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Global Efficiency Intelligence

# Corporates, Electricity, and Renewables

## An Analysis of Industrial Electricity Use and $CO_2$ Emissions Across the Globe

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# Acknowledgements

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## Disclaimer



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# Executive Summary

Industrial companies' use of electricity significantly contributes to global $CO_2$ emissions due to the reliance on fossil fuel-based power generation. The industry is responsible for about 44% of global electricity use. If companies procured electricity from wind and solar sources instead, it would substantially reduce their carbon footprint, helping to mitigate climate change. This report provides an essential analysis of electricity usage and emissions in the manufacturing sector globally and across 22 countries, serving as a critical reference for policymakers, business leaders, and other stakeholders. Most of the selected countries have a coal-intensive power generation.

By understanding the driving forces behind industrial electricity use and emissions, stakeholders can gain a clearer perspective on where the corporate sector is fueling global coal use through its electricity consumption and identify opportunities for actions and decarbonization. This study addresses the significant gap in understanding the landscape of global industrial electricity use, offering a data-driven foundation for more informed decisions in the race to achieve net-zero climate targets.

**Some of the key findings of this study are:**

1. Corporates in the industrial sectors are one of the main consumers of electricity in countries with significant operational coal-fired power generation capacity.
2. China, and therefore corporates operating directly or through their supply chains, is the largest manufacturing electricity consumer and $CO_2$ emitter. Manufacturing electricity-related $CO_2$ emissions in China in 2019 was equal to 2.5 gigatons (Gt $CO_2$). This is higher than total annual $CO_2$ emissions of India in 2019 (2.3 Gt $CO_2$), which is the 3rd largest $CO_2$ emitting country in the world after China and the U.S.
3. Outside of China, the United States, India, Japan and South Korea have the largest manufacturing electricity use in the world (Figure ES1). The top five electricity-consuming countries were responsible for 67% of global manufacturing electricity usage and 73% of corresponding $CO_2$ emissions.
4. Top 5 electricity-consuming industrial subsectors are: 1) iron and steel, 2) chemicals and petrochemicals, 3) machinery, electrical and electronic equipment, 4) non-ferrous metals such as aluminum and copper, and 5) non-metallic minerals such as cement and glass. These sectors account for approximately 72% of global manufacturing electricity use (Figure ES2).
5. Global manufacturing electricity demand will increase substantially by 2030. Especially countries in Southeast Asia will see a more substantial growth in the manufacturing electricity use. In these countries, corporate clean electricity procurement will be critical as companies cannot only rely on grid decarbonisation spearheaded by local government.

The assessment included countries within key geographical regions characterized by significant amounts of operational coal and where industrial electricity use is significant. The regions covered include Africa (South Africa, Morocco), Asia (China, Japan, The Republic of Korea, Taiwan), Southeast Asia (Indonesia, Vietnam, Thailand, Malaysia, Philippines), Europe (Germany, Italy, Poland, Turkey), South and Central Asia (India, Kazakhstan), North America (United States), Latin America (Brazil, Chile, Mexico) and Oceania (Australia). The 22 selected countries in this study represented 75% of global manufacturing electricity use and were responsible for 89% of global manufacturing electricity-related CO2 emissions. These countries therefore represent the highest emissions cutting potential through corporates' renewable energy procurement.

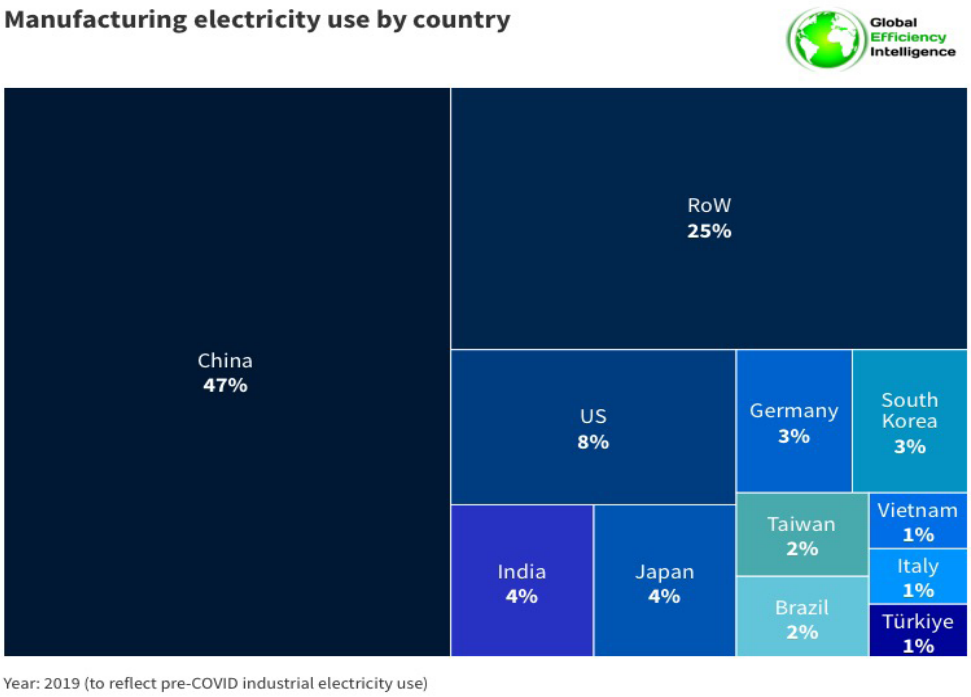


Figure ES1. (a) Share of countries from manufacturing electricity use in 2019

The bigger picture is the urgent need to decarbonize the industrial sector, which in 2019 accounted for 38% of total final energy consumption. A crucial aspect of this decarbonization process is reducing electricity-related $CO_2$ emissions. In addition, the electrification of industrial processes in the coming years will increase electricity demand and necessitates a parallel transition towards renewable electricity sources. We show how and where the industry sector is driving global fossil fuel use through their electricity use and highlight the potential for corporate renewable energy procurement to reduce $CO_2$ emissions associated with electricity consumption.

We also highlight the varying electricity-consuming manufacturing subsectors across different countries, emphasizing the need for tailored policies and renewable electricity procurement strategies. The global electricity demand for the industry is expected to increase between 2019 and 2030, but by assuming zero-carbon power generation by 2050, the industrial electricity-related $CO_2$ emissions are estimated to decrease by 2030 for most countries and manufacturing subsectors studied.

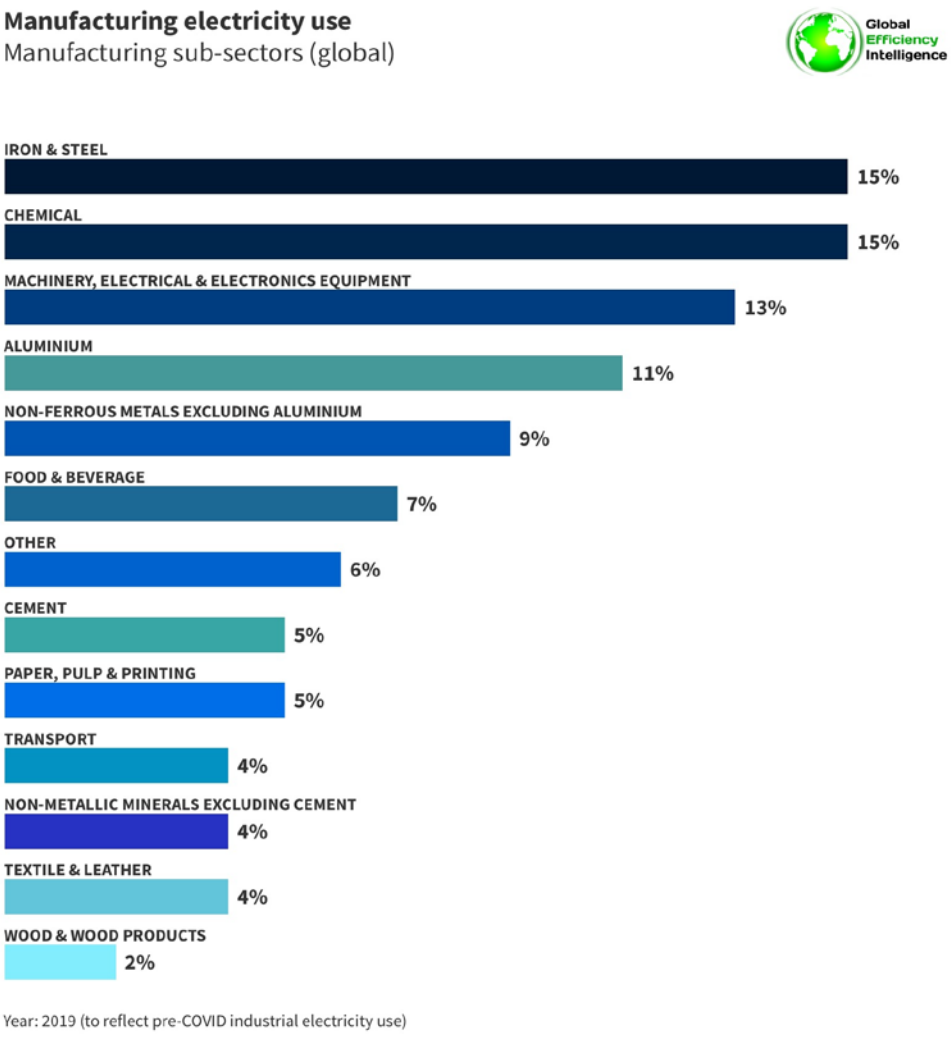


Figure ES2. Global manufacturing electricity use by sub-sector in 2019

Therefore, it is crucial that electricity grid decarbonization takes place alongside the growth in electricity demand from the industry sector, with additional electricity demand met by renewable sources. Our analysis reveals that manufacturing electricity demand in most countries exceeds annual clean energy generation, emphasizing the urgent need for expanding renewable energy capacity and promoting corporate renewable electricity procurement.

Our findings emphasize the need for additional renewable electricity generation resources and the role of policies, such as renewable portfolio standards (RPS), in driving the transition towards greener electricity sources. We also explore the role of corporate renewable electricity procurement in driving change within the industry sector. There are a variety of models for corporate renewable energy procurement, depending on the market and size of the buyer. Through power purchase agreements (PPAs) and onsite or offsite renewable electricity generation, companies can reduce their carbon footprint, save money, and improve their reputation. However, companies in electricity-intensive industries, such as chemical and petrochemical, iron and steel, non-ferrous metals, and cement, are lagging behind in adopting renewable electricity procurement strategies.

By delving into the complexities of global industrial electricity use and emissions, this study aims to guide the transition towards a low-carbon industry and power sector, identifying opportunities for corporations to drive change by using renewable electricity and contribute to the global effort to reach net-zero climate targets.

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# 1 Introduction

The industry sector globally consumed about 38% of total final energy and direct emissions from industry (excluding emissions from industrial electricity use) accounted for about a quarter of total global $CO_2$ emissions (IEA, 2022a). Thus, industrial decarbonization will play an important role in achieving net-zero climate targets. Although fossil fuels account for most of the industrial energy demand, electricity is already a crucial input for industry, powering a vast array of machines and processes integral to modern manufacturing and production.

The electricity is typically used in manufacturing sector for electric motor-driven systems (EMDS), process heating, process cooling/refrigeration, electrochemical processes, and other non-process related end uses such as lighting and HVAC. Electric motor-driven systems account for around 70% of the electricity used in the industry (Rao et al., 2021; Hasanbeigi, 2017). Table 1 below provides the shares of electricity used for EMDS for various manufacturing subsectors. Given the large share of electricity used by EMDS, energy efficiency improvement in EMDS is a key pathway to reducing manufacturing electricity use and corresponding $CO_2$ emissions. Energy efficiency technologies and measures for motor systems are presented in appendix 4. Moreover, electricity is used in process heating in industry and the electrification of process heat is considered as one of the key pathways for deep decarbonization of the industry. As a result, it is anticipated that electricity demand will grow in the future in the industry sector (IEA, 2020).

Table 1. Shares of electric motor-driven systems in total electricity use for various manufacturing subsectors (Rao et al., 2021)[1]

| Subsector | Share of sector's electricity used by motor systems |
|---|---|
| Food | 66% |
| Beverage/Tobacco | 72% |
| Chemical | 79% |
| Computer/Electronic | 38% |
| Electrical Equipment | 66% |
| Fabricated Metal | 61% |
| Machinery | 68% |
| Non-metallic Minerals | 70% |
| Paper | 80% |
| Petroleum Refining | 80% |
| Plastic/Rubber | 72% |
| Primary Metals | 50% |
| Textile | 79% |
| Transportation Equipment | 70% |
| Total Manufacturing | 70% |

1 The numbers presented in this table represent typical shares. These may vary for different countries.

The use of electricity in the industry also results in indirect $CO_2$ emissions (also called Scope 2 emissions). The amount of indirect $CO_2$ emissions depends on the electricity use intensity of the manufacturing sector and the $CO_2$ emission intensity of the power generation in the country. Therefore, it is also important that along with industrial decarbonization, simultaneous decarbonization of the electricity grid should take place, and the electricity demand in the industry should be fulfilled with renewable sources.

In order to prioritize the electricity grid decarbonization, it is important to identify the most significant countries in terms of industrial electricity use as well as the most electricity-consuming end-use sectors for each country. This report presents an analysis of the current state of electricity use and corresponding $CO_2$ emissions in the industry from various perspectives. In particular, we focus on electricity use in the manufacturing subsectors of various countries, many of which have $CO_2$-intensive electricity generation and top electricity-consuming manufacturing sectors. We present the analysis of electricity use in the manufacturing sectors of 22 countries and several energy-intensive manufacturing subsectors.

The analysis of key electricity-consuming manufacturing subsectors in selected countries is complemented by the short-term forecasts of the electricity use and corresponding $CO_2$ emissions for selected subsectors until 2030. The estimated shares of current installed power generation capacities that are utilized for manufacturing electricity demand for each country are presented in this report, along with the comparison of manufacturing electricity used in 2019 and the clean electricity generation for each country studied.

# 2 Electricity use in the Global Industry Sector

The share of electricity in total final energy use globally was about 20% as of 2019 (IEA, 2022c). The global electricity demand reached nearly 26,500 TWh in 2019, with industry accounting for about 44% of total electricity demand, followed by the residential sector (28%), tertiary sector (22%), agriculture (4%) and transport (2%) (IEA, 2022; Figure 1).

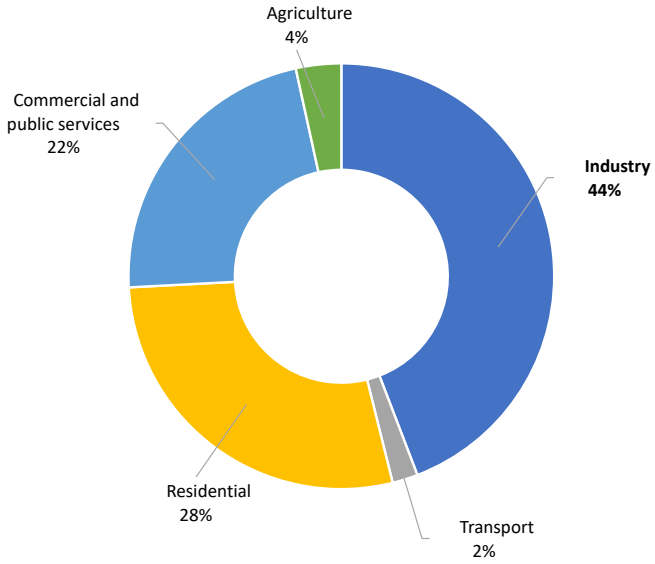



Figure 1. Shares of economic sectors in global electricity demand in 2019 (IEA, 2022c)

The industry sector typically consists of manufacturing, construction and mining subsectors. Globally, the manufacturing subsector was responsible for about 90% of global industrial electricity demand in 2019, followed by mining and quarrying (5%) and construction (3%). The remaining 2% of electricity demand could not be attributed to any industry subsector due to reporting discrepancies at the level of subsectors for some of the countries (Figure 2). Due to the large share of electricity used in manufacturing, the analysis presented in the rest of the report will focus on in manufacturing sector's electricity use.

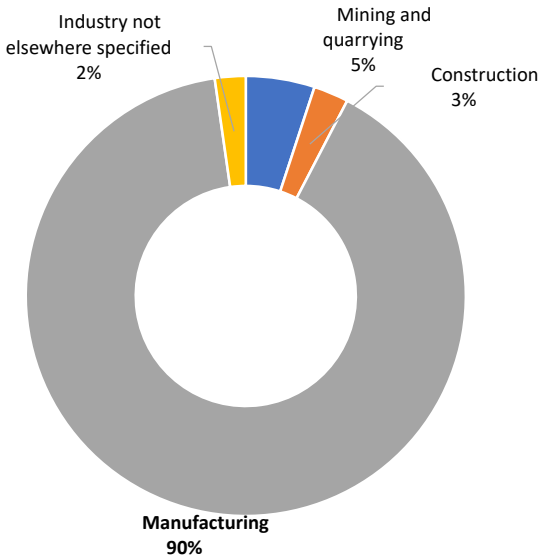



Figure 2. Share of industrial subsectors in industrial energy use in 2019 (IEA, 2022c)

Manufacturing electricity use is attributed to 12 specific manufacturing subsectors and "other manufacturing" subsector. Iron and steel (15%) and chemicals (15%) industries represented the largest shares of global manufacturing electricity use, followed by non-ferrous metals (20%) (aluminum,11% and other non-ferrous metals, 9%), machinery and electrical equipment (13%), and non-metallic minerals (9%) (cement, 5% and other non-metallic minerals, 4%). These top five electricity-consuming manufacturing subsectors were responsible for about 72% of global manufacturing electricity use in 2019. The remaining manufacturing subsectors, along with the "other manufacturing" were responsible for 28% of manufacturing electricity demand globally in 2019 (Figure 3).

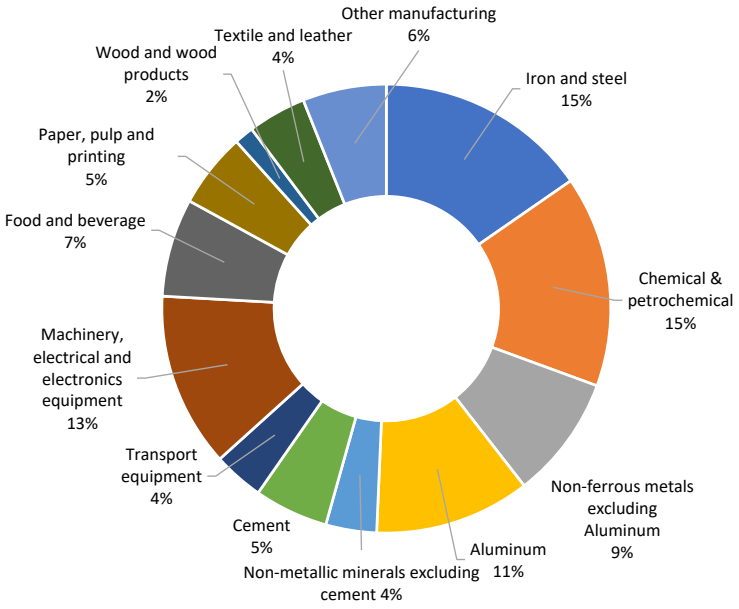



Figure 3. Shares of manufacturing subsectors in global manufacturing electricity use in 2019 (Estimated using IEA, 2022c, Hasanbeigi 2022, Hasanbeigi et al. 2022).

Although industry was responsible for about 44% of global electricity use in 2019, industrial electricity use only contributed about 14% of global $CO_2$ emissions. The remaining electricity-related $CO_2$ emissions can be attributed to electricity demand in residential (9%), the commercial and public sector (7%), agriculture sector (1%), and transport sector (< 1%). Other non-electricity-related $CO_2$ emissions, mainly from fossil fuel used in the industry, buildings, and transport sectors were responsible for 69% of global $CO_2$ emissions in 2019 (Figure 4).

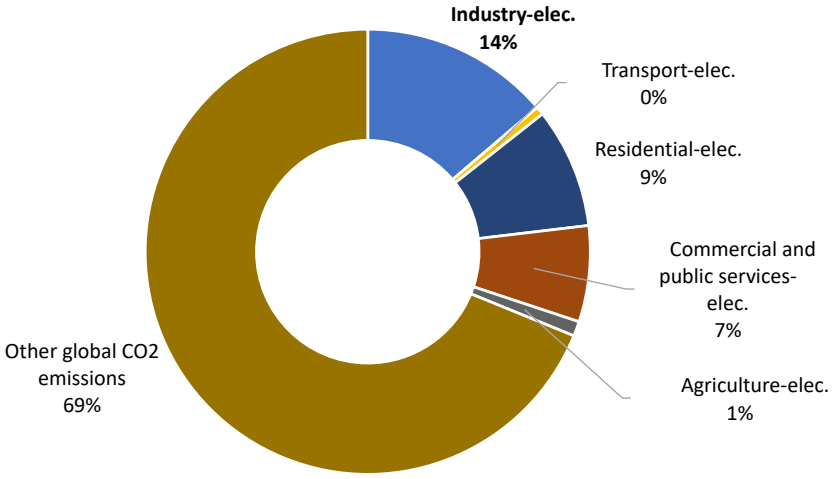



Figure 4. Share of electricity and non-electricity-related $CO_2$ emissions by sector in 2019 (Estimated using IEA, 2022c)

The selected countries in this report represent 75% of global manufacturing electricity use, while being responsible for 80% of global manufacturing electricity-related $CO_2$ emissions. Figure 5 shows some of the top countries in terms of industrial electricity use and electricity-related $CO_2$ emissions among the selected countries in this study.

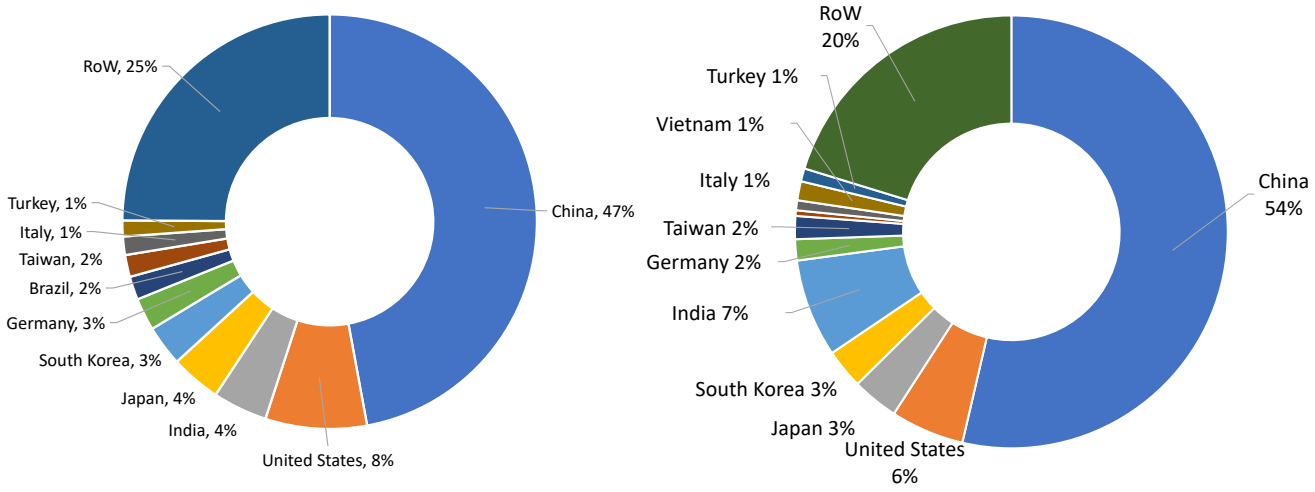



Figure 5. (a) Electricity use shares of various countries in the manufacturing sector in 2019 (IEA, 2022c) (b) Shares of manufacturing electricity-related $CO_2$ emissions from various countries in 2019

The top 5 countries studied in this report were responsible for 67% of global manufacturing-related electricity use. China, being responsible for 48% of global manufacturing electricity use, was by far the largest consumer, followed by the U.S. (8%), India (4%), Japan and South Korea (3%). However, the top five largest manufacturing-related electricity consumers were responsible for 72% of manufacturing electricity-related $CO_2$ emissions, with China being responsible for 53% of $CO_2$ emissions, followed by India (7%), the U.S. (6%).

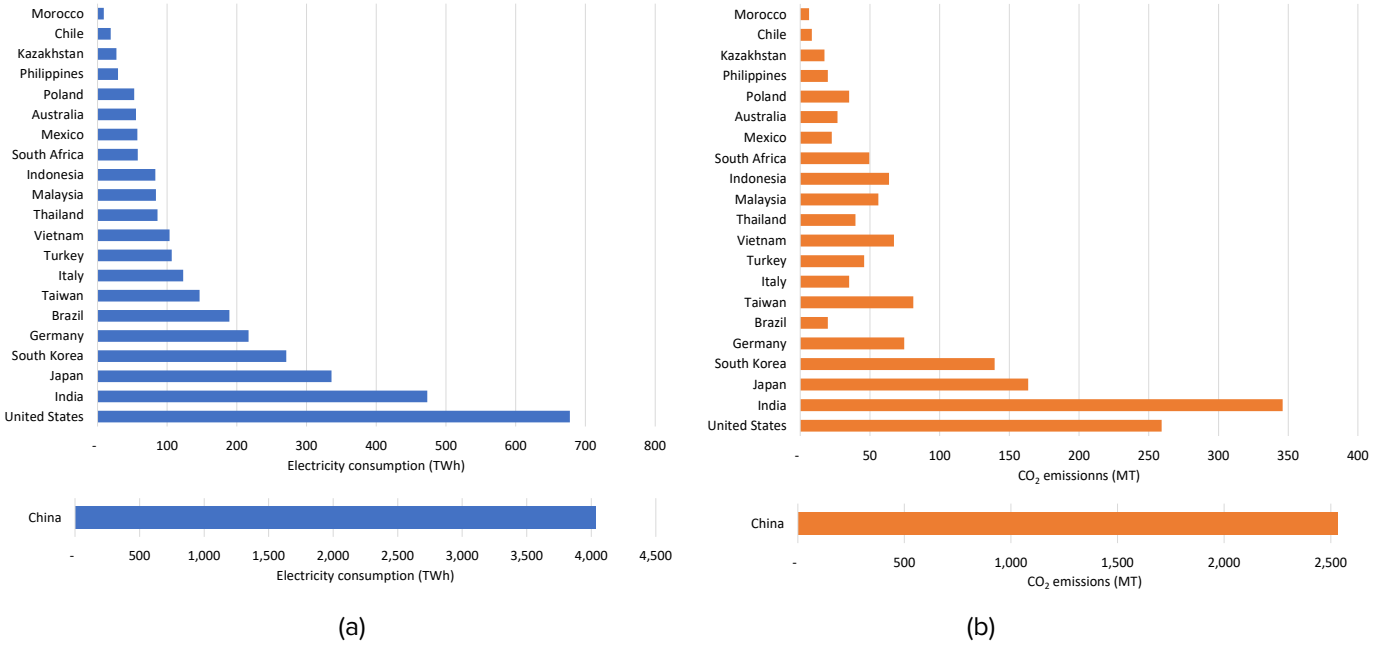



Figure 6. (a) Manufacturing electricity demand for selected countries in 2019 (IEA, 2022c) (b) Manufacturing electricity-related $CO_2$ emissions for selected countries in 2019 (estimated using IEA, 2022c)

# 3 Country-level Manufacturing Electricity use

This section presents the profiles of electricity use in the manufacturing sector for selected countries. These profiles help identify the key industry subsectors in terms of electricity demand in each country. The analysis of electricity use in the top five countries in terms of manufacturing electricity use is presented in this section. The results for the remaining seventeen countries are presented in the appendix. The top five countries in terms of manufacturing electricity use were responsible for 67% of global manufacturing electricity use and 72% of corresponding $CO_2$ emissions in 2019.

Figure 7 presents the shares of electricity use by various manufacturing subsectors for all countries included in this report. The top electricity-consuming manufacturing subsectors vary by country. Iron and steel and chemicals and petrochemicals are the largest manufacturing electricity consumers for the majority of the countries analyzed in this report. However, electricity-intensive subsectors like aluminum and other non-ferrous metals dominate the electricity use in the manufacturing sector in some countries like Australia, Malaysia, South Africa. In some east Asian economies like Taiwan, South Korea, Japan, Thailand and Philippines the machinery, electrical, and electronic equipment manufacturing has a large share of the current manufacturing electricity use. Below we present in more detail the electricity used in manufacturing in several major electricity consuming countries.

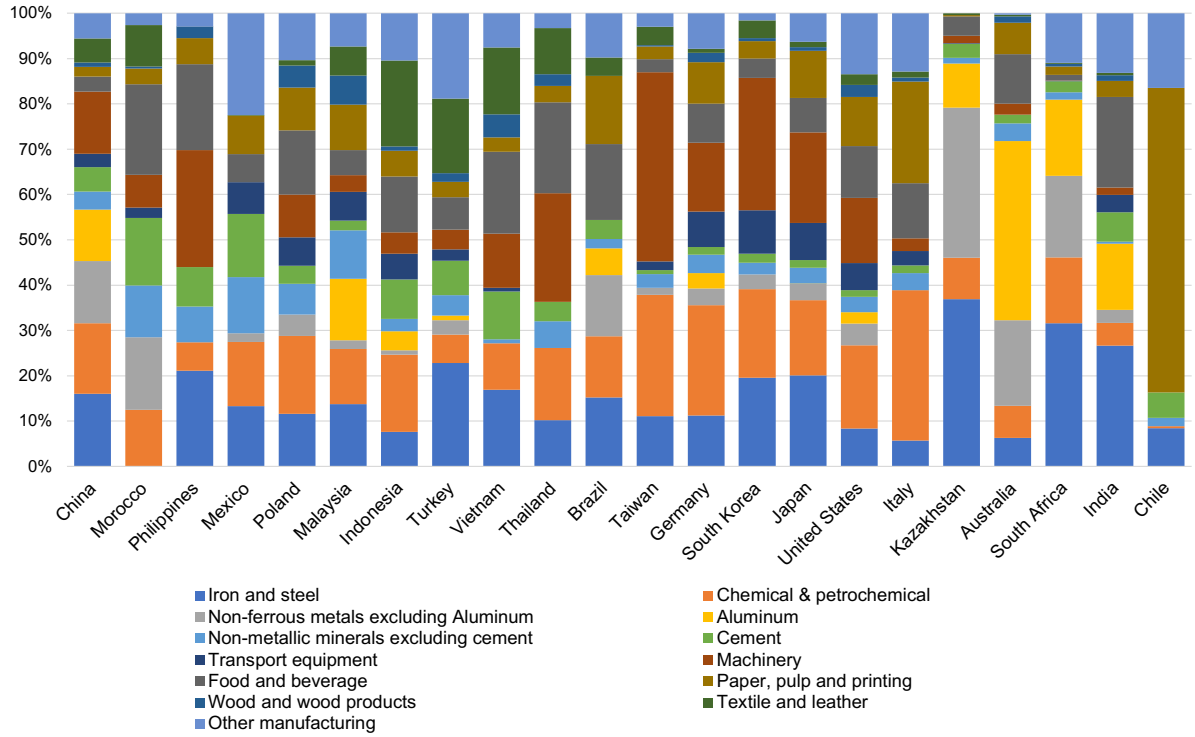



Figure 7. Electricity shares of manufacturing sectors for countries included in this report for 2019 (IEA, 2022c)

## China

China's manufacturing industry is dominated by the production of energy-intensive products such as iron and steel, cement, chemicals, and non-ferrous metals. Due to its massive scale of production, China is the world's largest consumer of manufacturing electricity, accounting for almost half of the global consumption.

In 2019, the iron and steel industry in China was the largest consumer of electricity, followed closely by the chemicals and petrochemicals industry and the machinery and electrical and electronic manufacturing industry. These subsectors also had a significant impact on the environment, contributing to the country's manufacturing electricity-related $CO_2$ emissions.

The non-ferrous metals industry, including aluminum and other non-ferrous metals, accounted for a quarter of China's manufacturing electricity use. The production of these metals is energy-intensive, requiring large amounts of electricity to power the extraction and refinement processes. The non-metallic minerals manufacturing industry, which includes cement and other non-metallic minerals, also accounted for a significant portion of China's manufacturing electricity use (Figure 8).

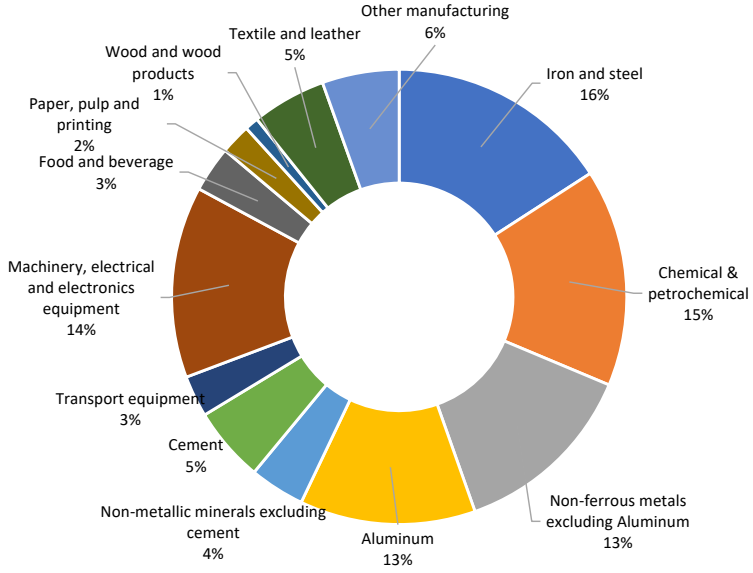



Figure 8. Shares of manufacturing subsector in annual electricity use for China in 2019 (source: IEA, 2022c)

## United States

The manufacturing sector is a major consumer of electricity globally, and the U.S. is the second-largest electricity-consuming manufacturing sector worldwide. The sector's electricity consumption and related CO2 emissions are significant, accounting for 8% and 6% of global manufacturing electricity use and emissions, respectively.

The chemicals and petrochemical industry is the largest electricity-consuming subsector in the U.S. manufacturing sector, responsible for about 18% of electricity consumed in manufacturing in 2019. This industry's significant electricity consumption is primarily due to the energy-intensive nature of its processes, which require large amounts of electricity to manufacture various chemical and petrochemical products.

Non-energy-intensive sectors such as machinery, electrical and electronic manufacturing, and food and beverage also contribute significantly to the U.S. manufacturing sector's electricity consumption. These subsectors rely heavily on electricity to power their processes, machinery, and equipment. On the other hand, energy-intensive sectors such as pulp and paper and iron and steel industries consume a significant amount of electricity due to the nature of their processes, which involve heating, melting, and shaping metals or paper pulp, requiring high levels of energy input. It's worth noting that a considerable share of manufacturing electricity use is attributed to other manufacturing, which typically includes non-energy intensive subsectors (Figure 9).

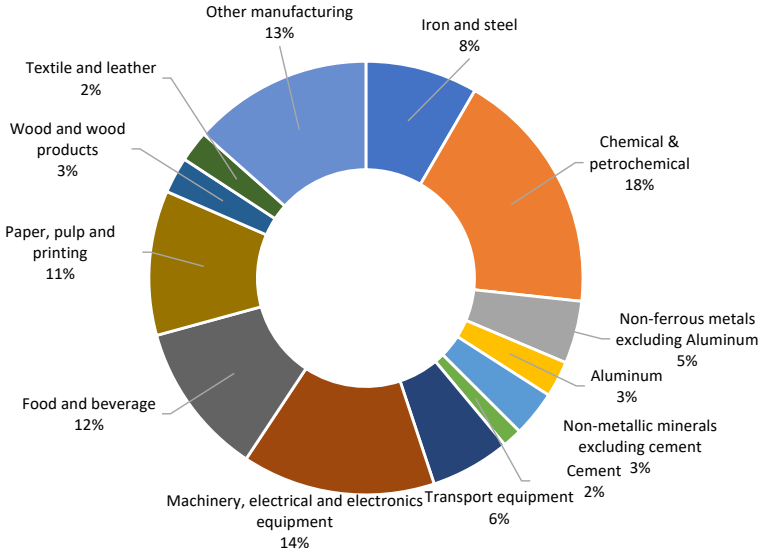



Figure 9. Shares of manufacturing subsector in annual electricity use for the United States in 2019 (source: IEA, 2022c)

## India

India ranked third in terms of annual electricity use in the year 2019, with a total consumption of 240 TWh.

Within the Indian manufacturing sector, the iron and steel industry emerged as the largest consumer of electricity, accounting for approximately one-fifth (20%) of the sector's overall electricity consumption. This was closely followed by the chemicals and petrochemical industry, which represented the second-largest share of manufacturing electricity use, with a consumption of 19%. The food and beverage industry ranked third in terms of electricity consumption, accounting for 15% of the manufacturing sector's overall electricity use.

Other subsectors within the Indian manufacturing sector also contributed significantly to the country's electricity consumption. The non-ferrous metals industry, for example, was responsible for 14% of the electricity used in the sector, with the majority of electricity being utilized for aluminum manufacturing. However, it is worth noting that all of the electricity used for primary aluminum manufacturing in India was produced onsite using coal-based captive power plants (Hasanbeigi et al., 2022).
The non-metallic minerals industry was responsible for 10% of the electricity consumed in the Indian manufacturing sector, with electricity use split evenly between cement manufacturing and other non-metallic minerals manufacturing. Textile and leather, transport equipment, pulp and paper, wood products, machinery, electrical and electronic equipment, and other manufacturing together accounted for the remaining 22% of the electricity consumed by the Indian manufacturing sector. (Figure 10).

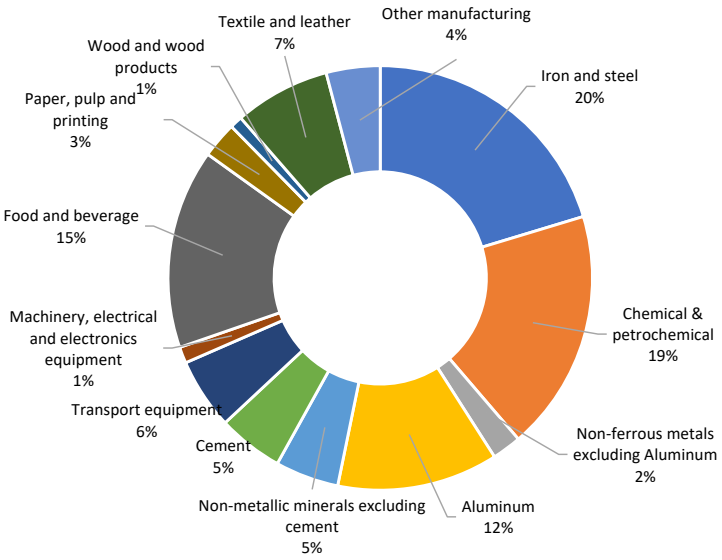



Figure 10. Shares of manufacturing subsector in annual manufacturing electricity use for India in 2019 (source: estimations based on IEA, 2022c)

## Japan

In 2019, the Japanese manufacturing sector accounted for approximately 4% of global manufacturing electricity demand, making it the fourth largest consumer of manufacturing electricity.

Iron and steel manufacturing, machinery, electrical and electronic equipment manufacturing, and chemicals and petrochemicals manufacturing were the three largest consumers of electricity in Japan's manufacturing sector, together accounting for more than half of the country's manufacturing electricity use. These industries are essential for Japan's infrastructure and economic growth, but their energy-intensive processes have a significant impact on the environment.

Other subsectors in Japan's manufacturing industry also contributed to the country's electricity consumption, including pulp and paper manufacturing, food and beverage, transport equipment, non-metallic minerals, non-ferrous metals, and other manufacturing.

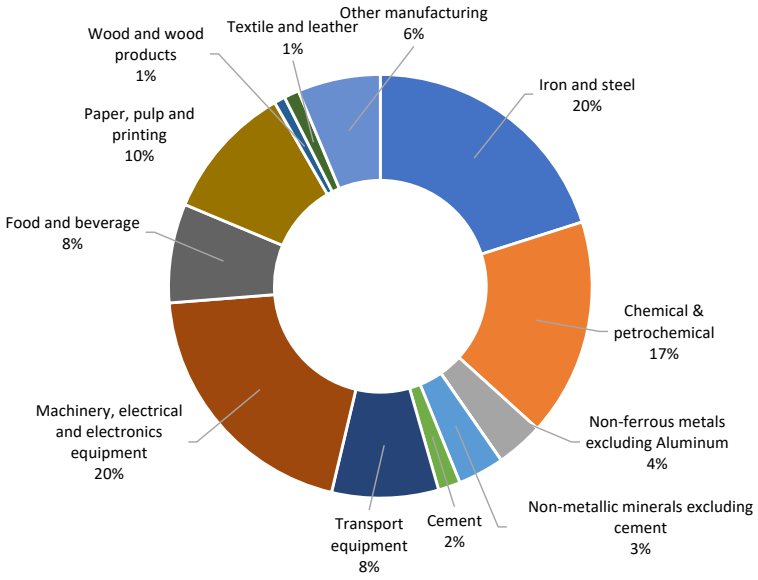



Figure 11. Shares of manufacturing subsector in annual manufacturing electricity use for Japan in 2019 (source: IEA, 2022c)

## South Korea

South Korea is a significant contributor to global manufacturing electricity use, ranking fifth among the countries included in this report. The country's manufacturing industry plays an essential role in driving economic growth and employment opportunities.

The electricity consumption in South Korea's manufacturing sector is primarily attributed to machinery, electrical and electronic equipment manufacturing, iron and steel, and chemicals and petrochemicals. These industries are vital to South Korea's infrastructure, but their energy-intensive processes have a significant impact on the environment.

Other subsectors in South Korea's manufacturing industry also contributed to the country's electricity consumption, including transport equipment manufacturing, non-metallic minerals, food and beverage, pulp and paper, textile and leather, non-ferrous metals, and other manufacturing. While these subsectors account for a relatively smaller proportion of manufacturing electricity use in South Korea, they still require substantial amounts of electricity to operate.

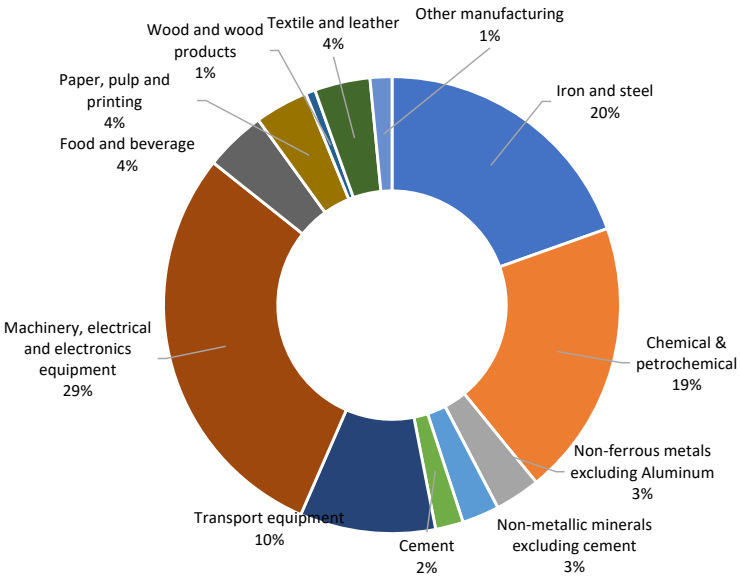



Figure 12. Shares of manufacturing subsector in annual manufacturing electricity use for South Korea in 2019 (source: IEA, 2022c)

# 4 Electricity use in Manufacturing Subsectors

The following section presents the electricity use and corresponding $CO_2$ emissions in various countries for the largest electricity-consuming manufacturing sectors. Iron and steel manufacturing, chemicals and petrochemicals manufacturing, Machinery, electrical, and electronic equipment manufacturing, non-ferrous metals manufacturing and non-metallic minerals manufacturing are the leading electricity-consuming manufacturing subsectors globally. These top five electricity-consuming subsectors were responsible for about 72% of global manufacturing electricity use in 2019. That is why these five subsectors are chosen for deeper dive in the following subsections.

## 4.1. Chemicals and petrochemicals industry's electricity use and electricity-related $CO_2$ emissions

The chemical and petrochemical industry is one of the largest electricity-consuming manufacturing sectors globally. This sector was responsible for 15% of global manufacturing electricity use in 2019. Typically, chemical and petrochemical manufacturing includes several electricity-intensive processes such as compression, refrigeration, electrolysis, etc. Overall, electricity accounts for about 14% total energy consumed in the chemical industry (IEA 2022c). Chemical and petrochemical manufacturing in China was responsible for 48% of this subsector's electricity use globally in 2019 (Figure 13).

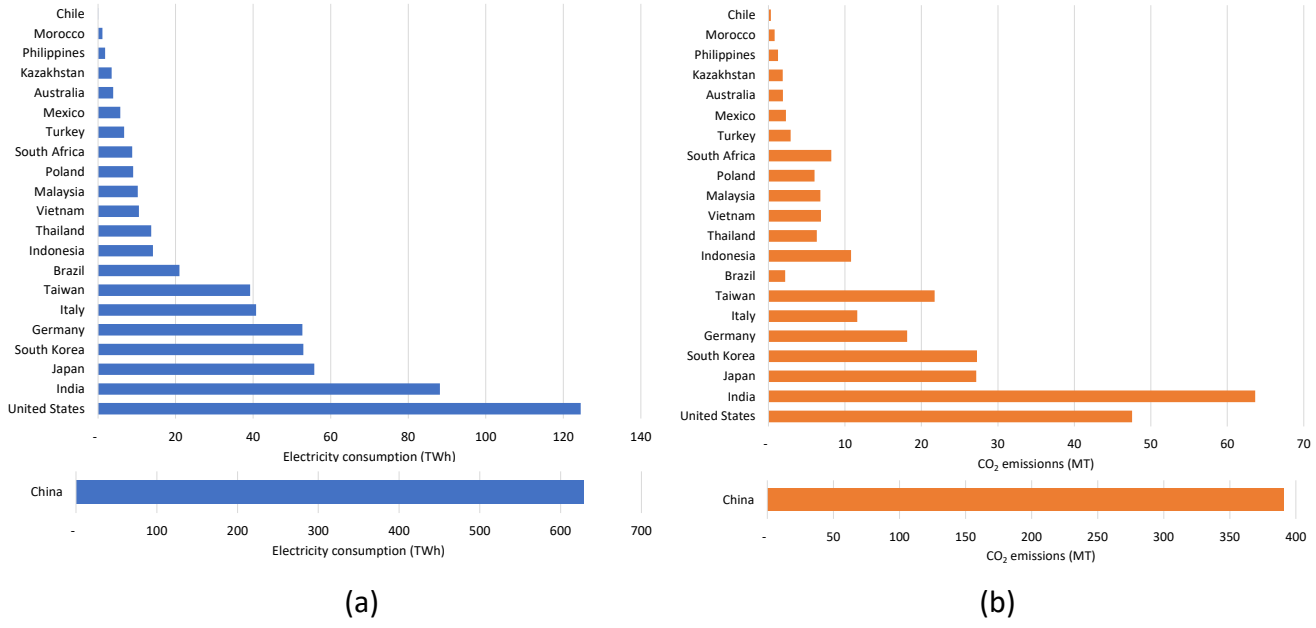



Figure 13. (a) Electricity used for chemicals and petrochemicals manufacturing in selected countries in 2019 (source: IEA, 2022c) (b) $CO_2$ emissions caused by electricity use in chemicals and petrochemicals manufacturing in selected countries (Source: this study)[2]

The electricity used in the Chinese chemical manufacturing sector was responsible for about 391 MT of $CO_2$ emissions. The chemical manufacturing sector in the U.S. used about 10% of total electricity use globally and was responsible for about 48 MT of $CO_2$ emissions in 2019. India was responsible for 7% of global chemical manufacturing electricity use, followed by Japan and South Korea (4% each). Electricity use from the top five chemicals and petrochemical manufacturing countries studied was responsible for 90% of electricity-related

2 Due to a large difference in electricity use and $CO_2$ emissions between China and the rest of the countries, the data for China are presented on a separate scale throughout the report.

$CO_2$ emissions from this sector globally. Despite the lower electricity use in Indian chemical manufacturing compared to that of the U.S., it was responsible for 64 MT of electricity-related $CO_2$ emissions. Japanese and South Korean chemical manufacturing were responsible for 27 Mt of $CO_2$ emissions each in 2019.

## 4.2. Iron and steel industry's electricity use and electricity-related $CO_2$ emissions

The iron and steel industry is one of the largest electricity-consuming manufacturing subsectors. Electricity in the steel industry is predominantly used for electric arc furnaces (EAF) and EMDS. Typically, about 20% of the energy consumed for steel production through the blast furnace – blast oxygen furnace (BF-BOF) and 50% of the energy consumed for the electric arc furnace (EAF) is electricity (Hasanbeigi et al., 2022). The top five steel manufacturing countries in the world were responsible for 70% of electricity consumed in the iron and steel industry in 2019. As a result of being responsible for about 53% of global steel production, the Chinese steel industry was responsible for about half of the global electricity used in the iron and steel industry in 2019. India was the second largest steel-producing country after China. However, the electricity consumption for the Indian steel industry was about 15% of China (or 7% of global iron and steel manufacturing electricity use). Japanese iron and steel industry was responsible for about 5% of global electricity use in the iron and steel industry. The U.S. and South Korea each represented around 4% of global electricity use in the steel industry (Figure 14).

The top five steel-producing countries studied were responsible for about 89% of total electricity-related $CO_2$ emissions from the global steel industry in 2019. The electricity use in Chinese steel manufacturing was responsible for generating 402 MT of $CO_2$ emissions in 2019 (i.e., 64% of total $CO_2$ emissions from electricity use in the global iron and steel industry). Electricity used in the Indian iron and steel industry generated about 70 MT of $CO_2$ emissions in 2019, followed by Japan (33 MT), the U.S. (22 Mt), and South Korea (27 MT). Due to its relatively cleaner grid, the iron and steel industry in the U.S. generates the least $CO_2$ emissions among the top five steel-producing countries.

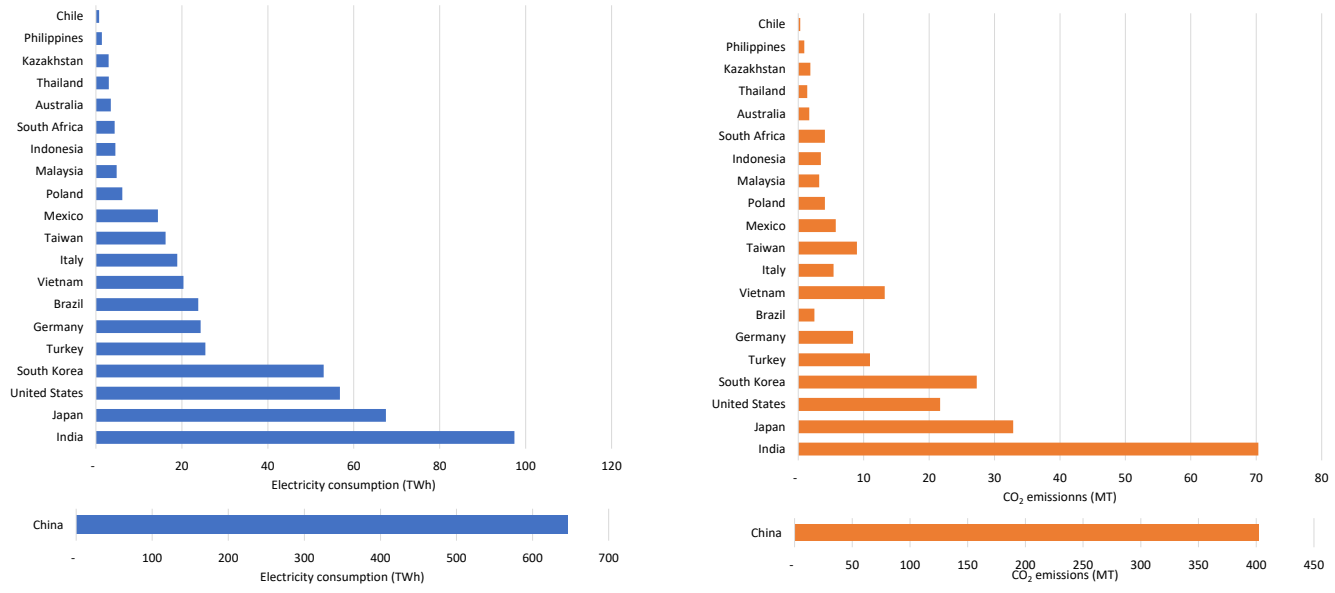



Figure 14. (a) Electricity used for iron and steel manufacturing in selected countries in 2019 (source: IEA, 2022c) (b) $CO_2$ emissions caused by electricity use in iron and steel manufacturing in selected countries (Source: this study)

## 4.3. Machinery, electrical, and electronic equipment manufacturing's electricity use and electricity-related $CO_2$ emissions

The machinery, electrical and electronic equipment manufacturing subsector (MEEEM) is one of the most heterogenous subsectors. Electricity use in the MEEEM sector accounts for about 48% of the total final energy consumed in this subsector. Thus, despite consisting of relatively less electricity-intensive (i.e., kWh/tonne of products) production processes, it is still one of the largest electricity using subsectors (13% of global manufacturing electricity use). The top five countries studied in terms of electricity use for MEEEM subsector were responsible for 80% of the global MEEEM sector's electricity use in 2019. China's MEEEM subsectors was responsible for about half of the global MEEEM subsector's electricity used in 2019, followed by the U.S. (9%), South Korea (7%), Japan (6%) and Taiwan (6%) (Figure 15). The top five electricity-using countries for the MEEEM subsector were responsible for generating 96% of electricity-related $CO_2$ emissions from the MEEEM subsector in 2019. Due to its relatively cleaner grid, the U.S. MEEM subsector generated relatively fewer $CO_2$ emissions compared to South Korea, despite using more electricity.

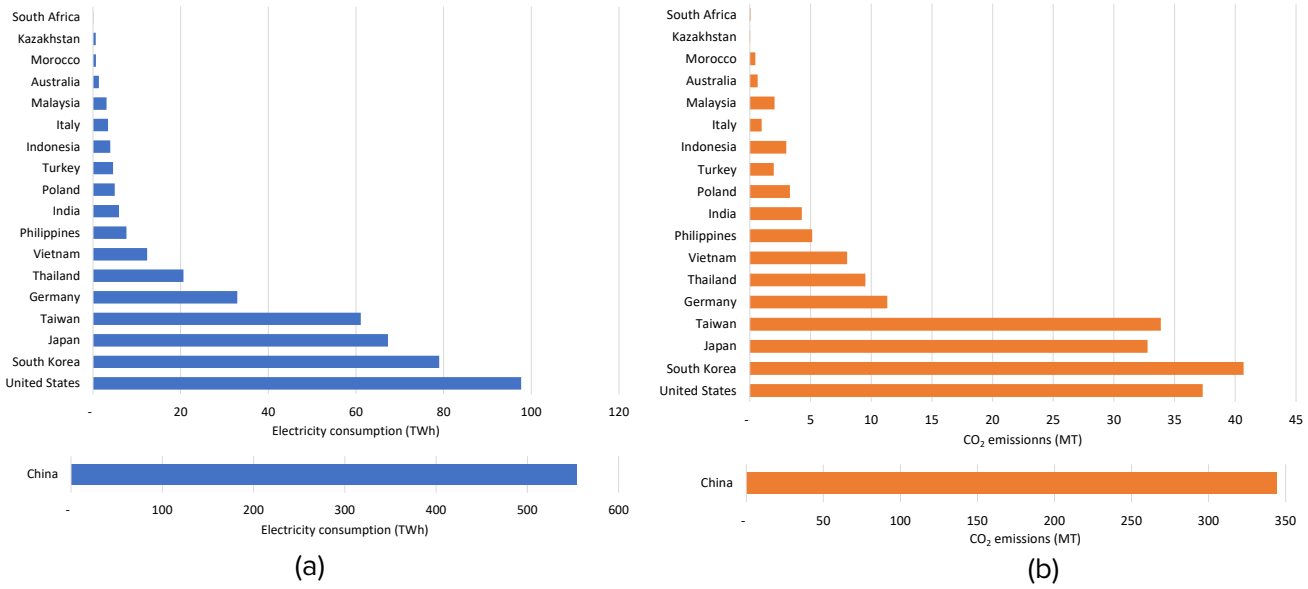
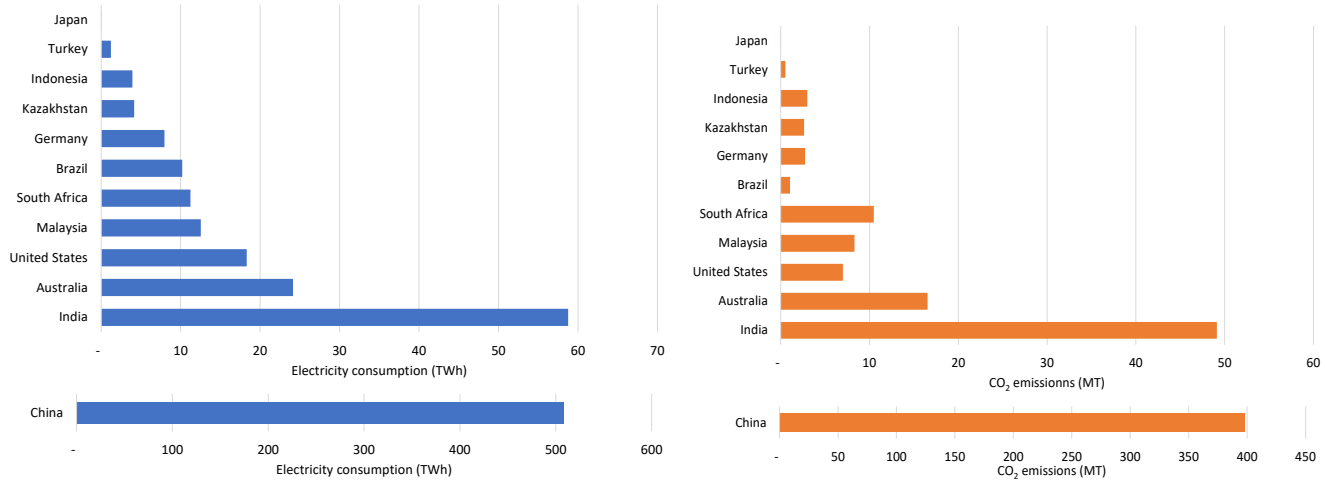



Figure 15. (a) Electricity used for machinery, electrical and electronic equipment manufacturing in selected countries in 2019 (source: IEA, 2022c) (b) $CO_2$ emissions caused by electricity use in iron and steel manufacturing in selected countries (Source: this study)

## 4.4. Non-ferrous metals industry's electricity use and electricity-related $CO_2$ emissions

### Primary aluminum industry

The primary aluminum industry is one of the most energy-intensive manufacturing sectors. The smelting process in primary aluminum manufacturing is one of the most electricity-intensive processes. As a result of the massive electricity required for smelting, a majority (60%) of global primary aluminum production uses captive power plants (Hasanbeigi et al., 2022). The top five aluminum-producing countries studied in this report were responsible for about 67% of global aluminum production and a similar share of electricity consumed globally for aluminum production in 2019. Primary aluminum industry in China was the leading electricity consumer, responsible for about 56% of total electricity consumed globally in the aluminum industry, followed by India (6%), Australia (3%), and the U.S. (2%) and Malaysia (1%) (Figure 16).



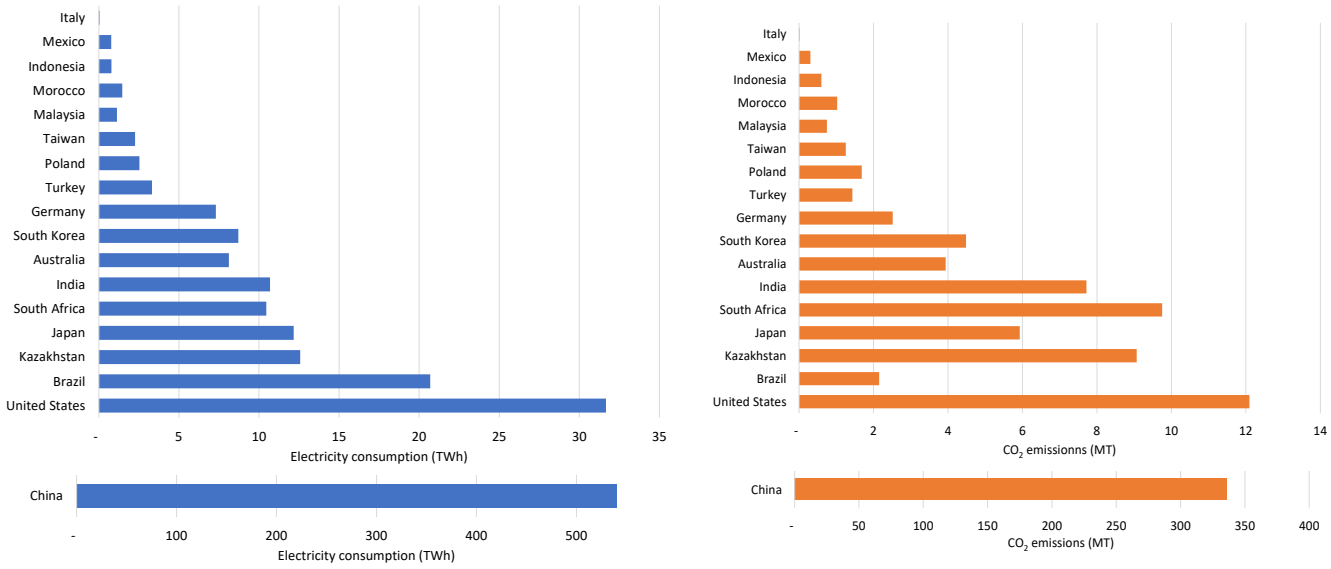

(a) (b)

Figure 16. (a) Electricity used for primary aluminum industry in selected countries in 2019 (source: IEA, 2022c) (b) $CO_2$ emissions caused by electricity use in primary aluminum manufacturing in selected countries (Source: this study)

**Other non-ferrous metals industry**

Other non-ferrous metals (ONFM) include metals such as copper, lead, nickel, tin, titanium, zinc, and their alloys. As a result of the high electricity intensity of the processes such as smelting and electrolysis, it is an important subsector in terms of reducing indirect $CO_2$ emissions (Scope 2 emissions) (Eurometaux, 2021). Electricity use in the ONFM industry was responsible for about 10% of global manufacturing electricity use. The top five countries studied in terms of electricity use in the ONFM industry were responsible for about 80% of electricity use in this subsector as of 2019. Chinese ONFM industry, with 70% share of global electricity use for the ONFM subsector, was the largest user of electricity, followed by the U.S. (4%), Brazil (3%), Kazakhstan (2%), and Japan (2%) (Figure 17).

The top five electricity-consuming countries for the ONFM industry were responsible for about 95% of $CO_2$ emissions caused by the electricity used in this subsector. The electricity use in the ONFM industry in China was responsible for 90% of global $CO_2$ emissions due to the subsector's electricity use. The electricity use in the U.S. ONFM industry was responsible for 3% of global electricity-related $CO_2$ emissions in this subsector. As a result of the cleanest electricity grid, despite consuming more electricity than Kazakhstan, Japan, and several other countries, the electricity use in Brazilian ONFM subsector caused lower $CO_2$ emissions.



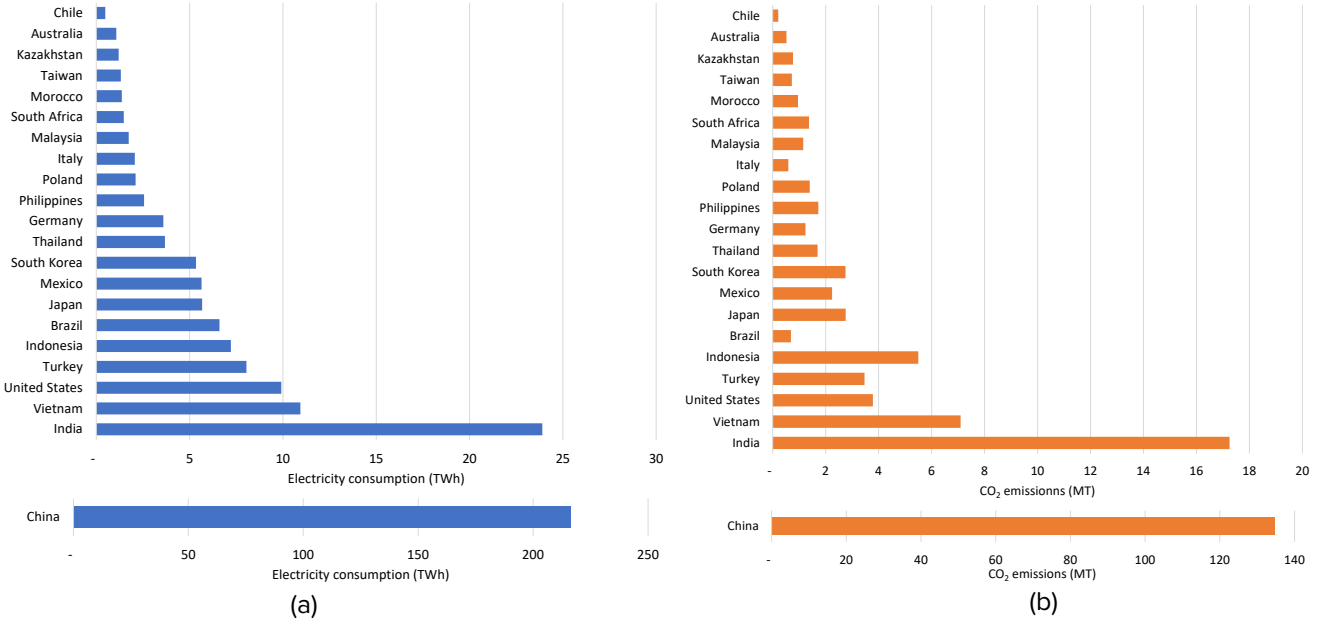

(a) (b)

Figure 17. (a) Electricity used for other non-ferrous metals manufacturing in selected countries in 2019 (source: IEA, 2022c) (b) $CO_2$ emissions caused by electricity use in non-ferrous metals manufacturing in selected countries (Source: this study)

## 4.5. Non-metallic minerals' electricity use and electricity-related $CO_2$ emissions

**Cement industry**

The cement industry is one of the most energy-intensive subsectors. However, electricity accounts for around 12% of the total final energy consumption in cement production (Cembureau, 2022). Globally, the cement industry is responsible for about 5% of manufacturing electricity use. The top five cement-producing countries studied in this report were responsible for about 58% of total cement manufacturing's electricity use in 2019. Due to producing about 57% of total cement in 2019, Chinese cement manufacturing accounted for about 46% of electricity demand in global cement industry. Being responsible for 7% of global cement production, India is the second largest cement-producing country in the world and the Indian cement manufacturing consumed about 5% of global cement manufacturing's electricity. Vietnam, U.S. and Turkey were responsible for around 2% of global production and cement manufacturing's electricity use each in 2019 (Figure 18).

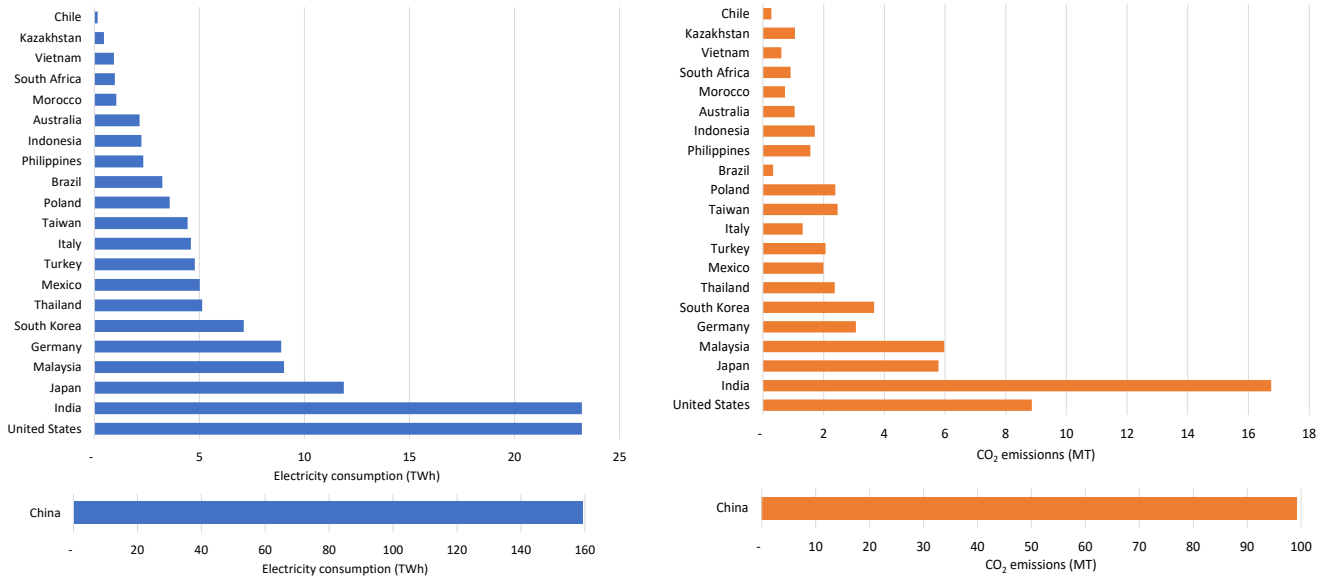



(a) (b)

Figure 18. (a) Electricity used for cement manufacturing in selected countries in 2019 (source: IEA, 2022c) (b) $CO_2$ emissions caused by electricity use in cement manufacturing in selected countries (Source: this study)

### Other non-metallic minerals industry

Other non-metallic minerals include products like glass, bricks, lime, ceramics, etc. The manufacturing of other non-metallic minerals was responsible for 4% of global manufacturing electricity use in 2019. The top five countries studied in this subsector were responsible for 72% of the subsector's global electricity use and 92% of its electricity-related $CO_2$ emissions (Figure 19). The manufacturing of other non-metallic minerals in China was responsible for about half of the subsector's global electricity use, which leads to about 100 MT $CO_2$ emissions (67% of subsector's global electricity-related $CO_2$ emissions). The U.S. and India both represent 3%, each share of subsectors global electricity use. However, the electricity use in India's other non-metallic minerals industry emits higher electricity-related $CO_2$ emissions due to the relatively more $CO_2$-intensive electric grid.




(a) (b)

Figure 19. (a) Electricity used for other non-metallic minerals manufacturing in selected countries in 2019 (source: IEA, 2022c) (b) CO2 emissions caused by electricity use in other non-metallic minerals manufacturing in selected countries (Source: this study)

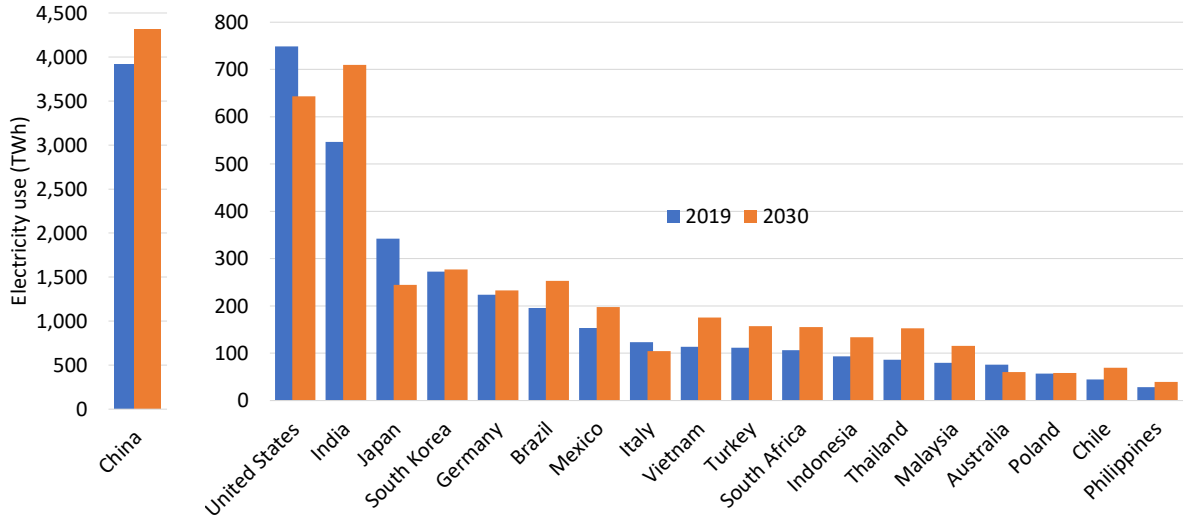
# 5 Industrial Electricity use and Electricity-related $CO_2$ Emissions Forecasts

The following section presents the forecast values for electricity use and corresponding $CO_2$ emissions for selected countries until 2030. The forecasts are presented for overall industrial electricity use, followed by the forecast for three high electricity-consuming sectors, i.e., cement, iron and steel, and aluminum industry in selected countries. The forecasts for subsectors are made based on the projected production volumes in each country for the given subsector and assuming an annual energy efficiency improvement rate of 0.5%. The forecasts for electricity-related $CO_2$ emissions are made using the electricity consumption forecasts and assuming a gradual reduction in grid $CO_2$ emissions factors to zero in 2050.

## 5.1. Total industrial electricity use forecast up to 2030

The 2019 industrial electricity use and corresponding $CO_2$ emissions forecast until 2030 for selected countries are adopted from the energy outlooks and other sources of the respective countries[3]. While the industrial electricity demand is expected to grow in 15 countries, with global electricity use forecasted to increase by 2030, the industrial electricity demand is forecasted to either reduce or remain constant for a few developed countries in 2030.

Industrial electricity-related $CO_2$ emissions, on the other hand, can be expected to reduce at a slightly faster rate between 2019 and 2030. Developed economies such as U.S., Japan, Australia, and the EU countries are expected to reduce electricity-related $CO_2$ emissions at the fastest rate (reductions in range of 30% to 50% until 2030). While some developing economies such as India, Brazil, and Mexico are expected to reduce their electricity-related $CO_2$ emissions by about 17% by 2030, countries like China, South Africa, Turkey, Indonesia, Malaysia, and the Philippines are expected to reduce the electricity-related $CO_2$ emissions by 6% to 10% in 2030 compared to their 2019 emission levels.




(a)

3 Sources for industrial electricity forecast are presented in appendix 3

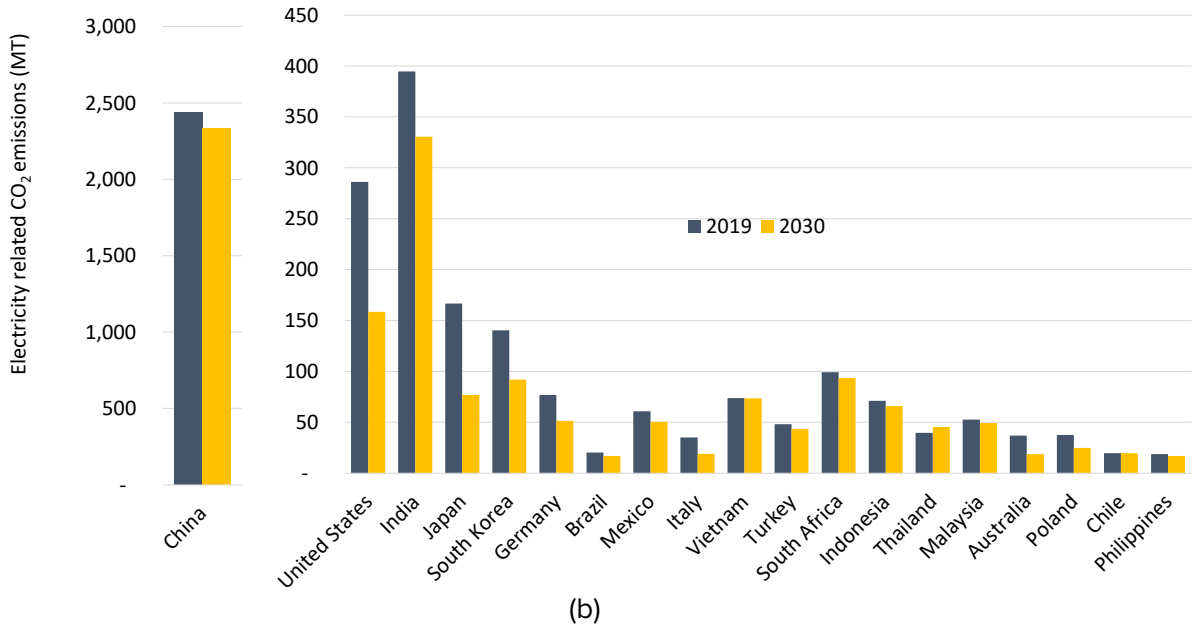



Figure 20. (a) Industrial electricity[4] use forecast in 2030 for selected countries (source: this study)
(b) Industrial electricity-related $CO_2$ emissions forecast in 2030 (source: this study)

Note: The CO2 emission factors for electricity in 2030 are estimated by assuming a gradual reduction in grid CO2 emissions factors to zero in all countries studied in 2050.

## 5.2. Cement industry's electricity use forecast up to 2030

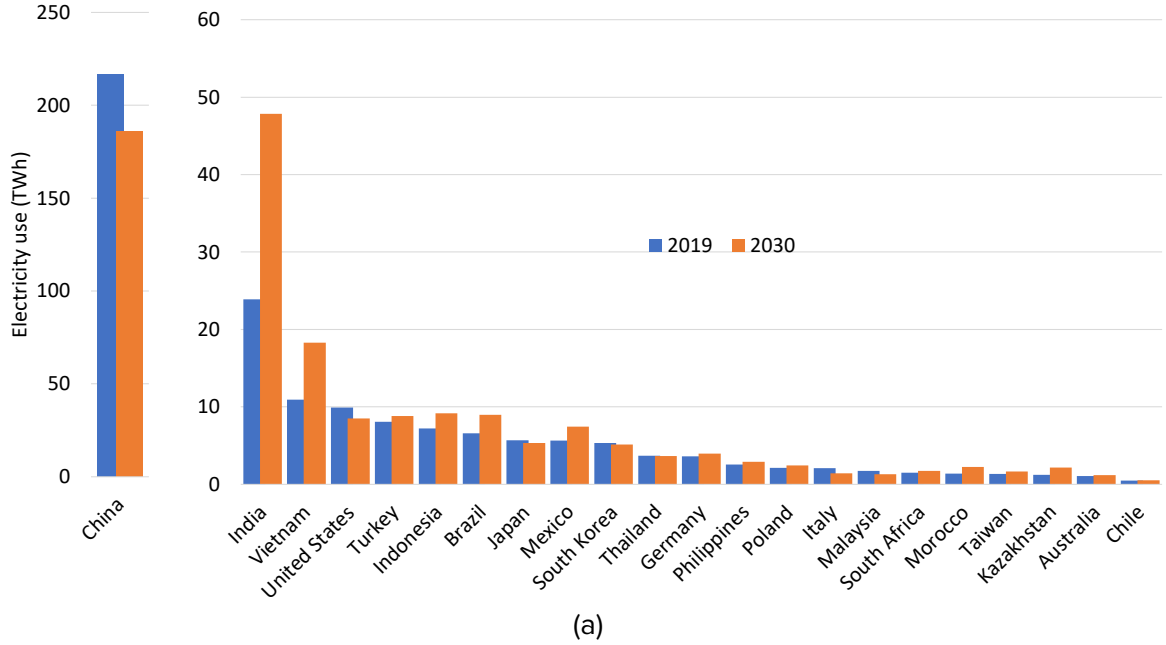
The following section presents the forecast of electricity use and corresponding $CO_2$ emissions for the cement industry until 2030. Electricity demand for cement production is estimated based on the production forecast and the electricity consumption intensity for cement manufacturing of respective countries. Electricity intensity of cement production on the other hand, is assumed to decrease at an annual rate of 0.5% p.a. until 2030.

Figure 21 presents a comparison of electricity use and corresponding $CO_2$ emissions in 2019 and 2030. Out of 22 countries analyzed in this report, the electricity consumption for cement manufacturing in 16 countries can be expected to either increase or remain constant, whereas the cement industry in the remaining six countries is expected to experience a reduction in electricity use. As a result of the forecasted slow-down in the growth of global cement production, overall electricity consumption of global cement industry is expected to increase by about 4% until 2030.

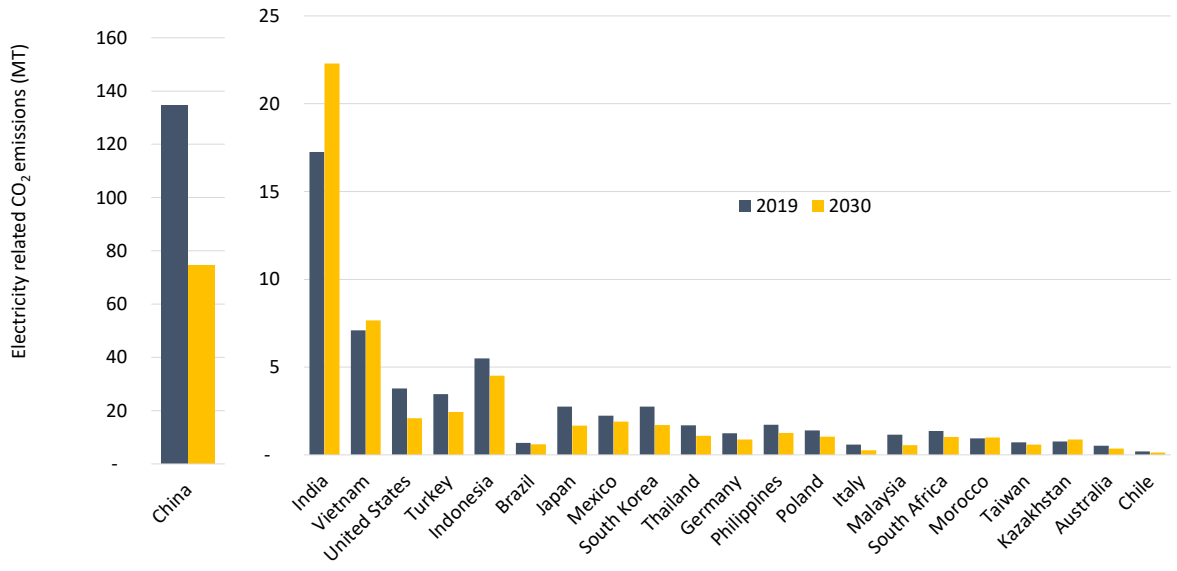
Cement production in China and India, two of the largest cement-producing countries, is expected to head in opposite directions in the next decade (IEA 2022b). Due to the expected slow-down in cement production in China for the next decade, the electricity consumption for cement production can is expected to drop by about 14% in 2030 compared to its value in 2019. Electricity consumption for the Indian cement industry on the other hand, is expected to almost double between 2019 and 2030. The cement industries in Kazakhstan, Vietnam, and Morocco are expected to increase their electricity demand by about 60% to 80% until 2030. Countries such as the U.S., Malaysia and Italy, are to see the electricity demand for cement production to drop by up to 30% between 2019 and 2030.

4 The forecasts included in this section are made for entire industry. Due to the data limitation, forecasts for the manufacturing sector could not be made.

As a result of the low rate of the expected increase in cement production and projected reduction in the grid emission factors, electricity-related $CO_2$ emissions are expected to drop by 2030 compared to 2019 emissions levels for the majority of countries studied (Figure 21b). The electricity-related $CO_2$ emissions for the cement industry globally are expected to drop by about 30% between 2019 and 2030. The largest cement manufacturer, China, along with the U.S., Malaysia, and Italy are expected to experience the reduction in the electricity-related $CO_2$ emissions in the range of 45% to 55% until 2030, whereas for some of the other large cement-producing countries like India and Vietnam, the electricity-related $CO_2$ emissions are expected to increase between 2019 and 2030.




(a)




(b)

Figure 21. (a) Cement manufacturing electricity use forecast until 2030 for selected countries (source: this study) (b) Cement manufacturing electricity-related $CO_2$ emissions forecast until 2030 (source: this study)

Note: The $CO_2$ emission factors for electricity in 2030 are estimated by assuming a gradual reduction in grid $CO_2$ emissions factors to zero in all countries studied in 2050.

## 5.3. Iron and steel industry's electricity use forecast up to 2030

The electricity consumption in the iron and steel sector depends on electricity consumption intensity as well as the share of electric arc furnaces in total steel production. The forecasts are based on the projections of steel production, electricity intensity, and share of EAF for respective countries until 2030, except for countries where the electricity demand forecasts are already published e.g., the U.S. (EIA, 2022), Germany, Poland and Italy (JRC, 2021). The electricity consumption intensities for both EAF and BF-BOF are assumed to improve at an annual rate of 0.5%. The projected shares of EAF in steel production in 2030 for the countries included in this report are adopted based on the literature (Bataille et al., 2021 and Hasanbeigi et al., 2023).

Figure 22 presents the comparison of electricity use and corresponding $CO_2$ emissions of the iron and steel industry in 2019 and 2030 in selected countries. Global steel production is expected to increase by about 12% between 2019 and 2030. The global share of EAF is expected to reach 40% in 2030 (Bataille et al., 2021). As a result, globally, the electricity demand for the iron and steel industry is expected to increase by about 8% between 2019 and 2030. Out of 22 countries analyzed in this report, the steel industries in ten countries are expected to experience a reduction in electricity demand in 2030 compared to their levels in 2019.

Due to the expected reduction in steel production in the largest steel-producing country, China, until 2030, the electricity demand is expected to drop by 10%. The second largest steel-producing country, India, on the other hand, plans to double its steel production capacity in the next decade (Hall et al., 2022). Due to the expected growth in steel production accompanied by the increase in the share of EAF in steel production (from the current 56% to 80% in 2030; Bataille et al., 2021) the electricity demand of the Indian steel industry will likely double by 2030. The steel industry in some of the other countries studied, such as Vietnam, Malaysia, and Brazil, is expected to experience close to 50% increase in electricity demand between 2019 and 2030. The electricity demand of the steel industry in some of the east Asian countries (Japan, Taiwan, and South Korea), Australia, and the EU countries is expected to drop by 15% to 30% in 2030 compared to the values in 2019.

A reduction of almost 30% in the global electricity-related $CO_2$ emissions from the iron and steel sector is expected between 2019 and 2030. Most of the countries included in this analysis are expected to reduce their electricity-related $CO_2$ emissions from their iron and steel industry except India and Vietnam (Figure 22b). The electricity-related $CO_2$ emissions from the steel industry in India are expected to increase by about 26%, whereas in the Philippines, Brazil, and Malaysia, are expected to remain relatively unchanged between 2019 and 2030. The steel industry in all the remaining countries is expected to see electricity-related $CO_2$ emissions reductions in the range of 12% to 50% between 2019 and 2030.

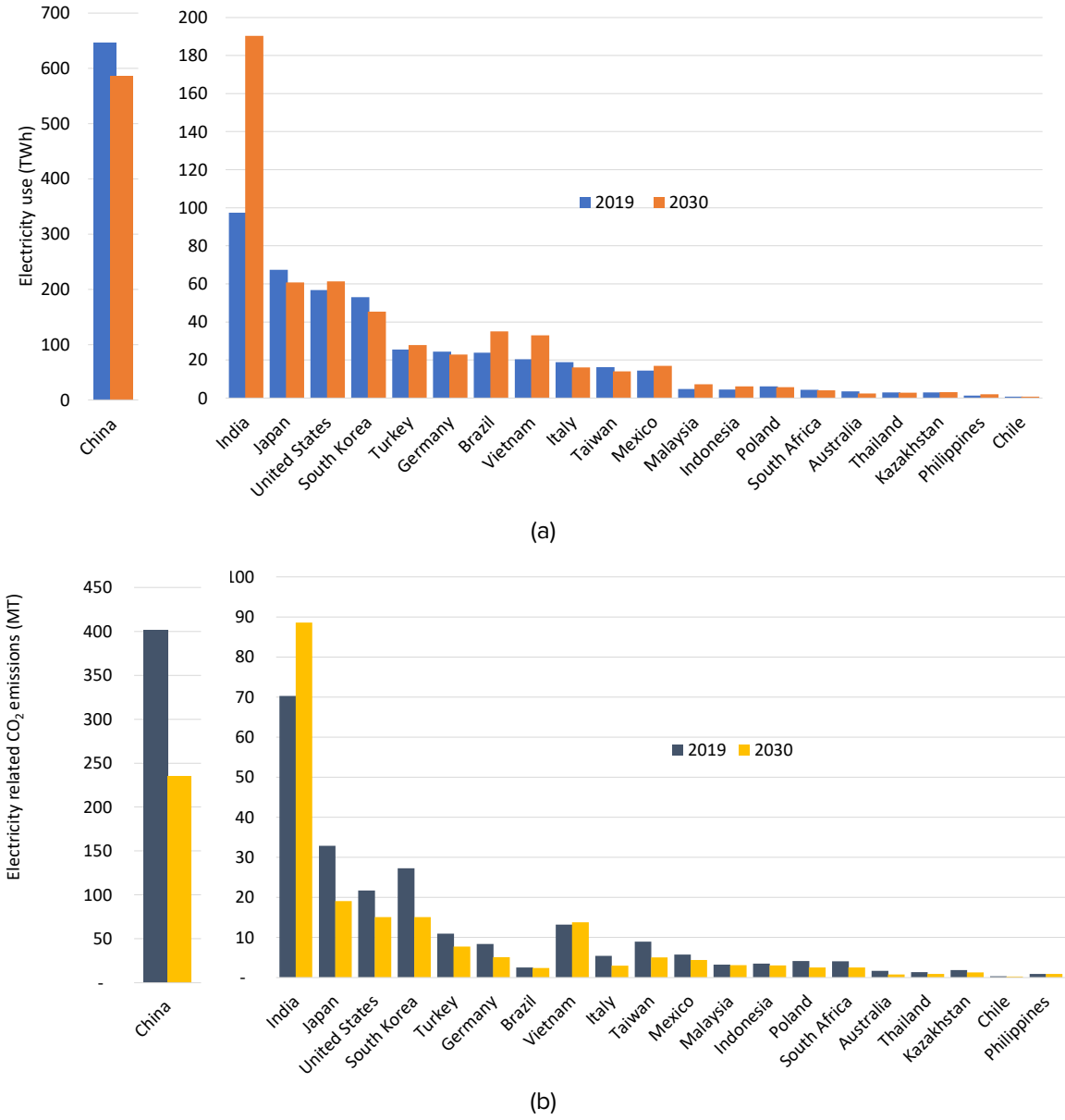



Figure 22. (a) Iron and steel manufacturing electricity use forecast until 2030 for selected countries (source: this study) (b) Iron and steel manufacturing electricity-related $CO_2$ emissions forecast until 2030 (source: this study)

Note: The $CO_2$ emission factors for electricity in 2030 are estimated by assuming a gradual reduction in grid $CO_2$ emissions factors to zero in all countries studied in 205

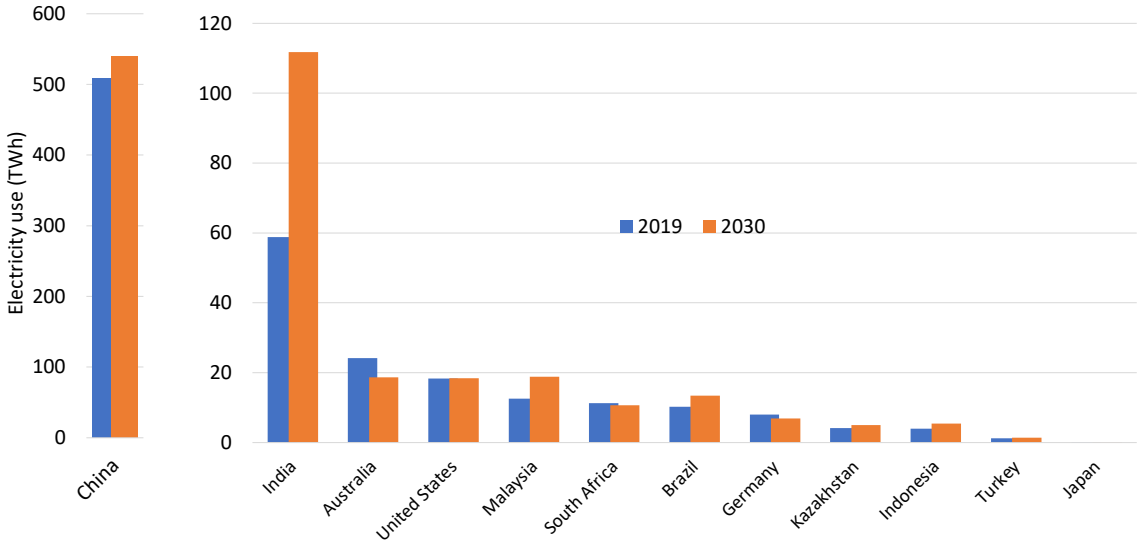
## 5.4. Primary aluminum industry's electricity use forecast up to 2030

Similar to the cement and steel industry, the electricity demand for primary aluminum is forecasted based on the production and electricity intensity projections. However, due to data limitations, the electricity demand for primary aluminum production could not be forecasted for all the countries analyzed in the report.

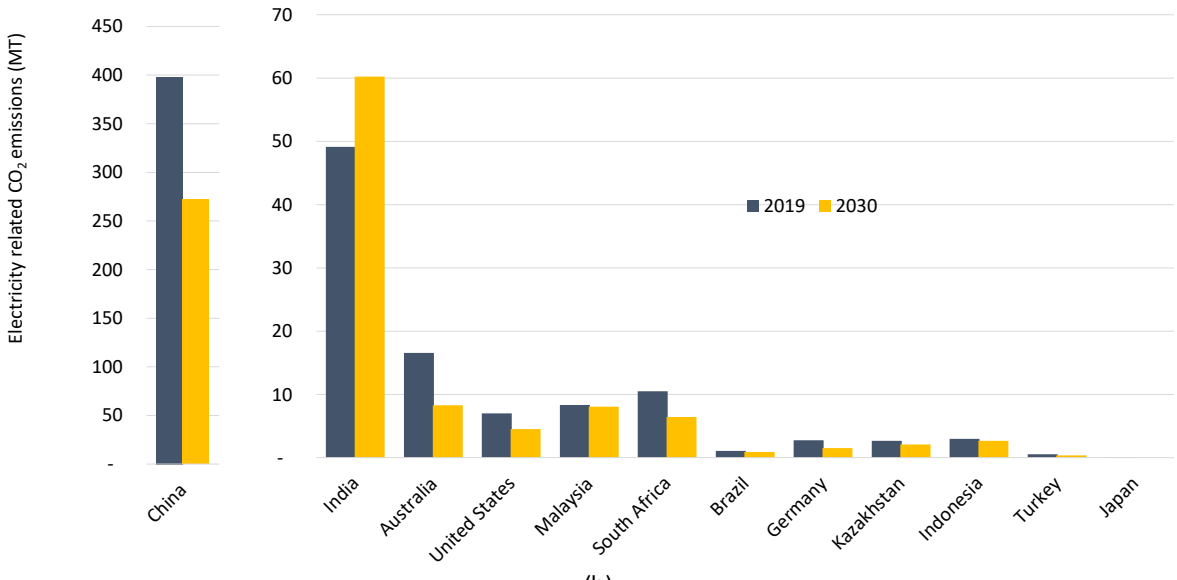
Globally, the electricity demand for primary aluminum industry is expected to increase by 13% until 2030. Out of 12 countries analyzed for the primary aluminum industry's forecast, electricity demand is expected to drop for four countries, increase for seven countries and remain unchanged for one country between 2019 and 2030. While the electricity demand

for primary aluminum production in India is expected to increase by nearly 90%, the primary aluminum industry's electricity demand in Malaysia, Indonesia, and Brazil is expected to experience an increase by almost 50% to 30% between 2019 and 2030. The primary aluminum industry in Germany, Japan, and Australia is expected to see a reduction in the electricity use in the range of 15% to 20% by 2030. Electricity demand for aluminum industry in Turkey and China is expected to increase by only up to 10% until 2030, whereas the electricity demand for U.S. aluminum manufacturing is expected to remain unchanged in between 2019 and 2030.

The electricity-related $CO_2$ emissions from the global aluminum manufacturing sector are expected to drop by 40% between 2019 and 2030. The majority of primary aluminum-producing countries are expected to see the reductions in the range of 11% to 50% in electricity-related $CO_2$ emissions from the primary aluminum sector, whereas the electricity-related $CO_2$ emissions from the primary aluminum industry in India is expected to increase by close to 22% between 2019 and 2030.




(a)




(b)

Figure 23. Aluminum manufacturing electricity use forecast until 2030 for selected countries (source: this study) (b) Aluminum manufacturing electricity-related $CO_2$ emissions forecast until 2030 (source: this study)

Note: The $CO_2$ emission factors for electricity in 2030 are estimated by assuming a gradual reduction in grid $CO_2$ emissions factors to zero in all countries studied in 2050.

# 6 Clean Electricity Generation for Industrial Electricity Demand

To decarbonize the industry sector, it is imperative that the electricity grid should be decarbonized, and additional electricity demand caused by the electrification of heating or industrial growth should be met with renewable sources. The following section presents the comparison of the current clean electricity generation and current electricity demand for manufacturing in selected countries, along with the portion of total annual electricity generation utilized for the manufacturing sector.

Figure 24 presents the share of manufacturing electricity demand from total annual power generation for selected countries in 2019. About 45% of the total annual electricity generated in China is used to meet manufacturing electricity demand. The U.S. has the second largest manufacturing electricity demand after China. However, only 14% of the total annual electricity generated is utilized for the manufacturing sector. Manufacturing in Mexico and Chile utilizes the lowest portions (9% of annually generated electricity), whereas manufacturing in Taiwan (51%) utilizes the largest portion of annually generated electricity among the countries analyzed in this report.

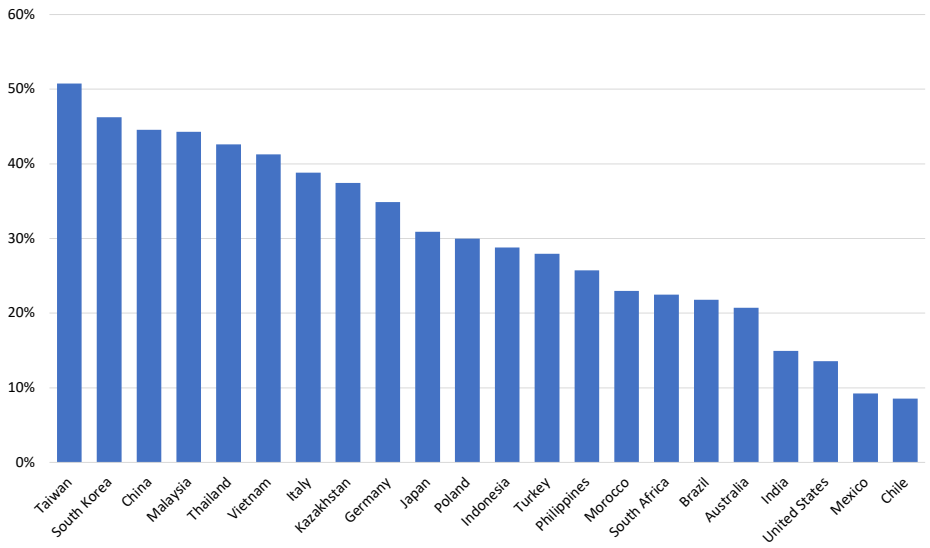



Figure 24. The share of manufacturing electricity demand from total annual power generation for selected countries in 2019 (source: IRENA, 2022; IEA 2023)

Figure 25 compares the total electricity used in the manufacturing sector (including captive power) with the annual clean electricity generation (wind, solar, hydro, and nuclear) for countries analyzed in this report. The total electricity used in the Chinese manufacturing sector exceeds China's annual clean electricity generation. Similarly, the electricity demand for the manufacturing sectors in the majority of Asian countries studied in this report (India, Japan, South Korea, Taiwan, Vietnam, Thailand, Malaysia, Kazakhstan), along with Poland and South Africa, exceeds the annual clean electricity generation in these countries. On the other hand, the electricity demand in the manufacturing sectors in several countries like the U.S., Brazil, Turkey, Mexico, Australia, and Chile is lower than the annual clean electricity generation in those countries.

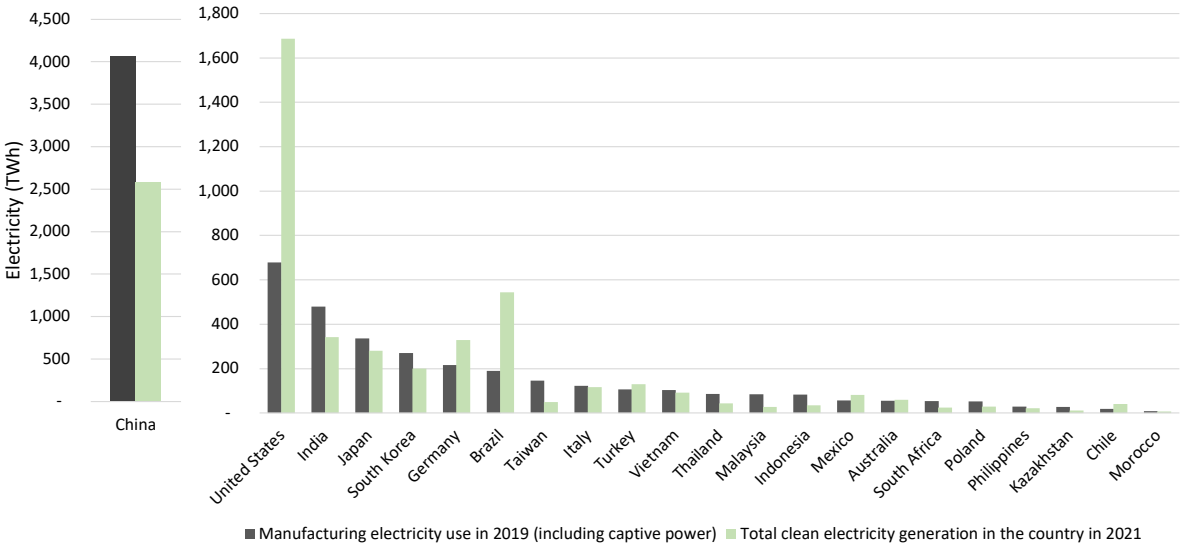



Figure 25. Total annual clean electricity generation in 2021 and manufacturing electricity use for selected countries in 2019 (Source: IRENA, 2022; IEA, 2023)

Note: clean electricity includes electricity generated from all renewable sources (e.g., solar, wind, and hydro) and nuclear.

# 7 Corporate Renewable Electricity Procurement

Corporate renewable electricity procurement refers to the process by which companies secure their electricity from renewable energy sources, such as solar or wind power, instead of traditional fossil fuels like coal or natural gas. Companies worldwide are shifting their consumption to renewable energy sources, driven both by climate and environmental considerations, as well as commercial attractiveness. Initiatives such as RE100, the global corporate renewable energy initiative bringing together over 400 large and ambitious businesses committed to 100% renewable electricity, show that some corporate commitments are genuine and demand is growing (RE100, 2023).

There are several ways companies can procure renewable electricity. Self-generation, where the company produces renewable electricity from facilities it owns (both on-site and off-site), is generally considered the highest quality form of corporate renewables sourcing. Companies have direct control and full attribution over generation and can match directly to their consumption. Rooftop solar is a common form of self-generation but some companies own private solar and wind facilities directly wired to their operations. While high quality, self-generation is not always commercially or operationally feasible for companies.

One of the most popular ways that companies procure renewable electricity is through power purchase agreements (PPAs). A PPA is a long-term contract between a corporate buyer and a renewable energy supplier that generally provides the buyer with a long-term price for electricity generated by the supplier's renewable electricity project. PPAs are a 'win-win' for buyer and seller in that corporate buyers lock in predictable, long-term electricity prices and energy suppliers can more easily secure financing for long term projects.

PPAs are generally only available in more competitive and advanced electricity markets. Even in those markets, PPAs are mostly only accessible to larger electricity buyers; that is, companies with substantial physical operations. Corporate interest in PPAs continues to grow but PPAs are still not practically or legally possible in many countries.

Globally, corporations bought about 31 GW of clean energy in 2021 through PPAs (BloombergNEF 2022). Figure 26 shows the EY PPA Index of select countries, ranking these countries on the development and competitiveness of their PPA markets. Spain, Germany, and the U.S. rank the top three markets for PPA attractiveness (EY 2022).

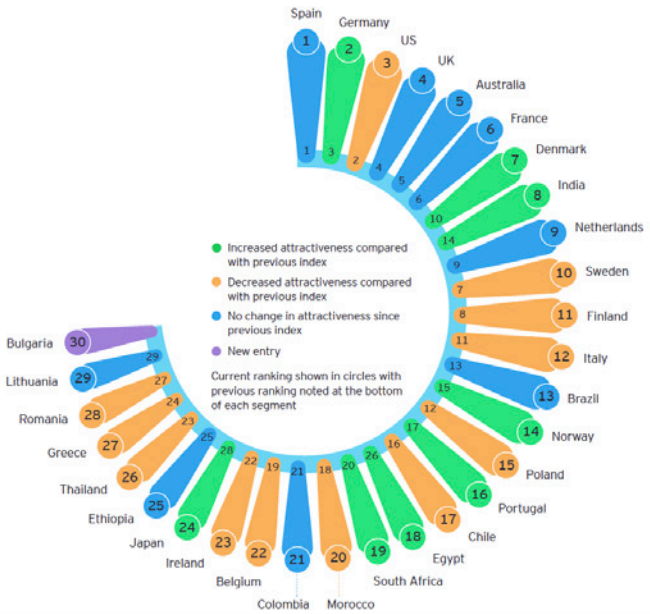



Figure 26. PPA Index in different countries (EY 2022)

Companies can also procure renewable electricity through standard contracts and passive procurement from energy suppliers. This generally involves companies obtaining energy attribute certificates (EACs), which can be used to verify claims of renewable electricity usage. Such procurement often occurs through green tariff and renewable energy certificate (REC) schemes, provided by energy suppliers. Unbundled EACs and RECs are generally thought to have less impact than self-generation and direct procurement because corporates cannot inherently claim additionality from their usage.

Corporate renewable electricity procurement has gained so much momentum because of both environmental and commercial drivers. First and foremost, it directly reduces the carbon emissions of companies in a verifiable way, demonstrating their commitment to climate and sustainability impact. Consumers and investors are increasingly demanding that companies, and their supply chains, aim to procure 100% renewable electricity, creating both competitive threats and opportunities.

Renewable electricity generation also provides substantial cost reduction and stability potential, with renewable electricity generally being cheaper and more price stable than fossil fuel-based electricity when market conditions are fair. Self-generation and long-term supply contracts, such as PPAs, protect companies against energy price volatility and provide unparalleled predictability.

In addition to the environmental and financial benefits, corporate renewable electricity procurement can also have positive impacts on local communities. Renewable energy projects create clean jobs, stimulate economic development, and can provide additional revenue streams for landowners and rural communities.

The benefits of corporate renewable electricity procurement are clear, but corporates continue to face many market and policy barriers. In some markets, PPAs and substantial self-generation projects are not legal or face prohibitive bureaucratic and regulatory hurdles. The availability of renewable energy sources varies by geography, and efficient and effective renewable electricity markets require good grid infrastructure, including balancing power and storage. Governments worldwide have committed to improving the enabling environment for renewables in their electricity markets and companies continue to push for solutions, including through initiatives such as RE100.

Despite these challenges, more companies are continuing to pursue renewable electricity procurement to reduce their carbon footprint, cut costs, and enhance their reputation. As renewable energy sources become more accessible and affordable, it is likely that more businesses will adopt these approaches in the coming years. However, companies in electricity-intensive industrial subsectors such as iron and steel, chemical and petrochemical, non-ferrous metals (e.g. aluminum), and cement industry are significantly lagging behind in corporate renewable electricity procurement.

# 8 Conclusions

The industry sector uses a substantial amount of electricity globally. As the industry sectors grow in many developing nations and as industries adopt electrification of heating and hydrogen as decarbonization strategies, considerable growth in electricity demand from the industry is anticipated. While fulfilling this demand, it is imperative that electricity grid decarbonization should take place simultaneously, and that additional electricity demand should be met with renewable sources. In order to aid the prioritization of electricity grid decarbonization, the current report presented an analysis of electricity use for various manufacturing sectors in 22 countries. Many of the countries included in this report have a $CO_2$-intensive power sector.

The industry sector is responsible for 44% of current global electricity use. However, electricity use in the industry sector currently accounts for 14% of global $CO_2$ emissions. While manufacturing represents 90% of industrial electricity use globally, the remaining 10% of electricity use can be attributed to construction, mining and electricity use that are not categorized.

The selected countries represented 75% of global manufacturing electricity use but were responsible for 80% of global manufacturing electricity-related $CO_2$ emissions. As a result of being a leading producer of several commodities, China is by far the largest industrial electricity consumer, responsible for 48% of global manufacturing's electricity use and 62% of global manufacturing's electricity-related $CO_2$ emissions. The top five countries analyzed in this report in terms of manufacturing electricity use were responsible for 67% of the manufacturing sector's electricity use and 73% of global manufacturing's electricity-related $CO_2$ emissions as of 2019.

The chemicals and petrochemicals industry, Iron and steel industry, Machinery, electrical, and electronic equipment manufacturing, non-ferrous metals industry, and non-metallic minerals industry are the leading electricity using manufacturing subsectors globally. These top 5 electricity-consuming manufacturing subsectors were responsible for about 72% of global manufacturing electricity use in 2019. The top electricity-consuming manufacturing subsectors vary by country. The iron and steel and chemicals and petrochemicals industry are the largest electricity consumers for the majority of the countries analyzed in this report. In several east Asian countries like Taiwan, South Korea, Japan, Thailand, and the Philippines, non-energy-intensive subsectors such as Machinery, electrical, and electronic equipment manufacturing is the largest electricity-consuming sector.

The overall manufacturing sector electricity use is expected to increase by 23% between 2019 and 2030. The electricity demand will likely increase by 4% for cement, by 8% for steel, and by 13% for primary aluminum between 2019 and 2030. As a result of the reduction in electricity use in some electricity-intensive subsectors and the reduction in grid $CO_2$ emissions intensity, electricity-related $CO_2$ emissions of the global manufacturing sector, as well as the studied subsectors, are expected to drop by almost 20% between 2019 and 2030.

Due to the large electricity demand, China currently utilizes 45% of its total annually generated electricity to meet the manufacturing electricity demand. Taiwan uses the largest share of its annually generated electricity for manufacturing electricity demand, whereas the manufacturing sector in Mexico utilizes the smallest share of currently annually generated electricity. Based on the comparison of current manufacturing electricity demand and clean power

generation, the manufacturing electricity demand in countries like China, India, Japan, South Korea, Taiwan, Vietnam, Thailand, Malaysia, Poland, South Africa, and Kazakhstan exceeds the annual clean energy generation, whereas for the remaining countries analyzed in this report, the manufacturing electricity demand is lower than annual clean electricity generation.

To reduce emissions from the industrial sector, renewable energy sources must be used for electricity generation. The potential emissions reductions of electrification can be realized by making sure that renewable electricity is used while electrifying industrial operations. In order to enhance the use of renewable electricity in the industrial, transportation, and building sectors, considerable renewable electricity resources must be built in the countries under study.

Apart from grid decarbonization efforts at the national level, corporations can reduce $CO_2$ emissions associated with their electricity use through corporate renewable energy procurement. This can be done through power purchase agreements (PPAs), onsite renewable electricity generation, or renewable energy certificates (RECs).

To lessen their carbon footprint, save money, and improve their reputation, more companies are pursuing the purchase of renewable electricity. In the upcoming years, it is anticipated that more firms will embrace these strategies as renewable energy sources become more widely available and more reasonably priced. However, businesses in industries that use large amounts of electricity, like chemical and petrochemical, iron and steel, non-ferrous metals, and cement, are far behind in the use of corporate renewable electricity procurement and need considerable action in this regard to lower their electricity-related (Scope 2) $CO_2$ emissions.

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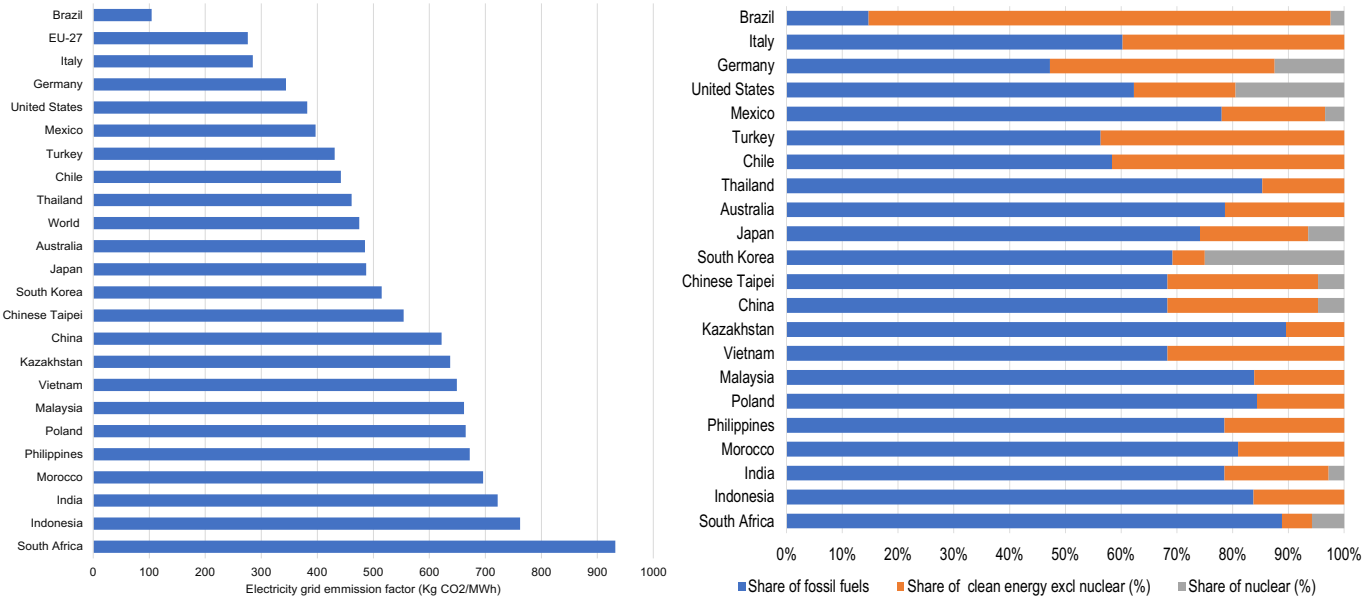
# Appendices

## Appendix 1: Electricity grid emission factors and power sector's fuel mix in countries




(a) (b)

FigureA1. (a) Electricity grid emission factors in 2019 (b) electricity production fuel mix for countries included in this study in 2019 (source:

## Appendix 2: Electricity use shares by subsectors for different countries

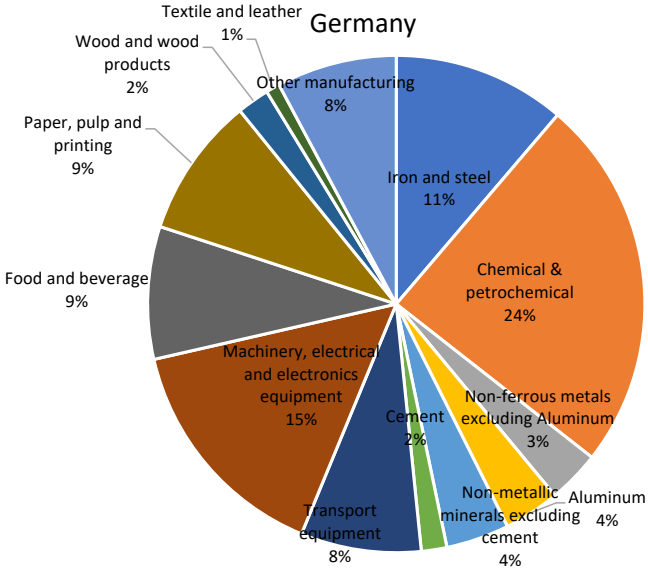



Figure A2. Shares of manufacturing subsector in annual manufacturing electricity use for Germany in 2019 (source: IEA, 2022c)

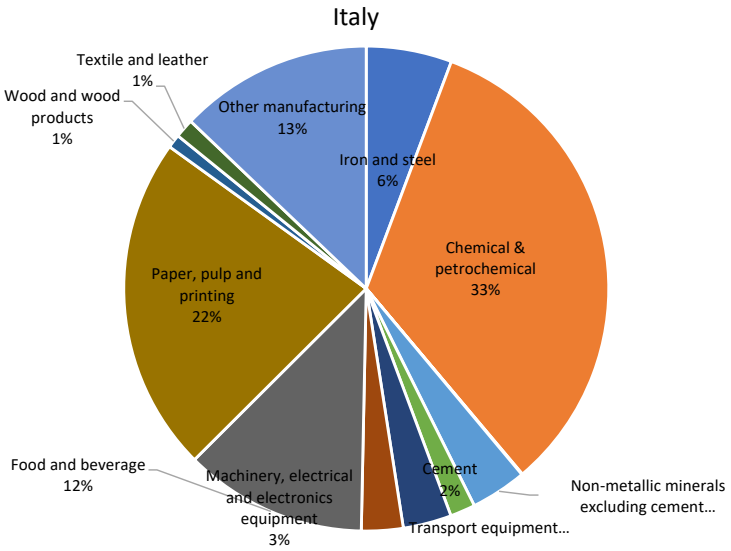



Figure A3. Shares of manufacturing subsector in annual manufacturing electricity use for Italy in 2019 (source: IEA, 2022c)

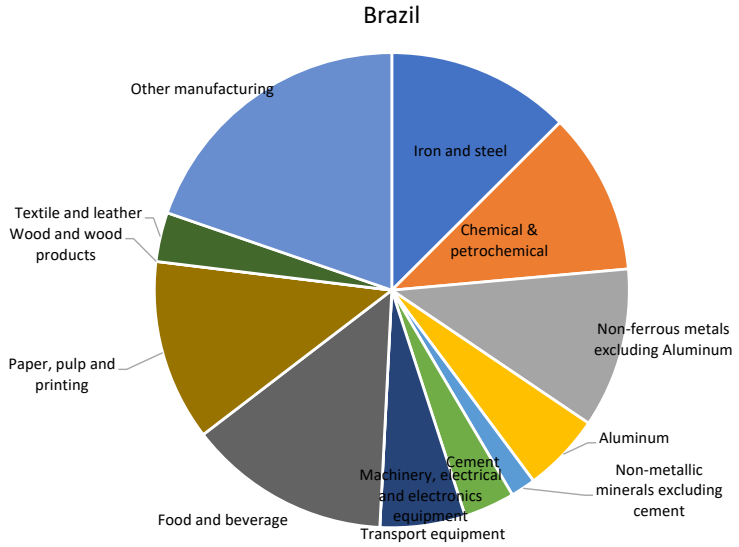



Figure A4. Shares of manufacturing subsector in annual manufacturing electricity use for Brazil in 2019 (source: IEA, 2022c)

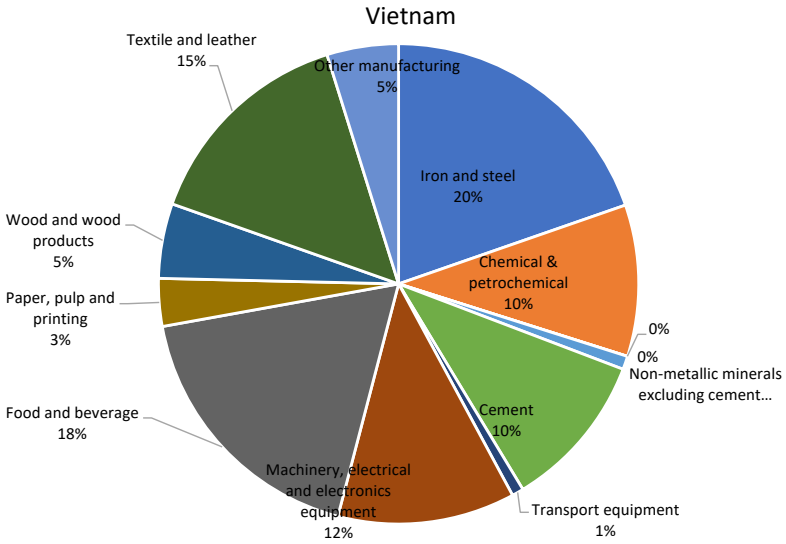



Figure A5. Shares of manufacturing subsector in annual manufacturing electricity use for Vietnam in 2019 (source: IEA, 2022c)

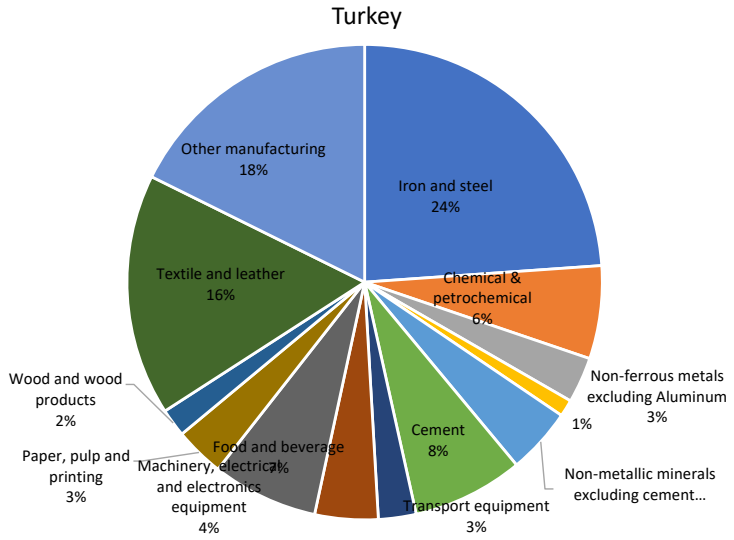



Figure A6. Shares of manufacturing subsector in annual manufacturing electricity use for Turkey in 2019 (source: IEA, 2022c)

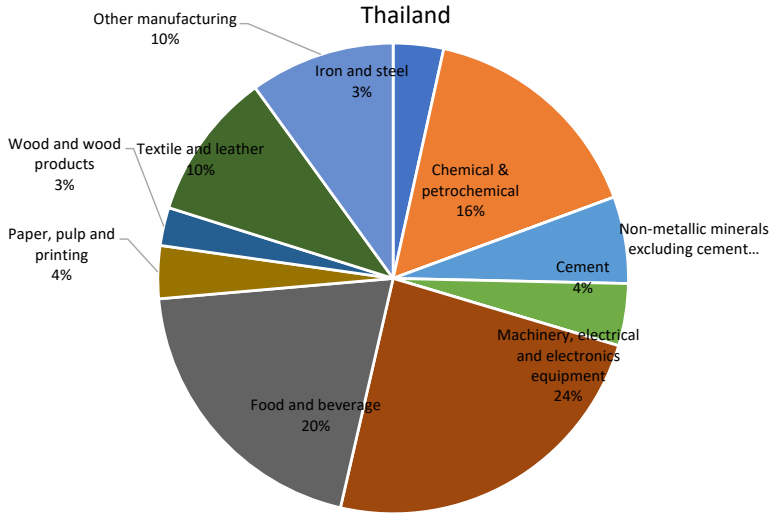



Figure A7. Shares of manufacturing subsector in annual manufacturing electricity use for Thailand in 2019 (source: estimated based on IEA, 2022c)

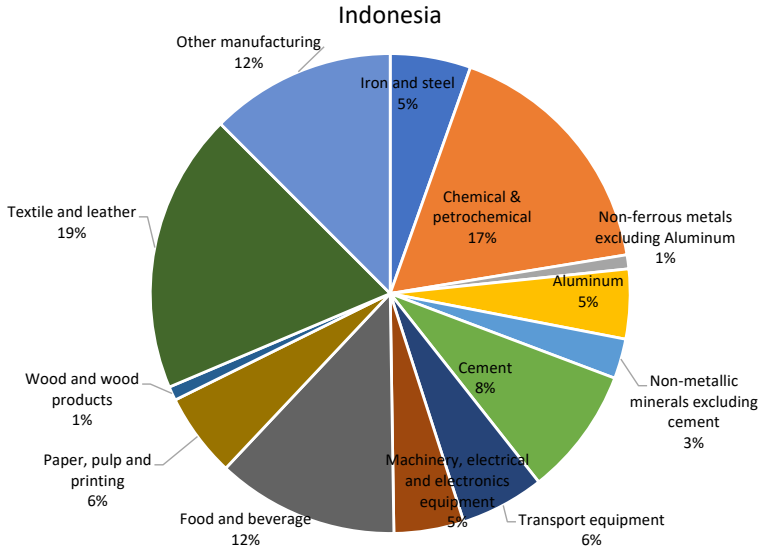



Figure A8. Shares of manufacturing subsector in annual manufacturing electricity use for Indonesia in 2019 (source: IEA, 2022c)

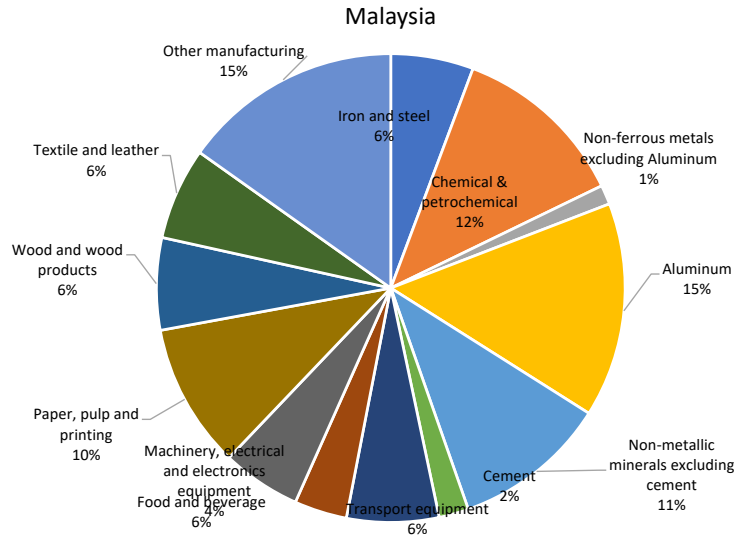



Figure A9. Shares of manufacturing subsector in annual manufacturing electricity use for Malaysia in 2019 (source: estimated based on IEA, 2022c)

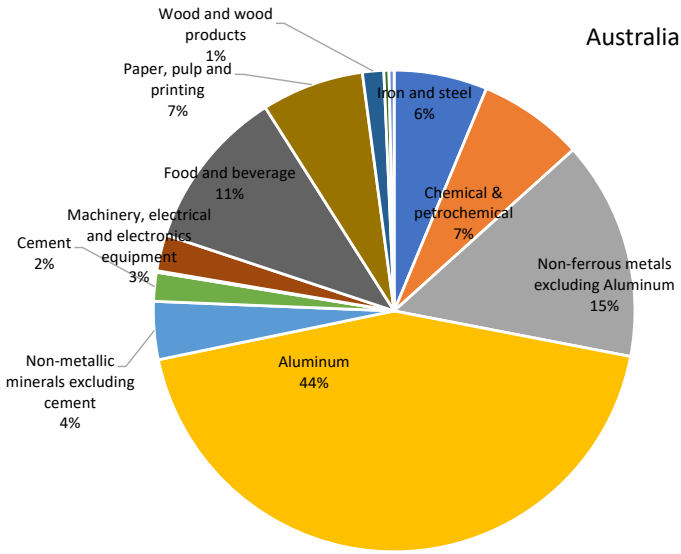



Figure A10. Shares of manufacturing subsector in annual manufacturing electricity use for Australia in 2019 (source: estimated based on IEA, 2022c)

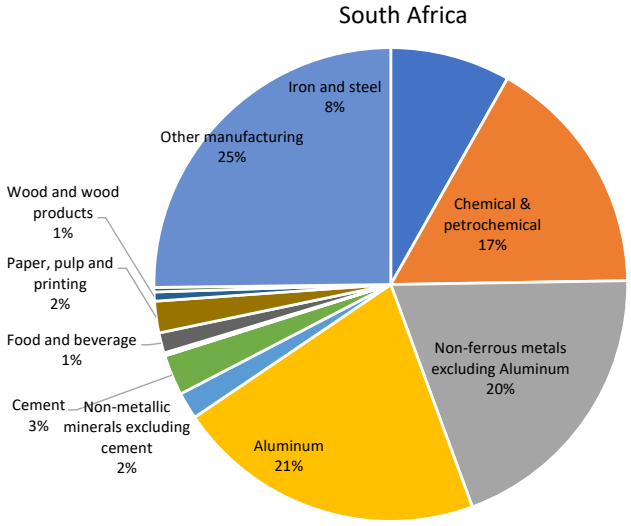



Figure A11. Shares of manufacturing subsector in annual manufacturing electricity use for South Africa in 2019 (source: estimated based on IEA, 2022c)

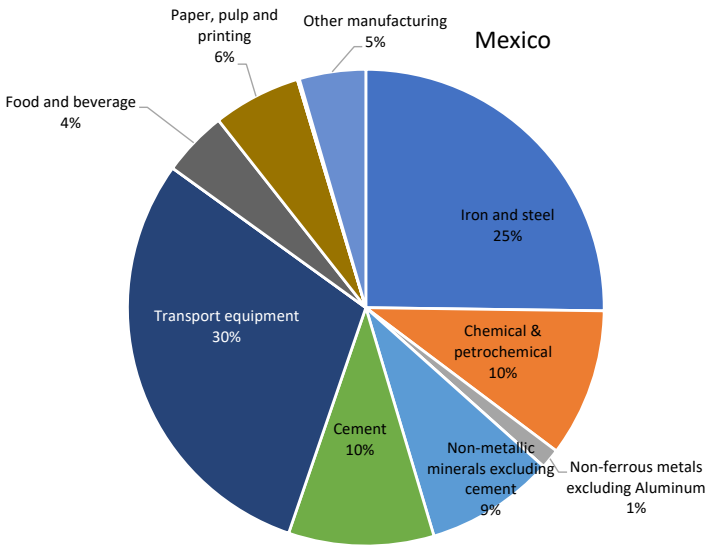



Figure A12. Shares of manufacturing subsector in annual manufacturing electricity use for Mexico in 2019 (source: estimated based on IEA, 2022c)

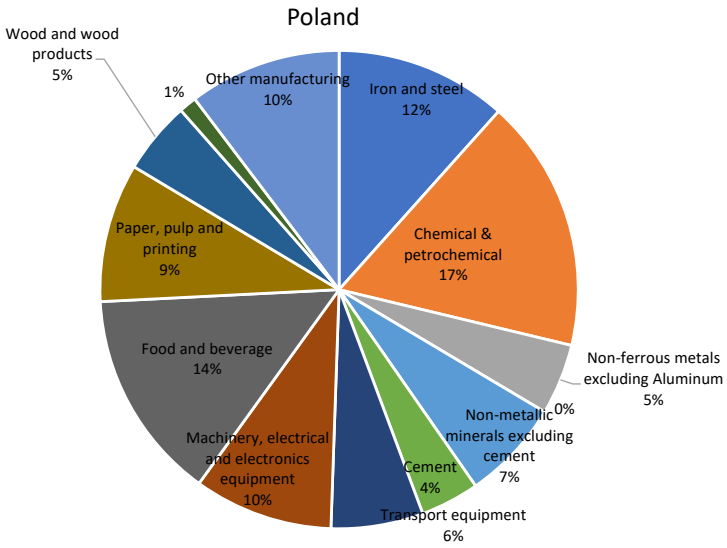



Figure A13. Shares of manufacturing subsector in annual manufacturing electricity use for Poland in 2019 (source: estimated based on IEA, 2022c)

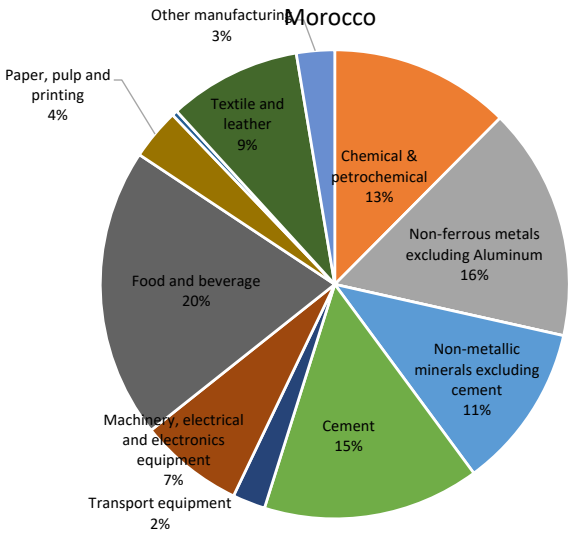



Figure A14. Shares of manufacturing subsector in annual manufacturing electricity use for Morocco in 2019 (source: estimated based on IEA, 2022c)

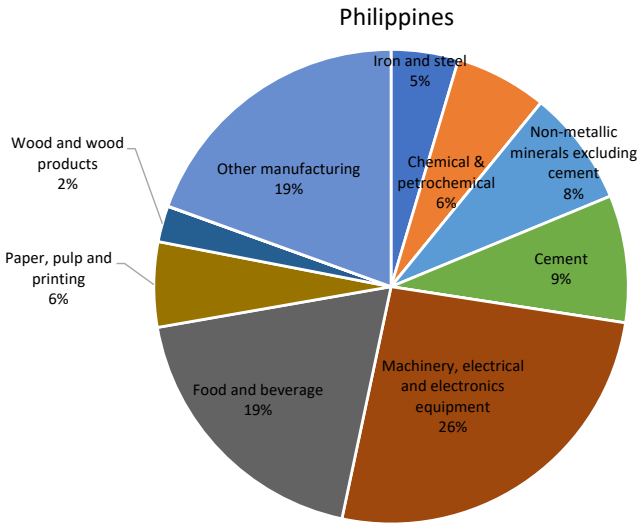



Figure A15. Shares of manufacturing subsector in annual manufacturing electricity use for Philippines in 2019 (source: estimated based on IEA, 2022c)

## Appendix 3: Sources of industrial electricity demand forecast

| Country | Source |
|---|---|
| China | IEA world energy outlook |
| United States | EIA, 2022 |
| Japan | ERIA, 2022 |
| South Korea | ERIA, 2022 |
| India | IEA, 2021b |
| Germany | JRC Potencia model, 2018 |
| Brazil | Torinni et al., 2016 |
| Italy | JRC Potencia model, 2018 |
| Vietnam | ERIA, 2022 |
| Turkey | IICEC, 2020 |
| Thailand | ERIA, 2022 |
| Indonesia | ERIA, 2022 |
| Malaysia | ERIA, 2022 |
| Australia | ERIA, 2022 |
| Poland | JRC Potencia model, 2018 |
| Mexico | IEA, 2016 |
| Philippines | ERIA, 2022 |
| Chile | ERIA, 2022 |
| World | IEA World Energy outlook |

## Appendix 4: Energy efficiency measures for electric motor driven systems

Table A2. Example of energy efficiency measures for electric motor driven systems (adopted from Hasanbeigi et al., 2017)

| Motor System | Energy efficiency measure |
|---|---|
| Pumps | Isolate flow paths to non-essential/non-working equipment |
| | Leakage repair |
| | Trim or change impeller to match output requirement |
| | Remove sediment/build-up in piping |
| | Use of pressure switches to shut down unnecessary pumps |
| | Variable speed drives |
| | More efficient pump/motor |
| Fans | Isolate flow paths to non-essential/non-working equipment |
| | Correct damper problems |
| | Replace inefficient belt drives |
| | Correct poor inflow conditions at flan inlet and outlet |
| | Replace oversized fans |
| | Variable speed drives |
| | More efficient motor |
| Compressed air system | Leakage repair, adjust compressor controls |
| | Initiate predictive maintenance program |
| | Install sequencer |
| | Improve end use efficiency, shut-off idle equipment |
| | Eliminate inappropriate compressed air uses |
| | Pressure optimization |
| | Match air treatment demand side needs |
| | Appropriate compressor sizing |
| | Variable speed drive |