International Labour Organization

The future of work in the electronics industry

Advancing decent work in more inclusive, sustainable and resilient electronics supply chains

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Foreword

The International Labour Organization (ILO) is the United Nations specialized agency dedicated to advancing opportunities for women and men to obtain decent and productive work in conditions of freedom, equity, security and human dignity. The ILO Sectoral Policies Department (SECTOR) promotes decent work by supporting the Organization's tripartite constituency, namely governments, employers and workers, in creating opportunities and addressing challenges in 22 different economic and social sectors at the global, regional and national levels.

The electronics industry is one of the world's largest and fastest-growing manufacturing industries. Characterized by high levels of outsourcing and offshoring, the industry is extremely fragmented at the global level. The goods produced by the electronics industry have had a significant impact on the way we live, work, produce and consume. Ongoing innovation in the industry, which has led to the development of portable devices, wearable electronics and self-driving cars, continues to transform our everyday lives in numerous ways. In fact, the industry is now powering the fourth industrial revolution and driving forward rapid advances in automation and digitalization.

In this paper on the future of work in the electronics industry, an overview is provided of the industry, its production systems and value-added. It elaborates on employment trends within the industry and provides modelled estimates of employment in the industry at the global level. The paper then explores how recent developments and trends, including technological advances, globalization, demographic trends and climate change, are affecting the electronics industry and shaping the future of employment in the industry and its supply chains. The most prominent decent work challenges and opportunities in the industry are then identified and the paper concludes with a discussion of potential steps that can be taken to ensure that the industry and its supply chains are inclusive, sustainable and resilient.

This paper has been drafted with the aim of informing decisions by ILO constituents and, it is hoped, will serve as a basis for dialogue on actions that can be taken to ensure a future that works for all in the electronics industry, including the thousands of enterprises involved in the production of electronics components and the millions of women and men that produce the computers, phones and other electronic equipment that so many of us depend on in our work and daily lives.

This paper was prepared and drafted by Francine Ndong under the supervision of Casper Edmonds and finalized by Diederik Bos under the overall supervision of SECTOR Deputy Director, Yukiko Arai, and Director, Frank Hagemann. Valuable input, comments and guidance were received from Stefan Kühn, Margherita Licata, Yves Perardel, David Kapya, Arianna Rossi and Miguel Sanchez Martinez.

Frank Hagemann
Director
Sectoral Policies Department

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1. Introduction

The electronics industry emerged in the twentieth century and is now one the world's largest and fastest-growing manufacturing industries. It is a prime example of a "propulsive industry" as it has had a significant impact on economic growth and has enhanced overall productivity in other industries and across entire economies.

With an estimated total value of some €1.5 trillion, the electronics assembly industry is one of the world's largest, and is expected to continue to grow at around 4 per cent a year.[1] The goods produced by the industry have had a significant impact on the way we live, work, produce and consume, while ongoing innovation in the industry continues to transform our everyday lives in numerous ways. The electronics industry is now powering the fourth industrial revolution and driving forward rapid advances in automation and digitalization.

The electronics industry is key to the economic and social development of many countries and is an entry point to many global supply chains and markets. It provided direct employment opportunities to more than 17.4 million women and men in 2023, and to even greater numbers through indirect employment, including in other industries along the electronics industry supply chain, in turn helping to lift millions more out of poverty.

At the same time, the use of electronics goods and services generates significant greenhouse gas emissions. Electrical and electronic equipment waste, widely known as e-waste, is one of the world's fastest growing waste streams. The significant environmental footprint of electronics manufacturing, concerns about working conditions in electronics supply chains in certain countries and privacy issues stemming from the use of certain electronics goods all mean that the industry is under increasing pressure to reduce its negative externalities and to advance decent and sustainable work.

Because of its size and socio-economic impact, the electronics industry is key to implementing the 2030 Agenda for Sustainable Development, and particularly the achievement of Sustainable Development Goal 8, namely: "Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all". If the negative repercussions of electronics production and use can be addressed, the industry could also play a role in advancing the achievement of other Sustainable Development Goals, including Goal 3, on good health and well-being, Goal 4, on quality education and lifelong learning, Goal 5, on gender equality, Goal 9, on industry, innovation and infrastructure; Goal 10, on reduced inequalities, Goal 11, on sustainable cities and communities, and Goal 12, on responsible consumption and production.

In this paper, an overview is provided of the electronics industry today (Chapter 2) and the ways in which key megatrends and drivers, including technological advances, globalization, demographic trends and climate change, are likely to shape the future of work in the industry (Chapter 3). Analysis is then provided on key challenges and opportunities for decent work stemming from those megatrends and drivers, bearing in mind the principles enshrined in the Decent Work Agenda of the ILO (Chapter 4). The paper concludes with a call for action (Chapter 5) with a view to supporting efforts by governments, employers and workers and all other relevant stakeholders to shape a future that works for all, including the thousands of enterprises and millions of women and men involved in the production of electronics components, computers, telephones and other electronic equipment that so many of us depend on in our work and daily lives.

[1] Roland Berger, *How Industry 4.0 will impact electronics assembly*, October 2018. Available at: www.rolandberger.com/en/Insights/Publications/How-Industry-4.0-will-impact-electronics-assembly.html.

2. The current state of the electronics industry

The electronics industry is global in scope, highly fragmented and in rapid development. The focus of this paper is the manufacture of computer, electronic and optical products, as defined in Division 26 of the International Standard Industrial Classification of All Economic Activities (ISIC), Revision 4, published by the United Nations Department of Economic and Social Affairs of the United Nations.[2]

Electronics manufacturers include enterprises that produce millions of cell phones each year and enterprises that produce only limited quantities of specialized electronic components and equipment. Given the complexity of the industry, the variety of goods and services that are produced, and the use of those goods and services across a wide range of economic sectors,[3] the available data and statistics on electronics manufacturing are also diverse and often disparate in nature.

2.1. Structure of the industry and its supply chains

Electronics industry supply chains comprise numerous stakeholders, including home-based workers and micro-, small and medium-sized enterprises, contract manufacturers, global electronics production conglomerates and large multinational enterprises.

According to recent data, more than 3,756 enterprises operate in the global consumer electronics segment alone,[4] while more than 44,000 enterprises are active within the broader global electronics industry.[5] An overview of enterprises operating in various segments of the electronics industry is provided in box 1.

Each segment of the electronics industry supply chain has its own particular characteristics and priorities, but collaboration and seamless integration among those segments are crucial for the successful development, production and distribution of electronic products in global markets. On that basis, few companies limit their activities to only one of the categories listed above. That is particularly the case for multinational enterprises and major electronics manufacturing brands in consumer electronics. Indeed, although those enterprises may be heavily reliant on raw material suppliers and electronics component manufacturers, they often establish their own factories for product assembly and create in-house retail and customer service departments.

The manufacturing of electronics parts and products is commonly outsourced. In fact, production processes and associated functions occur across many countries and regions in what has gradually become a global production network. In that connection, it should be noted that small and medium-sized enterprises are found along the entire electronic industry supply chain but are much more prevalent within lower supply chain tiers.

In recent decades, the development of the electronics industry has spurred the emergence of specialized companies operating in niche areas. These include large multinational enterprises involved in the production of key electronic components, including semiconductors, which are often able to capture a large share

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2 Available at: unstats.un.org/unsd/publication/seriesM/seriesm_4rev4e.pdf. Division 26 includes: the manufacture of electronic components and boards; the manufacture of computers and peripheral equipment; the manufacture of communication equipment; the manufacture of consumer electronics; the manufacture of measuring, testing, navigating and control equipment; the manufacture of watches and clocks; the manufacture of irradiation, electromedical and electrotherapeutic equipment; the manufacture of optical instruments and photographic equipment; and the manufacture of magnetic and optical media.

3 These include the automotive, aviation, defence, telecommunications, entertainment and healthcare sectors. Electronics components are used in many products and industries. These range from discrete components such as integrated circuits, to consumer electronics such as televisions, smartphones and computers, to medical equipment such as heart-rate monitors and dialysis machines, to communication and networking equipment, including routers and switchboards, all the way to mechanical equipment such as robots.

4 For further details, see: IBIS World, "Global Consumer Electronics Manufacturing - Market Size, Industry Analysis, Trends and Forecasts". Available at: https://www.ibisworld.com/global/number-of-businesses/global-consumer-electronics-manufacturing/970/ Accessed September 2024.

5 ILO, *Responsible business conduct in China electronics supply chains*, 2023. Available at: https://webapps.ilo.org/wcmsp5/groups/public/---asia/---ro-bangkok/documents/projectdocumentation/wcms_865462.pdf.

▶ Box 1. Enterprises active in the electronics industry

- **Raw material suppliers:** raw material suppliers provide components and materials essential for electronics manufacturing, such as semiconductors, metals, plastics and specialized chemicals. These companies often focus on producing high-quality materials, ensuring consistency and meeting the specifications required by manufacturers. They may have global distribution networks and invest heavily in research and development with a view to developing innovative materials.
- **Electronics component manufacturers:** these companies produce individual components, such as semiconductors, capacitors, resistors and displays used in electronic devices. Component manufacturers emphasize precision engineering, scalability and technological innovation. They may specialize in the production of specific components and often operate on a global scale, supplying components to a number of electronics assembly companies.
- **Electronics assembly companies:** these companies assemble individual components into finished electronic devices or products, such as smartphones, computers and other consumer electronics. Assembly firms focus on efficient manufacturing processes, automation, quality control and meeting production deadlines. They may have facilities worldwide to cater to global demand and often collaborate with designers and manufacturers to optimize production.
- **Original equipment manufacturers:** these manufacturers design and develop electronic products, often outsourcing manufacturing to assembly companies. These companies focus on innovation, product differentiation and branding. They invest heavily in research and development to create cutting-edge products, manage supply chains and collaborate with assembly firms to facilitate the production process.
- **Original design manufacturers:** these manufacturers design and manufacture products based on specifications provided by original equipment manufacturers, often contributing to the entire product development cycle. Original design manufacturers tend to emphasize flexibility, rapid prototyping and efficient manufacturing capabilities. They may specialize in certain product categories and offer customization services for original equipment manufacturers.
- **Distributors and retailers:** distributors procure finished electronic products from manufacturers and supply them to retailers or directly to consumers. Distributors focus on logistics, warehousing and managing large inventories. Retailers prioritize marketing, customer service and sales strategies to reach end consumers, often managing extensive distribution networks.
- **Aftermarket and service providers:** these companies offer repair services, maintenance, upgrades and aftermarket products for electronic devices. Aftermarket and service providers focus on technical expertise, customer support and warranty services. They may collaborate with original design manufacturers to provide authorized repairs or offer third-party solutions.

of the value-added generated by electronics supply chains. In 2020, the three largest semiconductor manufacturing enterprises generated an estimated US$188 billion in revenue – almost as much as the next 12 largest semiconductor manufacturers combined.

The increasing demand for electronics products has fuelled the emergence of a competitive and dynamic industry characterized by high levels of innovation and investment. The industry is particularly capital-intensive and has historically attracted significant foreign direct investment (FDI). In the information and communications technology (ICT) industry, investments in greenfield FDI projects increased by more

than 22 per cent in the period 2019 to 2020 to reach an estimated total of US$81 billion.[6] In 2023, the electronics and electrical industry maintained its second position in the top 10 industries with a valuation of US$183 billion in announced greenfield projects.[7]

The electronics industry is characterized by continuous product development and constant improvements in product design and technology and is one of the world's most research and development-intensive manufacturing industries (alongside pharmaceuticals and transport equipment manufacturing). The semiconductor subsector is a research and development powerhouse that attracts huge investments and drives innovation in the electronics industry. In 2020, over 10 per cent of semiconductor revenues were re-invested into research and development, with total research and development investment reaching some US$68.4 billion.[8] It should be noted, moreover, that the United States of America accounts for the majority of that investment, with enterprises in the United States investing some US$59.3 billion in research and development in 2023, confirming that country's leadership role in semiconductor chip development.[9]

Numerous mergers and acquisitions, involving both large and smaller brands and manufacturers, attest to the industry's dynamism. In the European electronics ecosystem alone, the total value of mergers and acquisitions was estimated at more than US$63 billion in 2020.[10] The electronics and electrical equipment industry has also seen a significant increase in net cross-border merger and acquisition activity, which rose from US$21 billion in 2019 to US$40 billion in 2020.[11]

It should be noted, however, that many enterprises lack the capacity to sustain research and development at the levels necessary to keep pace with the rapid change that characterizes the industry. This is particularly the case in the network and communications equipment subsector, where half the companies in the Fortune Global 500, an annual ranking of the top 500 corporations worldwide as measured by revenue, generate around the same revenue as they did a decade ago.

2.2. Value-added and production trends

According to the United Nations Industrial Development Organization (UNIDO), there is considerable variation among countries in terms of their electronics manufacturing value-added. Estimates of value-added in the electronics industry for selected economies, most of which have significant export sectors, are shown in Table 1.

An overview of global electronics and information technology manufacturing trends, estimated in monetary terms relative to global gross domestic product (GDP), is provided in figure 1, which shows that production increased from US$261 billion in 2012 to US$353 billion in 2023.

As explained in box 2, semiconductors lie at the core of global electronics industry supply chains. Trends in the production of semiconductors are closely correlated with broader trends in electronics production. The design, manufacture, assembly, testing and packaging of semiconductors takes place, primarily, in the United States, the Republic of Korea, Japan, China, Taiwan Province of China and certain European countries.

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6 United Nations Conference on Trade and Development (UNCTAD), *World Investment Report 2021*. Available at: https://unctad.org/system/files/official-document/wir2021_en.pdf.

7 United Nations Conference on Trade and Development (UNCTAD), *World Investment Report 2024*, P.22 Available at: https://unctad.org/system/files/official-document/wir2024_en.pdf.

8 Onlinecomponents.com, "2021 semiconductor R&D to rise 4%" (blog), n,d. Available at: www.onlinecomponents.com/en/blogpost/2021-semiconductor-rd-spend-to-rise-4-357/.

9 Semiconductor Industry Association, "Semiconductor Industry Association Factbook 2024".

10 Anne-Françoise Pelé, "2020 in Review: Acquisitions in the European Electronics Industry", *EE Times Europe*, 16 December 2020. Available at: https://www.eetimes.eu/2020-in-review-acquisitions-in-the-european-electronics-industry/.

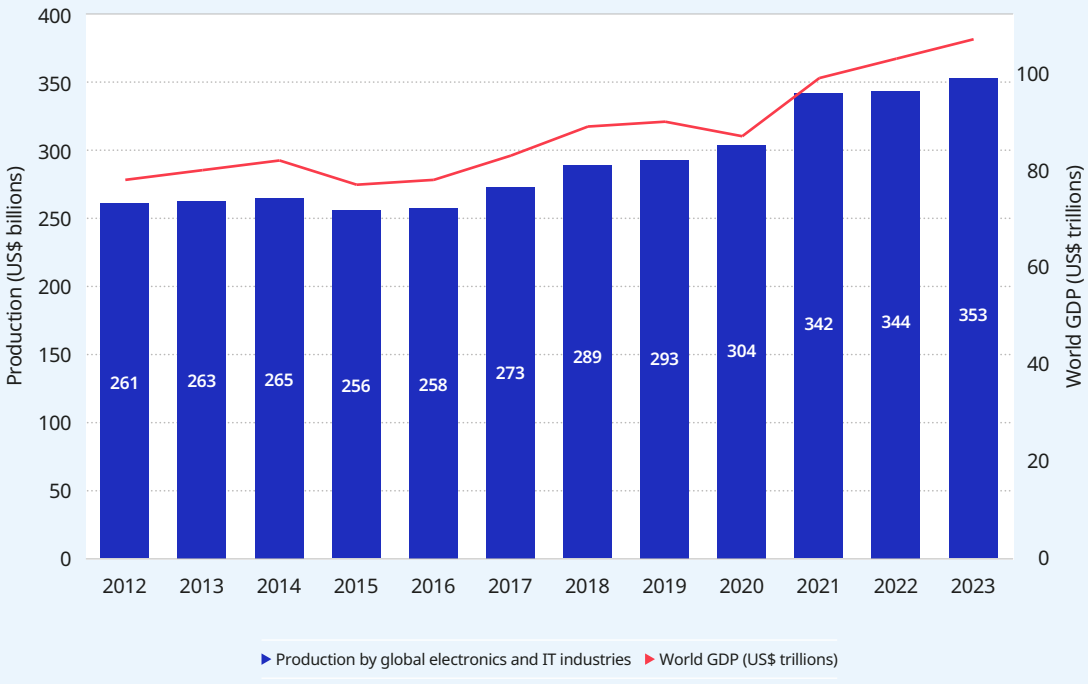
11 UNCTAD, *World Investment Report 2021*.

▶ Table 1. Top ten economies (with available data) ranked in terms of electronics manufacturing value-added, 2021 estimates (billion US dollars)

Ranking	Country	Value-added (US$ billion)
1	United States of America	187.46
2	Republic of Korea	159.11
3	Taiwan Province of China	152.53 (2022)
4	Japan	148.58
5	Germany	48.78
6	Singapore	41.00
7	Switzerland	28.42
8	Viet Nam	24.33
9	France	16.12
10	Thailand	14.17

Source: UNIDO Industrial Statistics Database, INDSTAT ISIC Revision 4, accessed 24 September 2024. Available at: https://stat.unido.org/.

▶ Figure 1. Production in global electronics and information technology industries, 2012-2023 (billion US dollars)



Source: Japan Electronics and Information Technology Industries Association (JEITA), 2022.

▶ Box 2. Production of semiconductors

- Semiconductor manufacturing requires silicon, rare-earth elements, critical minerals and many other raw materials used at different stages of the production process. The market for materials used in semiconductor production was estimated at US$46.8 billion in 2019.[a]
- Total semiconductor unit shipments were expected to rise by 13 per cent in 2021 to some 1,135.3 billion units, a new all-time annual record.[b] This followed a 3 per cent increase in 2020, a year in which the global response to the coronavirus disease (COVID-19) pandemic had a serious impact on electronic industry supply chains (see section 2.5).

Notes: [a] Saif Khan, Alexander Mann and Dahlia Peterson, "The Semiconductor Supply Chain: Assessing National Competitiveness", Georgetown University Center for Security and Emerging Technology Issue Brief, 2021. Available at: https://cset.georgetown.edu/wp-content/uploads/The-Semiconductor-Supply-Chain-Issue-Brief.pdf. [b] IC Insights "Semiconductor Units Forecast To Exceed 1 Trillion Devices Again in 2021", Research Bulletin, 7 April 2021. Available at: https://www.icinsights.com/data/articles/documents/1363.pdf.

2.3. Global sales and trade trends

The COVID-19 pandemic initially caused demand for electronic devices to plummet. Some electronic industry sectors recovered quickly, however, and demand for their products remains strong. For example, computer sales increased notably as more people engaged in telework, while, as explained in box 3, more semiconductors were needed to strengthen the capacity of data centres struggling to address rapidly increasing telecommunications volumes and more sophisticated uses of data. Furthermore, global smartphone sales to end users reached US$328.8 million in the second quarter of 2021, an increase of 10.8 per cent compared to 2020.[12]

The United Nations Conference on Trade and Development (UNCTAD) also estimates that the global trade in computers and peripheral equipment, communication equipment, consumer electronic equipment and

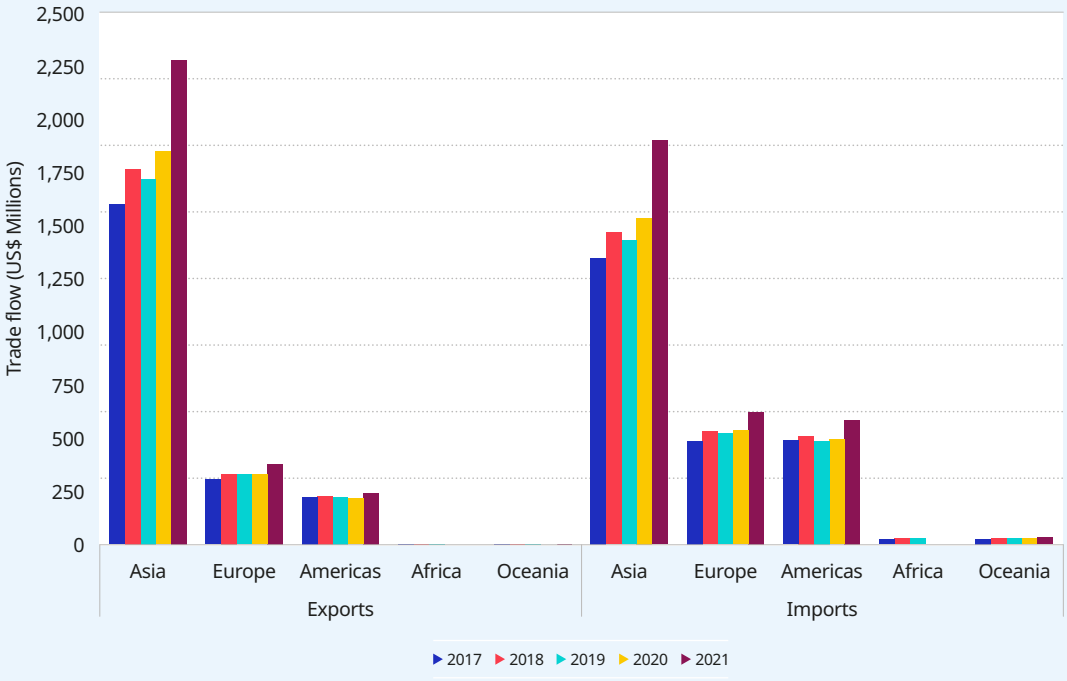
▶ Box 3. Sales of semiconductors

- Between 1995 and 2015, an estimated US$3 trillion in global GDP was directly attributed to semiconductor innovation, along with an additional US$11 trillion in indirect impact. Following strong sales of US$555.9 billion in 2021, global semiconductor sales in 2022 increased by 3.2 per cent to US$574.1 billion.
- In 2001, the Asia-Pacific semiconductors market surpassed all other regional markets in sales, as electronic equipment production shifted to the region. It has multiplied in size since then and increased from US$39.8 billion in 2001 to more than US$343 billion in 2021.
- The largest market within the Asia-Pacific region, China, accounted for 56 per cent of the region's semiconductor market and 35 per cent of the global market in 2021.

Sources: Semiconductor Industry Association (SIA), 2023 State of the U.S. Semiconductor Industry. Available at: www.semiconductors.org/2023-state-of-the-u-s-semiconductor-industry/; SIA Factbook 2022. Available at: www.semiconductors.org/wp-content/uploads/2022/05/SIA-2022-Factbook_May-2022.pdf.

[12] Gartner, Inc. "Gartner Says Worldwide Smartphone Sales Grew 10.8% in Second Quarter of 2021", Press release, 1 September 2021. Available at: www.gartner.com/en/newsroom/press-releases/2021-09-01-2q21-smartphone-market-share#:~:text=Global%20smartphone%20sales%20to%20end,production%20disruption%20and%20component%20shortages.

▶ **Figure 2. Trade flow of ICT goods in different global regions, 2017–2021** (billion US dollars)



Note: ICT goods categories include: computers and peripheral equipment, communication equipment, consumer electronic equipment, electronic components and miscellaneous.

Source: UNCTAD database, "Bilateral trade flows by ICT goods categories, annual", accessed September 2024.

electronic components (ICT products) has gained momentum.[13] Electronic components continue to account for the largest share of the trade in ICT goods, comprising just over 40 per cent of global imports.

As illustrated in figure 2, global trade in ICT goods is concentrated in Asia, followed by Europe and the Americas. The African continent imported more ICT goods than it exported in 2021 (around US$20 billion versus US$3.65 billion, respectively).

China is one of the main drivers of trade in ICT goods in the world. It accounted for 29.52 per cent and 20.1 per cent of global exports and imports respectively in2021.[14] In 2020, Viet Nam had one of the highest economic growth rates in the world,[15] with growth primarily driven by a rapid increase in electronics exports and its expanding services sector.[16] Furthermore, a number of large tech companies have relocated their production to Viet Nam, increasing the country's electronics production and positioning it as one of the key suppliers of electronics products to other countries, including the United States.[17]

13 UNCTAD refers to these categories as "Information and communications technologies (ICT) products".

14 UNCTADSTAT, "Bilateral trade flows by ICT goods categories, annual", accessed September 2024.

15 Era Dabla-Norris and Yuanyan Sophia Zhang, *Vietnam: Successfully Navigating the Pandemic*, (International Monetary Fund, 2021). Available at: https://www.imf.org/en/News/Articles/2021/03/09/na031021-vietnam-successfully-navigating-the-pandemic.

16 IMF, "Vietnam: IMF Country report No. 21/42", March 2021

17 "US-China Trade War Seen as Boosting Viet Nam Growth", VOA News, 12 January 2020. Available at: https://www.voanews.com/a/east-asia-pacific_us-china-trade-war-seen-boosting-vietnam-growth/6182492.html; ILO, *Viet Nam's electronics supply chain: Decent work challenges and opportunities*, 2022. Available at: webapps.ilo.org/wcmsp5/groups/public/---ed_dialogue/---sector/documents/publication/wcms_865520.pdf.

▶ Box 4. Global semiconductor chip shortages during the COVID-19 pandemic

- The tech industry has, in recent years, faced a number of challenges due to a global semiconductor chip shortage. That crisis began long before the COVID-19 pandemic but was accentuated by the COVID-19 crisis.
- Given the relatively long production timelines for chips, which average more than 18 months, it has been challenging for the industry to keep up with soaring demand, which is expected to increase even further in the coming years and decades.
- Policy makers have raised concerns regarding their countries' dependence on producing countries to meet their chip demand and ensure the functioning of critical infrastructure, including national defence. To address those concerns, the Chinese Government has set an ambitious target of producing 70 per cent of its semiconductors domestically by 2025, while the United States Government is also seeking to strengthen its domestic semiconductor manufacturing base.

Sources: Coco Liu, Cheng Ting-Fang and Lauly Li, "China chip designers say Beijing goals impossible without US tech", (*NikkeiAsia*, 24 June 2019). Available at: asia.nikkei.com/Business/China-tech/China-chip-designers-say-Beijing-goals-impossible-without-US-tech; Coco Liu and Cheng Ting-Fang, "Alibaba unveils first microchip as China aims for self-sufficiency" (NikkeiAsia, 25 July 2019). Available at: asia.nikkei.com/Business/China-tech/Alibaba-unveils-first-microchip-as-China-aims-for-self-sufficiency; The White House, Building Resilient Supply Chains, Revitalizing American Manufacturing, and Fostering Broad-based Growth, 2021. Available at: https://www.whitehouse.gov/wp-content/uploads/2021/06/100-day-supply-chain-review-report.pdf.

While trade flows have increased rapidly in recent years, the global electronics industry experienced significant supply chain disruptions during the COVID-19 pandemic, leading to a global chip shortage that severely affected countries with large electronics manufacturing sectors (see box 4).

2.4. Employment trends

2.4.1. Global employment

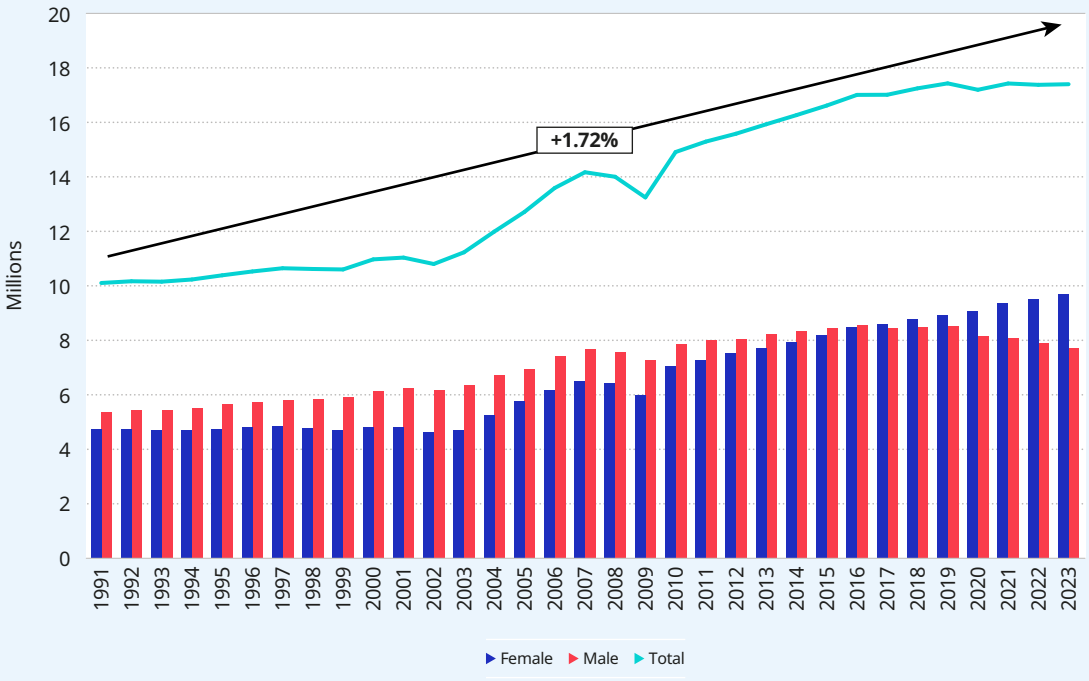
According to recent estimates by ILO, approximately 17.4 million workers were employed in the manufacture and assembly of electronics hardware in 2023. Those workers comprised almost 3.5 per cent of global manufacturing employment.

Employment levels in the electronics industry have increased steadily since 1991. A notable reversal in that upward trend occurred as a result of the 2008–09 global financial crisis, when global employment contracted. Employment in the electronics industry then resumed its upward trajectory, reaching approximately 17 million workers in 2016, after which it plateaued. Between 1991 and 2023, the industry grew at a compound annual growth rate (CAGR) of 1.72 per cent (figure 3).

The employment of female workers in the electronics industry has been increasing and surpassed the male employment level in 2017. Between 1991 and 2023, women's employment in the industry increased at a CAGR of 2.27 per cent, compared to 1.14 per cent for men. In 2023, women accounted for 55.67 per cent of all workers in the industry worldwide.

In 2023, approximately 78.15 per cent of all workers in the electronics industry were employed in Asia and the Pacific. Between 1991 and 2023, employment in electronics manufacturing in Asia and the Pacific grew at a CAGR of 3.2 per cent. In Europe and the Americas on the other hand, employment decreased by 1 and 1.2 per cent, respectively, over the same period. Africa and the Arab States experienced positive net growth in employment in the industry at a CAGR of 1.6 per cent and 3.4 per cent, respectively, between 1991 and

▶ **Figure 3. Global employment in the electronics industry disaggregated by gender, 1991–2019**
(no. of workers)



Source: ILO calculations based on data from the ILO Harmonized Microdata Repository

2023, although the number of workers employed in the industry remains low and stood at slightly over 369 thousand and 76 thousand in 2023, respectively (figure 4).

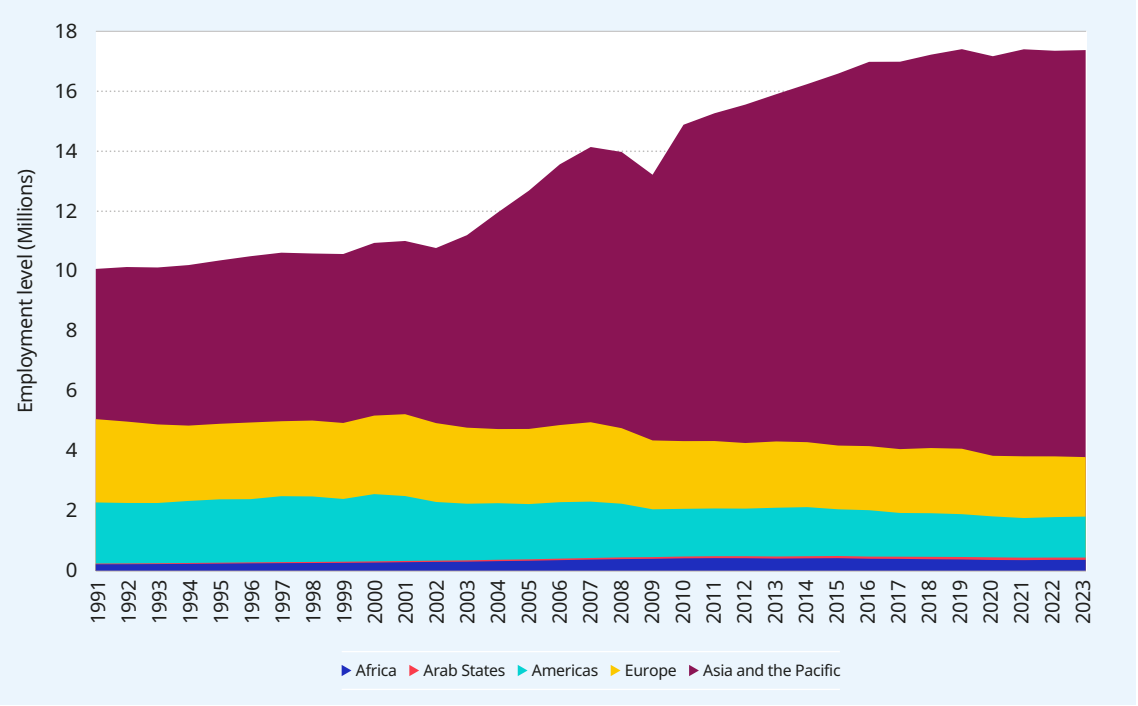
As illustrated in figure 5, around 57.66 per cent of electronics manufacturing workers are employed in East Asia, with China topping the list of countries with the highest global share of employment (43.20 per cent). Following China are Taiwan Province of China (6.79 per cent), Viet Nam (5.29 per cent), India (5.14 per cent), the United States (4.26), Japan (4.17), the Republic of Korea (3.41 per cent), the Philippines (2.8 per cent), Thailand (2.3) and Germany (2.15 per cent).

From 1991 onwards, China's share of employment in the electronics industry increased at a CAGR of 5.77 per cent, reaching a total of 7.5 million workers in 2023. Between 1991 and 2023, employment in China's electronics industry increased seven times than in the rest of the world.

In Africa, the sub-Saharan subregion accounts for the lion's share of employment in the industry. In 2023, the top four countries in terms of employment were Ethiopia (27.38 per cent), Democratic Republic of Congo (24.04 per cent), Nigeria (8.97 per cent) and South Africa (5.83 per cent). Those countries were followed by Egypt (4.07 per cent) and Algeria (3.87 per cent) in the North Africa subregion. A recent report by UNCTAD highlights the opportunity for African economies to leverage the continent's significant reserves of the critical minerals required for technology-intensive industries and become key suppliers of parts and components for those industries, including electronics manufacturing.[18] Efforts are ongoing to step up electronics manufacturing on the continent. Rwanda, for example, is investing in initiatives to facilitate

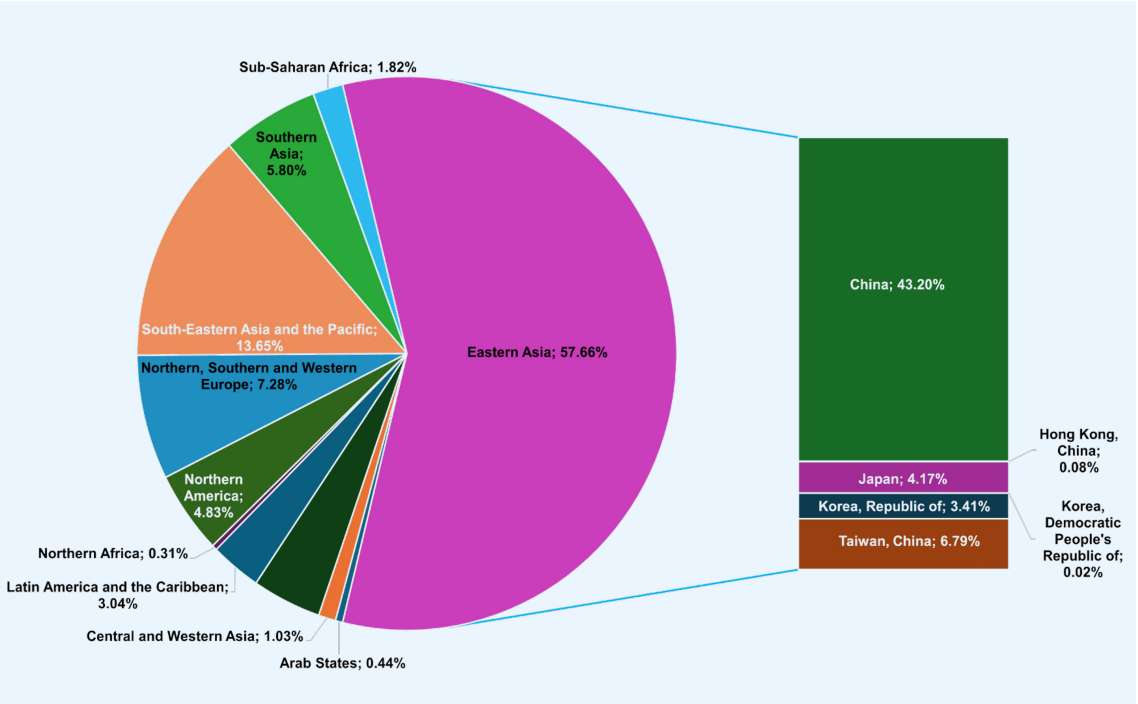
[18] UNCTAD, *Economic Development in Africa Report 2023: The Potential of Africa to Capture Technology-Intensive Global Supply Chains*. Available at: https://unctad.org/system/files/official-document/aldcafrica2023_en.pdf.

▶ **Figure 4. Global employment in the electronics industry in different global regions, 1991-2023** (no. of workers)



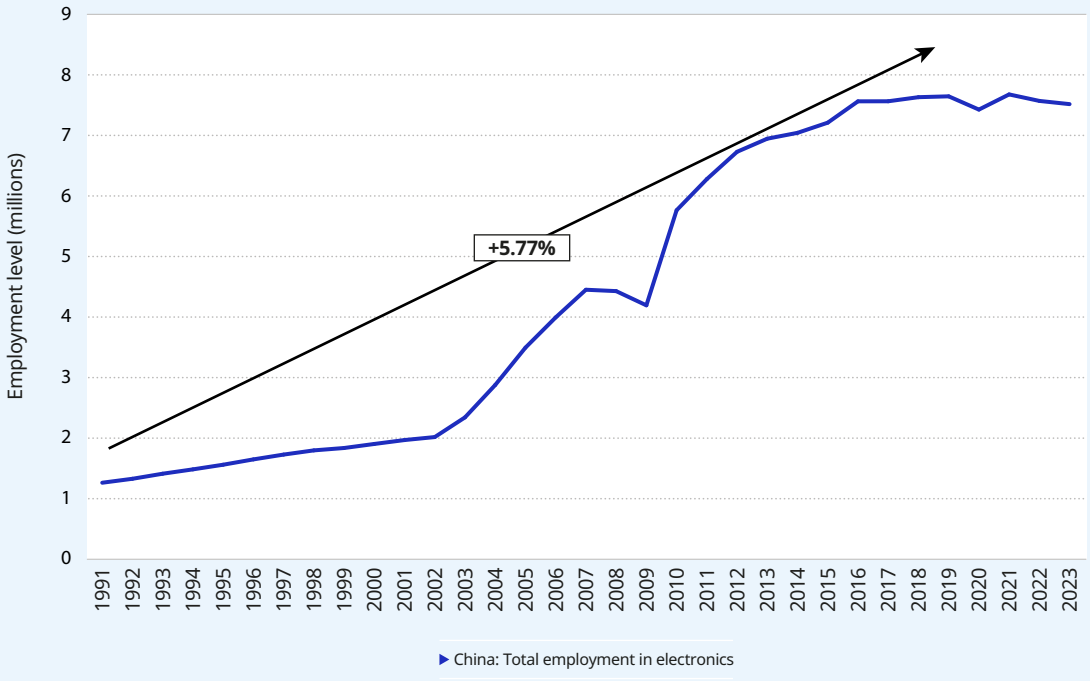
Source: ILO calculations based on data from the ILO Harmonized Microdata Repository

▶ **Figure 5. Distribution of global employment in the electronics industry in different global subregions, and in Eastern Asia, 2023** (percentage of total employment in the electronics industry)



Source: ILO calculations based on data from the ILO Harmonized Microdata Repository

▶ **Figure 6. Total employment in the electronics industry in China, 1991–2023** (no. of workers)



Source: ILO calculations based on data from the ILO Harmonized Microdata Repository

the manufacture of smartphones completely within the country, from chip design to final assembly. Those initiatives are supported by the Government not only with a view to boosting economic growth and producing smartphones at affordable prices, but also in order to promote financial inclusion as well as access to and delivery of public services.[19] In its report, UNCTAD underscores that the production of mobile telephones on the continent "can unlock further potential in the electronics supply chain and open up market opportunities towards the production of tablets, laptops and high-performance servers, and data storage solutions."

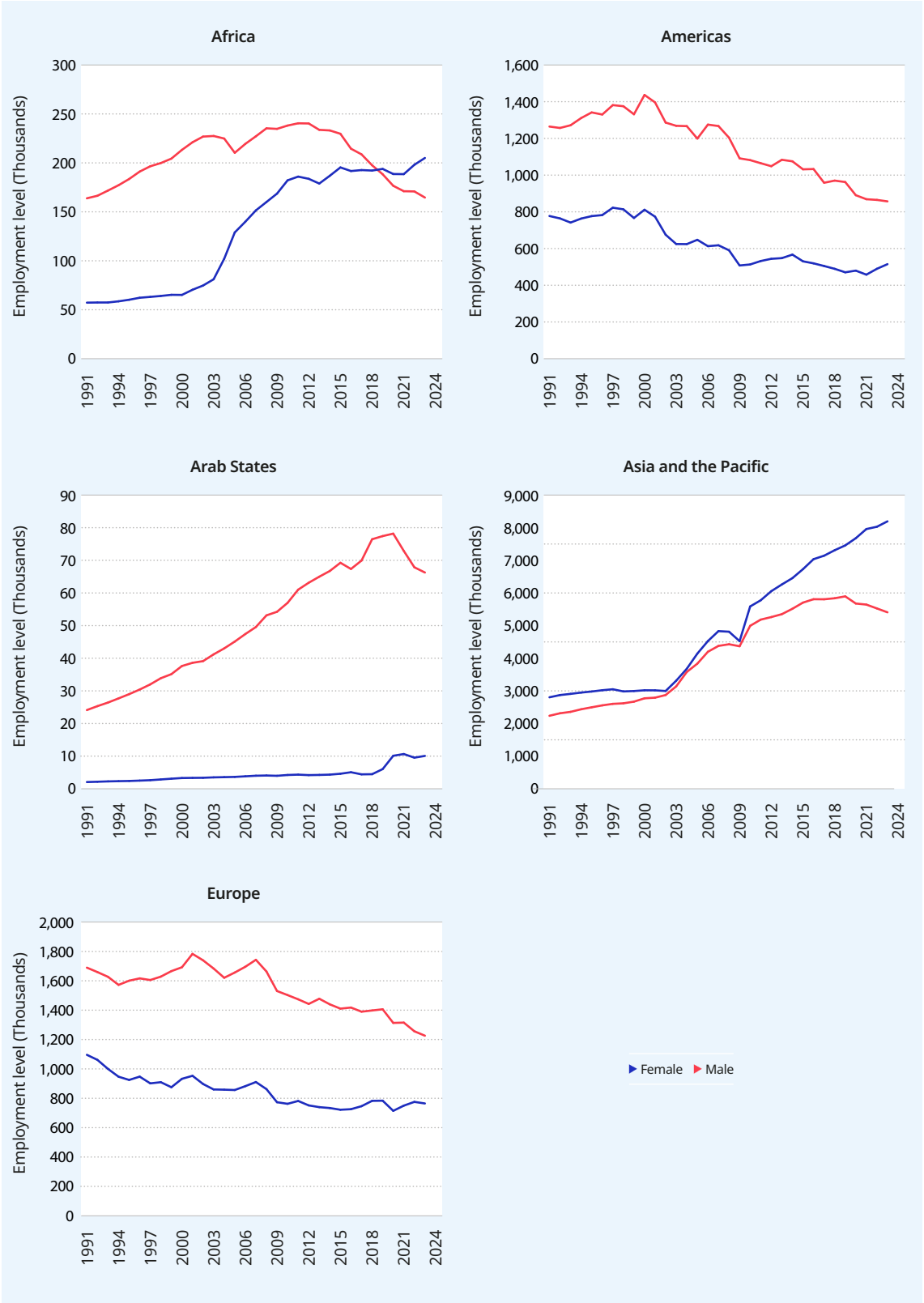
The North America region includes Canada and the United States of America, with the latter accounting for more than 88 per cent of employment on the continent in 2023. In Latin America and the Caribbean, Mexico and Brazil are at the forefront of electronics manufacturing, employing 46 and 34 per cent of electronics workers in the region, respectively.

2.4.2. Gender breakdown of employment

As illustrated in figure 7, 9.7 million women were employed in the global electronics industry in 2023, accounting for some 55.67 per cent of workers in the industry worldwide. In Africa, and Asia and the Pacific regions, most of the electronics workers are women, accounting for 55.49 per cent and 60.27 per cent of the sector's workforce in 2023, respectively. Prior to 2019, women accounted for less than half of employment in the electronics industry in Africa. Since then, women have constituted more than half of all jobs in the electronics industry. Between 1991 and 2023, employment among women grew at a CAGR of 4.09 per cent compared to 0.01 per cent for men. In Asia and the Pacific, women's employment increased at a CAGR of 3.42 per cent from 2.8 million in 1991 to reach 8.2 million in 2023 against the 2.81 per cent CAGR for men.

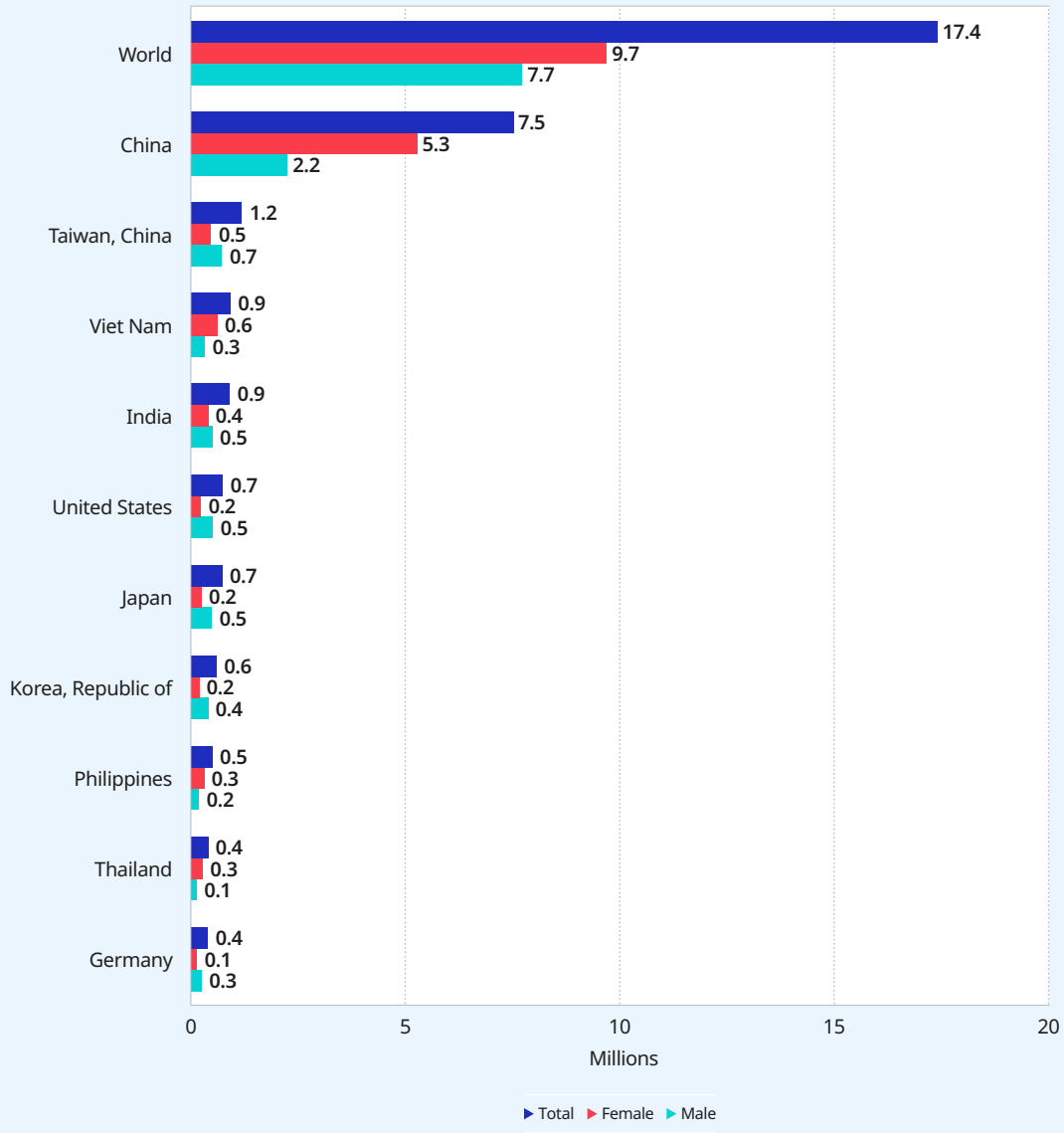
[19] Collins Mwai, Kagame: "The Mara Phone is a milestone for Rwanda", *New Times*, 8 October 2019. Available at: www.newtimes.co.rw/article/170233/News/kagame-the-mara-phone-is-a-milestone-for-rwanda.

▶ **Figure 7. Global employment in the electronics industry in different global regions, disaggregated by gender, 2007–2019** (no. of workers)



Source: ILO calculations based on data from the ILO Harmonized Microdata Repository

▶ Figure 8. Total employment and employment disaggregated by gender in the electronics industry, world and in the Top 10 countries with the largest electronics industries, 2023 (Millions)



Source: ILO calculations based on data from the ILO Harmonized Microdata Repository

In the Americas, Europe and the Arab States on the other hand, most workers in the electronics industry are men, who, in 2023, accounted for 62.52 per cent, 61.63 per cent and 86.96 per cent, respectively, of electronics industry workers on those continents.

Most workers in the global electronics industry are employed in East Asia, where they numbered more than 10.04 million in 2023. East Asia was followed by the Southeast Asia and the Pacific subregion, where the industry employed some 2.4 million workers.[20] In both subregions, women comprised the largest share

[20] ILO calculations based on data from the ILO Harmonized Microdata Repository

▶ **Table 2. Female employment in the electronics industry, top ten electronics industry exporting countries and globally, 2023**

Country	Proportion of women working in the global electronics industry employed in the country (%)	Proportion of women in the electronics industry workforce in the country (%)
China	54.51	70.25
Viet Nam	6.22	65.52
Taiwan, China	4.78	39.19
India	4.12	44.60
Philippines	3.18	63.25
Thailand	2.82	68.22
Japan	2.47	33.00
United States	2.38	31.18
Korea, Republic of	1.94	31.70
Germany	1.27	32.98
Top 10 exporting countries	**83.70**	n/a
Rest of the world	16.30	n/a
World	**100**	**55.67**

Source: ILO calculations based on data from the ILO Harmonized Microdata Repository.

of the workforce and accounted for 63.76 per cent and 15.44 per cent, respectively, of the total number of women employed in the industry worldwide.[21]

As shown in figure 8, there is considerable variation among countries in terms of the proportions of female and male workers employed in their electronics industries.

The top ten exporting countries account for 83.70 per cent of the total female workforce in the industry worldwide (see Table 2). An analysis of the female workforce in different countries reveals significant variations, however. In Viet Nam, for example, women comprise most workers in the industry (65.52 per cent), while in the United States women comprise only 31.18 per cent of the industry's workforce.

2.5. Lessons learned from global crises

As with almost all other industries, the electronics industry was deeply affected by the economic crisis of 2007–2009 and the sharp reduction in global employment that occurred as a result, with employment in the industry falling by an estimated 6.42 per cent.

The global response to the COVID-19 pandemic also had a noticeable impact on the electronics industry, although not as severe as on the tourism, aviation or textiles and garment industries.[22] Not only were the production and assembly of electronics parts and end products affected, but also the production and assembly of inputs that were critical to their manufacture, such as steel baskets for cleaning and curing

[21] ILO calculations based on data from the ILO Harmonized Microdata Repository

[22] ILO, "COVID-19 and the World of Work: Sectoral impact, responses and recommendations". Policy briefs, n.d. Available at: https://www.ilo.org/topics/covid-19-and-world-work/sectoral-impact-responses-and-recommendations.

printed circuit boards. Indeed, almost all links in electronics manufacturing supply chains were affected by disruptions to the trade in both goods and services.

Despite those disruptions and challenges, however, the global response to the COVID-19 pandemic caused an overall increase in the trade in ICT goods, which had declined somewhat prior to the pandemic.[23] In fact, the overall output of computers, electronics and optical products, and of electrical equipment, increased by nearly 22 per cent in the second quarter of 2021,[24] reflecting the increased reliance of populations on digital technologies during lockdowns and other restrictions on movement imposed by the authorities.

[23] UNCTAD, "Will COVID-19 reverse pre-pandemic fall in trade in ICT goods?", 1 April 2021. Available at: https://unctad.org/news/will-covid-19-reverse-pre-pandemic-fall-trade-ict-goods.

[24] UNIDO, World Manufacturing Production – Quarterly Report (Q1 2021). Available at: https://stat.unido.org/content/publications/world-manufacturing-production---quarterly-report.

3. Megatrends and drivers of change: what is at stake?

Technological advances, globalization, demographic trends and climate change are broad and interconnected megatrends that have driven and continue to drive profound change in the electronics industry. In this chapter, a detailed analysis is provided of those megatrends and drivers and their potential future impact on the industry.

3.1. Technological advances and innovation

Technology and ICT constitute an essential part of our everyday lives and our societies are becoming increasingly dependent on digital technologies. The digitalization process has driven demand for innovative and improved technologies, products and models. Those technological advances have, in turn, played a critical role in the expansion and structural transformation of the electronics industry.

3.1.1. Robotics and automation

Electronics manufacturing is dependent on precision engineering and the manipulation of small and fragile parts. Intense competition, cost pressures and short product life cycles mean that manufacturers are constantly seeking ways to process, assemble and package goods more rapidly, while simultaneously trying to maximize revenue. As a result, smart factories, robotics and automation increasingly play a role in helping enterprises reduce costs and maintain quality standards throughout production processes.

At the global level, the electrical and electronics industry became the largest customer of industrial robots in 2020 and has since maintained the position. Between 2020 and 2022, the annual installations of industrial robots in the electrical and electronics industry increased by 40 per cent.

China, Japan, the United States of America, the Republic of Korea and Germany – all among the top ten exporters of electronics goods – account for approximately 79 per cent of all installations of industrial robots.[25] In 2018, the automation boom in the electrical and electronics industry resulted in a 30 per cent increase in sales of industrial robots.[26]

Advances in technology mean that more and more tasks can be automated and businesses around the world are increasingly using robots to replace labour-intensive, repetitive manual processes in electronics assembly. While automation offers many advantages for enterprises, concerns have been voiced that robotization in the electronics sector may lead to job losses in some countries and segments of the supply chain. However, in a recent report, the ILO offers a more nuanced analysis, emphasizing that electronics assembly automation could lead to labour augmentation rather than to job displacement, with robots aiding workers rather than replacing them (see section 4.1.1).[27]

Apart from their potential impact on employment, robots and automation may increase the pace of work in electronics manufacturing, with a potentially negative impact on the health, safety and well-being of workers. At the same time, however, automation could improve occupational safety and health in the electronics industry by performing hazardous and repetitive tasks and decreasing workers' exposure to physical hazards, hazardous substances and ergonomic hazards arising from repetitive work (see section 4.2.2).

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25 International Federation of Robotics, "Executive Summary World Robotics 2023 Industrial Robots", 2024

26 International Federation of Robotics, "Automation boom in electrical /electronics industry drives 30% increase in sales of industrial robots". 7 November 2018. Available at: https://ifr.org/post/automation-boom-in-electrical-electronics-industry-drives-30-increase-in-sa.

27 ILO, *Automation, employment, and reshoring: Case studies of the apparel and electronics industries*, 2020. Available at: www.ilo.org/publications/automation-employment-and-reshoring-case-studies-apparel-and-electronics.

3.1.2. Digitalization

Digitalization is leading to a new era of advanced manufacturing in the electronics industry – elements of which have been described as Industry 4.0. Digital technologies include the integration of advanced analytics, artificial intelligence, sensor technologies, cloud computing, blockchain technology, cyber-physical systems, machine learning, robotics and 3D printing into electronics supply chains, manufacturing, marketing, accounting, sales and after-sales services. Table 3 provides examples of digital technologies and their use in the electronics industry. Those technologies have revolutionized the industry by streamlining production, enhancing quality control, optimizing supply chains, and fostering innovation in manufacturing processes.

From a supply chain management perspective, digitalization allows for more efficient product design and development while facilitating lean manufacturing or just-in-time production. Experts predict that Industry 4.0 technologies and processes in electronics assembly could, potentially, improve the return on capital employed by 20 per cent.[28]

This could speed up the shift from labour-intensive to capital-intensive production in the electronics industry. The impact of new digital technologies on electronics supply chains is uncertain, however: they could be used to reduce the length of supply chains, thereby facilitating the re- or near-shoring of manufacturing production and reducing opportunities for developing countries to participate in electronics industry supply chains. Advanced digital technologies could, however, also be used to strengthen supply chains by reducing coordination and matching costs, thus accelerating the development of a truly global production network.

Both workers and employers in the electronics industry have struggled to update their skills on an ongoing basis so as to keep pace with the rapidly developing technological landscape. This has led to skills shortages and skills mismatches in many countries and segments of the supply chain (see chapter 4). For governments, employers and workers to harness the opportunities stemming from digitalization, investments are urgently needed in initiatives to promote skills development and lifelong learning.

▶ **Table 3. Examples of digital technologies and their potential uses in the electronics industry**

Technology	Potential use in the electronics industry
Internet of things	Monitoring and optimizing manufacturing processes, predictive maintenance
Artificial intelligence	Quality control, predictive analytics, process automation
Robotics	Automated assembly, handling and packaging of electronic components
Augmented reality	Training, maintenance guidance, and troubleshooting for workers
Big data analytics	Analysing large datasets to improve supply chain efficiency and forecasting
3D printing/additive manufacturing	Prototyping and creating complex components with precision
Blockchain technology	Securing supply chain transparency, tracking component origins
Cloud computing	Data storage, collaborative design, access to shared resources

Source: ILO, 2023

[28] Michael Alexander, "Between a rock and a hard place. OSAT companies need a new playbook", (Roland Berger, 11 April 2019). Available at: https://www.rolandberger.com/en/Insights/Publications/Between-a-rock-and-a-hard-place-OSAT-companies-need-a-new-playbook.html.

3.1.3. Advanced materials

Advanced materials refer to either newly developed materials or existing materials with particular engineered properties that are created through specialized processing and the application of synthesis technologies, including ceramics, high value-added metals, electronic materials, composites, polymers, and biomaterials.

Fast chipset and biochips, quantum dots, flexible batteries, semiconductors, three-dimensional integrated circuits, organic electronics, smart glass, photonic crystals, superconductors, and so on, are increasingly integrated into advanced materials, and numerous new materials with a variety of electronics built in are under development. It was, moreover, predicted that the value of advanced electronic materials would grow at a CAGR of 17 per cent, from US$5.4 billion in 2018 to US$11.9 billion by 2023.[29]

In the electronics industry, materials are also used to package and protect electronic components and products when they are transported from one stage of production to another, and to ensure that the final product reaches the end customer in one piece. The market for global electronics packaging materials was valued at US$22 billion in 2022.[30]

Because of growing concerns about climate change and shifting consumer preferences, there is increasing demand in many countries for biodegradable packaging materials and packaging design enhancements. To address those concerns, many large consumer electronics brands are taking action to reduce waste. Some enterprises have also set ambitious targets for the use of recycled materials and renewable plastics in the production of new electronics products.

3.1.4. New products

The electronics industry is constantly creating new and innovative products. For instance, at-home smart devices have become increasingly common due to the development of innovative technologies such as voice command.

Remote communications technologies, the use of which has accelerated in the wake of the COVID-19 pandemic, includes both hardware and software. For example, new technologies and devices that facilitate videoconferencing, smart virtual assistants and immersive team apps are revolutionizing the workplace. Indeed, the electronic audio and video equipment market is expanding rapidly. In the United States alone, the market size, measured by revenue, of the audio and video equipment manufacturing industry had reached US$4 billion in 2023.[31]

The electronics industry is also powering the development and manufacture of new products in other sectors, including the automotive industry, battery production and renewable energy:

- The shift to electronic vehicles is an opportunity to tackle environmental challenges while responding to consumer preferences. Projections suggest that the market for those vehicles will continue to expand in the coming years.
- Rechargeable lithium-ion and lithium-polymer batteries are already widely used in consumer electronic products, including cell phones and laptop computers, due to their light weight, safety and good thermal stability, and they are increasingly used in electric vehicles and private homes. The production and recycling of batteries is increasing rapidly in China, the Republic of Korea, North America, and the European Union.
- Electronics are critical to the generation of renewable energy, whether it be wind turbines, hydropower, solar photovoltaics or solar heating and cooling, and to the creation of smart grids. Ultracapacitors and new renewable energy technologies such as printable organic solar cells are among the key technologies that are transforming the landscape for renewable energy and modalities for its distribution.

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29 BCC Research, *New Electronic Materials and Device Technologies: Global Markets*, 2018. Available at: https://www.bccresearch.com/market-research/advanced-materials/new-electronic-materials-and-device-technologies-global-markets.html.

30 Allied Market Research, *Consumer Electronics Packaging 2023*.

31 IBIS World, *Audio & Video Equipment Manufacturing in the US - Market Size (2004–2029)*, Updated 19 February 2024. Available at: www.ibisworld.com/industry-statistics/market-size/audio-video-equipment-manufacturing-united-states/.

3.2. Globalization

The outsourcing of production in the electronics industry started in the 1960s. The location of electronics manufacturing has changed markedly since then, from a concentration of manufacturing in the United States, Japan, and several countries in Western Europe, to production in China and other Asian countries that have been able to produce goods at increasingly competitive prices. Today, most manufacturing takes place in Asia, which now accounts for approximately 70 per cent of electronics output.

There are signs that the global production network of the electronics industry is entering a new era, in which current production models maintain considerable momentum but are qualified by uncertainty due to geopolitical tensions and shifts in the balance of economic power, increasing trade tensions and restrictions, and underlying structural adjustments in the industry, among other factors.

▶ Box 5. Resilience strategies of multinational enterprises

- Supply chain resilience can be improved through three key strategies:
  - Production network restructuring – with a focus on reshoring and diversification – has implications for international production and FDI. Reshoring is associated with disinvestment, with a negative impact on future FDI flows and existing stock. Diversification would bring changes to the nature of FDI, with a shift from efficiency-seeking to market-seeking investment.
  - Risk management solutions are focused daily operations that provide alternative options for enterprises seeking to strengthen the capacity of their networks and absorb shocks. The adoption of those solutions may require investments in technology to enhance value chain control and coordination, increase productive capacity, or shift operating models from "just-in-time" to "just-in-case" production. The impact on FDI is less significant than for production network restructuring as risk management solutions do not entail the structural relocation of physical assets.
  - Sustainable business practices can also improve supply chain resilience by mitigating environmental, social and governance risks. Those practices can have a significant impact on FDI and international production at different levels: from introducing disparities in the application of environmental standards and regulations across borders, to inducing market-driven changes in products and processes, to changing the design of global supply chains towards more local and sustainable configurations.
- Sharper focus on resilience will add a new dimension to the way enterprises make their strategic choices, although considerations such as cost efficiency and (risk) benefit will remain paramount in determining production locations. What will change is the relative weight of the two sides of the equation, with multinational enterprises expected to relinquish some cost efficiency to secure resilience gains. Despite efforts to foster resilience, geopolitical and trade tensions will continue to pose a long-term risk for the organization and functioning of supply chains in the post-COVID-19 era.[a]

Note: [a] Chris Price, How should we future-proof our supply chains? (World Economic Forum, 2020). Available at: www.weforum.org/agenda/2020/09/how-to-build-supply-chains-fit-for-the-future/.

Source: UNCTAD, *World Investment Report 2021*.

Defined by UNCTAD as a global value chain-intensive industry,[32] the electronics industry has been among the industries most exposed to supply chain risks and disruptions, characterized by the high economic barriers to production network restructuring. The COVID-19 pandemic forced electronics manufacturers to mitigate risks related to the geographic coverage, interdependence and concentration of their supply chains. Moreover, in the light of concerns about the long-term security of supplies of raw materials, the industry is increasingly focusing on strengthening supply chain resilience and is moving from a "just-in-time" to a "just-in-case" production model (see box 5).

The electronics industry is capital-intensive, and enterprises therefore seek to leverage the economies of scale generated by concentrated and specialized production hubs to optimize their operational efficiency and reduce supply costs. With technological advances offsetting many of the costs associated with manufacturing in developed countries (see section 3.1), some argue that there is a strong case for reshoring or nearshoring business operations. Others maintain that, in the absence of policy drivers and incentives for reshoring, multinational enterprises should instead focus on risk management strategies in order to build supply chain resilience, and should place less emphasis on identifying low-cost factors of production and incorporating them into international production networks.

However, the risk of disruptions in the supply of materials required to produce electronic components and goods remain significant. Indeed, the COVID-19 pandemic revealed that supply chains that provide raw materials that are crucial in the manufacture of electronic components and equipment are often vulnerable to social, geopolitical, and technical disruptions. In the light of those risks, industry stakeholders should consider transitioning to circular practices, in which new materials, technologies and products lead to the adaptation or transformation of electronics supply chains.

Uncertainty in the organization of supply chains is particularly challenging for micro, small and medium-sized enterprises in developing countries and emerging markets because of their limited access to finance,[33] as well as a lag in digital adoption and access to technology.[34] Nonetheless, emerging economies are increasingly offering financial incentives to attract major industry players. This is the case in India, where, in 2020, the Government launched a production-linked incentive scheme targeting several manufacturing sectors, including the electronics industry. The scheme has attracted several global electronics brands and has reportedly helped to boost exports of mobile phones.[35]

3.3. Demographics

Shifting demographics are likely to influence consumption patterns and demand in electronics and related industries. Those shifts include changes in global population growth, transformations in the age structure of populations across regions, and changes in consumer preferences and demand. Predicting and responding to shifts in business and consumer demand will prove challenging but will also offer significant opportunities for the electronics industry and its workers.

The United Nations forecasts that the world's population will reach 8.5 billion in 2030 and peak at nearly 11 billion around 2100. More than half of that population growth will occur in just nine countries, eight of them developing or emerging economies.[36] Sub-Saharan Africa is projected to have the highest growth rate, with the population of the region doubling by 2050.[37]

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[32] The following industries are considered global value chain-intensive: automotive, electronics, machinery and equipment, and textiles and apparel. All these industries have highly cost-efficient network configurations, as reflected also by the capital and labour intensity of their typical investment projects. For further information see UNCTAD, 2021.

[33] World Bank Group, "Small and Medium Enterprises (SMEs) Finance", 16 October 2019. Available at: https://www.worldbank.org/en/topic/smefinance.

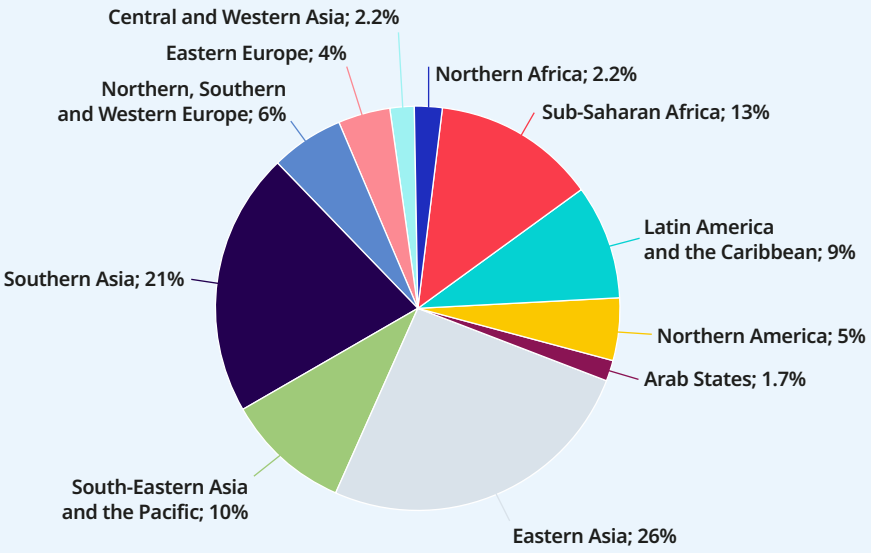
[34] OECD, "Digital tools and practices: SME access and uptake", in *The Digital Transformation of SMEs*, 2021. Available at: https://www.oecd-ilibrary.org/sites/9816a98d-en/index.html?itemId=/content/component/9816a98d-en#chapter-d1e748.

[35] "India gives over $1 bn incentives to private firms under its manufacturing scheme, official says", *The Economic Times*, updated 4 April 2024.

[36] In descending order of expected population increase, those nine countries are: India, Nigeria, Pakistan, the Democratic Republic of the Congo, Ethiopia, the United Republic of Tanzania, Indonesia, Egypt and the United States.

[37] United Nations, Department of Economic and Social Affairs, Population Division (2019). World Population Prospects 2019, custom data acquired via website.

▶ **Figure 9. Regional shares of the global labour force, 2022** (percentage)



Source: ILOSTAT, Statistics on the population and labour force, ILO Modelled Estimates and Projections Database, Nov. 2022 edition, accessed 5 December 2023. Available at: https://ilostat.ilo.org/topics/population-and-labour-force/.

The global middle-class increased from 899 million in 2011 to 1.34 billion in 2019, an average increase of 54 million people annually. That growth was undermined by the global response to the COVID-19 pandemic, with the 2020 global middle-class population almost the same size as it had been in 2019.[38] Most of the global middle-class is found in Asia and the Pacific. Another global trend that continues to affect populations is the migration of people from rural to urban areas. In fact, the world's urban population is expected to increase by 57 per cent by 2050. Increasing urbanization and the growing middle class are expected to result in an increase in the consumption of electronics goods, notably in Asia and the Pacific.

In the light of an increasing global population and the fact that electrical and electronics products have become an integral part of our modern societies, global demand for new and innovative products is expected to rise. For example, the global printed electronics market is projected to grow at a CAGR of 18.3 per cent in the next few years, rising from US$9.9 billion in 2021 to US$23 billion by 2026.[39] It should be noted, however, that rising demand is likely to be accompanied by a growing sense of ecological responsibility and the adoption of more sustainable production and consumption processes. Some consumers today not only demand new and innovative products but also products that are greener, respectful of the environment and more sustainable (see section 3.4).

[38] Rakesh Kochhar, *The Pandemic Stalls Growth in the Global Middle Class, Pushes Poverty Up Sharply*, (Pew Research Center, 2021). Available at: www.pewresearch.org/global/2021/03/18/the-pandemic-stalls-growth-in-the-global-middle-class-pushes-poverty-up-sharply/.

[39] MarketsandMarkets, *Printed Electronics Market with COVID-19 Impact Analysis by Printing Technology (Screen Printing, Inkjet Printing), Application (Displays, PV Cells), Resolution, Material (Inks, Substrates), End-use Industry, and Geography – Global Forecast to 2026*, 2021. Available at: www.marketresearch.com/MarketsandMarkets-v3719/Printed-Electronics-COVID-Impact-Printing-30218912/. Note: Printed electronics is a set of printing methods used to create electrical devices on various substrates.

Furthermore, while workforces are ageing in many parts of the world, working-age populations are increasing in some countries, and this is expected to affect the location of electronics production. In the electronics industry, enterprises in countries with ageing populations, such as Japan,[40] often relocate manufacturing to countries such as Cambodia, China and Viet Nam with younger workforces.[41]

It is predicted that, by 2030, the working-age population of sub-Saharan Africa will be almost as large as that of China. According to the International Monetary Fund, a 50 per cent increase in income per capita could be expected if the demographic transition in sub-Saharan Africa is complemented with supportive policies.[42] However, in most countries and subregions in which rapid growth in the working-age population is predicted to occur, unemployment rates remain high, especially among young people.[43]

Providing decent jobs is key to harnessing opportunities for economic growth resulting from the so-called "demographic dividend". In this regard, the African Union roadmap on harnessing the demographic dividend through investments in youth presents four interconnected pillars that are most critical to that process: employment and entrepreneurship; education and skills development; health and well-being; and rights, governance and youth empowerment.[44] The roadmap was formulated to facilitate efforts by African countries to implement the 2030 Agenda for Sustainable Development and Agenda 2063: The Africa We Want, and sets out a call for key actions and massive investments in sectors with high job-multiplier effects, including ICT, manufacturing and agriculture, in order to generate employment and spur inclusive growth. The roadmap also emphasizes the need to ensure that the skills acquired by workers match those required by enterprises and highlights the need to invest in people's capabilities through early education and lifelong learning (see section 4.1.1).

3.4. Climate change

The world of work is increasingly affected by climate change, which has resulted in rising temperatures and more frequent and unpredictable severe weather events. As stated in the Emissions Gap Report 2023, published by the United Nations Environment Programme (UNEP), there is a 66 per cent chance that the world will experience a global temperature rise of 2.7°C by the end of the century, even if all new unconditional nationally determined contributions are met and net-zero pledges realized.[45] Beyond its impact on our health and the environment, climate change also affects the economy and the way we work. Furthermore, in a recent study, the ILO estimated that the projected increase in global temperatures will render 2 per cent of all work hours too hot to work by 2030.[46]

In their efforts to meet commitments made within the context of the Paris Agreement on climate change, adopted in 2015,[47] several countries have outlined initiatives to reduce their net carbon emissions. At the twenty-eighth session of the Conference of the Parties to the United Nations Framework Convention on

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40 European Parliament, "Japan's Ageing Society", Continental Democracies Briefing, 2020. Available at: www.europarl.europa.eu/RegData/etudes/BRIE/2020/659419/EPRS_BRI(2020)659419_EN.pdf.

41 ILO, "The electronics industry in Indonesia and its integration into global supply chains", Sectoral Policies Department Working Paper No. 330. 2019. Available at: https://webapps.ilo.org/wcmsp5/groups/public/---ed_dialogue/---sector/documents/publication/wcms_732119.pdf.

42 International Monetary Fund, "How Can Sub-Saharan Africa Harness the Demographic Dividend?" in *Regional Economic Outlook: Sub-Saharan Africa*, 2015. Available at: https://www.imf.org/~/media/Websites/IMF/imported-flagship-issues/external/pubs/ft/reo/2015/afr/eng/pdf/_chap2pdf.ashx.

43 ILO, *Global Employment Trends for Youth 2020: Africa*. Briefing note. Available at: https://webapps.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/documents/briefingnote/wcms_737670.pdf.

44 The Roadmap is available at: https://wcaro.unfpa.org/sites/default/files/pub-pdf/AU%202017%20DD%20ROADMAP%20Final%20-%20EN.pdf.

45 United Nations Environment Programme, *Emissions Gap Report 2023*. Available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/43922/EGR2023.pdf?sequence=3&isAllowed=y.

46 ILO, *World Employment and Social Outlook 2018: Greening wth Jobs*. Available at: https://www.ilo.org/publications/world-employment-and-social-outlook-2018-greening-jobs.

47 The Paris Agreement is available at: https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf.

Climate Change (COP28), held in the United Arab Emirates in 2023, pledges were made to triple the global installed renewable energy generation capacity, improve energy efficiency and reduce sectoral emissions.[48]

In the electronics industry, sustainability and durability are major concerns as the production, use and disposal of electronics products and components can have major repercussions on our health and on the environment. The industry is one of eight industries that, together, account for more than 50 per cent of overall global greenhouse gas emissions. As a result, the activities of businesses operating in the electronics industry have come under scrutiny. This has placed additional pressure on workers in the industry. Concerns regarding the carbon footprint of the industry have also spurred action by governments and key stakeholders along electronics supply chains.

Some 77 per cent of electronics industry greenhouse gas emissions are generated along industry supply chains, including during the extraction of raw materials and during the manufacture, assembly and distribution of electronics goods.[49] In 2019, the carbon footprint of electronics products was estimated at 2.7 per cent of global greenhouse gas emissions.[50] The ICT sector's carbon footprint accounted for 1.4 per cent of global emissions in 2015, while the sector used 3.6 per cent of electricity generated globally in its operations.[51,52] By 2030, ICT is likely to account for as much as 20 per cent of global energy demand and, by 2040, is expected to account for up to 14 per cent of carbon emissions.[53,54] Research shows, however, that the ICT sector's carbon footprint could be reduced by more than 80 per cent if production were based on renewable energy sources.[55]

Although it can boost company revenues and profits, the increased rate at which consumer electronics goods are produced and consumed is undermining efforts to achieve environmental sustainability. Electronics products can be easily discarded by consumers, thus creating significant amounts of e-waste, which is one of the fastest-growing waste streams in the world. In 2022, 62 million tonnes of e-waste were generated, and it is predicted that that figure will rise to 82 million tonnes by 2030.[56] That increase is not only linked to higher consumption rates of electronics, but also to short product life cycles and limited repair options. Only 22.3 per cent of e-waste is formally collected and recycled,[57] while the remaining is either disposed through residual waste streams or dumped, traded or treated in substandard conditions.

Due to the vast amounts of energy and hazardous substances required in the mining of raw materials and manufacturing of electronics products, a linear electronics system poses environmental and health risks both at the production stage and at disposal. To become truly environmentally sustainable, the electronics industry should foster a circular economy (see box 6), reduce greenhouse gas emissions through efficiency gains and the use of renewable energy, and minimize or eliminate chemicals used during the production cycle.

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48 For further information on the outcome of the twenty-eighth Session, see: "Summary of Global Climate Action at COP 28", available at: https://unfccc.int/sites/default/files/resource/Summary_GCA_COP28.pdf.

49 World Economic Forum and Boston Consulting Group, *Net-Zero Challenge: The supply chain opportunity – Insight Report*, 2021. Available at: https://www3.weforum.org/docs/WEF_Net_Zero_Challenge_The_Supply_Chain_Opportunity_2021.pdf. Note: Food, construction, fashion, fast-moving consumer goods, electronics, automotive, professional services and freight account for more than half of all global greenhouse gas emissions.

50 Green Journal, "What Impacts Can Electronic Emissions Have on the Environment?", 12 April 2020. Available at: www.greenjournal.co.uk/2020/04/what-impacts-can-electronic-emissions-have-on-the-environment/.

51 It should be noted that, here, the ICT sector's carbon footprint includes user devices, such as phones, tablets and computers, as well as networks and data centres. ICT-related emissions of services such as gaming, social media and online advertising are also taken into account.

52 Jens Malmodin and Dag Lundén, "The Energy and Carbon Footprint of the Global ICT and E&M Sectors 2010–2015", *EPiC Series in Computing* Volume 52 (2018), pp. 187–208. Available at: https://easychair.org/publications/paper/MRdh.

53 Green Journal, "What Impacts Can Electronic Emissions Have on the Environment?", 12 April 2020.

54 Alan Crawford, Ian King, and Debby Wu, "The Chip Industry Has a Problem With Its Giant Carbon Footprint", (Bloomberg, 8 April 2021). Available at: www.bloomberg.com/news/articles/2021-04-08/the-chip-industry-has-a-problem-with-its-giant-carbon-footprint.

55 Ericcson, *A quick guide to your digital carbon footprint: Deconstructing Information and Communication Technology's carbon emissions*, 2020. Available at: https://www.ericsson.com/4907a4/assets/local/reports-papers/consumerlab/reports/2020/ericsson-true-or-false-report-screen.pdf.

56 UNITAR, "The Global E-waste Monitor 2024", UNITAR, 2024. Available at: https://ewastemonitor.info/the-global-e-waste-monitor-2024/.

57 UNITAR, "The Global E-waste Monitor 2024", UNITAR, 2024. Available at: https://ewastemonitor.info/the-global-e-waste-monitor-2024/.

▶ Box 6. The circular economy

- A circular economy model aims to design out waste and pollution, keep products and materials in use and regenerate natural systems – therefore gradually decoupling economic activity from the consumption of finite resources.
- Embracing the circular economy can also be a source of job creation and re-creation and can result in net job gains. The ILO estimates that up to 7 million new employment opportunities could be created across the world through the adoption of circular economy principles.
- Numerous initiatives promoting a circular economy have been developed at different levels:
  - Under the European Green Deal, the European Commission adopted the Circular Economy Action Plan in March 2020, which provides for a circular electronics initiative to promote longer product lifetimes.
  - In a report by the Ellen MacArthur Foundation entitled "Circular Economy Opportunity for Urban and Industrial Innovation in China", the authors show that applying circular economy principles at scale in Chinese cities could save businesses and households the monetary equivalent of 16 per cent of the GDP of China by 2040.
  - ILO and other international organizations and initiatives, including the ILO-Circle Economy-World Bank Group Jobs in the Circular Economy initiative, are demonstrating that a circular economy can promote decent work and accelerate a just transition towards environmentally sustainable economies and societies.

Sources: ILO, *Guidelines for a just transition towards environmentally sustainable economies and societies for all*, 2015; ILO, *World Employment Social Outlook*, 2018; Green Policy Platform, *The Circular Economy Opportunity for Urban and Industrial Innovation in China*, 2018; European Parliament, *Circular economy: definition, importance and benefits*, 2021; Ellen MacArthur Foundation, What is a circular economy?, n.d..

4. Challenges and opportunities for decent work: what is needed for a brighter future?

4.1. Employment

The megatrends and drivers identified in the previous chapter will affect the number and types of jobs available in the future in the electronics industry in a number of ways.

On the one hand, population growth, the growing numbers of middle-class consumers and the digitalization of society will lead to increasing demand for electronics products that will, in turn, generate employment in the industry. Furthermore, the continued pursuit of innovation and investments in innovative products and technologies – geared toward meeting evolving consumer preferences, including for eco-friendly products – hold the promise of creating further employment opportunities in the industry.

On the other hand, technological innovations in the industry, such as increased automation and digitalization, along with uncertainties and disruptions in global trade, which may be exacerbated by geopolitical tensions, could potentially lead to significant job transformation or job losses in the electronics industry and its supply chains.

4.1.1. Job creation, job transformation, job losses

Surging demand for electronic products worldwide in recent years has necessitated a larger workforce to undertake tasks such as product design, manufacturing and support services to cater to global markets. The expansion of electronics manufacturing has, in particular, generated job opportunities in emerging economies with relatively low labour costs.

Overall, industry consultants and analysts are optimistic about the potential for job creation in the electronics industry in the coming decades. Analysts at McKinsey & Company, a global management consulting firm, for example, believe that the increasing demand for tech products and services will create the need for an additional 20 million to 46 million incremental workers (55 per cent direct and 45 per cent indirect) globally, net of automation.[58] China, Germany, India, the Netherlands, and the United States, all significant importers and exporters of electronics products, are likely to account for more than half of that additional workforce. In addition, jobs may also be created in related or supporting industries, such as semiconductor manufacturing and in the transition to a circular economy, particularly in the collection and processing of e-waste (see boxes 7 and 8).

In the retail sector, numerous jobs are being created in e-commerce and related industries, such as warehousing and last-mile delivery services.[59] The need for new skills and the resulting skills gaps, in particular for digital and ICT skills, is likely to shape and drive the employability of workers and the productivity and competitiveness of enterprises (see section 4.1.3).[60] According to a recent report by ILO on the future of work in the retail sector, digitalization in the sector is more likely to be characterized by job transformation rather than job losses. Job transformation may require reforms to protection frameworks for workers, as well as action to address productivity growth in order to improve the productive capacity of capital and workers.[61]

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58 McKinsey & Company, *Jobs lost, jobs gained: Workforce transitions in a time of automation*, 2017. Available at: https://www.mckinsey.com/~/media/BAB489A30B724BECB5DEDC41E9BB9FAC.ashx.

59 ILO, *The future of work in retail: Digitalization as an engine for sustainable economic recovery and decent work – Report for discussion at the Technical Meeting on Digitalization in the Retail Sector*, TMDRS/2023. Available at: https://webapps.ilo.org/wcmsp5/groups/public/---ed_dialogue/---sector/documents/publication/wcms_890930.pdf.

60 ILO, *The future of work in retail*, 2023.

61 ILO, *The future of work in retail*, 2023.

▶ Box 7. Job creation through the growth of the semiconductor industry

- The growth of the semiconductor segment of the supply chain, driven by the development of new and innovative products in other sectors, is expected to accelerate job creation.
- Semiconductors and other electronic components are a key input in many sectors of the economy, including the automotive sector, with cars becoming increasingly advanced and electrified; textiles and clothing, with smart bras that monitor users' fitness; and footwear, with electronic shoes that provide navigation instructions.[a]

Note: [a] ILO, *ASEAN in transformation – Electrical and electronics: on and off the grid*, 2016. Available at: https://webapps.ilo.org/wcmsp5/groups/public/---ed_dialogue/---act_emp/documents/publication/wcms_579559.pdf.

▶ Box 8. Job creation in the reverse electronics supply chain through e-waste

- Other opportunities to create decent jobs and build sustainable enterprises can arise from the transition to a circular economy, especially in the area of e-waste collection and recycling.
- If e-waste is properly managed it could support more and better livelihoods, generate employment, provide access to technology, enable technological upgrading, skills acquisition and knowledge transfer, and mobilize capital to facilitate the production of second-hand commodities and the recovery of materials.
- Repair activities have one of the highest levels of labour intensity among circular activities. Repair of electrical appliances and electronics therefore has significant potential for local job creation in both developed and developing countries.
- E-waste, recycling and repair activity jobs are also likely to be created in response to increasing environmental concerns that urge the industry to redefine business models and establish more resilient, inclusive and sustainable supply chains.

At the same time, several studies highlight that employment in labour-intensive segments of electronics supply chains is at risk of automation. In that regard, a 2017 study by Frey and Osborne ranked occupations from least to most at risk of being automated; the study showed that, in the electronics industry, electronics engineering jobs are among those occupations least likely to be automated, whereas the jobs performed by electrical and electronic equipment assemblers, which comprise the majority of jobs in the industry in countries such as the Philippines and Thailand, are among those most at risk of automation.[62]

However, other studies highlight that technological innovation may further contribute to employment growth. A recent ILO study has shown that instead of shrinking employment in emerging economies, the adoption of technology may have contributed to job growth.[63] This is not only because major electronics corporations have continued to assemble most of their electronics products in labour-intensive, low-cost locations,[64] but also because collaborative robots – or "cobots" – have led to labour augmentation rather than displacement.[65] It is worth noting here that the use of robots is uneven across the different segments

[62] Carl Frey and Michael Osborne, "The Future of Employment: How Susceptible are Jobs to Computerisation?", *Technological Forecasting and Social Change 114*, pp. 254–280, 2017. Available at: https://www.oxfordmartin.ox.ac.uk/downloads/academic/The_Future_of_Employment.pdf.

[63] ILO, *Automation, employment, and reshoring: Case studies of the apparel and electronics industries*, 2020. Available at: https://www.ilo.org/publications/automation-employment-and-reshoring-case-studies-apparel-and-electronics.

[64] ILO, *Automation, employment, and reshoring*, 2020.

[65] ILO, *ASEAN in transformation – Electrical and electronics: on and off the grid*, 2016.

of the electronics industry, with robot uptake some three times higher in components manufacturing than in electronics assembly.[66]

In conclusion, the global electronics industry has been characterized by significant job creation in recent years, particularly in response to growing demand for electronic products. Researchers disagree, however, on how technological innovation and automation will affect employment in the industry and the extent to which they will lead to job displacement, labour augmentation and job transformation in the future. In that connection, it should be emphasized that, given the industry's dynamic nature, job transformation is an ongoing process, as new skills and work arrangements are constantly needed for enterprises to remain competitive (see section 4.1.3.).

4.1.2. Enterprises

Sustainable enterprises play a crucial role in promoting innovation and generating inclusive growth, productive employment and other decent work outcomes.

The global electronics industry is characterized by a mix of small and medium-sized enterprises and larger corporations. However, the ratio of small and medium-sized enterprises to large firms varies across industry segments and geographic regions. While multinational enterprises primarily drive employment creation due to their size, small and medium-sized enterprises play a strategic role in fostering sustainable and decent work in the industry.

4.1.2.1. Small and medium-sized enterprises

The electronics industry makes heavy use of outsourcing and subcontracting practices. Those practices became widespread following the restructuring by multinational enterprises of their business operations in the 1980s. Outsourcing and subcontracting has resulted in the creation of extensive and complex supply chains, with small and medium-sized enterprises playing a key role in driving expansion and creating global sourcing networks.[67]

While small and medium-sized enterprises in the electronics industry can bring agility, specialization and niche expertise to supply chains, thereby complementing the operations of larger firms, many of them face challenges related to access to finance, technology and an enabling environment that will allow them to grow in highly competitive global markets. Compared to other light manufacturing industries such as textiles, clothing, leather and footwear, the electronics industry comprises a smaller proportion of small and medium-sized enterprises, primarily due to the high costs associated with operating in an increasingly automated manufacturing industry. Operating within complex supply chains, small and medium-sized enterprises often specialize in raw material supply, component production, design services, assembly and packaging, or are contracted to manufacture goods in smaller production runs.

The adoption of supportive policy frameworks, tailored to national circumstances, is crucial if countries are to empower small and medium-sized enterprises to attain their full potential as job creators in the electronics industry and as sources of decent and sustainable employment. Those frameworks should be based on sound macroeconomic policies, strategies aimed at improving enforcement and compliance, appropriate education and skills acquisition policies, and policies to promote social dialogue, freedom of association, collective bargaining and social protection".[68]

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66 "Components relates to ISIC Rev 4 codes 260 (manufacture of electronic components and devices) and 261 (semiconductors, LCDs, and LEDs) whereas assembly encompasses ISIC Rev 4 codes 262 (computers and peripheral equipment) and 263 (information and communications equipment domestic and professional without automotive parts), as defined in IFR, WORLD INDUSTRIAL ROBOTS 2017 (2017)." Source: ILO, *Automation, employment, and reshoring*, 2020.

67 ILO, *Sectoral Studies on Decent Work in Global Supply Chains*, 2016. Available at: https://webapps.ilo.org/wcmsp5/groups/public/---ed_dialogue/---sector/documents/publication/wcms_485367.pdf.

68 ILO, Resolution concerning small and medium-sized enterprises and decent and productive employment creation, International Labour Conference, 104th Session, 2015. Available at: https://webapps.ilo.org/wcmsp5/groups/public/---ed_norm/---relconf/documents/meetingdocument/wcms_380779.pdf.

4.1.2.2. Large brands and multinational enterprises

The multinational enterprises that operate in the electronics industry are some of the largest private-sector companies the world has ever seen. While many large brands in the electronics industry are multinationals and well-known household names, not all large companies operate on a global scale. In fact, some large brands focus, primarily, on domestic markets or operate within specific geographic regions. However, all those multinational enterprises continue to drive technological change, introduce innovative products to consumers, and redefine work practices and skill requirements within the industry.

Through their global operations and supply chains, multinational enterprises headquartered in a handful of countries tend to influence employment practices, labour rights, workplace safety and fair employment conditions worldwide. Furthermore, corporate social responsibility practices adopted by those enterprises are often implemented through their supply chains and can have an impact across the industry and beyond. In two recent studies, the ILO emphasized the impact of large brands on electronics supply chains. In one of those studies, the ILO highlighted the ways in which multinational enterprises operating in the electronics sector have supported decent work and labour rights, including through the establishment of apprenticeship training centres and collective wage negotiation systems and the adoption of strengthened occupational safety and health measures.[69] In the second study, the ILO highlighted how foreign enterprises and Vietnamese business organizations are helping to promote corporate social responsibility in Viet Nam.[70]

In addition to ensuring that labour rights are respected, multinational enterprises and other large brands active in the electronics industry are increasingly making commitments to promote sustainability, circular economic practices and the greening of their manufacturing processes. Many have firmly announced

▶ Box 9. The way forward

- By adopting innovative initiatives and strategies, large electronics brands and multinational enterprises can align their manufacturing processes with sustainable practices, thereby reducing their environmental footprint and promoting circularity within the industry.
- Large enterprises operating in the electronics sector are increasingly subject to due diligence guidelines and regulations to prevent human rights violations within their supply chains.
- Pursuant to the adoption of relevant national, regional and international frameworks and instruments, including the United Nations Guiding Principles on Business and Human Rights,[a] the Tripartite Declaration of Principles concerning Multinational Enterprises and Social Policy,[b] and the OECD Guidelines for Multinational Enterprises on Responsible Business Conduct,[c] enterprises are being held responsible for upholding human rights and promoting environmental sustainability within their operations and supply chains, and are increasingly making use of their reporting obligations to inform decision-making.
- The aforementioned actions and initiatives are likely to have a significant impact on future employment and working conditions in the electronics industry, shaping job creation and transformation and the skills required by enterprises.

Notes: [a] Endorsed in 2011 by the Human Rights Council of the United Nations in its resolution 17/4. Available at: www.ohchr.org/sites/default/files/documents/publications/guidingprinciplesbusinesshr_en.pdf. [b] Adopted by the ILO Governing Body at its 204th Session, held in 1977. The sixth edition of the Declaration is available at: https://webapps.ilo.org/wcmsp5/groups/public/---ed_emp/---emp_ent/---multi/documents/publication/wcms_094386.pdf. [c] Introduced in 1976 by the OECD and last updated in 2023. Available at: https://mneguidelines.oecd.org/mneguidelines/.

69 ILO, *Responsible business conduct in China electronics supply chains*, 2023.

70 ILO, *Viet Nam's electronics supply chain: Decent work challenges and opportunities*, 2022.

net-zero carbon and sustainability objectives, including through measures to reduce energy consumption, extend product lifecycles, incorporate recycled materials in electronics manufacturing, manage electronic waste responsibly, enhance water resource efficiency, and promote supply chain sustainability through ethical sourcing and green technology investments (see box 9).[71]

4.1.3. Skills needs and development

To meet the growing demand for electronics products in an ever-evolving industry, manufacturers are increasingly competing for skilled workers. Rapid technological progress and the need for enhanced analytics at the factory level, together with increased human-machine collaboration, are reshaping job requirements in the industry. While the need for physical and manual skills is diminishing, advanced skill sets are in increasing demand.

According to a report by the McKinsey Global Institute on anticipated workforce requirements in Europe, there is likely to be a pressing need across the continent by 2030 for highly-skilled electrical and electronic trades workers.[72] Furthermore, in a report on the electronics industry in Association of Southeast Asian Nations (ASEAN) member countries, the ILO similarly emphasized the urgent need to enhance skills levels and align skills development with enterprise needs.[73] A survey conducted by the World Economic Forum within the digital communication and information technology segment of the electronics industry also provides an overview of emerging job roles within organizations, revealing a substantial increase in demand for professionals with advanced technical competencies, including artificial intelligence and machine learning specialists, data analysts and scientists, information security analysts and process automation specialists.[74,75]

Employers not only seek to attract workers with technical prowess but also seek to attract workers with soft skills, such as critical, analytical, and creative thinking, along with interdisciplinary competencies. In a recent report by ILO on the electronics industry in Viet Nam, employers emphasized that there was a general lack of workers with higher skills and soft skills,[76] while an in-depth analysis by ILO of the global demand for ICT specialists highlighted that a lack of highly-skilled workers is likely to constrain the future economic growth of the ICT and other economic sectors, and that demand for jobs in science, technology, engineering and mathematics (STEM) is expected to increase by 8 per cent between 2013 and 2025.[77] A study conducted by ILO on skills shortages and labour migration in the field of information and communication technology in a number of developed and developing economies revealed that many factors must be considered in determining the potential demand for jobs in the electronics industry, the industry's potential impact on a country's economy, global market shares, employment in the industry and industrial policies.[78]

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71 Japan External Trade Organization, *JETRO Global Trade and Investment Report 2023*, page 37. Available at: https://www.jetro.go.jp/ext_images/en/reports/white_paper/trade_invest_2023_rev2.pdf; Climate Reality Project, "Five Major Businesses Powered by Renewable Energy", 25 November 2016. Available at: https://www.climaterealityproject.org/blog/5-major-businesses-powered-renewable-energy; Yole Group, "Power electronics: meeting the shift towards electrification and renewable energy trends", 26 October 2023. Available at: https://www.yolegroup.com/strategy-insights/power-electronics-meeting-the-shift-towards-electrification-and-renewable-energy-trends/; MachineDesign, "Engineers Look to Adopt a More Sustainable Approach to Electronic Design", 5 October 2023. Available at: https://www.machinedesign.com/markets/article/21275041/engineers-look-to-adopt-a-more-sustainable-approach-to-electronic-design.

72 McKinsey Global Institute, The future of work in Europe, 2020. Available at: www.mckinsey.com/~/media/mckinsey/featured%20insights/future%20of%20organizations/the%20future%20of%20work%20in%20europe/mgi-the-future-of-work-in-europe-discussion-paper.pdf.

73 ILO, *ASEAN in transformation – Electrical and electronics: on and off the grid*, 2016.

74 World Economic Forum, *The Future of Jobs Report 2020*, Available at: https://www3.weforum.org/docs/WEF_Future_of_Jobs_2020.pdf.

75 McKinsey Global Institute, *Jobs lost, jobs gained: What the future of work will mean for jobs, skills, and wages*, 2017. Available at: www.mckinsey.com/featured-insights/future-of-work/jobs-lost-jobs-gained-what-the-future-of-work-will-mean-for-jobs-skills-and-wages.

76 ILO, *Viet Nam's electronics supply chain: Decent work challenges and opportunities*, 2022.

77 ILO, "The Future of Work in ICT" project, *Skills shortages and labour migration in the field of information and communication technology in Canada, China, Germany and Singapore*, 2020. Available at: https://webapps.ilo.org/wcmsp5/groups/public/---ed_dialogue/---sector/documents/publication/wcms_755663.pdf.

78 ILO, "The Future of Work in ICT" project – *synthesis report, Skills shortages and labour migration in the field of information and communication technology in Canada, China, Germany, India, Indonesia, Singapore and Thailand*, 2020. Available at: https://webapps.ilo.org/wcmsp5/groups/public/---ed_dialogue/---sector/documents/publication/wcms_755929.pdf.

Identifying skills needs and skills development should go hand-in-hand with the promotion of gender equality and non-discrimination (see section 4.2.3.). For instance, gender imbalances in STEM fields are major issues that must be addressed, as women make up almost half (49 per cent) of total employment across non-STEM occupations but only 29.2 per cent of all STEM workers worldwide.[79] Addressing that gap requires significant and systemic changes in educational systems.

Governments, enterprises, and other key industry stakeholders are now implementing measures to address skills shortages, anticipate future demand and bridge existing skills gaps. Integral to that endeavour are a number of key concepts, including reskilling, upskilling, lifelong learning and vocational training. Singapore is one of a growing number of countries that is developing a skills framework for the electronics industry to promote skills development and lifelong learning for workers, employers and training providers in that industry.[80] The Indian Government is also seeking to build a conducive environment for skills development in the manufacturing industry through its adoption in 2019 of the National Policy on Electronics.[81] That Policy was adopted to increase the human resources available to serve the needs of the industry, including by facilitating the work of two of the country's 36 Skills Councils, namely the Telecom Sector Skill Council and the Electronics Sector Skill Council. The Policy provides for action to be taken to increase the number

▶ Box 10. Responses to skills shortages in the semiconductor industry

- In a 2017 survey of semiconductor manufacturers in the United States, 77 per cent of respondents stated that they believed that there was a talent deficit in the industry. Another 14 per cent anticipated a critical shortage by 2020.
- Many Japanese companies, which import nearly two thirds of their chips from the Republic of Korea and Taiwan Province of China, are struggling to fill job vacancies requiring expertise in artificial intelligence, quantum computing and other cutting-edge technologies used in advanced chip design.
- The government of Taiwan Province of China and local semiconductor chip manufacturers are investing hundreds of millions of dollars to support relevant training programmes at universities.
- Due to skills gaps, China has struggled to fill hundreds of thousands of semiconductor engineering job vacancies, despite adopting an ambitious investment strategy in 2014. Beijing reportedly still needs 400,000 more semiconductor employees to meet its established production targets.
- In 2019, SEMI, an industry association comprising companies involved in the electronics design and manufacturing supply chain, and 19 partners from 14 countries launched the MicroElectronics Training, Industry and Skills (METIS) initiative to address skills gaps and boost workforce diversity by strengthening collaboration between the microelectronics industry and education providers. The four-year project focuses on the skills and related training needed to support emerging technologies and sectors, including artificial intelligence, autonomous driving, and Industry 4.0 in Europe.

Sources: Elliot Silverberg, and Eleanor Hughes "Semiconductor skills shortage", (Lowy Institute, 15 September 2021). Available at: www.lowyinstitute.org/the-interpreter/semiconductors-skills-shortage; Anne-Françoise Pelé, "Semiconductor Industry Needs to Close Talent Gap", *EE Times Europe*, 8 July 2021. Available at: https://www.eetimes.eu/semiconductor-industry-needs-to-close-talent-gap/.

[79] World Economic Forum, *Gender Gap Report 2023*. Available at: https://www.weforum.org/publications/global-gender-gap-report-2023/in-full/gender-gaps-in-the-workforce/.

[80] SkillsFuture, "Skills Framework for Electronics". Available at: https://www.skillsfuture.gov.sg/skills-framework/electronics.

[81] The text of the National Policy is available at: https://www.meity.gov.in/writereaddata/files/Notification_NPE2019_dated25.02.2019.pdf.

of skilled workers with advanced degrees in electronics and information technology and the creation of training academies. In addition, major brands and manufacturers have launched skills enhancement programmes, collaborating with educational institutions to ensure that workers acquire the skills needed by the electronics industry. In that regard, a large electronics retail company has pledged US$700 million to upskill 100,000 of its workers by 2025.[82]

The need to invest in skills and lifelong learning in the semiconductor industry is particularly urgent. Responses to critical skills shortages around the world range from policy formulation to practical guidance and training schemes to support skills development (see box 10).

In a number of recent reports, ILO has emphasized that skills development strategies should give special attention to the most vulnerable workers, especially women and migrant workers. Although they comprise more than 60 per cent of workers in the global electronics industry (see section 2.4.2.), women tend to be more poorly educated than men and are often employed in assembly line jobs and supply chain logistics, while relatively few women are employed in engineering, design, and research and development. Migrant workers are often found in labour-intensive occupations, particularly in countries with relatively low labour costs. Governments and employers in the industry must adopt more sustainable, integrated and inclusive approaches so as to ensure that all workers enjoy access to lifelong learning and acquire the skills they need for companies to maintain a competitive advantage in the marketplace. Efforts must also be made to reskill workers in countries or segments of the supply chain where the electronics industry is in decline. This will require a radical overhaul of education and training systems, coupled with significantly increased investments in human resource development for the millions of workers in the industry.

4.2. Rights at work

The electronics industry has fuelled economic growth and opportunities in high-, middle- and low-income countries alike. Over time, the industry's complex supply chains have made it challenging to trace the origins of all materials used in its countless end products. In turn, the great number of components that make up electronic products make it especially arduous for enterprises in the electronics industry to detect and mitigate labour risks and challenges along their supply chains.

While all ILO Member States have an obligation to respect, promote, and realize the fundamental principles and rights at work, there are segments of the industry's supply chains in which substandard working conditions and human rights violations persist.[83],[84] This is particularly the case in countries with large informal economies and weak enforcement of labour laws.[85] Although all Member States are encouraged to ratify the fundamental Conventions of the ILO, in addition to the Protocol of 2014 to the Forced Labour Convention, 1930, not all countries with significant numbers of workers employed in the electronics industry have done so, as illustrated in table 4.

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82 Deloitte, "Beyond reskilling: Investing in resilience for uncertain futures", 15 May 2020. Available at: https://www2.deloitte.com/us/en/insights/focus/human-capital-trends/2020/reskilling-the-workforce-to-be-resilient.html.

83 Business & Human Rights Resource Centre, "Global ICT hardware companies fail to address forced labor risks, new report finds", 9 January 2023. Available at: https://www.business-humanrights.org/en/from-us/media-centre/report-global-ict-hardware-companies-fail-to-address-forced-labor-risks/.

84 Business & Human Rights Resource Centre, "China: Working conditions at electronics factories remain concerning, with reports of continuous labor rights violations at Apple's suppliers Pegatron and Foxconn", 15 January 2024. Available at: https://www.business-humanrights.org/en/latest-news/china-working-conditions-at-electronics-factories-remain-concerning-with-reports-of-continuous-labor-rights-violations-at-apples-suppliers-pegatron-and-foxconn/.

85 The ILO Declaration on Fundamental Principles and Rights at Work, adopted in 1998 and amended in 2022, is an expression of commitment by governments, employers' and workers' organizations to uphold basic human values – values that are vital to our social and economic lives. It affirms the obligations and commitments that are inherent in membership of the ILO, namely: freedom of association and the effective recognition of the right to collective bargaining; the elimination of all forms of forced or compulsory labour; the effective abolition of child labour; the elimination of discrimination in respect of employment and occupation; and a safe and healthy working environment.

▶ **Table 4. State of ratification of the fundamental Conventions of the ILO by the countries with the highest number of workers in the electronics industry**

Country	Freedom of association and collective bargaining		Elimination of forced labour		Abolition of child labour		Elimination of discrimination		Promotion of health and safety	
	Freedom of Association and Protection of the Right to Organise Convention, 1948 (No.87)	Right to Organise and Collective Bargaining Convention, 1949 (No. 98)	Forced Labour Convention, 1930 (No.29)	Abolition of Forced Labour Convention, 1957 (No. 105)	Minimum Age Convention, 1973, (No 138)	Worst Forms of Child Labour Convention, 1999 (No. 182)	Equal Remuneration Convention, 1951 (No. 100)	Discrimination (Employment and Occupation), 1958 (No. 111)	Occupational Safety and Health Convention, 1981 (No. 155)	Promotional Framework for Occupational Safety and Health Convention, 2006 (No. 187)
China	▶	▶	▶	▶	▶	▶	▶	▶	▶	▶
Malaysia	▶	▶	▶	▶	▶	▶	▶	▶	▶	▶
Republic of Korea	▶	▶	▶	▶	▶	▶	▶	▶	▶	▶
Viet Nam	▶	▶	▶	▶	▶	▶	▶	▶	▶	▶
United States	▶	▶	▶	▶	▶	▶	▶	▶	▶	▶
India	▶	▶	▶	▶	▶	▶	▶	▶	▶	▶
Germany	▶	▶	▶	▶	▶	▶	▶	▶	▶	▶
Philippines	▶	▶	▶	▶	▶	▶	▶	▶	▶	▶
Thailand	▶	▶	▶	▶	▶	▶	▶	▶	▶	▶

Source: ILO, Information System on International Labour Standards (NORMLEX), accessed 16 November 2023.

Legend: ▶ Ratified ▶ Not ratified

Note: The list of countries is based on ILO Modelled Estimates and Projections Database: Employment by sector estimates, October 2019, accessed 3 November 2021.

4.2.1. Ensuring freedom of association and the effective recognition of the right to collective bargaining

Freedom of association is crucial in that it enables workers and employers in all industries and economic sectors to organize effectively in order to negotiate work relations. It is incumbent on all governments to establish a stable political and civic climate, along with appropriate legal frameworks that foster the autonomous operation of employers' and workers' organizations, free from the threat of retaliation. When combined with robust freedom of association, effective collective bargaining practices ensure that both employers and workers have a voice in negotiations, leading to fairer and more equitable outcomes. Collective bargaining serves as a mechanism for crafting equitable employment relationships and averting costly labour disputes. Those enabling rights are pivotal in achieving all ILO strategic objectives. They empower robust and independent workers' and employers' organizations to contribute actively to the growth and development of the electronics industry.

As reflected in table 4 above, several of the countries with the highest number of workers in the electronics industry have not yet ratified the Freedom of Association and Protection of the Right to Organize Convention, 1948 (No. 87), and the Right to Organize and Collective Bargaining Convention, 1949 (No. 98). In the parts of Asia where most electronics manufacturing occurs, there are reports of significant challenges related to freedom of association and collective bargaining.[86]

In 2022, the World Benchmarking Alliance assessed 43 of the largest ICT companies in the world against its corporate human rights benchmark, assigning those companies an average score of only 18.3 per cent. None of the companies assessed were assigned a score above 40 per cent, and nearly two thirds were assigned a score below 20 per cent.[87] Another benchmarking organization, KnowTheChain, has highlighted shortcomings in its evaluation of 60 major publicly traded ICT companies, including in relation to their due diligence processes.[88] In its 2022 evaluation, 45 per cent of the companies assessed failed to disclose undertaking human rights risk assessments in their supply chains, and only 22 per cent of the companies disclosed forced labour risks. The 2022 evaluation also measured a "worker voice" indicator, with companies assigned an average score of 8 out of 100 points, down from 12 points in the 2020 assessment.[89] With regard to freedom of association in the industry, the 2022 evaluation revealed that very limited progress had been achieved since the previous evaluation in 2020. In response to those challenges and ongoing changes in the industry, global unions are actively organizing workers, including through the formulation of action plans to strengthen respect for labour rights in semiconductors and electronics manufacturing service companies (see section 4.4.3).[90]

4.2.2. Abolition of child labour and elimination of all forms of forced or compulsory labour

While child labour is not prevalent in the manufacturing segment of the electronics industry (the focus of this research paper), the industry relies heavily on a spectrum of raw materials sourced from regions and countries grappling with high rates of forced and child labour. Numerous reports have highlighted widespread instances of child and forced labour during the extraction of cobalt, coltan, gold, mica, tin and

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86 ILO, *Responsible business conduct in China electronics supply chains*, 2023; Kan Matsuzaki, Electronics Industry: Organizing and fighting against precarious work (IndustriALL, 2015). Available at: https://www.industriall-union.org/report-electronics-industry-organizing-and-fighting-against-precarious-work.

87 World Benchmarking Alliance, *Corporate Human Rights Benchmark 2022, Insights Report*, 2022. Available at: https://respect.international/wp-content/uploads/2022/11/Corporate-Human-Rights-Benchmark-2022-Insights-Report.pdf.

88 KnowTheChain, *2022 Information and Communications Technology Benchmark Findings Report*, 2022. Available at: https://knowthechain.org/wp-content/uploads/KTC-2022-ICT-Benchmark-Report.pdf/.

89 KnowTheChain, *2022 Information and Communications Technology Benchmark Findings Report*.

90 IndustriALL, "Unionizing in response to dramatic changes in ICT, electrical and electronics", 16 June 2022. Available at: https://www.industriall-union.org/unionizing-in-response-to-dramatic-changes-in-ict-electrical-and-electronics.

▶ Box 11. Migrant workers in the electronics industry

- Migrant workers in the electronics industry are employed in manufacturing facilities, contract manufacturing and supply chain logistics, as well as in construction and infrastructure development in new or expanding facilities.
- In the United States, 43.9 per cent of workers in the semiconductor manufacturing industry are foreign-born. Among those that are immigrants, 20.7 per cent are from Viet Nam and 16.8 per cent from Mexico.
- The electronics industry workforce mirrors global economic dynamics and labour migration patterns, reflecting the global industry's reliance on migrant workers.
- Concerns have been raised regarding labour rights, working conditions, wages and the recruitment of migrant workers in electronics industry supply chains. Those concerns regard practices that include withholding legal documents such as passports from workers and high recruitment fees.
- In numerous reports, relevant stakeholders have underscored the need for enhanced regulations and oversight mechanisms to safeguard the rights of migrant workers and ensure their equitable treatment.
- It is clear that there is an urgent need for measures to address labour rights violations and a framework to ensure fair and ethical treatment of migrant workers in the global electronics industry.

Sources: Anna Shepperson, "The Success of the CHIPS Act Depends on Skilled Immigrants", (*Immigration Impact*, 2 August 2023). Available at: https://immigrationimpact.com/2023/08/02/chips-act-needs-immigrants/; Kate Hodal and Annie Kelly, "Malaysia: forced labour casts dark shadow over electronics industry" (*The Guardian*, 21 November 2016). Available at: www.theguardian.com/global-development/2016/nov/21/malaysia-forced-labour-casts-dark-shadow-over-electronics-industry.

other minerals used in electronics manufacturing, including in the Democratic Republic of the Congo, where ILO has been working with the Government to address child labour in the cobalt mining industry.[91]

Within the electronics industry, migrant workers are at particular risk of being subjected to forced labour (see box 11), as highlighted in reports by a number of media and non-governmental organizations.[92] In recent years, forced labour among migrant workers in the electronics industry has been a matter of concern in Malaysia, for example. To address those concerns, the Malaysian Government adopted the National Action Plan on Forced Labour in 2021 in order to strengthen the right to organize and to ensure wage protections for migrant workers.[93] The Government and employers' and worker's organizations in the country are now working with ILO to support implementation of the commitments enshrined the Action Plan across the econ

[91] United States Department of Labor Bureau of International Labor Affairs, "Combatting Child Labor in the Democratic Republic of the Congo's Cobalt Industry (COTECCO)". Available at: https://www.dol.gov/agencies/ilab/combatting-child-labor-democratic-republic-congos-cobalt-industry-cotecco. Accessed on 17 November 2023; ILO, "We work to end child labour in DR Congo's cobalt mines", 9 November 2021. Available at: https://www.ilo.org/resource/we-work-end-child-labour-dr-congos-cobalt-mines.

[92] Sarah Bormann, Pathma Krishnan and Monika Neuner, *Migrant Workers in the Malaysian Electronics Industry: Case Studies on Jabil Circuit and Flextronics* (*World Economy, Ecology and Development*, 2010). Available at: https://www2.weed-online.org/uploads/migration_in_a_digital_age.pdf; Kate Hodal and Annie Kelly, "Malaysia: forced labour casts dark shadow over electronics industry" (*The Guardian*, 21 November 2016). Available at: www.theguardian.com/global-development/2016/nov/21/malaysia-forced-labour-casts-dark-shadow-over-electronics-industry; Nikolaj Houmann Mortensen, "How the global electronics industry came to rely on forced labour and debt bondage" (*Danwatch*, 28 June 2019). Available at: https://danwatch.dk/en/undersoegelse/how-the-global-electronics-industry-came-to-rely-on-forced-labour-and-debt-bondage/; Lauly Li and Cheng Ting-Fang, "Taiwan's army of migrant workers keep its chip economy running", (NikkeiAsia, 10 June 2021). Available at: https://asia.nikkei.com/Business/Tech/Semiconductors/Taiwan-s-army-of-migrant-workers-keep-its-chip-economy-running.

[93] The National Action Plan is available at: https://www.dol.gov/agencies/ilab/national-action-plan-forced-labour-2021-2025.

4.2.3. Promoting gender equality and non-discrimination

As is the case in many other industries, workers in the electronics industry are often subject to discrimination. Discrimination stifles opportunities, squanders human potential and exacerbates societal tensions and disparities. It is critical to implement measures to prevent and eradicate all forms of discrimination with a view to fostering an environment conducive to decent and sustainable work within the industry. While workplace discrimination can affect all workers, women are particularly vulnerable. Comprising more than 55 per cent of the electronics workforce, women often encounter significant challenges within the electronics manufacturing industry.

The Equal Remuneration Convention, 1951 (No. 100), the Discrimination (Employment and Occupation) Convention, 1958 (No. 111), the Convention on the Elimination of All Forms of Discrimination against Women[94] and the International Covenant on Economic, Social and Cultural Rights,[95] reaffirm the principles of gender equality and non-discrimination. They assert women's right to work and urge governments to enact comprehensive rules and regulations with a view to ensuring that women and men enjoy equal labour rights, both in written laws and in the practical application of those laws.

In Convention No. 111, ILO explicitly urges governments to eliminate laws, regulations and cultural practices that restrict the types of work women can pursue, curtail their freedom of movement, or allow gender-based discrimination, violence or harassment in the workplace. Essentially, governments are obligated to guarantee women the ability to work under conditions equal to those afforded to men.

The gender distribution in the electronics industry is uneven. [96] In general, more men work to create parts and components from raw materials or in maintenance-related tasks and management, while women are primarily employed in assembly line work. In this division of labour, women tend to perform the most basic tasks within the industry. This may negatively affect their pay compared with that of men working in the electronics industry. According to a study conducted by ILO on electronics manufacturing in Thailand, women were paid on average 16 per cent less than men in 2013.[97] Further research is needed, however, to deepen understanding of gender-related employment challenges in the electronics industry, including wage gaps.

It is essential to apply a gender lens to employment in the electronics industry in order to promote gender equality and non-discrimination and address violence and harassment. It should be recognized, moreover, that women are disproportionally at risk: interviews with stakeholders within the electronics industry have highlighted, for example, that women are sometimes preferred for employment due to perceptions that they are "more patient" and "easier to dominate".[98] In that regard, further efforts are needed to promote the ratification and implementation of the Violence and Harassment Convention, 2019 (No. 190), which specifically recognizes the right of everyone to a world of work free from violence and harassment.

4.2.4. Ensuring a safe and healthy working environment

Occupational safety and health is an integral component of worker protection and affects workers' productivity and enterprise competitiveness. Recognizing its importance to ensuring decent work, governments and employers' and workers' organizations agreed during the 110th Session (2022) of the International Labour Conference to include the right to a safe and healthy working environment as a

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94 The Convention is available at: www.un.org/womenwatch/daw/cedaw/text/econvention.htm.

95 The Covenant is available at: www.ohchr.org/en/instruments-mechanisms/instruments/international-covenant-economic-social-and-cultural-rights.

96 Dongyeon Koh, G Chan and Eric Yap, "World at work: The electronics industry", *Occupational and Environmental Medicine* 61(2):180–183. (2004). Available at: https://www.researchgate.net/publication/8907030_World_at_work_The_electronics_industry.

97 Lorenza Errighi and Charles Bodwell, "Electrical and electronics manufacturing in Thailand: Exploring challenges and good practices in the workplace", ILO Asia-Pacific Working Paper Series, 2017. Available at: www.ilo.org/publications/electrical-and-electronics-manufacturing-thailand-exploring-challenges-and.

98 Laura Villadiego, "The gender gap in electronics factories: women exposed to chemicals and lower pay", Equal Times, 22 December 2017. Available at: www.equaltimes.org/the-gender-gap-in-the-electronics?lang=en.

fundamental principle and right at work.[99] The key role of governments to ensure respect for this right is underscored in the Occupational Safety and Health Convention, 1981 (No. 155) and the Promotional Framework for Occupational Safety and Health Convention, 2006 (No. 187), which have both been elevated to the status of fundamental Conventions of the ILO.

A number of hazardous substances, including lead, mercury and cadmium, are prevalent in electronic products, potentially resulting in toxic, explosive, or corrosive effects. Those substances may cause severe health complications, including cancer, reproductive disorders and respiratory ailments.[100] Factory inspections in several Asian countries have often revealed the failure of enterprises to comply with established occupational exposure limits, the provision of little or no information to workers on hazardous substances, and a lack of tracking and reporting of diseases associated with the electronics industry.[101]

Physical hazards such as excessive noise or heat, exposure to unsafe levels of radiation and low humidity can have a very negative impact on workers and may significantly undermine their physical or psychological well-being.[102] Processes such as soldering can, for example, result in accidental lead inhalation and ingestion, potentially elevating blood pressure.[103]

Workers face ergonomic hazards when they perform repetitive tasks on assembly lines, such as prolonged periods of standing or sitting in awkward postures. Those hazards can lead to musculoskeletal disorders, of which carpal tunnel syndrome, prominent among circuit board assemblers, is only one example.[104]

Psychosocial hazards encompass social and psychological factors within the workplace, including stress, bullying, violence and harassment, long working hours, job insecurity and lack of support, all of which can impact workers' mental health and overall well-being. There have been reports of attempted suicides in electronics factories, underlining the grave impact that those factors can have on workers and the urgent need for action to address them.[105]

While biological hazards are less common, certain aspects of electronics manufacturing, such as the proximity among workers, pose risks of exposure to biological agents, including mould, bacteria and fungi and can facilitate the spread of communicable diseases.[106] As was seen at the outset of the COVID-19 pandemic, many workers in the electronics manufacturing factories were exposed to safety and health risks while at work.[107]

Women are particularly susceptible to occupational safety and health challenges in the workplace. Those challenges include inadequate access to women-only facilities (such as separate toilets or lactation rooms), a lack of occupational safety and health education and exposure to hazardous materials that may affect their reproductive health.

Women employed in several major electronics factories in Viet Nam have voiced concerns that they did not work in a safe and healthy working environment and that they lacked information regarding the chemicals they handled. Many of those women have also voiced concerns with regard to the uncertainties associated

99 ILO, "International Labour Conference adds safety and health to Fundamental Principles and Rights at Work", 10 June 2022. Available at: www.ilo.org/resource/news/ilc/110/international-labour-conference-adds-safety-and-health-fundamental.

100 Dongyeon Koh, G Chan and Eric Yap, "World at work: The electronics industry", 2004.

101 American Public Health Association, "Improving Occupational and Environmental Health in the Global Electronics Industry", 2012. Available at: https://apha.org/policies-and-advocacy/public-health-policy-statements/policy-database/2014/07/21/08/43/improving-occupational-and-environmental-health-in-the-global-electronics-industry.

102 Dongyeon Koh, G Chan and Eric Yap, "World at work: The electronics industry", 2004.

103 Electrical soldering is the process by which electronic components are connected to the circuit board using a filler material called solder to form the joint between them. Solder is a fusible alloy and has a melting point below 840°F.

104 United State Department of Labor Occupational Health and Safety Administration, *Safety and Health for the Microelectronics Industry*, 1988. Available at: https://apps.dtic.mil/sti/tr/pdf/ADA400601.pdf.

105 Garett Brown, "Global Electronics Factories in Spotlight", Occupational Health and Safety, 4 August 2010. Available at: ohsonline.com/articles/2010/08/04/global-electronics-factories-in-spotlight.aspx.

106 Dongyeon Koh, G Chan and Eric Yap, "World at work: The electronics industry", 2004.

107 Business & Human Rights Resource Centre, "Impacts of COVID-19 on supply chain workers in the electronics sector", 8 June 2020. Available at: www.business-humanrights.org/fr/derni%C3%A8res-actualit%C3%A9s/impacts-of-covid-19-on-supply-chain-workers-in-the-electronics-sector/.

with precarious employment, including the fact that they are often employed without a work contract, and with regard to their challenging working conditions, which often require prolonged standing periods at workstations with minimal breaks, which can rapidly lead to exhaustion.[108]

The division of labour also exposes women to greater health risks since, by working on electronics assembly lines, they are more likely to come into contact with harmful chemicals. A study conducted in 2018 examining chemical usage at two memory chip factories in the Republic of Korea revealed that out of the total chemical volume exceeding 45,000 tons in each factory, approximately 30 per cent comprised sulfuric acid, a highly carcinogenic substance. Among the more than 420 chemical products used, 40 per cent contained compounds protected by trade secret agreements, preventing an assessment of their impact on health. Consequently, the potential effects of those chemicals on women's health and well-being remain undisclosed and unmeasured.[109]

There is considerable debate regarding the future impact of megatrends and drivers of change on working conditions and the safety and health of workers in the electronics industry. As outlined in section 3.4., climate change poses an imminent threat to workers, especially in least developed countries with limited resources and infrastructure to protect workers from high temperatures, extreme weather events and air pollution. Conversely, technological progress and innovation offer potential benefits. Automation, for instance, could mitigate physical hazards by replacing workers performing repetitive or dangerous tasks with machines.[110,111] Chemical companies have also started offering newly developed safer chemicals to companies that manufacture electronic products.

Occupational safety and health challenges affect workers along the entire electronics industry supply chain, extending beyond the manufacturing segment into the extraction and processing of raw materials and components. Addressing those challenges necessitates concerted efforts among key stakeholders and the establishment of robust governance and operational mechanisms to safeguard workers' well-being throughout the industry.

4.3. Social and labour protection

Universal access to adequate, comprehensive and sustainable social protection mechanisms, anchored in the international human rights framework and international labour standards, is essential for social justice, decent work and inclusive and sustainable growth and development. An effective means of supporting income security, access to healthcare and the enjoyment of many other social and economic rights, social protection is a crucial factor in eradicating poverty, inequality and social exclusion. In addition, social protection mechanisms play a key role in strengthening resilience to crises and economic shocks and contributing to the establishment of sustainable enterprises and robust, well-functioning economies.

Social protection encompasses both social security and labour protection, which addresses both working time and wages.

4.3.1. Social security

Some 53 per cent of the world's population is still not covered by any social insurance or social assistance scheme, and many more people enjoy only partial coverage.[112] In countries that have adopted robust labour

[108] IPEN, *Stories of Women Workers in Vietnam's Electronics Industry*, 2017. Available at: https://ipen.org/sites/default/files/documents/FINAL_Stories%20of%20Women%20Workers%20in%20Vietnam's%20Electronics%20Industry%20FINAL%20Nov%202017.pdf.

[109] Sunju Kim and others, "Chemical use in the semiconductor manufacturing industry", *International Journal of Occupational and Environmental Health* 24(3–4), pp. 109–118 (2018).

[110] Dongyeon Koh, G Chan and Eric Yap, "World at work: The electronics industry", 2004.

[111] David Kucera and Fernanda Bárcia de Mattos, *Automation, employment, and reshoring: Case studies of the apparel and electronics industries*, (ILO, 2020). Available at: www.ilo.org/publications/automation-employment-and-reshoring-case-studies-apparel-and-electronics.

[112] ILO, *World Social Protection Report 2020–22: Social protection at the crossroads – in pursuit of a better future*, 2021. Available at: https://webapps.ilo.org/wcmsp5/groups/public/---ed_protect/---soc_sec/documents/publication/wcms_817572.pdf.

▶ Box 12. Maternity protection and childcare

- The demanding nature of the electronics industry, especially in manufacturing and in research and development, can make it challenging for women to balance their work and family responsibilities. Limited access to support mechanisms such as childcare facilities exacerbates the challenges they face.
- The Workers with Family Responsibilities Convention, 1981 (No. 156) stipulates that Members of ILO should make it an aim of national policy to enable persons with family responsibilities who are engaged or wish to engage in employment to exercise their right to do so without being subject to discrimination and, to the extent possible, without conflict between their employment and family responsibilities.
- The Maternity Protection Convention (No. 183) and Recommendation No. 191 (2000) further promote equal opportunities for women in employment or occupation by recognizing that maternity protection is a precondition for gender equality and non-discrimination.
- Those instruments provide for the right to a minimum leave period, entitlement to maternal and child healthcare, protections for pregnant and nursing workers to prevent their exposure to workplace health and safety hazards, protection against discrimination in employment and occupation, the right of women to return to their jobs after maternity leave, and breastfeeding breaks.

laws and regulations, workers in electronics manufacturing are often covered by comprehensive social security schemes. These may include health insurance schemes, retirement plans, unemployment benefit schemes and workplace injury compensation mechanisms (see box 12). In contrast, in many developing countries, where electronics manufacturing is prevalent, workers often face challenges accessing adequate protection.

Many workers in electronics manufacturing are in informal or precarious employment, which often means that they enjoy no or only limited access to social security mechanisms. The informal sector includes subcontracted workers and those employed in smaller-scale production facilities, where labour regulations and social security protections are rarely upheld. Workers in informal or precarious employment are often more vulnerable than other workers to various work-related risks, including health hazards, job insecurity and lack of access to essential benefits. This, in turn, makes them more vulnerable than other workers to the financial risks associated with illness, injury, unemployment and old age.

Workers in the electronics industry in temporary employment or on repeated short-term contracts are disproportionately affected by inadequate social protection coverage. It is critical to extend universal social protection to all workers employed along electronics industry supply chains including, in particular, those employed under precarious conditions.

4.3.2. Temporary and non-standard forms of employment

Temporary and alternative employment arrangements in electronics factories offer both advantages and disadvantages. Those arrangements are frequently a necessary measure for companies to manage fluctuations in demand. They offer benefits such as the flexibility to adjust the workforce size according to demand, introduce new skills into the enterprise and maintain competitiveness, ultimately fostering job creation and retention. Changes in the size of a company's workforce can pose certain risks for that company, however, including reduced productivity, potential exposure of trade secrets jeopardizing intellectual property, and high costs associated with the recruitment and training of temporary workers. Workers engaged under temporary contracts may also face challenges, including a lack of job security, difficulties in maintaining a work-life balance, less favourable working conditions and obstacles in exercising

their rights at work. Vulnerable subsets within the temporary workforce include women, young workers, and migrants.

Purchasing practices in the electronics industry have a significant impact on workers throughout the supply chain. Due to long lead times, seasonal demand, and short product life cycles,[113] workers often feel under immense pressure, which can undermine their physical and mental well-being.[114] Volatile purchasing patterns or sudden order shifts often result in job insecurity, especially for temporary workers. Stringent pricing demands can force suppliers to cut costs, potentially compromising labour conditions, leading to excessive overtime, low wages and inadequate safety measures for employees.

Some countries have established good labour practices through the adoption of clear labour contract laws. In 2021, 97.7 per cent of electronics industry workers in Viet Nam had reportedly signed an official labour contract. Under the 2019 Vietnamese Labour Code, there are two types of labour contract: indefinite-term contracts and definite-term contracts. The latter can last a maximum of 36 months or three years. [115] In China, the Labour Contract Law enshrines the right of workers to an open-ended contract after signing two consecutive fixed-term contracts. However, some companies try to bypass regulations in order to reduce costs and increase flexibility by outsourcing labour, despite laws in place that only allow a maximum of 10 per cent of part-time workers.[116]

4.3.3. Working time

Excessive working hours is a persistent issue in the electronics industry, an industry explicitly covered by the first Convention adopted by ILO, namely the Hours of Work (Industry) Convention, 1919 (No.1), which expressly addresses industries involved in the manufacture of goods. That Convention sets the basic principle of the 8-hour workday and 48-hour working week. As highlighted in section 4.3.2., several factors contribute to the prevalence of excessive working hours in electronics manufacturing, including production demands, seasonal fluctuations, contractual pressures, supply chain constraints, management practices and inadequate labour protections.

Working time in electronics manufacturing, including shift durations, total hours, breaks and overtime policies, varies widely. That variation stems from different industry standards, local labour laws, company policies and negotiation practices. Legislation in some jurisdictions sets strict limits on weekly hours or required breaks. In other jurisdictions, collective bargaining or agreements between employers and workers offer a degree of flexibility within legal frameworks. Electronics Watch, an industry-independent organization that promotes and protects the rights of workers in electronics industry supply chains, reported working weeks of between 60 and 80 hours, including between 20 and 40 hours of overtime, in certain factories in China in 2016,[117] while a recent ILO report found that electronics workers in Viet Nam averaged between 40 and 50 hours of overtime each month in 2021.[118]

Ensuring reasonable working hours, in line with legal regulations, and providing fair compensation for overtime are critical aspects of the promotion of decent work, work-life balance, workers' health and workplace safety, and can help foster the development of sustainable enterprises in electronics industry supply chains. Authorities should endeavour to formulate and adopt regulations that establish a maximum number of hours that can be worked per day and per week, irrespective of the type of employment relationship between employers and their workers.

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113 Ricarda McFalls, "The impact of procurement practices in the electronics sector on labour rights and temporary and other forms of employment", ILO Working Paper No. 313, 2016. Available at: https://webapps.ilo.org/wcmsp5/groups/public/---ed_dialogue/---sector/documents/publication/wcms_541524.pdf.

114 Malcolm Moore, ""Mass suicide" protest at Apple manufacturer Foxconn factory", *The Daily Telegraph*, 11 January 2012. Available at: Moore, M. Mass suicide' protest at Apple manufacturer Foxconn factory. *The Daily Telegraph*, 2012. Accessed on 28 November 2023.

115 ILO, *Viet Nam's electronics supply chain: Decent work challenges and opportunities*, 2022.

116 ILO, *Responsible business conduct in China electronics supply chains*, 2023.

117 Electronics Watch, *Regional Risk Assessment Electronics Industry, China*, 2016. Available at: https://electronicswatch.org/en/regional-risk-assessment-electronics-industry-in-china-october-2016_2522052.pdf.

118 ILO, *Viet Nam's electronics supply chain: Decent work challenges and opportunities*, 2022.

4.3.4. Wages

Wages in the electronics industry vary considerably, with workers' remuneration depending on their geographic location, job roles, skill sets and industry segment. Unskilled or low-skilled workers may receive minimum wages or slightly higher, whereas those performing specialized roles within a company, such as engineers or researchers, can command significantly higher salaries. In the United States, for example, the median annual wage for electronics engineers in 2022 was US$104,610,[119] while electronics technologists and technicians earned an average of US$66,390 annually.[120]

Geographic disparities further impact workers' remuneration, with relatively high wages often prevalent in jurisdictions with strong labour regulations or relatively high living costs. Increases in the wages paid by Japanese companies operating manufacturing plants in Asia and the Pacific ranged from 2.8 per cent to 11.2 per cent between 2022 and 2023.[121] Manufacturing engineers in China and Cambodia reported average annual wages of US$17,514 and US$6,980, respectively, in 2022.[122] Notably, in Viet Nam, electronics workers earned higher average salaries than their counterparts in other manufacturing sectors in 2021. There are, moreover, major differences in the monthly incomes of the highest and lowest paying occupations.[123] To help narrow pay gaps, enterprises should make additional efforts to ensure fair and equitable compensation and promote pay transparency.

4.4. Social dialogue and tripartism

Social dialogue and tripartism are essential in fostering cooperation and communication among governments, employers, and workers. Indeed, they facilitate consensus-building and democratic involvement among those stakeholders in the world of work.

The ILO plays a pivotal role in fostering social dialogue and tripartism by providing a platform for collaboration among governments, employers and workers. Through its conventions, recommendations, and initiatives, the ILO promotes dialogue, negotiation and cooperation among those parties, ensuring collective input in shaping labour policies and fostering harmonious industrial relations.

In the electronics industry, social dialogue involves negotiations, consultations and discussions among stakeholders to establish collective agreements, policies and practices that benefit all parties. That collaboration helps set industry standards, create regulations and resolve disputes effectively. Strong, independent and effective organizations are a prerequisite for social dialogue in the industry.

4.4.1. Labour administration and inspection

Governments are pivotal in nurturing social dialogue within the electronics industry, primarily by establishing policy frameworks, ensuring compliance with labour laws and supporting labour inspectorates. In recent years, a number of countries have incorporated labour-focused elements into their industrial policies or developed independent labour-centric strategies.

Through labour ministries and inspectorates, governments oversee the application of international labour standards and national laws. Labour inspectors play a vital role in enforcing those standards and providing guidance to both employers and workers with a view to improve working conditions. The work of labour

119 United States Bureau of Labor Statistics, "Electrical and Electronics Engineers", Occupational Outlook Handbook, accessed 30 November 2023. Available at: https://www.bls.gov/ooh/architecture-and-engineering/electrical-and-electronics-engineers.htm.

120 United States Bureau of Labor Statistics, "Electrical and Electronics Engineers".

121 Japan External Trade Organization, 2022 Survey on Business Conditions of Japanese Companies Operating Overseas (Asia and Oceania), February 2023. Available at: https://www.jetro.go.jp/ext_images/en/reports/survey/pdf/2022/EN_Asia_and_Oceania_2022.pdf.

122 Japan External Trade Organization, *2022 Survey on Business Conditions of Japanese Companies Operating Overseas (Asia and Oceania)*.

123 ILO, *Viet Nam's electronics supply chain: Decent work challenges and opportunities*, 2022.

inspectorates is sometimes impeded by serious challenges, however, particularly in developing countries. Those challenges include limited resources, corruption, and inadequate training for inspectorate staff.

Strategies such as raising awareness, strengthening existing inspection systems, modernizing outdated legislation, supporting the meticulous planning of regulatory activities, and empowering workers and their representatives regarding decent work all support the efficacy of labour inspections.

4.4.2. Employers' organizations

Electronic industry employer and business membership organizations serve to bring together businesses, manufacturers and other industry stakeholders in advocating for their shared interests, and to address challenges, set standards and foster collaboration and innovation. Those organizations often target their activities with the aim of supporting specific electronics segments, including in the areas of semiconductor manufacturing, consumer electronics and technology standards. In addition, they represent members when engaging with international bodies, including the International Organisation of Employers.

In addition to the International Organisation of Employers, global trade associations such as the Global Association for Electronics Manufacturing work to set industry standards in electronics manufacturing, while bodies such as the Electronics Components Industry Association emphasize networking and business intelligence across the component supply chain. Additionally, the Global Semiconductor Alliance and the Semiconductor Industry Association foster innovation and advocate for policies to support industry growth. The Responsible Business Alliance, formerly called the Electronics Industry Citizenship Coalition, is the world's largest industry coalition focused on responsible business conduct in global supply chains, including in the electronics industry. Regional and national bodies participating in the Coalition include the European Electronic Component Manufacturers Association and the Japan Electronics and Information Technology Industries Association.

In recent years, organizations such as the World Business Council for Sustainable Development, the Platform for Accelerating the Circular Economy and the Circular Economy Foundation have proactively engaged with stakeholders across the electronics industry to expedite the transition to a just and job-rich circular economy.

4.4.3. Workers' organizations

Trade unions in the electronics industry emerged during industry expansion in the middle of the twentieth century. Initially, unionization efforts were fragmented due to rapid industry growth, but during the 1960s and 1970s, particularly in Western countries, many unions made significant inroads in the areas of improved conditions, job security and fair compensation. In the 1980s and 1990s, the increase of electronics manufacturing located in Asia posed new challenges as unions adapted to diverse cultural, legal and labour circumstances across that continent. In response to growing concerns about globalization at the end of the twentieth century, trade unions collaborated on an international basis to address decent work issues globally.

Many national trade unions in the electronics industry are affiliated with IndustriALL Global Union and the International Trade Union Confederation. Those organizations champion worker rights and advocate for better labour standards, as well as foster collective bargaining and policy advocacy. At the twenty-eighth session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP28), held in the United Arab Emirates in 2023, both organizations emphasized the importance of a labour-inclusive and just transition to environmental sustainability, a crucial concern in the electronics industry.[124,125] Moreover, IndustriALL Global Union has facilitated discussions on semiconductor industry challenges and provided support to local and national organizations striving to uphold workers' rights.

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[124] International Trade Union Confederation, *COP28 Frontlines Briefing: COP28: Trade unions demand a labour inclusive Just Transition Work Programme*, 2023. Available at: https://www.ituc-csi.org/COP28-Trade-unions-demand-a-labour-inclusive-Just-Transition-Work-Programme.

[125] IndustriALL Global Union, "Just Transition: Unions demand bold action at CoP28", 23 November 2023. Available at: https://www.industriall-union.org/just-transition-unions-demand-bold-action-at-cop28.

National unions have also made strides in negotiating collective agreements in the electronics sector. For example, in 2022, the Austrian Trade Union Federation and the Professional Association of the Electrical and Electronics Industry agreed on working conditions, contract types, wages and other labour-related issues for all members.[126]

In addition, a number of other organizations seek to uphold the rights of workers in the electronics sector. Electronics Watch, for example, is as an independent monitoring organization focused on improving labour conditions. In collaboration with public sector buyers, Electronics Watch monitors supply chains for labour rights violations and seeks to enhance transparency within the electronics industry and improve working conditions for electronics industry workers around the world.

The radical transformation of the electronics industry that is currently underway is likely to pose challenges to the strength and resilience of employers' and workers' organizations in the future. In anticipation of those challenges, employers' and workers' organizations should take the following suggestions into consideration:

- With the advent of new production systems and markets offering innovative products and services, employers' organizations should endeavour to adapt their services to changing needs and reinforce their capacity to serve an increasingly diverse set of business interests;
- Trade unions should adopt innovative organizing strategies in order to engage with workers employed in non-traditional working environments with the aim of providing guidance and support to workers who have recently entered the industry.

[126] For further information see *Collective Agreement of the Austrian Electrical and Electronics Industry*, 2022. Available at: https://www.feei.at/wp-content/uploads/2023/01/collective-agreement-eei-2022.pdf.

5. The way forward

Governments are responsible for developing and implementing legislative and regulatory frameworks that protect workers' rights and well-being amid a complex landscape shaped by technological advances, globalization, climate change and shifting demographics. Rigorous enforcement of current regulations and updated policies that address emerging challenges are vital in securing decent work for all. Sustainable industrial policies are being pursued by an increasing number of countries to create better conditions for the electronics industry to grow. Governments should facilitate social dialogue among all stakeholders and should foster cooperation to shape policies that balance industry demands with workers' rights.

In addition, employers can play a crucial role in promoting decent work. Responsible business conduct is an essential factor in efforts to ensure fair wages, secure employment contracts, and avenues for skills development and career advancement. Ethical supply chain management practices, including a commitment to social responsibility and sustainability, should be at the forefront of corporate strategies. Employers should prioritize the well-being of their workers and must foster a culture that emphasizes diversity, equity and inclusion. Prioritizing a positive environment means ensuring fair treatment of workers across the supply chain, including subcontractors, as well as guaranteeing labour rights and promoting decent working conditions.

To defend their rights effectively, workers must be able to act collectively at the national, regional and global levels. In countries or regions with trade union proliferation and fragmentation, improved trade union cooperation can contribute to enhanced representation and weight in decision making. Skills development and investment in lifelong learning, supported by employers and facilitated by governments, are key to ensuring that workers benefit from technological advances and simultaneously address occupational safety and health risks. Since challenges facing the industry go beyond technological advances and automation, it is imperative that trade unions continue to engage in social dialogue to advance decent work and strengthen their efforts to organize and further the interests of workers in a rapidly changing employment landscape.

In that regard, the ILO is committed to playing a key role in fostering collaboration and advocating for decent work principles. By promoting the ratification and implementation of ILO Conventions and respect for the ILO Declaration on Fundamental Principles and Rights at Work, providing guidance to governments and labour inspectorates, and offering technical assistance to its constituents, ILO will continue to promote economic and working conditions that incentivize all workers, employers and governments to work toward peace, prosperity and progress. By assisting governments, employers and workers in addressing challenges and capitalizing on decent work opportunities, they can pave the way for a future that upholds the principles of decent work and fosters a just transition to environmental sustainability in the rapidly evolving electronics industry.

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