Institute of Materials, Minerals & Mining

The talent gap: critical skills for critical materials

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Author
Rachel Stonehouse

Graphic designer
Sophie McDonald

A. Executive Summary

The UK Critical Minerals Strategy sets out an ambition to *'review the UK's skills, education and training along the critical minerals value chain and define a critical minerals skills blueprint, recognising the full breadth of skills needed.'*

To support Government and the UK's Critical Minerals Intelligence Centre, IOM3 convened and consulted key stakeholders from across industry, associations and academia, to undertake a preliminary assessment of the current skills landscape and get a qualitative understanding of the skills gaps and challenges.

Critical minerals, identified for their importance to the UK economy and risk associated with their supply, are essential to a range of industries and technologies. Responsible and resilient sourcing and management of these materials underpins the UK economy and the transition to a low-carbon, resilient and resource efficient society. This will only be possible with enough people who have the required skills and access to the right training.

As the criticality assessment is dynamic, critical minerals are rarely relied on as individual materials and some are produced as co- or by- products, an understanding of the skills-related gaps and challenges across the materials, minerals and mining landscape is required.

With a backdrop of a growing global population, technology evolving faster than ever and a worldwide need to mitigate and adapt to climate change including moving to cleaner energy, the demand for minerals is increasing dramatically.

To meet the growing demand and ensure responsible practices, a significant increase in the workforce will be required. At the same time there is a decline in the availability of skilled people with many professionals in the workforce reaching retirement age. Alongside this there is insufficient new talent entering and developing through the industry to fill the positions.

Mining is considered the most international industry and with other countries facing similar shortages and moving to secure their supplies, the UK will be competing in an increasingly challenging and competitive labour market.

The lack of availability and pipeline of skilled workers is a significant risk facing the sector. There is a shortage of key professionals including exploration geologists, mining engineers, mineral planners and mineral processors. Across the value chain, metallurgical skills in all their guises were identified by stakeholders as critical and in short supply.

The sector has benefited from skilled professionals exiting the coal industry in the UK, but this suppressed demand for new entrants as companies will have found it easier to recruit ready trained former coal mining professionals than to sponsor new students and apprentices. The UK is reaching the end of this legacy that has largely sustained the industry to date.

The talent pipeline is unlikely to meet future demand for skilled individuals across the value chain. Enrolment in relevant education and training is decreasing in the UK and other countries such as Australia and the United States. This in turn leads to a reduction in supply and the cancelling of education and training courses.

The value chain faces significant issues with perception and awareness and therefore the attraction of talented individuals. Exploration, extraction and end of life recovery activities are typically perceived negatively; as environmentally damaging, risky (both in terms of stability and safety) and with poor working environments. Many roles, in the midstream in particular struggle with awareness, visibility and a lack of understanding of the career options available.

Updating and improving the perception of the value chain, in line with its role in underpinning the low-carbon transition and raising awareness of the career opportunities available, will be key to attracting skilled professionals and sustaining the industry.

Skill sets are changing, reflecting the evolving needs of the sector, with advancements in technology and a greater focus on data skills and environmental, social and governance standards. Greater integration of skills, combining different skill sets and understanding different aspects of the value chain is required, together with a greater provision for continuing professional development at a post-graduate level in order to bridge the gap from education to workplace.

Improving equity, diversity and inclusion is both necessary and beneficial. The extent of the skills gaps identified will require a significant increase in the size of the workforce, a challenge made harder if talent is not being accessed from the full pool available. Improved granular data is required, particularly for ethnic diversity and disability.

There are a number of initiatives that are contributing to raising awareness, addressing negative perceptions, enabling transferability, supporting retention and helping to build the talent pipeline for the future. Good practice should be learned from and scaled up to expand opportunities such as these to all areas.

The extent and growth rate of the skills gaps require short-, medium- and long-term action. This will require involvement across the ecosystem and all stakeholders to ensure sustainable impacts for both the existing and future workforce. To build on the qualitative findings in this report and enable all actors to put in place the steps necessary, a quantitative assessment should be undertaken to understand the future workforce capability needs, map competences and conduct a gap analysis on education and training provision and provider capacity.

Key points:

- The serious and growing skills gap is a significant risk facing value chain
- Mining engineering, mineral processing and metallurgical skills are in short supply
- Industry, academia and regulators all require access to the necessary skills
- Modernising perceptions will be key to attracting talent and sustaining the industry
- Every actor has a role to play to address the skills gaps and greater collaboration is required

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B. Summary report

IOM3 was asked to undertake a qualitative assessment of the skills gaps and pipelines for minerals-related skills in the UK. To do this IOM3 convened a series of stakeholder roundtables and undertook desk research.

I. Context

Materials are crucial to the UK economy and underpin our daily lives. They are the building blocks of modern society and technology and responsible sourcing and management of materials is of prime importance to the transition to a low-carbon, resilient and resource efficient society. Access to resilient and responsible supplies of materials has taken on a new salience in recent years and is of growing concern in the UK and across the world.

Materials defined as 'critical minerals' have high importance to the UK economy and there are risks associated with their supply. These materials and their value chains play vital roles in the transition to a low-carbon society. They are essential raw materials for a range of industries and technologies from automotive, defence and aerospace, to medical technologies and renewable energy infrastructure.

Demand for these minerals is forecast to increase significantly, driven by global population growth and development, technological changes and the mineral intensity of the low-carbon transition. As demand increases there will be a growing need for skilled professionals across the value chain. As other countries face similar issues the global labour market will become increasingly challenging and competitive.

At the same time there is a decline in the availability of skilled people. Fewer individuals are enrolling on relevant courses and training routes providing an insufficient talent pipeline to fill positions, while many professionals in the are reaching retirement age.

The criticality assessment provides a necessary focus, but the minerals identified are intrinsically part of a wider landscape. The skills related gaps, challenges and opportunities should be considered in this context because:

- Criticality is dynamic and influenced by a range of factors.
- Value chains are varied, complex and often interact; some minerals are produced as co-[1] or by-[2] products, there can be numerous stages of processing and many variations of product.
- Minerals are rarely relied on as individual minerals but rather as combinations processed into engineered materials.
- Materials essential for our modern and future way of life may not meet the critical rules definition but are likely to have similar skills implications.

[1] raw materials produced alongside the major raw materials that are bought or sold and contribute materially to the economics of a deposit
[2] lower value raw materials that make up <0.1% of an ore deposit and rarely form viable ore deposits on their own

II. Value chain

Mineral supply chains can be broadly divided into three segments: upstream, midstream and downstream. This high-level value chain provides a framework to consider the typical stages involved in the extraction and use of minerals and the associated skills-related gaps, challenges and opportunities.

III. UK strengths

The UK has numerous strengths across the value chain and related skills, both domestically and overseas. These include: a rich history of mineral and mining expertise; research, development and innovation excellence; a very strong higher education system; high environmental, social and governance standards; and globally significant investors, markets, policy influence, consultancies, industry associations and service providers.

IV. Skills

Four broad categories of roles were identified across the value chain: technical (e.g. mining engineer), trade (e.g. mechanic), statutory (e.g. surveyor) and business operations (e.g. IT).

Stakeholders expressed that a lack of skilled workers is a significant and growing risk facing the sector. This is widely reflected in industry surveys[3], market trend coverage[4], reports[5] and news articles[6]. For example, 86% of mining senior leaders and executives surveyed by McKinsey reported it is harder to recruit and retain the talent they need versus two years ago[7].

i. Challenges

There appears to be two main drivers for the decline in minerals-related skills, both within the UK and more broadly.

Probably the most significant is the weak appeal as a career. For example, in the recent work by McKinsey, mining was seen as a less attractive career than even oil and gas and well behind financial services or high tech. Our work and that of others, shows that this stems from a number of factors:

- **The public perception of mining as dirty, dangerous and damaging**

The general view of many people of mining is negative. Whether this is because of a connection with coal mining or because of history lessons on the disasters and related deaths, it has a big impact. This is of course made worse by the fact that in some very well-known instances, that negative perception has been substantiated by events. From Aberfan[8] to Brumadinho[9], Juukan Gorge[10] to Britannia Creek[11], the human, social and environmental cost of mining both within and beyond its immediate confines has often been significant.

[3] https://www.pwc.com/gx/en/industries/energy-utilities-resources/publications/mine.html
[4] https://www.iom3.org/resource/global-mining-market-predicted-to-reach-us-3-535-59-bln-in-2032.html
[5] https://irp.cdn-website.com/7bd9b7ac/files/uploaded/220812%20UKMEF%20Report%20on%20Strategic%20Need%20for%20Mining%20Graduates%20corrected%20for%20Deloitte%20%28PDF_4%29.pdf
[6] https://www.theguardian.com/australia-news/2022/dec/01/skills-shortage-could-hamper-new-mining-developments-in-north-queensland-industry-says
[7] https://www.mckinsey.com/industries/metals-and-mining/our-insights/has-mining-lost-its-luster-why-talent-is-moving-elsewhere-and-how-to-bring-them-back
[8] https://en.wikipedia.org/wiki/Aberfan_disaster
[9] https://en.wikipedia.org/wiki/Brumadinho_dam_disaster
[10] https://en.wikipedia.org/wiki/Juukan_Gorge
[11] https://en.wikipedia.org/wiki/Britannia_Beach#Britannia_Creek_pollution
[12] https://www.riotinto.com/en/sustainability/talent-diversity-inclusion/everyday-respect
[13] a raw material which can be bought or sold.

- **The generalised sense of an old-fashioned industry**

Outdated views on the treatment of women and minorities[12], shift patterns that are not family friendly and facilities that are basic and unwelcoming all act as a disincentive to join the sector. Coupled with the significant competition from other sectors for transferable skills such as digital and automation, this reduces the pool of potential employees significantly. In addition newer generations expect to have purpose in their work and collectively the industry has not yet managed to communicate the vital role it plays in the transition to a low-carbon society.

- **The impact of commodity cycles**

Prices of metal and mineral commodities[13] tend to rise and fall in cycles. Amongst those we spoke to who had pursued mining, the uncertainty of careers in a sector where companies cut back significantly on their employees when commodity prices dropped had two effects. One was to reinforce the view of the sector as not a great career choice. The other was to reduce the size of the potential pool over time – individuals who were let go might not remain in the sector, moving into other areas and never returning.

Taken together, these factors help to explain why the demand for relevant training and education is not strong. This in turn leads to a reduction in supply – the cancelling of undergraduate courses in the UK and elsewhere is largely due to ever smaller numbers of applicants for places. There may also be an element of student pressure for example, there have been campaigns to block mining companies from recruiting on campuses and in cases where there are still mining courses, campaigns by non-mining students to close them down.

However, there is an additional element to the story. The UK's National Coal Board (NCB) (and, briefly, its successor British Coal) was a world class talent developer at all levels and across multiple skills, from coal loaders and plumbers to design engineers and senior managers.

As the UK coal industry closed down that talent was released onto the market. Many skilled tradespeople will have moved into other industries and those with more specialised skills that were in global demand will have been employed by mining companies globally. This was positive for the companies and the people involved, but it supressed demand for new entrants and will likely have contributed to the reduction in relevant university and other courses as companies will have found it easier to recruit ready-trained former coal mining professionals than to sponsor new students and apprentices.

The systematic training programmes of the NCB/British Coal ended around the beginning of the 1990s, so over thirty years later we are coming to the end of that pool of trained people. This can be seen in the age demographic of qualified mining-related professionals in the UK – in 2022, of the 1,237 mining and mineral processing engineers registered with the Engineering Council via IOM3, 80% were over the age of 50, with 39% over the age of 66.

The world mining industry has been feasting on the carcass of the NCB, but the meat is almost gone.

ii. Gaps and opportunities

Skills gaps were identified across the value chain for technical, trade and statutory roles. Business operations skills appear to be available in the wider economy, but there are issues with recruiting into the mining industry. Figure 1 sets out some of the key skills gaps highlighted throughout the stakeholder engagement alongside opportunities and potential measures to improve supply and access to skills and talent.

Figure 1 the skills gaps highlighted through stakeholder engagement and potential opportunities to improve supply

Skills gap	Segment of the value chain	Measures to improve supply
Metallurgy	Full value chain	Update and improve perceptions
4-12 year experience	Upstream	Improve attractiveness as a career choice
Experience ranges corresponding to downcycles	Upstream	Raise awareness of career opportunities
Mineral planning	Upstream	Build a talent pipeline - target school students and their support networks
Regulator resource	Upstream	Training for the current workforce
Underground	Extraction	Facilitate transferability from related disciplines and industries
Integration	Full value chain	Promote/facilitate interaction between education and training and industry
Full life cycle understanding	Full value chain	Build better connections along the value chain e.g., between the understanding of mineral processing and design for products for end of life
Engineering	Full value chain	Improve retention
Recycling	Midstream	Recognition and inclusion of roles as green jobs
Design for a circular economy	Downstream	Improve equity, diversity and inclusion
Traceability	Downstream	Adapt and emulate best practice from other sectors or countries

Actions
Include and emphasise the role of minerals in the low-carbon transition in course and module descriptions
Community engagement and trust building
Professionals speaking positively about their roles and projects
Harness growth of domestic mining industry to showcase modern and responsible mining
Update the language used from a heritage activity to a modern industry with opportunity to affect change
Learn from other industries e.g., oil and gas
Showcase diverse career prospects and options
Embed responsible mining in the curriculum
Equip and enthuse teachers
Educate and raise awareness with adults and support networks
Promote courses through different platforms such as social media
Promote alternative training routes and pathways
Utilise remote learning
Showcase visible and diverse role models
Develop mentoring opportunities
Sponsorship programmes
Identification and elimination of pay gaps
Training and development programmes that address biases and promote inclusivity
Inclusive policies
Monitor market trends and adapt strategies to help navigate the cyclical nature of the industry
Investment in talent
Fostering collaborations with international organisations, universities and research institutions
Inclusion in Government industry working groups such as green jobs taskforce
Diversify recruitment efforts

V. Opportunities for the UK

The unique strengths and comparative advantage of the UK and how these can be leveraged must be considered, as well as what will be required for national and economic security. This should be translated into the skills requirements and targeted measures employed to ensure a skilled and sustainable workforce.

There are a number of opportunities for the UK including:

- UK deposits – providing domestic production and increasing resilience.
- Midstream – helping to secure supplies, improve traceability and support the use of secondary resources. This has a shorter time lag to market and greatest added value.
- Circular economy – maintaining and maximising the value of materials and minerals and harnessing the opportunity of secondary resources.

To exploit these opportunities, the skills-related gaps and challenges will need to be addressed and appropriate education and training made available to ensure an available and equipped current and future workforce.

VI. Next steps

Action will be required across the value chain and all stakeholders to address the challenges, close the skills gaps and ensure sustainable development of both the existing and future workforce. To build on the qualitative findings of this report, a quantitative assessment should be undertaken to understand the future workforce capability needs, map competences and conduct a gap analysis on education and training provision and provider capacity. This combined with implementing measures to tackle the challenges outlined in this report will enable Government, employers, education providers, relevant professional bodies and other stakeholders to put in place the steps necessary to address the gaps and secure a high quality and sustainable workforce and industry.

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C. Introduction

I. Context

Materials are crucial to the UK economy and underpin our daily lives. They are the building blocks of modern society and technology and responsible sourcing and management of materials is of prime importance in the transition to a low-carbon, resilient and resource efficient society.

The global population is predicted to reach 8.5 billion in 2030 and 9.7 billion in 2050[14], technology is evolving faster than ever and there is a global need for climate change mitigation and adaptation including moving to cleaner energy. The combination of these factors will lead to a rapid growth in demand for the materials that underpin the low-carbon transition and societal progress. With an evolving international landscape and a changing geopolitical environment access to stable and sustainable supplies of these materials has taken on a new salience in recent years and is of growing concern in the UK and across the world.

To support the launch of the UK Critical Minerals Strategy[15] the British Geological Survey (BGS) defined a cohort of materials with high criticality for the UK, based on their importance to the UK economy and risk associated with their supply[16].

The defined list of 'critical minerals' is established by necessity of focus and forms an important piece of a bigger picture. Critical minerals are rarely relied on as individual minerals but rather as combinations processed into engineered materials, often through multiple steps, for the unique properties they bestow.

The minerals identified as having high criticality for the UK are essential raw materials for a range of industries and technologies from automotive, defence and aerospace, to medical technologies and renewable energy infrastructure. These minerals and their value chains, play vital roles in the transition to a low-carbon, resilient and resource efficient society.

The projected increase in demand for is well documented. The World Bank predicts production of some minerals such as lithium, graphite and cobalt could see increases in demand of up to 500% from 2018 production levels by 2050[17]. This exceeds the rate at which new primary and secondary sources are currently being developed. Looking at commodity markets over the past year, the risks of inadequate supply are emerging. Price spikes in lithium and other minerals have resulted in significant increases in manufacturing costs of clean energy technologies such as wind and solar photovoltaics[18]. Shortages of supply risk weakening the UK's technological and manufacturing base, negatively affecting economic resilience and competitiveness, reducing attractiveness for investment and giving rise to a source of military vulnerability.

Shortages are likely to be exacerbated by fierce competition between countries and industries, with usage conflicts within and between industrial sectors[19]. This has been

[14] https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/wpp2022_summary_of_results.pdf
[15] https://www.gov.uk/government/publications/uk-critical-mineral-strategy
[16] https://www.bgs.ac.uk/download/uk-criticality-assessment-of-technology-critical-minerals-and-metals
[17] https://www.worldbank.org/en/news/press-release/2020/05/11/mineral-production-to-soar-as-demand-for-clean-energy-increases
[18] https://www.iea.org/commentaries/why-the-european-union-needs-bold-and-broad-strategies-for-critical-minerals
[19] https://www.europarl.europa.eu/RegData/etudes/BRIE/2023/739394/EPRS_BRI(2023)739394_EN.pdf

brought into sharp focus with a changing political landscape and ongoing supply chain disruptions including from the impacts of climate change, the COVID-19 pandemic and port strikes.

Countries worldwide are recognising the strategic importance of materials and different jurisdictions are taking action to secure their supplies such as the United States (US) Inflation Reduction Act[20], the European Union's (EU) Critical Raw Materials Act[21], the Indian Ministry of Mines actively seeking offtake agreements and Chinese subsidies for domestic production.

With a growing demand for minerals there will be a growth in demand for the required skills and talent across the supply chain, both in the UK and internationally. Demand for engineers is predicted to grow faster than for other occupations, vacancies for 'green engineering' roles in the UK have increased by more than half (55%) over the last five years[22].

At the same time there is a concerning and developing trend of declining availability of skilled people, with many professionals reaching retirement age and insufficient new talent entering and developing through the industry to fill the positions.

Enrolment in relevant degree courses is decreasing in the UK and other countries such as Australia[23] and the US[24]. In the UK the number of students studying geology at university has declined year-on-year since 2014 and the last remaining undergraduate mining engineering course in the UK has been put on hold[25].

Mining is considered the most international industry[26] and with countries moving to secure their supplies, the UK will be competing in an increasingly challenging and competitive labour market. It has been predicted that the US Inflation Reduction Act will create demand for 5.9 million new jobs in US clean energy and manufacturing over the next decade[27], the Australian economy will support an additional 115,100 to 329,000 full time equivalent jobs from 2023-2040[28] in the critical minerals and energy transition minerals sector and there will be a hiring gap of between 20,000 and 108,022 in Canada.[29]

II. Purpose of the report

The UK's Critical Minerals Strategy sets an ambition to review the UK's skills, education and training along the critical minerals value chain and define a critical minerals skills blueprint, recognising the full breadth of skills needed. Government is seeking to understand skills-related needs, gaps and opportunities to support a UK critical minerals value chain and support UK companies overseas. Recognising that the skills required for critical minerals value chains are more broadly applicable across the whole materials, minerals and mining sector, Government and the UK's Critical Minerals Intelligence Centre (CMIC) sought the support of IOM3 to undertake a preliminary assessment of the current skills landscape and get a qualitative understanding of any current and anticipated skills gaps.

[20] https://www.epa.gov/green-power-markets/summary-inflation-reduction-act-provisions-related-renewable-energy
[21] https://ec.europa.eu/commission/presscorner/detail/en/ip_23_1661
[22] https://www.engineeringuk.com/news-views/demand-for-engineers-increasing-with-rapid-growth-in-green-jobs/
[23] https://minerals.org.au/wp-content/uploads/2023/01/MTEC-Key-Performance-Measures-Report-2018.pdf
[24] https://datausa.io/profile/cip/mining-mineral-engineering
[25] https://cornishstuff.com/2020/09/04/camborne-school-of-mines-pauses-entry/ Though note the start of a degree apprenticeship for existing mining industry employees from 2023.
[26] https://unctad.org/system/files/official-document/wir2020_en.pdf
[27] https://www.bluegreenalliance.org/site/9-million-good-jobs-from-climate-action-the-inflation-reduction-act/
[28] https://www.industry.gov.au/sites/default/files/2023-06/economic-potential-of-australias-critical-minerals-and-energy-transition-minerals.pdf
[29] https://mihr.ca/wp-content/uploads/2023/03/Mihr-National-Outlook-EN-2023.pdf

D. Methodology

IOM3 convened and consulted a range of key stakeholders from across the value chain through a series of roundtables to inform this report. Three types of session, each targeting a different audience were designed to gather input:

- Employers and those with knowledge of the likely skills and training needs
- Education and training providers
- Users of the system including students and early career professionals

The emerging themes from these sessions were presented and refined at a workshop. This session was designed to bring together different actors from across the landscape and encourage multi-perspective dialogue.

The stakeholder engagement was framed using a model of the value chain consisting of the following phases: exploration, extraction, processing, manufacturing and end-of-life. This was used as a framework to structure the process and is not a comprehensive reflection of the complicated and differing stages in the value chains of the various minerals and end uses.

Whilst the designation of critical minerals gives a necessary focus, there is benefit in viewing the skills-related gaps, challenges and opportunities along the value chain as part of the wider materials, minerals and mining landscape. This is because:

- The defined critical minerals provide a snapshot of a dynamic landscape – the level of criticality for a material can change quickly, for example in the event of a market shock, or over a longer period of time due to changing demands.
- Value chains are varied, complex and often interact; some minerals are produced as co-[30] or by-[31] products of major commodities[32], there can be numerous stages of processing and many variations of product.
- Minerals are rarely relied on as individual minerals but rather as combinations processed into engineered materials.
- A range of materials are essential for our modern and future way of life that may not meet the critical rules definition, for example because supply is currently considered plentiful but the skills gaps and challenges are likely to be similar.

[30] raw materials produced alongside the major commodities that contribute materially to the economics of a deposit
[31] lower value commodities that make up <0.1% of an ore deposit and rarely form viable ore deposits on their own
[32] a raw material which can be bought or sold.


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E. The Value Chain

I. An overview

A high-level model of the value chain provides a framework to consider the typical stages and processes involved in the extraction and use of minerals. Value chains for minerals however, are very complex and varied depending upon a range of factors such as the mineral in question, extraction technique, geographical dispersion, processing method, market dynamics and the end products.

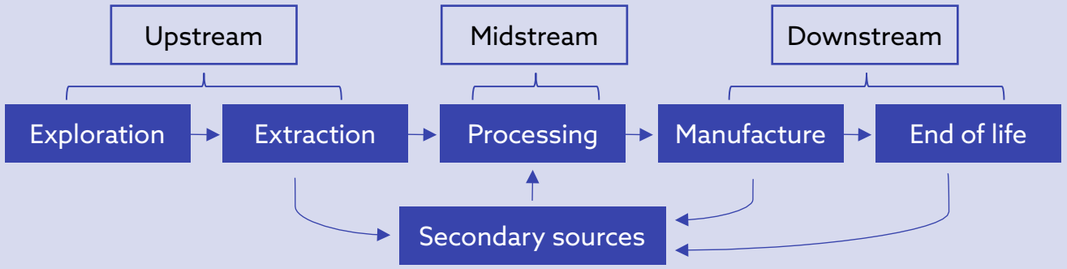


Figure 2 - a high-level model of the minerals value chain

Mineral supply chains can be broadly divided into three segments. Upstream refers to exploration for and extraction of the raw material. Midstream is the processing of that raw material into something more concentrated and usable and the point at which recovered material is introduced. Downstream is where those materials are converted into products and distributed on further. Waste produced from end-of-life products and from downstream operations such as by-products or faulty goods can be recycled to the midstream, providing a secondary source of minerals. Similarly, tailings and mining waste can be re-processed into the midstream.

An example would be for lithium as used in batteries:

- **Upstream** – exploration to identify new deposits; initial resource and reserve estimation; pilot facility; production facility.
- **Midstream** – crushing/grinding rock ores; evaporation or extraction of brines; processing into lithium carbonate or lithium hydroxide.
- **Downstream** – use of lithium carbonate or hydroxide to produce cell cathode and/or electrolyte; assembly into battery; installation of battery into product (car, phone, etc); distribution and sale of product.

II. Skills

Four broad categories of roles were identified across the value chain:

Category	Example job roles
Technical/skilled professional, typically with university education	Mining engineer, exploration geologist
Operational/trade, which may or may not require scientific or technical training	Electrician, mine operator
Statutory, roles laid down in legislation	Mine manager, surveyor
Typical business processes, common to many industries	Human resources, IT

III. UK strengths

As reflected in the UK's Critical Minerals Strategy, the UK has numerous strengths across the value chain and the corresponding skills – both domestically and overseas[33]. The UK's strengths include:

- Research and development excellence
- Renowned technological innovation
- Very strong and respected higher education system with prestigious educational institutions
- Investors and markets – a significant source of finance and influence
- High environmental, social and governance (ESG) standards and practices
- Government policy with considerable influence – for example, on corporate transparency, environmental performance and good governance
- A rich history of mineral and mining expertise
- Many mining companies, including many of the global mining majors, have their headquarters in the UK
- Globally significant consultancies, service providers, industry associations and standards agencies
- A well-developed end-of-life management ecosystem for many materials and products that could be the basis for future development

These strengths provide a strong foundation to build upon for some of the skills needs now and in the future.

[33] https://researchbriefings.files.parliament.uk/documents/POST-PB-0045/POST-PB-0045.pdf

F. Skills challenges and gaps

Stakeholders expressed that a lack of availability and pipeline of skilled workers is a significant risk facing the sector. There is a shortage of key professionals required across the value chain including exploration geology, mining engineering, mine planning, mineral processing and metallurgy[34]. 86% of mining senior leaders and executives surveyed by McKinsey reported it is harder to recruit and retain the talent they need versus two years ago. And 71% said that the talent shortage is holding them back from delivering on production targets and strategic objectives[35]. According to PwC's 26th Annual Global CEO Survey almost two-thirds of mining CEOs believe that skill shortages will have a large or very large impact on profitability over the next ten years[36].

There are cross-cutting challenges and gaps that affect multiple areas of the value chain and those that are more relevant to a specific stage.

Whilst it is helpful to consider the stages in turn, each is part of an often complex chain that requires all links to function effectively to build a more resilient and sustainable supply. Every activity in the value chain provides value to others and in turn depends on them to fully succeed. It is not enough to have access to the raw materials; access to the processed forms of these metals in the form of alloys or chemicals is also required[37].

I. Cross-cutting

i. Challenges

- **Perception, reputation and attraction to the industry**

Across the value chain there are significant challenges with perception, awareness and attraction to the industry. This is influenced by a range of factors such as a lack of public knowledge, misconceptions and misunderstandings, environmental concerns, limited or negative media coverage, complex supply chains and the decreasing availability of training and education.

The mining industry has strong negative perceptions as:

- risky; both in terms of safety and stability
- environmentally damaging
- negatively impacting local communities
- physically demanding, challenging and inflexible working environments and patterns such as remote work locations and long hours
- limited for career growth opportunities
- poor equity, diversity and inclusion
- a historical legacy with a declining industry in the UK

[34] Metallurgy means subtly different things at different stages in the value chain. In a mining context metallurgy generally refers to the mineral processing and extraction phases where the useful metal is won from its ore. In a materials science and engineering context, metallurgy is related to the characterisation (structure and properties) and manipulation of metallic materials such that their properties can be optimised for specific applications, and they can be formed and manufactured in to useful products.
[35] https://www.mckinsey.com/industries/metals-and-mining/our-insights/has-mining-lost-its-luster-why-talent-is-moving-elsewhere-and-how-to-bring-them-back
[36] https://www.pwc.com/gx/en/industries/energy-utilities-resources/publications/mine.html

These negative perceptions significantly impact the attractiveness of education and employment in the industry. 70% of young people aged 15-30 surveyed in Canada said that they definitely wouldn't or probably wouldn't work in mining[38].

The impact of negative perceptions also reaches beyond the individual, not only does it impact the attractiveness of the sector for employment and education and training, but it can lead to additional barriers. There have been active efforts to dissuade involvement in the sector such as recent action by some universities to prohibit mining companies from participating in university career services and protests on campus.

There are factors that further exacerbate these perceptions; from the school curriculum coverage of mining focussing on past disasters, to representation in the media such as miners appearing as the 'bad guys' in films, to some universities banning job posts or relationships with mining companies.

End of life management also suffers from negative perceptions with research indicating that the sector is not often seen as an attractive option for future careers[39].

In addition to the strong negative perceptions across parts of the value chain, there can be a general absence of awareness and limited knowledge of the industries involved and the opportunities available. Examples where there is commonly a lack of understanding include the discovery of new mineral deposits[40] and the technologies involved, the advancements in responsible mining practices, the processes involved in transforming minerals into useable products and their uses and recycling opportunities to reduce the reliance on primary supply and promote resource circularity.

A lack of awareness or understanding of what's involved in the value chain limits the pool of skilled candidates entering the industry and exacerbates skills gaps, which is particularly noticeable in technical roles.

Throughout the stakeholder engagement, a clear theme emerged that many involved in the sector found their career pathways by accident or had early interaction such as a relative working in it.

Lack of awareness is particularly an issue for the midstream; mineral processing has very limited visibility as an industry and is considered the unseen stage of the value chain. It is commonly invisible in the media and general public consciousness.

At the manufacturing stage there appears to be a shift in perception. Once minerals have been transformed into materials, components or products for technologies such as electric vehicle batteries or wind turbines, their role in the transition to a low-carbon society is much more well understood and these areas are often associated with a positive perception.

The BDO Future Workforce Report survey[41] reports a similar shift in career attraction between mining and renewables. Among Gen Z[42] respondents in the UK, 65% said

[37] https://www.birmingham.ac.uk/documents/college-eps/energy/policy/policy-comission-securing-technology-critical-metals-for-britain.pdf
[38] https://mihr.ca/wp-content/uploads/2021/03/MIHR-National-Outlook-LMI-Report-2021-E-web.pdf
[39] https://www.circularonline.co.uk/wp-content/uploads/2023/03/Beyond-Waste-Essential-Skills-for-a-Greener-Tomorrow.pdf
[40] a natural accumulation of a particular mineral at unusually high concentration in the Earth's crust
[41] https://www.bdo.global/en-gb/industries-en/natural-resources-energy/the-future-workforce-bdo-global-natural-resources-2022-survey-report
[42] Generation Z or Gen Z comprises individuals born in the late 1990s or the first decade of the 21st century.

they had considered a career in the natural resources industry. This is significantly higher than 39% across the global survey results but among those who had considered a career in natural resources, Gen Z lean significantly towards renewables: 82% put this as their first choice compared with 4% for mining. When asked why they prefer renewables, 53% say they are attracted to the idea of supporting the transition away from carbon-intensive energy towards cleaner energy.

Another lesson is the perception of renewables as a generally 'safer' sector in which to work. 30% of students in the survey said improving approaches to health and safety would be necessary to encourage their generation to join the mining sector, whereas just 13% of corporates surveyed identified this as being a concern for students.

There is a clear mismatch between the perception of the industry and the factors most likely to motivate the future workforce. Gen Z prioritise industries perceived to offer safety and certainty, with high ethical standards and prioritise factors such as work-life balance, diversity in the workplace and positive social and environmental impact[43].

79% of Gen Z in the UK say the availability of flexible or hybrid working is an important or essential factor when assessing their career options. However, only 50% of the natural resources corporates in the UK identify this as important to Gen Z. Just 24% of Gen Z say they believe a career in natural resources will offer them flexible or hybrid working options.

88% of Gen Z in the UK say working with interesting and diverse groups of people is an important or essential factor when evaluating their career choices. However, just 28% of Gen Z say they believe the natural resources industry has a diverse workforce and only half of UK natural resources corporate respondents said they have programmes in place to attract a diverse workforce[44].

- **Equity, diversity and inclusion**

It is well documented that a lack of diversity in the minerals value chain has been a longstanding issue. Stakeholders shared that there has been progress in recent years, but there remains room for significantly more and that for mine sites, other countries commonly have greater diversity and particularly a more gender-balanced workforce than UK sites.

The extent of the skills gaps identified will require a significant increase in the size of the workforce. Meeting this challenge is made harder by talent not being accessed from the widest pool possible.

A lack of diversity can be attributed to a range of issues. For example, in the extraction phase, historical biases, stereotypes and cultural norms that have shaped the perception

[43,44] https://www.bdo.global/getmedia/c092b963-f642-43b2-b0eb-a590b0fea6a0/BDO-Global-Natural-Resources-2022-Survey-Report.pdf.aspx
[45] ey-you-cant-be-what-you-cant-see-20220923.pdf
[46] https://www.weforum.org/reports/global-gender-gap-report-2021
[47] refers to a company's top management positions, where the "C" stands for "chief."
[48] https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/women-in-metals-mining-make-modest-gains-in-leadership-roles-75759082
[49] https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/articles/howmanypeopledomyjob/2023-05-31
[50] https://committees.parliament.uk/writtenevidence/42416/pdf

of mining as a white male-dominated and challenging working environment. These factors have contributed to limited opportunities and barriers to entry for individuals from diverse backgrounds, resulting in an imbalance in workforce composition and appeal. For example, stakeholders shared applications for apprenticeship programmes display a stark gender imbalance particularly amongst domestic applicants.

Gender diversity has long been a challenge for the mining sector despite having increasing interest from investors screening for ESG metrics. In 2022, women made up roughly 12% of the global mining and metals workforce[45], a gender imbalance second only to the construction sector[46]. For C-suite[47] and executive positions, women hold about 12.1% and 14% respectively[48].

In the occupation census for 2021 in England and Wales 7,220 people were counted as 'mining and quarry workers and related operatives'. Men made up 96.2% and women just 3.8%, compared with 52% and 48% across the whole working population[49].

As of mid-2021 just 16% of core and related engineering occupation roles were held by women compared with 47% of the overall UK workforce[50] and 18.5% of engineering and technology first degree undergraduate entrants were women, which is low compared to 56.5% of students across all subjects[51].

In the UK, black and minority ethnic engineers make up around 30% of engineering graduates and make up only 9% of professional engineers[52].

10.5% of engineering and technology first degree entrants had a known disability, compared to 15.1% for all subjects combined. Of people working as "mining and quarry workers and related operatives" in England and Wales, 8.3% were disabled, the average for all occupations is 9.6%[53].

Following the pandemic, 40% of employers have seen an increase in formal requests for flexible working[54]. When thinking about a new role, 71% of people say being able to have a flexible working pattern is important to them and 12% of employees say they have changed their careers/profession due to a lack of flexible working options within the sector.

Employees with a disability or long-term health condition are significantly more likely than those without to say they have left a job in the last year (21%) or changed their careers/profession (32%) due to a lack of flexible working.

At school age there are inequalities that can significantly affect children's experience of and access to high quality education[55,56]. For example, research shows that, in England, careers provision is 'patterned' around social inequalities and students who are most in need are less likely to receive careers education[57].

[51] https://www.engineeringuk.com/media/318874/engineering-in-higher-education_report_engineeringuk_march23_fv.pdf
[52] https://www.afbe.org.uk/about-us
[53] https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/articles/howmanypeopledomyjob/2023-05-31
[54] https://www.cipd.org/globalassets/media/knowledge/knowledge-hub/reports/2023-pdfs/2023-flexible-hybrid-working-practices-report-8392.pdf
[55] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/973596/The_road_not_taken_-_drivers_of_course_selection.pdf
[56] https://www.sciencecampaign.org.uk/app/uploads/2023/03/CaSE-Inspiring-Innovation-education-review-2021.pdf
[57] https://www.engineeringuk.com/media/232354/our-future-our-careers-2020.pdf

Improving equity, diversity and inclusion is both necessary and beneficial. It is the right thing to do to support employees and the value chain and it brings a range of advantages to the sector, including better problem solving, increased profitability, more effective governance and greater creativity. For example, McKinsey found that companies in the top quartile for gender diversity on executive teams were 25% more likely to have above-average profitability than companies in the lowest quartile. For ethnic and cultural diversity, top-quartile companies outperformed those in the fourth quartile by 36% in profitability[58]. Data from BHP also shows the most inclusive and diverse teams outperformed other teams and operated more safely. They delivered an average of 67% lower total recordable injury frequency and saw improved company culture and productivity. People in diverse teams are also 86% more likely to speak up and share ideas[59].

A key challenge is the limited availability of granular data which makes it difficult to understand the true extent of the challenge across the value chain.

- **Changing skill sets**

Reflecting the evolving needs of the industry, the value chain is experiencing advancements in technology including automation, digitalisation, data analytics and sustainable practices. These changes require different skill sets and there is a growing demand for individuals with relevant expertise.

Some examples of the evolving skillsets required include:

- Exploration: developing and implementing innovative exploration technologies such as remote sensing, machine learning, drones and automation.

- Extraction: automation and robotics and environmental management.

- Processing: metallurgical process optimisation and expertise in recycling techniques and resource recovery.

- Manufacturing: additive manufacturing, statistical analysis and testing methodologies, upskilling the workforce with integration of new systems into existing processes.

- End-of-life: robotics, machine learning, artificial intelligence and database management.

A World Economic Forum Survey asked mining executives which skills are in high demand at their organisations and in 2020 respondents named technology-use skills more often than any other kind[60]. There is an acceleration of the willingness to adopt new technologies with more than 85% of companies surveyed in the mining and metals industries expressing their likelihood to adopt, by 2025, big data analytics, internet of things and connected devices, nonhumanoid robots and cloud computing technologies.

[58] https://www.mckinsey.com/featured-insights/diversity-and-inclusion/diversity-wins-how-inclusion-matters
[59] https://www.bhp.com/news/prospects/2019/10/the-gender-equation
[60] https://www.weforum.org/reports/the-future-of-jobs-report-2020
[61] https://www.pwc.com/gx/en/industries/energy-utilities-resources/publications/mine.html

Many of the emerging skill sets required such as digital skills and materials modelling overlap with skill sets required by other industries and in particular, technology companies. This results in greater competition for these skills and with industries that commonly offer competitive salaries and have high appeal.

In addition to recruiting beyond the traditional talent pool, training of the existing workforce is required. In 2022, 38% of workers surveyed at metals and mining companies said that they're concerned about not getting sufficient training in digital and technology[61].

- **Cyclical industry**

The mining sector, globally and in the UK, experiences cyclical fluctuations characterised by alternating periods of growth and downturns driven by commodity prices, economic conditions and global demand. Technological advances, Government policies, public scrutiny and global events such as economic recessions or geopolitical tensions further shape the cyclical patterns.

Challenges arise when the industry experiences downturns or market fluctuations, which can lead to a reduction in skills supply and demand and the impact can be felt throughout the supply chain. Skills shortages and oversupply follow behind the commodity cycles and with each contraction, experience is lost from the sector. This cyclical nature and its impact on job security and stability can also act as a deterrent to people entering the industry.

- **Talent pipeline**

Stakeholders reported that the current talent pipeline supply is unlikely to meet future demand for skills across the value chain. This is reflected in the BDO Global Natural Resources Survey which outlines that across all sections of the industry, corporates agree there are not enough young people choosing degrees associated with the natural resources industry to generate a big enough pipeline to fill the available vacancies, particularly for specialist engineering, environmental or other technical roles.

New graduates provide a significant source of new talent for the industry and contribute to the next generation of employees vital for the continued growth of the sector. Enrolment in relevant degree courses is decreasing in the UK and countries internationally such as Australia[62] and the US[63]. In Canada, the three engineering disciplines the industry draws most notably in its operations, mining, geological and material and metallurgical engineering, experienced the lowest undergraduate enrolment among all engineering programmes from 2015 to 2019 (in comparison to other engineering programmes such as biosystems that has risen by 73% over the same period)[64].

In the UK the last remaining undergraduate mining engineering course in the UK has been put on hold and the number of students studying geology at university has

[62] https://minerals.org.au/wp-content/uploads/2023/01/MTEC-Key-Performance-Measures-Report-2018.pdf
[63] https://datausa.io/profile/cip/mining-mineral-engineering
[64] https://mihr.ca/wp-content/uploads/2021/03/MIHR-National-Outlook-LMI-Report-2021-E-web.pdf

declined year-on-year. Materials science and engineering degrees are seeing reducing numbers of applications and departments are closing or being merged with other areas. This is likely to limit industry's ability to meet future hiring needs as the pool of graduates becomes increasingly smaller. More detail about the talent pipeline challenges can be found in the sections specific to segments of the value chain.

- **Aging workforce**

At the same time as new entrants into the industry are reducing, many experienced professionals are reaching retirement age, with challenges in succession planning. Stakeholders reported this is a particular issue for mining, the mineral processing industry and roles reliant upon metallurgy skills.

This can be seen in the age demographic of qualified mining-related professionals in the UK – in 2022, of the 1,237 mining and mineral processing engineers registered with the Engineering Council via IOM3, 80% were over the age of 50, with 39% over the age of 66.

- **Visibility and promotion of training routes**

The focus of analysis, planning and conversations can often skew towards degree level training. This is confounded by experts working in this area being able to share their insight and with strength of voice. As teaching is less focussed at lower academic levels and there are fewer vocational training routes, there is less of a voice for these stages and routes. Spending on vocational training in the UK is half the EU average and just over a quarter of the level spent in France and Belgium[65].

- **Bridging the academia-industry gap**

Collaboration between industry and academia is vital to bridge the gap between theoretical knowledge and practical applications. Challenges were reported in aligning academic programmes with industry needs and fostering effective knowledge transfer.

- **Attracting international talent**

Stakeholders highlighted that the complexity and time required to get visas to bring skilled people in from abroad is a barrier to attracting international talent. It can be challenging for applicants and smaller businesses to navigate the system and the upfront cost in the UK is higher than international competitors[66].

- **Centres for Doctoral Training**

When establishing a Centre for Doctoral Training stakeholders reported that the weight of decision making can skew significantly towards the perceived quality of the research whereas the future skills requirements or workforce gaps have limited influence.

ii. Gaps

Skills gaps were identified for technical, trade and statutory roles. Typical business process skills appear to be available in the wider economy but there are issues with recruitment and retention in the mining industry.

[65] https://raeng.org.uk/media/hn4hdep3/perkins_report_jan19_final-web.pdf
[66] https://royalsociety.org/-/media/policy/Publications/2019/international-visa-systems-explainer-july-2019.pdf

- **Engineers**

Engineering skills are in short supply across the value chain and wider economy. Studies indicate that the UK economy suffers a loss of £1.5bn per year due to STEM (science, technology, engineering and mathematics) skills shortages, largely driven by a shortage of skilled engineers. To meet this gap the UK would need to generate an estimated 59,000 engineers annually, just to keep up with current demand[67]. With almost half of engineering businesses experiencing difficulties in the skills available to them when trying to recruit[68], it is a challenging and competitive hiring environment.

- **Metallurgy skills in all their guises**

Metallurgy is a significant and growing skills gap across the stages of the value chain and was highlighted as a challenging gap by stakeholders in both industry and academia. Many metallurgists are reaching retirement age and the end of their career with no suitable replacements available.

In addition, the hollowed-out nature of metallurgy expertise in the UK means it can be difficult for industry to identify researchers to work with in developing new ways of extracting minerals.

- **Supply and demand**

At university level there's still an appetite to provide courses but the demand isn't there from students and courses are struggling to get the numbers required. If the challenges highlighted such as the perception issue can be overcome, university courses could likely scale to meet the demand. However, vocational and technical training is unlikely to be able to respond in the say way as the absence of demand means organisations aren't stepping into the marketplace.

- **Integration of skills**

Greater integration of skills, combining different skill sets and understanding different aspects of the value chain is required. This includes moving beyond siloed specialisms, being more joined up with other actors in the value chain and having a bigger picture view. Examples include:

- Exploration geologists having an awareness of the full value chain, planning for mine closure from the beginning.

- Integration of exploration geology, mining, mineral processing and geometallurgy from the beginning of the value chain which can de-risk projects and prevent delays through incorrect samples.

- Integrating data skills and ESG awareness into all stages of the value chain.

- Combining technical and commercial skills is beneficial for sourcing teams in manufacturing organisations.

- Integrating the processes required for material recovery across the value chain,

[67] https://www.theiet.org/media/11077/engineering-kids-futures.pdf
[68] https://www.theiet.org/media/9234/2021-skills-survey.pdf

including design for disassembly.

- Social skills are becoming more important particularly with roles that are public or customer facing.

- **Postgraduate qualifications**

There is a training gap to bridge the knowledge and skill sets developed at degree level to what is required in the workplace.

II. Upstream – exploration

The exploration phase is the initial stage of the value chain and involves identification of potential deposits. It includes activities such as: geological mapping, remote sensing, geophysical surveys, geochemical sampling, drilling to obtain samples, assaying and analysis, resource estimation, environmental and social assessments and stakeholder engagement including with local communities.

Stakeholders shared that they are currently experiencing recruitment challenges from graduate level to senior specialist. With the global market for exploration activities and skills expected to continue to increase (exploration spending rose by 20% in 2022[69]) these gaps are likely to become more significant.

BGS, jointly supported by BGS National Capability funding and the Department for Business & Trade-funded UK CMIC published findings on the geological *Potential for Critical Raw Material Prospectivity in the UK*[70]. Current understanding of domestic deposits relies on evidence from historic mining and exploration, with targeted research. Minerals determined to have high criticality have gained importance with the advent of modern technologies and have not previously been the subject of any sustained, systematic UK exploration. The prospective highlighted areas will form the focus for collection of new geological, geochemical and geophysical data, in order to identify new prospects for detailed investigation.

This targeted approach and building an understanding of historic mines, will be pivotal to exploring and harnessing domestic supplies. Coupling geological mapping with chemical mapping and carrying out metallurgical assessments of the deposits can help to assess how viable extraction is and de-risk a potential project. These activities will lead to a direct skills requirement and in addition, could reveal potential future skills requirements through unveiling the extent of the UK's domestic potential.

The specific skills and job roles required varies depending on a range of factors including the target mineral, geological context and exploration methods employed.

Job roles include: exploration geologist, data scientist, metallurgist, remote sensing specialist, mineral surveyor, geographic information system (GIS) analyst, field technician, geochemist, data analyst, core logger, mapping specialist, project manager, environmental specialist, community engagement officer, regulatory compliance officer, mineral economist, hydrogeologist, geotechnical engineer, exploration manager, technical writer/communicator.

Skills required include: geological mapping and interpretation, planning and permitting expertise, drilling, geometallurgy, remote sensing and image analysis, geophysical survey techniques, GIS analysis, fieldwork and sample collection, geochemical analysis, data analysis and interpretation, core logging and description, mapping software proficiency, project management, environmental impact assessment, stakeholder engagement and communication, regulatory compliance, economic and financial analysis, data management and database skills, hydrogeological understanding, rock and mineral analysis, geotechnical analysis and site assessment, leadership and team management, technical writing and reporting.

i. Challenges

- **Talent pipeline**

The supply of individuals entering the profession is not keeping pace with the demand. At both school and university level there has been a decrease in numbers of students studying geology, resulting in a reduced talent pipeline to recruit from.

At school level, geology is commonly integrated into another subject and without standardisation, such as geography, chemistry or physics[71]. As a result geology can be deprioritised in the classroom with teachers possessing varying levels of knowledge.

The numbers of students studying GCSE and A-Level geology are in decline with A-Level enrolment falling from a peak of 2,240 in 2015 to 1,268 in 2019. The numbers studying geoscience at university are now following the same trend.

A joint report from The Geological Society of London and University Geoscience UK[72] outlines that the number of students studying geology at university has declined year-on-year since 2014, a total decrease of 43%. Stakeholders shared that exploration geology postgraduate degree enrolment numbers are decreasing, with around half the number of applicants levels of a few years ago and the expectation is the trend will continue next year.

This is reflected in other countries, for example in the US the number of 2020 geology and earth-sciences graduates was nearly 25% less than in 2015, according to the US National Center for Education Statistics[73]. Whereas during that period the total number of students graduating overall increased 8%.

There are a limited number of dedicated exploration geology courses at UK universities, with those available for 2023 including Cardiff University, Camborne School of Mines University of Exeter and University of St Andrews. Broader geology courses don't necessarily cover exploration and resource geology, further reducing the talent pool size.

[69] https://iea.blob.core.windows.net/assets/afc35261-41b2-47d4-86d6-d5d77fc259be/CriticalMineralsMarketReview2023.pdf
[70] https://ukcmic.org/downloads/reports/ukcmic-potential-for-critical-raw-material-prospectivity-in-the-uk-cr23024.pdf
[71] https://www.geolsoc.org.uk/Geoscientist/Archive/September-2019/Feature-2

[72] https://www.geolsoc.org.uk/~/media/shared/documents/education%20and%20careers/UGUK/resources/enrolment%20strategy.pdf?la=en
[73] https://nces.ed.gov/

Degree-level geoscience qualifications fail to attract students from a wide range of backgrounds in the UK; in the 2018/2019 school year, Black, Asian and Minority Ethnic (BAME) students made up only 11% of those studying towards their first degree, in contrast to 18% in the physical sciences[74].

ii. Gaps

- **Continuing professional development**

Degree courses vary in their content and it is unlikely that a new graduate will have the full and specific skill set required by an employer. For example, some geologists may not have the opportunity to take a minerals systems module, core logging, or field work (particularly in the years of COVID-19 restrictions). This is leaving a skills gap between what is required by employers and what new graduates are equipped with. Continuing professional development can help to bridge the gap but there are very few training opportunities available other than those provided in-house.

- **4-12 years experience**

Professionals with 4-12 years of experience commonly leave the UK to seek opportunities abroad, with greater financial benefits and to gain a range of experience cited as the driving reasons. After this timeframe it is common for individuals to return to the UK, often with additional knowledge and gained experience.

- **Mineral planning**

Navigating the UK's complex mineral planning process requires specialist knowledge and understanding. This was identified by stakeholders as a current and growing skills gap with an aging workforce and lack of new entrants.

- **Regulator**

There are several different regulatory regimes involved for minerals extraction. Mineral planning policy is devolved to local authority bodies designated as the Mineral Planning Authority. Environmental permits are issued by the relevant environment agency. Other regulators may include protection bodies for nature or heritage and in many cases, The Crown Estate. For the UK mining sector to thrive, a robust and workable regulatory process, with the knowledge and skills to deliver it is essential. Regulatory roles can face specific challenges such as lower salary ranges than industry roles, additional negative perceptions and capacity cuts, further concentrating the skills gap[75].

- **Developing modelling and technologies**

Modelling can provide an idea of which deposits the UK may be able to exploit for the kinds of minerals that can currently be processed domestically. With new technologies there are different options for processing which may require changes to modelling. Skills to develop new modelling and technologies to process different minerals/sources and broaden outside of the current geological box will be required.

[74] https://www.hesa.ac.uk/data-and-analysis/students/table-8
[75] https://www.criticalmineral.org/_files/ugd/5caeff_e7c71092beec4c8798efe5830c7988dc.pdf

- **Exploration drilling**

Stakeholders reported a shortage of UK based companies and individuals that are able to carry out exploration drilling which leads to international contractors typically being used. There is a Geo Drilling Apprenticeship Programme in Ireland delivered by South East Technological University and lead industry partner Geoscience Ireland[76] but there is a lack of relevant training in the UK.

III. Upstream - extraction

Once a viable deposit is identified the extraction phase begins. Different mining methods can be employed depending on the type of deposit, activities include mine planning and design, site preparation, extraction and transport.

Whilst the specific skill sets are dependent on the individual mineralogy, mining technique, processing steps and where beneficiation[77] is taking place, there are overarching themes that emerged through the stakeholder engagement.

Job roles include: mining engineer, geotechnical engineer, health and safety manager, construction, environmental engineer, electrical engineer, mechanical engineer, geologist, blasting engineer, maintenance technician, mine supervisor, drill and blast operator, equipment operator, surveyor, shift supervisor, process technician, transport driver, automation engineer, data scientist, water treatment specialist.

Skills required include: mining engineering, mine planning and design, geotechnical engineering, mineral processing, health and safety regulations and compliance, environmental management and sustainability, blasting techniques and safety, maintenance and equipment operation, surveying and mapping, shift supervision and team management, supply chain and logistics, process operations and optimisation, production scheduling and coordination, water treatment and quality control, environmental monitoring and compliance, risk assessment and mitigation, incident response and emergency preparedness, crushing and grinding operations, workplace safety and hazard identification, problem-solving and troubleshooting.

i. Challenges

- **Cyclical industry**

The cyclical nature of mining presents challenges for workforce planning and development. It becomes difficult to maintain a stable workforce with the right skill sets during periods of low activity while also being able to quickly ramp up operations when market conditions improve.

Additionally, the cyclical nature poses challenges for skills development and training. During downturns investment in training and development programmes may decrease, limiting opportunities for upskilling and reskilling. This can lead to a skills gap when the industry rebounds as there may not be enough qualified workers

[76] https://www.geoscience.ie/geo-drilling-apprenticeship/
[77] a process that improves the ore by removing the unwanted minerals, giving ore concentrate and tailings.

available to meet the increased demand.

- **Competition**

Mining is considered the most international industry[78] and with countries moving to secure their supplies the UK will be competing in an increasingly challenging and competitive labour market. It has been predicted that the US Inflation Reduction Act will create demand for 5.9 million new jobs in US clean energy and manufacturing over the next decade[79], the Australian economy will support an additional 115,100 to 329,000 full time equivalent jobs from 2023-2040[80] in the critical minerals and energy transition minerals sector and there will be a hiring gap of between 20,000 and 108,022 in Canada[81].

Talent attraction and retention can become challenging in the UK as other countries offer competitive packages and there are a wider range of opportunities available. Skilled workers from the UK seek employment abroad resulting in a loss of critical skills and expertise in the UK. Stakeholders reported this is often temporary and workers return bringing additional knowledge and expertise back to the UK.

Stakeholders shared that within the UK they are facing challenges with talent being drained by big projects.

- **Aging workforce**

In addition to the challenges of an aging workforce outlined in the cross-cutting section (F. I. i), there is an additional layer of complexity in the extraction phase. When the coal industry closed down the talent was released onto the market. This supressed demand for new entrants as companies will have found it easier to recruit ready trained former coal mining professionals than to sponsor new students and apprentices. It is likely that this contributed to the reduction in relevant university and other courses further compounding the impact. The UK's National Coal Board (NCB) (and, briefly, its successor British Coal) was a world class talent developer at all levels and across multiple skills, from coal loaders and plumbers to design engineers and senior managers. Thirty years ago, there were five university departments hosting over 300 mining undergraduates in the UK. With the systematic training programmes of the NCB/British Coal ending around the beginning of the 1990s, over 30 years later many of these individuals are now reaching retirement age and the UK is reaching the end of this legacy that has largely sustained the UK mining industry to date. There is no longer the training available or people coming through to fill the gaps or to pass knowledge onto.

- **Talent pipeline – degree level**

There is a decline in the number of students applying to study mining and mineral processing. Stakeholders from across universities offering BSc and MSc courses reported a challenge with recruitment and the supply of new entrants. The University

[78] https://unctad.org/system/files/official-document/wir2020_en.pdf
[79] https://www.bluegreenalliance.org/site/9-million-good-jobs-from-climate-action-the-inflation-reduction-act/
[80] https://www.industry.gov.au/sites/default/files/2023-06/economic-potential-of-australias-critical-minerals-and-energy-transition-minerals.pdf
[81] https://mihr.ca/wp-content/uploads/2023/03/Mihr-National-Outlook-EN-2023.pdf
[82] https://irp.cdn-website.com/7bd9b7ac/files/uploaded/220812%20UKMEF%20Report%20on%20Strategic%20Need%20for%20Mining%20Graduates%20corrected%20for%20Deloitte%20%28PDF_4%29.pdf

of Exeter has paused recruitment from 2021 entry onto its undergraduate Mining Engineering degree programme at the Camborne School of Mines (CSM), the only remaining undergraduate mining engineering course in the UK, as the current demand is not sufficient to sustain the course[82].

The international picture is similar; institutions overseas are reducing and producing fewer mining engineers. Mining centric countries such as Australia are facing significant challenges recruiting students, with a 63% drop in mining engineering enrolment in 2020 from 2014. The United States saw a 29% drop in mining graduates[83] and Canada's mining and mineral-engineering enrolment was down 10% in 2020 compared with 2016[84].

- **Transferability**

Transferability of skills offers an opportunity for translation of workforce at all levels. However, the skills gaps in UK exploration are not currently straightforward to transfer from other areas. For example, the oil and gas industry is a substantial source of talent with valuable safety training and leadership and management experience, however stakeholders with experience of attempting to transfer skills into mining roles relayed challenges, stating in particular that skills are unique for hard rock[85] mining and drill rigs are very different to those in oil and gas.

- **Approach to talent**

Industry has typically favoured a 'buy it' instead of 'build it' approach to talent acquisition. There has been limited focus or investment in reskilling and upskilling, despite 56% stating it as a priority last year and 60% highlighting it again for the year ahead[86].

ii. Gaps

As the mining sector in the UK is growing, there is a growing skills gap for operatives of all skills from mining engineering, supervisor and management skills. Outsourcing is a regular occurrence to fill the roles required.

Engineering skills for a host of roles are in short supply including mechanical engineering, electrical engineering and mining engineering. Stakeholders shared that whilst some skills required may be available in the civil world, such as geotechnical expertise, it can be difficult to find this for mining positions.

Other gaps highlighted included difficulty sourcing IT skills, ground support engineers, hydrologists and operators capable of understanding metallurgical beneficiation process (not necessarily with a degree).

- **Reflecting the cyclical nature of mining**

During downturns there can often be reductions in the workforce including reduced recruitment and experienced workers leaving the industry. This particularly affects the

[83] https://www.mckinsey.com/industries/metals-and-mining/our-insights/has-mining-lost-its-luster-why-talent-is-moving-elsewhere-and-how-to-bring-them-back
[84] https://www.wsj.com/articles/a-dirty-job-that-few-want-mining-companies-struggle-to-hire-for-the-energy-transition-7d62d2ae#:~:text=Canada's%20mining%20and%20mineral%2Dengineering,with%20lower%20density%20of%20metals.
[85] A term applied to igneous and metamorphic rocks that are distinguished from sedimentary rocks because they are typically more difficult to break up.
[86] https://assets.ey.com/content/dam/ey-sites/ey-com/en_gl/topics/mining-metals/ey-top-10-business-risks-and-opportunities-for-mining-and-metals-in-2023.pdf

upstream segment of the value chain. As a result, there is a skills 'demographic gap' of experience ranges that can be mapped to downturns, both from a lack of new entrants to the sector (and natural progression as in other more stable sectors) and sections of the workforce moving to employment in other sectors during a downturn.

- **General managers**

Stakeholders reported a lack of access to general managers. This role requires an understanding of a range of subjects to be able to manage all elements from environmental impacts to engineering impacts. As a result, the skill set required takes time to develop and there is not a quick fix solution to the growing gap.

- **4–12-year experience**

Echoing the exploration phase, there is a 4–12-year experience gap in the UK for mining engineers. These professionals commonly return after this period with additional experiences and knowledge. UK companies therefore face a challenge recruiting in this experience range to a greater extent than for roles requiring under 4 years or over 12 years of experience.

- **Construction**

Skills in common with other sectors, such those required for construction, are susceptible to wider shortages. For example, roles such as contractors, electrical engineers and mechanical engineers are required for a range of infrastructure projects and face competition with other sectors.

- **Underground**

There is a shortage of people qualified to work underground. There is a lack of training sufficient for underground working, other than that developed onsite. The current skills are therefore moving through the workforce towards retirement, with no new talent able to infill vacant positions.

- **Regulator capacity**

As outlined in the exploration phase section, there is a gap in regulatory skills, usually in terms of capacity. These skills or access to these skills is key to an effective and well-regulated industry.

IV. Midstream – processing

The processing phase involves the transformation of raw mineral materials into refined products that meet specific quality, purity and technical specifications.

This stage focusses on extracting and separating the desired minerals from the ore or concentrate obtained during the extraction stage. The processing stage plays an important role in unlocking the value of minerals for use in various industries and can include the following activities: crushing and grinding, beneficiation, hydrometallurgy, pyrometallurgy, chemical processes, drying and calcination, physical separation, size reduction and classification, product formulation and quality control and testing.

Job roles include: metallurgical engineer, process technician/operator, chemical engineer, hydrometallurgist, pyrometallurgist, quality control analyst, research and development scientist, environmental engineer/consultant, plant manager/supervisor, maintenance manager/technician, supply chain manager, regulatory compliance specialist, materials engineer, process control engineer, analytical chemist, product development engineer, energy efficiency specialist, water treatment engineer, safety and environmental compliance officer, logistics coordinator, research and development, quality assurance manager.

Skills required include: metallurgical processes and techniques, chemical separation processes, pyrometallurgy, hydrometallurgy, process operation and control, electrochemistry, strategic procurement, chemical process engineering, quality control and testing, research and development, environmental management and compliance, plant management and supervision, maintenance and equipment repair, supply chain management, regulatory compliance and permitting, materials analysis, science and engineering, process control systems and instrumentation, analytical chemistry techniques, product development and optimisation, energy efficiency analysis and implementation, water treatment and recycling methods, safety and environmental compliance, disassembly, robotics, logistics and inventory management, quality assurance and quality management systems.

i. Challenges

- **Awareness**

The mineral processing phase often operates 'behind the scenes' and receives much less visibility compared to the other stages of the value chain. It is commonly invisible in the media and general public consciousness. As a result, there is a lack of awareness of career options, leading to a smaller pool of talent actively interested in pursuing opportunities in mineral processing.

- **Declining expertise**

A previous decrease in mining activities in the UK has resulted in a shortage of skilled professionals with practical experience in mineral processing operations.

- **Mineral processing/extraction metallurgy talent pipeline**

The mineral processing phase faces a challenge accessing sufficient quantity and quality professionals. There is a limited talent pipeline, with declining opportunities to study mineral processing and extraction metallurgy in the UK. Examples of the few courses available include an MSc at the University of Dundee and an MSc at the Camborne School of Mines, University of Exeter.

In addition, metallurgy has been subsumed into materials engineering degrees, taken into a wider group of materials resulting in less time to focus on metallurgy and in particular specific areas such as extraction metallurgy.

i. Gaps

Mineral processing is key to developing resources yet there are limited numbers of mineral processors coming into the profession and UK companies are already looking overseas to recruit in the face of shortages. Whilst this is somewhat of an issue now it is expected to become much more significant in the future. This is further compounded by an increase in exploiting potentially more complex and different deposits that will require talented mineral processors and increased recycling activities.

Stakeholders identified electrochemistry as a particular skills gap, with many electrochemists electing to work in the battery industry.

- **Recycling**

A dramatic increase in recycling capacity and design for recycling will be needed to support a circular economy and improve access to available resources (See Section VI). The skills required to effectively recycle technologies such as electric vehicle batteries and wind turbines reflect those required for mineral processing.

There is a clear gap for skills focussing on application of mineral extraction techniques and technologies to end of life products to ensure materials can be recovered. There are few instances of this occurring in the UK. Typically, the current practice is to apply bulk pyrometallurgical (which uses high temperature) and hydrometallurgical (which involves the use of aqueous solution) processes. As recycling activity develops and increases this will put additional pressure on the demand and insufficient supply of mineral extraction skills.

V. Downstream – manufacture

Many manufacturing roles are in industries reliant on access to the materials that are won from minerals. The development of new technologies to support the transition to a low carbon, resource efficient and resilient society is not only dependent on the ability to extract natural resources, but also on having the skilled people available to research and develop new materials and process these into useful components and products.

The manufacturing and product development phase involves the conversion of processed materials from minerals into useable products or components for use in various industries and applications. This phase focusses on transforming refined materials into intermediate or final products or technologies through different manufacturing processes and can include the following activities: material formulation, chemical processing, shaping and forming, heat treatment, machining and fabrication, surface treatment and coating, assembly and integration, quality control and testing, innovation and supply chain co-ordination and logistics.

Job roles include: metallurgist, materials engineer, manufacturing engineer, production supervisor, electrochemist, automation engineer, supply chain manager, quality control manager, process improvement specialist, industrial designer, packaging engineer,

logistics coordinator, environmental sustainability manager, health and safety officer, materials scientist, research and development engineer, formulation scientist, product manager, sales and marketing manager, project manager, process engineer, life cycle assessment practitioners, materials modellers, (eco)toxicologist.

Skills required include: materials science and engineering, metallurgy, manufacturing process engineering, production management and supervision, automation and robotics, supply chain management, blockchain, electrochemistry, quality control and assurance, process improvement methodologies, industrial design principles, packaging design and optimisation, logistics and distribution management, environmental sustainability strategies, health and safety regulations and compliance, materials selection, research and development, data analysis, product lifecycle management, sales and marketing strategies, project management, cost accounting and analysis, regulatory compliance and reporting, equipment maintenance and repair.

i. Challenges

While the UK has strength in both its research base and capacity for technology innovation, manufacturers face difficulty in accessing the skilled workforce they need to turn such innovation into profit and maintain their competitiveness taking advantage of the latest technologies[87].

- **Awareness and attraction**

There is a mix of awareness and attraction levels for materials science and engineering and manufacturing roles and the skills required. For materials science and engineering, interest and therefore talent is moving away from traditional materials towards areas such as sustainable aviation fuel, next generation alloys and biomedical materials. This is leaving a skills gap around the more traditional materials. All materials science and engineering courses teach the fundamentals, but students typically opt to specialise and work in the 'trendier' sounding industries. This was also echoed with stakeholder experience with interns and their interests.

- **Talent pipeline**

Whilst the UK materials science and engineering skills base is of high quality, there are significant issues with quantity and diversity. A skills shortage for materials science and engineering already exists in the UK as a result of an imbalance between the supply and demand for talent.

At the same time the number of standalone materials departments at universities has significantly reduced over the last two decades, with materials being merged with other disciplines such as mechanical engineering. This further compounds the issue of recruiting students into materials science and engineering and means that less people are trained from their first undergraduate year in materials.

[87] https://hvm.catapult.org.uk/wp-content/uploads/2022/06/Manufacturing-the-Future-Workforce-Full-Report.pdf

There is a risk of materials science and engineering losing its profile within academia. There is concern about a cycle developing of knowledge and experience depletion and therefore a decline in interest and advocation, resulting in fewer opportunities and a reduced talent pool, further perpetuating the issue.

The value of materials is not recognised in the economy and society in the UK. Media discussions commonly focus on negative impacts such as emissions and material pollution. The perceived unattractiveness of materials science and engineering negatively impacts recruitment and retention in both industry and academia.

Metallurgy was identified as a key skill area across the value chain, yet it is not taught as a standalone topic for first degree at any UK university. Only three (Cambridge, Manchester and Sheffield) currently have undergraduate courses that explicitly mention metallurgy in their titles (a fourth at Birmingham has now closed to new entrants). And these are focussed on downstream metallurgy rather than extraction metallurgy. Generally, metallurgy is taught as part of wider materials science and engineering courses, which is offered at nine UK universities.

At pre-university level metallurgy training from operator to technical and then investigator/supervisor levels exist, but these tend to be short (mainly one-day) CPD type courses for people already working in the field and are typically for one very specific aspect of a very broad field.

There is some metals content in an option module of the BTEC Mechanical Engineering course at Level 3, but it is only about 12 hours learning out of a two-year course.

There are a few apprenticeships at Level 3 or 4 where apprentices require very limited knowledge of ferrous and non-ferrous metals, but this might be one or two statements out of 20-30 Knowledge Skills and Behaviours[88]. These are:

- Level 3 Plate welder
- Level 3 Pipe welder
- Level 3 Metal fabricator
- Level 3 Metal casting, foundry and pattern making technician
- Level 3 Engineering technician
- Level 4 Engineering manufacturing technician

• **Translating research and scaling technology**

The UK is good at fundamental lab-based research but less effective at focussing those skills in areas that will lead to commercial success or transitioning successful lab-based research to market.

There is a large chasm between a successful result in a laboratory and scaled success and the work it takes is often under-valued. Furthermore, students are commonly not taught about how technology is scaled. This can lead to difficulties in university-business partnerships and lack of skills for students transitioning from university into industry positions.

[88] The core attributes that you must have as an apprentice in order to be competent in the occupation that you're working in

ii. Gaps

• **Metallurgists**

Relatively short supply of all types of metallurgist were identified by stakeholders, whether it's alloy design and material development professional who takes account of critical raw materials issues, or a manufacturing control or technical surveillance audit professional, or someone dealing with supply chains and purchasing.

• **Design for the circular economy**

Minerals, products and components should be kept at their highest value for as long as possible. Skills are required to promote a circular economy, identifying opportunities to reduce material use, reuse and recycle. This is particularly important at the design stage to ensure materials aren't compromised and products can be effectively disassembled. An understanding of what materials are in a product, how they can be recovered and returned back to processing is key to ensuring the best use of resources available.

Design for recycle and reuse will play a key role in improving recycling rates. Dismantling is time consuming and expensive, often outweighing the financial benefit of extracting the minerals at present. Design decisions need to be made collaboratively with downstream processors to ensure factors affecting the quality of recycled material are considered.

Highly skilled engineers with the necessary experience in designing and creating products for the circular economy will be required and are in short supply. Skills that enable as much recovery as possible such as research and design skills for new manufacturing techniques that can help to reduce losses, for example this can be from 20 to 60% in the manufacturing of rare earth magnets[89].

• **Ethical sourcing and traceability**

The drive to reduce organisational risk and in some cases the impacts of the rules of origin are increasingly causing manufacturers to scrutinise their supply chains.

Full traceability of minerals will be key to building ethical, responsible value chains. The skills required to build and implement a traceability solution from extraction to end of life and back into the value chain will be needed. There is a requirement for the skills to build the infrastructure to enable assurance of source, tracking and tracing systems and standards.

Supply chain understanding combined with appropriate commercial measures that can be taken to secure those supplies are rare but essential skills.

[89] https://www.birmingham.ac.uk/documents/college-eps/energy/policy/policy-comission-securing-technology-critical-metals-for-britain.pdf

- **Ecotoxicologists**

Stakeholders reported that the UK isn't training enough (eco)toxicologists with competence in industrial chemical toxicology and risk assessment to support sustainable chemical/technology introductions. This causes a bottleneck in the new product/technology introductions process, leading to potential delays.

VI. End of life and secondary resources

The end-of-life phase refers to the management of products containing minerals once they reach the end of their useful life. This phase focusses on recovering minerals and their value, effectively managing waste and minimising environmental impacts. It typically involves activities such as collection and recovery, dismantling and disassembly, material recovery and recycling, waste management and treatment, environmental monitoring, circular economy strategies and compliance.

Recycling will play a role in sustaining future mineral supply and bridging the gap between demand and supply. Chemical engineers will be required to design new processes and maintenance skills will be needed to ensure plant efficiency and longevity.

Job roles include: recycling specialist, chemical engineers, chemist, waste management engineer, environmental compliance officer, circular economy analyst, sustainability manager, research and development engineer, regulatory affairs specialist, logistics coordinator, quality control analyst, reverse logistics coordinator, supply chain manager, product stewardship manager, materials recovery technician, sales and marketing manager, project manager, compliance auditor, energy efficiency specialist, environmental consultant, data analyst.

Skills required include: recycling technologies and processes, chemical engineering, waste management and disposal regulations, maintenance, environmental compliance and reporting, circular economy strategies, sustainability analysis and implementation, research and development, regulatory affairs and compliance, logistics and reverse logistics coordination, quality control and assurance, supply chain management, product stewardship and extended producer responsibility, materials recovery and separation techniques, sales and marketing strategies for recycled materials, project management, compliance auditing and monitoring, energy efficiency analysis and optimisation, environmental consulting and impact assessment, data analysis and reporting.

i. Challenges

- **Recycling**

Effective recycling and value extraction is still at its nascent stages in the UK and will require significant development. Minerals are often present in small quantities and require specialised technologies to effectively extract and recycle them. The skills to develop and use innovative new techniques and technologies will be required to help build a thriving recycling industry.

There is a limited pool of chemists experienced in metal recycling processes due to only a few centres of excellence in the UK. Chemical/process engineers are also demand in other industries leading to greater competition.

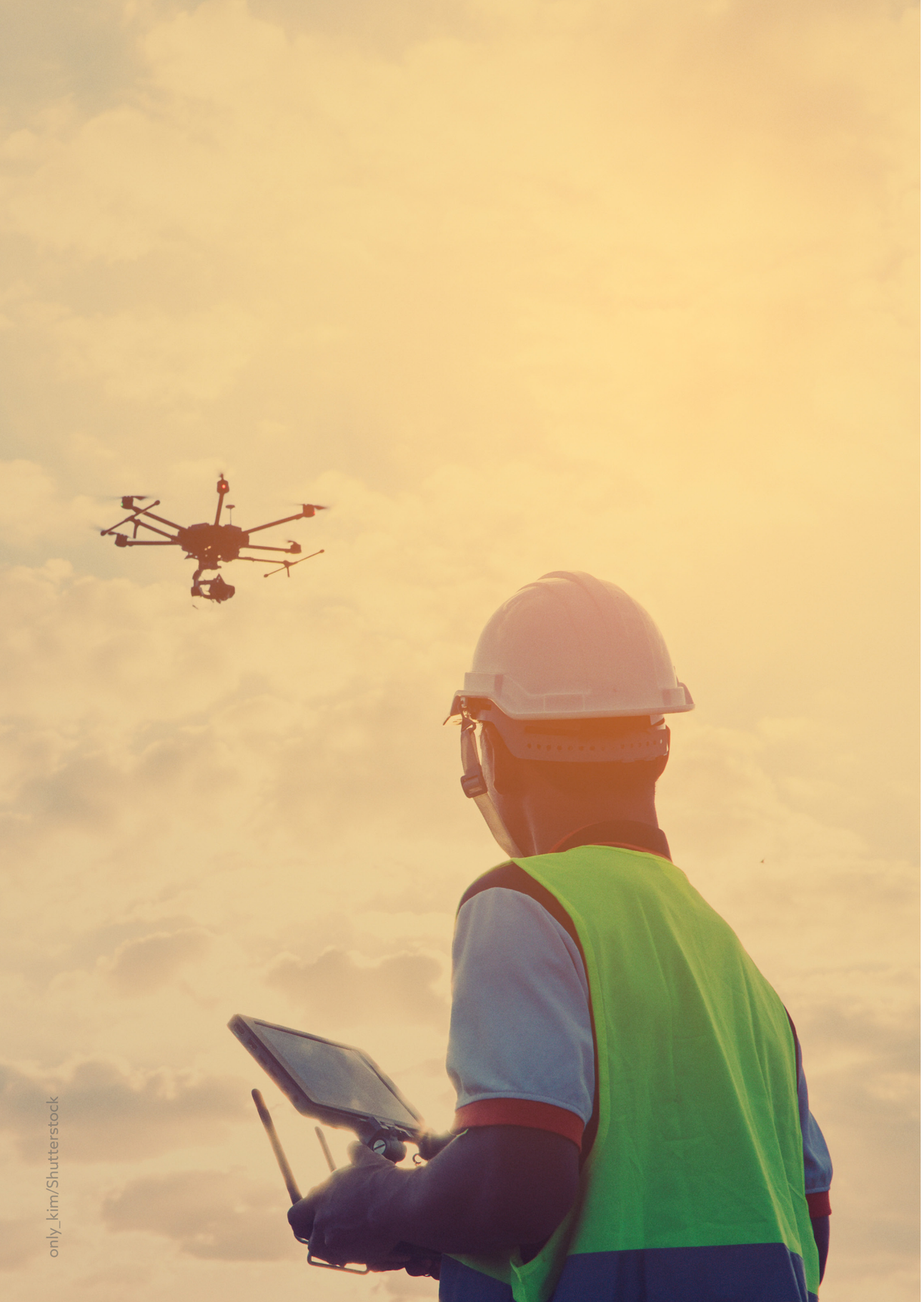
- **Linking disassembly with design**

Thinking about material recovery at end of life is not common during the design process which makes understanding what materials are in a product and how they can be extracted very difficult. This results in more generalised approaches being taken for recovery and material and value being lost.

ii. Gaps

- **Pyrometallurgy and hydrometallurgy**

Pyrometallurgical recovery and hydrometallurgical recovery skills are both in short supply and as demand increases, will result in growing skills gap.



only_kim/Shutterstock

G. Opportunities to improve skills supply

There are numerous opportunities available to address the skills gaps and challenges facing the minerals value chain. A multifaceted approach will be required, implemented in tandem to ensure the immediate challenge is overcome and the future of the industry is sustainable.

Overcoming the challenges outlined in this report will require the involvement of a range of actors and active engagement between industry, education and training providers, professional bodies and policy makers.

- **Attraction to the industry**

Updating and improving the perceptions and raising awareness of the career opportunities along the value chain is key to attracting skilled professionals.

Actively addressing the perception and awareness issues will help significantly towards creating a better-informed society that recognises the importance of minerals and the opportunities they present for sustainable development and the low-carbon transition. Combined with raising awareness of the career opportunities along the value chain, this is key to attracting skilled professionals.

The transition to a low-carbon society presents an opportunity to communicate the vital role of the full value chain for a sustainable future. Growth in the domestic mining industry, if done responsibly, offers potential for visual demonstration and to help improve the understanding of the role of mining. Reframing mining and changing the language associated with it from a 'heritage' activity to a modern industry with the opportunity to affect real change will be key to addressing the skills shortages. There are opportunities to learn from other sectors that have difficult perception issues such as oil and gas.

Effectively communicating the vital role of the sector in enabling the transition and improving the ESG narrative and following through on these commitments will help make the industry more attractive, particularly as most employees believe it is important for their company to have a purpose with which they can align[90].

There is a lot of good work going on to help tackle the negative perceptions from communications campaigns, to outreach in primary schools and community open days. More needs to be done however and across all stakeholders and levels, from first boots on the ground, to miners positively representing the industry and being conscious of the community, through schools and education providers and Government. All actors have a role to play from university courses updating the descriptions of modules and degree programmes, to industry building trust with local communities and individuals speaking positively about their roles and projects.

There are numerous opportunities available to address the perception and awareness issues, including:

- Education and outreach: increasing public education and awareness campaigns about the role and importance of minerals in everyday life and the low-carbon transition.
- Stakeholder engagement: engaging with local communities, environmental groups, career advice services and other stakeholders to foster open dialogue, address concerns and showcase responsible practices can build trust and improve perceptions.

[90] https://www.mckinsey.com/capabilities/people-and-organizational-performance/our-insights/purpose-shifting-from-why-to-how

- Collaboration: collaboration between industry, academia, innovating bodies, education and training systems and Government can help promote research, development and knowledge sharing to address challenges and highlight the positive contributions of the minerals supply chain.
- Media engagement: proactive engagement with the media to raise the visibility of the role of minerals and share success stories, technological advancements and responsible practices.

For both perception and visibility it is important there is visibility of career options and increasingly more important, how these careers can affect positive change.

There is an opportunity to harness the positive public image towards technologies associated with the low-carbon transition such as electric vehicles. For example, courses in the UK could be revisited to include midstream metallurgy within a wider green economy framework[91].

- **Careers guidance**

A good quality well-informed system for career advice and guidance is crucial to attracting more people to consider a position along the value chain. This should ensure focus expands beyond the university route.

The ease of access to information can have a significant impact on students' decisions. EngineeringUK showed 82% of young people aged 11 to 19 who said they knew quite a lot or a lot about engineering would consider a career in the sector, compared to just 40% who reported not knowing a lot about engineering[92].

Organisations such as STEM Learning[93] provide a range of support for schools to help them adhere to the Gatsby Good Careers Guidance Benchmarks, a framework of eight guidelines for good careers education, developed to support schools in providing students with the best possible careers guidance[94].

- **Building a talent pipeline**

To build the necessary talent pipeline, a multi-tiered approach is required. It is crucial to engage individuals from a young age and continuously throughout their education to inform their perceptions and career choices. School education has an important role in supporting a sustainable talent pipeline over the medium and longer term and offers an opportunity to help address inequalities in the workforce. Research has shown that children are influenced about their future education and career choices by the age of seven, making early engagement essential. A study in Europe has shown that interest in STEM drops off significantly between the ages of 15 and 16 for girls, with limited recovery[95].

This is particularly important for the UK where the education system drives earlier specialising than in other countries such as the US or Canada. In these countries, industry can have a significant impact by going into universities, but in the UK, specialising starts at GCSE stage which means it's essential to target students much earlier in their education.

Supporting a talent pipeline at all stages through modernising perceptions and increasing visibility of the minerals value chain and related careers, particularly its role in reaching net-zero and fuelling high tech industry can be achieved through various means, such as:

- Engaging STEM ambassadors who can inspire and educate students
- Ensuring the school curriculum is designed to support the skills needs of our future workforce that are required for the transition to a low-carbon resource efficient society
- Embedding responsible mining and its role in the transition into the curriculum
- Continuous professional development for teachers
- Influencing adults and support networks
- Showcasing job prospects and options
- Visibility of role models showcasing the range of people and roles working across the value chain
- Updating course descriptions to reflect the role in the transition
- Promoting courses through different platforms such as social media
- Facilitating transfer from related disciplines and industries
- Using remote learning
- Learning from other sectors and countries
- Greater interaction between universities and companies, for example, learning from oil and gas industry

- **Current initiatives**

There are a number of initiatives that are contributing to raising awareness, addressing perceptions, enabling transferability, supporting retention and helping to build the talent pipeline of the future. Good practice should be learned from and scaled up to ensure opportunities such as these can expand to all areas rather than be location specific or limited by current funding. Examples include:

> Geobus

GeoBus[96] is an educational outreach project supporting Earth science learning in schools in the UK. The project was developed by the Department of Earth & Environmental Sciences at the University of St Andrews in 2012 and GeoBus St Andrews has worked with over 80,000 Scottish school pupils delivering workshops, challenge days and fieldwork. GeoBus at UCL in London was launched in September 2016 and primarily visits primary schools in the London area, as well as providing outreach activities for families.

> Level 6 Mine Management Degree Apprenticeship at Camborne School of Mines

A four-year Degree Apprenticeship, with its first intake in 2023, designed to upskill those already holding roles within the mining industry. This course helps transition workers at a lower management/supervisory level and develops skills informed by

[91] https://www.criticalmineral.org/_files/ugd/5caeff_58f8a2c396e241219aa4b108e6c705db.pdf
[92] https://www.engineeringuk.com/media/232354/our-future-our-careers-2020.pdf
[93] https://www.stem.org.uk/
[94] https://www.sciencecampaign.org.uk/analysis-and-publications/detail/the-skills-opportunity/
[95] https://news.microsoft.com/wp-content/uploads/2017/02/Microsoft_girls_in_STEM_final-Whitepaper.pdf
[96] https://geobus.org.uk/

practical experience to become managers of the future. There is shared responsibility for delivery, with different environments to learn about different minerals. The qualifications gained are: IfATE Level 6 Mine Management Degree Apprenticeship, BEng (Hons) Mining Engineering and associateship of the Camborne School of Mines.

Apprentices will gain the knowledge and experience to enable them to:

- Understand the mining lifecycle and the investment and fundraising environment
- Design all aspects of mining operations to be safe and productive
- Address the challenges of environmental sustainability, governance and social responsibility

The apprenticeship involves approximately six hours a week of remote learning, up to four weeks of on-site activity per year and the implementation of this knowledge via the practicing of skills and behaviours in the workplace.

However, while the programme will greatly assist with addressing the shortfall of mine managers, it will not fill the positions created by moving people through the organisation or address the requirements of the wider industry.

Technical classification as a quarry currently prevents participation in the degree apprenticeship for some metalliferous mines. There is an opportunity to address this and increase the available pool of candidates and industry support.

> Mine to Magnet primary school workshop

Less Common Metals and Xplore Science Discovery Museum have created a Mine to Magnet workshop to be delivered in primary schools to ages 9 to 11. It is a 45-minute workshop that teaches the mine to magnet supply chain with six hands-on activities and takes the pupil through where rare earth elements come from, extraction and separation, crushing, heating and moulding of alloys, magnets/strengths of magnets and then lastly a 3D model of an electric car with magnets inside for the children to find.

A total of 375 people have been engaged so far, this includes 250 primary school children, 100 A-level students and 25 teaching staff.

> Metcelerate

Metcelerate acknowledge early career professionals are entering the industry and being expected to do a job they're not well skilled for or haven't had the opportunity to gain experience or learn from more senior professionals. It also enables chemical engineers to tranfer to mineral processing.

The curriculum, which takes about 18 months to complete, is made up of online weekly material, tutorials and excercises in industry which are then submitted for marking online.

> Minerals matter

Minerals Matter is a resource for young people, adults and their support networks (including family, carers, school teachers, career advisors and educators) about career options and what it's like to work in quarrying, mineral products and mineral processing.

[97] https://hvm.catapult.org.uk/wp-content/uploads/2022/06/Manufacturing-the-Future-Workforce-Full-Report.pdf
[98] https://hvm.catapult.org.uk/wp-content/uploads/2021/11/National-Electrification-Skills-Forum-Brochure-FINAL.pdf

It showcases diverse career opportunities and promotes the positive contribution of the industry to the economy and transition to net-zero.

> Education and outreach initiatives from IOM3

Designed to support the teaching of the materials, minerals and mining topics in the curriculum for 5- to 19-year-olds. These include presentations, lesson plans and hands-on activities aimed at primary and secondary schools to enhance and enrich classroom teaching, extra-curricular interventions such as one-day conferences, residential courses and exhibition stands to highlight the importance of materials, minerals and mining to the modern world and journey to a low-carbon, resource efficient and resilient society and CPD courses for teachers to ensure those educating the STEM professionals of tomorrow are equipped with up-to-date, accurate and objective knowledge and understanding.

> Discover Materials

An inter-University initiative sharing Materials Science and Engineering with young people, their home support networks and teachers across the UK. Discover Materials provides young people, their parents/carers and teachers with opportunities to find out more about Materials Science and Engineering as a career and degree choice. The Discover Materials Ambassadors take part in STEM events around the UK and are available to visit schools to provide enrichment sessions.

> Level 6 Materials Science Technologist Degree Apprenticeship

Started in 2019 and offered at a number of universities via several companies, this apprenticeship typically takes four years to complete and in addition to the apprenticeship qualification, candidates also achieve a BEng degree from their host university. The first apprentices are coming through to end point assessment now and their feedback suggests that the apprenticeship route to gaining a degree in materials is highly rated.

> Level 7 Materials Process Engineer Degree Apprenticeship at Cranfield University

Commenced in 2021, this two-year programme enables candidates to improve their knowledge and skills relating to materials in a manufacturing environment.

> Level 3 Composites Technician apprenticeship (running since 2017) and Level 3 Polymer Technician apprenticeship (awaiting approval)

Allow young people to achieve level 3 qualifications in their chosen area of materials while working in industry.

> STEM Learning's STEM Ambassador programme

Provides a ready-made infrastructure where individuals can sign up as STEM ambassadors to provide diverse and knowledgeable role models.

- **Learning from work elsewhere**

There is a range of previous and ongoing work such as the activity of the Green Jobs Taskforce, manufacturing the future workforce[97], National Electrification Skills Forum[98] and Perkins review revisited[99] that can be learned from and inform the next steps

[99] https://raeng.org.uk/media/hn4hdep3/perkins_report_jan19_final-web.pdf
[100] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1003570/gjtf-report.pdf

towards addressing the skills gaps and challenges facing the minerals value chain.

The Green Jobs Taskforce uses the term 'green job' to signify 'employment in an activity that directly contributes to - or indirectly supports - the achievement of the UK's net zero emissions target and other environmental goals, such as nature restoration and mitigation against climate risks.'

In the Green Jobs Taskforce report[100] a sectoral approach is used prioritising sectors where change will be 'crucial to meeting net zero' and the following sectors are included: power, business and industry, homes and building, transport, natural resources, enabling decarbonisation, climate adaptation.

The minerals supply chain underpins every one of these sectors, providing the materials necessary for the technology and infrastructure they rely on. The Net Zero and Nature Workforce Action Plan due to be published in 2024 should recognise the underpinning nature of the minerals supply chain with roles required that fit squarely within the definition outlined.

The learnings from the taskforce can be used to inform measures to build skills across the minerals value chain. Relevant recommendations include:

- ensure that the green jobs created by employers are good quality[101] as defined by the Good Work Plan[102]
- establish a UK-wide body with national representation to ensure momentum and coherence on workforce transition
- prioritise the creation of a diverse workforce
- attract and retain talented teachers
- ensure careers advice and pathways are a continuous offer for all
- map, review and enhance other training pathways (for example, traineeships, T-levels, internships and skills bootcamps) to ensure they support a diverse, inclusive workforce across the UK
- tackle barriers to retraining and upskilling

The Foresighting and Skills Value Chain approach (Figure 3) demonstrated by the High Value Manufacturing Catapult and Gatsby Foundation sets out a stepped approach connecting employers, Government investment, innovating bodies and education and training systems. It demonstrates how apparently separate workforce development activities should be connected to better achieve results for the wider system and for industrial initiatives.

[101] five foundational principles that jobs must be rated positively against to be considered good quality. These are overall worker satisfaction; fair pay; participation and progression; wellbeing, safety and security, and voice and autonomy.
[102] https://www.gov.uk/government/publications/good-work-plan/good-work-plan

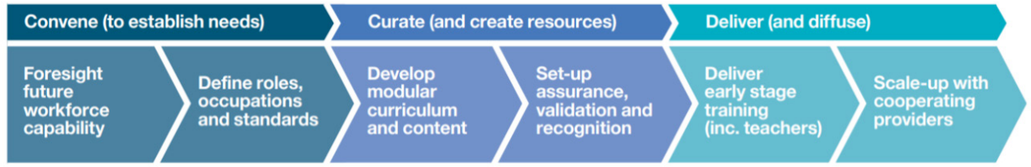


Figure 3 - Foresighting and Skills Value Chain approach[103]

There is also good practice or experiences in other countries that can be learned from. For example, in Sweden, university level programmes have tried a range of actions including changing the name of courses. The change that made the most significant difference to encourage enrolment on geoscience and geometallurgy courses was the introduction of full scholarships sponsored by industry.

- **Changing skills sets**

Whilst changing skill sets brings a challenge of wider competition, it also presents an opportunity of a wider pool to recruit from, unlocking talent from other disciplines and opening up the potential for transferability.

- **Cyclical industry**

The cyclical nature of the mining sector impacts investment, production levels and employment. Mining companies and Government should monitor market trends and adapt strategies to help navigate the cyclical nature of the industry and protect the pool of skills and talent.

By understanding the cyclical patterns and implementing long-term planning, the mining sector can strive for resilience and mitigate the challenge, supporting a sustainable and competitive industry.

In the UK, there has traditionally been an additional layer of uncertainty with changing policy and commercial direction. The Critical Minerals Strategy, published Refresh and related measures, provide a key element in providing greater certainty and confidence, both of which are important factors to encourage individuals to commit to an education and employment in the sector.

- **Bridging the industry-academia gap**

Encouraging closer collaboration, internships and industry placements can help to bridge the industry-academia gap.

[103] https://hvm.catapult.org.uk/wp-content/uploads/2022/06/Manufacturing-the-Future-Workforce-Full-Report.pdf
[104] https://www3.weforum.org/docs/WEF_Future_of_Jobs_2023.pdf

- **Equity, diversity and inclusion**

Promoting equity, diversity and inclusion is both the right thing to do and crucial for attracting talent. Enhancing diversity and inclusivity can bring fresh perspectives and experiences, driving innovation, improving decision making, broadening the talent pool and creating a more sustainable sector.

There are a range of strategies and actions that can be taken and many of the opportunities outlined in this section have the potential to support improved equity, diversity and inclusion, such as visible and diverse role models, effective outreach and updating the perceptions of the industry. A comprehensive and proactive approach is required across stakeholders and additional opportunities include mentoring and sponsorship programmes to support career development, improving recruitment practices, such as panel representation and identification and elimination of pay gaps (for example where these are gender or race-based). Better collection and reporting of data is essential and underpins many of these strategies.

Furthermore, training and development programmes that address biases and promote inclusivity at all levels including leadership can help to raise awareness, challenge biases and foster inclusive behaviours. This can involve workshops on unconscious bias, diversity and inclusion awareness and leadership development programmes. Changing workplace practices and culture can often require policies, incentives, targets and long-term strategies.

Inclusive policies such as flexible work arrangements can benefit employees from a range of backgrounds. This can include offering flexible hours, remote work options and parental leave policies that accommodate different needs and circumstances. For example, at the exploration phase, a fly in fly out geologist with a new baby might not be able or wish to continue with the same roster. If an individual takes just a few years out, this can lead to a greater likelihood of returning to a different role or leaving the industry. Inclusive policies can help to support individuals and improve retention.

- **Industry investment in talent**

Industry has a role to invest more in talent acquisition, maintenance, development and retention. Employers have a role to play in the maintenance of the pathways to training, in that the pathways can be created but if they are not used, they will be lost.

A transition will be required from the buy it rather than built it approach to employees and skills that has commonly been taken, with companies favouring recruiting directly into roles rather than investing and building talent towards developing individuals. Possessing an effective employee training programme is seen as the top talent-attracting policy available to a number of industries, yet only 17% of the mining and metals sector currently see this as an effective way to increase talent availability[104].

There is potential for lessons to be learned from other engineering industries and sectors such as oil and gas, which provide more stability through both the smooth and rough than the cyclical hiring and firing associated with the mining industries.

[105] https://green-alliance.org.uk/publication/closing-the-uks-green-skills-gap/

To support businesses that commit to investing in skills and training and help mitigate potential risks, policy tools such as grants or tax relief to encourage business to invest and adapt could be used. For example, the super-deduction, announced in the 2021 spring budget granted businesses tax relief of 130% on plant and machinery investment. There is an opportunity to extend such measures to stimulate investment in training and upskilling staff[105].

- **International competition**

Fostering collaborations with international organisations, universities and research institutions can help to leverage global expertise, share best practice and facilitate skills development.

- **Lower academic levels and vocational routes**

The focus is often on degree level, which can be confounded by this level having the strongest voice as there are few training providers at lower academic levels or vocational routes. Encouraging focus and provision of training at lower academic levels or through vocational routes would increase the options for intake into the sector.

- **Governance skills**

The UK is very good at the Environmental and Social elements of ESG but there is room for improvement in the Governance aspect. It has been recognised that the permitting process will require refreshing but this will take time and will require the relevant skill sets[106].

- **End of life management**

There is an opportunity and motivation to build a better connection between the understanding of mineral processing at one end and design for products for end of life at the other.

[106] https://www.criticalmineral.org/post/esg-workshop-uk-planning-permitting-for-critical-minerals

H. Opportunities for the UK

The UK must consider what its unique strengths are and how these can be leveraged to bring a competitive advantage as well as what will be required for national and economic security.

This must then be translated into the skills requirement and appropriate measures implemented to secure a skilled and sustainable workforce. For example, at present, there's a growth in domestic exploration and organisations are struggling with recruitment. The size of this gap will depend on the end demand. Government with support of others such as the BGS and CMIC should further investigate the potential in the UK and identify how much of the demand for minerals the UK might meet domestically versus internationally. A skills gap analysis will be a key element in this.

There are a number of opportunities available to the UK:

- **UK deposits**

There are a number of projects under development and proposed projects. To further investigate prospects suitable for further investigation in the UK, acquisition of high-resolution geological, geochemical and geophysical data sets will be necessary. This will provide a basis for the 'domestic production where it works for communities and our natural environment and increases resilience', as stated in the UK Critical Minerals Strategy Refresh of 2023. There is likely to be a growing skills gap, the extent of which the findings will help to inform. Many of the skills required are industry specific so it's unlikely transitioning skills from other industries will substantially contribute to closing the gap.

- **Midstream**

The UK is in a very strong position to create an environment for a successful midstream with the potential to help build security of supplies. The UK will not be able to meet its needs through extraction and recycling alone and will continue to rely on imports. The midstream is commonly the bottleneck for demand and where the most value is added.

Vertical integration with domestic processing and manufacturing enables greater traceability and assurance across the supply chain.

Secondary sources offer an opportunity to provide minerals to the UK, but a midstream industry to re-process and refine waste such as end of life products, by-products from extraction, processing and manufacturing is necessary to pursue this.

If the UK is to host a thriving midstream, it will need appropriate education and training including university courses to train the next generation of professionals.

- **Circular economy**

Keeping minerals and materials at their highest value for as long as possible can help to alleviate pressure on primary supply. Greater collaboration and communication along the value chain combined with skills linking material recovery at end of life and the design process can support value retention. Identification of the streams and opportunities that use high level technical competence to separate and recover material could reveal a place in the market and global network for the UK.

There is a substantial time lag to bring a new mine into production. Circular economy principles and recycling infrastructure have the potential to be implemented and built more quickly if sufficient people with the right skills are available.

I. Next steps

The skills-related challenges and gaps facing the minerals supply chain and the impact on critical mineral supply is of significant concern. The extent of the growing skills gaps require short-, medium- and long-term action. Action will be required across the ecosystem and all stakeholders to ensure sustainable impacts for both the existing and future workforce. To build on the qualitative findings of this report, a quantitative assessment should be undertaken to help focus resources including work to:

- understand the future workforce capability needs
- map competencies
- conduct a demand forecast and gap analysis
- conduct a gap analysis on education and training provision and provider capacity

This will enable Government, employers, education providers, relevant professional bodies and other stakeholders to put in place the steps necessary to address the gaps and secure a high quality and sustainable workforce and industry.

London office:
297 Euston Road, London NW1 3AD

Grantham office:
The Boilerhouse, Springfield Business Park, Caunt Road, Grantham NG31 7FZ

t. 020 7451 7300 • www.iom3.org