Institute of Materials, Minerals & Mining

Policy Paper
The Energy Transition: Getting to Net-zero

An IOM3 Policy Paper prepared with lead input from the IOM3 Energy Transition Group

Energy Transition Group

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The purpose of this policy paper is to describe the Institute of Materials, Minerals and Mining (IOM3) view on the strategies, goals, and directions to be taken, as the United Kingdom (UK), and the rest of the world, transitions from energy dependency based on burning fossil fuels (coal, oil and gas), to low carbon energy sources (including renewables such as wind, wave, geothermal, solar, and nuclear).

This paper recognises:

- Energy is fundamental to human existence: with population expected to grow by around 2 billion people by 2050, and associated urbanisation and economic development continuing to drive up energy demand, particularly in emerging economies.
- The UK Government's legislation to achieve 'net-zero' by the year 2050.
- The global carbon budget is running out. CO_2 emissions have increased every year since the Paris COP in 2015 (bar 2020).
- Extracting and burning fossil fuels for energy is a source of greenhouse gases (including CH_4 and CO_2) which contribute to climate change, with consequential pollution and harmful effects to mankind and the natural environment.
- Hydrocarbons still have a significant part to play while the use of low carbon energy is increased to ensure a secure energy supply is maintained.
- Hydrocarbons will continue to be feedstock for petrochemical products such as plastics, paints, pharmaceuticals, solvents etc.
- The latest UK Government data [(1)] shows that 78.5% of the UK's primary energy came from fossil fuels in 2022 with net import dependency of 37.3%. This is while the UK has extensive deposits of oil and gas (an estimated 4.4 billion BOE at the end of 2020 [(2)]) and the UK has a legislative requirement to maximise recovery from existing oil and gas fields (Petroleum Act 1998 and Infrastructure Act 2015).
- Analysis from the North Sea Transition Authority shows that the carbon intensity arising from imported Liquified Natural Gas (LNG) (due to production methods and related shipping activities) are on average 3.76 times those from domestic gas production. However, the carbon intensity of Norwegian gas (imported via pipeline) is an average of 2.63 times lower than UK produced gas. While it is imperative to reduce the use of fossil fuels and accelerate the move to low carbon energy, it will take time to build the renewable energy sources and infrastructure. In the meantime, where domestic sources are less carbon intensive than that produced elsewhere, the UK should continue to extract and use it in preference to more damaging sources [(3)(4)(5)].
- Hydrocarbon solids, fluids and gas extracted from deep underground and elsewhere are becoming more challenging to extract, and increasingly expensive (in part for political reasons – OPEC+).
- The time it will take for parts of the energy sector to transition away from fossil fuels highlights the importance of carbon dioxide removal via processes such as carbon capture, usage, and storage (CCUS) and Direct Air Capture (DAC).
- There are existing and developing low carbon energy sources which should be exploited to accelerate the energy transition and to improve the atmosphere, the environment and quality of life.
- Increasing British research into the development and optimisation of low carbon renewable energy sources is essential to the UK economy.
- The competencies of Science, Technology, Engineering and Mathematics (STEM) personnel are essential to energy transition technologies.

- The UK needs to transition towards a circular economy, where end-of-life and efficient material usage is prioritised at the earliest design stages.
- The development of novel materials and manufacturing methods will be crucial to increasing energy efficiency and developing new technology to be able to achieve net-zero.
- The availability and supply security of strategic metals (eg lithium, cobalt, nickel, chromium, etc) to the UK economy is essential. The global demand for copper, nickel and lithium is forecast to increase by factors of 2 to 3, 2.5 to 4 and 25 to 60 respectively by 2040 [6] necessitating significant increases in responsible mining.
- In parallel, the UK needs to reduce dependency on mining ores from the ground for raw materials by significantly increasing recycling technology and infrastructure.

Introduction

Energy is fundamental to human existence, be it nuclear fission or fusion to generate electricity, or wood fires to cook food and boil water in more remote parts of the world. The use of energy for food and clean water is essential to health by making food more digestible and killing harmful bacteria and parasites, which in turn improves quality of life and reduces demand on public health services.

The energy transition is likely to take decades to fully occur, however, good progress has already been made with 48.5% of the UK's electricity coming from low carbon sources and only 40% coming from hydrocarbons in 2022(1), and the Ember global electricity review predicting that global energy-based emissions may have peaked in 2022(7).

It has been highlighted by average annual energy bills doubling between 2021 and 2022(8) that the UK is currently vulnerable to the volatility of the international hydrocarbon markets. Although there could be benefits from developing UK onshore tight oil and gas resources(5), the UK has decided not to pursue that option. Since 2000 the UK has seen domestic hydrocarbon production drop by over 50% (9).

As well as decreasing overall greenhouse emissions, the transition from a fossil fuel-based economy to one in which energy is predominantly from domestic low carbon sources, including nuclear, would provide improved energy security to the UK.

The energy transition will also require the transition to net-zero solutions for private, public and commercial transport. This will require a mixture of more efficient technologies, including battery and low carbon hydrogen fuel cell electric vehicles and alternative fuels(10). Biofuels and bio-methane are two possible options; however, the former takes up valuable agricultural land, and both still create significant amounts of greenhouse gases when burned. Therefore, whilst useful in the transition period, these technologies are of questionable long-term benefit.

Critical to the energy transition is the role of materials, be it in terms of their availability and recyclability, but also the understanding of the limits of performance of materials, which requires both industry and academic institutions to be involved.

Low carbon hydrogen is increasingly being seen as a long-term alternative energy vector such as for heavy duty transport and industrial applications, however, with talk of 'grey', 'blue', 'pink' and 'green' hydrogen, it is important to understand that green (generated by electrolysis using renewable energy), pink (generated by electrolysis using nuclear energy) and blue (generated by steam methane reforming along with CCUS) are the accepted sources of low carbon hydrogen, with green and pink the only ones that are greenhouse gas free.

It is also important to recognise the energy needs of the developing world, with some parts of the world barely participating in the hydrocarbon age before being thrust into the low carbon and renewables era. These parts of the world are likely to have limited energy infrastructure in place to support large scale electrification. In these scenarios, it is likely that localised renewable energy solutions will be needed.

Globally there has been an accelerating trend of urbanisation, with people migrating from an agrarian environment into cities. This trend brings major stresses on space, transport and access to education and health resources, all of which require energy, which, when in the form of hydrocarbons used in transport causes local pollution with adverse health effects. Population growth combined with urbanisation, economic development and climate change will significantly increase the demand for energy, for example the World Bank forecasts energy demand for transportation increasing by 80-130% by 2050 [11] and the International Energy Agency forecasts the number of air conditioners increasing from 1.5 to 4.4 billion units by 2050 [12].

Increasing Energy Efficiency

Increasing low carbon renewable energy generation alone will not achieve net-zero; energy efficiency is essential to reduce waste and overall energy demand. This has been demonstrated by the overall UK electricity demand falling 13% since 2011[13] even though population has increased. The International Energy Agency highlights the critical importance of increasing global energy efficiency if low carbon renewable energy supply is to reliably keep up with demand [12]. It is vital that energy efficiency is extended to manufacturing and transportation industries, with companies given incentives to improve efficiencies.

Increasing energy efficiency will require several materials problems to be solved:

- Increasing the effectiveness, affordability, and sustainability of insulation solutions to increase the energy efficiency of the entire UK building stock (including many houses that are decades and even hundreds of years old).
- Reducing the amount of material used within current and future products through innovative materials solutions, overcoming the inherent material issues with additive manufacturing and by utilising material modelling capabilities.
- Reducing the losses incurred when transporting energy (either electricity or fuels) by increasing materials reliability.
- Increased battery life and efficiency will be key to allowing effective low carbon renewable energy storage and thus full utilisation.
- Reducing the amount of consumption by increasing the lifespan of products and by removing built-in obsolescence.
- The life extension of existing major assets eg bridges, roads, factories, power stations through the increased understanding of material failure mechanisms and corrosion.
- Reducing material usage by repurposing existing assets (eg retrofitting the hydrocarbon infrastructure for use in the hydrogen economy and for carbon capture and storage).

Critical Materials

The transition to net-zero requires a focus on materials of all types and is going to significantly increase the global demand for critical materials. The types of mineral resources needed for each technology vary, but since 2010 the mineral usage per unit of power generation has increased by 50% [14]. This is only set to increase with the increased adoption of electric vehicles and increased low carbon renewable energy generation, for example, it is currently projected that a 25-to-60-fold increase in lithium will be needed in 2050 compared to 2020 levels [15]. Lithium supply is such a critical issue that exploratory work and mining developments are already occurring in the UK, in particular Cornwall.

To meet this global demand, several materials challenges will need to be overcome:

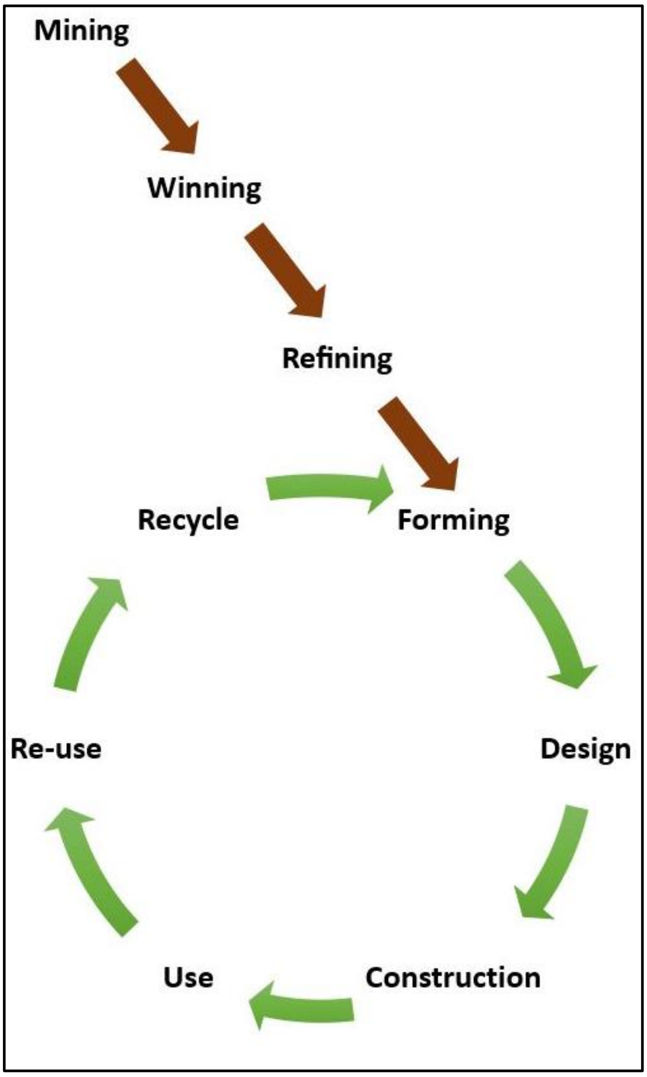
- A significant expansion of responsible mineral mining and refining activities will be needed across the globe. This will put huge strains on the existing limited human resources available as well as require improvements in recovery efficiency as reserves decrease [16].
- Decreased usage of critical, highly valuable materials by designing them out of products, for example through novel material developments, materials substitution and additive manufacturing.

- A drastic increase in recycling rates which will require increased materials reprocessing efficiencies and novel materials recycling methods.
- Design for End-of-Life which makes critical materials recovery a key priority. For example, by reducing the use of resins which make mineral recovery economically and practically infeasible.
- There is a need for the closed loop cycling of polymers and composites which are widely used in industrial and domestic use, where the design for end of life should be included within the initial design.

Circular Economy

The metals lifecycle from mining to recycling is shown in the figure below, with the most energy intensive sections being mining, winning, and refining. Whilst primary production will continue to be necessary to meet the growing demand, keeping materials within the recycling loop improves energy and materials efficiencies. For example, analysis indicates that recovering key minerals from printed circuit boards requires just 5% of the energy compared to gaining the materials from primary mining [17].

By heading towards a circular economy, the UK will be able to reduce the embedded greenhouse gasses within the materials it uses and be able to increase the security of mineral supply. However, this can only be realised if large-scale investment is immediately made into recycling technology, processes, and infrastructure.



An example of this is with solar photovoltaic (PV) panels, which have a life expectancy of around 30 years. By 2050, it is estimated that decommissioned PV panels will reach 5.5-6 million tonnes per year; this almost matches the expected mass of installations of around 6.7 million tonnes [18]. PVs contain many different minerals; therefore, an effective recycling process could realise a significant supply chain as well as significantly reduce the energy required in new PV production. Productive recycling of lithium-ion batteries is another example. This represents a significant market opportunity for the UK to be global leaders in this field.

To fully achieve a circular economy, it will also be necessary to consider the original design and manufacture of components, which will allow for economically and technologically feasible decommissioning, dismantlement, and recycling.

Education, Skills & Competencies

All of the previous highlighted materials challenges share a common problem: they require highly competent people at each stage of the life cycle. Across the UK, over 200,000 people were directly employed in the low carbon economy in 2020 with this expected to rise to 1.18 million by 2050[19]; this does not include the people employed within the supply chain, which will significantly increase this number. Specialist capabilities are already in short supply in all areas, from metal ore mining to recycling materials at end-of-life. These include:

- Electrochemists
- Materials engineers
- Metallurgists
- Mining and mineral processing engineers
- Geologists
- Mechanical engineers
- Design engineers
- Machine operators
- Electricians
- Digital expertise (eg for Materials 4.0, data driven lifetime prediction and digital twins)
- Wide range of support staff with some STEM education

With demand set to drastically increase, an influx of competent and passionate personnel is desperately needed. Competency does not just mean university graduates but includes all persons associated with the materials life cycle, including technicians, plant operatives and support staff. Personnel working at the human/machine interface are essential for safe and efficient operations.

Competency is based upon people having suitable:

1. Qualifications
2. Training
3. Experience

The UK should endeavour to develop its human resources. Developing the necessary competencies will require the UK to have a suitable and well-funded education system, starting at primary school, through to universities, colleges, and vocational courses.

There is some public disdain for hydrocarbon products (eg 'Just Stop Oil') and materials extraction in general; however, hydrocarbons will be needed for a long time to come for various domestic products including pharmaceuticals, solvents, paints, plastics and many more, and as set out above, mining must expand if we are to meet the challenge of net-zero. There is also public resistance to the 'industrialisation of the countryside' associated with ever larger onshore wind turbines, more overhead pylons, and large transmission sites. Likewise flooding countryside to create new hydroelectric schemes will elicit negative public reaction. The transition will also take time to complete, with research, cost effective and efficient technology, resources and competent personnel needed in all industries (including hydrocarbons) to enable the transition. Effort is needed to change the negative perception associated with the extractives industries (both hydrocarbon and mining) and to encourage positive participation in the energy transition.

The UK has a critical shortage of qualified mining and mineral processing engineers, with just one higher education establishment, Camborne School of Mines (University of Exeter), still offering an undergraduate degree (its degree apprenticeship). A key factor behind the demise of mining and mineral processing education in the UK has been the negative view of mining promoted within education and the media which has resulted in few candidates for the courses. This issue is not restricted to the UK, with similar graduate recruitment issues in for example Namibia and Australia[20]. There is also a significant shortage in skills related to the nuclear industry.

However, education goes beyond the personnel directly involved within the energy transition. It should be a priority to educate the public on the importance and value of efficient energy consumption and technology if the global net-zero goals are to be met.

Key Required Actions

IOM3 considers the following actions are required to improve the UK's energy efficiency, security and essential/strategic metals availability that will ensure that the UK can meet its net-zero energy goals:

1. Decisions should be evidence-based and analyse information across the entire product lifecycle.
2. The UK should invest time and resources developing its own human competencies by utilising high quality learning opportunities, potentially available to all UK citizens, at all stages of a pupil's education.
    a. Where there are shortages of essential skills such as in the STEM subjects (such as in materials, minerals and mining) the government and industry should provide additional financial incentives to UK universities and their students.
    b. Accessible apprenticeships for personnel who do not wish to go down the academic route, and/or have practical skills which are needed in industry, particularly those working at the human-machine interface.
3. Public perception of STEM subjects needs to be improved, particularly in the mining[20] and hydrocarbon industries which will be vital in achieving the energy transition.
4. Experienced personnel should be encouraged to mentor younger colleagues, as well as give peripatetic presentations to undergraduates.
5. The UK needs to encourage significant private and public investment into research and development that focuses on key areas such as: the circular economy, improving energy efficiency, and increasing low carbon renewable energy generation.
6. Significant investment is needed to develop novel materials that will solve significant problems for developing technology.
7. Critical manufacturing and recycling infrastructure is vital for the UK to be able to increase its domestic materials supply chain and security.
8. Effort is needed to close the gap between academic research and industrial problems so that the time to market of new technology is shortened and key industrial problems are actively researched.
9. Cross-industry collaboration should be prioritised so that knowledge and resources can be effectively shared.
10. Energy efficient design and technology should be encouraged in all sectors, with an emphasis given to design for end-of-life and critical mineral availability at the earliest stages.

Many of the measures listed above will happen organically, but these will be reactive to the global markets. For the UK to be positioned to be a global leader in the energy transition, government and private capital intervention and investment is needed to proactively encourage these measures so that the UK can capitalise on the market potential. There is evidence that companies are not choosing to invest in UK energy projects with resources (skilled people and equipment) being redeployed from the UK. If the UK is to meet its net-zero targets, it is becoming increasingly urgent that action is taken to ensure that the UK remains an attractive environment to invest in, with the skilled people and resources to execute the required activity.

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