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Cambridge Industrial Innovation Policy

UK INNOVATION REPORT 2024

Benchmarking the UK's industrial and innovation performance in a global context

Institute for Manufacturing, University of Cambridge

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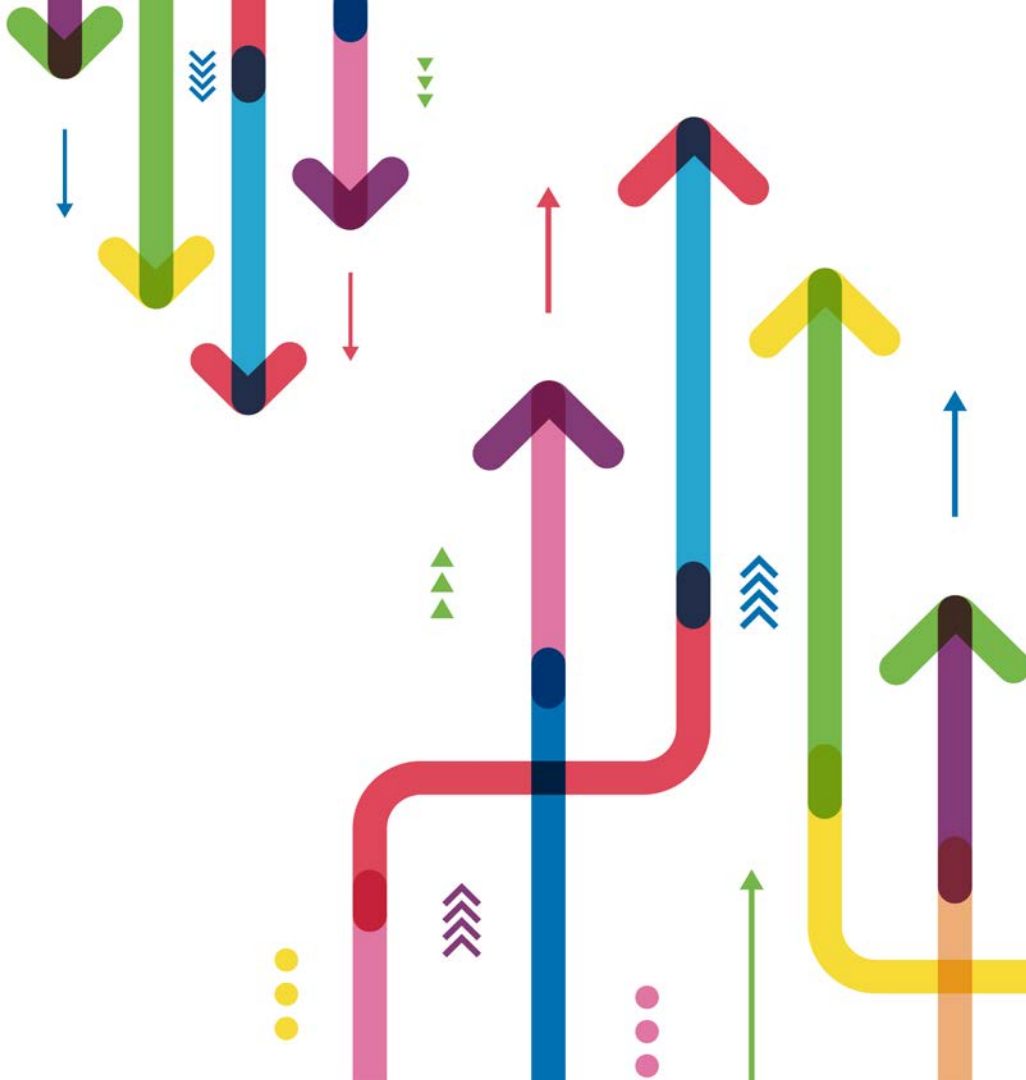

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What makes the report different?

The aim of the *UK Innovation Report* is to facilitate policy discussions on innovation and industrial performance – and the interplay between them. While numerous sources of data on the topic of innovation exist, the aim of the *UK Innovation Report* is to make a contribution by bringing together, in a single place, **innovation and value-added indicators** in a concise and accessible format.

Instead of structuring the report according to traditional input and output indicators, the intention with the report is to include data that provides rich quantitative representations of the vitality of both the **UK's innovation activity** and its **industrial performance** in an **international context**.

An important theme throughout the report is the analysis of **sectoral** and **regional** data to better understand the drivers of national performance and provide more granular policy insights.

While the report does not make specific policy recommendations, it does highlight areas where additional evidence and policy action may be required.

Motivation

- To review the UK's innovation and industrial performance and compare it with that of other selected countries;
- To facilitate discussions on the relation between innovation and sectoral competitiveness; and
- To contribute to the evidence base that is available to inform industrial and innovation policy.

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Introduction

The *UK Innovation Report* remains a crucial guide to navigating the evolving landscape of innovation and technological progress in the UK.

Last year's report highlighted the establishment of two pivotal new departments: the Department for Business and Trade (DBT) and the Department for Science, Innovation and Technology (DSIT).

In November 2023, DBT released its *Advanced Manufacturing Plan*, the aim of which is to support the sector's long-term success. The plan includes £4.5 billion of funding over 5 years (starting from 2025) to strategic manufacturing sectors such as **automotive**, **aerospace**, **life sciences** and **clean energy**, all of which have been analysed in previous editions of the *UK Innovation Report*.

In February 2024, DSIT published an update on progress of its *Science & Technology Framework*, which confirms the commitment to progress towards total government investment in R&D reaching £20 billion per annum by the financial year 2024/25. The latest update emphasises the delivery, development and deployment of five critical technologies: **AI**, **engineering biology**, **future telecommunications**, **semiconductors** and **quantum technologies**. Section 2 of this year's report analyses the country's position in international patenting activity for these essential technologies.

It is unclear what strategic direction the government will take after 2024. With the prospect of an impending election, the dynamics of political leadership may soon transform, potentially ushering in alterations to policy directions, funding priorities and the administrative landscape of **UK innovation**. This underlines the importance of policy frameworks that can adapt to evolving political climates while ensuring continuity in the support and growth of critical technology sectors.

In an ever-changing landscape, the *UK Innovation Report* remains steadfast in its commitment to provide timely updates on the implications for **the UK**'s innovation ecosystem.

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What is new in the 2024 edition of the *UK Innovation Report*?

The *UK Innovation Report 2024* maintains last year's core policy-guiding questions but uses new indicators and longer time series and integrates additional data sources. It presents a deep dive into a different sector: the **machinery and equipment manufacturing sector**. The report is organised as follows:

- **Section 1** reviews **the UK's sectoral productivity and economic restructuring** during the COVID-19 pandemic and its aftermath.
- **Section 2** examines the latest data on **UK research and development (R&D)** expenditure and reviews the country's performance across various stages of innovation.
- **Section 3** delves into the performance of **the UK's machinery and equipment manufacturing sector**, incorporating insights from industry expert consultations.
- **Section 4** analyses **the UK's production of science, technology, engineering and mathematics (STEM)** graduates and their job opportunities.
- **Section 5** reviews **the UK's low-carbon and renewable energy economy (LCREE)** and examines the decoupling of the UK's economic growth from its greenhouse-gas emissions.

Contributors and acknowledgements

Cambridge Industrial Innovation Policy

Cambridge Industrial Innovation Policy (CIIP) is a global, not-for-profit policy group based at the Institute for Manufacturing (IfM), the University of Cambridge. CIIP works with governments and global organisations to promote industrial competitiveness and technological innovation. We offer new evidence, insights and tools based on the latest academic thinking and international best practice. This report was delivered through IfM Engage, the knowledge-transfer arm of the Institute for Manufacturing (IfM), the University of Cambridge.

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Please reference this report as: Cambridge Industrial Innovation Policy (2024). *UK Innovation Report 2024*. IfM Engage. Institute for Manufacturing, the University of Cambridge.

Executive summary

UK INNOVATION REPORT 2024

Theme 1: Structure and performance of the UK economy

KEY FINDINGS

UK productivity rebounded quickly after the COVID-19 pandemic.

- Among the five economies examined, **the UK** experienced the most pronounced decline in labour productivity (-9.2%) in 2020**. France** followed with a decline of 7.3%, while **Germany** experienced a decline of 3.3%.
- However, in 2021 **the UK** displayed the fastest growth rate (8.8%), closing the gap on pre-pandemic levels. **Switzerland** followed with a growth rate of 5%, and **Germany** with 3.3%.

Knowledge-intensive services and manufacturing have led the COVID-19 recovery.

- Between 2019 and 2021, **knowledge-intensive services** and **manufacturing** saw some of the fastest productivity growth among the economies analysed. In **the UK**, for instance, labour productivity in **manufacturing** increased by 9.7%, while in **information and communication** it rose by 12.2%.
- This positive trajectory persisted to some degree in 2022. For example, **Switzerland** stands out for the rapid growth of its **manufacturing industry**, largely driven by its chemical and pharmaceutical industries. In contrast, **the UK** experienced a setback, with a decline of -3.3% in **manufacturing value added** in 2022.

Knowledge-intensive services are expanding their contribution to the economy.

- Between 2019 and 2021, **knowledge-intensive services**, such as information and communication and professional, scientific and technical activities, significantly increased their contributions to the economies analysed.
- In **the UK**, these sectors together accounted for an increase of 0.4 percentage points in employment shares and 1.8 percentage points in value added shares. Although their growth moderated in 2022, rapid expansions are expected to continue in the future.

Theme 2: Investment in innovation

KEY FINDINGS

The UK is considered to be a leading global hub for scientific knowledge.

- **The UK** produces more academic publications than any other country, except **China** and **the US**, but 57% more than **the US** and six times more than **China** in per capita terms.
- **The UK** is the world leader in field-weighted citation impact (FWCI), a common benchmark for research quality.

However, the UK falls behind in converting scientific knowledge into commercial success.

- Compared to **the US**, **the UK** lags behind in **development** and **scale-up** metrics.
- The proportion of the workforce employed in **medium and high value added manufacturing** is lower than in competitor nations, and the **value added per worker** in these sectors is less than half of that in the US.

The UK's spending on R&D is higher than the average of the OECD countries, but it is still below that of leading nations.

- **The UK's** gross domestic expenditure on **research and development (GERD)** as a share of GDP was **2.91%** in 2021, above the **OECD** average of **2.72%**. However, **the UK** still lags behind countries such as **Korea**, **the US**, **Japan** and **Germany**.
- In 2021, UK government-funded R&D amounted to 0.57% of GDP, below the OECD average of 0.63%.

Among the top 100 R&D-investing companies in the world, only three have headquarters in the UK.

- This is quite low, considering that in 2022 **the UK** was home to a total of 95 of the world's top 2,500 **R&D-investing** companies.
- **The UK** ranks fifth behind **the US**, which has 827; **China**, which has 679; **Japan**, which has 229; and **Germany**, which has 113 such companies.

Theme 3: Machinery and equipment manufacturing sector

KEY TRENDS

The UK machinery and equipment (M&E) sector is a major global player, but some sub-sectors have contracted significantly.

- According to OECD data, **the UK** ranked among the top players in the world by value added in 2021, behind **Japan**, **the US**, **Germany** and **Italy** but ahead of **the Netherlands**, **France** and **Switzerland**.
- Between 2008 and 2021, value added in some M&E sub-sectors experienced substantial expansion, with **other general-purpose machinery** and **lifting and handling equipment** growing by 41% and 36%, respectively. Conversely, some sub-sectors have experienced a significant contraction, particularly **other engines** and **machinery for plastic and rubber**, which declined by 50% and 90%, respectively.
- Overall, value added in the **M&E sector** contracted from £13.1 billion in 2008 to £12.5 billion in 2021. However, the productivity of the **M&E** sector remains 37% higher than the average productivity of the whole **manufacturing sector** and 60% higher than the whole economy.

A decline in employment across 17 out of 21 UK M&E sub-sectors resulted in a loss of 28,000 jobs between 2011 and 2021.

- The **UK M&E sector** ranked sixth in terms of employment among **OECD** countries in 2021, employing 162,000 people.
- This represents a loss of 28,000 jobs compared to 2011, amounting to a 15% reduction over the course of 10 years.
- Among **M&E sub-sectors**, the most significant job losses between 2011 and 2021 were reported in **machinery for mining, quarrying and construction** (-5,300), **machinery for plastics and rubber** (-4,000), **office machinery** (-3,200) and **pumps and compressors** (-3,200).

While the UK is the 10th largest M&E exporter in the world, the country has one of the largest trade deficits.

- The **UK's** trade deficit in the **M&E sector** more than tripled between 2011 and 2022, ranking 176th out of 188 countries in trade balance.
- The largest **UK M&E sub-sectors** by trade value in 2022 were **other engines** and **machinery for mining, quarrying and construction**.
- **China**, the largest M&E exporter, has been gradually gaining market share at the expense of other competitor countries.

Growth of business expenditure on R&D (BERD) in the UK M&E sector has been slower than in the manufacturing sector as a whole.

- Business expenditure on R&D (BERD) in the **M&E sector** represented 5.9% of total BERD in the **UK manufacturing sector** in 2022.
- BERD in the **UK M&E sector** rose from £0.7 billion in 2000 to £1 billion in 2020, with a compound annual growth rate (CAGR) of 1.9%.
- This is lower than the compound annual growth rate observed for overall **UK** manufacturing (2.9%) during the same period.

Theme 3: Machinery and equipment manufacturing sector

KEY DRIVERS

- **The M&E market depends on demand from other sectors and is typically sensitive to economic cycles.** The UK M&E sector aggregates many sub-sectors, which are quite distinct from each other and which respond differently to economic cycles. Sales orders in the M&E sector are usually tied to the long-term investment plans of other sectors. In periods of economic uncertainty, these plans are often postponed.
- **High production costs, political uncertainty and foreign ownership are among the factors influencing offshoring decisions in some sub-sectors.** Reasons for offshoring appear to be the loss of key suppliers and high production costs in the UK. For example, the fluid power equipment and the valves and actuators sub-sectors are affected by the high cost and low availability of steel in the UK. As a result, many products are designed in the UK but manufactured in China. The UK's exit from the EU has contributed to the consolidation in Europe of manufacturing in the pumps and compressors sub-sector, which is dominated by European firms.
- **Changes in regulations, intra-industry trade and policy changes in export markets may have impacted UK imports and exports.** New trade rules with the EU have impacted the ability of SMEs to export to Europe. The decision to move away from the European CE conformity assessment marking, and to create a UK-specific UKCA marking, followed by a reversal of this decision, has also affected some sub-sectors. New regulations require certain valves to be tested within China by a local inspector, adding costs to qualify for the Chinese market.
- **Labour shortages have impacted growth and incentivised automation across sub-sectors.** The consulted firms reported difficulties hiring younger and more diverse workers for the sector. These difficulties cut across sub-sectors and functions, affecting both engineering and technician positions. New skills are also needed, for example, cyber-security, robotics, IoT, advanced manufacturing, cloud and big data. Investments in automation and factory optimisation have been occurring in the sector and partly explain the reduction in employment.
- **R&D investment decisions in the UK M&E sector are often made abroad.** There is a dominant presence of foreign-owned original equipment manufacturers (OEMs) and distributors across UK M&E sub-sectors. The consulted stakeholders perceive UK M&E companies to be less R&D-intensive than foreign ones, except for some large internationally competitive firms. The UK M&E sector is dominated by SMEs, which might have fewer resources available for R&D and fewer advisory and support options from the broader innovation ecosystem than large firms.
- **Sustainability, digitalisation and materials research trends have shaped the direction of innovation efforts in recent years.** Emissions regulations, such as those for non-road mobile machinery, and net-zero targets make it imperative to develop more energy-efficient and environmentally sustainable machines and equipment.

Theme 4: Science and engineering workforce

KEY FINDINGS

The UK has a relatively high proportion of science, technology, engineering and mathematics (STEM) graduates.

- During the academic year 2021/22, 42% of all graduates in **the UK** completed STEM disciplines.
- **The UK** produces more **STEM** graduates per capita in the 20–34-year-old population than comparator countries. In 2020 **the UK** awarded 1,393 first university degrees per 100,000 individuals in **STEM** fields, compared to 1,317 in **the US**, and 690 and 650 in **India** and **China**, respectively.

However, the UK is producing fewer graduates in engineering, manufacturing and construction.

- In 2022 more than half (52%) of **the UK's STEM** graduates pursued health-related disciplines.
- In 2021 the percentage of graduates in **engineering**, **manufacturing** and **construction** in **the UK** was only 9.1%, which is significantly lower than **Italy**, **Switzerland**, **Japan**, **Korea** and **Germany**. In these countries, the percentage of graduates in these disciplines ranged from 14.4% to 22.1%.

Despite the high proportion of STEM graduates, there are significant STEM-related skills gaps in the UK labour market.

- In **the UK** 934,000 vacancies were recorded towards the end of 2023, 46% of which were in fields related to **STEM** disciplines. At the beginning of 2024, 12% of **UK** firms in **manufacturing** and 6.9% in **information and communication** said they were experiencing a shortage of workers.
- For **UK** employers, it is difficult to find individuals with skills related to **medical knowledge, scientific knowledge, production and technology knowledge** and **digital skills** compared to the **OECD** average and **the EU**.

Theme 5: Net zero innovation

KEY FINDINGS

The UK has successfully decoupled GDP growth from greenhouse-gas (GHG) emissions.

- While **the UK's** GDP doubled between 1990 and 2021, the country achieved a 40% reduction in GHG emissions during this period. However, further work is required to achieve the target set by the Climate Change Act, which commits **the UK** government to reducing GHG emissions by at least 100% of the 1990 levels (net zero) by 2050.
- Only five industries failed to reduce emissions from 1990 to 2021: **wholesale and retail trade and repair of motor vehicles; construction; accommodation and food services; administrative and support service activities**; and **real estate** activities.

The UK low-carbon and renewable energy economy (LCREE) has performed strongly since 2019.

- The LCREE economy reported a £54.4 billion turnover in 2021, compared to £45.8 billion in 2019, and over 27,000 and 42,000 more businesses and employees, respectively, in 2021 than in 2019.
- The sectors with the highest turnover in 2021 were: **energy-efficient products** (£14.01 billion); **low-emission vehicles** and **infrastructure** (£8.52 billion); and **offshore wind** (£8.42 billion).

The UK consistently ranked among the top six countries in public R&D expenditure on low-carbon renewable energy technologies from 2010 to 2022.

- At $1.6 billion, **the UK's** public R&D budget in **low-carbon and renewable energy technologies** in 2022 was lower than Germany ($2 billion), **Japan** ($3.4 billion), **France** ($4.9 billion) and **the US** ($9.6 billion) but higher than **Canada** ($1.2 billion).
- Among **low-carbon technologies**, the highest public R&D expenditure in the **UK** in 2022 was on nuclear power technologies, followed by **energy efficiency and renewables**.

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THEME ONE

Structure and performance of the UK economy

How did UK sectoral productivity perform during and in the aftermath of the COVID-19 pandemic?

How did the structure of the UK economy change over this period?

How do these trends and patterns compare with those of other countries?

Structure and performance of the UK economy

KEY FINDINGS

UK productivity rebounded quickly after the COVID-19 pandemic.

- Among the five economies examined, **the UK** experienced the most pronounced decline in labour productivity (-9.2%) in 2020**. France** followed with a decline of 7.3%, while **Germany** experienced a decline of 3.3%.
- However, in 2021 **the UK** displayed the fastest growth rate (8.8%), closing the gap on pre-pandemic levels. **Switzerland** followed with a growth rate of 5%, and **Germany** with 3.3%.

Knowledge-intensive services and manufacturing have led the COVID-19 recovery.

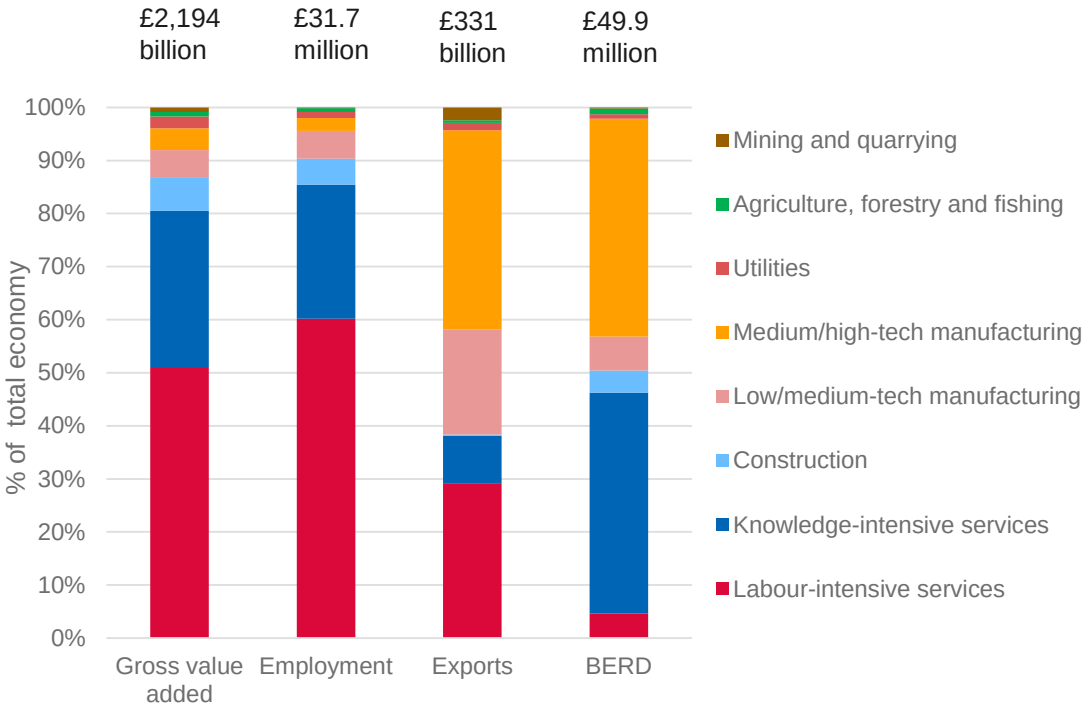
- Between 2019 and 2021, **knowledge-intensive services** and **manufacturing** saw some of the fastest productivity growth among the economies analysed. In **the UK**, for instance, labour productivity in **manufacturing** increased by 9.7%, while in **information and communication** it rose by 12.2%.
- This positive trajectory persisted to some degree in 2022. For example, **Switzerland** stands out for the rapid growth of its **manufacturing industry**, largely driven by its chemical and pharmaceutical industries. In contrast, **the UK** experienced a setback, with a decline of -3.3% in **manufacturing value added** in 2022.

Knowledge-intensive services are expanding their contribution to the economy.

- Between 2019 and 2021, **knowledge-intensive services**, such as information and communication and professional, scientific and technical activities, significantly increased their contributions to the economies analysed.
- In **the UK**, these sectors together accounted for an increase of 0.4 percentage points in employment shares and 1.8 percentage points in value added shares. Although their growth moderated in 2022, rapid expansions are expected to continue in the future.

Chart 1.1. Structure of the UK economy, 2022

Gross value added, employment, exports of goods and business R&D expenditure (BERD) [1]



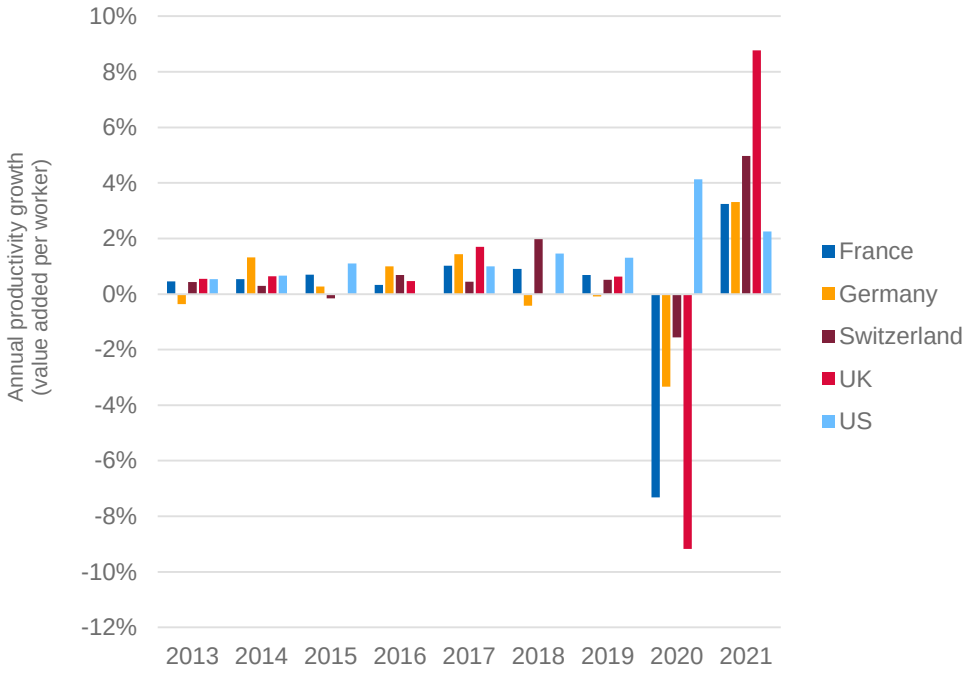
Note: [1] Export data corresponds to goods exported in 2021, with industry percentages based on Office for National Statistics experimental data, and does not include category unknown industry.
Source: Office for National Statistics.

- In 2022 **knowledge-intensive**[1] and **labour-intensive services**[1] contributed to approximately 80% of **the UK** economy's gross value added and employment.
- While **medium/high-tech manufacturing**[1] accounted for 4.1% of gross value added and 2.4% of employment, this sector stands out for its contribution to exports and R&D. It represented the largest share of goods exports, amounting to 37.1% in 2021, and the second largest share of business R&D expenditure, approximately 41.1% in 2022.
- The main change observed in the structure of **the UK** economy, compared to the pre-pandemic period, is the expansion of **knowledge-intensive services**, as depicted in Charts 1.4 and 1.5.

Note: [1] Appendix 1.1 presents definitions of these classifications of sectors.

Chart 1.2. Labour productivity growth in selected economies, 2013–2021

Value added per worker, annual growth rate



Source: OECD Data Explorer.

- The economies analysed witnessed substantial declines in productivity in 2020, with **the US** being the only exception. However, all these economies resumed growth in 2021.
- Notably, **the UK** experienced the most pronounced decline in productivity growth in 2020 (-9.2%), followed by **France** (-7.3%) and **Germany** (-3.3%). However, in 2021 **the UK** displayed the fastest growth rate (8.8%), closing the gap on pre-pandemic levels (in real terms). **Switzerland** followed with a growth rate of 5%, and **Germany** with 3.3%.
- Recent research suggests that **the US** managed to record a positive productivity growth in 2020 (4.1%), because most of the jobs lost were in low-wage activities, and investment and capacity utilisation recovered rapidly.[1] The distinct treatment of furlough schemes also played a role.[2] For further insights on this issue, please refer to the related blog.
- Among the European economies studied, **Switzerland** saw the strongest productivity performance. This can be partly explained by its lower dependence on **the hospitality sector** and robust **chemical and pharmaceutical industries**.[3]

Source: [1] Stewart (2022); [2] Vries, Erumban and van Ark (2021) and Office for National Statistics (2020); [3] FDFA (2023) and OECD (2022).

Chart 1.3. Sectoral labour productivity growth in selected economies, 2019–2021

Value added per worker, annual growth rate

Productivity growth: Positive - Fastest / Negative

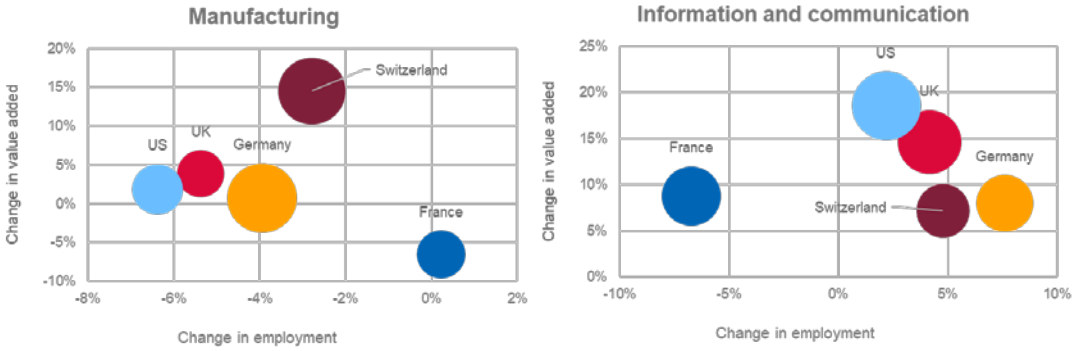
Economic activity	France	Germany	Switzerland	UK	US
Manufacturing	-6.7%	4.9%	17.8%	9.7%	8.8%
Financial and insurance activities	5.3%	7.1%	10.2%	0.5%	9.8%
Information and communication	1.1%	3.0%	2.9%	12.2%	13.6%
Professional, scientific and technical activities	-3.9%	4.3%	6.3%	6.5%	15.1%
Mining and quarrying	0.4%	18.4%	11.7%	-19.5%	2.3%
Wholesale and retail trade; repair of motor vehicles and motorcycles	2.0%	0.5%	-3.0%	3.1%	2.1%
Water supply; sewerage, waste management and remediation activities	-0.4%	-9.9%	3.1%	0.6%	9.5%
Agriculture, forestry and fishing	-8.3%	18.4%	-1.7%	-6.1%	-3.9%
Real estate activities	-5.9%	3.1%	-2.3%	-1.2%	2.7%
Human health and social work activities	-2.3%	-1.7%	1.6%	-9.3%	5.4%
Public administration and defence; compulsory social security	0.1%	-0.9%	-1.5%	-8.9%	-0.9%
Administrative and support service activities	-5.6%	-5.1%	-0.5%	-8.1%	7.0%
Construction	-12.2%	-5.5%	1.4%	3.6%	-0.6%
Other service activities	-12.1%	-4.7%	1.6%	-3.5%	-0.1%
Education	-3.4%	-10.3%	-7.3%	-9.9%	3.4%
Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	1.3%	-3.9%	-17.3%	-29.4%	11.8%
Arts, entertainment and recreation	-29.4%	-19.3%	14.5%	-9.8%	4.2%
Electricity, gas, steam and air conditioning supply	-2.0%	-8.6%	-24.7%	-27.3%	4.5%
Transportation and storage	-16.4%	-6.2%	-21.3%	-25.2%	-8.6%
Accommodation and food service activities	-34.7%	-30.6%	-32.9%	-14.7%	9.0%

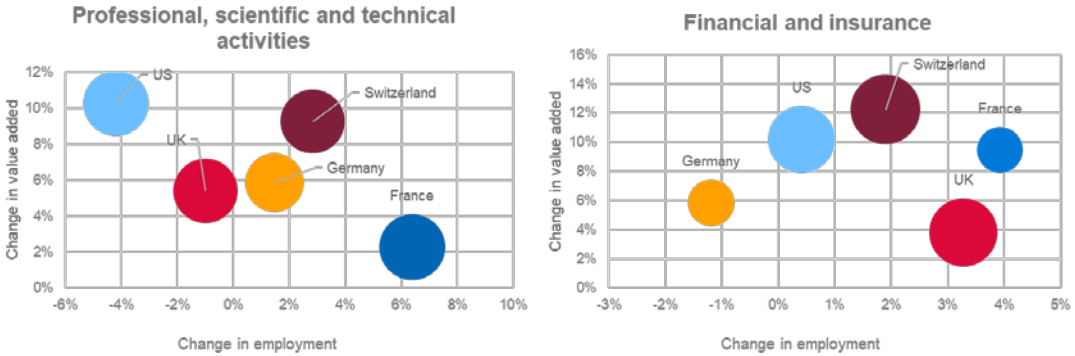
Source: OECD Data Explorer.

- Across the economies analysed, the sectors that were impacted the most in 2020, such as **accommodation and food service activities, the arts, entertainment and recreation, and administrative and support services**, also bounced back quickly in 2021, albeit to productivity levels below those seen pre-pandemic.
- In contrast, **knowledge-intensive services** and **manufacturing** experienced among the fastest productivity growth between 2019 and 2021.
- Between 2019 and 2021, **Switzerland** led with the swiftest productivity growth in the **manufacturing** sector, at 17.8%, followed by **the UK** at 9.7%, and **the US** at 8.8%.
- **The US** (13.6%) and **the UK** (12.2%) also experienced the fastest growth **in information and communication**, along with **professional, scientific and technical activities** (the **US** at 15.1%; the **UK** at 6.5%), followed closely by **Switzerland** (at 6.3%).
- In **financial and insurance** activities, the fastest productivity growth was observed in **Switzerland** (10.2%), **the US** (9.8%) and **Germany** (7.1%).

Chart 1.4. Growth in value added and employment in selected sectors and economies, 2019–2021

Growth rates – size of bubbles represents 2021 value added shares





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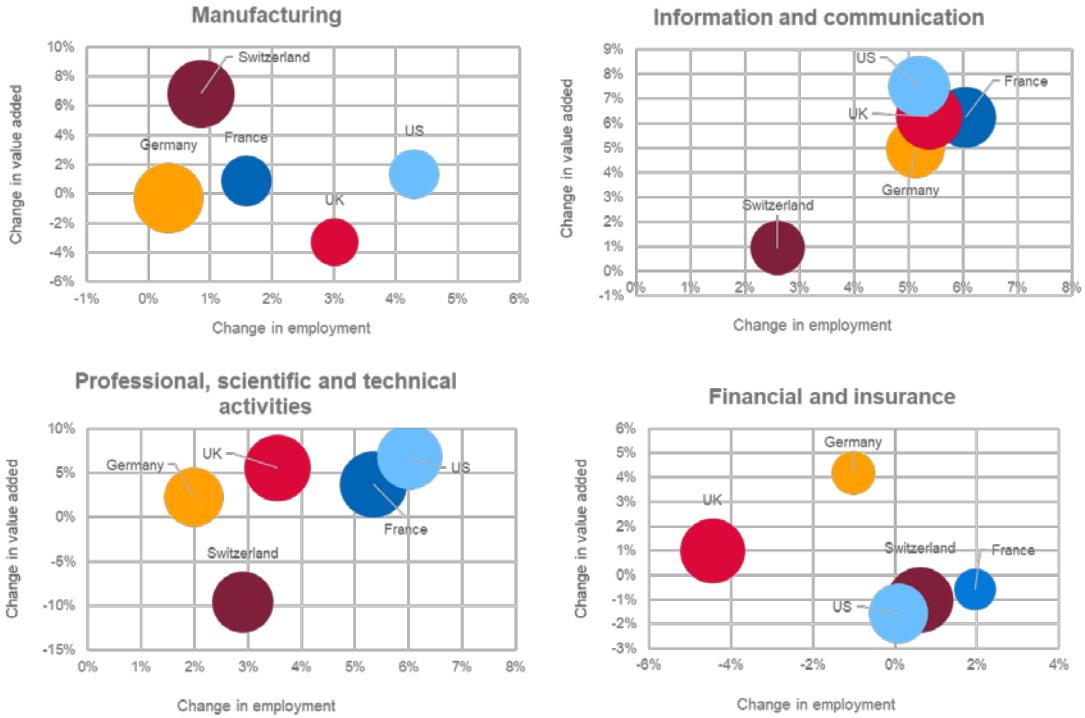
Source: OECD Data Explorer.

- Differences in how sectoral productivity grew between 2019 and 2021 were identified.
- **Knowledge-intensive services**, such as **information and communication**, **financial and insurance activities**, and **professional, scientific and technical activities** generally experienced expansions in both value added and employment.
- In **the UK** these sectors together accounted for an increase of 0.4 percentage points in employment shares and 1.8 percentage points in value added shares.
- In contrast, the rapid productivity surge observed in **the UK manufacturing** sector in 2021 (Chart 1.3) is explained by a combination of increased value added and a reduction in employment levels. These figures should be interpreted in the context of both temporary lay-offs and labour shortages.[1] For further insights on this issue, please refer to the related blog.
- Across countries, **the US** experienced reductions in employment or slower growth than other economies. This may reflect the different treatment of furlough schemes, which was not reflected as a cost in value added in the US but had a negative impact on employment.

Source: [1] Make UK (2022); Randstand (2022).

Chart 1.5. Growth in value added and employment in selected sectors and economies, 2021–2022

Growth rates – size of bubbles represents 2022 value added shares



Source: OECD Data Explorer, Office for National Statistics, US Bureau of Labor Statistics, US Bureau of Economic Analysis.

- Recent data shows that the **information and communication** sector maintained a positive trend in 2022.
- Except for Switzerland, **professional, scientific and technical services** also sustained a positive trend, albeit at a slower pace in 2022, and rapid expansions are expected in the future.[1]
- In contrast, the **financial and insurance sector** saw negative value added growth in 2022 in **France**, **Switzerland** and **the US**. In comparison, **Germany** stood out for its relatively strong value added growth in this sector (4.2%).
- Several countries have launched strategies to strengthen their **manufacturing** sectors, signalling an intention to expand this industry in the future. In 2022 expansions in employment were observed in all economies analysed.
- In terms of value added, **Switzerland** (6.8%) led the growth in **manufacturing**, largely supported by the performance of its **chemical and pharmaceutical** industries. In contrast, **the UK** recorded negative rates (-3.3%), with the largest falls (in absolute terms) observed across **machinery and equipment, transport equipment** and **basic metals and metal products**.

Source: [1] US Bureau of Labor Statistics (2023); McKinsey & Company (2020).

Appendix 1.1. Sector classification and statistical codes

Classification of sectors based on the UK Standard Industrial Classification (SIC)							
Classification	**Section**	**Division**	**Description**	**Classification**	**Section**	**Division**	**Description**
Low/medium-tech manufacturing	C	10–12	Food products, beverages and tobacco	Knowledge-intensive services	J	58–63	Information and communication
	C	13–15	Textiles, wearing apparel, leather and related products		K	64–66	Financial and insurance activities
	C	16–18	Wood and paper products, and printing		M	69–82	Professional, scientific and technical activities
	C	19	Coke and refined petroleum products		P	85	Education
	C	22–23	Rubber and plastics products, and other non-metallic mineral products	Labour-intensive services	G	45–47	Wholesale and retail trade, repair of motor vehicles and motorcycles
	C	24–25	Basic metals and fabricated metal products, except machinery and equipment		H	49–53	Transportation and storage
	C	31–33	Furniture; other manufacturing; repair and installation of machinery and equipment		I	55–56	Accommodation and food service activities
Medium/high-tech manufacturing	C	20	Chemicals and chemical products		L	68	Real estate activities
	C	21	Basic pharmaceutical products and pharmaceutical preparations		N	77–82	Administrative and support service activities
	C	26	Computer, electronic and optical products		O	84	Public administration and defence; compulsory social security
	C	27	Electrical equipment		Q	86–88	Human health and social work activities
	C	28	Machinery and equipment n.e.c.		R	90–93	Arts, entertainment and recreation
	C	29	Motor vehicles, trailers and semi-trailers		S	94–96	Other service activities
	C	30	Other transport equipment		T	97–98	Activities of households as employers; undifferentiated activities of households for own use
Other production	A	01–03	Agriculture, hunting, forestry and fishing	Utilities	D	35	Electricity, gas, steam and air conditioning supply – utilities
	B	05–09	Mining and quarrying		E	36–39	Water supply; sewerage, waste management and remediation activities – utilities
	F	41–43	Construction				

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THEME TWO

Investment in innovation

Is the UK spending enough on R&D?

How do the public and private sectors contribute to national expenditure on innovation?

How does the UK perform at different stages of innovation?

Theme 2: Investment in innovation

KEY FINDINGS

The UK is considered to be a leading global hub for scientific knowledge.

- **The UK** produces more academic publications than any other country, except **China** and **the US**, but 57% more than **the US** and six times more than **China** in per capita terms.
- **The UK** is the world leader in field-weighted citation impact (FWCI), a common benchmark for research quality.

However, the UK falls behind in converting scientific knowledge into commercial success.

- Compared to **the US**, **the UK** lags behind in **development** and **scale-up** metrics.
- The proportion of the workforce employed in **medium and high value added manufacturing** is lower than in competitor nations, and the **value added per worker** in these sectors is less than half of that in the US.

The UK's spending on R&D is higher than the average of the OECD countries, but it is still below that of leading nations.

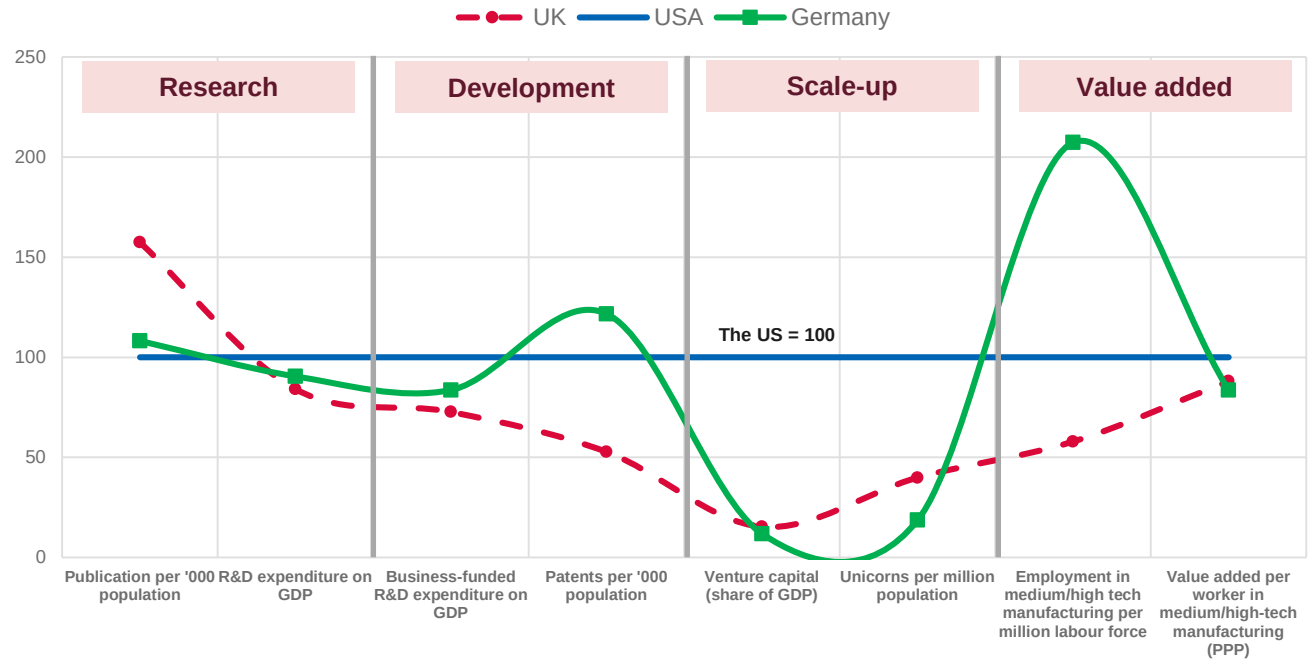
- **The UK's** gross domestic expenditure on **research and development (GERD)** as a share of GDP was **2.91%** in 2021, above the **OECD** average of **2.72%**. However, **the UK** still lags behind countries such as **Korea**, **the US**, **Japan** and **Germany**.
- In 2021, UK government-funded R&D amounted to 0.57% of GDP, below the OECD average of 0.63%.

Among the top 100 R&D-investing companies in the world, only three have headquarters in the UK.

- This is quite low, considering that in 2022 **the UK** was home to a total of 95 of the world's top 2,500 **R&D-investing** companies.
- **The UK** ranks fifth behind **the US**, which has 827; **China**, which has 679; **Japan**, which has 229; and **Germany**, which has 113 such companies.

Chart 2.1. The UK's performance in research, development, scale-up and industrial value added compared

Index, the US = 100, 2023 or latest available



US	2.14	3.46%	2.35%	1.55	0.75%	1.98	39,172	$ 203,073
UK	3.36	2.91%	1.71%	0.82	0.11%	0.79	22,687	$ 178,763
Germany	2.31	3.13%	1.96%	1.88	0.09%	0.37	81,200	$ 169,685

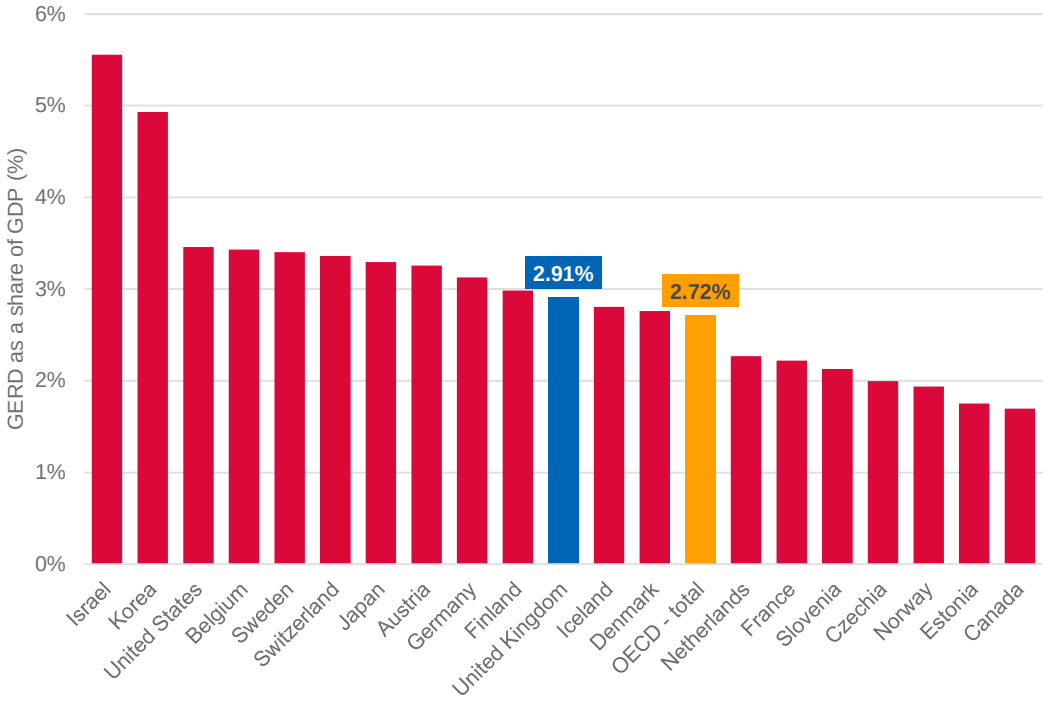
Note: Medium/high-tech manufacturing includes: chemical products; pharmaceuticals; computer and electronics, electrical equipment; machinery and equipment n.e.c; automotive and aerospace.
Source: Publication – DSIT (2022). International comparison of the UK research base, 2022; R&D expenditure on GDP, and Business-funded R&D on GDP – OECD (2023). Main Science and Technology Indicators, September edition; Patents – WIPO (2023) Database: Indicator:1 – Total patent applications (direct and PCT national phase entries); Venture Capital – OECD (2023). Venture capital investments Unicorns – CB Insights (2023). Global Unicorn Club; Employment and value added data – OECD (2024). National Accounts; Population and labour force data – World Bank (2024). World Development Indicators.

- **The UK** is a leading global research hub, producing more academic publications than any other country, after **China** and **the US,** but **57%** more than **the US** and six times more than **China** in per capita terms.[1]
- In **field-weighted citation impact** (FWCI), a common benchmark for research quality, **the UK** comes top in the world. In 2020 **the UK's** FWCI was **57%** higher than the world average and **34%** higher than **the EU 27** average.[1]
- Compared to **the US**, **the UK** lags behind in **development** and **scale-up** metrics like business-funded R&D, patents, venture capital and the creation of unicorns.
- The proportion of the workforce employed in **medium and high value-added manufacturing** is lower than in competitor nations. In absolute terms, **value added per worker** in these sectors is less than in **the US**.

Note: [1] Data refers to 2020 – DSIT (2022) International comparison of the UK research base.

Chart 2.2. R&D intensity: international comparison

Gross domestic expenditure on R&D (GERD) as a share of GDP, %, 2021



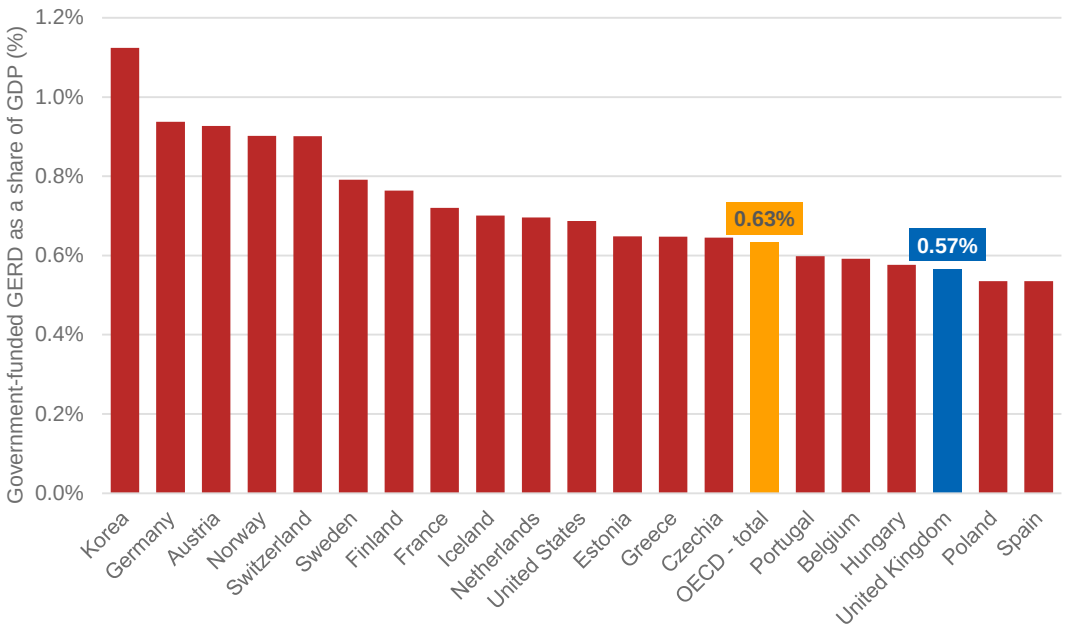
Source: OECD (2023). Main Science and Technology Indicators, September edition.

- **The latest OECD estimate of the UK's gross domestic expenditure on research and development (GERD) as a share of GDP was 2.91% in 2021, above the OECD average of 2.72%.**
- **The UK** lags behind countries such as **Korea, the US, Japan** and **Germany,** which in 2021 invested between **3.13%** and **4.93%** of their GDP in R&D.
- In 2022 the UK's Office for National Statistics (ONS) introduced major revisions to the way in which GERD, performed by **the business sector** and the **higher education sector**, is measured.[1]
- Based on the ONS revised methodology, **the UK's GERD amounted to £66.2 billion in 2021**, an increase of £4.3 billion from 2020.[2]
- As of February 2024, ONS had not published the official estimates of GERD on GDP incorporating the methodological revisions introduced in 2022.
- For 2020, the Department for Science, Innovation and Technology (DSIT) estimated **the UK's R&D** intensity to be between 2.9% and 3.0%.[3]

Note: [1] ONS (2022). Gross domestic expenditure on research and development, UK: 2020 (published on 22 November 2022). See also Section 2 of the 2023 edition of the *UK Innovation Report*.
[2] ONS (2023). Gross domestic expenditure on research and development, UK: 2021 (published on 17 July 2023).
[3] Nurse, P. (2023). *Independent Review of the Research, Development and Innovation Organisational Landscape – Final Report and Recommendations.*

Chart 2.3. Government-funded expenditure on R&D

Share of GDP, %, 2021



Note: Data for Israel and Denmark is not available.
Source: OECD (2023). Main Science and Technology Indicators, September edition.

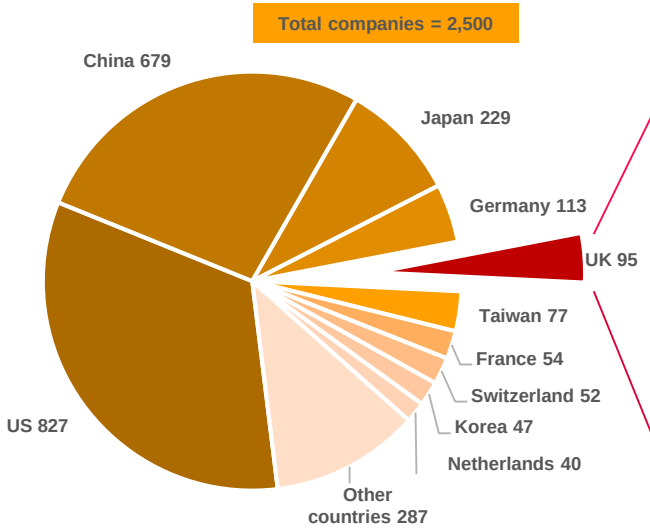
- The methodological revisions introduced by ONS to measure the expenditure on **R&D in the UK** have not impacted the R&D funded by the government.
- In **2021** the R&D funded by the government in **the UK**:[1]
  - amounted to **£12.8 billion**, an increase of £700 million from 2020; and
  - represented the second source of R&D funding, after the business sector, which contributed £38.7 billion, and before higher education (£5.6 billion), the private non-profit sector (£1.9 billion) and funding from overseas (£7 billion).
- In **2021** government-funded R&D represented **0.57%** of **the UK's** GDP, below **the OECD** average (**0.63%**).
- The government contribution to R&D in countries at the top of this measure, such as **Korea**, **Germany** and **the US,** was between **0.69%** and **1.12%** of GDP.

Note: [1] For the UK, government includes central government, UK Research and Innovation, and the Higher Education Funding Councils. ONS (2023). Gross domestic expenditure on research and development, UK: 2021 (published on 17 July 2023).

Chart 2.4. Top R&D-investing companies in the world

Top 10 countries by number of companies, and main sectors in the UK, 2022

Number of companies, by country's headquarters



Main sectors in the UK

United Kingdom	
Sector	**Number of companies**
Pharmaceuticals and biotechnology	17
Electronic and electrical equipment	8
Software and computer services	8
Support services	6
Automobiles and parts	5
General retailers	4
Healthcare equipment and services	4
Industrial engineering	4
Personal goods	4
Real estate investment and services	4
Travel and leisure	4
Rest of the economy	27
Total	**95**

- **In 2022, among the top 100 R&D-investing companies in the world, only three companies had headquarters in the UK:** AstraZeneca (14th) and GSK (39th) in **the pharma and biotech sector**; and HSBC (86th) in **the banking sector**.
- **This is quite low, considering that the UK is home to 95 of the world's top 2,500 R&D-investing companies, ranking fifth in the world**, behind **the US**, which has 827; **China**, which has 679; **Japan**, which has 229; and **Germany**, which has 113 such companies.

Note: The 2023 *EU Industrial R&D Investment Scoreboard* provides economic and financial information on the world's top 2,500 firms investing in R&D. These companies have headquarters in 42 countries and over 1 million subsidiaries globally.
Source: European Commission (2023). The 2023 *EU Industrial R&D Investment Scoreboard*.

Chart 2.5. Patent applications in key technologies

Number of patent applications by top three patent offices and the UK, share of world patents, 2021

Total patents

World rank	Country	World share
1st	China	55.6%
2nd	US	15.7%
3rd	Japan	8.1%
	…	
	…	
10th	**UK**	**0.6%**

Artificial intelligence

World rank	Country	World share
1st	China	66.5%
2nd	US	16.9%
3rd	Korea	8.7%
	…	
	…	
10th	**UK**	**0.2%**

Biotechnology

World rank	Country	World share
1st	China	34.7%
2nd	US	13.8%
3rd	EPO*	7.5%
	…	
	…	
23rd	**UK**	**0.16%**

Telecommunication

World rank	Country	World share
1st	China	39.4%
2nd	US	21.2%
3rd	EPO*	8.2%
	…	
	…	
13th	**UK**	**0.3%**

Semiconductors

World rank	Country	World share
1st	China	33.4%
2nd	US	23.4%
3rd	Korea	11.1%
	…	
	…	
13th	**UK**	**0.1%**

Quantum technologies

World rank	Country	World share
1st	China	36.7%
2nd	US	35.5%
3rd	Korea	8.4%
	…	
	…	
10th	**UK**	**0.6%**

Note: *EPO = European Patent Office.
In the tables, only patent applications filed directly with national and regional offices are included. Utility models, design patents and plant patents are excluded. Data refers to published patent applications filed in 2021. See Appendix 2.1 for the correspondence table between International Patent Classification (IPC) symbols and the five technology fields.
Source: WIPO Statistics Database and EPO PATSTAT database (PATSTAT 2023 Autumn version).

- The *UK Science and Technology Framework,* released in March 2023, identified **five "critical technologies"** that will underpin the strategy approach to make **the UK** a science and technology superpower by 2030:[1]
  - *Artificial intelligence*
  - *Engineering biology*
  - *Future telecommunications*
  - *Semiconductors*
  - *Quantum technologies*
- The chart shows **the UK** patenting activity position in the five critical technologies by looking at the patent offices with the highest number of patent applications for each technology.
- Patent applicants may choose to file a patent where the invention is expected to have broader application and/or higher return.[2]
- In **2021** the UK Intellectual Property Office (**UKIPO**) ranked **10th** in the world for total patent applications, receiving **0.61%** of the total world patent applications, in a rank dominated by **China** and **the US**.
- **UKIPO** ranks between **10th** and **13th** position for four of the five critical technologies, with only the world share of patents in biotechnology at **23rd** position.

Note: [1] UK Gov (2023). The UK Science and Technology Framework
[2] WIPO (2019). Artificial Intelligence – Technology Trend.

Appendix 2.1. Correspondence table between the International Patent Classification (IPC) codes and the five technology fields

Technology areas	IPC codes	Sources
Semiconductors	H01L; H10	WIPO IP Statistics *Semiconductors is one of the fields of technology identified by WIPO. For further information, please refer to Concept of a Technology Classification for Country Comparisons and https://www.wipo.int/ipstats/en/
Biotechnology	(C07G; C07K; C12M; C12N; C12P; C12Q; C12R; C12S) not A61K	WIPO IP Statistics *Biotechnology is one of the fields of technology identified by WIPO. For further information, please refer to Concept of a Technology Classification for Country Comparisons and https://www.wipo.int/ipstats/en/
Telecommunication	G08C; H01P; H01Q; H04B; H04H; H04J; H04K; H04M; H04N001; H04N-007; H04N-011; H04Q; H04L; H04N21; H04W	WIPO IP Statistics *Telecommunication in this slide is to merge two technology fields identified by WIPO: telecommunications and digital communication. For further information, please refer to Concept of a Technology Classification for Country Comparisons and https://www.wipo.int/ipstats/en/
Quantum technology	H04L 9/08; H04L 9/12; H04L 9/00; H04K 1/00; H04B 10/00; H04B 10/04; H04L 9/32; H04B 10/70; H04B 10/06; H04B 10/30 **(quantum telecommunications)** G06N 99/00; G06N 1/00; H01L 29/06; H01L 39/22; H01L 29/66; G02F 3/00; H03K 19/195; H01L 29/02; G06E 3/00; G06F 15/00 **(quantum computation)** G01R 33/035; G01R 33/02; A61B 5/05; H01L 39/22; G01N 27/72; A61B 5/055; G01R 33/12; G01N 27/82; G01V 3/00; H01L 39/04 **(quantum sensor)** G04F 5/14; H03L 7/26; H01S 1/06; H03B 17/00; G04F 5/00; H01S 1/00; H03H 3/02; H03H 9/02; H03H 9/19 **(quantum timing and atomic clock)**	Patstat online (Patstat 2023 Autumn version) *The IPC codes used here to identify quantum-technology-related patents were applied by the UK Intellectual Property Office in the Eight Great Technologies Quantum Technologies A patent overview report.
Artificial intelligence	G06F19/24; G06N3; G06N5; G06N7/02; G06N7/04; G06N7/06; G06N20; G06T1/40; G16B40/20; G16B40/30; G16C20/70	Patstat online (Patstat 2023 Autumn version) *The IPC codes used here to identify AI-related patents were applied by the UK Intellectual Property Office in the Artificial Intelligence A worldwide overview of AI patents and patenting by the UK AI sector report.

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THEME THREE

Industrial performance

– focus on the UK machinery and equipment (M&E) manufacturing sector

How does the UK machinery and equipment (M&E) manufacturing sector perform in international comparison?

Is the UK M&E sector investing enough in R&D compared to the rest of UK manufacturing?

What are the drivers behind the productivity, value added and employment economic trends in the UK M&E sector?

Theme 3: Machinery and equipment manufacturing sector

KEY TRENDS

The UK machinery and equipment (M&E) sector is a major global player, but some sub-sectors have contracted significantly.

- According to OECD data, **the UK** ranked among the top players in the world by value added in 2021, behind **Japan**, **the US**, **Germany** and **Italy** but ahead of **the Netherlands**, **France** and **Switzerland**.
- Between 2008 and 2021, value added in some M&E sub-sectors experienced substantial expansion, with **other general-purpose machinery** and **lifting and handling equipment** growing by 41% and 36%, respectively. Conversely, some sub-sectors have experienced a significant contraction, particularly **other engines** and **machinery for plastic and rubber**, which declined by 50% and 90%, respectively.
- Overall, value added in the **M&E sector** contracted from £13.1 billion in 2008 to £12.5 billion in 2021. However, the productivity of the **M&E** sector remains 37% higher than the average productivity of the whole **manufacturing sector** and 60% higher than the whole economy.

A decline in employment across 17 out of 21 UK M&E sub-sectors resulted in a loss of 28,000 jobs between 2011 and 2021.

- The **UK M&E sector** ranked sixth in terms of employment among **OECD** countries in 2021, employing 162,000 people.
- This represents a loss of 28,000 jobs compared to 2011, amounting to a 15% reduction over the course of 10 years.
- Among **M&E sub-sectors**, the most significant job losses between 2011 and 2021 were reported in **machinery for mining, quarrying and construction** (-5,300), **machinery for plastics and rubber** (-4,000), **office machinery** (-3,200) and **pumps and compressors** (-3,200).

While the UK is the 10th largest M&E exporter in the world, the country has one of the largest trade deficits.

- The **UK's** trade deficit in the **M&E sector** more than tripled between 2011 and 2022, ranking 176th out of 188 countries in trade balance.
- The largest **UK M&E sub-sectors** by trade value in 2022 were **other engines** and **machinery for mining, quarrying and construction**.
- **China**, the largest M&E exporter, has been gradually gaining market share at the expense of other competitor countries.

Growth of business expenditure on R&D (BERD) in the UK M&E sector has been slower than in the manufacturing sector as a whole.

- Business expenditure on R&D (BERD) in the **M&E sector** represented 5.9% of total BERD in the **UK manufacturing sector** in 2022.
- BERD in the **UK M&E sector** rose from £0.7 billion in 2000 to £1 billion in 2020, with a compound annual growth rate (CAGR) of 1.9%.
- This is lower than the compound annual growth rate observed for overall **UK** manufacturing (2.9%) during the same period.

Theme 3: Machinery and equipment manufacturing sector

KEY DRIVERS

- **The M&E market depends on demand from other sectors and is typically sensitive to economic cycles.** The UK M&E sector aggregates many sub-sectors, which are quite distinct from each other and which respond differently to economic cycles. Sales orders in the M&E sector are usually tied to the long-term investment plans of other sectors. In periods of economic uncertainty, these plans are often postponed.
- **High production costs, political uncertainty and foreign ownership are among the factors influencing offshoring decisions in some sub-sectors.** Reasons for offshoring appear to be the loss of key suppliers and high production costs in the UK. For example, the fluid power equipment and the valves and actuators sub-sectors are affected by the high cost and low availability of steel in the UK. As a result, many products are designed in the UK but manufactured in China. The UK's exit from the EU has contributed to the consolidation in Europe of manufacturing in the pumps and compressors sub-sector, which is dominated by European firms.
- **Changes in regulations, intra-industry trade and policy changes in export markets may have impacted UK imports and exports.** New trade rules with the EU have impacted the ability of SMEs to export to Europe. The decision to move away from the European CE conformity assessment marking, and to create a UK-specific UKCA marking, followed by a reversal of this decision, has also affected some sub-sectors. New regulations require certain valves to be tested within China by a local inspector, adding costs to qualify for the Chinese market.
- **Labour shortages have impacted growth and incentivised automation across sub-sectors.** The consulted firms reported difficulties hiring younger and more diverse workers for the sector. These difficulties cut across sub-sectors and functions, affecting both engineering and technician positions. New skills are also needed, for example, cyber-security, robotics, IoT, advanced manufacturing, cloud and big data. Investments in automation and factory optimisation have been occurring in the sector and partly explain the reduction in employment.
- **R&D investment decisions in the UK M&E sector are often made abroad.** There is a dominant presence of foreign-owned original equipment manufacturers (OEMs) and distributors across UK M&E sub-sectors. The consulted stakeholders perceive UK M&E companies to be less R&D-intensive than foreign ones, except for some large internationally competitive firms. The UK M&E sector is dominated by SMEs, which might have fewer resources available for R&D and fewer advisory and support options from the broader innovation ecosystem than large firms.
- **Sustainability, digitalisation and materials research trends have shaped the direction of innovation efforts in recent years.** Emissions regulations, such as those for non-road mobile machinery, and net-zero targets make it imperative to develop more energy-efficient and environmentally sustainable machines and equipment.

Machinery and equipment(M&E) manufacturing – statistical definition*

This report uses the statistical definition applied by the UK Office of National Statistics (ONS) – UK SIC 2007 code Division 28: Manufacture of machinery and equipment n.e.c., which includes:

- Group 28.1: Manufacture of general purpose machinery
  - Other engines; fluid power equipment; other pumps and compressors; other taps and valves; and bearings, gears, gearing and driving elements.
- Group 28.2: Manufacture of other general-purpose machinery
  - Ovens, furnaces and furnace burners; lifting and handling equipment; office machinery; power-driven hand tools; non-domestic cooling and ventilation equipment; other general-purpose machinery n.e.c.
- Group 28.3: Manufacture of agricultural and forestry machinery
- Group 28.4: Manufacture of metal forming machinery and machine tools
- Group 28.9: Manufacture of other special-purpose machinery
  - Machinery for metallurgy; machinery for mining, quarrying and construction; machinery for food, beverage and tobacco processing; machinery for textile, apparel and leather production; machinery for paper and paperboard production; plastics and rubber machinery; and other special-purpose machinery n.e.c..

The definition excludes:

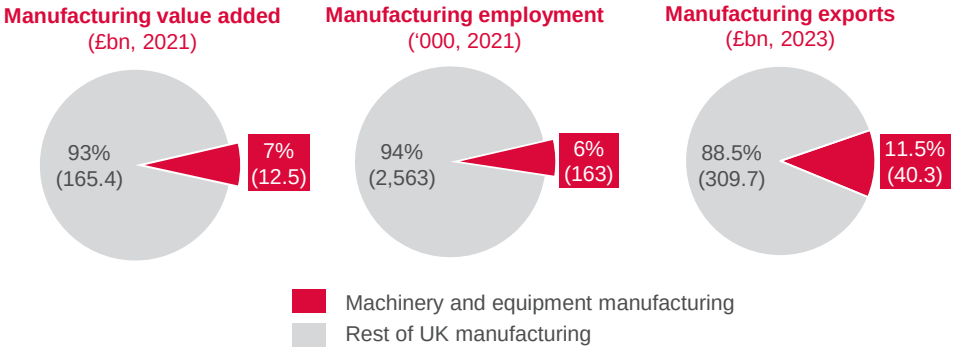
The manufacture of metal products for general use, associated control devices, computer equipment, measurement and testing equipment, electricity distribution and control apparatus, and general-purpose motor vehicles.

***Note:** the repair and maintenance services of machinery and equipment are coded in Class 33.12 in the UK SIC 2007. For the detailed statistical definition for each subsector within the machinery and equipment manufacturing, please refer to the UK Standard Industrial Classification (SIC) Hierarchy published by the ONS
Source: ONS, 2023.

Chart 3.1. Machinery and equipment (M&E) manufacturing – contribution to the UK economy

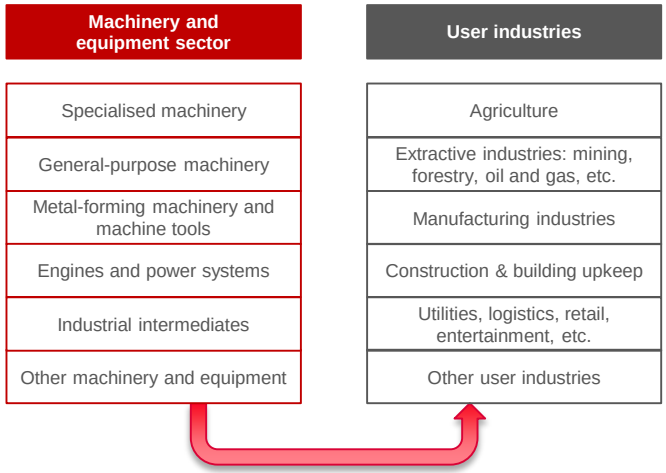
The sector contributes significantly to the UK economy, not only on its own but also through its impact on other sectors

M&E *direct* contribution to the UK economy



M&E *indirect* contribution to the UK economy

- Suppliers of technology for industrial and service businesses
- Role in the diffusion of innovations and retrofitting/upgrading
- Determinant of factory productivity



Source: ONS (2023). Annual business survey; ONS (2012–22). Business register and employment survey; ONS (2023). EMP13: Employment by industry; ONS (2024). UK trade in goods by classification of product by activity time series.

Chart 3.2. Machinery and equipment (M&E) manufacturing – value added, employment and labour productivity

Top 10 OECD countries by value added in 2021

Rank	OECD Country	Value added (billion USD)	Employment (thousand persons)	Labour productivity (value added per employee) (thousand USD)
1	US	174.3	1170	149.0
2	Japan	154.9	1661	93.2
3	Germany	131.6	1145	114.9
4	Italy	48.1	477	100.8
5	**UK**	**22.2**	**162**	**137.1**
6	Netherlands	21.8	93	234.7
7	France	14.7	148	99.1
8	Switzerland	13.1	73	179.5
9	Sweden	13.0	80	163.1
10	Mexico	12.0	376	32.0

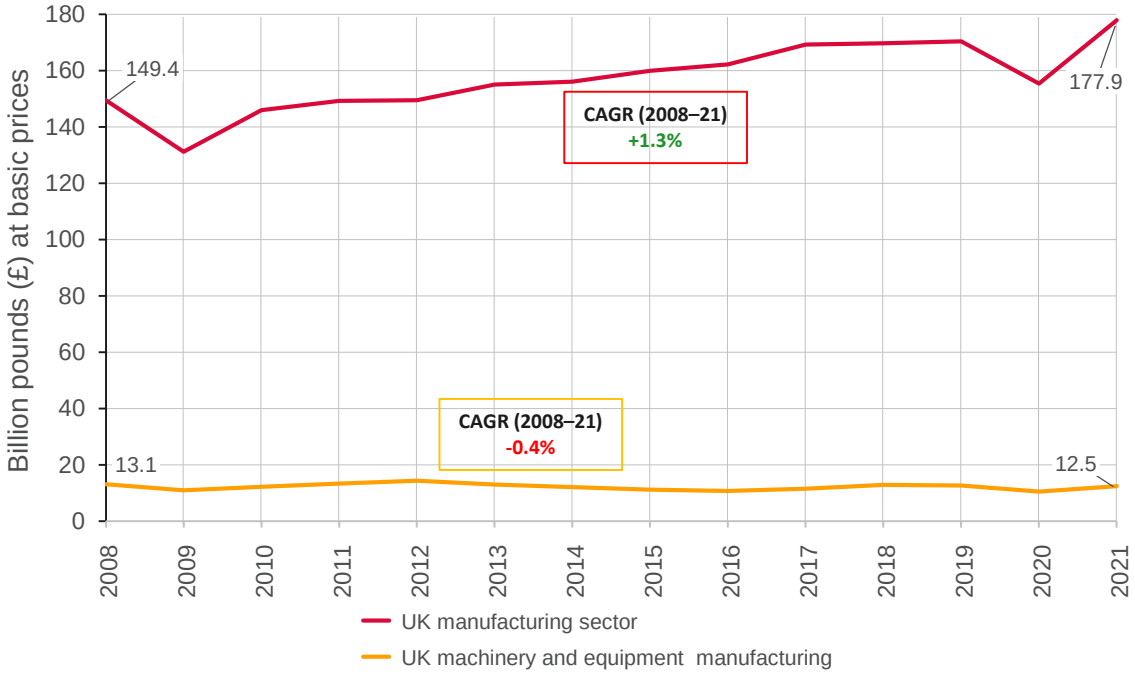
Note: OECD provides the value added for each country in its national currency in current prices; these were converted into USD by referring to annual exchange rates provided by OECD. Labour productivity is estimated as value added divided by employment.
Source: OECD data explorer. Annual value added and its components by economic activity (accessed in February 2024); OECD data explorer. Exchange rates (accessed in February 2024); OECD data explorer. Annual employment by detailed economic activity, domestic concept (accessed in January 2024).

- Based on **OECD** data, **the UK** ranked fifth among member countries by **machinery and equipment (M&E)** manufacturing value added in 2021, behind **Japan**, **the US**, **Germany** and **Italy** but ahead of the **Netherlands**, **France** and **Switzerland** [1].
- The **M&E** value added for **the US** was eight times larger than for **the UK** in 2021.
- In terms of employment, **the UK** ranked sixth among OECD member countries, with 162,000 people employed in the sector, below **the US**, **Japan**, **Germany**, **Italy** and **Mexico**.
- A labour productivity value of USD137,100 per employee places **the UK M&E sector** fifth among OECD comparator nations, ahead of countries such as **Japan**, **Germany** and **Italy**.
- The consulted stakeholders suggested that the high productivity of **the Netherlands** could be attributed to its focus on high value-added **M&E** segments such as machinery for semiconductors.
- The **UK** is **Europe's** leading producer of **construction equipment**, accounting for 28% of total European production, followed by **Germany** with 21% [2].

[1] Data does not cover China, Korea or India.
[2] Construction Equipment Association (2023) The UK's Construction Equipment Sector Report 2023.

Chart 3.3. UK machinery and equipment (M&E) manufacturing – value added (1/2)

Billion pounds (£) at basic prices, 2008-21



Source: ONS (2023). Annual business survey.

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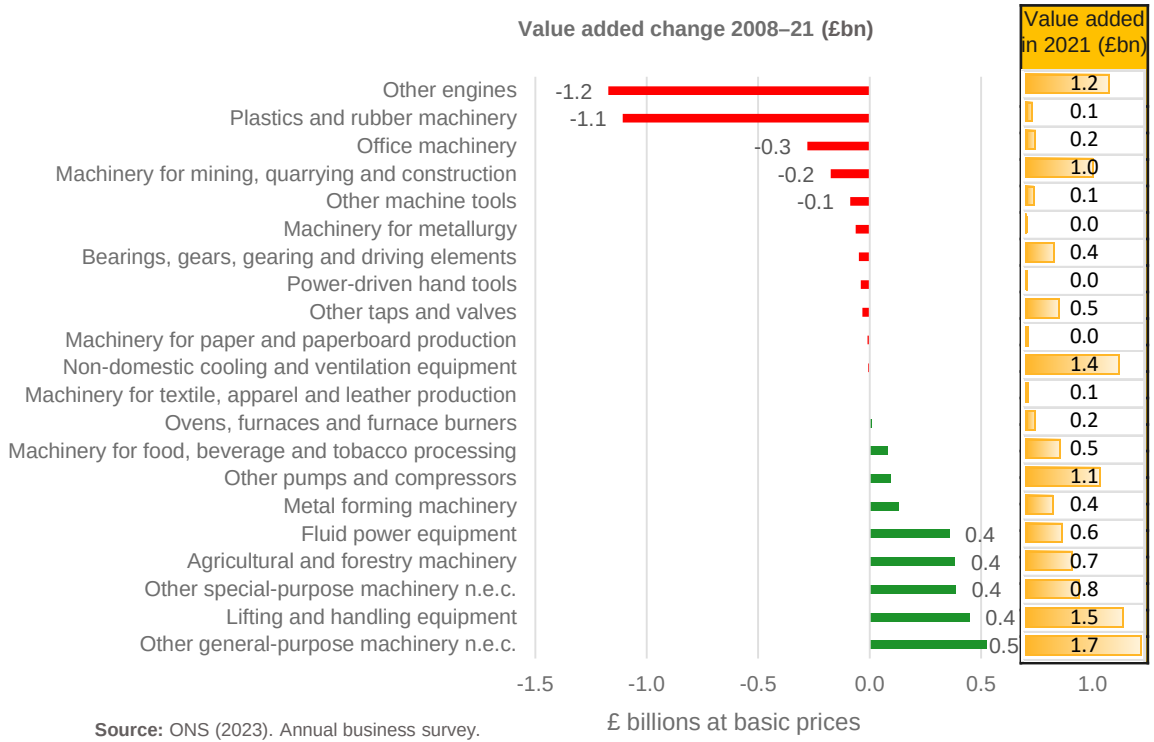
- According to ONS data, value added for **the UK M&E sector** experienced a contraction between 2008 and 2021, with a compound annual growth rate (CAGR) of -0.4%.
- In contrast, value added for **the UK manufacturing sector** grew with a compound annual growth rate (CAGR) of 1.3% during the same period.
- **The UK M&E sector** aggregates many sub-sectors that are quite distinct from one another and that show variable degrees of sensitivity to economic cycles and instability.
- In general, sales orders are tied to the long-term investment plans of other companies. In periods of economic uncertainty, these plans are often postponed. For example, a large share of demand for **valves and actuators** comes from **the oil and gas sector** and is indirectly affected by global oil prices and investments in oil and gas projects.
- The consulted stakeholders pointed out that **M&E** sectoral growth may have been constrained by regulatory uncertainties, rising costs and the loss of key suppliers, which could have resulted in the offshoring of various operations. For example, offshoring in the **fluid power equipment** and the **valves and actuators** subsectors have been driven by labour and energy costs and low availability of raw materials such as steel in the UK.

Chart 3.4. UK machinery and equipment (M&E) manufacturing – value added (2/2)

Value added by sub-sector, billion pounds (£) at basic prices, 2008-21



Source: ONS (2023). Annual business survey.

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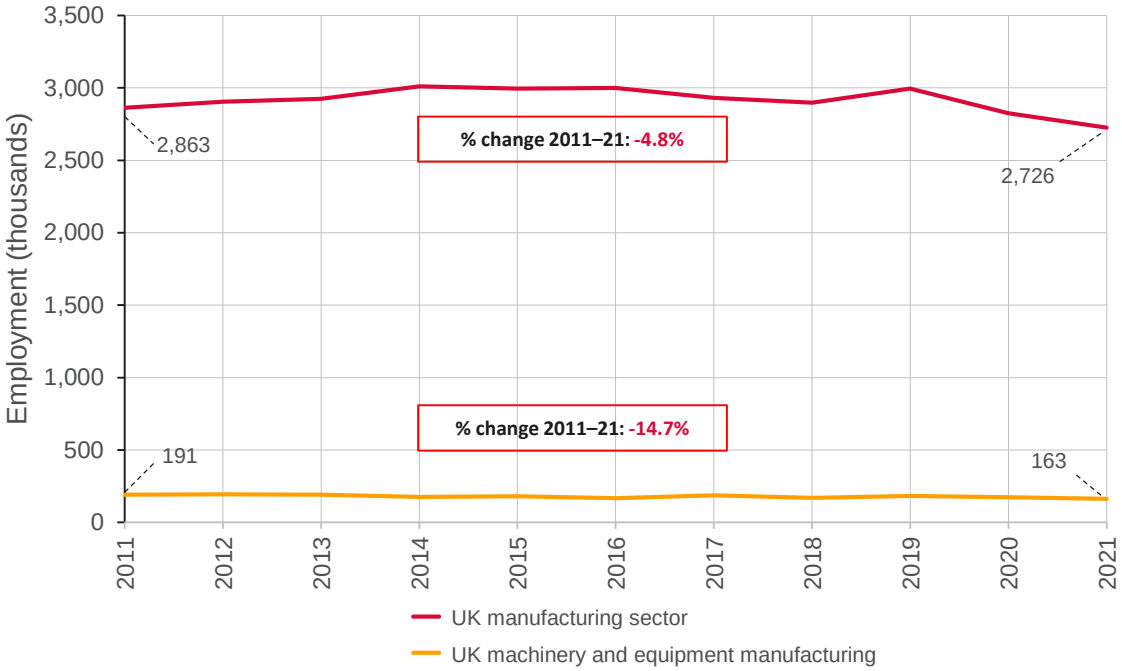
- Within **M&E** sub-sectors**, other engines**[1] and **machinery for plastic and rubber** were the sub-sectors that experienced the highest reduction in value added between 2008 and 2021, losing £1.2 billion (50%) and £1.1 billion (90%), respectively.
- In contrast, **lifting and handling equipment** and **other general-purpose machinery** experienced the highest value added increments during the same period, gaining £0.4 billion (41%) and £0.5 billion (36%), respectively, becoming the two sub-sectors with the largest value added in 2021.
- Other sectors that experienced significant value added growth between 2008 and 2021 include **other special-purpose machinery, agricultural and forestry machinery,** and **fluid power equipment.**

[1] "Other engines" includes the manufacturing of internal combustion engines, steam and other vapour turbines, hydraulic turbines, and wind and gas turbines. In addition, this sub-sector includes the manufacturing of parts such as pistons, piston rings, carburettors and exhaust valves. The manufacturing of motor vehicle, aircraft and cycle propulsion engines and generator sets is excluded from this sub-sector.

Chart 3.5. UK machinery and equipment (M&E) manufacturing – employment (1/2)

Machinery and equipment (M&E) and total manufacturing, 2011-21

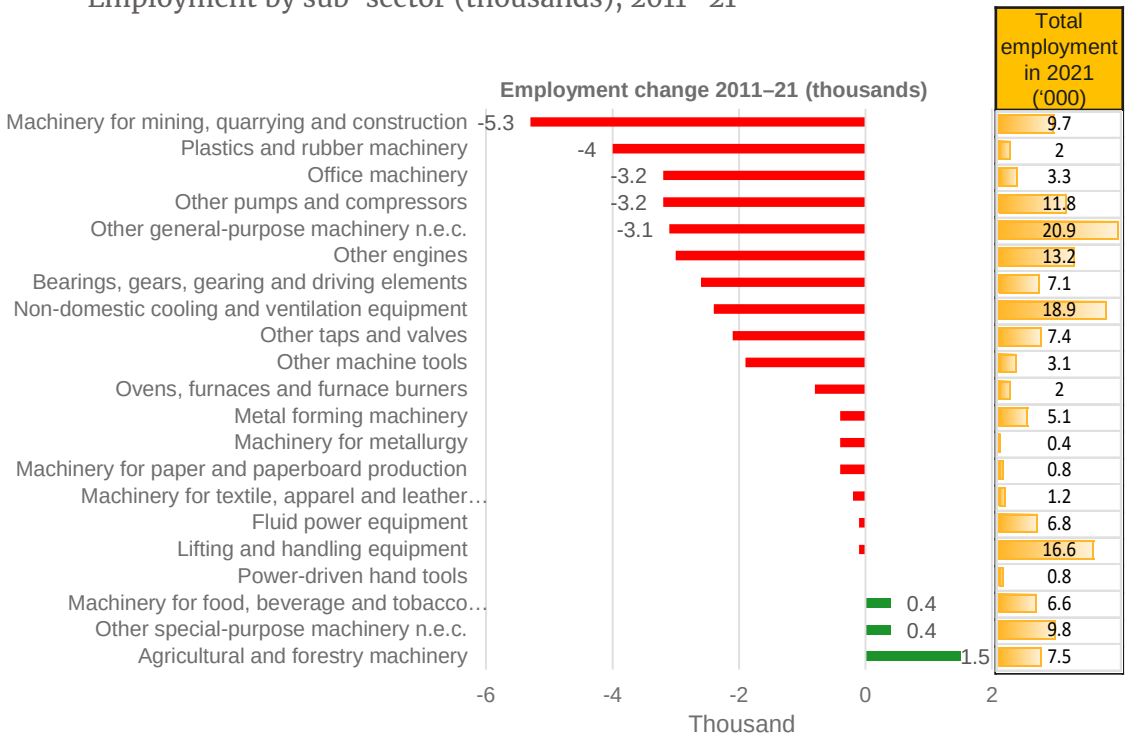


Note: Employment figures include employees and self-employed.
Source: ONS (2012–22). Business register and employment survey; ONS (2023). EMP13: Employment by industry.

- With 163,000 total employment in 2021, **the UK M&E sector** employed 28,000 fewer people than in 2011 (14.7% reduction).
- This reduction is higher than that experienced by **the UK manufacturing sector**, which employed 2.7 million people in 2021, around 4.8% fewer than in 2011.
- Despite the fall in employment, the consulted stakeholders reported difficulties hiring younger and more diverse workers for the sector. New entrants are also seen as not having the right specialised skills. These difficulties cut across sub-sectors and functions, affecting both engineering and technician positions.
- According to consulted stakeholders, some companies used the idle periods and furlough schemes of the pandemic as an opportunity to automate and rationalise their operations, often leading to reductions in headcount. However, automation does not fully explain the recent downward trend in **UK** employment in this sector, which could also be attributed to the poor performance of some sub-sectors.

Chart 3.6. UK machinery and equipment (M&E) manufacturing – employment (2/2)

Employment by sub-sector (thousands), 2011–21



Note: Employment data for Great Britain only; data for Northern Ireland unavailable.
Source: ONS (2012–22). Business register and employment survey.

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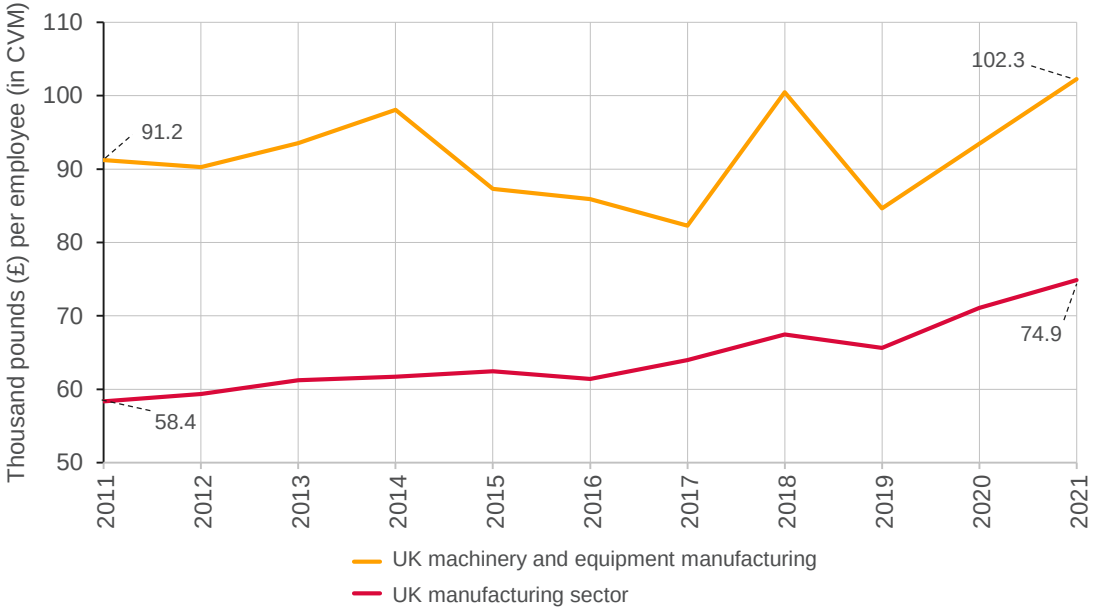
- The 28,000 reduction in employment experienced by **the UK M&E sector** between 2011 and 2021 can be attributed to a loss in employment in 17 out of 21 sub-sectors.
- **Machinery for mining, quarrying and construction** (-5,300), **for plastics and rubber** (-4,000), **office machinery** (-3,200), **pumps and compressors** (-3,200) and **other general-purpose machinery** (-3,100) experienced the highest reductions in employment.
- **Machinery for food, beverages and tobacco** (+400), **other special purposes** (+400) and **agriculture and forestry** (+1,500) were the only sub-sectors to increase their employment levels during the same period.
- In absolute terms, **the UK M&E sub-sectors** with the highest employment in 2021 were **other general-purpose machinery** (20,900), **non-domestic ventilation and cooling equipment** (18,900), **lifting and handling equipment** (16,600)**, other engines** (13,200) and **other pumps and compressors** (11,800). Together, these sub-sectors accounted for 52.5% of total employment in **the UK M&E sector** in 2021.

Chart 3.7. UK machinery and equipment (M&E) manufacturing – labour productivity

Value added (VA) per employee (£ thousand in chained volume measure – CVM)



Note: Productivity estimated as value added divided by number of employed; productivity data corresponds to the whole machinery and equipment (M&E) sector. Data for each M&E sub-sector might show different trends.
Source: ONS (2024). GDP output approach – low-level aggregates; ONS (2012–22). Business register and employment survey; ONS (2023). EMP13: Employment by industry.

- In 2021 productivity of the **M&E sector** was 37% higher than the average productivity of the whole manufacturing sector and 60% higher than the whole economy.
- Overall, **the UK M&E sector's** productivity (measured in value added per employee) was higher in 2021 than 2011, mostly driven by a reduction in employment during this period.
- Productivity in **the UK M&E sector** has remained consistently higher than **the UK manufacturing sector** as a whole between 2011 and 2021.
- Despite this gap, the difference between **M&E** productivity and the productivity of **the UK manufacturing sector** narrowed, from £32,800 per employee in 2011 to £27,400 per employee in 2021.

Chart 3.8. Machinery and equipment (M&E) manufacturing – trade balance

Global ranking by trade balance in M&E manufacturing, 2011 and 2022

Trade balance 2011		
Rank*	Country	USD billion
1	Germany	127.3
2	Japan	125.3
3	Italy	61.6
4	Netherlands	15.0
5	Switzerland	12.1
…		
144	**UK**	**-2.0**
…		
187	Canada	-24.6
188	Russian Federation	-38.5

Trade balance 2022		
Rank*	Country	USD billion
1	China	167.5
2	Germany	102.2
3	Japan	89.7
4	Italy	50.1
5	Netherlands	21.7
…		
176	**UK**	**-7.2**
…		
187	Canada	-30.8
188	US	-102.5

UK exports		
2011 (USD billion)	2022 (USD billion)	CAGR (2011–22)
44.2	42.0	-0.5%

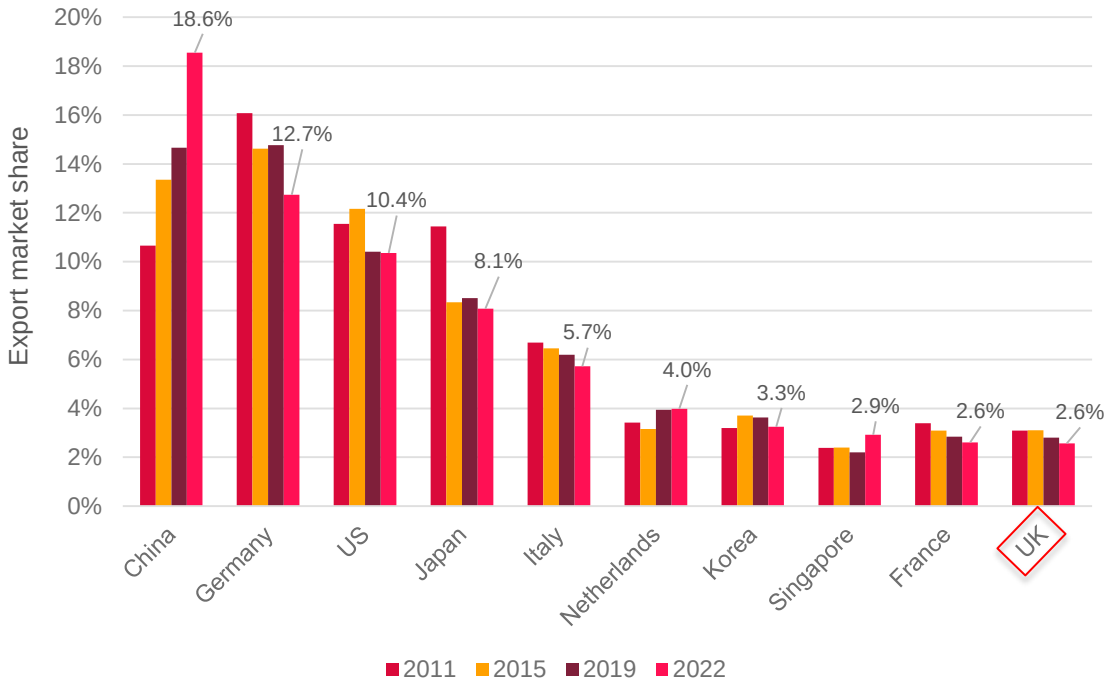
UK imports		
2011 (USD billion)	2022 (USD billion)	CAGR (2011–22)
46.1	49.2	0.6%

Note: *The mapping between SIC 2007 code and HS code is based on the "Correspondence Tables" published by OECD. Appendix 3.1 provides the summary for the mapping. For more information, please refer to the Correspondance Tables for Classification Codes published by ONS in April 2020.
Source: UN Comtrade (accessed February 2024).

- Based on **UN** trade data, **the UK** trade deficit in the **M&E sector** widened to USD7.2 billion in 2022 from USD2 billion in 2011, driven by a **reduction in exports** (CAGR: -0.5%) and an **expansion in imports** (CAGR: 0.6%) during this period.
- The widening **M&E** trade deficit meant that **the UK** moved down to 176th position out of 188 countries in terms of trade balance in 2022.
- **China** climbed to the top of the trade balance ranking by becoming the top net exporter in the global **M&E sector** in 2022, while **the US** became the biggest net importer.
- New trade rules with **the EU** were mentioned by the consulted stakeholders as a factor influencing long-term investment decisions and trade. The rules have particularly impacted the ability of SMEs to export to **Europe**, as many lack the organisational capabilities to deal with the additional certifications and bureaucracy.
- As value chains become fragmented, and **UK** companies offshore their manufacturing activities, the trend in some sub-sectors is for companies to keep only the early stages (e.g. R&D and design) and final stages (e.g. testing, inspection, assembling and marketing) of production in **the UK**, which could explain a large share of the rise in imports in the country.

Chart 3.9. Machinery and equipment (M&E) manufacturing – global export market share

Top 10 countries by export market share in 2022



Source: UN Comtrade (accessed February 2024).

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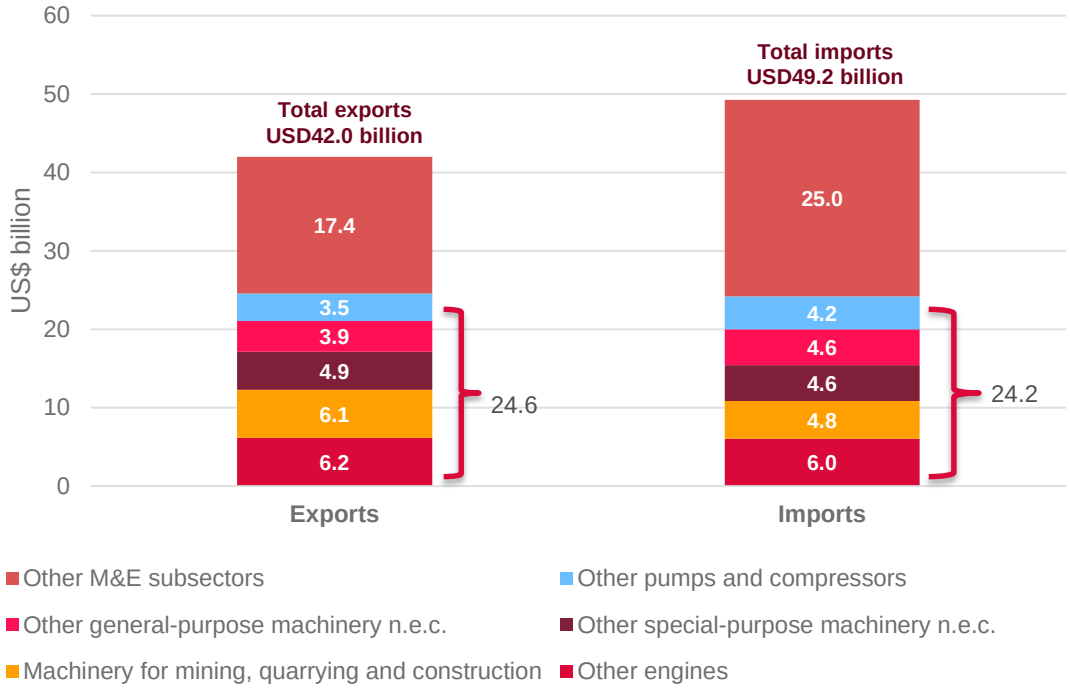
- **UK M&E** companies are highly export-oriented. The Construction Equipment Association (CEA) estimates that over 60% of UK's output in **construction equipment** is exported [1]. Similarly, the Manufacturing Technologies Association (MTA) calculates that over 80% of UK **machine tools**, **cutting tools** and **tool/work-holding equipment** production was exported in 2021 [2].
- **The UK** had the 10th largest global market share (2.6%) in **M&E** goods in 2022, down from 3.1% in 2011.
- **China** had the largest export market share in 2022, increasing from 10.7% to 18.6% and overtaking **Germany**, **the US** and **Japan.**
- In 2022, the top 10 global exporters of **M&E** manufacturing goods accounted for 71% of the global market.[1]
- **Equipment for semiconductor manufacturing** was the top export category for **the US** (USD17.6 billion), **Japan** (USD18.9 billion), **the Netherlands** (USD17.4 billion) and **Singapore** (USD13.5 billion) in 2022.[3]
- For **the UK**, the **M&E** product with the highest export value in 2022 was **other diesel or semi-diesel engines**.[4]

[1] Construction Equipment Association (2023) The UK's Construction Equipment Sector Report 2023
[2] Manufacturing Technologies Association (2023) Basic Facts 2023
[3] UN Comtrade.
[4] UN Comtrade items under other diesel or semi-diesel engines include engines and compression-ignition internal combustion piston engines (diesel or semi-diesel engines), of a kind used for other than marine propulsion or vehicles.

Chart 3.10. UK machinery and equipment (M&E) manufacturing – exports and imports

Top UK machinery and equipment (M&E) sub-sectors, USD billion, 2022

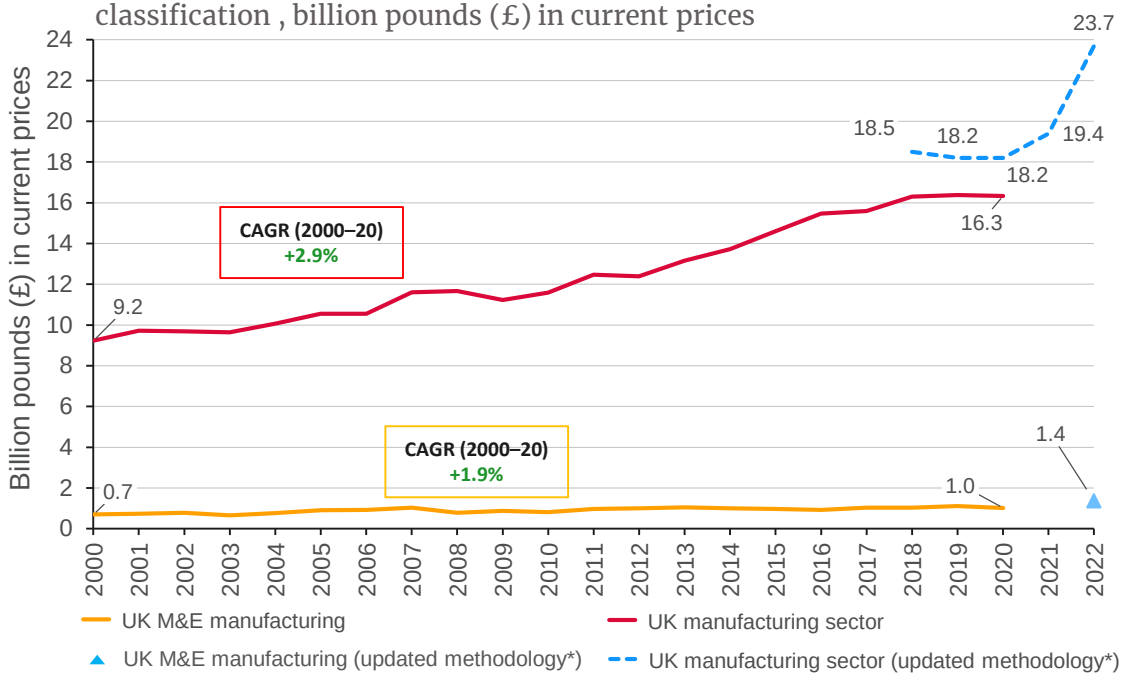


Source: UN Comtrade (accessed February 2024).

- In 2022 the top five **UK M&E sub-sectors** accounted for 58.6% of exports and 49.2% of imports of the total sector.
- Of these five sub-sectors, **pumps and compressors** and **other general-purpose machinery** had trade deficits of USD0.7 billion each.
- In contrast, **machinery for other special purposes**, **machinery for mining, quarrying and construction** and **other engines** had trade surpluses of USD0.3 billion, USD1.3 billion and USD0.2 billion, respectively.
- Overall, the largest **UK M&E sub-sectors** by trade value (considering both exports and imports) in 2022 were **other engines** and **machinery for mining, quarrying and construction**.

Chart 3.11. UK machinery and equipment (M&E) manufacturing – business spending on R&D

Business enterprise expenditure on R&D (BERD) by product group classification , billion pounds (£) in current prices



Note: Developed by ONS, the term "product group" refers to business R&D expenditure allocated to the product group that best describes the subject type of R&D activities carried out by firms, rather than being based on the economic activities SIC classification. *ONS has revised the methodology for BERD since 2022. Please see ONS (2023). Update on transformation of research and development statistics: November 2023.

Source: ONS (2021). Business enterprise research and development time series; ONS (2022). Business enterprise research and development, UK (designated as official statistics), worksheet 3: expenditure on R&D performed in UK businesses: broad product groups, 2018 to 2021 current prices (not designated as national statistics); ONS (2024). Business enterprise research and development, UK (designated as official statistics), worksheet 2: expenditure on R&D performed in UK businesses: detailed product groups, 2022 (not designated as national statistics).

- ONS data by product group classification shows that **the UK** business enterprise expenditure on R&D in the **M&E sector** was £1.4 billion in 2022, accounting for 5.9% of total **UK** BERD in the **manufacturing sector**.
- Business spending on R&D in **the UK M&E sector** increased from £0.7 billion in 2000 to £1 billion in 2020, with a compound annual growth rate (CAGR) of 1.9% during this period.
- The 1.9% annual growth rate was lower than the compound annual growth rate observed for **UK manufacturing** (2.9%) in the same period.
- ONS manufacturing BERD data, estimated with an updated methodology for 2018–22, shows a higher growth trend (dotted blue line) than data calculated using the previous methodology. The 2022 **M&E** BERD estimate obtained under the new methodology is 40% higher (£1.4 billion) than the last data point available for the old methodology in 2020 (£1 billion).
- The consulted stakeholders perceived **UK M&E** companies to be less R&D-intensive than foreign ones, except for some large internationally competitive firms, such as JCB and Cummins.
- Environmental sustainability and digitalisation were seen by interviewees as the main current drivers of R&D in the sector.

Drivers behind the trends in the machinery and equipment (M&E) manufacturing sector

Insights from the literature review and consultations with sector experts

What is driving value added, employment, productivity and trade trends in M&E manufacturing? (1)

Key trends identified

- The UK machinery and equipment (M&E) sector is a major global player, but some sub-sectors have contracted significantly.
- A decline in employment across 17 out of 21 UK M&E sub-sectors resulted in a loss of 28,000 jobs between 2011 and 2021.
- While the UK is the 10th largest M&E exporter in the world, the country has one of the largest trade deficits.

Potential drivers identified from the literature review and consultations with sector experts (see Appendix 3.2 for details)

The M&E market depends on demand from other sectors and is typically sensitive to domestic and global economic performance.

- **The UK M&E sector** aggregates many sub-sectors that are quite distinct from one another and which show variable degrees of sensitivity to economic cycles and instability. In general, sales orders are tied to the long-term investment plans of other companies. In periods of economic uncertainty, these plans are often postponed.
- For example, a large share of demand for valves and actuators comes from **the oil and gas** sector and is indirectly affected by global oil prices and the timing of investments in oil and gas projects. In the case of **mining, quarrying and construction equipment**, government investment (e.g. public works) is a crucial source of demand.

M&E sub-sectors show variable resilience levels to recession and external events.

- Events such as the COVID-19 pandemic affected the various segments of the sector differently. For example, while the consulted stakeholders mentioned that the value added for **machinery for mining, quarrying and construction** was acutely affected by the pandemic (and in 2021 had not recovered to pre-pandemic levels), **lifting and handling equipment**, **pumps and compressors**, **fluid power equipmen**t and **agricultural and forestry equipment** did not suffer the same effect and recovered well in 2021. In particular, segments such as **agricultural and forestry equipment** are not easily affected by external events, as they deal with essential products from sectors with inelastic demand, such as **agriculture**.
- In the case of **mining, quarrying and construction**, **UK** companies faced supply chain issues in the aftermath of the pandemic, which allowed **Chinese** firms to supply new equipment faster and may partly explain the increase in **M&E** imports observed after 2020. This effect may be observed in other sub-sectors such as **machinery for agriculture and forestry**.

High production costs, political uncertainty and foreign ownership are among the factors boosting offshoring in some sub-sectors.

- Across some sub-sectors, there has been a relocation of manufacturing activities to other locations in **Europe**, **the US** and **Asia**. This is driven by **UK** firms setting up facilities abroad and by **European** firms consolidating production in **Europe**. Key reasons for this movement appear to be the loss of key suppliers and high production costs in **the UK**.
- For example, offshoring in the **valves and actuators** industry has been driven by the high cost and low availability of raw materials such as steel in **the UK**, which represent 30%–50% of the final cost of products. This has led to a situation where many products are **UK-designed** but manufactured in subsidiary plants in **China** or other lower-cost countries.
- The **pumps and compressors** and **fluid power equipment** segments have also experienced offshoring, according to the consulted interviewees. **The UK's** exit from the **EU** contributed to the consolidation of manufacturing activities in Europe to facilitate exports to the **EU**, thus reducing manufacturing employment in **the UK**.

What is driving value added, employment, productivity and trade trends in M&E manufacturing? (2)

Key trends identified

- The UK machinery and equipment (M&E) sector is a major global player, but some sub-sectors have contracted significantly.
- A decline in employment across 17 out of 21 UK M&E sub-sectors resulted in a loss of 28,000 jobs between 2011 and 2021.
- While the UK is the 10th largest M&E exporter in the world, the country has one of the largest trade deficits.

Potential drivers identified from the literature review and consultations with sector experts (see Appendix 3.2 for details)

Changes in regulations, intra-industry trade and policy changes in export markets may have impacted UK imports and exports.

Changes in trade regulations and rules

- New trade rules with **the EU** were mentioned by the consulted stakeholders as a factor influencing long-term investment decisions. They have particularly impacted the ability of SMEs to export to **Europe**, as many do not have the organisational capabilities to deal with the additional certification and bureaucracy. The stakeholders also claimed the decision to move away from the European CE conformity assessment marking, and to create a UK-specific UKCA marking, followed by a reversal of this decision (DBT, 2023; DBT, 2024), has also affected some segments.
- Interviewed stakeholders suggested that **the UK** government's changes to its export promotion policy, focusing on a narrower selection of sectors, while closing down some export promotion units, has reduced sectoral promotion overseas. Slow processes for dual-use (civil and military) exports also affect the sector's ability to compete internationally in some segments.

Vertical disintegration

- As value chains become fragmented, and **UK** companies offshore their manufacturing activities, the trend in some sub-sectors is for companies to keep only the early stages (e.g. R&D and design) and final stages (e.g. testing, inspection and marketing) of production in **the UK**, which could explain a significant share of the rise in imports in the country.

Policy changes in export markets

- For example, the **Chinese** government has created extra requirements for foreign products to enter the country by implementing in-country mandatory auditing. In the **valves and actuators sector**, all valves of a certain specification will have to be tested in **China** by a local inspector, adding costs to qualify for the **Chinese** market, according to the interviewed stakeholders.

Labour shortages have impacted growth and incentivised automation across subsectors

- Consulted firms have reported difficulties in hiring younger and more diverse workers for the sector. The younger workforce is also seen as not having the right skills, especially the traditional mechanical and electrical skillsets which are essential for age-long sub-sectors, such as fluid power equipment, pumps and compressors. These difficulties cut across sub-sectors and functions, affecting both engineering and technician positions. New skills are also needed, for example, cybersecurity, robotics, IoT, advanced manufacturing, cloud, and Big Data (European Commission, 2021).
- According to consulted stakeholders, some companies used the idle periods of the pandemic and furlough schemes as an opportunity to automate and rationalise operations, often leading to reductions in headcount. The increasing productivity of the sector reflects these investments in production efficiency. However, automation does not fully explain the recent downward trend in **UK** employment in this sector, which could also be attributed to the poor performance in some sub-sectors.

What is driving business R&D expenditure trends in M&E manufacturing?

Key trend identified	• **Growth of business expenditure on R&D (BERD) in the UK M&E sector has been slower than in the manufacturing sector as a whole.**
Potential drivers identified from the literature review and consultations with sector experts (see Appendix 3.2 for details)	**The prominent presence of foreign-owned OEMs and distributors across UK M&E sub-sectors may impact BERD figures, with R&D investment decisions often made abroad.** ▪ Despite **the UK** having a high-quality R&D ecosystem, including the Catapult network and high-quality research institutions, the consulted stakeholders perceive **UK M&E** companies to be less R&D-intensive than foreign ones, except for some large internationally competitive firms, such as JCB and Cummins. The **UK M&E** sector is dominated by SMEs, which might have fewer resources available for R&D and fewer advisory and support options from the broader innovation ecosystem. **Environmental sustainability, digitalisation and materials research trends have shaped the direction of innovation efforts in recent years** ▪ **Environmental sustainability:** emissions regulations, such as those for **non-road mobile machinery**, and firm-level net zero targets, create an imperative for the development of more energy-efficient and environmentally sustainable machines and equipment. For example: o **Mining, quarrying, and construction equipment:** The segment has had to adapt to comply with Stage V emissions standards (ICCT, 2016), which required innovation, investments, and development of new products and services (CEA, 2023). Also, London's Low Emission Zone is anticipated to transition to a Zero Emission Zone for construction equipment in the mid-2030s, driving further investments in zero-emission technologies and solutions within the industry. Other efforts towards decarbonisation include developing full electric machines, utilising hydrogen fuel cells, and hydrogen combustion engines (CEA, 2023). o **Valves and actuators:** According to the consulted stakeholders, there is a strong focus on this segment becoming an enabler for hydrogen- and carbon-capture national infrastructure, as the current valves are not adapted to hydrogen gas. In this regard, interviewees perceive limitations in the availability of government R&D funding to support innovation at established players, beyond the existing focus of supporting R&D in academic organisations. o **Pumps and compressors:** Interviewees suggested that energy efficiency is one of the most important competitiveness drivers in this sub-sector, as energy represents around 80% of the costs in compressed air. New compressors are around 30% more energy efficient than those of 15 years ago. However, a significant incentive policy for the acquisition of energy-efficient compressors in **the UK** is lacking (DESNZ, 2024). o **Other Engines**: more stringent industrial emission regulations in **the UK** have incentivised the manufacturers to invest more on the R&D of low-emission industrial engines. Meanwhile, wind turbines and combined-cycle gas turbines have seen significant opportunities from the **UK**'s Net Zero target by 2050 (IBIS World, 2023). **Other R&D trends:** ▪ **Digitalisation:** Smart machines, telematics, human-machine interaction, 3D printing, digital supply-chain tracking and digital modelling have also been important R&D trends in **the UK M&E sector**. For example, 3D printing enables faster modelling and prototyping of complex valves and components, and digital passports enable tracking of components and production processes within the supply chain. ▪ **Materials:** Significant R&D in the sector is dedicated to developing, adopting, and adapting new materials. The **M&E sector** is heavily reliant on steel, with an emerging trend towards green steel necessitating substantial increases in renewable electricity and green hydrogen production.

Appendix 3.1 Mapping between SIC 2007 code and HS code

HS codes relevant to the M&E sector		
Chapters in HS 2007 relevant to the M&E sector	**Chapter titles**	**No. of relevant subheading included in the chapter**
84	Nuclear reactors, boilers, machinery and mechanical appliances; parts thereof.	441
85	Electrical machinery and equipment and parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles.	8
87	Vehicles other than railway or tramway rolling-stock, and parts and accessories thereof.	8
73	Articles of iron or steel.	3
90	Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; parts and accessories thereof.	3
95	Furniture; bedding, mattresses, mattress supports, cushions and similar stuffed furnishings; lamps and lighting fittings, not elsewhere specified or included; illuminated signs, illuminated name-plates and the like; prefabricated buildings.	3
88	Aircraft, spacecraft, and parts thereof.	1

Note: OECD Correspondence Tables

Appendix 3.2 References and consultations

References used and stakeholders consulted

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Other useful sources

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Consulted stakeholders

- Department for Business and Trade (DBT)
- British Valve and Actuator Association (BVAA)
- British Compressed Air Society (BCAS)
- Engineering and Machinery Alliance (EAMA)
- Manufacturing Technologies Association (MTA)
- J C Bamford Excavators Ltd (JCB)
- Cummins UK
- British Fluid Power Association (BFPA)
- Agricultural Engineering Association (AEA)
- KGP Powertrain Intelligence

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THEME FOUR

Science and engineering workforce

- Is the UK producing enough scientists and engineers?
- Are there skills mismatches in science, technology, engineering and mathematics (STEM) disciplines in the UK?
- How does this compare with other countries?

Theme 4: Science and engineering workforce

KEY FINDINGS

The UK has a relatively high proportion of science, technology, engineering and mathematics (STEM) graduates.

- During the academic year 2021/22, 42% of all graduates in **the UK** completed STEM disciplines.
- **The UK** produces more **STEM** graduates per capita in the 20–34-year-old population than comparator countries. In 2020 **the UK** awarded 1,393 first university degrees per 100,000 individuals in **STEM** fields, compared to 1,317 in **the US**, and 690 and 650 in **India** and **China**, respectively.

However, the UK is producing fewer graduates in engineering, manufacturing and construction.

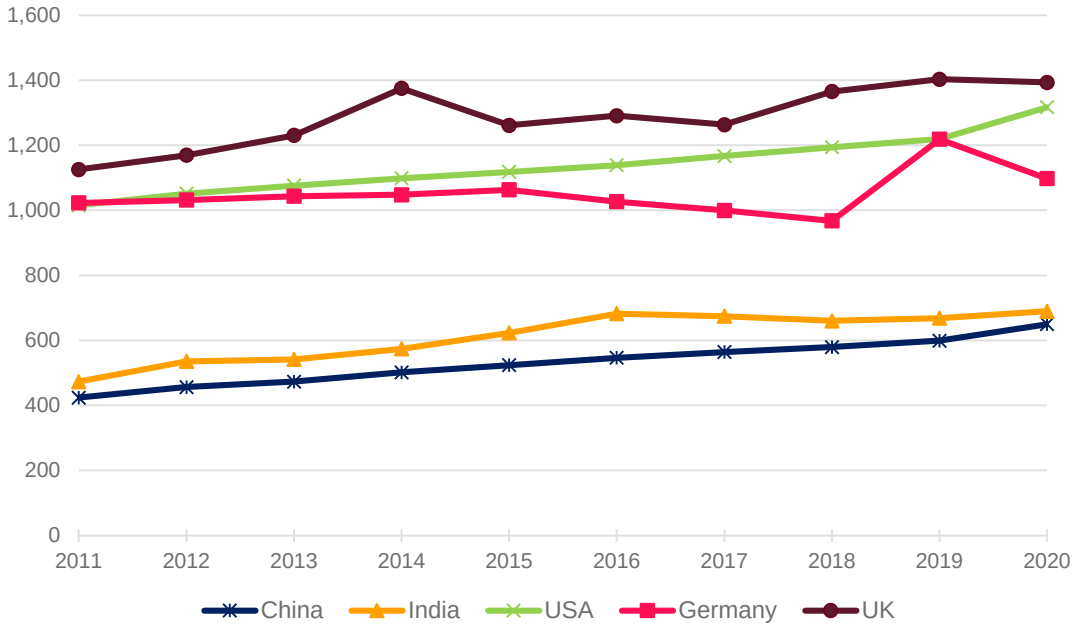
- In 2022 more than half (52%) of **the UK's STEM** graduates pursued health-related disciplines.
- In 2021 the percentage of graduates in **engineering**, **manufacturing** and **construction** in **the UK** was only 9.1%, which is significantly lower than **Italy**, **Switzerland**, **Japan**, **Korea** and **Germany**. In these countries, the percentage of graduates in these disciplines ranged from 14.4% to 22.1%.

Despite the high proportion of STEM graduates, there are significant STEM-related skills gaps in the UK labour market.

- In **the UK** 934,000 vacancies were recorded towards the end of 2023, 46% of which were in fields related to **STEM** disciplines. At the beginning of 2024, 12% of **UK** firms in **manufacturing** and 6.9% in **information and communication** said they were experiencing a shortage of workers.
- For **UK** employers, it is difficult to find individuals with skills related to **medical knowledge, scientific knowledge, production and technology knowledge** and **digital skills** compared to the **OECD** average and **the EU**.

Chart 4.1. STEM degree production intensity

First university degrees awarded per 100,000 of the 20–34-year-old population, selected countries, 2011–20



Note: The chart shows the top five countries by STEM doctorates awarded in 2020; medicine and subjects allied to medicine are not included; international students are included in the computation.
Source: National Science Foundation (2023). Higher Education in Science and Engineering – Figure HED-33.

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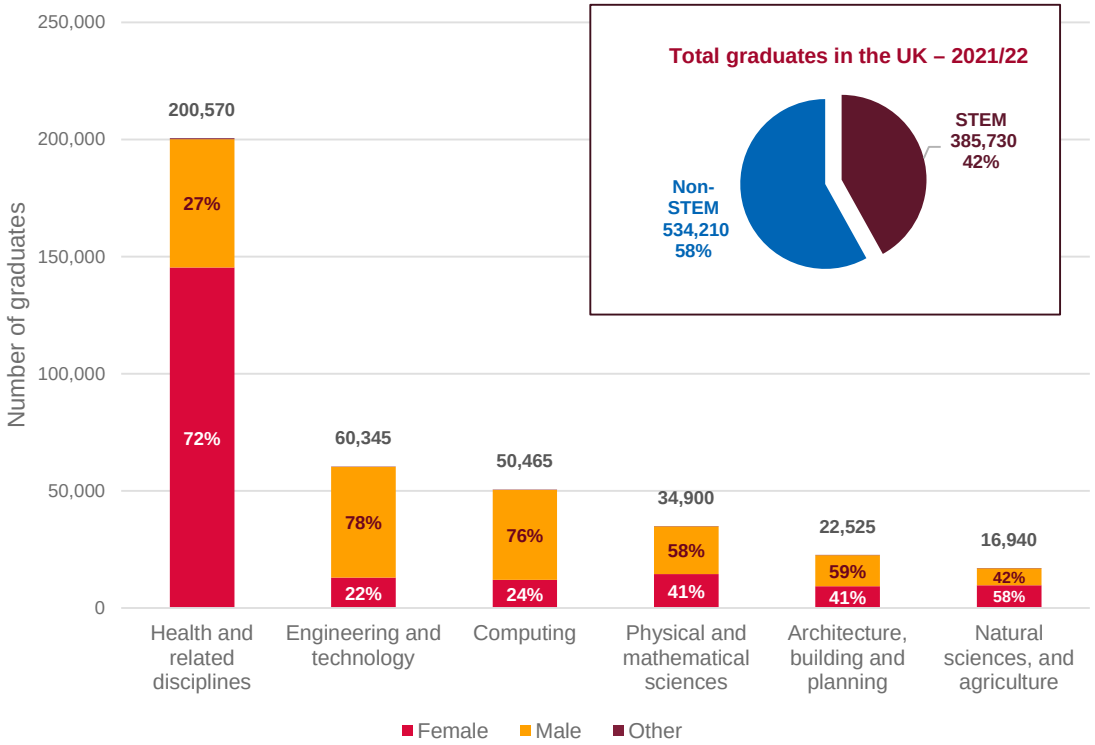
- **The UK** performs relatively well in terms of tertiary education attainment levels. In 2022 the share of the population with tertiary education in **the UK** was 57.7%, compared to 47.4% of **the OECD** average.[1]
- **Science, technology, engineering and mathematics (STEM)** disciplines are particularly important for innovation activities.[2]
- In a study conducted for **the UK** government, it is estimated that **the UK** will need to fill around 382,000 **research and development (R&D)** jobs by 2027. Engineering UK, an advocacy group, estimates that 173,000 new **engineering and technology** jobs will be created by 2030.[3]
- In 2020 **the UK** awarded 183,000 first university degrees in **STEM** disciplines, compared to 2.5 million in **India**, 2 million in **China** and 900,000 in **the US**.[4]
- When normalising for the population in the 20–34-year-old population, however, **the UK** produces a higher proportion of **STEM** graduates. In 2020 **the UK** awarded 1,393 first university degrees per 100,000 people in **STEM** disciplines, compared to 1,317 in **the US** and 690 and 650 in **India** and **China**, respectively.

Note: [1] Tertiary education attainment is measured as the percentage of the population aged 25–34, in the same age group. OECD (2024). Population with tertiary education (indicator).
[2] There is no accepted definition of STEM disciplines, particularly regarding which subject disciplines to include in the classification. Therefore, differences among data sources may depend on the chosen classification.
[3] DSIT/BEIS (2021). The R&D Pipeline. BEIS Research Paper Number: 2021/22. Engineering UK (2023). Engineering skills needs – now and into the future.
[4] Source: National Science Foundation (2023). Higher Education in Science and Engineering – Figure HED-29.

Chart 4.2. STEM graduates in the UK

Undergraduate and postgraduate programmes, academic year 2021/22



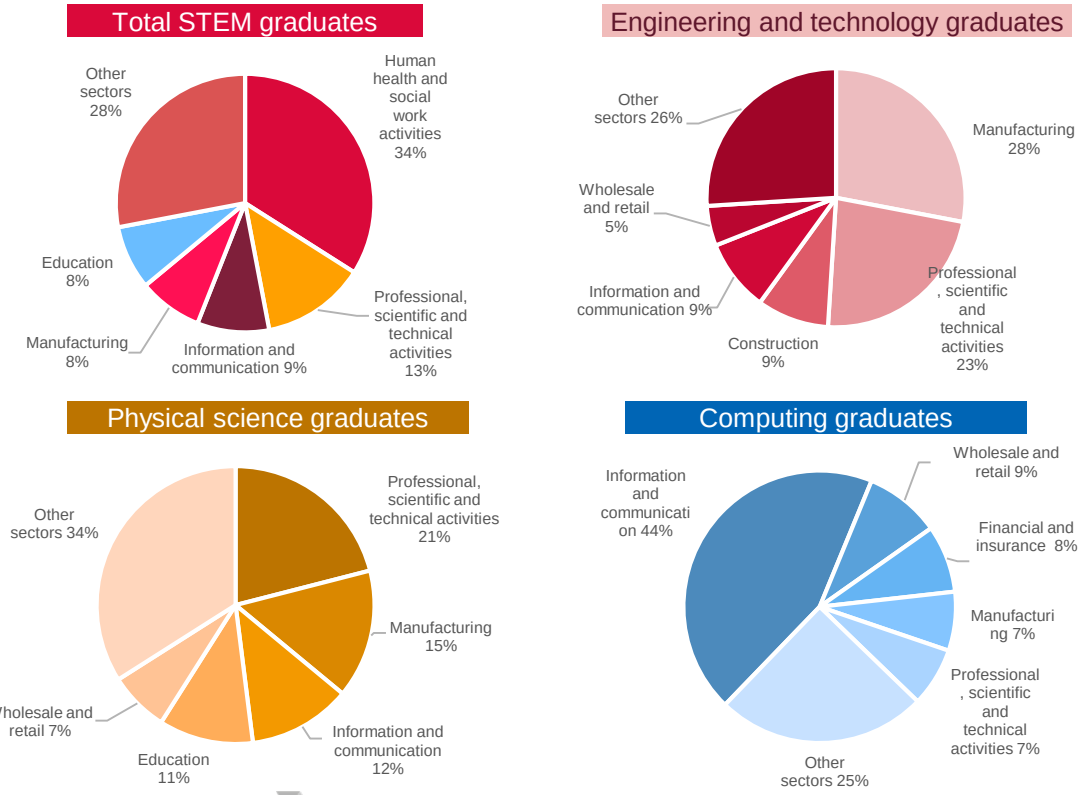
Note: Health and related disciplines include: medicine and dentistry; subjects allied to medicine; psychology; biological and sport sciences; veterinary sciences.
Source: HESA (2023). Figure 17 – HE qualifications obtained by CAH level 1 subject and sex.

- In the academic year 2021/22, graduates from **STEM** disciplines accounted for 42% of all graduates in the UK**,** a value above that for 2020/21 (40%) and 2019/20 (41%).
- In 2022 **health and related disciplines** represented 52% of **UK STEM** graduates**.**
- Women are under-represented among certain **STEM** disciplines in the UK. For example, in 2021 women represented 53% of total **STEM** graduates, compared to 61% of the share of women who graduated in **non-STEM** disciplines.
- In disciplines such as **engineering and technology**, and **computing**, women represent only 22% and 24% of graduates, respectively.
- Analysis presented in previous editions of this report has found that the UK has a relatively low share of graduates in **engineering, manufacturing and construction** compared to other countries.[1]
- For example, in 2021 the number of graduates in **engineering, manufacturing and construction** as a share of all graduates in **the UK** was 9.1%, compared to **Italy**, **Switzerland**, **Japan** and **Germany**, whose share of graduates in these disciplines was between 14.4% and 22.1%.[1]

[1] **Source**: OECD (2023). Graduates by field – database.
Note: The classification used by the OECD differs from that used in Chart 4.2.

Chart 4.3. Where do UK STEM graduates work?

Graduates entering work in the UK by field of study and economic sector, 2020/21

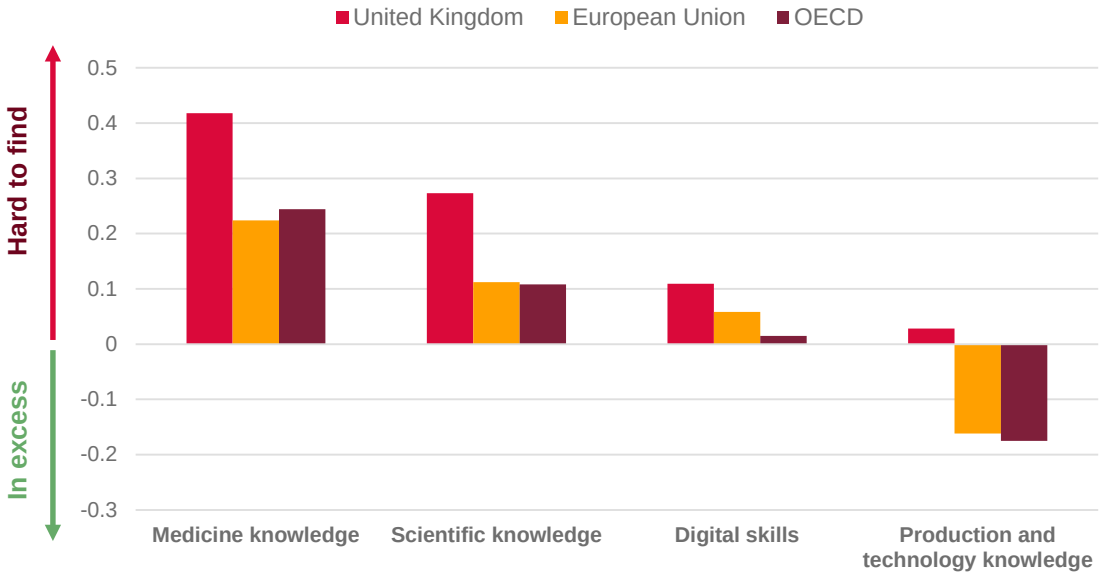


Source: HESA (2023). Figure 11 – standard industrial classification of graduates entering work in the UK by subject area of degree – higher education providers (HEPs) – academic year 2020/21.

- Upon obtaining a degree, graduates with **STEM** skills are employed across a variety of economic sectors.
- For the academic year 2020/21:
  - **Total STEM graduates**: only 13% were employed in **professional, scientific and technical activities,** 9% in **information and communication** and 8% in **manufacturing.**
  - **Engineering and technology graduates:** 28% were working in **manufacturing**, 23% in **professional, scientific and technical activities** and 9% in **construction**, while an additional 26% was spread across **public administration**, **finance**, **education** and **public utilities**.
  - **Physical sciences graduates:** 21% were working in **professional, scientific and technical activities**, 15% in **manufacturing** and 12% in **information and communication**.
  - **Computing graduates:** 44% were working in **information and communication**.

Chart 4.4. Skills needs: international comparison

Index, selected skills and countries, 2019



How to read: the value of 1 represents the largest shortage of skills; and the value of -1 the largest surplus of skills

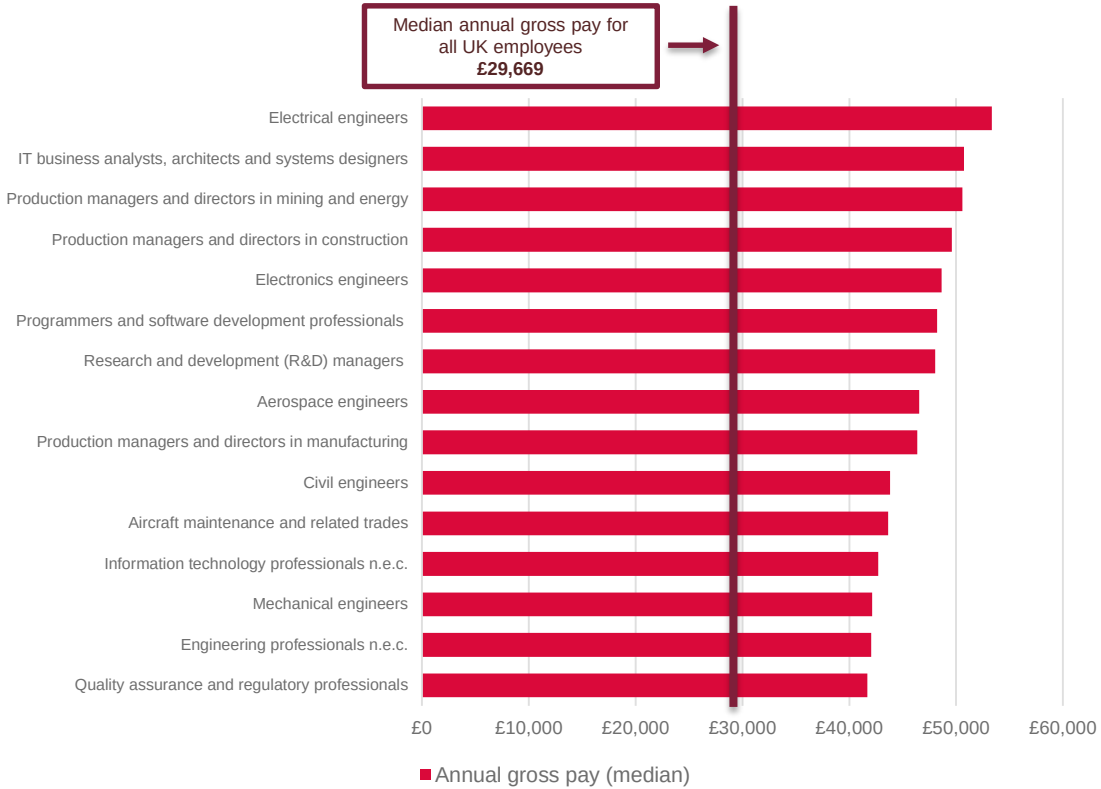
Note: *Medicine knowledge:* medicine, dentistry, psychology, etc. *Scientific knowledge*: biology, chemistry, physics, etc *Digital skills*: computer programming, data processing, ICT safety and network, office tools and collaboration software, etc. *Production and technology knowledge*: building and construction, design, engineering and technology, quality control analysis, etc..
In the OECD Skills for Jobs database: "Skills are defined as hard-to-find (or in shortage) when employers are unable to recruit staff with the required skills in the accessible labour market and at the going rate of pay and working conditions. Skills surpluses arise in the opposite case, when the supply exceeds demand for a given skill. The indicators measuring skills shortage and surplus are constructed on the basis of signals extracted from five sub-indices: wage growth; employment growth; hours worked growth; unemployment rate; under-qualification growth." See OECD (2022). OECD Skills for Jobs database: Measuring skill needs in the new era of work.
Source: OECD (2022). Skills need by country – data set.

- The OECD Skills for Jobs database shows how **the UK** compares to **the OECD** average and **the EU** in terms of "hard-to-find" skills.
- In **the UK** it is relatively hard to find skills related to **medicine, scientific knowledge** (biology, chemistry, physics), **digital skills** (computer programming, data processing, ICT safety and network, office tools and collaboration software) and **production and technology knowledge** (building and construction, design, engineering and technology, quality control analysis).
- Other analyses have highlighted labour shortages in **the UK**.[1] In October–December 2023, there were 934,000 vacancies in the country. Although this number is lower than its highest value, reached in March–May 2022 (1.3 million), it is still above the pre-pandemic value (801,000 in January–March 2020).[2]
- In October–December 2023, 46% of vacancies were in sectors where **STEM** graduates are most likely to be employed, including **human health** (18%), **professional scientific and technical activities** (10%), **manufacturing** (7%), **education** (7%) and **information and communication** (4%).[2]
- At the beginning of 2024, 12% of **UK** firms in **manufacturing** and 6.9% in **information and communication**, for example, said they were experiencing a shortage of workers.[3]

Note: [1] Francis-Devine B. and Buchanan I. (2023). Skills and labour shortages. House of Common Library.
[2] ONS (2024). VACS02: Vacancies by industry.
[3] ONS (2024). Business insights and impact on the UK economy – Wave 101.

Chart 4.5. Engineering profession salaries

Gross annual pay, median, full-time and part-time employees, 2023



Note: Standard Occupational Classification (SOC) codes for the engineering professions are based on Engineering UK (2018). The State of Engineering 2018; SOC2010 Codes were updated to SOC2020 Codes based on ONS (2022). SOC 2020 Volume 2: the coding index and coding rules and conventions.
Source: ONS (2022). Annual Survey of Hours and Earnings (ASHE).

- In 2023 the median gross salaries for the majority of core **engineering** occupations in **the UK** were higher than the average in the job market.[1]
- For example, the median annual gross salary for an **electrical engineer** was 80% higher than the median salary for all **UK** employees.
- Although **engineering** professions are better paid, women are under-represented in the profession. In 2023 women represented just 14% of the core engineering workforce, compared to 52% of the rest of the workforce.[2]

Note: [1] For the definition of core engineering professions, see Engineering UK (2018). The State of Engineering 2018.
[2] Core engineering workforce, as defined by Engineering UK (2018). Data for the UK workforce: ONS (2023) Annual population survey – Occupation (SOC2020) by sex, employment status and full/part-time.

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THEME FIVE

Net zero innovation

Is the UK successfully decoupling economic growth from greenhouse-gas emissions?

How have the low-carbon and renewable energy economy (LCREE) sectors performed?

How does the UK's investment in low-carbon and renewable energy technology research and development (R&D) stand in comparison to other countries?

Theme 5: Net zero innovation

KEY FINDINGS

The UK has successfully decoupled GDP growth from greenhouse-gas (GHG) emissions.

- While **the UK's** GDP doubled between 1990 and 2021, the country achieved a 40% reduction in GHG emissions during this period. However, further work is required to achieve the target set by the Climate Change Act, which commits **the UK** government to reducing GHG emissions by at least 100% of the 1990 levels (net zero) by 2050.
- Only five industries failed to reduce emissions from 1990 to 2021: **wholesale and retail trade and repair of motor vehicles; construction; accommodation and food services; administrative and support service activities**; and **real estate** activities.

The UK low-carbon and renewable energy economy (LCREE) has performed strongly since 2019.

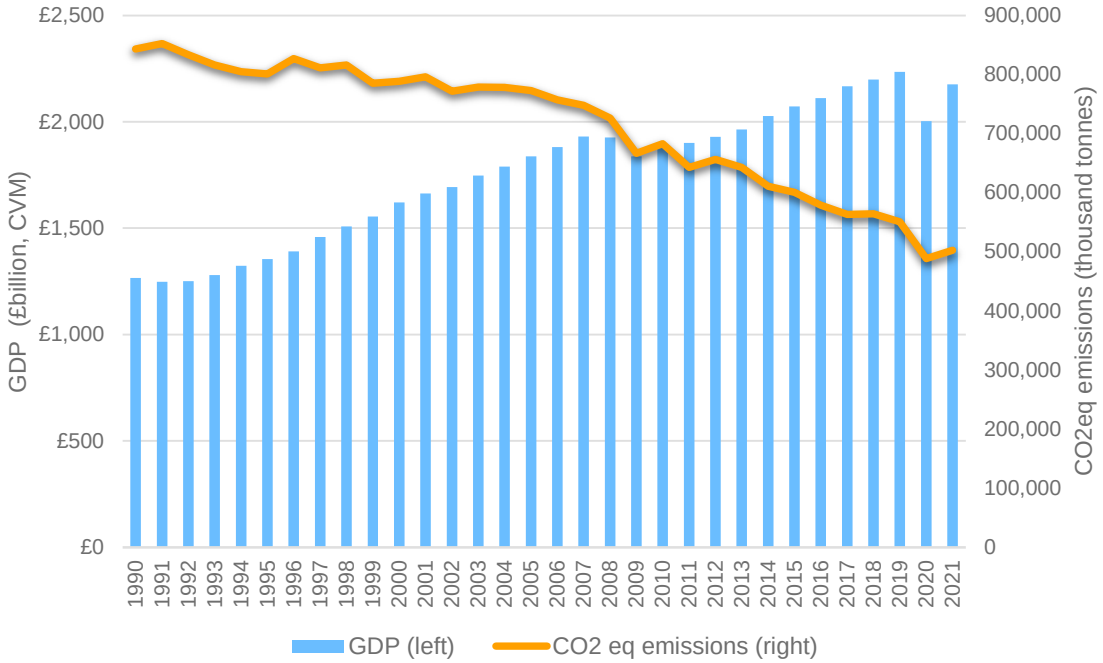
- The LCREE economy reported a £54.4 billion turnover in 2021, compared to £45.8 billion in 2019, and over 27,000 and 42,000 more businesses and employees, respectively, in 2021 than in 2019.
- The sectors with the highest turnover in 2021 were: **energy-efficient products** (£14.01 billion); **low-emission vehicles** and **infrastructure** (£8.52 billion); and **offshore wind** (£8.42 billion).

The UK consistently ranked among the top six countries in public R&D expenditure on low-carbon renewable energy technologies from 2010 to 2022.

- At $1.6 billion, **the UK's** public R&D budget in **low-carbon and renewable energy technologies** in 2022 was lower than Germany ($2 billion), **Japan** ($3.4 billion), **France** ($4.9 billion) and **the US** ($9.6 billion) but higher than **Canada** ($1.2 billion).
- Among **low-carbon technologies**, the highest public R&D expenditure in the **UK** in 2022 was on nuclear power technologies, followed by **energy efficiency and renewables**.

Chart 5.1. UK carbon emissions against gross domestic product (GDP)

GDP in chained volume measures (CVM), £bn; CO2 equivalent emissions in thousand tonnes



Note: UK resident basis, greenhouse gases under the Kyoto Protocol.

Source: ONS (2023). Atmospheric emissions: greenhouse gases by industry. Industry definitions provided in Appendix 5.1; ONS (2023). Gross Domestic Product: chained volume measures: Seasonally adjusted £m.

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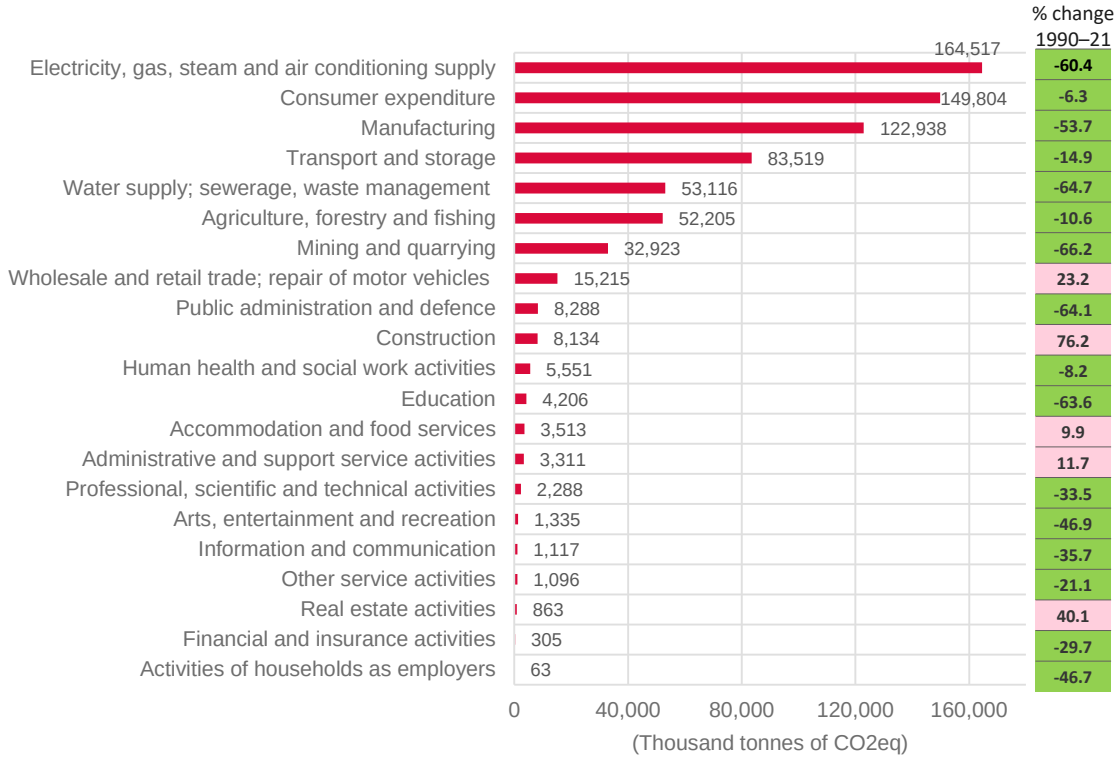
- The Climate Change Act commits **the UK** government by law to achieving "net zero", which is to reduce greenhouse-gas emissions by at least 100% of 1990 levels by 2050.[1]
- Significant progress was made to decouple GDP growth from GHG emissions between 1990 and 2021, resulting in a 40% reduction in emissions during this period, in which GDP nearly doubled.
- In an international context, **the UK's** total emissions in 2020 were the 20th largest in the world,[2] while the country ranked 71st in emissions per capita.[3]

Note: Residence-based emissions, sometimes referred to as production emissions, cover emissions by UK residents and UK-registered businesses, whether in the UK or overseas. An important use of this measure is that it enables direct comparison of emissions by sector of UK industry and households, with the main economic indicators including gross value added (GVA). These estimates are part of the UK's Environmental Accounts and are aligned with the national accounts because they are compiled in accordance with the UN System of Environmental Economic Accounting (SEEA). Following this framework also enables international comparisons.

[1] Climate Change Committee (2024). A legal duty to act.
[2] World Bank (2024). Total greenhouse gas emissions (kt of CO2 equivalent), 2020 figures.
[3] Climate Watch (2024). Historical GHG Emissions. 2020 figures.

Chart 5.2. UK carbon emissions by industry

Average annual greenhouse emissions, 1990-2021 (thousand tonnes of CO2eq)

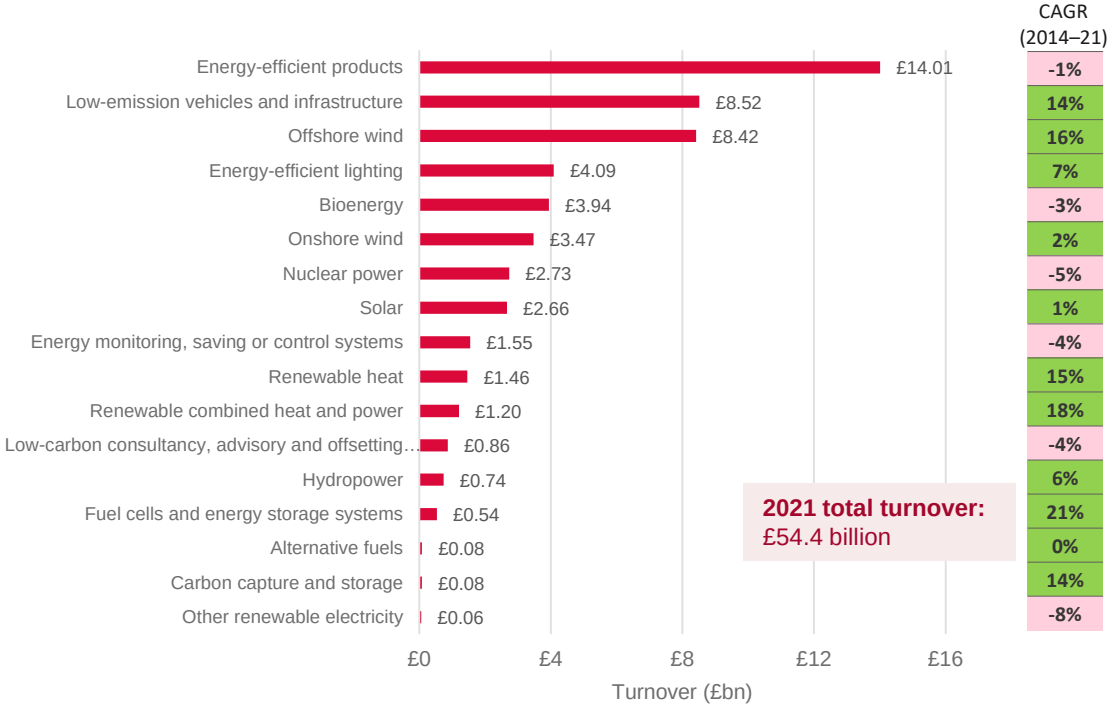


- For greenhouse-gas emissions per industry, the sectors with the highest average annual emissions between 1990 and 2021 were: **electricity, gas, steam and air conditioning supply; consumer expenditure; manufacturing; transport and storage; water supply, sewerage and waste management;** and **agriculture, forestry and fishing**.
- Between 1990 and 2021, only five industries did not experience a reduction in emissions: **wholesale and retail trade and repair of motor vehicles; construction; accommodation and food services; administrative and support service activities;** and **real estate activities**.
- The **construction sector** and **real estate activities** recorded the largest increases in emissions, with increments of 76.2% and 40.1%, respectively.
- In contrast, significant emission reductions were observed in sectors such as: **mining and quarrying** (-66.2%); **water supply, sewerage and waste management** (-64.7%); **public administration and defence** (-64.1%); **education** (-63.6%); and **electricity, gas, steam and air conditioning supply** (-60.4%).

Note: UK resident basis, greenhouse gases under the Kyoto Protocol
Source: ONS (2023). Atmospheric emissions: greenhouse gases by industry. Industry definitions provided in Appendix 5.1.

Chart 5.3. UK low-carbon and renewable energy economy (LCREE) sector performance

Total turnover (£bn, 2021) and compound annual growth rate (2014–21)



Note: This analysis uses results from the low-carbon and renewable energy economy (LCREE) survey, run by the ONS, which identifies 17 low-carbon sectors within the UK economy (see Appendix 5.2 for full details).

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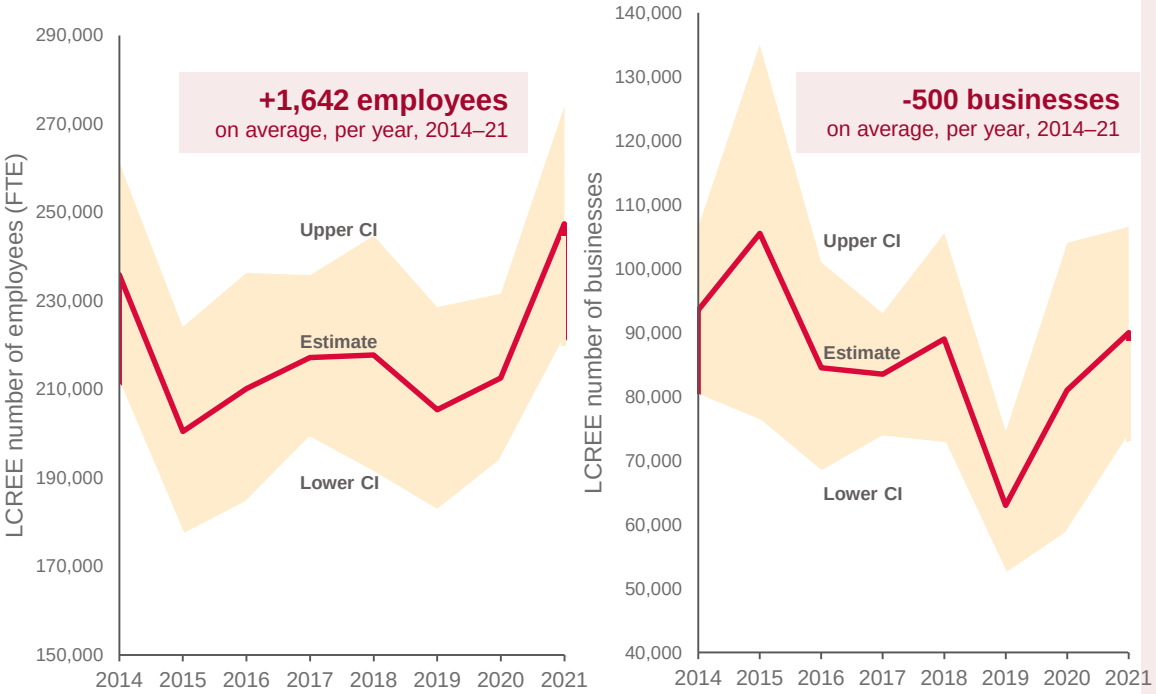
Source: ONS (2023). Low Carbon and Renewable Energy Economy (LCREE) survey estimates, the UK, 2014 to 2021.

- The overall turnover of the **low-carbon and renewable energy economy (LCREE)** sectors experienced a positive trend, increasing from £43.7 billion in 2014 to £54.4 billion in 2021.
- The sectors with the highest turnover in 2021 were: **energy-efficient products** (£14.01 billion); **low-emission vehicles and infrastructure** (£8.52 billion)**; offshore wind** (£8.42 billion)**; energy-efficient lighting** (£4.09 billion); and **bioenergy** (£3.94 billion).
- Overall, six sectors showed negative compound annual growth rates between 2014 and 2021: **energy-efficient products** (-1%)**; bioenergy** (-3%)**; energy monitoring, saving or control systems** (-4%)**; low-carbon consultancy, advisory and offsetting services** (-4%)**; nuclear power** (-5%); and **other renewable electricity** (-8%).
- In terms of growth, the most significant sectors between 2014 and 2021 were: **fuel cells and energy storage systems** (21%); **renewable combined heat and power** (18%); **offshore wind** (16%); **renewable heat** (15%); **low-emission vehicles and infrastructure** (14%); and **carbon capture and storage** (14%).

Chart 5.4. Employment and number of businesses in the low-carbon and renewable energy economy (LCREE)

Number of employees and businesses between 2014 and 2021

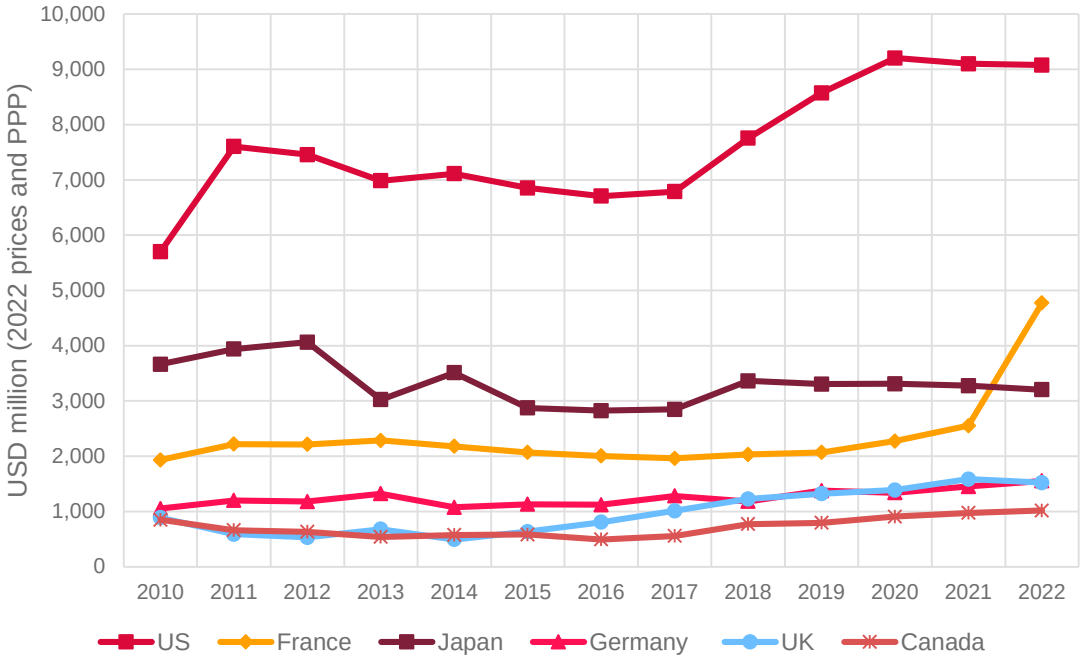


Source: ONS (2023). Low Carbon and Renewable Energy Economy (LCREE) survey estimates, the UK, 2014 to 2021.

- In 2021 the **LCREE** sector employed 247,400 people in 90,000 businesses.
- The number of business and employees in **the UK LCREE** sectors fluctuated significantly between 2014 and 2021.
- There were 3,500 fewer businesses in 2021 than in 2014, a net loss of ~500 businesses per year.
- Despite the loss of businesses, there were 11,500 more jobs in the **LCREE** sectors in 2021 than in 2014, a net increment of ~1,642 jobs per year.
- **LCREE** turnover for businesses with 250 or more employees increased from £19.9 billion in 2014 to £28.6 billion in 2021.
- Similarly, **LCREE** employment for businesses with 250 or more employees increased from 57,900 in 2014 to 80,000 in 2021.

Chart 5.5. Public R&D spending on low-carbon and renewable energy technologies – total budgets

Top six spenders in the International Energy Agency's Energy Technology RD&D Budgets database



Source: IEA (2023). IEA Energy Technology RD&D Budgets - October 2023.

- **The UK** was consistently among the top six countries with the highest public R&D expenditure on low-carbon renewable energy technologies between 2010 and 2022 in the research, development and demonstration (RD&D) data set compiled by the International Energy Agency (IEA).
- IEA estimates that in 2022 **the UK's** public R&D budget in low-carbon and renewable energy technologies was $1.5 billion, lower than **Germany** (USD 1.6 billion), **Japan** (USD 3.2 billion), **France** (USD 4.8 billion) and **the US** (USD 9.1 billion) but higher than **Canada** (USD 1.0 billion).[1]
- Categories in the IEA analysis include: **energy efficiency**; **renewable energy sources**; **nuclear fission and fusion**; **hydrogen and fuel cells**; other **power and storage technologies**; and other **cross-cutting technologies or research**.

[1] **Note:** Prices are in 2022 USD and purchasing power parity (PPP).
Source: IEA (2023). IEA Energy Technology RD&D Budgets - October 2023.

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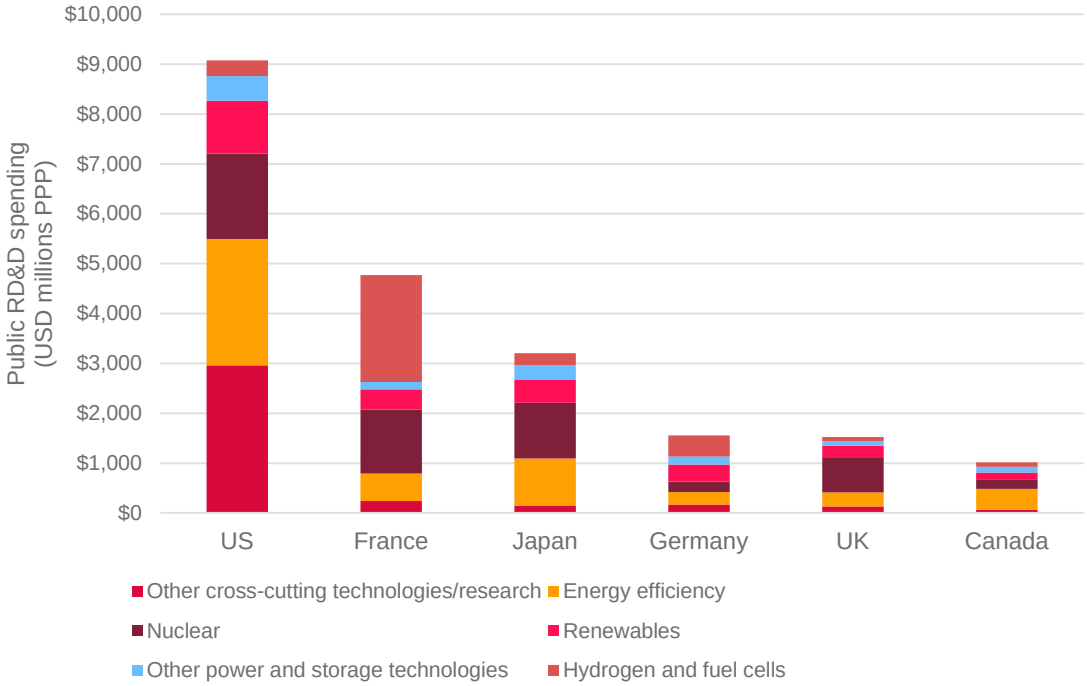
Note: IEA categories included are energy efficiency, renewables, nuclear, hydrogen and fuel cells, other power and storage technologies, and other cross-cutting technologies/research.

Chart 5.6. Public R&D spending on low-carbon and renewable energy technologies – by technology

Technology breakdown, USD million PPP, 2022



Source: IEA (2023). IEA Energy Technology RD&D Budgets - October 2023.

Note: IEA categories included are energy efficiency, renewables, nuclear, hydrogen and fuel cells, other power and storage technologies, and other cross-cutting technologies/research.

- Based on the data provided by the International Energy Agency (IEA), the research area that received the highest public R&D expenditure in **the UK** in 2022 was **nuclear power technologies**. This was followed by **energy efficiency**, **renewables**, other **cross-cutting technologies**, other **power and storage technologies** and **hydrogen and fuel cells.**
- Different specialisations can be observed among top public R&D spenders, based on which research categories observed the highest expenditure:
  - **The US**: other **cross-cutting technologies**
  - **France** and **Germany**: **hydrogen** and **fuel cells**
  - **Japan** and **the UK**: **nuclear power technologies**
  - **Canada**: **energy efficiency**

Appendix 5.1. Sectoral breakdown for ONS (2023) atmospheric emissions: greenhouse gases by industry and gas [1]

Electricity, gas, steam and air conditioning supply	Electricity production – coal	Manufacturing	Aluminium production	Motor vehicles, trailers and semi-trailers
	Electricity production – gas		Basic pharmaceutical products and pharmaceutical preparations	Other manufactured goods
	Electricity production – nuclear		Building of ships and boats	Other nitrogen compounds
	Electricity production – oil		Computer, electronic, communication and optical products	Paper and paper products
	Electricity production – other		Electrical equipment	Plastics products
	Manufacture of gas; distribution of gaseous fuels through mains and steam and air conditioning supply		Fabricated metal products, except machinery and equipment, excluding weapons and ammunition	Printing and recording services
Transport and storage	Air transport services		Fertilisers	Processing and preserving of fish, crustaceans, molluscs, fruit and vegetables
	Buses, coaches, trams and similar public urban transport n.e.c		Furniture	Processing and preserving of meat and production of meat products
	Freight transport by road and removal services		Leather and related products	Processing of nuclear fuel
	Postal and courier services		Machinery and equipment n.e.c.	Repair and maintenance of aircraft and spacecraft
	Rail transport		Manufacture of air and spacecraft and related machinery	Repair and maintenance of ships
	Taxis and other renting of private cars with driver		Manufacture of alcoholic beverages, including spirits, wine, cider, beer and malt	Rest of repair; installation
	Transport via pipeline		Manufacture of articles of concrete, cement and plaster	Rubber products
	Underground, metro, other non inter-urban rail services		Manufacture of bakery and farinaceous products	Textiles
	Warehousing and support services for transportation		Manufacture of basic iron and steel	Tobacco products
	Water transport services		Manufacture of cement	Wearing apparel
Consumer expenditure	Consumer expenditure – not travel		Manufacture of cleaning and toilet preparations	Wood and products made of wood and cork, except furniture; articles of straw and plaiting materials
	Consumer expenditure – travel		Manufacture of coke oven products	
Agriculture, forestry and fishing	Fish and other fishing products; aquaculture products; support services to fishing		Manufacture of dairy products	
	Products of agriculture, hunting and related services		Manufacture of dyestuffs, agro-chemicals	
	Products of forestry, logging and related services		Manufacture of glass, refractory, clay, other porcelain and ceramic products, stone and abrasive products	
Water supply; sewerage, waste management and remediation activities	Natural water; water treatment and supply services		Manufacture of grain mill products, starches and starch products	
	Remediation services and other waste management services		Manufacture of industrial gases and non-nitrogen-based inorganic chemicals	
	Sewerage services; sewage sludge		Manufacture of lime	
	Waste collection, treatment and disposal services; materials recovery services		Manufacture of other basic metals and casting (excluding nuclear fuel and aluminium)	
Mining and quarrying	Crude petroleum and natural gas		Manufacture of other chemical products and man-made fibres	
	Mining of coal and lignite		Manufacture of other food products	
	Mining of metal ores		Manufacture of other transport equipment, excluding ships, boats, air and spacecraft	
	Mining support services		Manufacture of paints, varnishes and ink	
	Other mining and quarrying products		Manufacture of petrochemicals	
Wholesale and retail trade; repair of motor vehicles and motorcycles	Retail trade services, except motor vehicles and motorcycles		Manufacture of plaster	
	Wholesale and retail trade and repair services of motor vehicles and motorcycles		Manufacture of prepared animal feeds	
	Wholesale trade services, except motor vehicles and motorcycles		Manufacture of refined petroleum products	
Construction	Buildings and building construction works		Manufacture of soft drinks: production of mineral waters and other bottled waters	
	Constructions and construction works for civil engineering		Manufacture of vegetable and animal oils and fats	
	Specialised construction works		Manufacture of weapons and ammunition	

[1] ONS (2023). Atmospheric emissions: greenhouse gases by industry.

Appendix 5.2. Key definitions – low-carbon and renewable energy economy (LCREE)

Defining low-carbon and renewable energy economy (LCREE) sectors within the UK

The low-carbon and renewable energy economy (LCREE) survey, run by ONS (2023), asks UK businesses to self-classify into 17 low-carbon and renewable energy sectors:

- offshore wind
- onshore wind
- solar photovoltaic
- hydropower
- other renewable electricity
- bioenergy
- alternative fuels
- renewable heat
- renewable combined heat and power
- energy-efficient lighting
- energy-efficient products
- energy monitoring, saving or control systems
- low-carbon consultancy, advisory and offsetting services
- low-emission vehicles and infrastructure
- carbon capture and storage
- nuclear power
- fuel cells and energy storage systems

A business can be active in more than one sector. Within this report, these sectors are used as the best available proxy to understand the dynamics of the UK's climate-change mitigation technology economy.

More information is available at: https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/finalestimates/latest#glossary

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Cambridge Industrial Innovation Policy (CIIP) is a global, not-for-profit policy group based at the Institute for Manufacturing (IfM), the University of Cambridge. CIIP works with governments and global organisations to promote industrial competitiveness and technological innovation. We offer new evidence, insights and tools based on the latest academic thinking and international best practice. This report was delivered through IfM Engage, the knowledge-transfer arm of the Institute for Manufacturing (IfM), the University of Cambridge.

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