarding emissions from electricity production.

The first study was conducted in 2011, and the data came from 2004 (EcoInvent) and 2006–2008 (IEA). For the update that took place in 2016, the data came from 2012 for both EcoInvent and GaBi Professional. The second update occurred in 2020, and the data came from 2016 (GaBi Professional) and 2018 (EcoInvent).

In general, the values are lower compared to the ones in the previous update. This is likely due to a reduction in the share of fossil fuels in electricity production in both the EU and OECD countries from 2012 to 2019.

8 Usability of the data

Information about the data's usability is obtained from IVL's four background reports for the calculations made in 2011, 2016, 2020 and 2023.

8.1 Electricity

The data on CO_2e emissions from electricity production presented in this report provides a good indication of the approximate scale of CO_2e emissions associated with electricity production and consumption in each respective country.

However, the data on CO_2e emissions from electricity production presented in this report should not be used as an exact description of CO_2e emissions from electricity production or consumption, as many influencing parameters are not included in the calculation (e.g., labeled electricity, residual mix, and varying production mixes from year to year)

Production mix refers to the composition of different types of power plants in a country, weighted based on the national production of each type. Residual mix is the production mix that remains after all labeled electricity is removed. In the case of Sweden, this simplistically corresponds to the electricity sold on NordPol that is not labeled – this electricity typically has a significantly larger proportion of coal power and, consequently, higher environmental impact than Sweden's production mix. The results presented in the report are based on production mix data since that is what is generally available.

The electricity presented in this report is referred to as average electricity, which aggregates emissions per kWh for different types of power plants (e.g., wind or coal) used in electricity generation within a country. Another way to view electricity is as marginal electricity, which describes the type of power plant used when demand increases and decreases. Both approaches have their limitations and issues, but a common division is to use marginal electricity to answer the question of what effect it has on increasing or decreasing electricity consumption and to use average electricity when summing up emissions from ongoing production.

If two or more countries have a common, well-functioning electricity market, it may sometimes be more relevant to look at the total average for all these countries' electricity production. However, this project has not investigated whether any of the countries concerned are part of such well-functioning electricity markets. Generally, this is not the case worldwide.

9 Results

Based on the background data presented by IVL (Appendix 1) and the assumptions described in Chapter 6, calculations have been performed for current casting metals. For steel, emissions from both induction furnaces and electric arc furnaces have been calculated.

The figures used in producing the diagrams are shown in Table 2. The results for the various metals are reported in Figure 3 to Figure 10.

Table 2. Results of completed calculations for each metal in 2022.

Country	Iron	Steel (Induction)	Steel (Arc Furnace)	Alumi-num	Bronze	Brass	Zinc	Magnesium
Brazil	126	178	132	109	59	84	58	136
China	826	1164	865	715	390	553	378	889
Czech Republic	585	824	612	506	276	391	267	629
Denmark	184	259	193	159	87	123	84	198
Finland	193	271	202	167	91	129	88	207
France	67	95	71	58	32	45	31	73
Germany	410	577	429	354	193	274	187	441
Great Britain	256	361	269	222	121	172	117	276
India	1146	1616	1201	992	541	768	524	1234
Italy	347	490	364	301	164	233	159	374
Japan	582	820	610	504	274	390	266	626
Mexico	557	784	583	482	262	373	254	599
Netherlands	440	620	461	381	208	295	201	474
Norway	24	33	25	20	11	16	11	25
Poland	824	1162	864	713	389	552	377	887
Slovenia	313	442	328	271	148	210	143	337
South Africa	936	1320	981	810	442	627	428	1008
Spain	231	326	242	200	109	155	106	249
Sweden	29	41	30	25	14	19	13	31
Turkey	506	713	530	438	239	339	231	544
USA	411	580	431	356	194	275	188	443

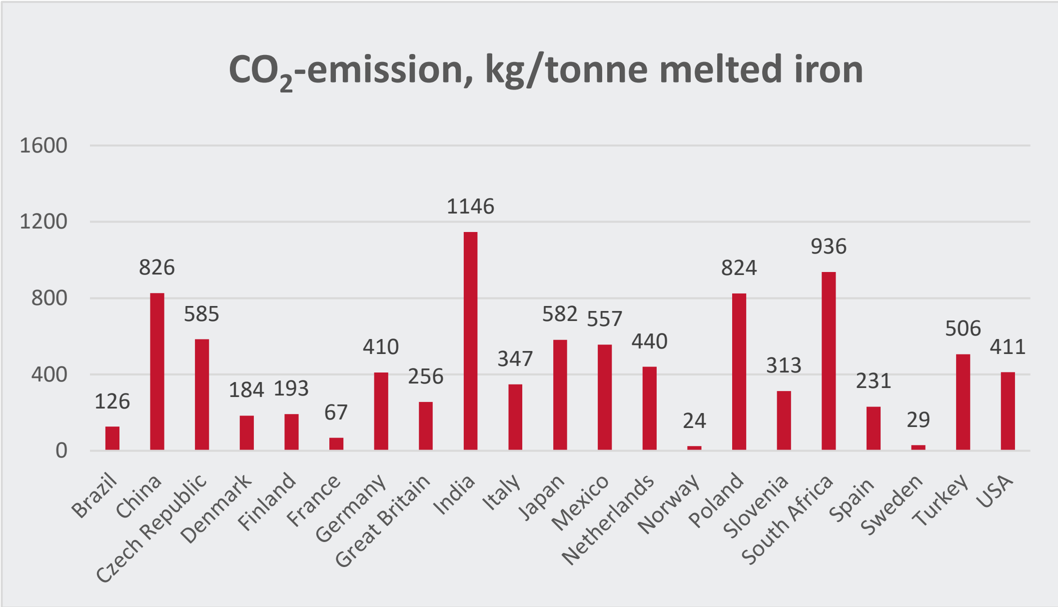


Figure 3. Carbon dioxide emissions for the melting of metal for one tonne of cast components.

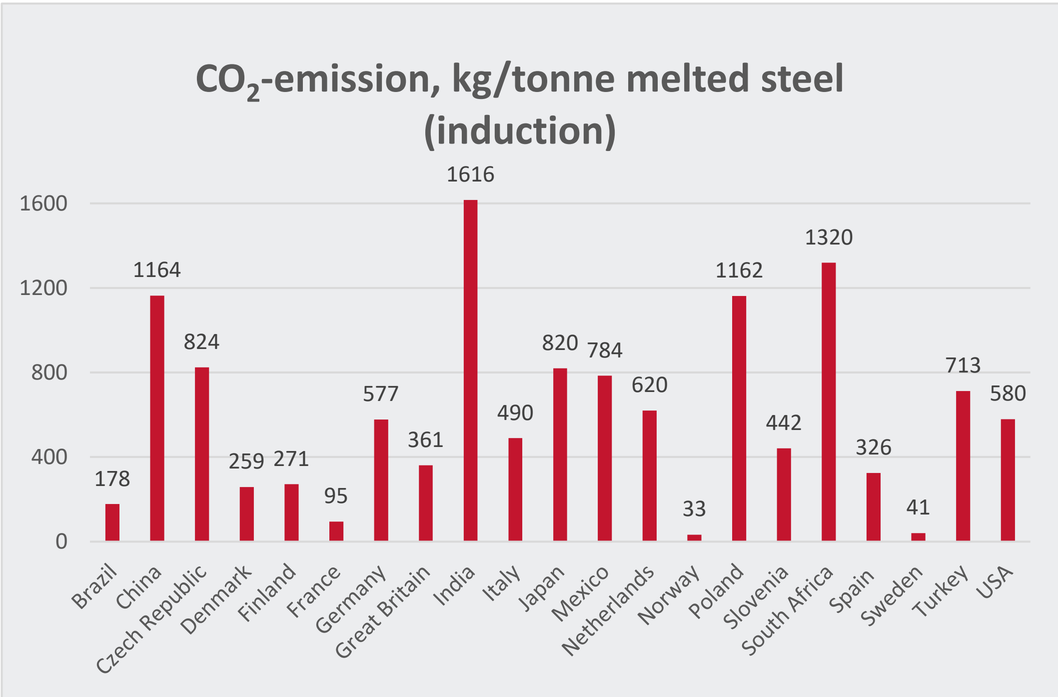


Figure 4. Carbon dioxide emissions for the melting of metal for one tonne of cast components.

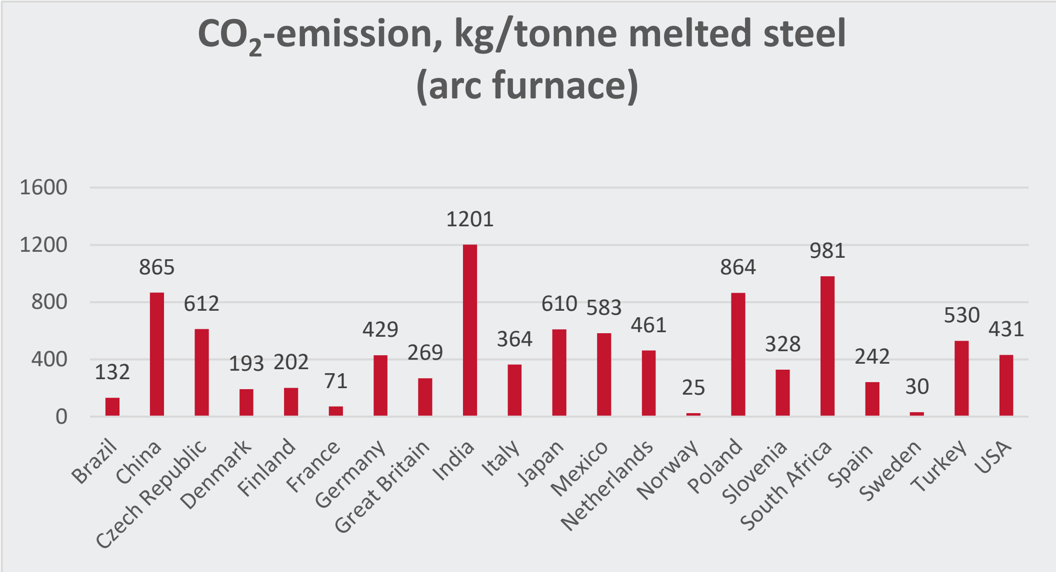


Figure 5. Carbon dioxide emissions for the melting of metal for one tonne of cast components.

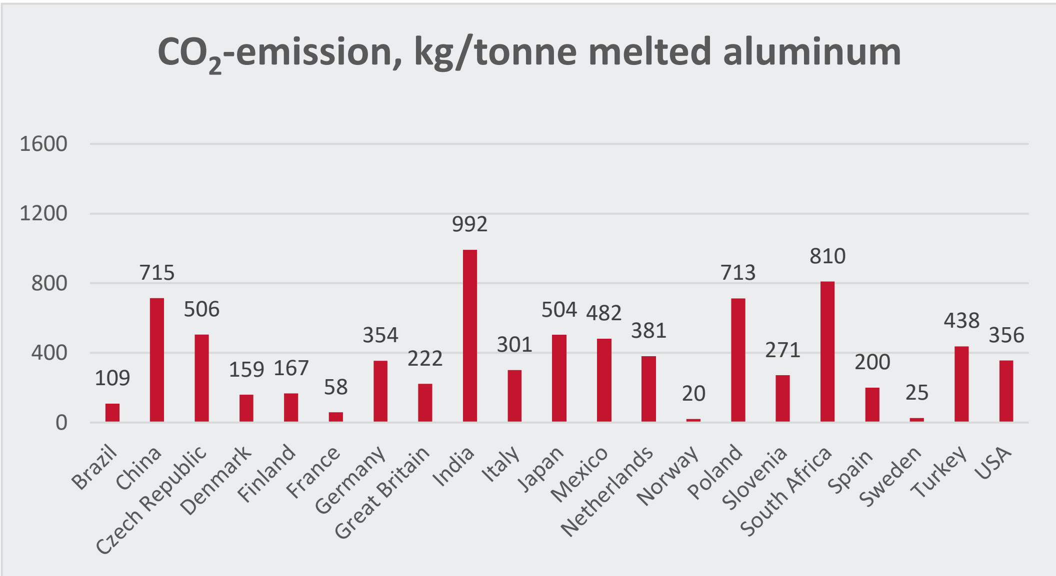


Figure 6. Carbon dioxide emissions for the melting of metal for one tonne of cast components.

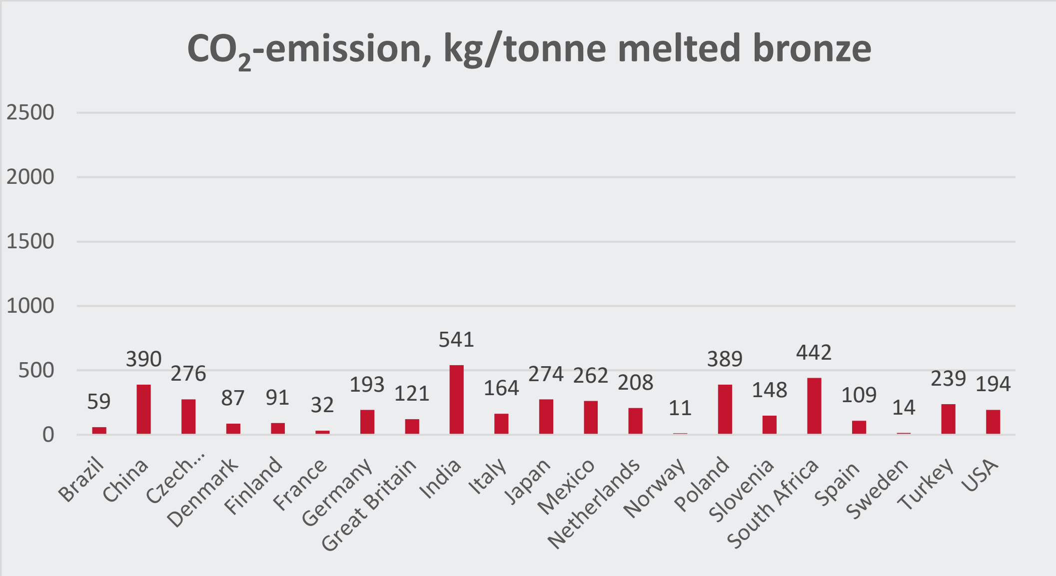


Figure 7. Carbon dioxide emissions for the melting of metal for one tonne of cast components.

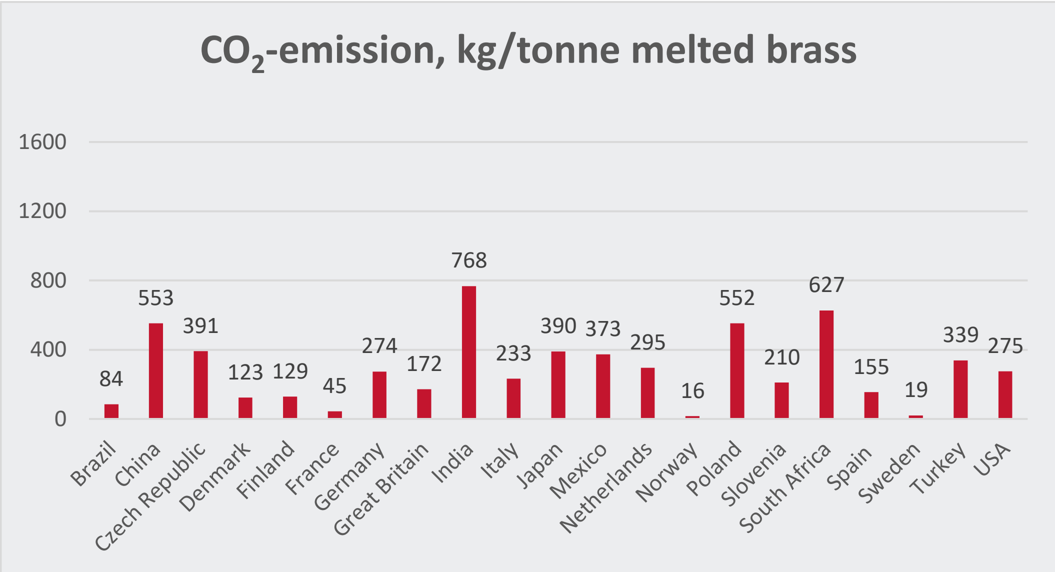


Figure 8. Carbon dioxide emissions for the melting of metal for one tonne of cast components.

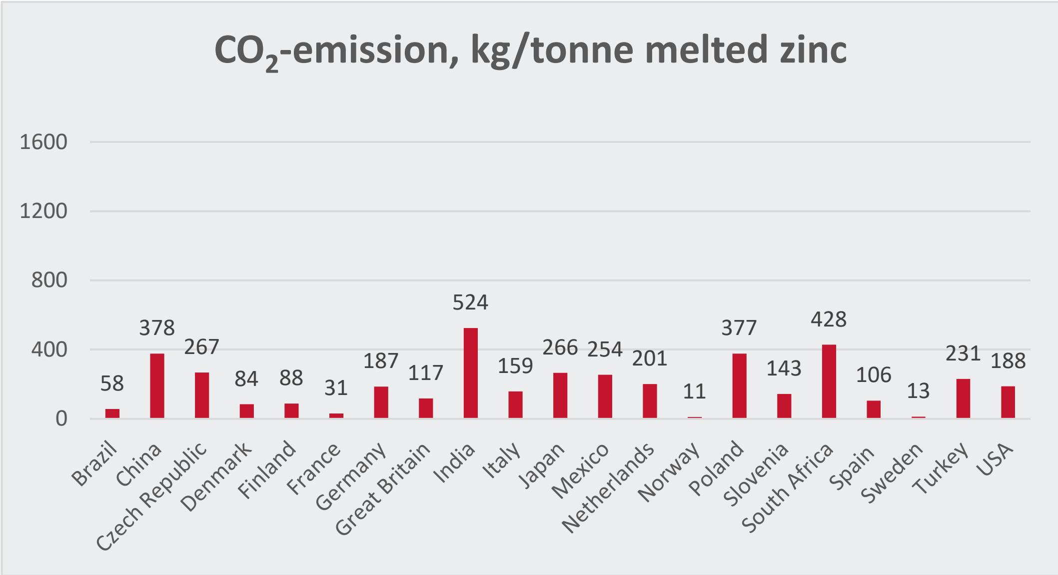


Figure 9. Carbon dioxide emissions for the melting of metal for one tonne of cast components.

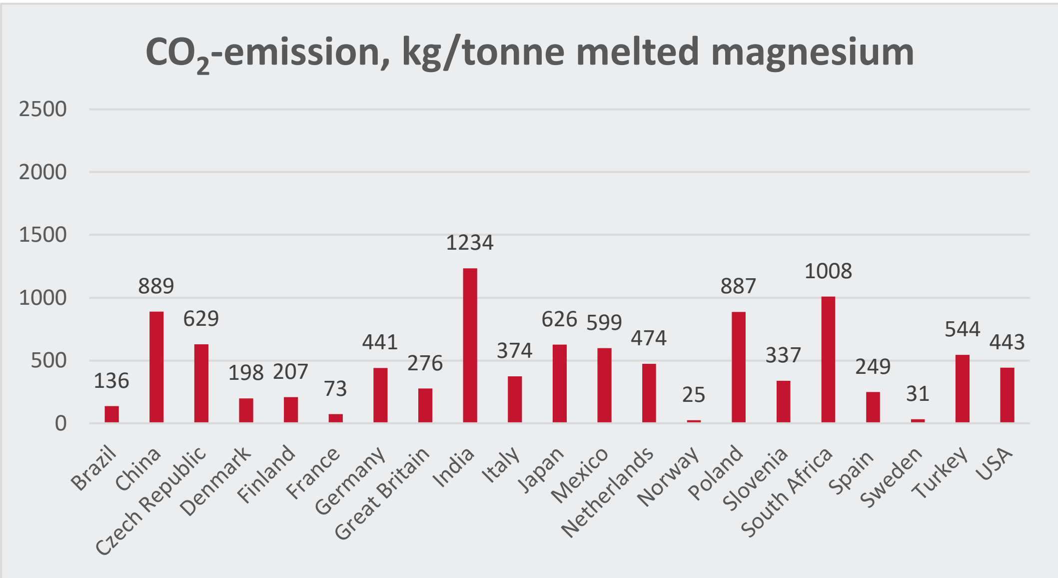


Figure 10. Carbon dioxide emissions for the melting of metal for one tonne of cast components.

10 Discussion

The results suggest that there are variations in the environmental impact of manufacturing cast components across different countries, primarily due to differences in their energy sources. Sweden stands out positively in this regard, with a significant portion of its electricity generated from low-emission hydroelectric and nuclear power sources.

It's important to note that the results are influenced by the choice of data sources, and they should not be viewed as absolute figures but rather as indicative of the overall situation.

Another source of uncertainty lies in the conversion of theoretical energy consumption values for smelting into actual values. The literature-derived actual values are more than a decade old, and changes in production efficiency and methods may have occurred in various parts of the world.

Misinterpretation of these results could lead to complacency within Swedish foundry companies, thinking they need not focus on energy efficiency improvements. However, such a misconception may hinder the Swedish foundry industry's competitiveness in the long run. If other foundries worldwide are making strides in reducing their environmental impact while Swedish foundries do not, there's a risk of falling behind in terms of productivity and sustainability.

The climate indicator used in this report primarily relies on the electricity generation mix, rather than individual foundry or country-specific streamlining efforts. The data used for electricity generation in different countries is based on data from 2022. It's essential to consider that the expansion of renewable electricity production is rapidly increasing worldwide, as seen, for instance, in China. This can have a significant impact on the relative positions of different countries within just a few years.

It's also important to emphasize that this report does not consider the entire lifecycle perspective of cast materials. It does not address whether cast products can lead to reduced carbon dioxide emissions during their use phase or if the lifespan of cast components varies based on their place of production around the world.

11 Further work

It would be relevant to conduct in-depth studies, such as individual foundries producing similar products, to gather more up-to-date data on actual energy usage.

Additionally, it would be beneficial to examine what the world's leading foundries can achieve regarding energy efficiency compared to those that have not streamlined their processes. This could help reduce emissions of climate-affecting gases regardless of where the castings are produced.

The proportion of recycled materials in the batch and the availability of scrap in the foundry's vicinity also play a significant role. Another important study would involve adopting a life cycle perspective on the environmental impact of the cast component, considering how the component affects emissions during its usage phase. Such an approach aligns with the future circular economies, where a life cycle perspective on the climate impact of castings has a crucial role to play.

12 References

[1] Data from Our World in Data. 2023. https://ourworldindata.org/grapher/share-electricity-low-carbon?tab=table&country=%7EOWID_WRL

[2] European Commission, Integrated Pollution Prevention and Control. Reference Document on Best Available Techniques in the Smitheries and Foundies Industry (2005).

[3] U.S. Department of Energy. Theoretical/Best Practice Energy Use in Metalcasting Operation.

Uppdatering 2023

Klimatsmart gjutgods

Rapportnummer: U6772
Författare: Julia Lindholm, Marie Gottfridsson

På uppdrag av: Svenska Gjuteriföreningen

Granskare: Karin Sanne
Godkännare: Karin Sanne

Innehållsförteckning

.

1 Inledning

På begäran från Svenska Gjuteriföreningen har IVL Svenska Miljöinstitutet tagit fram indikativa, generella data på koldioxidutsläpp från elproduktion från 21 länder som har en gjutgodsindustri, 13 europeiska länder plus Kina, Turkiet, USA, Brasilien, Mexico, Japan, Sydafrika och Indien. Syftet är att bidra med underlag till förenklade klimatpåverkansanalyser för gjutgods som Gjuteriföreningen genomför. Rapporten och resultattabellen får ej delas externt.

Detta är en tredje uppdatering av ett projekt som genomfördes år 2011. Mycket innehåll i detta dokument är samma men allt väsentligt har uppdaterats. Antalet inkluderade länder har utökats i denna uppdatering.

2 GWP-utsläpp från elproduktion, genomsnitts-el (g CO_2-e / kWh)

Klimatpåverkande utsläpp per kWh från produktion av elektricitet (g CO_2-ekvivalenter / kWh exkluderat biogent kol). Data gäller för år 2019 vilket är den senaste statistik som finns tillgänglig i databaserna.

Tabell 1. GWP-utsläpp från elproduktion (g CO_2-e/kWh) för ecoinvent respektive GaBi Professional (numera kallas databasen för Managed LCA Content).

Land	**g CO2-e/kWh (Medelvärde)**	ecoinvent	GaBi professional
Brasilien	**196**	*144*	*247*
Danmark	**206**	*210*	*201*
Finland	**199**	*220*	*178*
Frankrike	**74**	*77*	*72*
Indien	**1116**	*1310*	*922*
Italien	**382**	*397*	*366*
Japan	**621**	*665*	*577*
Kina	**856**	*944*	*768*
Mexico	**600**	*636*	*563*
Nederländerna	**457**	*503*	*410*
Norge	**32**	*27*	*36*
Polen	**873**	*942*	*803*
Slovenien	**332**	*358*	*305*
Spanien	**269**	*264*	*274*
Storbritannien	**271**	*293*	*248*
Sverige	**36**	*33*	*40*
Sydafrika	**1050**	*1070*	*1030*
Tjeckien	**603**	*668*	*537*
Turkiet	**546**	*578*	*514*
Tyskland	**447**	*468*	*426*
USA	**463**	*470*	*456*

Datakälla: ecoinvent (v.3.9.1) och GaBi Professional Database (v. 2023.2).

3 Tolkning och användbarhet av data

3.1 CO2-utsläpp från elproduktion

Data på CO2e-utsläpp från elproduktion presenterade i denna rapport ger en god indikation om ungefärlig storlek av CO2e-utsläpp förknippade med elproduktion och elkonsumtion i respektive land.

Data på CO2e-utsläpp från elproduktion presenterade i denna rapport bör ej användas som en exakt beskrivning av CO2e-utsläpp från elproduktion eller elkonsumtion, då många påverkande parametrar ej är inkluderade i beräkningen (t.ex. ursprungsmärkt el, residual-mix och varierande produktions-mix från år till år).

3.1.1 ecoinvent

Data gäller CO2e-emissioner från hela livscykeln för medelspänning i elnätet, för respektive land. Beräkningarna bygger på data från 2019 vilket är den senaste statistik som finns tillgänglig i databasen.

3.1.2 GaBi Professional

Data gäller CO2e-emissioner från hela livscykeln för medelspänning i elnätet, för respektive land. Beräkningarna bygger på data från 2019 vilket är den senaste statistik som finns tillgänglig i databasen.

3.1.3 ecoinvent jämfört med GaBi Professional

Båda organisationerna har hög trovärdighet och producerar generellt bra data, ecoinvent är dock lite mer lättillgänglig och antas ha något större spridning. ecoinvent ligger generellt högre än GaBi Professional, men det går utifrån denna studie inte att avgöra exakt vad det beror på. Både ecoinvent och GaBi professional använder International Energy Agency[1] (IEA) som källa för andelen energislag i elmixen som ligger till grund för beräkningarna av

[1] World Energy Balances 2019 https://doi.org/10.1787/3a876031-en

klimatpåverkan för elproduktion. Ett medelvärde av dessa två datakällor rekommenderas för Gjuteriföreningens beräkningar av indikativ klimatpåverkan från gjutgods.

3.1.4 Skillnader jämfört med förra uppdateringen

Den första studien utfördes år 2011, och dataunderlaget kom från 2004 (ecoinvent) och 2006–2008 (IEA). För uppdateringen som skedde 2016 kom dataunderlaget från 2012 för både ecoinvent och GaBi professional. Den andra uppdateringen skedde 2020 och då kom dataunderlaget från 2016 (GaBi professional) och 2018 (ecoinvent).

Generellt är värdena lägre än vid förra uppdateringarna och detta beror sannolikt på en minskning av andelen fossila bränslen i elproduktionen både i EU och OECD-länder från 2012 till 2019, vilket kan ses Figur 1, i bilaga 1.

3.1.5 Residual-mix och produktions-mix

Produktions-mixen är sammansättningen av de olika kraftverksslag som finns i ett land, viktat utifrån hur mycket som produceras nationellt av varje slag. Residual-mixen är den produktions-mix som kvarstår efter att all ursprungsmärkt el plockas bort, i Sverige motsvaras detta förenklat av den el som säljs på NordPol och inte är ursprungsmärkt – den elen har tex en väsentligt större andel kolkraft, och därmed även högre GWP-värde, än Sveriges produktions-mix. De resultat som presenteras i rapporten bygger på produktions-mix-data eftersom det är vad som generellt finns tillgängligt och är relevant för detta syfte.

3.1.6 Genomsnitts-el och marginal-el

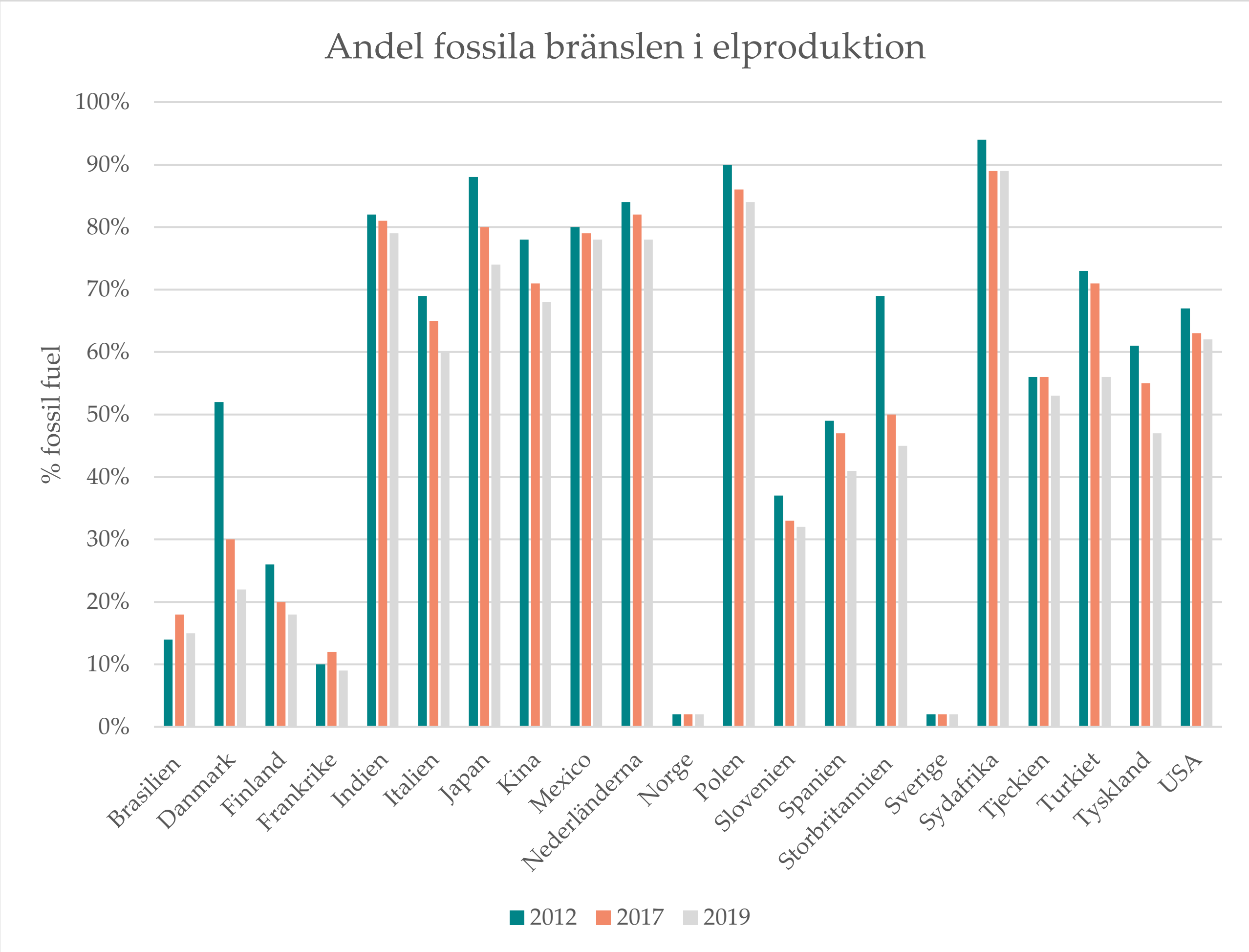
Elen presenterad i denna rapport är så kallad genomsnitts-el som summerar utsläppen per kWh för de olika kraftverksslag (t.ex. vind- eller kolkraft) som används vid tillverkning av el inom, i detta fall, ett land. Ett annat sätt att se på el är som marginal-el som i stället beskriver vilket kraftverksslag som utnyttjas vid ökad efterfrågan, och som då även minskar vid fallande efterfrågan. Båda sätten att se på el har sina begränsningar och problem, men en vanlig uppdelning att använda marginal-el för att svara på frågan vilken effekt det får om man ökar eller minskar elkonsumtionen, och att använda genomsnitts-el när man summerar utsläpp från pågående produktion.

3.1.7 Internationella elmarknader

Om två eller fler länder har en gemensam, väl fungerande, elmarknad så kan det ibland vara mer relevant att i stället titta på det totala genomsnittet för alla dessa länders elproduktion.

Detta projekt har dock ej undersökt huruvida några av de berörda länderna ingår i sådana, väl fungerande, elmarknader.

4 Bilaga



Figur 1. Överblick över förändringar i andel fossila bränslen i elproduktion från 2012, 2017 och 2019. Källa: Our World in data[2]

[2] https://ourworldindata.org/grapher/share-electricity-low-carbon?tab=table&country=~OWID_WRL

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Rapporten har granskats och godkänts i enlighet med IVL:s ledningssystem