UK Critical Minerals
Intelligence Centre

Future material demand and secondary supply potential for UK net zero technologies

Decarbonisation and Resource Management Programme

Open Report OR/26/027

Department for Business & Trade

British Geological Survey

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BRITISH GEOLOGICAL SURVEY

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E Petavratzi, R Shaw, N Singh, T Bide, H Grant, E Raycraft, J Torrubia Torralba

Editors

E Rodriguez Ciriza, J M Hannaford

Contributors

A Luce, R Donaldson

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British Geological Survey offices

Nicker Hill, Keyworth,
Nottingham NG12 5GG

Tel 0115 936 3100

BGS Central Enquiries Desk

Tel 0115 936 3143
email enquiries@bgs.ac.uk

BGS Sales

Tel 0115 936 3241
email sales@bgs.ac.uk

The Lyell Centre, Research Avenue South,
Edinburgh EH14 4AP

Tel 0131 667 1000
email scotsales@bgs.ac.uk

Natural History Museum, Cromwell Road,
London SW7 5BD

Tel 020 7589 4090
Tel 020 7942 5344/45
email bgslondonstaff@bgs.ac.uk

Cardiff University, Main Building, Park Place,
Cardiff CF10 3AT

Tel 029 2167 4280

Geological Survey of Northern Ireland, Department for the Economy, Dundonald House, Upper Newtownards Road, Ballymiscaw, Belfast, BT4 3SB

Tel 0289 038 8462
www2.bgs.ac.uk/gsni/

Natural Environment Research Council, Polaris House, North Star Avenue, Swindon SN2 1EU

Tel 01793 411500 Fax 01793 411501
www.nerc.ac.uk

UK Research and Innovation, Polaris House, Swindon SN2 1FL

Tel 01793 444000
www.ukri.org

Website www.bgs.ac.uk
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Executive Summary

This study provides the first integrated assessment of the UK's future demand for key technology metals and the potential contribution of end-of-life (EoL) materials to domestic supply across electric vehicle (EV) traction motors and lithium-ion batteries (LIB), wind turbines and solar photovoltaics (PV). It identifies when secondary materials could meaningfully reduce import dependence and the actions required to build a resilient national supply chain.

Key Findings:

- UK demand for critical technology metals, especially copper (Cu), graphite (C), lithium (Li), nickel (Ni), cobalt (Co), manganese (Mn) and rare earth elements (Nd, Pr, Dy, Tb), rises sharply to 2040 due to rapid deployment of low carbon technologies.
- EoL material availability remains limited until the 2040s. Significant secondary flows emerge only once EV traction motors, EV batteries, wind turbines and PV modules begin reaching EoL.
- By 2050, EoL material availability (before recovery) could meet:
    - 60 to 75% of UK demand for major battery metals
    - 85 to 97% for Nd, Pr and Dy from EV traction motors and wind turbines
    - A substantial share of silver (Ag) and tin (Sn) demand in the PV sector
- Based on the modelling outcomes and the state of industrial capabilities under development, the most significant opportunities for establishing circular value chains, initially focused on recycling, are in permanent magnets (from EVs and wind turbines), EV batteries, and copper.
- The UK's 2035 target to meet 20% of critical mineral demand through recycling is unlikely to be met for most materials, due to low EoL volumes.
- Primary supply will remain essential through to 2050 as growth in EVs, wind turbines and batteries outpace the availability of secondary materials.

Implications for UK Resilience:

- The UK currently has limited recycling and processing capability. Significant quantities of high value materials, including REE magnets, battery black mass and Cu scrap, are exported overseas or lost through low grade recycling.
- Without coordinated development of domestic reverse supply chain infrastructure, the UK risks missing opportunities to retain critical materials as EoL flows expand after 2040.

Future Work:

- Develop domestic reverse supply chain infrastructure, including collection systems, dismantling, pre –processing and disassembly capacity.
- Technological advancements in product design in enabling secondary supply. Design choices that prioritise modularity, disassembly and material transparency can significantly improve the recoverability, purity and economic viability of recycling technology metals at end-of-life.
- Expand UK metallurgical capabilities, such as refining of Li, Co, Ni, Cu, and REE separation and magnet to magnet recycling, which are currently limited or only at pilot scale.
- Support the establishment of regional recovery hubs and integrated value chains to retain economic value that is currently lost through overseas export.

- Consider regulatory reforms that ensure end-of-life stocks remain within the UK and that existing barriers to treating waste as a resource are reviewed and, where appropriate, removed. Such changes would be critical to enabling the development of domestic secondary supply chains for technology metals.
- Address workforce shortages in reverse engineering, metallurgy and materials processing, which are identified as barriers to scaling secondary supply.
- Improve data availability and modelling through systematic data collection, improved transparency and regular updates to material intensity and lifetime assumptions.

Strategic Implication:

Secondary materials could materially improve UK supply security from the 2040s onward, provided the UK develops the capability and infrastructure required to capture them. Until then, the UK will remain reliant on primary imports through the 2020s to 2030s.

Summary

OVERVIEW OF RESULTS

This study provides the first integrated assessment of the UK's future demand for key technology metals and the potential contribution of end-of-life (EoL) materials to domestic supply across electric vehicle (EV) traction motors and lithium-ion batteries (LIBs), wind turbines and solar photovoltaics (PVs).

Across all technologies, demand for raw materials will rise rapidly between 2030 and 2040, reflecting the large-scale deployment of low-carbon infrastructure. Beyond the 2040s, demand will stabilise but remain high as the UK transitions from large-scale deployment to maintenance, repowering and replacement cycles.

In-use stocks of materials will grow quickly after 2030, though timing and pace differ by sector. Stocks for EV batteries, traction motors and wind turbines will accumulate fastest, driven by accelerated rollout and relatively short technology lifetimes. PV stocks will grow more gradually. These dynamics directly influence when secondary materials will become available: EoL flows will remain limited until the 2040s, after which they will increase sharply as first-generation installations reach the end of their useful lives.

Cumulative demand over the next two decades will be dominated by copper (Cu) and graphite, both exceeding several million tonnes, followed by significant demand for lithium (Li), nickel (Ni), cobalt (Co) and manganese (Mn). There will also be major demand for permanent-magnet rare earth elements (REEs) (neodymium (Nd), praseodymium (Pr), dysprosium (Dy) and terbium (Tb)), particularly for EV traction motors and offshore wind generators. In the PV sector, near-term demand will be associated with silicon (Si), tin (Sn) and silver (Ag), while materials used in emerging tandem-cell PVs such as indium (In), gallium (Ga), bismuth (Bi) and arsenic (As) will play a larger role post-2040.

By 2050, modelled EoL availability will approach or exceed domestic demand for several critical materials. Secondary availability of battery metals will rise to 60 to 75 per cent of UK demand, while Nd, Pr and Dy from traction motors and wind turbines will reach 85 to 97 per cent of demand. For PV technologies, secondary supply potential will be high for Ag and Sn, with convergence toward demand between 2040 and 2050. For most other PV metals, EoL availability will remain low due to limited physical availability or insufficiently valuable quantities (tens of tonnes) to support economically viable recovery.

ALIGNMENT WITH UK POLICY OBJECTIVES

The UK Critical Minerals Strategy sets an aspiration of meeting 20 per cent of critical mineral demand from recycling and recovery by 2035. Model outputs indicate that only a small number of PV materials such as Si, Sn, Se, cadmium (Cd) and tellurium (Te) could theoretically reach or exceed this threshold by the mid-2030s. However, actual recoverable output is expected to be significantly lower due to limited collection volumes, complex material configurations, hazardous waste-handling requirements and the absence of commercial-scale recycling pathways. For most of these materials (except Si and Sn), absolute quantities are also likely to be too small to justify economic recovery. For the majority of battery materials, REEs and Cu, secondary EoL supply will remain well below the 20 per cent threshold by 2035, primarily due to limited stock turnover and long product lifetimes. From the 2040s onwards, however, EoL secondary supply will become a major contributor to national demand, particularly for Cu, Nd, Pr, Dy, Ag, Sn and key battery metals.

Ambiguity in the UK 2025 Critical Minerals Strategy, specifically whether the 20 per cent target applies per material or in aggregate and whether measured by mass, value or criticality, makes progress difficult to evaluate and risks obscuring supply challenges.

ROLE OF PRIMARY SUPPLY DURING THE TRANSITION

Despite promising long-term secondary potential, primary supply will remain essential until 2050. Rapid growth in EVs, wind turbines and batteries throughout the 2020s and 2030s will far exceed the availability of secondary materials. This will necessitate continued reliance on imports of Li, Ni, Co, Mn, Cu and REEs, and highlights the importance of supply chain diversification, responsible sourcing and strategic international partnerships.

Between 2040 and 2050, secondary supply will begin to offset primary demand, but primary production will remain necessary to meet growth sectors, fill supply gaps and account for unavoidable material losses or non-recovery. Other circularity interventions, for example extending product lifetimes and promoting reuse, repair, refurbishment and remanufacture have the potential to reduce overall demand for technology metals. However, many of these circularity options remain at an early stage of development and are not widely implemented at scale. Further policy support, market incentives and enabling infrastructure are required to strengthen their commercial viability and accelerate their adoption.

IMPLICATIONS FOR UK SUPPLY CHAIN RESILIENCE

In the short to medium term, the UK will remain exposed to global supply risks due to limited domestic refining, processing and recycling capacity. Without coordinated development of reverse supply chain infrastructure, the UK risks losing high-value materials through export or low-grade processing.

Beyond 2040, provided sufficient investment is made in collection systems, disassembly capacity, metallurgical processing and skilled workforce development, secondary materials could play a significant role in mitigating supply risks. From the 2050s, large domestic flows of EoL batteries, motors, PV modules and wind turbine components could materially improve national supply security and support domestic manufacturing.

INFRASTRUCTURE AND CAPACITY REQUIREMENTS

Expansion is needed across the entire recovery chain to realise the UK's secondary supply potential. While the UK has established collection systems for EVs and PV modules, domestic infrastructure for advanced separation, metallurgy and refining capacity remains small in scale. Significant quantities of high-value waste, including REE magnets, battery black mass and copper scrap, are currently exported overseas for refining or lost during segregation and product recycling routes (for example, shredding).

Scaling up domestic capacity will require:

- coordinated investment in dismantling, pre-processing and recycling infrastructure
- expansion of domestic metallurgical capabilities (for example, Li, Co, Ni and Cu refining; REE separation; magnet-to-magnet recycling)
- development of regional recovery hubs
- establishment of integrated value chains to retain economic value
- actions to address workforce shortages in reverse engineering, metallurgy and materials processing

Without these enablers, the UK will be unable to capture the secondary material potential identified through this assessment.

FUTURE WORK

To strengthen the evidence base and support the UK's transition toward secure, resilient supplies of critical and technology metals, priority areas for future research and analysis include:

- integrating UK manufacturing demand into future modelling to provide a full national picture of material requirements and align with industrial strategy objectives
- expanding the scope of assessed EoL products and sectors, including electrical and electronic equipment, data centres, construction and additional clean energy technologies, to better capture the composition and evolution of the UK anthropogenic stock
- enhancing modelling to reflect realistic recovery potential by incorporating factors such as collection rates, disassembly and processing constraints, technical recovery yields, contamination losses and recycling economics
- developing integrated primary- and secondary-supply assessments to understand long-term supply/demand balances and identify where secondary supply could offset primary imports
- improving data availability and transparency, supported by systematic data collection, stakeholder engagement and regular updates to material intensity and lifetime assumptions
- undertaking formal sensitivity and uncertainty analyses to test how variations in key assumptions influence model outputs and to increase confidence in long-term projections

CONCLUSION

This study demonstrates that secondary supply of technology metals has the potential to become a major contributor to UK material security beyond 2040, with several elements approaching or exceeding domestic demand by mid-century. However, realising this potential will depend on:

- clear policy direction on technology metals recovery
- investment in recycling and refining infrastructure
- proof of economic viability
- development of integrated reverse supply chains and skilled labour

In the near term, primary supply will remain essential but, with timely and coordinated action, the UK can build a more resilient, circular and secure critical materials system capable of supporting its 2050 net zero ambitions.

1 Introduction

The UK has committed to achieving net zero greenhouse gas emissions by 2050 (Burnett et al., 2025). Meeting this target will require the widespread deployment of a range of decarbonisation technologies, all of which, including critical minerals, depend on a secure supply of materials for their manufacture and integration into energy systems.

The UK Government's Critical Minerals Strategy (Department for Business and Trade, 2025a) highlights the important role of the circular economy in strengthening security of supply and unlocking domestic opportunities for recovery, recycling and other circular business models. The strategy highlights the need for recycling and midstream processing to mitigate risks from external shocks associated with materials supply. This is supported by others; for example, the UK Critical Minerals Recycling and Midstream Processing Capability Assessment (Department for Business and Trade, 2025a) identified a range of existing UK recycling initiatives on iron and steel, platinum group metals, rare earth elements (REEs), Li-ion batteries (LIBs) and more. However, many of these efforts are currently only at pilot scale. The report also emphasises that future opportunities for recovery of critical minerals from end-of-life (EoL) technologies (including batteries, wind turbines, solar panels and electric vehicles (EVs)) can provide valuable feedstock for domestic manufacturing (UK Government, 2025).

Further initiatives, for example the Circular Economy Centre for Technology Metals (Met4Tech), have developed product-specific roadmaps for magnets and batteries. These roadmaps outline UK opportunities to reduce material dependency, enhance circularity across product streams, create additional value through innovative circular business models and transition towards a low-carbon economy (Met4Tech, 2025a, b).

Technology-specific roadmaps, for example the '2024 roadmap for sustainable batteries' (Titirici et al., 2024), the 'Roadmap for a sustainable circular economy in lithium-ion and future battery technologies' (Harper et al., 2023) and the 'International technology roadmap for photovoltaics' (Fischer, 2025) outline anticipated technological trends and provide recommendations to advance technology, enhance sustainability and accelerate the transition towards a circular economy. These roadmaps are important for developing secure and sustainable material supply chains; however, they do not quantify the potential for secondary material supply, which is essential for developing a circular economy.

Given the UK's ambition, as stated in the UK Critical Minerals Strategy (Department for Business and Trade, 2025b), to meet 20 per cent of domestic demand for critical minerals through recycling and recovery from EoL products by 2035, it is vital to assess the role of secondary supply of critical and technology metals and evaluate whether this target is achievable.

Building on previous foresight studies that assessed UK demand for materials essential to net zero technologies, this report provides updated demand figures and evaluates the availability of these materials within EoL stocks of decarbonisation technologies in the UK. These EoL stocks represent a significant opportunity to contribute to domestic supply and strengthen the resilience of UK mineral supply chains.

2 Methodology

2.1 MATERIAL FLOW ANALYSIS

Material flow analysis (MFA) is a method used to quantify the flows and stocks of materials within a system defined in space and time (Baccini, 2012). MFA connects the inputs, stocks and outputs of processes taking place across material supply chains and is based on the law of conservation of mass and energy (Brunner and Rechberger, 2016). Because MFA uses the mass-balance principles, the method is powerful in assessing resource use and environmental management, and for policy assessments.

Figure 1 Concept of material flow analysis for a single process, where inputs, stocks and outputs are quantified using the mass balance principles. BGS © UKRI 2026.

The key steps in MFA (Meskers, 2023) include:

1. Setting a system definition: the scope and boundaries of an analysis are determined. This involves identifying the processes within a system, the location of materials stocks and the flows of materials between processes (inputs; outputs) without assigning quantities at this stage. A well-described system provides the essential conceptual framework for any assessment and is critical for effective resource and environmental management.
2. Data collection: gathering the information required to quantify material inputs, outputs and in-use stocks. This data typically originates from a wide range of sources, including industry and government reports, peer-reviewed literature, publicly available statistics, commercial databases and stakeholder engagement. However, data availability and quality often present significant challenges. Information is frequently fragmented, inconsistent or missing entirely, as no single source provides the full breadth of data needed for a comprehensive MFA. Additionally, data is rarely reported with sufficient system context, such as clear definitions of the life-cycle stage being described or the metadata that is needed to understand underlying assumptions. Differences in terminology and classification across sources further complicate their use, requiring substantial harmonisation efforts to ensure compatibility and analytical robustness.
3. Modelling and scenario development: the quantification of material cycles using the mass-balance principle. Modelling takes into consideration inputs to the system (for example, raw materials; compounds; semi-manufactured products), outputs that leave the system (materials; products; emissions; waste, etc.) and stocks that represent materials retained in the system (products in use; stocks during manufacturing). Models are used to monitor historic or current material cycles and to forecast resource demand and supply. The quality and reliability of model outputs depend directly on the robustness of the system definition and the quality of the underlying data. Investing sufficient time in understanding system processes, refining assumptions and validating input data is therefore essential for producing credible results.

2.1.1 Dynamic material flow analysis

Dynamic MFA (dMFA) extends the scope of static MFA by incorporating time-dependent changes in material flows and stocks. It models how materials move through the system over time (past, present and future), considering product lifetimes, technology evolution rates and EoL scenarios.

There are different approaches to conducting dMFAs (Liu, 2014). The top-down method calculates stocks and outflows based on series of inflow data (such as trade, imports and consumption) and lifetime distribution information. The bottom-up method calculates the inflows and outflows based on series of stock data and lifetime distribution data.

The prospective assessment of secondary material availability in this report is based on dMFA using a bottom-up (stock-driven) approach. By applying dMFA, the study produces a forward-looking evaluation of material flows, enabling the estimation of when and how secondary materials will become available from EoL products. This approach provides essential evidence to support reporting against the UK's ambition to meet 20 per cent of critical mineral demand through recycling by 2035. The resulting dMFA models generate projections of secondary material availability out to 2050.

2.2 MODELLING FUTURE UK DEMAND AND END-OF-LIFE FLOWS

The methodology applied in this study is consistent across all technologies assessed and is implemented in a unified and systematic manner. It builds on the approach developed in previous foresight studies, while enhancing the quantification of future material requirements and secondary material availability using dMFA.

The methodology comprises four main steps.

1. Definition of technologies and subtechnologies: the assessment begins with the identification of decarbonisation technologies and their associated subtechnologies, aligned with the structure used in earlier foresight work. Further information on the definition of technologies and subtechnologies can be found in Section 2.3 and in the previously published synthesis and individual technology reports (Petavratzi et al., 2024a; Petavratzi et al., 2024b; Petavratzi et al., 2024c, d). In this study, a more focused set of technologies is examined due to the increased complexity and data requirements of the forward-looking dMFA models. These models generate both updated demand projections and estimates of future secondary material availability.
2. Allocation of elements to technologies: the allocation of elements to specific technologies follows the same principles as the previous foresight studies. Materials are selected based on the functional role they perform within each technology. Components and materials associated with supporting infrastructure (for example, steel used in wind turbine towers or concrete foundations) fall outside the scope of this assessment and are therefore excluded.
3. Quantification of UK demand and EoL flows using dMFA: UK material demand and EoL flows are quantified using a dynamic, stock-driven MFA approach. The National Grid Future Energy Scenarios 2025 (FES) (National Energy System Operator, 2025) provide the underlying pathways for UK decarbonisation. Stock projections from these scenarios, together with lifetime distribution data, are used to estimate inflows (for example, new vehicle demand) and outflows (for example, EoL vehicles). Material intensity data is then applied to translate these inflows and outflows into projections of primary material demand and secondary material supply through to 2050 (stock-driven method).
4. Comparison of demand and secondary supply: by modelling inflows and outflows at the material level, the study directly compares future UK material demand with projected secondary material availability. This enables an assessment of the maximum potential contribution of recycling to future supply and supports evaluation against national ambitions for critical mineral resilience.

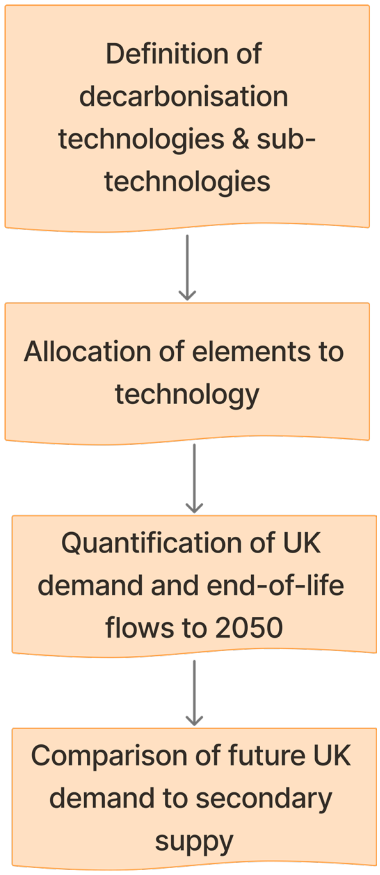


Figure 2 Key stages of the circular economy foresight study methodology. BGS © UKRI 2026.

2.3 DECARBONISATION TECHNOLOGIES

The UK decarbonisation strategy focuses on a broad range of technologies including electrification, hydrogen, carbon capture and energy efficiency, with key applications in industry, heat and buildings, transport and power all aimed at achieving the net zero target by 2050 (Government Office for Science, 2025).

Decarbonisation technologies such as EVs, wind turbines and photovoltaics (PVs) rely heavily on minerals, some of which are designated as critical and growth minerals, including Li, Co, Ni, Cu and REEs used in batteries, magnets and PV systems. These are expected to face significant future demand as deployment accelerates (Department for Business and Trade, 2025b). A series of previous foresight studies has quantified the UK future demand for these technologies to 2050 (Petavratzi et al., 2024a). In this assessment, we update the previous demand projections for selected technologies examined in the earlier foresight studies and provide new insights into the potential secondary raw-material supply arising from their EoL streams.

This assessment focuses on:

- batteries for EVs
- wind turbines
- traction motors for EVs
- PVs

The technologies and subtechnologies considered in this study are shown in Table 1. They align with those used in the earlier foresight studies to ensure methodological consistency and enable direct comparison between assessments. The subtechnologies were identified through market analysis and evidence on expected future technology trajectories, ensuring that their technological evolution is fully captured in the assessment. Key components in each subtechnology were selected for detailed evaluation; for example, cathodes and anodes in batteries, gearbox and direct drive generators in wind turbines and different cell types in solar PVs.

This assessment excludes an analysis of UK manufacturing and associated manufacturing waste streams. A different modelling approach is required to quantify these, so they fall outside the scope of this study. Instead, the focus is on secondary raw-material supply generated from EoL products after their use phase.

Table 1 Decarbonisation technologies and subtechnologies considered in this study. BGS © UKRI 2026.

Batteries	Wind turbines	Traction motors	Photovoltaic
Lithium-ion batteries (LIB)	Gearbox-Double-fed Induction generator (GB-DFIG)	Permanent magnet synchronous motors (PMSM)	Passivated emitter and rear contact (PERC)
	Gearbox-Permanent Magnet Synchronous Generator (GB-PMSG)	Induction motors (IM)	Silicon heterojunction (SHJ)
	Direct Drive-Permanent Magnet Synchronous Generator (DD-PMSG)	Externally excited synchronous motors (EESM)	CIGS and CdTe thin film cells
	Direct Drive-External Excitation Synchronous Generator (DD-EESG)		III-V/Si thin film tandem solar cells

2.3.1 Batteries

Batteries play a critical role in the energy transition. They enable the integration of intermittent renewable power (solar and wind) and provide a cost-effective route to decarbonising transport. Batteries are important to personal and commercial transportation, including hybrid and fully electric cars, buses, vans and lorries (Department for Business and Trade, 2023). They are also widely used in power tools, medical equipment and portable electronics, and underpin important national security, defence and communication capabilities. A detailed foresight study for batteries is available in (Petavratzi et al., 2024c).

This study focuses on LIBs used in EV passenger cars. Other subtechnologies, such as sodium-ion (SIB) and next-generation (lithium sulfur, Li-S) batteries, are excluded, as they are in an early stage of market development or in research and development (R&D) stages.

LIBs will remain the dominant technology in the UK and are expected to retain this position through to 2050. However, the market share of emerging technologies, such as SIBs, Li-S and other next-generation batteries, is expected to expand steadily, potentially reaching between 15 and 30 per cent by 2050 (Marie and Gifford, 2023). This study focuses on the active materials in battery cathodes and anodes, many of which are designated as critical in the UK due to their strategic importance, supply chain vulnerabilities and essential role in electrification.

The chemistry of a LIB used in EVs is primarily defined by the cathode active materials. Li is essential in all cathode types. The primary battery chemistries currently employed are (International Energy Agency (IEA), 2025):

- Ni-Mn-Co (NMC) group
- Ni-Co-Al (NCA) group
- Li-Fe-phosphate (LFP) group

Li is essential across all of these chemistries, both in the cathode and within the electrolyte. In addition to these dominant battery chemistry groups, this analysis also considers evolving chemistries, including Li-Mn-Fe-phosphate (LMFP), Li-Mn oxide (LMO) and others.

On the battery anode, graphite will remain the predominant active material and is anticipated to dominate the market through to 2050 (European Carbon and Graphite Association, 2023). Accordingly, this assessment includes only graphite-based anodes. Future emerging technologies, such as Si-doped graphite anodes, Si anodes, niobium (Nb), or Nb-tungsten anodes, are in development, but have not yet reached commercial deployment. There is limited information available on their prospective market share in the UK or suitability for the automobile sector. These technologies have therefore been excluded from this assessment.

NMC battery chemistries remain the most widely used in the UK, Europe and the USA. This is not the case for major consuming nations, such as China, where LFP batteries dominate the market as they cost around 30 per cent less per kilowatt-hour (kWh) than NMC batteries. Although NMC batteries still offer higher energy density, the performance gap has narrowed in recent years (International Energy Agency (IEA), 2025). Considering the focus in the UK on NMC LIB chemistries, this assessment includes a range of different configurations within the NMC group (for example, NMC111, NMC532, NMC622, NMC811 and NMC955).

Wind turbines

A wind turbine is a device that converts the kinetic energy of wind into electrical energy. It is a well-established renewable technology, available at various scales from small domestic units to large-scale wind farm installations. The UK has set an ambitious target of deploying up to 50 gigawatts (GW) of power from offshore wind and 27 to 29 GW of power from onshore wind by 2030, and potentially up to 125 GW of power from offshore wind by 2050. By the end of 2025, the UK's total installed wind capacity reached over 32 GW, with a nearly equal split of 16 GW for offshore and 16 GW for onshore. To reach 50 GW, the UK will require around 2600 additional large offshore turbines to be built (RenewableUK, 2026; Waters, 2025). A detailed foresight study for wind turbines is available in (Petavratzi et al., 2024a; Petavratzi et al., 2024b).

Wind turbines are complex machines comprising many components including the foundations, tower, nacelle and rotor blades. The nacelle, positioned at the top of the tower, contains the generator, along with other critical equipment such as the main shaft, control systems and, depending on the turbine design, a gearbox. In some wind turbines, the generator is directly linked to the rotor, a setup commonly known as a direct drive, which operates at a low rotational speed. Conversely, in other turbines, the rotor links to the generator through the shaft and a gearbox, which amplifies the rotational speed. Each configuration presents different material requirements, performance characteristics and maintenance needs.

This study focuses on the four most common turbine technologies used in onshore and offshore wind applications. These include:

- gearbox double-fed induction generators (GB-DFIG)
- gearbox permanent magnet synchronous generators (GB-PMSG)
- direct-drive permanent magnet synchronous generators (DD-PMSG)
- direct-drive electrically excited synchronous (DD-EESG) generators

GB-PMSG and DD-PMSG are widely employed in offshore wind farms due to their high efficiency, low maintenance requirements and compact design. GB-DFIG and DD-EESG are typically used in onshore wind applications. GB-PMSG and DD-PMSG are likely to dominate the industry in both offshore and onshore applications due to their superior efficiency and reliability, and their suitability for larger, higher-capacity turbines (Jung et al., 2024). **Traction motors**

Traction motors are specialised electric motors that transform electrical energy into mechanical torque to propel vehicles such as electric trains, locomotives and EVs. These powerful, high-torque and generally small motors are intended to handle varied speeds and, in many cases, function as generators for regenerative braking (Ennovi, 2024).

Permanent magnet synchronous motors (PMSMs) are currently the dominant traction technology in the EV market, capturing 91 per cent of the UK market share in 2025 (Advanced Propulsion Centre UK, 2024). They are favoured for their ability to deliver high power density and superior efficiency, which directly correlates to longer driving ranges for a given battery size. The remaining market is mainly occupied by induction motors (IMs) at 9 per cent and externally excited synchronous motors (EESMs) at less than 1 per cent. These three types of traction motor are considered in this study.

Synchronous motors consist of a stator with windings that generate a rotating field and a rotor with either permanent magnets or an excitation winding. In PMSMs, strong magnets are inserted in the rotor to generate a constant magnetic field. The main permanent magnet type used in PMSM is Nd-Fe-boron (NdFeB) due to its optimal magnetic properties (Nordelöf et al., 2018). High efficiency, power density, torque density, compactness and ease of control are some of the benefits that make PMSMs ideal for EV applications.

IMs are the most mature motor technology; they are simpler, more durable and less expensive than PMSMs since they do not use permanent magnets to generate a magnetic field. Instead, they generate a magnetic field by inducing an electric current onto the rotor. However, disadvantages such as lower efficiency (less range) and power density compared to PMSMs make them less attractive for EV applications (Gear and Collins, 2020) .

EESMs are synchronous electric motors that consists of a rotor and a stator. In EESMs, the magnetic field in the rotor is generated by an additional power supply (Haggenmüller, 2025). Whilst EESMs do not represent the dominant technology for EV applications, their use by manufacturers such as Renault, Nissan and BMW has been reported (EVKX, 2025). The key advantages of EESMs are that they do not require REEs in the magnets and can achieve high efficiency due to their ability to control the rotor circuit impedance, allowing for optimal motor performance under different load conditions.

IMs and EESMs are anticipated to gain market share in the future, whereas PMSMs are anticipated to lose market share due to the increased market penetration of REE-free alternative technologies.

2.3.4 Photovoltaics

PV technologies convert sunlight directly into electricity using semiconductor materials, primarily Si, and perovskites or organic materials, amongst others. PV technologies have developed into a mature, diverse and rapidly increasing sector, ranging from small-scale residential rooftop panels to very large, utility-scale power plants. Crystalline polysilicon (c-Si) continues to be the leading PV module technology, accounting for more than 98 per cent of the market. Various types of wafers and cells are utilised in c-Si solar PVs, with some being more efficient than others (International Energy Agency (IEA), 2022).

PV cells are classified into generations based on their material, efficiency and commercial maturity:

- first generation (c-Si)
- second generation (thin-film PV)
- third generation (emerging technologies)

PV systems consist of solar panels (modules), inverters that convert DC to AC, racking, cabling and charge controllers. Core components include monocrystalline or polycrystalline cells, junction boxes, back-sheets and batteries for storage (Franklin, 2018). Individual cells are linked together to make a panel, each installed in a metal frame within a glass casing.

A detailed foresight study for PVs is available in (Petavratzi et al., 2024d). The study considered a variety of subtechnologies, including dominant commercial technologies, growing specialised solutions and high-efficiency niche-market or emerging technologies now in use or in pilot production (Gervais et al., 2021; Smith et al., 2020):

- passivated emitter and rear solar cells (PERC): currently the most widely used technology
- Si heterojunction solar cells (SHJ): currently have the second largest share in the PV market and their importance is expected to increase in the future
- thin-film cells, such as Cu-In-Ga diselenide (CIGS) and Cd telluride (CdTe): more flexible than c-Si cells and can potentially be used in a wide range of applications; however, their efficiency is lower and they are relatively expensive to manufacture
- III-V/Si thin-film tandem solar cells: currently only used in high-specification applications, such as space technologies, but are likely to become available commercially after 2035 (Boyer-Richard et al., 2023).

2.4 SELECTED MATERIALS AND ELEMENTS

The materials and elements evaluated for the different technologies are shown in Figure 3. The selection of materials for this assessment was guided by two key criteria: materials essential to the core function of the technology and materials classified as critical.

The analysis only included materials that were essential to each technology's functioning. For example, in a battery, the cathode and anode active materials were assessed. In a PV cell, the materials used in the semiconductor layers and in solder for electrical connections between cells were analysed, while those used in the structure, in the glass cover and in casings were excluded. REEs (Nd, Pr, Dy and Tb) and boron (B) for high-performance magnets and Cu for high-conductivity windings were analysed for the wind turbines and traction motors. In general, structural and power transmission materials, such as glass, aluminium and steel, were excluded.

Materials that are classified as critical in the UK Criticality Assessment (Mudd et al., 2024) were all included in the analysis.

	UK critical minerals																		
	Bi	C	Co	Ga	In	Li	Ni	Mn	REE	Si	Sn	Te	Zn	B	Cu	Cd	Se	Ag	As
Batteries		●	●			●	●	●							●				
Wind turbines									●					●	●				
Traction motors									●					●	●				
Photovoltaics	●			●	●					●	●	●	●		●	●	●	●	●

● Elements included in the analysis

Figure 3 Elements included in this study. UK critical minerals are highlighted in dark grey. (Mudd et al., 2024).). BGS © UKRI 2026.

2.5 FUTURE ENERGY SCENARIOS

The future deployment of decarbonisation technologies forms the foundation of this assessment. The aim of the study is to quantify both the material requirements and the potential secondary material availability associated with key decarbonisation technologies, ensuring that the UK's energy transition can progress in a resource-secure and sustainable manner.

The analysis is underpinned by the National Grid FES 2025 (National Energy System Operator, 2025), which model the evolution of UK energy supply and demand through to 2050. These scenarios provide comprehensive pathways illustrating how the UK could achieve net zero by 2050. As whole energy-system models, the FES 2025 incorporate consistent assumptions across electricity, heat, transport, industry and infrastructure, making them well suited to supporting a unified assessment of the technologies included in this study.

The FES 2025 framework includes four distinct pathways: falling behind, hydrogen evolution, electric engagement and holistic transition.

- Falling behind: some decarbonisation progress is achieved compared with today, but the pace is insufficient to meet the 2050 net zero target
- Hydrogen evolution: net zero is reached through rapid adoption of hydrogen across industry and heating, supported by widespread access to a national hydrogen network
- Electric engagement: net zero is delivered primarily through large-scale electrification across the energy system
- Holistic transition: a balanced pathway combining electrification and hydrogen deployment to meet net zero

The FES 2025 scenarios differ from the FES scenarios used in previous foresight studies (National Grid, 2023). As a result, the material demand presented in this report also represents an update of earlier projections, reflecting the latest scenario conditions, modelling assumptions and technology outlooks.

Demand, stock evolution and EoL material availability were modelled for each technology based on two pathways: a high transition (HT) pathway and a low transition (LT) pathway. For all technologies, the LT pathway equates to the 'Falling behind' FES. However, for the HT pathway, the corresponding FES selected for modelling varies by technology. For example, the HT pathway for traction motors is equivalent to the 'Holistic transition' scenario, whereas the HT pathway for photovoltaics aligns with the 'Electric engagement' scenario. Table 2 provides a full breakdown of scenarios chosen for modelling per technology.

Table 2 Each FES 2025 chosen for modelling HT and LT pathways by technology.

Technology	Falling behind	Electric engagement	Hydrogen evolution	Holistic transition
Traction motors	LT		HT	
Wind turbines	LT			HT
PVs	LT	HT		
Batteries	LT		HT	

Understanding how technologies evolve over time is essential for projecting future embedded material demand and secondary material availability. As new or improved technologies enter the market and their adoption accelerates, the material composition of the energy system can change significantly. These shifts in technology dynamics directly influence material requirements, making it critical that they are explicitly incorporated into forward-looking assessments.

Technology evolution was also considered in previous foresight studies and this report maintains consistency with that approach. For PVs and wind turbines, the same technology-evolution scenarios used previously are applied here. These scenarios capture expected changes in market shares between different technology types (for example, PV cell technologies or wind turbine configurations) and a declining trend in material intensity for most materials over time (as shown in Sections 2.5.1, 2.5.2).

Additional detail on the projected future market shares for PV and wind technologies is provided in Appendix 1, with further technical discussion available in the earlier technology-specific reports (Petavratzi et al., 2024b; Petavratzi et al., 2024d).

2.5.1 Technology evolution: traction motors

An overview of the motor technology market shares expected in the UK EV fleet (passenger cars only) to 2050 is shown in Figure 4. PMSMs currently dominate the UK EV market and are projected to maintain their leading position through to 2050. However, concerns about supply chain resilience, particularly regarding permanent magnets, are expected to reduce their market share gradually to around 57 per cent by 2050. At the same time, EESMs and IMs are projected to gain market share, reaching approximately 17 per cent and 26 per cent by 2050, respectively. The increased adoption of these technologies will support diversification and help mitigate risks linked to critical mineral supply chains.

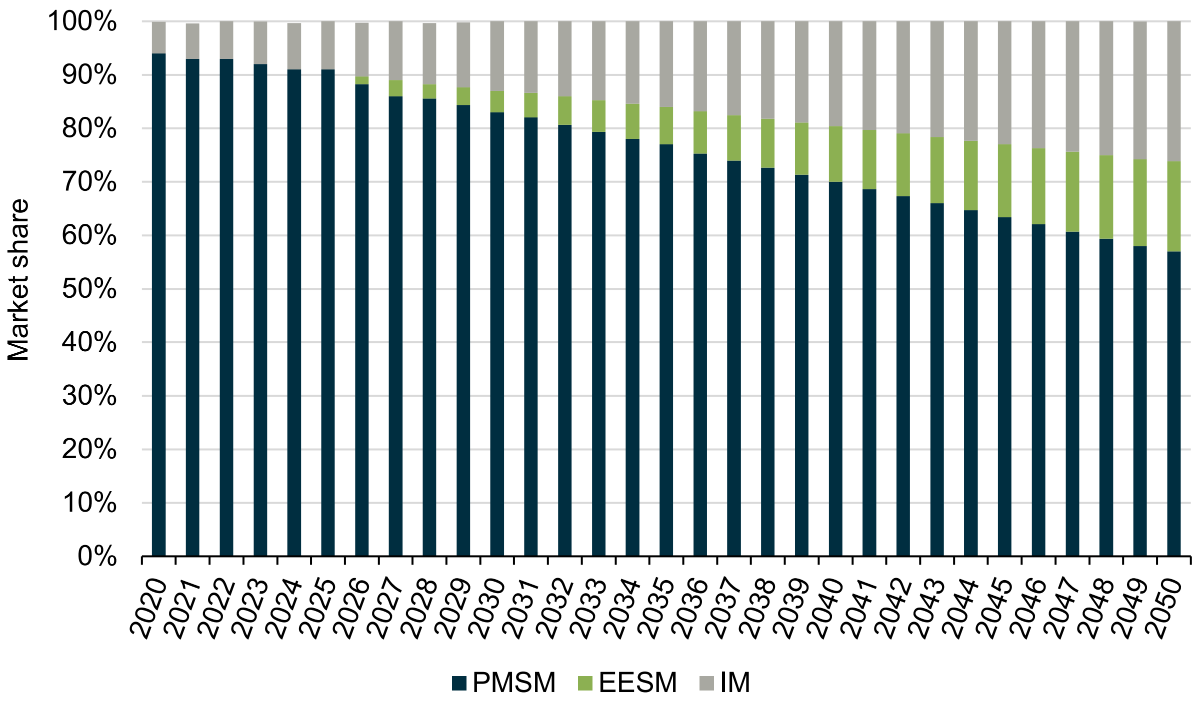


Figure 4 Evolution of the EV traction motors market between 2000 and 2050 showing the projected technology transformation. Data represent own model based on stakeholder engagement information. BGS © UKRI 2026.

The trade landscape for REEs and REE-containing products has experienced significant volatility over the past 12 months. China introduced export restrictions and new licensing requirements for medium to heavy REEs in April 2025, contributing to substantial market uncertainty. Although the Chinese Ministry of Commerce subsequently suspended the implementation of these restrictions until 10 November 2026 (Global Trade Alert, 2025; Risse et al., 2025), the temporary pause has not fully stabilised the market. Industries reliant on permanent magnets, such as automotive, wind power and electronics, continue to express concern over ongoing supply risks and are increasingly exploring alternative solutions, including REE-free motor designs (Neville et al., 2026).

2.5.2 Technology evolution: batteries

An overview of the projected technological evolution of the battery chemistry in the UK EV fleet (passenger cars only) to 2050 is presented in Figure 5. The analysis illustrates a gradual transition of battery chemistries from 2020 onwards, extending recent trends and drawing on projections from Marie and Gifford (2023).

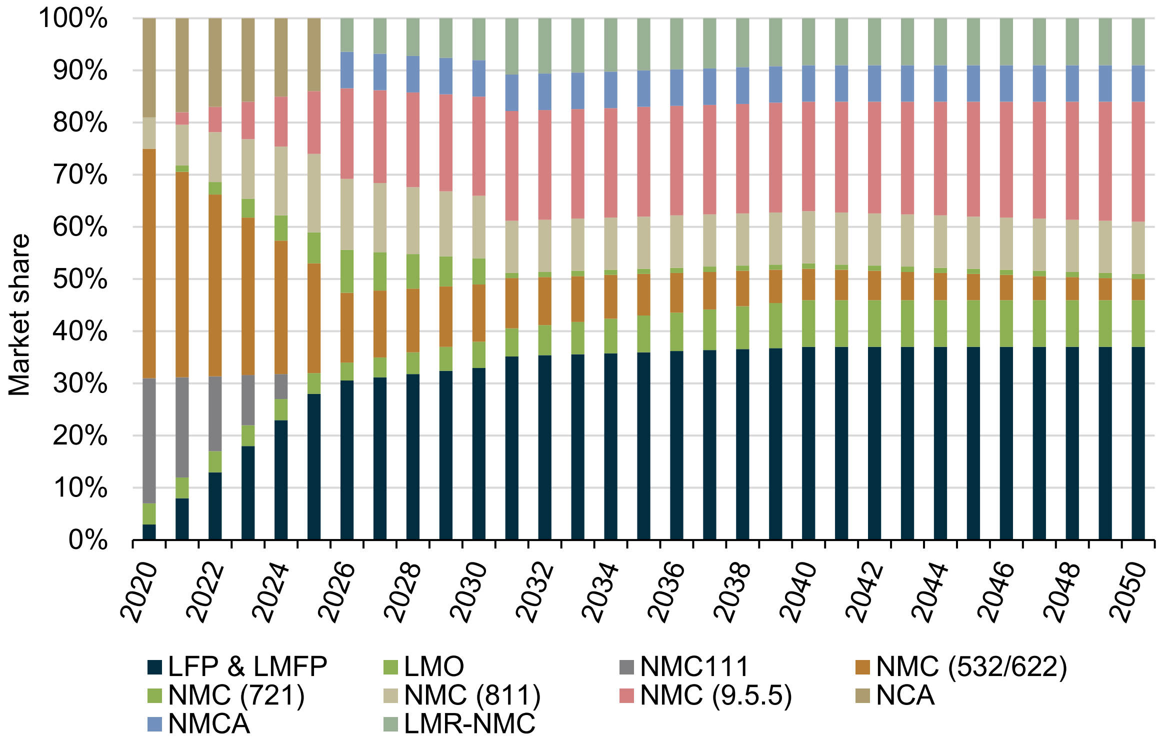


Figure 5 Evolution of the EV battery market between 2020 and 2050 showing the technology transformation that is likely to take place (Marie and Gifford, 2023). BGS © UKRI 2026.

In 2020, NMC cathode chemistries dominated the market, with a 75 per cent share, and are expected to remain market leaders until 2040. By 2040, the NMC chemistries are projected to decline to around 47 per cent as the use of the cheaper LFP chemistry becomes more widespread — LFP batteries are forecast to reach a 37 per cent market share by 2040. This trend is consistent with global developments: in 2025, LFPs overtook Ni-based chemistries to become the dominant EV battery chemistry worldwide, driven largely by rapid adoption in China, growing uptake in Europe and Asia and China's expanding role in international EV markets (Whitcombe, 2026).

The key characteristics of LFP batteries are lower cost, strong safety profile and long cycle life. As Chinese manufacturers increase their share of overseas EV sales, LFP batteries are expected to comprise a growing portion of the UK EV fleet. For example, in 2025, approximately 9.7 per cent of new EV registrations in the UK were vehicles manufactured in China, a proportion likely to rise further in the coming years (Jolly, 2026) .

These developments have direct implications for EoL battery flows. Assuming a mean EV lifespan of around 14 years, the composition of EoL batteries will increasingly reflect today's market trends. By 2040, approximately 10 per cent of batteries reaching EoL in the UK could be LFP-based, with this share expected to grow substantially thereafter as LFP penetration rises.

Next-generation chemistries such as SIBs, Li-S and other emerging systems are not included in this analysis as robust material-intensity data is currently lacking and there is insufficient evidence to validate their deployment within the present UK EV fleet.

2.5.3 Lifetime disruption of products

Understanding the lifetime of products is essential in dMFA modelling to estimate the annual demand of materials and the quantity of materials that reach EoL. In general, shorter product lifetimes require higher levels of demand to maintain stock levels; shorter lifetimes also increase the frequency at which a product reaches its EoL. As a result, both the annual demand and EoL material availability increase, the latter resulting in material becoming available for recycling. On the other hand, longer product lifetimes lower annual demand and limit the availability of EoL materials.

Product lifetimes can be visualised using statistical distributions. Product lifetime distributions describe how long products last before they fail. The area under the curve effectively represents product reliability; the horizontal axis is elapsed time, and the vertical axis is frequency of failures or, in the case of this study, the frequency with which a product reaches EoL. There are several types of distributions that are used to describe product lifetimes depending on the scope of an assessment (for example, product reliability or product warranty). In this study, the most suitable product lifetime distributions are normal and Weibull.

In the case of a normal distribution, the lifetime of products clusters around a mean. The peak of the curve (mean lifetime) represents the most common failure time. The curve is perfectly symmetrical, which means that there is equal chance of product failure before and after the mean. The spread (standard deviation) indicates the variability in product lifetime. For example, in the case of EVs (Figure 6), the normal distribution curve is narrow, indicating that EV lifetimes are more predictable and relatively uniform. The narrow distribution curve is also centred around the 14-year point, indicating that this is the average lifetime for an EV. This also highlights that the probability of an EV reaching EoL is much lower when the vehicle is new (zero to eight years old); however, as time progresses, the probability function decreases to zero indicating that an EV is no longer in use and has instead reached the EoL stage. The normal distribution works well in the case of EVs, because only one type of technology is being considered (battery passenger EVs).

A Weibull distribution shows how and why products fail over time. The scale represents the typical lifetime of a product and the shape parameter describes the failure behaviour of a product. One benefit of using the Weibull distribution is that it can accommodate different failure rates and product usage patterns. For example, in the case of PVs, there are several subtechnologies that have varying lifetimes; there is also a difference in lifetime between commercial-scale solar operations and small, domestic installations. This can be seen in Figure 6, where the distribution curve for PVs is lower and broader, indicating EoL may be reached at varying points. The curve centre is around 30 years, which is taken to be the typical lifetime.

Figure 6 shows that EVs have the shortest lifetime, followed by wind turbines, then PVs. Almost all EVs reach EoL within 26 years, compared to around 40 years for wind turbines and 44 years for PVs. Consequently, EV-related materials contribute significantly to annual demand and EoL flows within the study period, while wind and PV materials accumulate and retire over a much longer timeframe.

Table 3 Lifetime distributions, their type and parameters for the technologies of this study. Note that the same lifetime distribution is used for the traction motor and the lithium-ion battery of an EV.

Technology	Type	Mean/scale	Stdev/shape	Source
PV	Weibull	30	5.4	(Weckend et al., 2016)
Wind turbine	Normal	25	5	(Li et al., 2020)
EV	Normal	14	3	(Kamran et al., 2021)

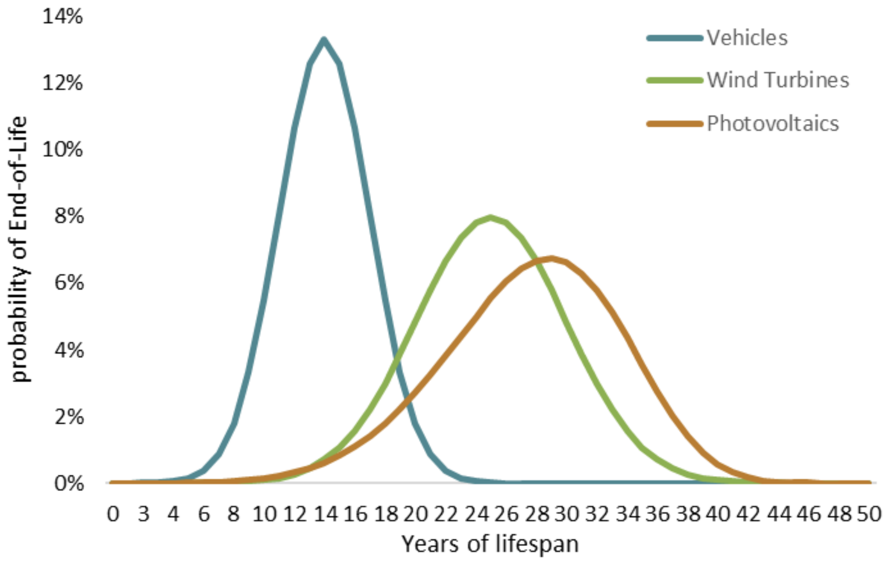


Figure 6 Lifespan distributions for EVs, wind turbines and PVs, considering the normal and Weibull parameters of Table 3. BGS © UKRI 2026.

2.5.4 Bills of materials

With stock evolution established from the FES 2025 scenarios, technology shares and lifetime distributions, the final input to the model in this foresight study is the material intensity of each subtechnology and its bill of materials.

The bills of materials show the relationship between a product and the mass of material required to produce it in a given year. The bills of materials are shown in:

- Table 4 for PV panels by subtechnology in kg/MW
- Table 5 for wind turbines by subtechnology (kg/MW)
- Table 6 for electric vehicles for metals present in motor magnets (kg/vehicle) and for metals present in vehicle batteries (kg/kWh)

It is important to note that this study assumes an average EV battery capacity of 65 kWh per vehicle for battery EVs (BEVs) and 11 kWh per vehicle for plug-in hybrid EVs (PHEV). Hybrid EVs are not included in the assessment.

The range of material intensity values used in this assessment and presented in Table 4, Table 5 and Table 6 were taken from various sources. The material intensity is modelled dynamically in this assessment, meaning that it varies depending on the year in which a product enters the market and becomes part of the in-use stock. Thus, the range of material intensity represents the maximum and minimum values within the years of the study. This dynamic approach accounts for expected technological improvements over time, which are likely to reduce the quantity of material required to achieve the same installed megawatt capacity or vehicle performance compared with earlier generations of the technology.

Table 4 Material intensity data used for modelling PVs. The unit is in kg/MW. Abbreviations are described in Section 2.3.4. (European Commission et al., 2020a; Gervais et al., 2021).

Subtechnology	Ag	As	Bi	Cd	Cu	Ga	In	Se	Si	Sn	Te	Zn
PERC	6–18		0–56		670–894				1544–3065	35–56		
SHJ	11–42				643–785		0–5		1235–2568	0–1		1–2
CIGS				0–20	33–84	9–24	18–46	89–226				26–30
III-V/Si		210–262	32–40		487–609	35–52	9.7–14.5		3605–4506	24–30		0.02–0.03
CdTe				62			7.95				70	

Table 5 Material intensity data used for modelling wind turbines. The unit is in kg/MW. Abbreviations are described in Section 2.3.2. (European Commission et al., 2020a; European Commission et al., 2020b).

Subtechnologies	B	Cu	Dy	Nd	Pr	Tb
GB-DIFG		1400	1.4–2	8.4–12		
GB-PMSG	1	950	4.2–6	36–51	4	1
DD-PMSG	6	3000	14–17	126–180	24.5–35	7
DD-EESG		5000	4.2–6	19.6–28	9	1

Table 6 Material intensity data used for modelling EV traction motors (kg/vehicle) and EV lithium-ion batteries (kg/kWh). (Alves Dias et al., 2020; Ballinger et al., 2019; Dunn et al., 2021; Liang et al., 2023) and stakeholder engagement.

kg/vehicle	B	Cu	Dy	Nd	Pr	Tb
PM motor	0.02	3.9–4.5	0.06–0.05	0.313–0.360	0.096–0.110	0.015
kg/kWh	**C**	**Co**	**Cu**	**Li**	**Mn**	**Ni**
Battery	0–1.09	0–0.96	0–0.95	0.07–0.14	0–1.4	0–1.01

3 Results by technology

3.1 BATTERIES IN EV PASSENDER CARS

3.1.1 Future consumption of materials

The forecast demand for the raw materials required for manufacturing LIBs in EV passenger cars (BEVs and PHEVs) has been modelled using three key parameters:

- evolution of the LIB market between 2020 and 2050: projected battery technology shares are based on current trends and developments reported by major EV and battery manufacturers. These trends reflect a significant evolution in battery technology over the next 20 years, but NMC batteries remain the dominant technology
- UK EV sales projections: future BEV and PHEV sales used in this assessment correspond to FES 2025 by selecting the HT and LT pathways. In the case of EVs, these correspond to the ‘Hydrogen evolution’ and ‘Falling behind’ scenarios
- material intensity of each battery type: material intensities (kilogram per kilowatt hour) were applied to estimate the metal content of each battery type. The analysis covers carbon (C), Cu, Co, Li, Mn and Ni

Further detail on these parameters is provided in Section 2.

The transition to electric mobility has a direct influence on the demand for a range of elements used in LIBs, particularly Li, Co, Ni (used in cathodes) and graphite (used in anodes). Figure 7 presents projected annual demand for C, Co, Ni and Li under the two pathways (HT and LT). Scenario differences (HT vs. LT) are consistent across all materials.

The LT scenario yields somewhat lower demand due to slower EV adoption, but the relative differences are modest. The main difference is the point at which maximum demand for EVs is reached: approximately five years earlier (2035) in the HT pathway than the LT pathway.

Li demand in 2025 is estimated at 4973 t (HT), increasing to a peak of 23 317 t in 2035, driven by continued uptake of NMC (various chemistries), LFP and LMFP batteries. After 2035, Li demand under the HT pathway will gradually stabilise to around 20 000 t. The LT pathway will take approximately six years longer to approach peak demand from 2041 onwards, with peak demand reached in 2045 at 23 169 t Li, then stabilisation up to 2050. The LT pathway will remain close to peak demand for longer than the HT pathway and will take longer to stabilise due to the slower uptake of EVs compared to the HT scenario. The LT pathway demand from 2047 onwards will mirror the HT pathway, albeit at lower demand.

For other elements (C, Co, Ni and Cu), Table 7 and present annual demand figures. Their trajectories will broadly follow the same pattern as Li, rapidly rising to 2035 (HT) or after 2040 (LT), before stabilising to 2050. However, the absolute scale differs substantially between elements, which is important for supply chain planning. For example, C (and Cu — see Appendix 2) demand will be an order of magnitude greater than Co and Li, reflecting the composition of modelled batteries. Both Cu and C demand are estimated to be over 100 000 t per year beyond 2030, making them a major contributor to overall material requirements for EV manufacture. The forecasted demand for Ni is also substantial, peaking at approximately 93 474 t in the mid-2030s and fluctuating between 75 000 t and 94 000 t over the period 2035 to 2050.

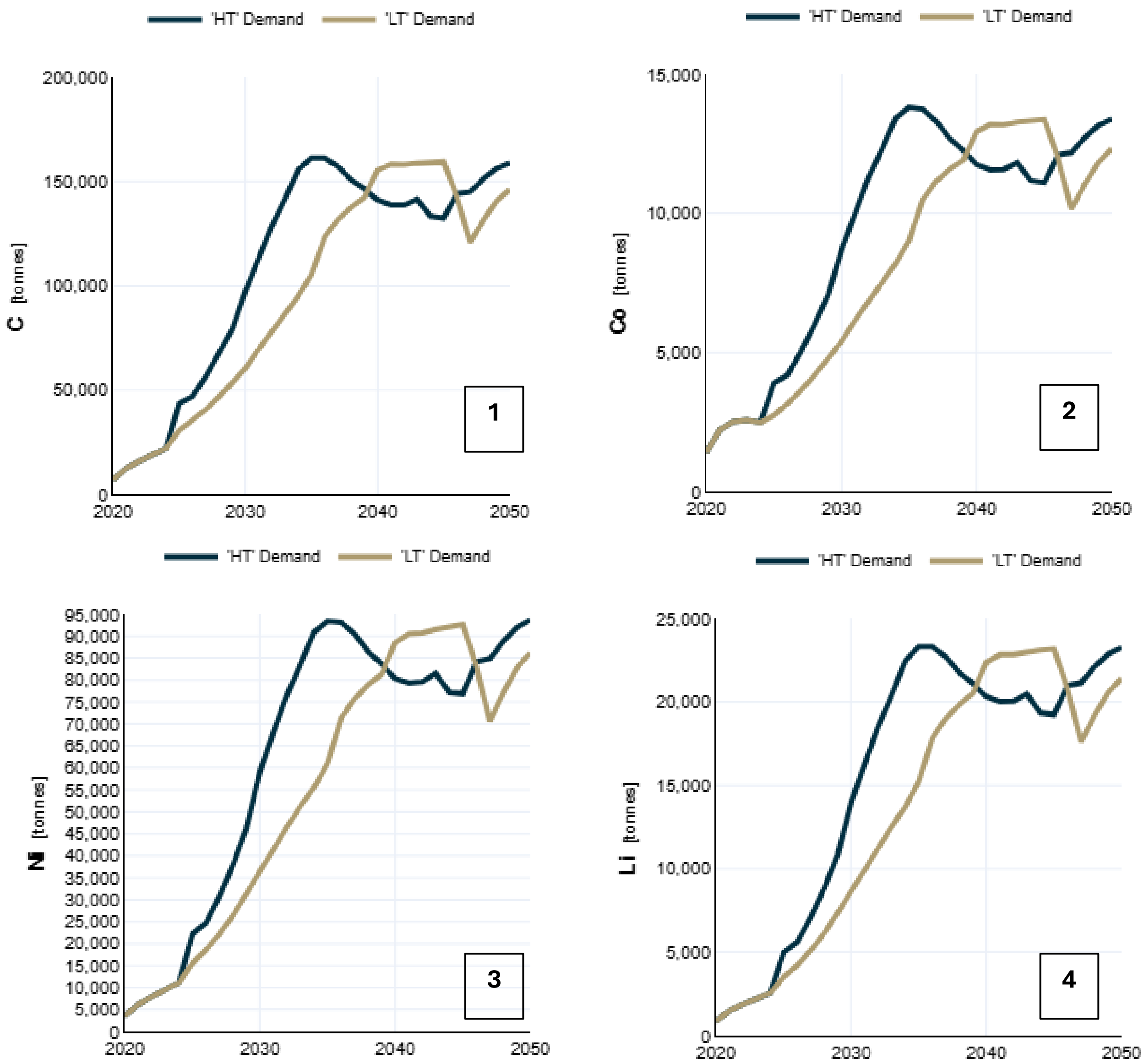


Figure 7 Annual UK demand of (1) C; (2) Co; (3) Ni; (4) Li in EV battery motors between 2020 and 2050. The graphs estimate demand under HT and LT pathways. The unit is tonnes. (Graphs for Mn and Cu are in Appendix 2). BGS © UKRI 2026.

Table 7 Annual demand figures for selected elements in 2025, 2035 and 2050. Demand figures are presented under a high transition (HT) and low transition (LT) pathway.

Year	C demand (t)		Co demand (t)		Ni demand (t)		Li demand (t)	
Pathways	HT	LT	HT	LT	HT	LT	HT	LT
2025	43 543	30 625	3901	2744	22 133	15 567	4973	3498
2035	161 666	105 191	13 809	9013	93 474	61 009	23 317	15 218
2050	158 620	145 979	13 384	12 318	93 726	86 256	23 244	21 392

Key points from the demand modelling assessment:

- the projections presented in this report reflect the material requirements associated with the UK's transition to electric passenger cars (BEV and PHEV), therefore they represent UK consumption demand linked to the in-use vehicle stock, rather than total industrial demand
- the analysis focuses exclusively on PHEV and BEV passenger cars (as described in Section 2.5.4); other road transport segments, including heavy goods vehicles (HGVs), buses and micromobility, are not assessed here and would add substantially to overall material requirements
- total UK demand for battery materials (manufacturing and consumption across all vehicle types) is expected to be significantly higher than the values reported in this study
- peak demand for all assessed elements is projected around 2035 (HT pathway) or after 2040 (LT pathway), demonstrating the rapid increase in demand over a short time across all scenarios. Beyond this, a stabilisation or declining demand for EV materials will be seen due to the mature transition to an electrical fleet and the evolution of hydrogen-powered vehicles
- C will be the dominant material by mass, with annual demand exceeding that of Co by an order of magnitude, which reflects its essential role in battery anodes
- Cu will have high levels of demand similar to C, as it is essential not only in cathodes but also across the broader EV electrical architecture
- compared to Cu, Ni will have a slightly lower but still very high total tonnage in terms of demand, demonstrating the continued reliance on Ni in battery technologies
- Li demand will remain substantial: continued use in EV battery technology has important implications for supply chain resilience, refining capacity and future recycling strategies
- differences between HT and LT pathways will be modest — even under slower decarbonisation pathways, material requirements will remain high and follow similar trajectories, indicating structurally strong demand for EV battery materials under all plausible pathways

3.1.2 Stock evolution

The progressive expansion of the UK's electrified vehicle fleet will lead to a substantial increase in the stocks of battery materials. Figure 8 presents the projected evolution of C, Co, Ni and Li contained in UK EV LIBs from 2020 to 2050 under the HT and LT pathways. In both cases, material stocks will rise sharply throughout the 2020s and 2030s. This growth reflects the rapid uptake of EV and the continued dominance of NMC battery technology.

For example, the contained Li in UK EV fleet stocks under the HT pathway will increase from below 1734 t in 2020 to 243 858 t by 2040, with the upward trend of contained Li in stocks beginning to slow from 2043 onwards. The LT stock pathway will have a slower upward trajectory compared to the HT pathway, reflecting less contained Li within stocks due to lower EV uptake. The LT upward trend will slow from 2046, three years later than the HT pathway.

After peaking, stocks for all elements will gradually begin to stabilise towards 2050. This stabilisation is likely because the EV fleet will reach a mature, steady-state size, where fleet growth slows and material additions are driven mainly by replacement demand rather than expansion. All analysed components show an order of magnitude increase between 2025 to 2050, particularly Ni (Table 8).

Across all materials assessed, the maximum amount of contained metals in stocks will be between 2043 and 2046, but the absolute quantities vary greatly between elements. For example, C stocks will peak at approximately 2 038 184 t. Cu stocks will exceed 1 816 662 t over the same period, reflecting Cu's substantial role not only in batteries but also in broader vehicle electrical systems, which have not been quantified in this instance. These differences highlight the varying scale of supply chain challenges and opportunities associated with different elements.

Although the HT pathway generates higher overall stock accumulation than the LT pathway, the shape and timing of trends are broadly consistent across both pathways and for all elements (see Appendix 2 for Mn and Cu). This indicates that underlying drivers — for example, EV uptake patterns, technology choices and battery design evolution — remain similar even under different decarbonisation trajectories.

The steep growth in stocks of C, Co, Li and Ni underscores the importance of accelerating the development of reverse supply chains to recover these materials from EoL vehicles. Establishing a viable recycling and refining infrastructure will be critical for enhancing domestic supply resilience and reducing reliance on imported raw materials.

Finally, because this assessment focuses exclusively on passenger EV cars, the total stock of these materials across the entire UK EV fleet will be considerably higher than the values presented here. In addition, any material requirements associated with UK battery manufacturing will add further demand. Battery manufacturing was outside the scope of this assessment and these additional requirements are therefore not included in the figures reported.

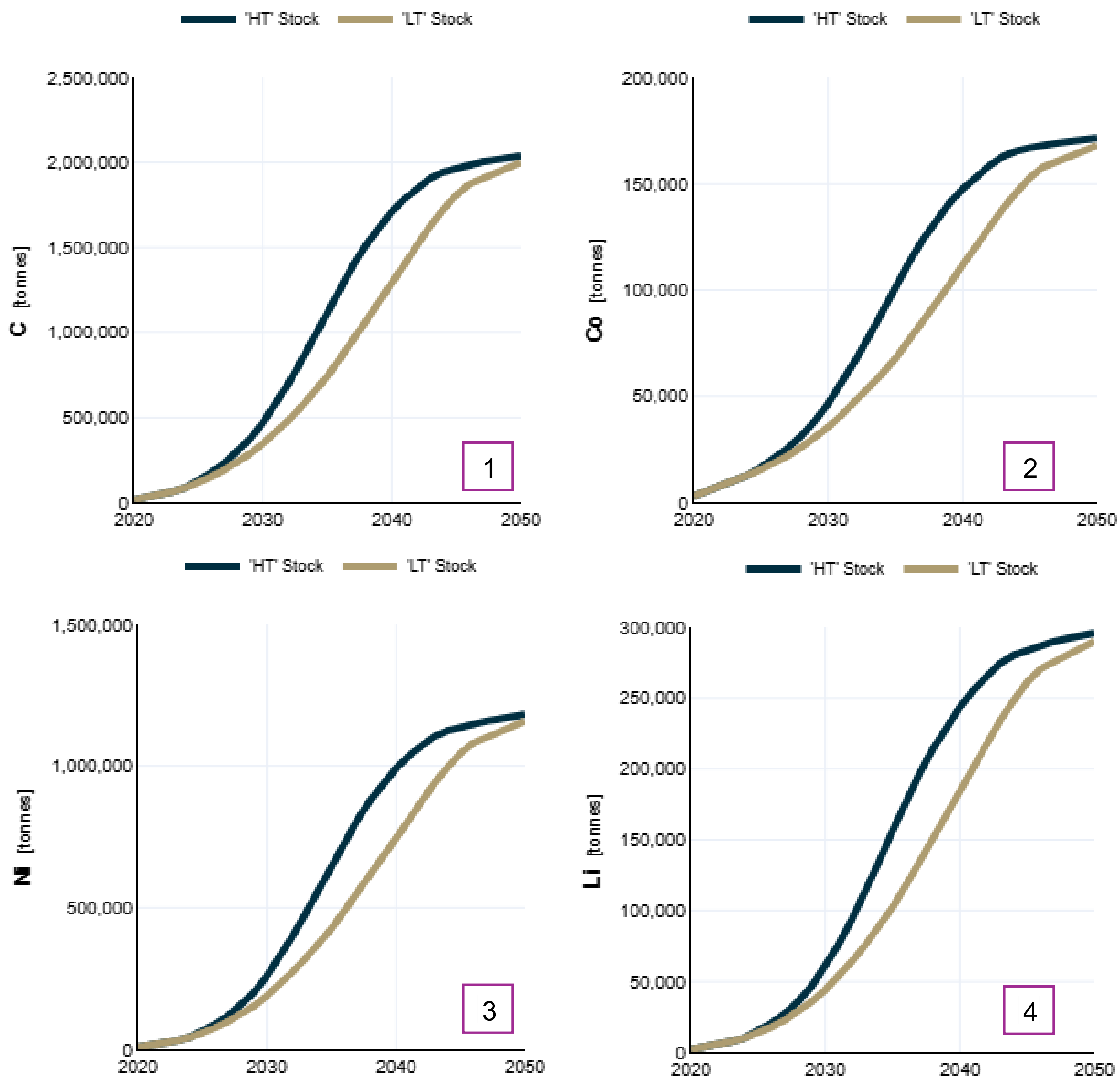


Figure 8 Stock evolution of (1) C; (2) Co; (3) Ni; (4) Li in batteries between 2020 and 2050. The graphs estimate stocks under two different pathways: HT and LT. The unit is tonnes. (Graphs for Mn and Cu are in Appendix 2). BGS © UKRI 2026.

Table 8 Annual stock evolution of the UK passenger car EV fleet for selected contained elements in 2025, 2035 and 2050. Figures are presented under a high transition (HT) and low transition (LT) pathway.

Year	C in stocks (t)		Co in stocks (t)		Ni in stocks (t)		Li in stocks (t)	
Pathways	HT	LT	HT	LT	HT	LT	HT	LT
2025	126 676	113 758	16 437	15 280	63 774	57 208	14 808	13 333
2035	1 125 798	741 197	101 444	67 679	651 379	426 666	156 414	102 284
2050	2 038 184	1 998 934	171 448	167,959	1 182 902	1 159 131	295 806	290 060

3.1.3 End-of-life availability of materials

The quantities of technology metals expected to become available from EoL batteries increase substantially towards 2050. As shown in Figure 9, EoL flows will remain relatively small in the early years of both transition pathways, reflecting the still-limited retirement of first generation EVs, but will begin to rise sharply from the early-mid 2030s onward as larger volumes of vehicles reach the end of their operational lifetimes.

For example, Li contained within EoL batteries will amount to around 25 t in 2025 across both pathways. By 2035, this will increase to 1781 t in the HT pathway and 1570 t in the LT pathway. By 2050, Li availability will diverge markedly, rising to around 21 314 t (HT) compared with 16 838 t (LT). By 2050, the rise in contained Li in EoL batteries will begin to tail off and stabilise, likely reflecting that many of the EVs have reached EoL. Conversely, under the LT pathway in 2050, Li contained in EoL batteries from passenger cars will still be on an upward trend. Similar trajectories are observed for C, Co and Ni, with an order of magnitude increase for many elements between 2035 and 2050 (Figure 9 and Table 9).

C shows one of the largest EoL material availabilities by 2050 (HT), with around 21 per cent more C reaching EoL compared with the LT pathway. This difference reflects the substantially higher mass of graphite in batteries relative to other battery materials, nearly double that of Ni and an order of magnitude larger than Co and Li. The scale of this effect is evident in the 2050 EoL projection: 147 719 t (HT) compared to 116 698 t (LT) (Table 9). This equates to an additional 31 021 t of EoL C being available in 2050 under the fastest decarbonisation pathway.

These trends highlight the strong influence that transition pathways have on future EoL material availability, driven primarily by differences in the rate of EV fleet growth. The HT pathway will produce significantly higher annual EoL flows, with peak EoL quantities available sooner compared to the LT scenario. Under HT, EoL quantities will begin to plateau around 2050, reflecting the stabilisation of the mature EV fleet. In contrast, the LT pathway will continue to show rising EoL flows beyond 2050, consistent with its slower electrification curve.

It is also important to emphasise that these EoL projections relate only to EV passenger cars, as other vehicle categories are not included in this assessment. The total availability of technology metals from the entire UK EV fleet is therefore expected to be significantly higher than the values shown here. Additional modelling across the full road transport sector is needed to establish a complete national picture of future secondary material availability. The UK's ambition to scale domestic battery manufacturing will also influence future EoL projections, as manufacturing scrap and production waste are likely to add to the EoL material volumes modelled in this assessment.

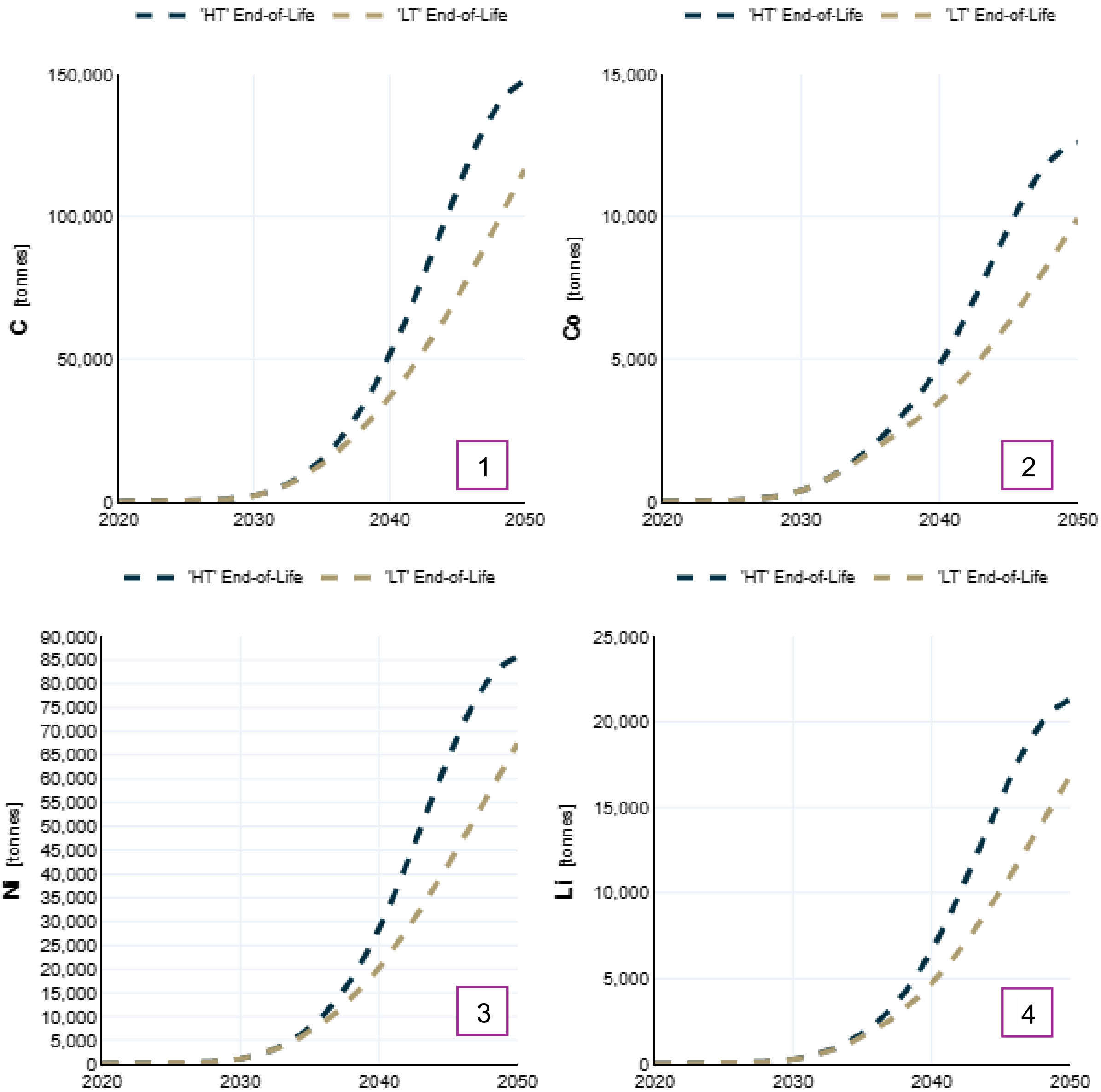


Figure 9 Annual EoL quantities of (1) C; (2) Co; (3) Ni; (4) Li in batteries between 2020 and 2050. The graphs estimate EoL material flows under two different pathways: HT and LT. The unit is tonnes. (Graphs for Mn and Cu are in Appendix 2). BGS © UKRI 2026.

Table 9 Annual EoL quantities of selected battery elements available from the UK passenger car EV fleet in 2025, 2035 and 2050. Figures are presented under a HT and LT pathway.

Year	C in EoL (t)		Co in EoL (t)		Ni in EoL (t)		Li in EoL (t)	
Pathways	HT	LT	HT	LT	HT	LT	HT	LT
2025	204	204	40	40	101	101	25	25
2035	14 883	13 148	1900	1745	7643	6717	1781	1570
2050	147 719	116 698	12 608	9929	85 673	67 526	21 314	16 838

3.2 TRACTION MOTORS IN PASSENGER CARS

3.2.1 Future consumption of materials

The forecast demand for raw materials required for the manufacture of EV traction motors has been modelled using three key parameters:

- future market shares of electric motor technologies (2020 to 2050): projected motor technology shares are based on current trends and developments reported by major mass-market original equipment manufacturers (OEM). These trends reflect a gradual shift away from PMSMs, which rely on REE permanent magnets, towards EESMs and IMs. This shift is motivated by OEM concerns over cost volatility, geopolitical supply risk and the environmental footprint associated with REE extraction and magnet manufacture (Advanced Propulsion Centre UK, 2025)
- UK EV sales projections: future EV sales used in this assessment correspond to the National Grid FES 2025 (National Energy System Operator (2025) by selecting the HT and LT pathways. In the case of EVs, these correspond to the ‘Hydrogen evolution’ and ‘Falling behind’ scenarios
- material intensity of each electric motor type: material intensities (kilogram per vehicle) were applied to estimate the metal content of each motor type. The analysis covers REEs (Nd; Dy; Pr; Tb), Cu and B

Further detail on these parameters is provided in Section 2.

The transition to electric mobility has a direct influence on the demand for the REEs used in traction motors, particularly Nd and Dy, which are essential for high-performance permanent magnets. Figure 10 presents projected annual demand for Nd under the two pathways (HT and LT). Nd demand in 2025 is estimated at 275 t (HT), increasing to 765 t in 2035, driven by continued uptake of PMSMs. After 2035, Nd demand will gradually decline to 500 t by 2050, reflecting a combination of rising hydrogen-fuelled vehicle deployment and increasing substitution away from PMSMs. The LT pathway shows a similar profile but with marginally lower values due to slower EV uptake.

For other elements (Dy; Cu; B), Figure 10 and Table 10 present annual demand figures. Their trajectories broadly follow the same pattern as Nd, rising to 2035 and stabilising or slightly declining thereafter. However, the absolute scale differs substantially between elements, which is important for supply-chain planning. For example, Dy and B demand will be in the tens of tonnes, reflecting their use primarily in high-performance magnets. Cu demand will be several thousand tonnes per year, making it a major contributor to overall material requirements for motor manufacture.

Scenario differences (HT vs. LT) are consistent across all materials: the LT scenario yields somewhat lower demand due to slower EV adoption, but the relative differences are modest, particularly for Cu where both scenarios show there will be strong, sustained demand.

The decrease in demand observed between 2030 and 2050 reflects the point at which the UK EV fleet will reach a mature, steady-state level. This essentially means that the transition to an electrified fleet has been achieved. After this peak, demand will enter a cyclical pattern: periods of lower demand will occur as fewer new vehicles are required to expand the fleet, followed by periods of increased demand as older vehicles reach end-of-life and are replaced. These fluctuations represent the natural stabilisation of a fully electrified fleet, where material requirements are driven primarily by replacement cycles rather than rapid growth.

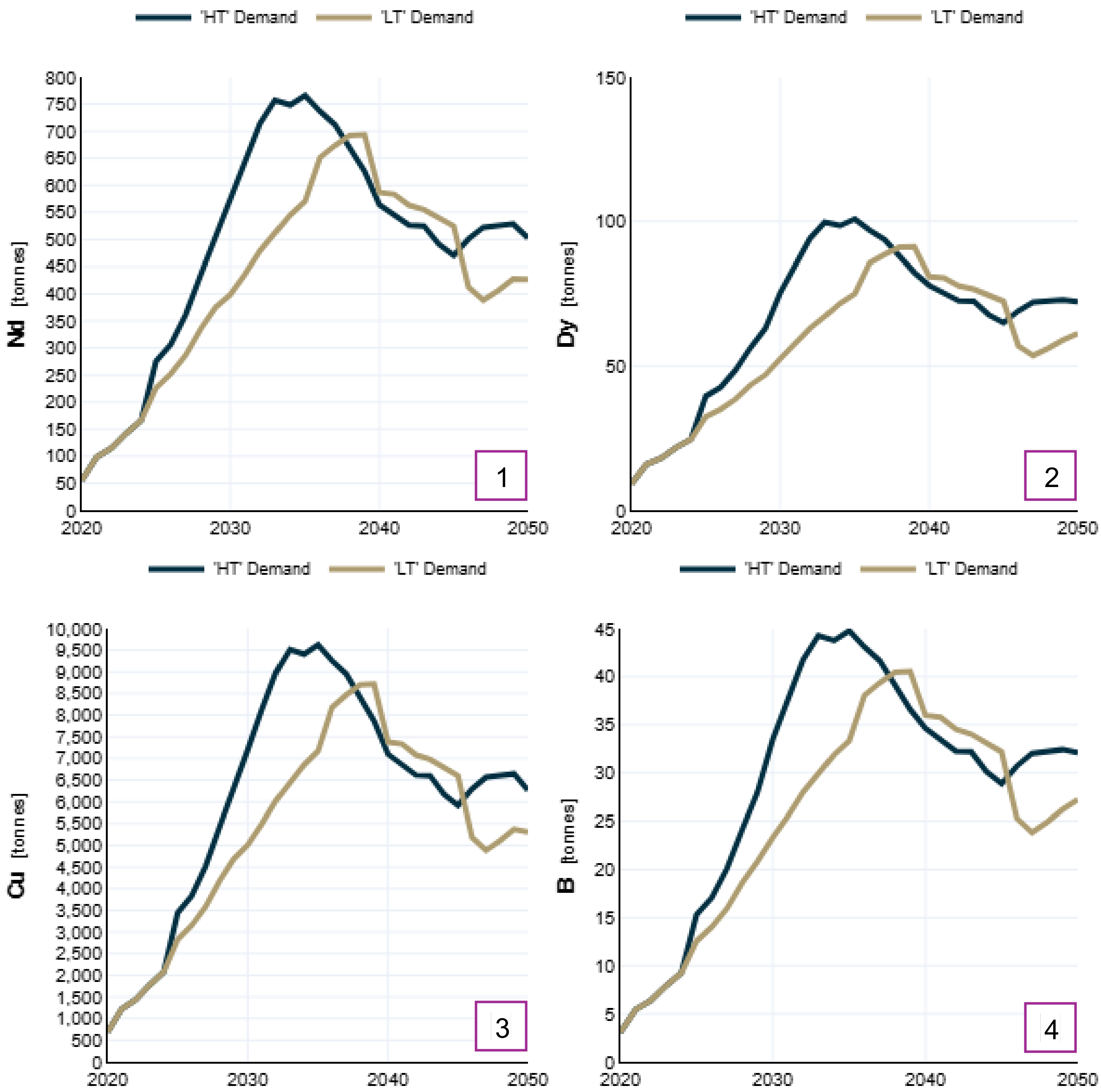


Figure 10 Annual UK demand for (1) Nd; (2) Dy; (3) Cu; (4) B in traction motors between 2020 and 2050. The graphs estimate demand under two different pathways: HT and LT. The unit is tonnes. BGS © UKRI 2026.

Table 10 Annual demand figures for selected elements in 2025, 2035 and 2050. Demand figures are presented under an HT and an LT pathway.

Year	Nd demand (t)		Dy demand (t)		Cu demand (t)		B demand (t)	
Pathways	HT	LT	HT	LT	HT	LT	HT	LT
2025	275	225	40	32	3440	2820	15	12
2035	765	570	101	75	9630	7170	45	33
2050	500	426	72	61	6260	5310	32	27

Key points from the demand modelling assessment are:

- the projections presented in this report reflect the material requirements associated with the UK's transition to electric passenger cars, therefore they represent UK consumption-driven demand linked to the in-use vehicle stock rather than total industrial demand
- demand associated with domestic manufacturing is not included; estimating manufacturing-sector requirements would require a different set of modelling assumptions, such as UK production volumes, additional material-intensity information, export ratios and technology choices, which were outside the scope of this study
- the analysis focuses exclusively on passenger cars: other road transport segments, including HGVs, buses and micromobility, are not assessed here and will add substantially to overall material requirements
- total UK demand for critical materials (manufacturing plus consumption across all vehicle types) is expected to be significantly higher than the values reported in this study
- peak demand for all assessed elements is projected around 2035, which coincides with the period of maximum penetration of PMSMs before diversification into other motor technologies and the increasing adoption of hydrogen-powered vehicles
- Cu will be the dominant material by mass, with annual demand exceeding that of REEs by two orders of magnitude, reflecting Cu's essential role not only in traction motors but also across the broader EV electrical architecture
- REE demand will remain substantial, especially for Nd and Dy. Their continued use in high-performance magnets will have important implications for supply-chain resilience, refining capacity and future recycling strategies
- differences between HT and LT pathways will be modest; even under slower decarbonisation, material requirements will remain high and follow similar trajectories, indicating strong demand for traction-motor materials under all pathways

3.2.2 Stock evolution

The progressive expansion of the UK's EV fleet will lead to a substantial increase in the stocks of technology metals embedded in electric traction motors. Figure 11 presents the projected evolution of Nd, Dy, Cu, and B contained in UK traction motors from 2020 to 2050 under two scenarios: the HT and LT pathways. In both scenarios, material stocks will rise sharply throughout the 2020s and 2030s. This growth reflects the rapid uptake of battery EVs and the continued dominance of PMSMs, which rely heavily on NdFeB permanent magnets.

For example, Nd stocks will increase from below 500 t in 2020 to around 8800 t (HT) by 2040, with the LT scenario showing a similar pattern but reaching a lower peak of approximately 8000 t in the mid-2040s. Following this peak, Nd stocks will gradually decline toward 2050. This reduction will be driven by a combination of factors, including diversification of motor technologies (with increased uptake of REE-free motor types), improvements in magnet efficiency and the growing adoption of hydrogen-powered vehicles later in the transition. Most importantly, it reflects the EV fleet reaching a mature, steady-state phase where stock growth has slowed and material additions will be driven primarily by replacement rather than expansion.

Across all materials assessed, stocks will peak around 2040, but the absolute quantities vary greatly. For example, Dy stocks will peak at approximately 1174 t, while Cu stocks will exceed 100 000 t over the same period, reflecting Cu's substantial role not only in motors but also in broader vehicle electrical systems (which have not been quantified in this instance). These differences highlight the varying scale of supply chain challenges and opportunities associated with different elements. Although the HT pathway will generate higher overall stock accumulation than LT, the shape and timing of trends are broadly consistent across both pathways and for all four elements. This indicates that underlying drivers, for example EV uptake patterns, technology choices and motor design evolution, will remain similar even under different decarbonisation trajectories.

The steep growth in stocks of REEs and Cu underscores the importance of accelerating the development of reverse supply chains to recover these materials from EoL vehicles. Establishing a viable recycling, refining and metal alloying infrastructure will be critical for enhancing domestic supply resilience and reducing reliance on imported raw materials.

Finally, because this assessment focuses exclusively on passenger cars, the total stock of these materials across the entire UK EV fleet will be considerably higher than the values presented here. Additional contributions will also arise from EV and traction-motor manufacturing activity within the UK. These manufacturing-related requirements were outside the scope of this assessment and are therefore not reflected in the results.

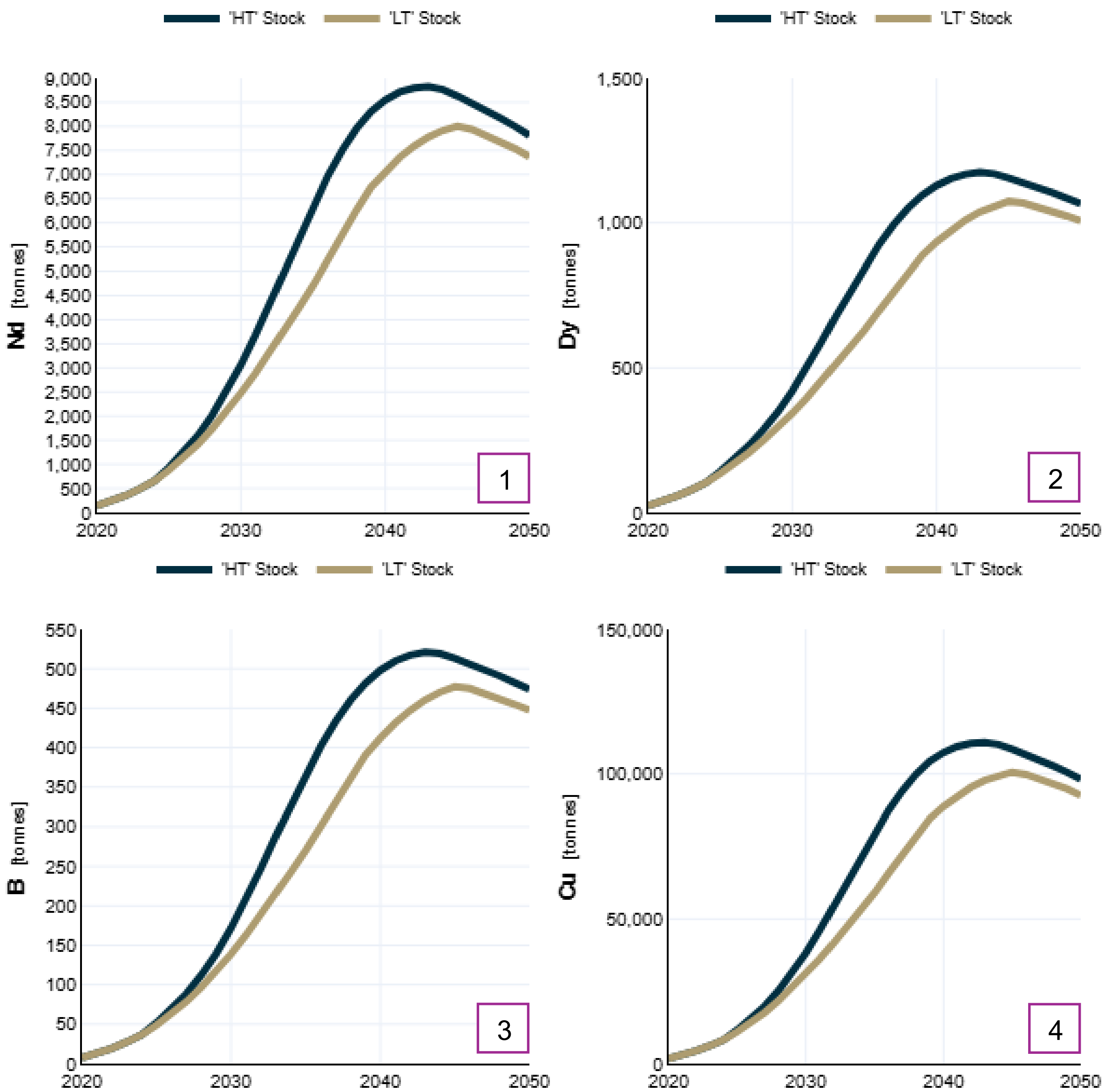


Figure 11 Stock evolution of (1) Nd; (2) Dy; (3) Cu; (4) B in traction motors between 2020 and 2050. The graphs estimate stocks under two different pathways: HT and LT. The unit is tonnes. BGS © UKRI 2026.

3.2.3 End-of-life availability of materials

The quantities of technology metals expected to become available from EoL traction motors will increase substantially towards 2050. As shown in Figure 12, EoL flows will remain relatively small in the early years of the transition, reflecting the still-limited retirement of first generation EVs, but will begin to rise sharply from the mid-2030s onward as larger volumes of vehicles reach the end of their operational lifetimes.

For example, estimated Nd from EoL traction motors will amount to just over 2 t in 2025 across both scenarios. By 2035, this will increase to 107 t (HT pathway) and 99 t (LT pathway). By 2050, Nd availability will diverge markedly between scenarios, rising to around 690 t (HT) compared with 594 t (LT). Similar upward trajectories will be observed for Dy, Cu and B, though Cu will exhibit EoL quantities an order of magnitude larger, due to its much higher mass content within traction motors.

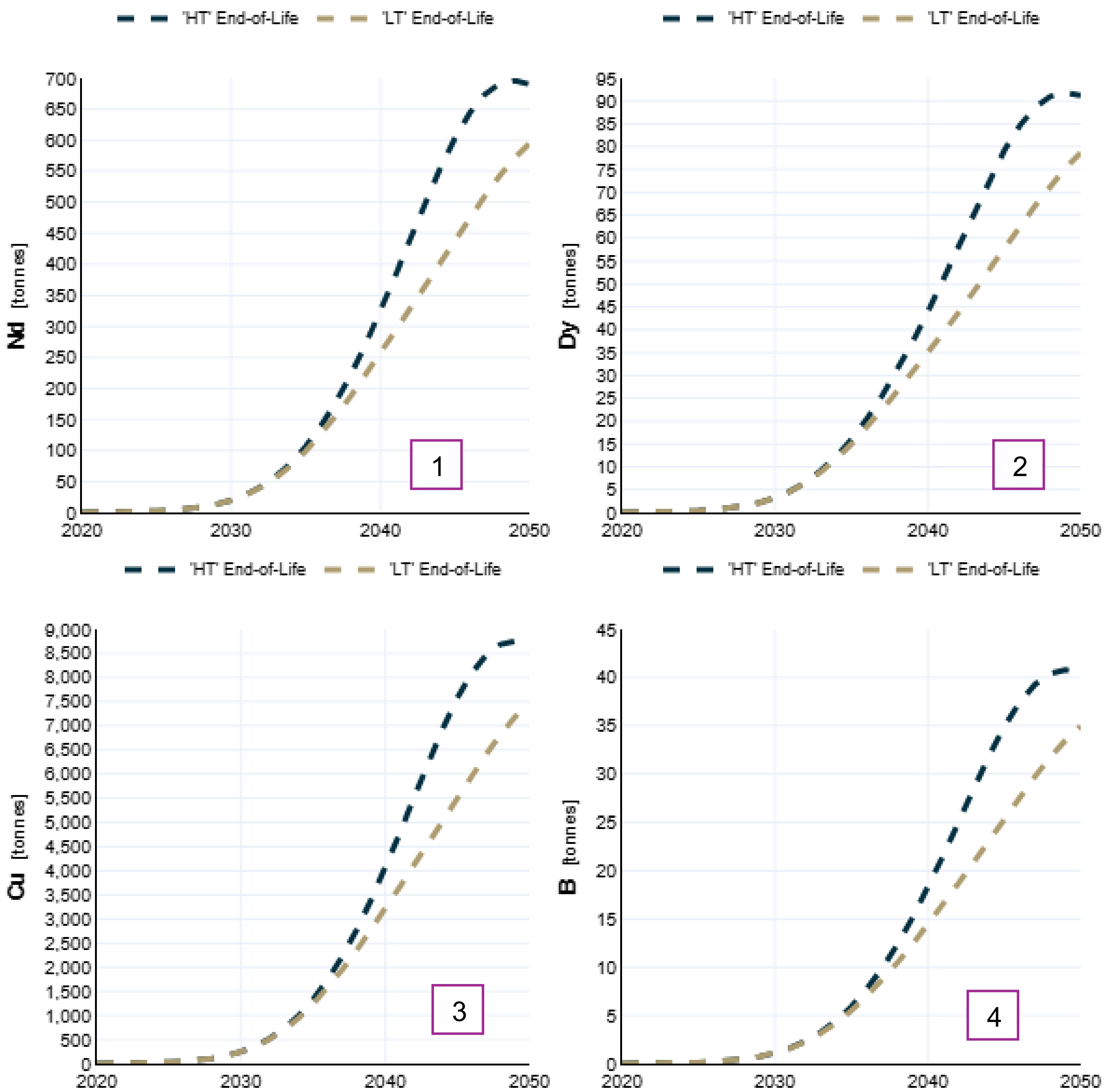


Figure 12 Annual EoL quantities of (1) Nd; (2) Dy; (3) Cu; (4) B in traction motors between 2020 and 2050. The graphs estimate EoL material flows under two different pathways: HT and LT. The unit is tonnes. BGS © UKRI 2026.

These trends highlight the strong influence that transition pathways have on future EoL material availability, driven primarily by differences in the rate of EV fleet growth. The HT pathway will produce significantly higher annual EoL flows, with peak EoL quantities beginning to plateau around 2050, reflecting the stabilisation of the mature EV fleet. In contrast, the LT pathway will continue to show rising EoL flows beyond 2050, consistent with its slower electrification rate.

It is also important to emphasise that these EoL projections relate only to EV passenger cars. Other vehicle categories are not included in this assessment; neither is any manufacturing waste from EVs nor traction motor manufacture in the UK. The total availability of technology metals from the entire UK EV fleet and manufacturing activity will therefore be expected to be significantly higher than the values shown here. Additional modelling across the full road transport sector and manufacturing will be needed to establish a complete national picture of future secondary material availability.

3.3 WIND TURBINES

3.3.1 Future consumption of materials

Future consumption of materials required for wind energy technologies is expected to rise rapidly, driven by the UK's ambitious targets to achieve net zero emissions by 2050. These include (Department for Energy Security and Net Zero, 2023, 2025):

- up to 50 GW of offshore wind capacity
- 27 to 29 GW of onshore wind across Great Britain
- up to 5 GW of new floating wind deployments by 2030

In addition, the Climate Change Committee estimates that as much as 125 GW of offshore wind may be required by 2050 to meet long-term decarbonisation goals (Committee on Climate Change, 2020).

To assess the implications for raw material consumption, projections for both offshore and onshore wind turbine generators were modelled using three key parameters:

- future market shares of wind turbine technologies (2020 to 2050): projected generator technology market shares are based on current industry trends and insights from past research, which indicate a steady shift towards permanent magnet synchronous generators (PMSGs) in both DD-PMSG and GB-PMSG configurations. The increasing adoption of these technologies reflects the need for larger, more powerful turbines with higher efficiency and reduced maintenance requirements, particularly in offshore environments
- UK wind energy deployment: wind deployment trajectories follow FES 2025, selecting the HT and LT pathways. In the HT pathway, rapid expansion of wind generation aligns with the UK's net zero ambitions, while the LT pathway reflects a slower pace of deployment where net zero is not achieved by 2050. For wind energy, these correspond to the 'Holistic transition' and 'Falling behind' scenarios
- material intensity of generator types: material intensities (kilogram per megawatt) were applied to each generator type, covering embedded quantities of REEs (Nd; Dy; Pr; Tb) used in permanent magnets, as well as Cu and B

Today, most offshore wind turbines and an increasing share of onshore turbines use NdFeB permanent magnets. This reliance is expected to continue as turbine size and rated capacity increase. The consumption projections shown in Figure 13 closely track the UK's deployment pathways.

Under the HT pathway, demand for all assessed materials will peak around 2030, coinciding with the rapid build out required to meet the UK targets. Under the LT pathway, the peak will shift later and will be lower in magnitude, reflecting slower capacity additions and delayed technology uptake. After the 2030 peak in the HT pathway, material demand will decline sharply as major build out targets are reached. Beyond 2040, demand will stabilise at lower but gradually increasing levels, reflecting ongoing generator replacement, repowering activity and steady-state expansion of wind capacity.

Nd consumption will peak at slightly above 2000 t around 2030 in the HT scenario and just over 1500 t in the LT pathway. Nd demand will then decline substantially as deployment slows, before stabilising at a lower level towards 2050. All materials will follow similar temporal patterns, but the scale of consumption will vary considerably:

- Dy will peak around 200 t per year (HT)
- B will peak at approximately 75 t per year (HT)
- Cu demand will reach around 45 000 t per year (HT)

Cu consumption will be significantly larger than for REEs because Cu is used extensively in wind generator coils, cabling and other electrical components, whereas REEs are concentrated specifically in permanent magnets.

This assessment accounts for a range of conventional offshore and onshore wind turbine technologies, each with different material intensity profiles. However, floating wind turbine technologies are excluded, as their design configurations and material intensity data fall outside the scope of the current analysis.

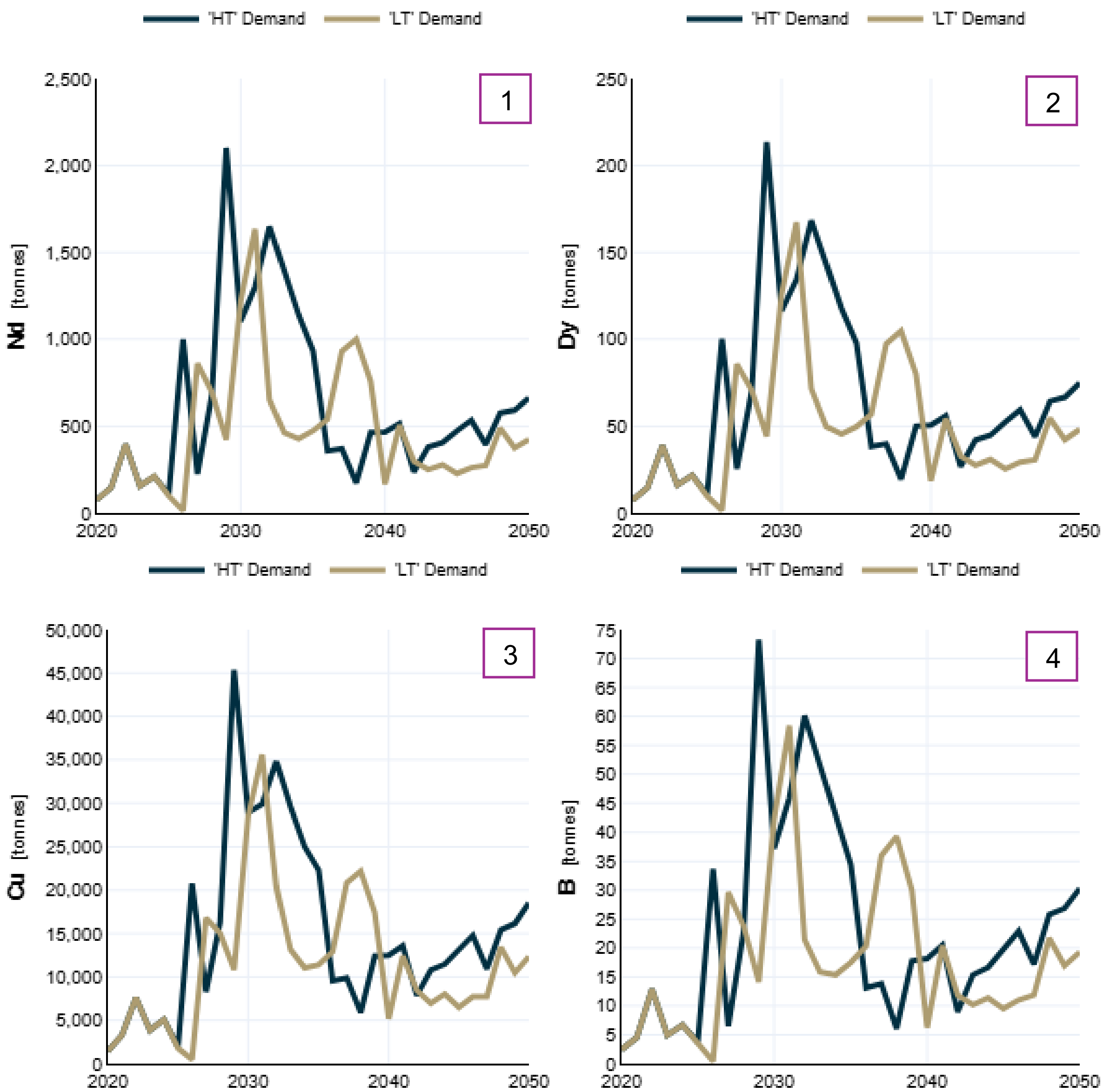


Figure 13 Annual UK demand of (1) Nd; (2) Dy; (3) Cu; (4) B in wind turbines between 2020 and 2050. The graphs estimate demand under two different pathways: HT and LT. The unit is tonnes. BGS © UKRI 2026.

3.3.2 Stock evolution

The rapid expansion of wind energy technologies will have a direct implication on the material stock build up in wind turbines in the UK. Figure 14 presents the stock development of selected materials including Nd, Dy, Cu and B embedded in wind turbines under the two different pathways (HT and LT). In both scenarios, there is a steep increase in the stock of materials up to 2035 (HT) and up to 2040 (LT). At this point, the stock continues to increase but at a slightly reduced rate.

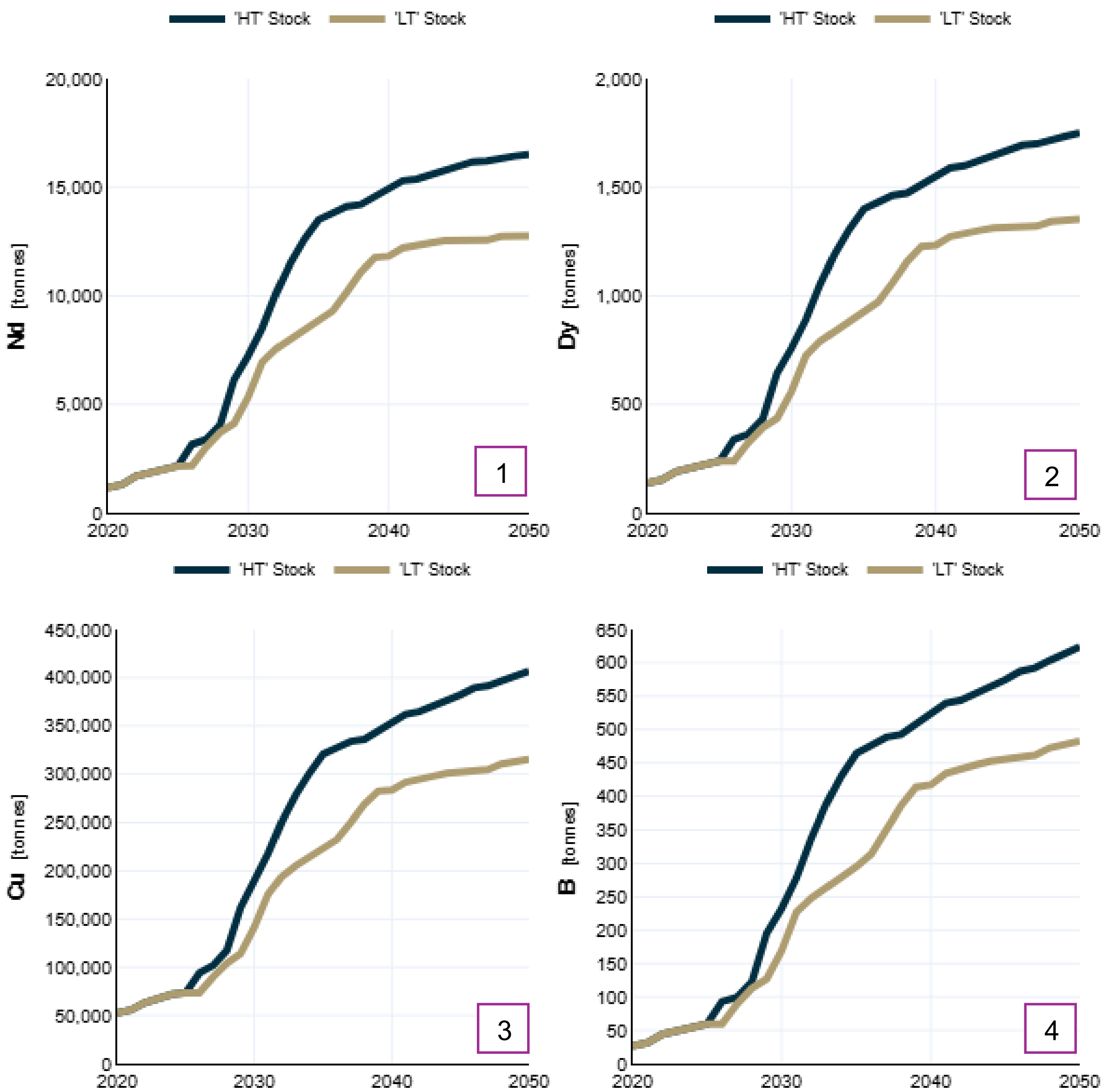


Figure 14 Stock evolution of (1) Nd; (2) Dy; (3) Cu; (4) B in wind turbines between 2020 and 2050. The graphs estimate stocks under two different pathways: HT and LT. The unit is tonnes. BGS © UKRI 2026.

For example:

- Nd stock increases from a little over 1000 t in 2020, to 13 500 t in 2035 and over 16 000 t by 2050.
- Cu stock increases from 52 000 t in 2020 to 321 000 t in 2035 and 401 000 t in 2050.
- Dy stock increases from slight over 100 t in 2020 to over 1700 t in 2050.
- B stock increases from 26 t in 2020 to 624 t in 2050.

Across all materials assessed, stock levels do not reach a peak within the study period (2020 to 2050), indicating that accumulation will continue beyond 2050. The step increase in stock of permanent magnet materials and Cu reflects both the rapid expansion of wind turbines and the widespread use of these materials across wind turbine designs.

The fast accumulation of material stocks provides strong evidence of the substantial potential for these resources to contribute to domestic supply once they reach EoL. However, realising this potential will require significant investment in infrastructure, skills and capacity to enable safe and efficient decommissioning as well as effective recovery and recycling of key components and metals.

3.3.3 End-of-life availability of materials

The availability of materials in EoL wind turbines will increase significantly in the future, reflecting the expansion of wind energy technologies in the UK. Figure 15 provides insight into the EoL flows for Nd, Dy, Cu and B.

Materials quantities will remain small up to 2040, due to the approximate mean lifetime of wind turbines of 25 years. Materials reaching EoL in 2050 will correspond to turbines installed around 2025. As turbine deployment increases significantly between 2030 and 2040, most of these assets are not expected to reach the EoL within the modelling window, which explains why EoL flows continue to increase without reaching a plateau (Figure 15).

Material specific assessments show:

- Nd: there will be negligible EoL availability in the 2020s, rising to around 50 t in the mid-2030s, 200 t by the mid-2040s and reaching approximately 600 t by 2050 (HT)
- Dy: EoL flows will remain in the tens of tonnes, increasing to 60 t by 2050 (HT)
- Cu: EoL flows will rise to 4200 t by 2040 and 13 000 t by 2050 (HT), reflecting the much larger mass of Cu embedded in wind generator systems relative to REEs

Scenario trajectories will be very similar up to 2040; HT and LT produce almost identical EoL values, diverging only slightly between 2040 and 2050.

The projected increases in EoL flows provide compelling evidence of the future potential for secondary materials from wind energy technologies, particularly for REEs and Cu. As more turbines reach EoL beyond 2050, flows are expected to grow substantially, creating opportunities for domestic recycling, recovery and circular economy strategies.

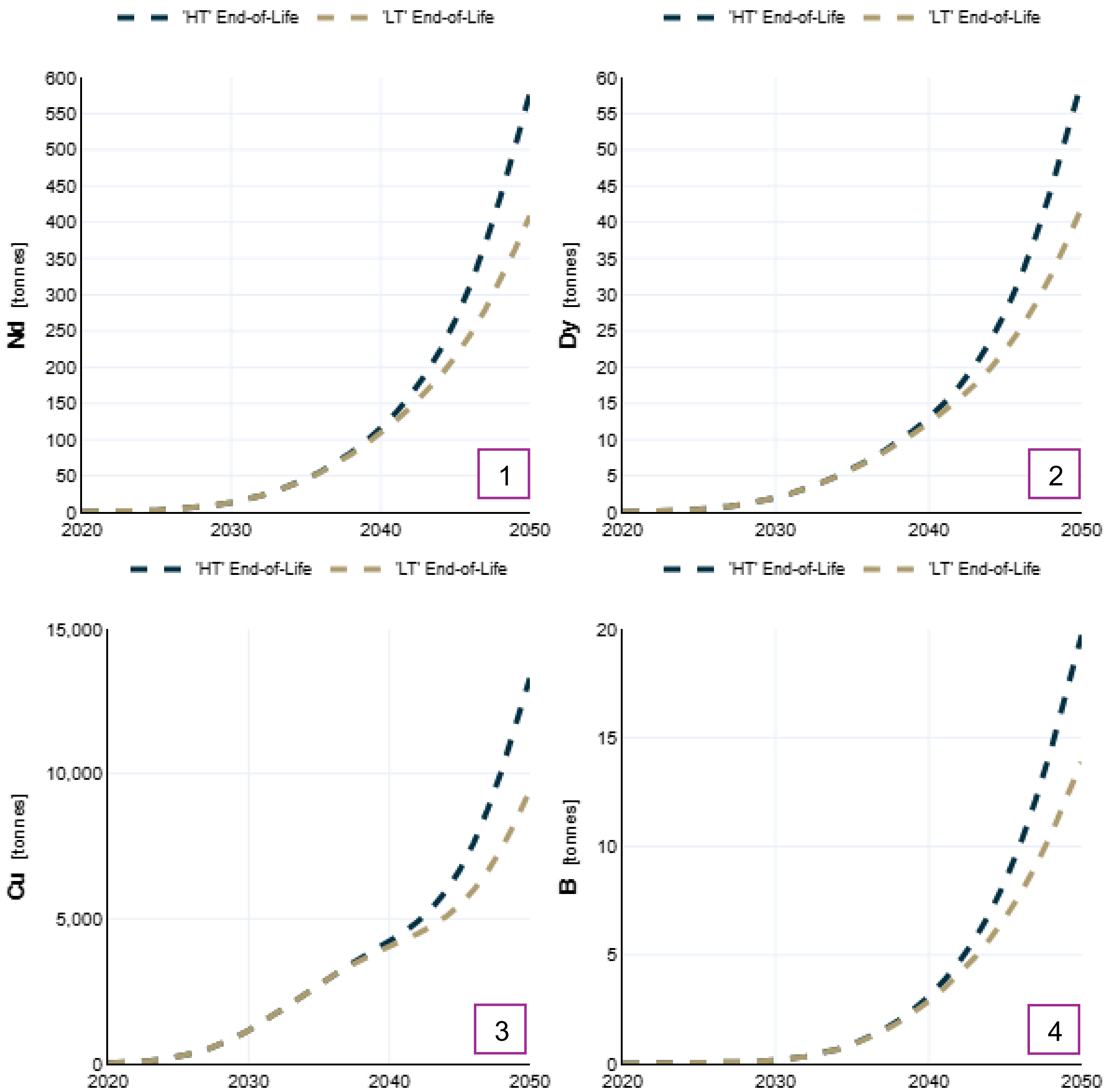


Figure 15 Annual EoL quantities of (1) Nd; (2) Dy; (3) Cu; (4) B in wind turbines between 2020 and 2050. The graphs estimate EoL material flows under two different pathways: HT and LT. The unit is tonnes. BGS © UKRI 2026.

3.4 PHOTOVOLTAICS

3.4.1 Future consumption of materials

The future demand for materials required for PVs has been modelled considering three parameters:

- PV technology evolution: a moderate roadmap for the evolution of PV technologies is considered in this study. In future decades, mature PV cell types and proven production processes are anticipated to maintain their market leadership. The adoption of next-generation PV technologies, such as III-V tandem cells on silicon substrates, appears unavoidable given their significant technological advantages, but is expected to occur in the distant future (2040 to 2050) (Gervais et al., 2021)
- UK PV installed capacity: PV deployment trajectories follow the FES 2025, selecting the HT and LT pathways

- material intensity: to estimate metal demand for each PV subtechnology, the study applied material intensity values (kilogram per megawatt) specific to each PV cell type

The assessment includes twelve key materials: Ag, As, Bi, Cd, Cu, Ga, In, Se, Si, Sn, Te and Zn. Further information on the material intensity data and the allocation of elements per technology are provided in Section 2.5.4 and Table 4.

The materials used in PV vary greatly depending on the type of subtechnology. None of the listed materials are used in all PV types; however, four distinct patterns have been identified, depending on the materials that dominate each cell architecture. These four patterns are represented by the materials shown in Figure 16. Graphs for the rest of the materials are available in Appendix 2.

Demand patterns for Si, Cu, Bi and Sn in PVs will be very similar, being characterised by steady demand over the study period. Based on the HT pathway, there will be two annual demand peaks for Si, one in 2028 and one in 2045, with peak magnitudes of 14 500 t and 15 700 t, respectively. Annual demand between these peaks will be relatively steady, although a small peak of 10 000 t is observed around 2037. Demand for Cu, Bi and Sn will follow similar timing (2028; 2045), but at lower volumes. For example, in 2028, annual demand for Cu will be 5000 t, 172 t for Bi and 218 t for Sn.

The LT scenario also shows two distinct demand peaks occurring in 2030 and 2047. Overall LT volumes are lower; for example, in 2030, Si demand will be about 9000 t and Cu demand 3400 t, with demand for Bi and Sn being very similar to demand in 2028 under the HT pathway. The reason the results are so similar for these materials is that Si, Cu, Bi and Sn are used in solar cell technologies with a significant market share (for example, PERC; SHJ; III-V/Si). They will also have a slightly decreasing material intensity during the study period (2020 to 2050) as technologies evolve.

Ag and Zn have very similar demand pathways. Under the HT scenario, Ag demand will peak at 114 t in 2028 and fall to 23 t by 2050. Zn demand will peak at 6 t in 2030, decreasing to just over 1 t by 2050. These declines will be driven by:

- Ag: gradual reduction in material intensity as manufactures shift to III-V/Si technologies
- Zn: near complete phase-out of CIGS technology by 2040

Demand for In will increase sharply, with similar patterns observed for Ga and As. Annual demand will be low in 2035 (2 t In) and will rise rapidly to 13 t by 2050. Ga and As behave similarly, but with higher mass flows (As will reach 270 t by 2050). These materials' trajectories reflect their concentration in III-V/Si cell technology, whose market share is projected to expand significantly between 2040 and 2050 (for example, PERC; SHJ).

Demand for Cd, Te and Se will decline sharply. Peak demand will occur in 2028 (HT) and 2030 (LT), with peak volumes of 17 t (Cd), 19 t (Te) and just under 10 t (Se). Demand will decrease to near zero by 2040, reflecting the rapid market decline of CdTe cell technology.

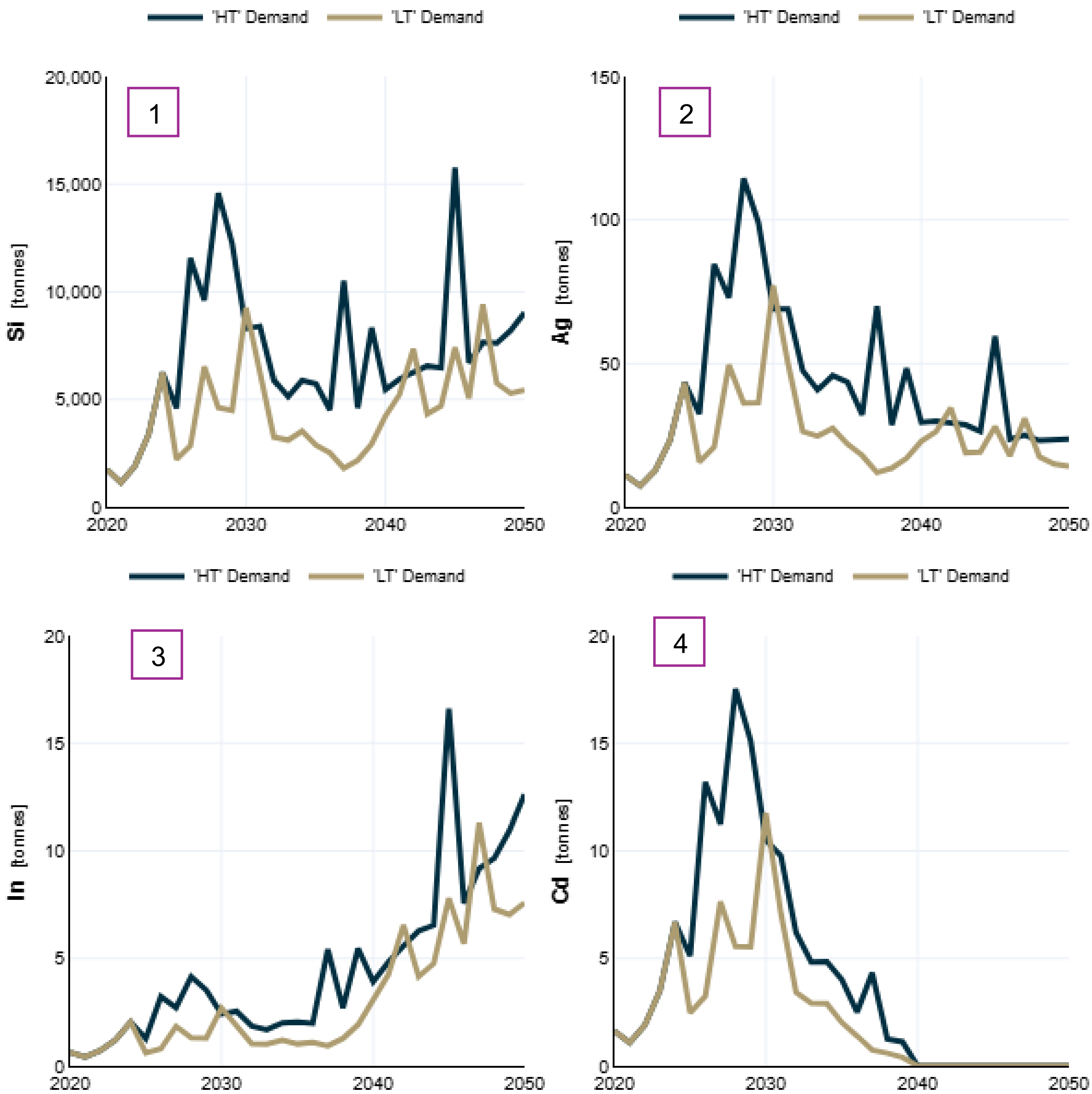


Figure 16 Annual UK demand of (1) Si; (2) Ag; (3) In; (4) Cd in PVs between 2020 and 2050. The graphs estimate demand under two different pathways: HT and LT. The unit is tonnes. BGS © UKRI 2026.

Key conclusions from the demand modelling assessment are:

- results reflect UK consumption demand linked to installed PV stock, not manufacturing demand
- analysis focuses on PERC, SHJ, CIGS/CdTe thin-films and III-V/Si tandems; actual UK demand will vary with real world market adoption
- peak demand will vary widely (2028 to 2048), driven by phase-down of CdTe/CIGS, entry of III-V/Si tandems (around mid-2030s) and declining material intensities (for example, Ag)
- Si is the most dominant material by mass, with annual demand exceeding that of all the other metals considered in this study. This indicates its critical role in PV material manufacture. Si, along with Cu, Bi, Sn and In, has seen a continuous growth in demand as it is used in emerging cell technologies

- Ag demand will remain substantial in the near term (for use in PERC and SHJ, for example) but will decline over time as intensity falls and market share shifts toward next-generation tandems
- Differences between HT and LT will be modest; even under slower transition, material requirements will remain high with similar trajectories, indicating structurally strong PV demand across plausible pathways

3.4.2 Stock evolution

The rapid expansion of PV technologies in the UK is leading to a substantial increase in the stocks of the materials embedded within PV cells. Figure 17 presents the projected stock evolution for Si, Ag, In and Cd from 2020 to 2050 under the HT and LT pathways. These materials were selected because each illustrates a distinct pattern observed across the assessed materials. The stock curves for the remaining materials are provided in.

Across both scenarios, there will be a consistent rise in material stocks through to around 2035, but the rate and shape of the increase will differ depending on the material. After 2035, trends will diverge, with the stock for some materials continuing to grow steadily (Si; In), others stabilising (Cu; Ag) and some declining (Se; Te).

For example, Si, which is widely used in technologies such as PERC and SHJ, shows a continuous increase in both scenarios (HT and LT), rising from 40 000 t in 2020 to between 126 000 t (LT) and 200 000 t (HT) by 2050. Materials with similar trajectories include Cu, Bi and Sn, which will all experience steady accumulation due to sustained deployment of silicon-based PV technologies and only modest declines in material intensity over time.

In contrast, Ag displays growth up to around 2040 before entering a period of stagnation, reflecting ongoing Ag thrifting and the gradual replacement of Ag-rich PV technologies. Stocks will increase from 254 t in 2020 to around 1200 t (HT) and 700 t (LT) by 2040, remaining relatively constant thereafter. A comparable pattern is seen with Zn, due to the declining market share of the CIGS technologies in which it is predominantly used.

A different pattern is seen for In, which, together with Ga and As, shows a sharp late-period increase as III-V/Si tandem cells gain market presence after 2040. For instance, In stocks will grow from 35 t (HT) and 26 t (LT) in 2030 to 136 t (HT) and 91 t (LT) by 2050. These materials will exhibit the strongest late-century growth as next-generation PV architectures become more prominent.

Finally, Cd, used mainly in CdTe technologies, exhibits a bell-shaped profile. Stocks will rise to a mid-2030 peak, reaching 151 t (HT) and 100 t (LT) around 2035 to 2040, before declining due to a falling market share for CdTe modules and the phase-out of this technology. Similar behaviour is observed for Te and Se, which are also components of the CdTe technology.

These patterns highlight the secondary supply potential for selected materials, particularly Ag, Sn and Si, where the build-up of in-use stocks is sufficient to create economically attractive opportunities for future recovery and recycling.

Finally, it is important to note that these stocks estimates refer only to materials embedded within PV cells. They do not include other components of PV systems, such as module frames, mounting structures or cables, which will contribute additional material stocks and future EoL flows.

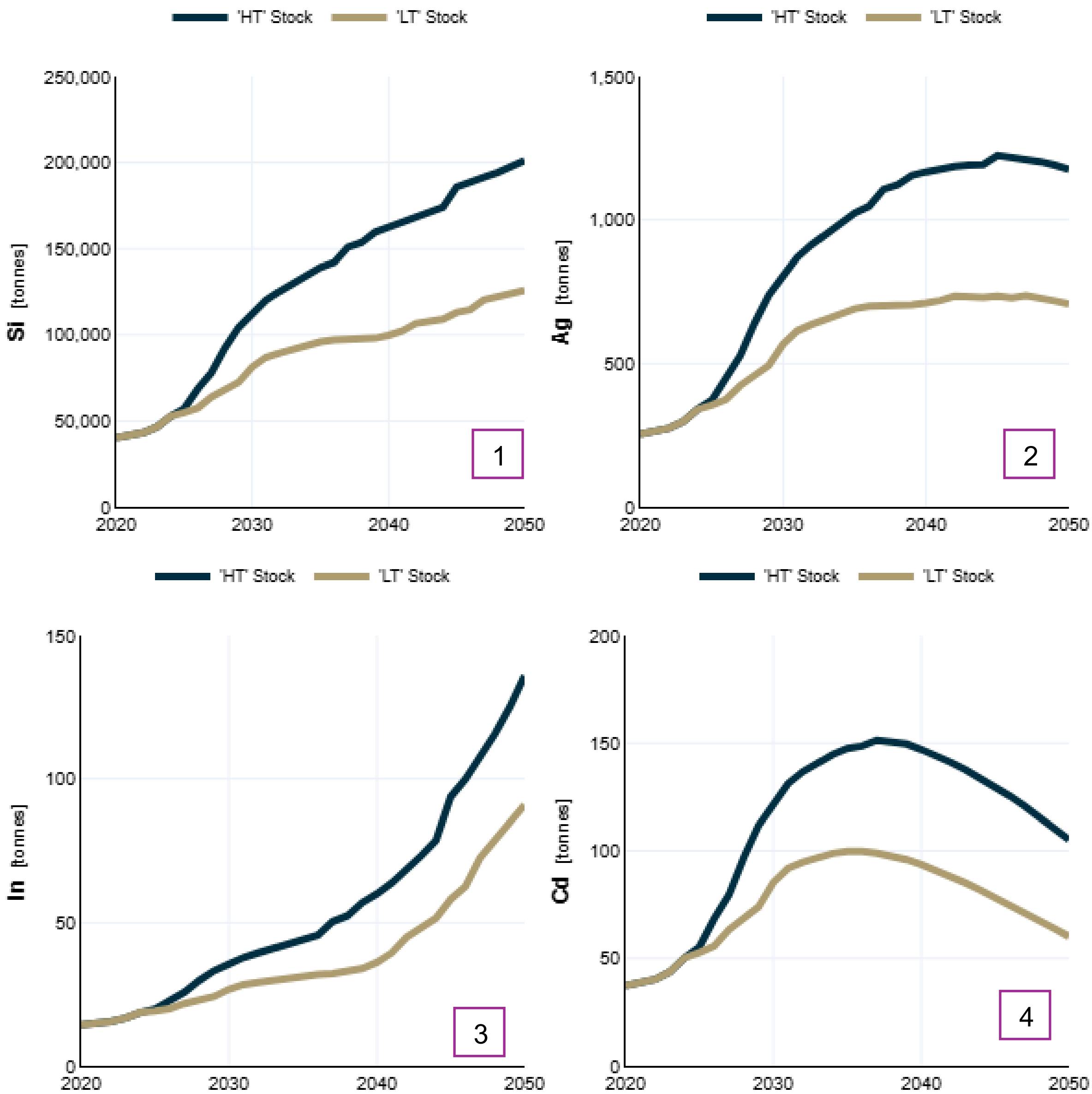


Figure 17 Stock evolution of (1) Si; (2) Ag; (3) In; (4) Cd in wind turbines between 2020 and 2050. The graphs estimate stocks under two different pathways: HT and LT. The unit is tonnes. BGS © UKRI 2026.

3.4.3 End-of-life availability of materials

The availability of materials from EoL PV systems is expected to increase over the coming decades, reflecting the continued expansion of PV deployment in the UK. Figure 18 presents indicative EoL flows for Si, Ag, In, As, Ga and Cd under the HT and LT pathways. As with wind energy, absolute EoL quantities remain small in the early years and rise more rapidly as earlier installation cohorts approach EoL. This timing is governed by year of installation effects and the average service life of PV modules, so EoL volumes observed around 2050 primarily relate to installations entering service from the mid-2020s onward.

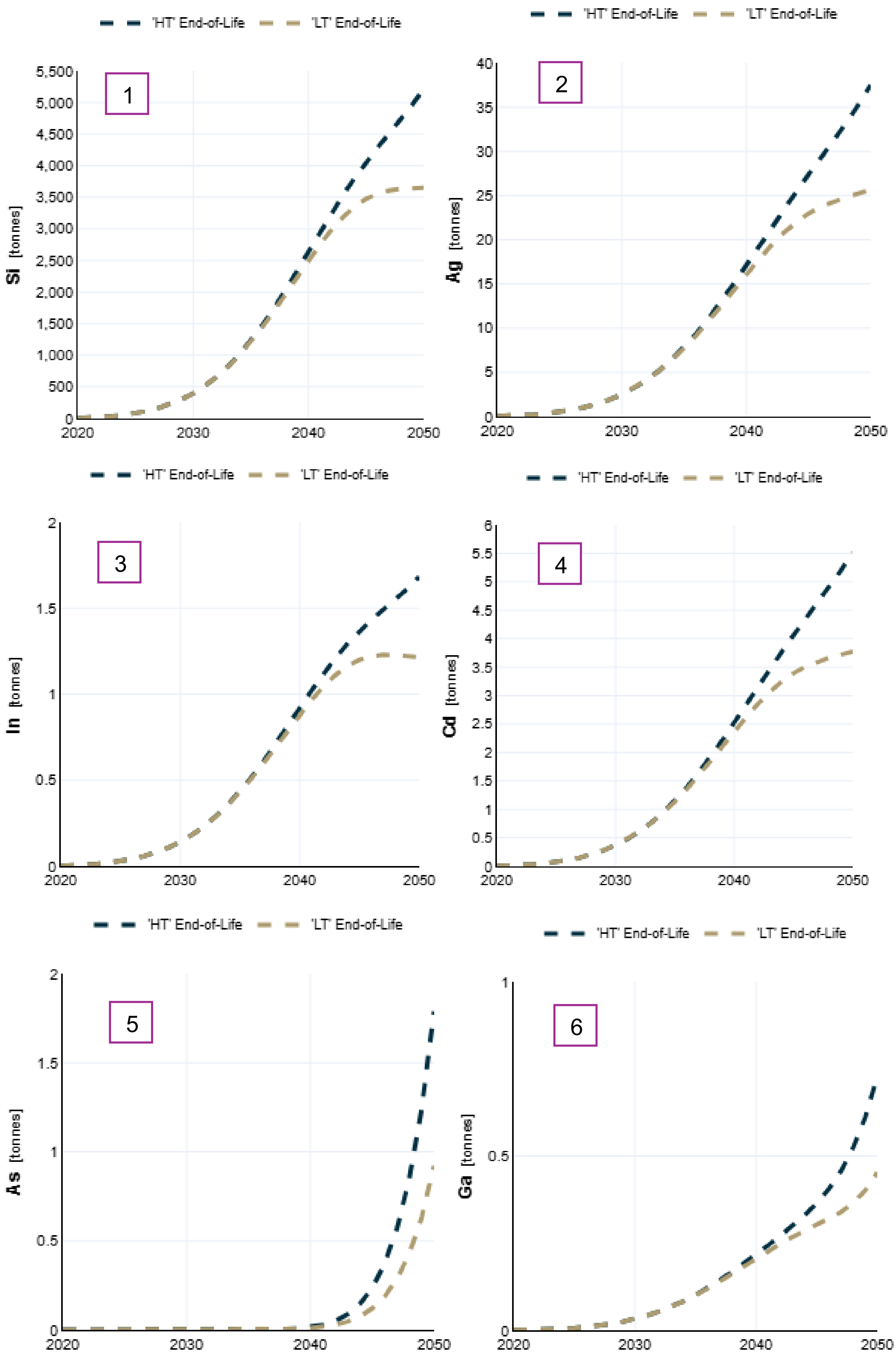


Figure 18 Annual EoL quantities of (1) Si; (2) Ag; (3) In; (4) Cd; (5) As; (6) Ga in PVs between 2020 and 2050. The graphs estimate EoL material flows under two different pathways: HT and LT. The unit is tonnes. BGS © UKRI 2026.

Looking at material-specific results, three distinct patterns emerge:

- Si, Ag, In, Cd (also Cu, Se, Sn, Te): a steady increase in EoL material availability is observed (HT). For these materials, EoL quantities will grow almost linearly from around 2030 in the HT scenario, while in LT they follow a similar trajectory until 2045 and then begin to stabilise due to the slower pace of deployment. These patterns reflect the significant early market shares of PERC, SHJ, CIGS and CdTe technologies. By 2050, annual EoL availability will reach (approximately):
    - Si:
        - HT: 5200 t
        - LT: 3600 t
    - Ag:
        - HT: 37.4 t
        - LT: 25.6 t
    - In:
        - HT: 1.7 t
        - LT: 2 t
    - Cd:
        - HT: 5.5 t
        - LT 3.7 t
- As (and Bi): EoL flows will be negligible through to 2040 and then rise steeply as the III-V/Si tandem PV installations begin to retire. As will increase from about 0.01 t in 2040 to about 1.7 t (HT) and 1.0 t (LT) by 2050
- Ga (and Zn): a moderate growth of EoL material availability is expected between 2030 and 2040, followed by faster increases toward 2050 as III-V/Si tandem cells gain share and offset the decline of CIGS. Ga will grow from about 0.03 t in 2030 to 0.72 t (HT) and 0.45 t (LT) in 2050

Across both scenarios, the trajectories will be broadly similar, with EoL quantities for most PV materials remaining modest until the 2040s. After 2040, they will begin to increase more quickly, with some divergence thereafter as higher deployment in HT translates into larger EoL streams by 2050. For several elements, particularly Ga, Zn and As, as well as Cd, Se and Te, absolute annual EoL volumes will remain small through 2050, either because the associated technologies enter the market late (III-V/Si) or because their market share is limited or declining (CdTe; CIGS).

The projected increase in EoL flows provides clear evidence of future secondary supply opportunities from the PV sector, especially for materials linked to mainstream Si-based technologies (such as Si, Ag, Cu and Sn). Realising this potential will require timely investment in:

- collection
- diagnostics
- safe handling
- disassembly and sorting
- metallurgical processing
- skills and capacity needed to recover materials efficiently and at high quality

Finally, the EoL estimates here refer only to materials embedded within PV cells and exclude other system components such as module frames, mounting structures, cabling and inverters, which constitute additional material stocks and future EoL flows.

4 Synthesis of results

4.1 FUTURE CONSUMPTION AND END-OF-LIFE FLOWS OF MATERIALS

4.1.1 Batteries in passenger cars

To evaluate the potential contribution of secondary supply from EV batteries, the modelling results compare UK material demand with EoL availability for key battery elements. As shown in Figure 19, the trajectories of demand and EoL flows follow a broadly similar long-term shape across the assessed materials, although with notable differences in timing and magnitude between the demand and EoL curves due to the lifetime profile of EV batteries.

For all the battery raw materials assessed, demand will increase rapidly from 2020 through to the early 2030s in both the HT and LT pathways, driven by the strong uptake of EVs and the continued dominance of LIB chemistries. Demand will peak earlier in the HT pathway, at around 2035, before stabilising, while demand will peak closer to 2040 in the LT scenario. After these peaks, demand will decrease moderately and then stabilise as the EV fleet reaches maturity and growth slows.

In contrast, EoL material availability will remain extremely low until approximately 2035, reflecting the average 10- to 15-year lifetime of EV batteries. As larger numbers of vehicles sold in the late 2020s and early 2030s begin to retire, EoL flows will increase sharply throughout the 2040s. EoL availability reaches a level close to the demand projections for all assessed elements by 2050, suggesting a substantial opportunity for secondary supply. The gap between demand and secondary supply availability will narrow significantly between the mid-2040s and 2050 regardless of the assessment scenario.

By 2050, secondary battery raw material availability will approach the scale of domestic demand under both scenarios (Figure 19 and Table 11).

This convergence indicates that, beyond 2050, EoL EV batteries could become an important source of domestic supply of battery raw materials, substantially reducing the UK’s reliance on primary imports.

The graphs also reveal a clear time lag between peak demand and meaningful EoL flows, which indicates that primary supply for battery raw materials will play a dominant role between now and the mid-2040s. Early planning is essential for this secondary supply potential to be realised, to ensure that collection systems, sufficient recycling capacity and processing infrastructure are in place before large volumes of batteries begin entering the waste stream.

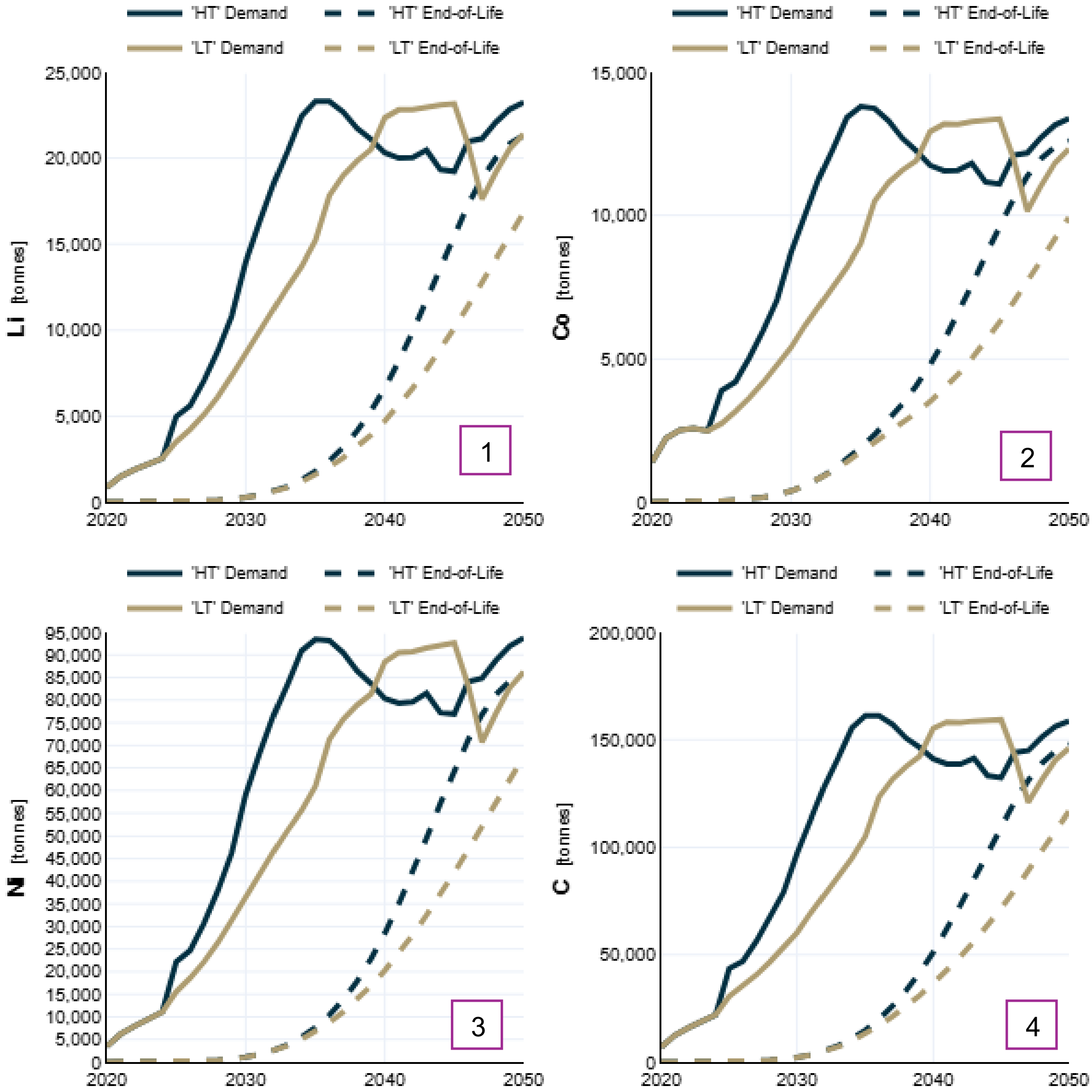


Figure 19 Annual demand and EoL quantities for (1) Li; (2) Co; (3) Ni; (4)C in EV batteries between 2020 and 2050 under the HT and LT pathways. The unit is tonnes. BGS © UKRI 2026.

Table 11 Projected demand and EoL material availability for the assessed battery raw materials in 2050. The unit is kilotonnes (kt).

Projection in 2050	Li	Co	Ni	C	Mn	Cu
Demand	23	13.5	94	159	36	142
EoL	21	13	86	148	31	130

4.1.2 Traction motors in passenger cars

Modelling of future UK demand and EoL material availability has been undertaken to assess the potential of secondary supply. For traction motor materials (Nd, Pr, Dy, Tb, B and Cu) demand trajectories are generally the same, with a steady increase in demand that peaks in 2035 (HT)

(Figure 20). The trajectory when following the LT shows a similar steady growth, although overall demand is lower and the peak is offset, occurring in 2039. This reflects the slower EV adoption rate outlined in the LT scenario. The decrease in demand after 2035 for both HT and LT pathways indicates a mature market and the adoption of new technologies (for example, hydrogen vehicles).

EoL trajectories are similar for all materials, with early years (2020 to 2030) showing only minimal availability of EoL materials (for example, almost 3 t of Dy in 2030), reflecting the limited retirement of early-generation EVs. As time progresses, the HT and LT trajectories diverge and the amount of EoL material increases (for example, about 44 t Dy in 2040), reflecting the different growth rates in the EV fleet.

By 2043, the HT EoL curve will meet the demand curve, indicating that annual demand by 2043 will be met by EoL material. For example, UK demand for Pr in traction motors will be about 23 t, which is the same as the EoL material available. It is worth noting that 2043 is almost ten years past the 2035 target published in the Critical Minerals Strategy (UK Government, 2025). EoL material availability is forecast to exceed demand under both the HT and LT pathways by 2050, meaning traction motor materials from EoL supply are likely to be in surplus. For example, it is estimated traction motor demand for Nd will be about 503 t in the year 2050, whereas EoL quantities are forecast to be 690 t, resulting in a surplus of 187 t. A similar level of surplus (168 t) is observed based on the LT pathway.

The results show that demand can be met by EoL material and additional material may potentially be available for other applications.

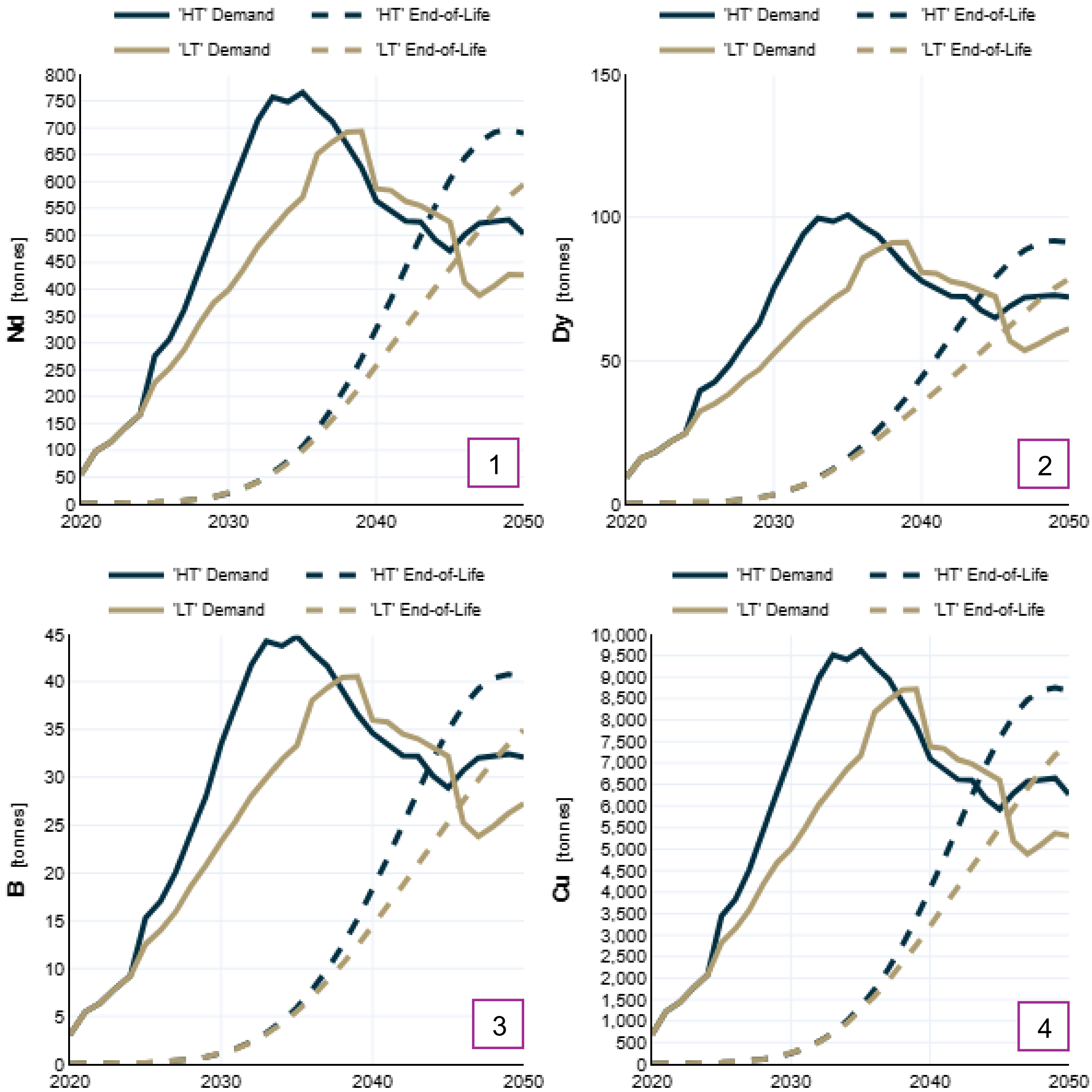


Figure 20 Annual demand and EoL quantities for (1) Nd; (2) Dy; (3) Cu; (4) B in traction motors between 2020 and 2050 under the HT and LT pathways. The unit is tonnes. BGS © UKRI 2026.

4.1.3 Wind turbines

To assess the potential contribution of secondary supply from wind turbines, the modelling results for UK demand and EoL material availability have been compared for each element. Across all materials, the demand and EoL curves follow broadly similar long-term trajectories. Figure 21 shows a rapid rise in demand up to around 2030, driven by the increased deployment of wind energy capacity. This is followed by a decline in demand as deployment slows and stabilises in the 2030s and 2040s.

In contrast, EoL availability will remain extremely low until the early 2040s, reflecting the typical 20 to 25-year operational lifetime of wind turbines. From the 2040s onward, however, EoL flows will increase steadily as the large cohorts of turbines installed in the 2020s and 2030s begin to reach retirement age. By 2050, the EoL availability of key materials will approach the level of annual demand. For example, UK demand for Nd from wind turbines in 2050 is estimated at

660 t, while EoL availability will reach about 578 t. Similarly, Dy demand is projected to be 74 t in 2050, with EoL availability of around 59 t. Cu and B follow the same pattern, with demand and EoL quantities converging closely by 2050. This convergence indicates that secondary supply from retired wind turbines could meet a large share of material demand beyond 2050, particularly for Nd, Dy, Pr and Tb (see Appendix 2 for graphs) and Cu.

The results also highlight a clear time lag between demand peaks and EoL flows, a direct consequence of the long service lifetime of wind turbines.

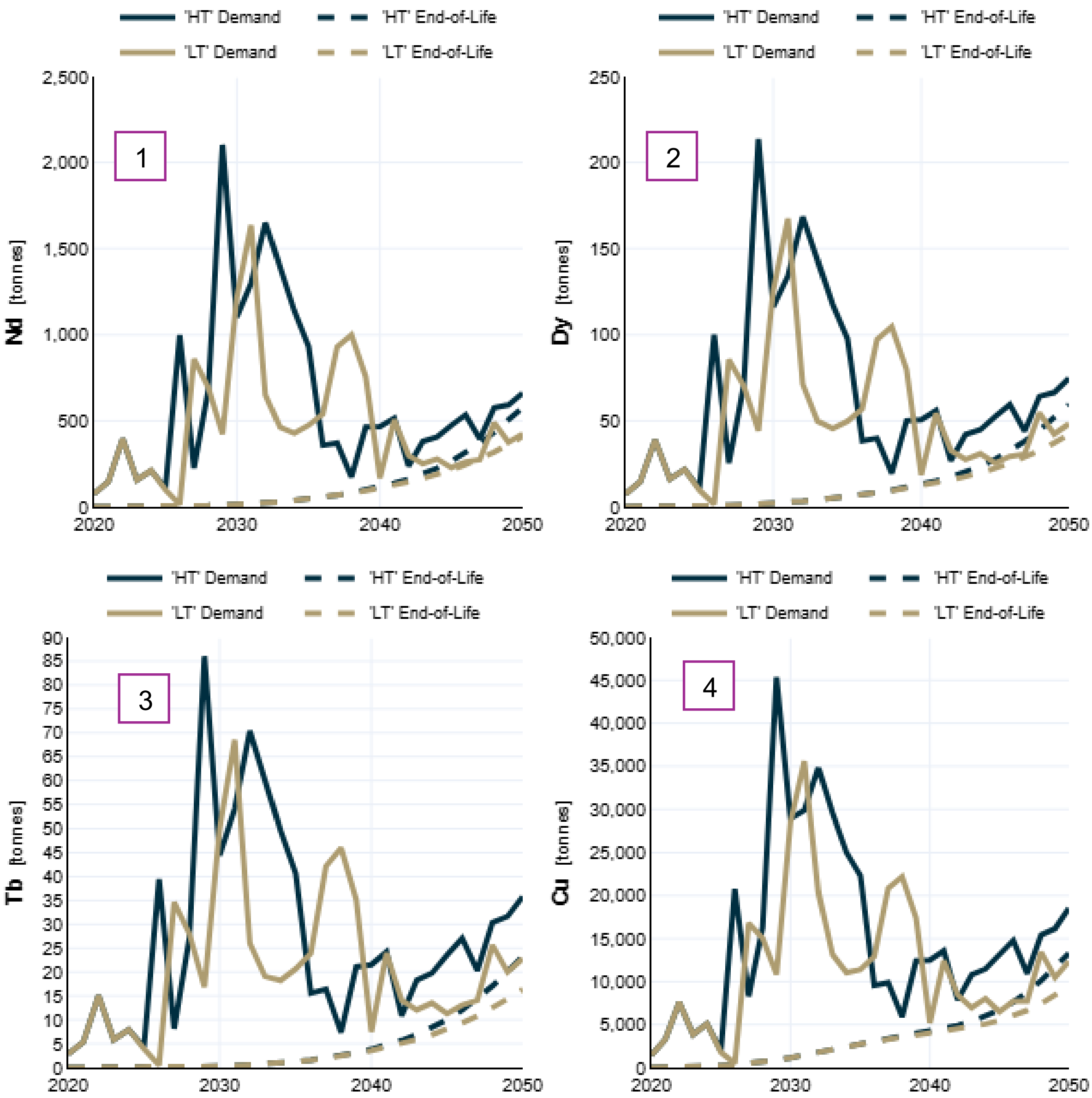


Figure 21 Annual demand and EoL quantities for (1) Nd; (2) Dy; (3) Tb; (4) Cu in wind turbines between 2020 and 2050 under the HT and LT pathways. The unit is tonnes. BGS © UKRI 2026.

4.1.4 Photovoltaics

The potential for secondary supply from PVs has been evaluated based on annual demand and EoL material availability for each element. This study considers 12 key elements used in PVs. Due to the greater number of elements compared to other technologies, the elements have been grouped according to common patterns in their demand and EoL material availability.

Figure 22 shows the annual demand and EoL material availability for Si, Ag, In and Cd. Each of these elements has a specific demand and EoL pattern that is shared by other PV elements.

The annual demand for Si will increase rapidly between 2020 and 2030 and then stabilise between 2030 and 2050, while EoL availability begins to grow rapidly from 2030 onwards, eventually converging with demand by 2050. However, EoL supply will not exceed annual demand under either HT or LT; even though EoL supply could potentially contribute to reducing primary demand for metals, the need for primary material will still be necessary. For example, in 2050 under the HT scenario, the annual demand for Si will be 9000 t while the EoL availability will be 5200 t. Similar patterns of demand and EoL availability are observed for Cu and Sn.

In the case of Ag, the EoL availability is forecast to be higher than annual demand by 2050. There will be a rapid increase in demand between 2020 and 2030, then a decrease towards 2050; meanwhile EoL availability will begin to grow rapidly from 2030 onwards. This means that annual demand could potentially be met in full by secondary metals from EoL. For example, in 2050 under the HT scenario, the annual demand for Ag will be 24 t while the EoL availability will be 37 t. A similar pattern of demand and EoL is observed for Zn, although demand and EoL volumes are smaller.

Patterns for the demand of In show that future annual demand will be greater than the volume of secondary material from EoL. In contrast to the PV materials discussed previously, there will be a rapid increase in demand for In between 2030 and 2050, whereas the potential for EoL supply remains very low. This is because these materials are found in PV technologies, whose market share will become significant from 2030 onwards (for example, tandem solar cells). Combined with the long lifetime of PVs, this means the recovery of these EoL materials will not make a significant contribution to annual demand during the study period (until 2050). For example, in 2050 under the HT scenario, the annual demand for In will be almost 13 t, whereas EoL availability is much smaller at 1.7 t. Similar patterns of demand and EoL supply are observed for Ga, As and Bi, although demand for As and Bi is much higher, in the region of 270 t and 133 t respectively.

Annual demand for Cd is forecast to rapidly increase between 2020 and 2030, followed by a sharp decrease to zero tonnes by 2040, whereas EoL material availability will steadily increase between 2030 and 2050. This pattern of demand and EoL supply is driven by PV technologies that are forecast to have zero market share by 2040, for example CIGS and CdTe. For example, in 2050, Cd demand will be zero tonnes, whereas EoL material availability will be 5.5 t. Both Te and Se have similar patterns of demand and EoL material availability. The quantities of the aforementioned materials available from EoL PV systems are only a few tonnes until 2050, indicating that the economic viability of recovering them is likely to be low.

Across all PV materials, the demand and EoL curves have broadly similar long-term trends. However, the peak demand for all assessed materials varies significantly from 2028 to 2048 Figure 22 and Appendix 2). This can be explained by the decommissioning of certain technologies, like CdTe and CIGS cells, and the introduction of next-generation, thin-film tandem (III-V/Si) solar cells onto the market by about 2035. Furthermore, the decrease in material intensity caused by either design improvements or material substitution for selected materials over time will also influence the demand and EoL trajectories. Material demands and EoL curves follow similar patterns even with slower roll-out of decarbonisation technologies (LT pathway).

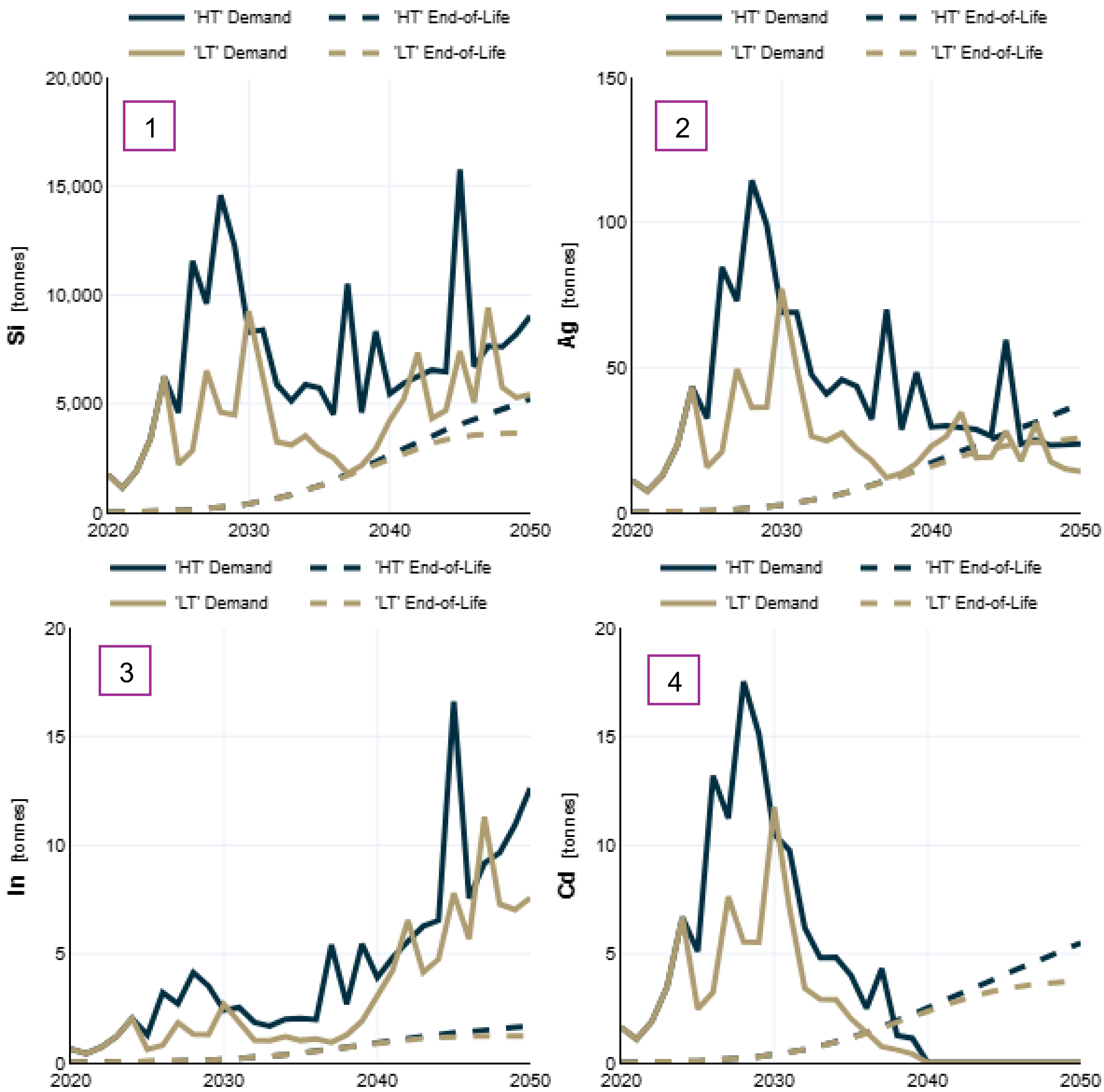


Figure 22 Annual demand and EoL quantities for (1) Si; (2) Ag; (3) In; (4) Cd in PVs between 2020 and 2050 under the HT and LT pathways. The unit is tonnes. BGS © UKRI 2026.

The EoL availability remains extremely low until the early 2040s, reflecting the typical 25- to 35-year operational lifetime of PV modules. However, beginning in the 2040s, EoL flows will steadily increase as significant numbers of PVs that were installed in the 2020s and 2030s start to be retired.

Based on the previous, the most significant materials (in terms of volume) that might be recovered from EoL PV technologies are Si, Ag, Cu and Sn, which reflects their importance in current PV technologies such as PERC and SHJ. The EoL volumes for other materials are generally smaller, which partly reflects their use in less common PV technologies, for example CdTe and CIGS.

4.2 CUMULATIVE DEMAND FOR SELECTED MATERIALS

4.2.1 REEs and copper

The bills of materials for traction motors and wind turbines are similar, with both containing appreciable amounts of REEs (Nd; Dy; Pr; Tb), B and Cu. UK demand for each of these materials has been plotted to show decadal cumulative demand across both applications (Figure 23). The percentage of that demand that can be met by EoL material per technology is also shown.

Under the HT pathway, B demand for wind turbines and tractions motors in 2020 to 2030 will be just under 400 t, with slightly more being required for wind turbines (about 210 t). Between 2030 and 2040, demand will increase to almost 800 t; however, during this decade it is traction motors that will demand the larger share at 440 t. Demand from 2040 to 2050 will decrease to under 600 t for both technologies, with the larger share (350 t) being allocated to traction motors. These patterns broadly mirror those observed in the annual demand data; that is, peak demand in 2035 will come from traction motors followed by a decrease in demand as the EV market matures. EoL material availability will rise from less than 1 per cent in 2020 to 2030 to over 80 per cent by 2040 to 2050, again mirroring the annual EoL supply modelling that shows increasing availability of material up to 2050 (Figure 23). Demand and EoL supply patterns for B in wind turbines and traction motors will be very similar under the LT pathway; however, the overall volumes will be smaller.

The cumulative demand patterns under the HT pathway for REEs will be similar to B, with lower demand in 2020 to 2030 and limited availability of EoL material:

- Dy: 1.5 per cent
- Nd: 1.1 per cent
- Pr: 1.1 per cent
- Tb: 0.8 per cent

During the decade 2030 to 2040, a significant increase in demand will be seen across both technologies, with equal demand shares between traction motors and wind turbines for Dy (1967 t), but with traction motors driving demand for Pr (2306 t). The demand share for Nd (9355 t) and Tb (402 t) will be greater for wind turbines. By 2040 to 2050, overall demand for all REEs will decrease; however, the greatest demand share for Nd, Pr and Dy will come from traction motors. Demand for Tb during this period will be equally split between traction motors and wind turbines.

EoL material availability will increase decade on decade, with 2030 to 2040 figures being in the range of 10.7 per cent (Tb) to 14.4 per cent (Dy), and 2040 to 2050 figures being higher, in the range of 75 per cent (Tb) to 84.7per cent (Dy). Traction motors will be the dominant source of EoL material for all REEs, highlighting the importance of EVs as a future source of secondary REEs (Figure 23). Demand and EoL supply patterns for all REEs in wind turbines and traction motors will be very similar under the LT pathway; however, the overall volumes will be smaller.

Future cumulative Cu demand has been plotted on a decadal basis for traction motors, PVs, batteries and wind turbines. For all decades, the demand and EoL material supply will be dominated by batteries, with only small contributions from other applications. A similar pattern of EoL availability is observed for Cu as for B and the REEs, with EoL availability being limited in 2020 to 2030 (1.6 per cent), rising to just over 12 per cent in 2030 to 2040 and then to almost 72 per cent in 2040 to 2050. In the decade 2040 to 2050, almost 84 per cent of the available EoL material will come from batteries (Figure 23).

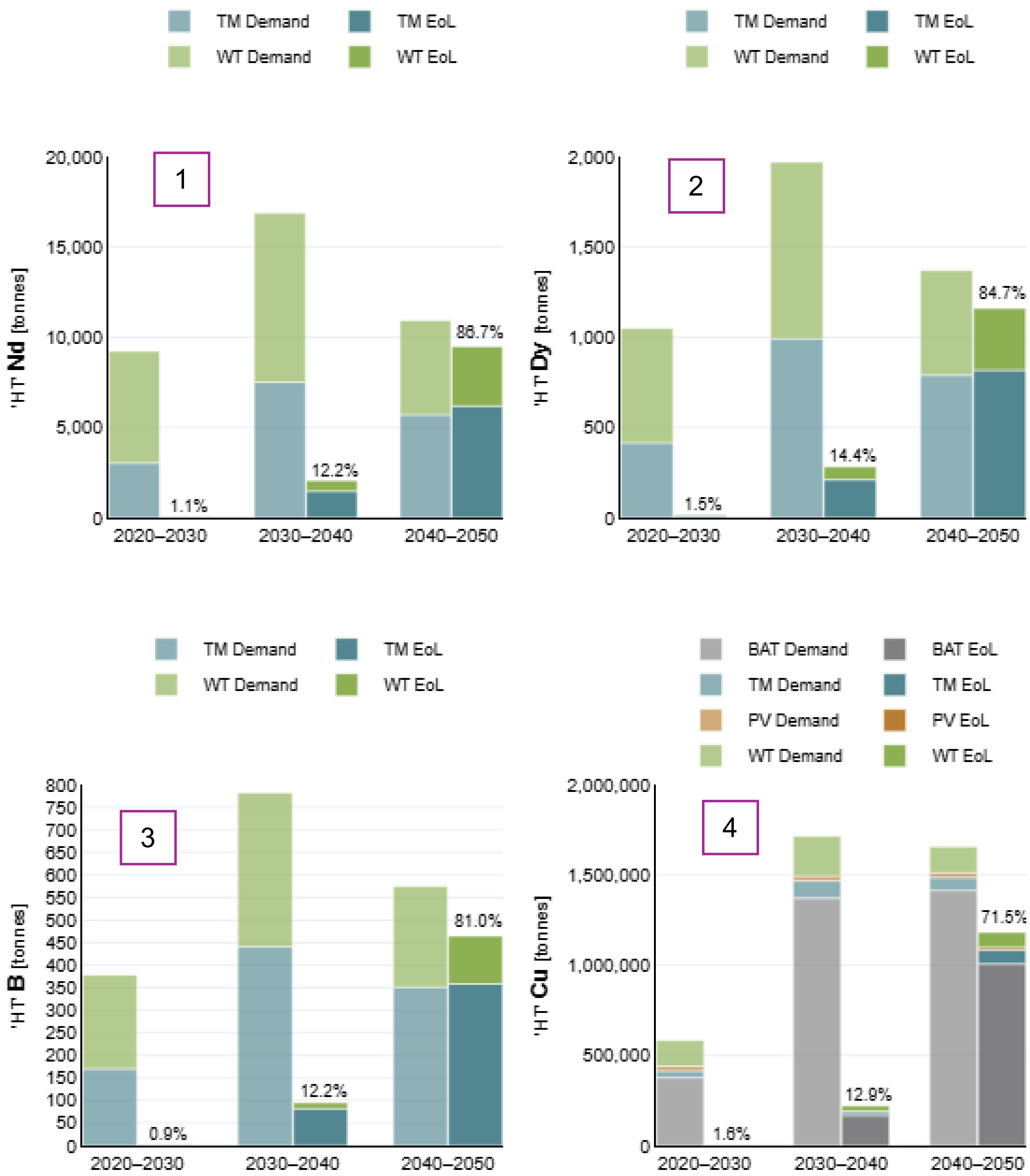


Figure 23 Cumulative demand and EoL quantities for (1) Nd; (2) Dy; (3) B in wind turbines and traction motors, and (4) Cu in all technologies (wind turbines; traction motors; PVs; batteries) for the decades 2020 to 2030, 2030 to 2040 and 2040 to 2050 under the HT pathway. The unit is tonnes. BGS © UKRI 2026.

4.2.2 Lithium and cobalt

Under the HT pathway, cumulative demand for Li in EV batteries in 2020 to 2030 will be about 60 000 t; however, only 710 t (1.2 per cent) of demand could be potentially met by EoL supply. There will be an almost four-fold increase in cumulative demand in the decade 2030 to 2040 to almost 225 000 t; demand increases further in 2040 to 2050 to almost 230 000 t. End-of-life supply will also increase decade on decade, with EoL supply potentially meeting 71.4 per cent of demand in the decade 2040 to 2050. However, it should be noted that the EoL supply figure in 2030 to 2040 is only 12 per cent. A similar pattern of demand and EoL supply is observed under the LT pathway; however, demand will be higher in 2040 to 2050 (almost 237 000 t) but EoL supply will be lower (48.3 per cent) (Figure 24). This observed offset under the LT pathway is a function of delayed EV adoption and vehicle retirement.

Cumulative demand for Co in EV batteries in 2020 to 2030 will be almost 50 000 t; however, only 1084 t (2.3 per cent) of demand could be potentially met by EoL supply. Demand will increase to just over 133 000 t in 2030 to 2040, then there will be a very slight decrease in 2040 to 2050 (about 132 500 t). The potential supply from EoL material increases from 2.3 per cent in 2020 to 2030 to almost 18 per cent in 2030 to 2040, rising to a maximum 76.8 per cent in the decade 2040 to 2050. Similar to Li, the demand for Co in EV batteries under the LT pathway will reach its maximum in the decade 2040 to 2050 and will have a lower EoL supply potential (52 per cent), which is again driven by delayed EV adoption and retirement (Figure 19).

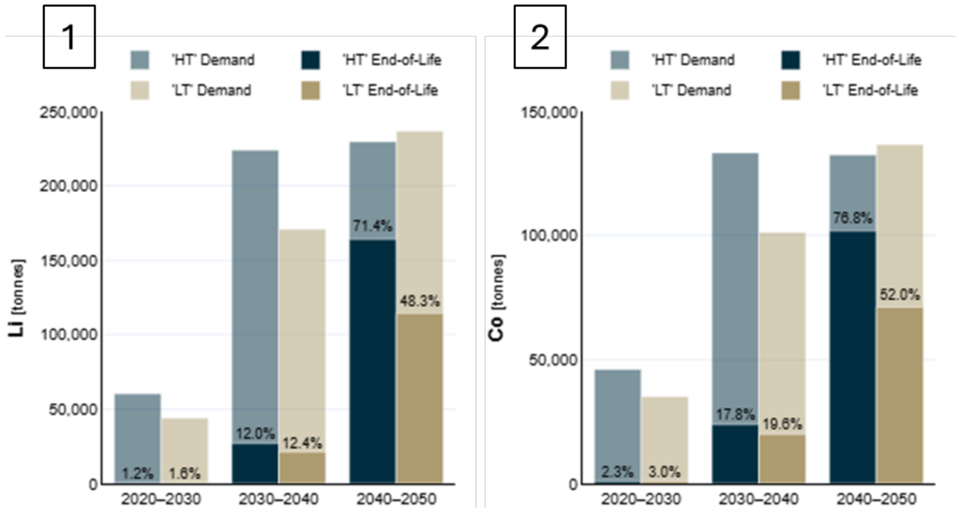


Figure 24 Cumulative demand and EoL quantities under the HT and LT pathways for (1) Li and (2) Co in EV batteries for the decades 2020 to 2030, 2030 to 2040 and 2040 to 2050. The unit is tonnes. BGS © UKRI 2026.

4.2.3 Silver, tin and silicon

Under the HT pathway, cumulative demand for Ag in PVs in 2020 to 2030 will be almost 570 t, with EoL supply potentially meeting 1.6 per cent (9 t) of that demand. Demand will decrease decade on decade, with the sharpest decrease being observed in 2040 to 2050, where demand drops to about 322 t; however, potential EoL supply in the same decade will be just over 93 per cent.

Cumulative demand for Si in PVs will increase decade on decade, to a maximum of nearly 86 000 t in 2040 to 2050. End-of-life supply figures will also increase decade on decade; however, at no point in the future does EoL supply fully meet demand. For example, in 2040 to 2050, demand is about 86 000 t, but EoL supply will only be 51.3 per cent, which equates to almost 44 000 t.

Cumulative demand for Sn shows a general decrease towards 2040 to 2050, where demand is about 990 t, compared to almost 1200 t in 2020 to 2030. However, EoL supply will increase over the same period from only 2.3 per cent (25 t) in 2020 to 2030 to 74.6 per cent (almost 738 t) in 2040 to 2050.

Demand for In will increase decade on decade from only 22 t in 2020 to 2030 to about 94 t in 2040 to 2050. Interestingly, in terms of EoL supply, the increase will be relatively small decade on decade, with about 2 per cent of demand being met by EoL material in 2020 to 2030 and only 15.7 per cent of demand being met in 2040 to 2050 (Figure 25).

With the exception of Sn, key PV materials (such as Si, Ag and In) show a similar pattern of demand and EoL supply potential under the LT pathway, with a general increase in demand

and a general increase in EoL material availability. Sn is unusual in that, under the LT pathway, demand shows a general increase rather than the decrease observed under the HT scenario. There are also several elements, for example Te, Se and Cd, where the demand trend is quite different; for these materials, an increase in demand is observed in 2030 to 2040, followed by a very sharp decrease to zero demand in 2040 to 2050. Another interesting point about Te, Se and Cd is that bewteen 2030 and 2040, the EoL supply potential will be greater than 20 per cent (the 2035 target). However, the volumes available are very small — in the tens of tonnes region. Therefore, it is unlikely that it will be economically attractive to recover such small volumes from technologically challenging material.

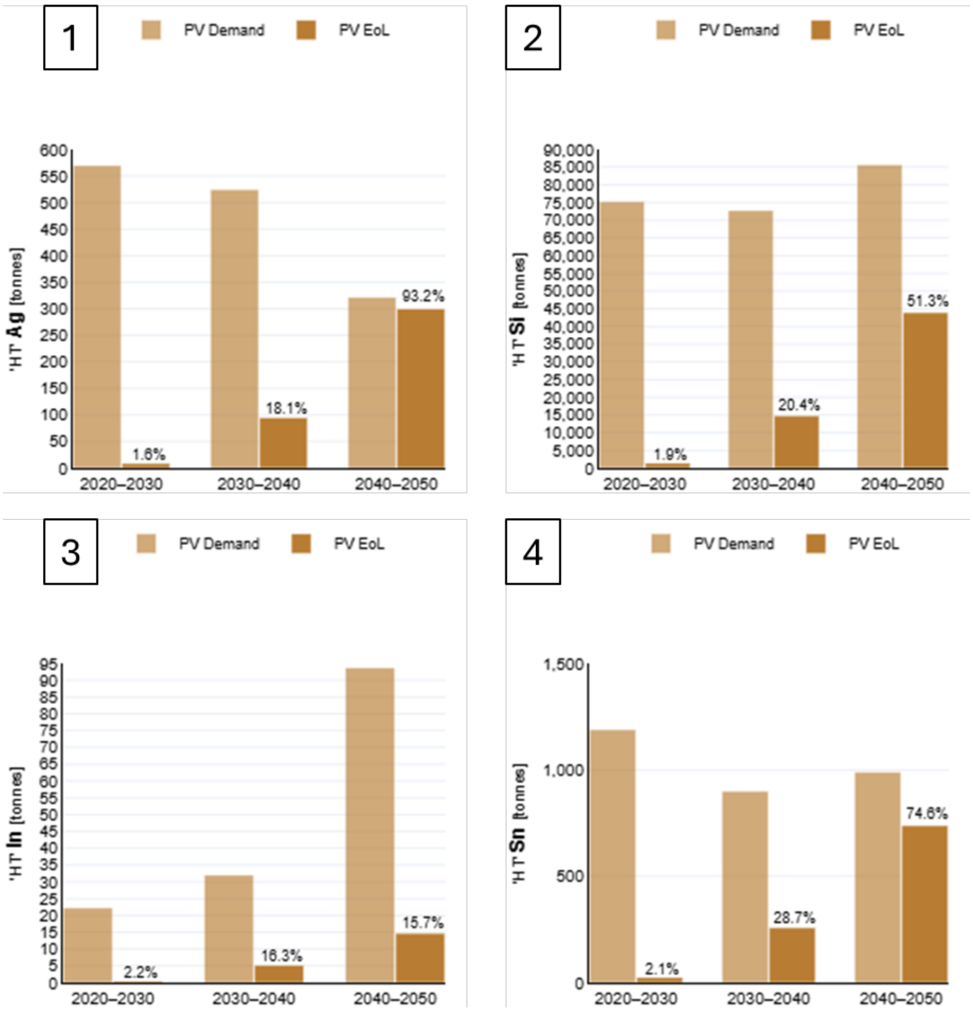


Figure 25 Cumulative demand and EoL quantities for (1) Ag; (2) Si; (3) In; (4) Sn in PVs for the decades 2020 to 2030, 2030 to 2040 and 2040 to 2050 under the HT pathway. The unit is tonnes. BGS © UKRI 2026.

5 Discussion and conclusions

5.1 IDENTIFIED OPPORTUNITIES FOR SECONDARY SUPPLY IN THE UK

Material demand will rise quickly across all technologies, with 2030 to 2040 marking the steepest increase as decarbonisation projects scale up. After major build-out targets are met, demand will ease but remain elevated through the 2040s, reflecting a transition from expansion to maintenance and replacement cycles.

In-use stocks will increase rapidly for most assessed materials after 2030 but variations in deployment pace will lead to asynchronous stock build-up. EV batteries, traction motors and wind turbines will accumulate faster than PVs, which will show a more gradual trajectory due to differing rollout profiles and lifetimes.

EoL flows for many materials will rise sharply from the 2040s, reflecting product lifetimes and earlier deployment waves. Material intensity, product lifetime and technology shifts will vary by sector, directly influencing EoL quantities. A whole-system view is needed to develop a complete picture of secondary supply across multiple sectors and to understand the full potential of the UK's anthropogenic stock.

Material-specific highlights include:

- cumulative demand (2030 to 2040) for Cu and C will be in the range of millions of tonnes (Mt); for example, 1.7 Mt Cu across all assessed technologies and 1.5 Mt C for batteries
- for battery raw materials other than C, the cumulative demand (2030 to 2040) will be in the range of hundreds of thousands of tonnes, for example:
    - Ni: 900 kt
    - Co:130 kt
    - Li: 220 kt
    - Mn: 320:kt
- cumulative demand (2030 to 2040) for permanent magnet REEs required by traction motors and wind turbines is expected to be around 25 kt
- cumulative demand for key PV elements will happen during the 2020 to 2030 decade and is estimated at:
    - Si: 75 kt
    - Sn: 1000 t
    - Ag: 570 t
- demand for minor elements (for example Zn, Cd, Te and Se) used in existing PV technologies in period 2030 to 2040 will range from 25 to 100 t
- cumulative demand for materials used in emerging technologies is anticipated after 2040
- demand for metals such as In, Ga, Bi and As in tandem solar cells ranges from 95 to 2000 t

Convergence of EoL availability and demand by 2050:

- secondary availability of battery materials will approach domestic demand by 2050
- EoL permanent magnet REEs from traction motors and wind turbines will approach UK demand by 2050
    - for traction motors, EoL availability will meet UK demand by the mid-2040s
- in PVs, secondary supply potential will be high for Ag and will closely track UK demand between 2040 and 2050; for most other PV materials, EoL availability will remain below the demand trajectory

5.2 ALIGNMENT WITH UK POLICY OBJECTIVES

The UK's aspiration to derive 20 per cent of its total annual critical mineral demand through recycling and recovery from EoL products by 2035 is stated in the recently published Critical Minerals Strategy (UK Government, 2025) . To estimate the potential to meet this ambition, we have compared modelled EoL material availability with UK demand for our priority technologies and elements over two windows: 2030 to 2040 (as a proxy for 2035) and 2040 to 2050 (Table 12).

It is unclear whether the 20 per cent in UK Government (2025) refers to each material individually or an aggregate across all critical minerals, and whether it is measured by mass, value, or criticality weighting. This ambiguity affects how progress should be reported.

At first glance, the 20 per cent by 2035 aspiration looks potentially achievable for some PV elements (for example, Si, Sn, Cd, Se and Te). However, the quantities of material that are likely to be available by 2035 for most of them, except for Si and potentially Sn, are very low, hence commercial viability is questionable. For most battery metals, REEs and Cu appear below target in the mid-2030s due to the lack of sufficient stock at that time and long product lifetimes. Secondary supply will become a major source for many materials from the 2040s onward, with the potential to substantially offset primary materials, especially for Ag, Cu, REEs and battery materials (Table 12).

Table 12 reports EoL availability relative to demand, not guaranteed recovered output. In reality, the quantity of materials that can be recovered will be considerably lower than the EoL availability percentages shown in Table 12. As a result, it is unlikely that any of the assessed materials will meet the UK's 20 per cent recycling ambition by 2035. This gap reflects the fact that EoL availability represents a theoretical maximum, whereas actual recovered output depends on multiple limiting factors, including collection rates, dismantling feasibility, process yields, contamination, component design, UK processing capacity and economic viability. In addition, the lack of investment, policy interventions, market incentives, enabling technology and infrastructure limit the availability of secondary raw materials for manufacturing and production.

For example, stakeholder engagement has highlighted that the recovery potential for many technology metals used in PV systems is currently very limited due to:

- technological barriers: for example, materials embedded in complex architectures and thin-film concentrations below recovery thresholds
- legislative and health and safety barriers: for example, thin-film PV panels are hazardous materials
- poor economic viability at present installation volumes

Similar constraints are likely to affect magnets, motors and batteries. In addition, material intensities, lifetimes and technology shares evolve (for example, battery chemistries; motor types; turbine technologies), which may shift both demand and EoL material flows.

While the modelling suggests that theoretical EoL availability for many materials could approach or even exceed domestic demand by the middle of the century, the actual recovered output will depend heavily on the effectiveness of the UK's circular economy policies. At present, Wales, Northern Ireland and Scotland have published their circular economy strategies (Department for the Economy, 2022; Director-General Net Zero, 2026; Miller Research (UK) Ltd., 2020), while England is expected to release their strategy and roadmap in 2026 (European Recycling Platform, 2026).

These policy frameworks will shape the regulatory, economic and logistical conditions under which secondary technology-metal supply can develop. Emerging circular economy strategies are likely to be highly influential in the future of secondary technology-metal supply in the UK, but remain highly dependent on:

- the specific instruments adopted
- the degree of UK-wide policy alignment
- whether governments choose to prioritise recovery of critical minerals alongside wider circular economy objectives such as waste reduction, re-use and repair

Table 12 End-of-life material contribution relative to UK cumulative demand (%) and alignment with the 20 per cent recycling ambition outlined in the Critical Minerals Strategy (UK Government, 2025). *Proxy to the 2035 Critical Mineral Strategy ambition: green: likely sufficient to meet the 20 per cent ambition by around 2035; light green: close to 20 per cent by around 2035; white: insufficient by around 2035; pink: far below 20 per cent by around 2035.

Technology	Element	EoL contribution potential as a percentage of UK demand (%)	
		2030–2040*	2040–2050
PV	Ag	18.1	93.2
	As	0.0	0.3
	Bi	0.4	10.3
	Cd	28.3	-
	Ga	1.7	1.3
	In	16.3	15.7
	Se	39.5	-
	Si	20.4	51.3
	Sn	28.7	74.6
	Te	26.3	-
	Zn	5.8	61.8
LIB	Li	12.0	71.4
	Co	17.8	76.8
	Ni	12.8	73.6
	Mn	10.7	62.4
	C	13.9	73.5
Traction motors and wind turbines	Nd	12.2	86.7
	Pr	13.3	90.7
	Dy	14.4	84.7
	Tb	10.7	75.0
	B	12.2	81.0
All technologies	Cu	12.9	71.5

5.3 THE ROLE OF PRIMARY SUPPLY TO MEET DEMAND DURING THE ENERGY TRANSITION

Even with substantial long-term potential from secondary (EoL) supply, primary production will remain essential for meeting material demand throughout most of the transition period. In the 2020s and 2030s, demand for key materials, such as battery raw materials and permanent magnet REEs, will significantly exceed the availability of secondary supply, due to long product lifetimes and the rapid scale-up of EVs, wind turbines and PVs.

As a result, primary supply will be required to support EV fleet growth (traction motors; batteries) and renewable technology deployment (wind turbines; PVs). Expansion of primary mining, refining and processing capacity will be required to match projected material requirements to 2050. Therefore, diversification of supply chains to reduce risks and the development of strategic partnerships will remain essential. Even after secondary supply becomes significant (post-2040 or post-2050, depending on the material), primary supply will still be needed to cover gaps, supply growth sectors and substitute for non-recoverable losses.

The long-term trajectory suggests that secondary supply will gradually offset primary demand, especially beyond 2050 when large volumes of batteries, motors and turbines begin retiring. However, primary supply remains the dominant source for the foreseeable future, underscoring the importance of responsible sourcing, supply chain resilience and domestic processing capacity development. Other circularity interventions, for example extending product lifetimes and promoting reuse, repair, refurbishment and remanufacture have the potential to reduce overall demand for technology metals. However, many of these circularity options remain at an early stage of development and are not widely implemented at scale. Further policy support, market incentives and enabling infrastructure are required to strengthen their commercial viability and accelerate their adoption.

5.4 IMPLICATIONS FOR UK SUPPLY CHAIN RESILIENCE

While the potential for domestic production of technology metals beyond 2040 appears strong, the short- to medium-term outlook (up to 2040) remains characterised by significant supply risks and continued reliance on primary overseas sources. In the absence of mature reverse supply chain infrastructure, domestic refining capacity and recovery systems, the UK will remain exposed to global market volatility and geopolitical constraints during this period.

However, beyond 2040 and assuming timely and coordinated investment in domestic capabilities, infrastructure and skills, the growing volume of EoL technologies entering the waste stream could substantially reduce these risks. With the right interventions, the UK could begin to utilise its expanding secondary stock of batteries, permanent magnets in motors, and wind turbine components and technology metals in PV modules, enabling secondary production to become an increasingly important contributor to national supply security from 2050 onwards.

5.5 INFRASTRUCTURE AND CAPACITY REQUIREMENTS FOR SECONDARY SUPPLY

The modelling work undertaken in this study highlights that, for some materials, there is significant potential for secondary supply from EoL material. For example, by 2040 to 2050, there is potential for almost 10 000 t of Nd to become available from EoL traction motors and wind turbines; however, physical availability of material will be only one aspect of future supply. In conjunction with physical availability, there needs to be industrial capacity to recover technology metals and produce the materials that manufacturers require. In the UK, collection and sorting of EoL products, such as EVs and PVs, is reasonably well established, but other material transformation stages, such as advanced separation and metallurgy, are less well developed (Figure 26). The has the UK capacity to process materials derived from traction motors and batteries from EVs; however, this is mainly in the R&D stage or is only at pilot scale. For example, Ionic Technologies is developing a long-loop recycling process to produce separated REE oxides from EoL magnets and Cell Cycle is developing a process to recover Li, Co, Mn, Ni and graphite from black mass. However, neither of these is currently operating at commercial scale.

The situation is the same for Cu, where collection of copper-bearing EoL products is already taking place, as is basic sorting and separation; however, refining capacity is limited. Evolve Metals is developing capacity to refine Cu using hydrometallurgy, although, as with Ionic and Cell Cycle, this is not currently at commercial scale. As such, significant amounts of Cu waste and scrap leave the UK each year. Mudd et al. (2025) estimates that, between 2021 and 2025, the UK was exporting about 250 000 t Cu waste and scrap each year.

A first and critical step toward securing access to secondary supply is to ensure that end-of-life products embedded with key technology metals remain within the UK for further processing and use. Achieving this will require enabling regulatory frameworks and tailored export conditions that prioritise domestic retention of valuable secondary resources.

To maximise the benefits of secondary supply of technology materials, the UK will need to further develop collection systems and disassembly technologies for EoL products at scale and across the whole value chain. More fully integrated value chains will improve access to feedstock material by reducing UK reliance on imports. Integrated value chains will also improve value retention. For example, the UK currently exports black mass for advanced separation, with only small volumes being processed for R&D purposes. By developing reverse logistics and scaling up processing capacity, the UK could produce high-value products from black mass, such as nickel sulfate, lithium carbonate and cobalt oxide. Black mass sells for between US$3000 and US$30 000 per tonne, depending on battery chemistry, whereas individual materials are much higher value; a tonne of cobalt oxide is worth about US$47 000 alone (Shanghai Metals Market, 2026).

Integration of value chains and scaling up of industrial capacity will also require a skilled workforce, including but not limited to engineers and metallurgists. However, there is currently a shortage of people with these skills in the UK, as highlighted in Institute of Materials (2024) , which states that engineers and metallurgists are in short supply across all stages of the value chain and that there is decreasing demand for these subjects in UK universities. The report concludes that ‘the serious and growing skills gap is a significant risk facing value chains. Similar findings have also been published in the ‘UK STEM skills pipeline’ report (Greaves and Brawley, 2025). These skill gaps need to be urgently addressed to ensure domestic production of technology materials in the future.

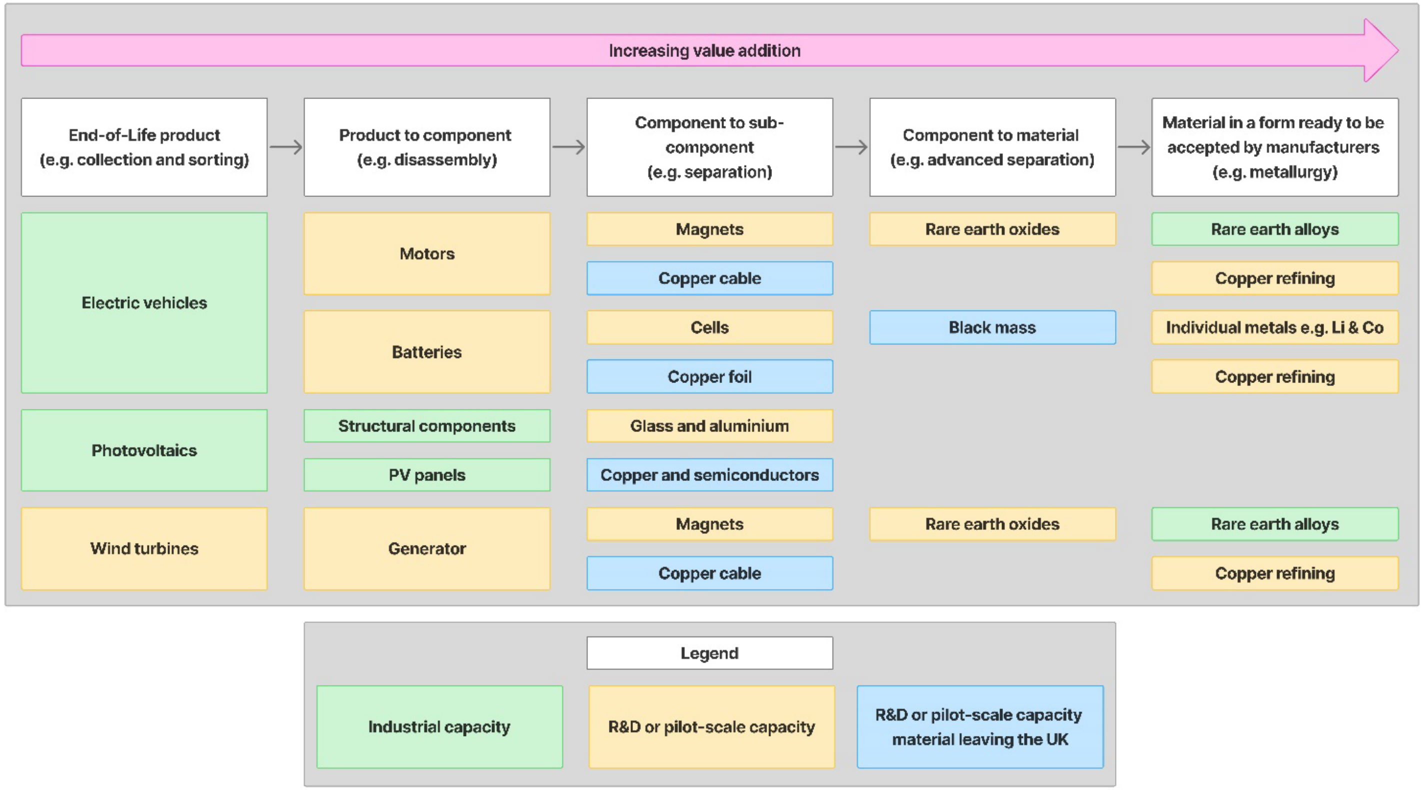


Figure 26 The material transformation stages where the UK has industrial capacity (green boxes) and where capacity is being developed (orange boxes) to recover technology materials from EoL products. Blue boxes indicate capacity development but highlight materials that are currently exported for further refining outside of the UK. Compiled using expert knowledge and stakeholder consultation. BGS © UKRI 2026.

5.6 LIMITATIONS OF CURRENT ASSESSSMENT

Despite extensive efforts to compile a comprehensive and fit-for-purpose dataset to underpin this assessment, several data limitations and uncertainties remain. Many of these challenges stem from the absence of suitable or authoritative data sources or from datasets lacking sufficient clarity or metadata to allow confident interpretation. In some cases, the meaning, context or system boundary of available data is ambiguous, making consistent integration into the modelling framework difficult.

A further limitation relates to the lack of detailed bills of materials for many components and products, particularly for emerging technologies where commercial sensitivity restricts disclosure. In addition, UK-specific data, including information on anthropogenic stock composition, historical evolution of the in-use stock and UK-specific product lifetimes, are often limited or unavailable. As a result, the assessment relies partly on European or global datasets where UK specific information is missing, which introduces additional uncertainty.

The modelling also depends on the underlying deployment scenarios provided by the National Grid Future Energy Scenarios (National Energy System Operator, 2021). Although these scenarios are appropriate for assessing progress toward net zero, the absence of comprehensive UK technology roadmaps or coordinated foresight studies means that several assumptions were required to characterise the future evolution of the assessed technologies. These include assumptions about market share trajectories, material intensity changes and technology substitution patterns.

To reduce uncertainty, stakeholder engagement has been extensively used to validate assumptions and fill data gaps. However, this engagement reflects inputs gathered over multiple years and across a range of projects, rather than a single, unified consultation exercise for this assessment. While this contributes to a more robust evidence base, it also reflects the uneven availability of sector-specific expertise and datasets across different technology areas.

Taken together, these limitations highlight the need for improved data transparency, coordinated UK technology road mapping and continued engagement with industry to strengthen the evidence base for future assessments of material demand and secondary supply potential.

6 Recommendations

6.1 UK PRIORITIES FOR SECONDARY MATERIAL SUPPLY

The modelling outcomes (Table 13) indicate that the contribution of secondary technology metals could become highly significant beyond 2040, provided the right enabling conditions are in place. In particular, Ag and Sn from EoL PV modules, cathode and anode materials from LIBs and the permanent-magnet REEs (Nd, Pr, Dy and Tb) used in traction motors and wind turbine generators exhibit strong, long-term, secondary supply potential. Cu, used across all technologies, also shows considerable potential, with EoL flows meeting approximately 70 per cent of projected UK demand by 2050.

However, realising this potential requires further work to understand what proportion of these theoretical EoL flows can be recovered. A detailed evaluation of recovery feasibility, covering the collection, pre-processing, disassembly, material separation, refining and recycling stages, is essential. This includes defining realistic technical recovery rates, mapping EoL pathways, assessing collection and capture efficiency and identifying losses across each stage of the recovery chain.

Crucially, proof of economic viability and demonstrable technological feasibility will be required before secondary production can scale up. Without this evidence, the UK will not be able to convert its growing secondary resource base into reliable domestic supply.

Table 13 End-of-life material contribution relative to UK demand (%) in 2040 to 2050, with identified priority areas. Green: suggested priority areas for domestic secondary supply.

Technology	Element	EoL contribution potential as a percentage of UK demand (%)
		2040–2050
PVs	Ag	93.2
	As	0.3
	Bi	10.3
	Cd	-
	Ga	1.3
	In	15.7
	Se	-
	Si	51.3
	Sn	74.6
	Te	-
	Zn	61.8
LIBs	Li	71.4
	Co	76.8
	Ni	73.6
	Mn	62.4
	C	73.5
Traction motors and wind turbines	Nd	86.7
	Pr	90.7
	Dy	84.7
	Tb	75.0
	B	81.0
All	Cu	71.5

6.2 STRENGTHENING THE EVIDENCE BASE

This assessment offers a comprehensive evaluation of demand and theoretical EoL availability, but several areas of future work are needed to strengthen the evidence base for policy and investment decisions.

A priority area for future research is the integration of UK manufacturing demand into the modelling framework. This study focuses solely on consumption-based demand and does not consider the material requirements of domestic manufacturing. Incorporating UK manufacturing demand and manufacturing waste streams would enable a more complete national assessment and better alignment with industrial strategy objectives.

Further work is also required to move from theoretical estimates of secondary material availability to realistic recovery potential. The EoL material flows quantified in this study represent upper bound estimates and do not account for practical factors such as:

- collection rates
- disassembly constraints
- technical recovery yields
- contamination rates
- economics of recycling

Quantifying these parameters will be critical to determining how much material can truly be recovered and how secondary supply could contribute to future resource security.

The scope of the assessment should also be expanded to include a broader range of EoL products and sectors. To help quantify the full scale of the UK anthropogenic stock and its future secondary supply potential, future work should incorporate a number of product streams, including but not limited to:

- HGVs
- buses
- vans
- micromobility
- stationary energy-storage systems
- industrial motors
- grid infrastructure
- electrical and electronic equipment
- additional renewable energy components

There is also a need to improve data availability for emerging and next-generation technologies. For several battery chemistries, advanced PV architectures, novel motor designs and alternative generator technologies, material intensity data and deployment trajectories remain uncertain or incomplete. As these technologies evolve, updated datasets, industry engagement and technology-specific research will be needed to ensure future scenarios reflect realistic material requirements and EoL profiles.

The modelling outputs are inherently sensitive to assumptions around technology mix, deployment trajectories, product lifetimes and material intensities. As technologies and markets evolve, regular updates and formal sensitivity analyses will be needed to understand uncertainty and to interpret results within a robust analytical framework. This would include exploring a wider range of scenarios, including circularity scenarios and alternative decarbonisation pathways, as well as targeted sensitivity tests for specific materials.

6.3 INTEGRATEING PRIMARY AND SECONDARY SUPPLY PLANNING

A key future priority is the integration of primary and secondary supply modelling. Understanding how domestic secondary flows interact with imported primary materials, global supply risks, refining capacity and trade dependencies is essential for long-term planning. This integrated view will help identify materials where secondary supply could play a major role beyond 2040 to 2050 and those where new primary-supply partnerships remain essential.

6.4 ROLE OF REGULATION AND CIRCULAR ECONOMY INSTRUMENTS

Together with updates to the Waste Electrical and Electronic Equipment Regulations (UK Government, 2010), the Waste Batteries and Accumulators Regulations (UK Government, 2009) and the End-of-Life Vehicles Regulations (UK Government, 2003), emerging circular economy strategies across England, Northern Ireland, Scotland and Wales will play a critical role in shaping the future of secondary supply for technology metals. Their impact may be positive or constraining depending on the design of specific instruments.

For example:

- higher collection rates for EoL products will increase the volume of material entering recovery, but only if accompanied by explicit requirements or incentives for recovering critical and technology metals — without clear recovery obligations, higher collection will not automatically translate into increased secondary supply
- repair, remanufacture and refurbishment initiatives may help retain value in the economy and reduce primary demand; however, extending product lifetimes could delay or reduce the flow of EoL materials, lowering the near-term availability of technology metals for recycling
- policies promoting modular design and design for disassembly could significantly improve the recoverability of components embedded with critical metals and well-designed standards could raise recovery yields and improve economic viability

Understanding how these instruments affect collection, treatment, recovery and export leakage will be crucial for determining actual recovery rates and the UK's ability to meet its critical-minerals objectives.

6.5 ENABLING REVERSE SUPPLY CHAINS AND INFRASTRUCTURE DEVELOPMENT

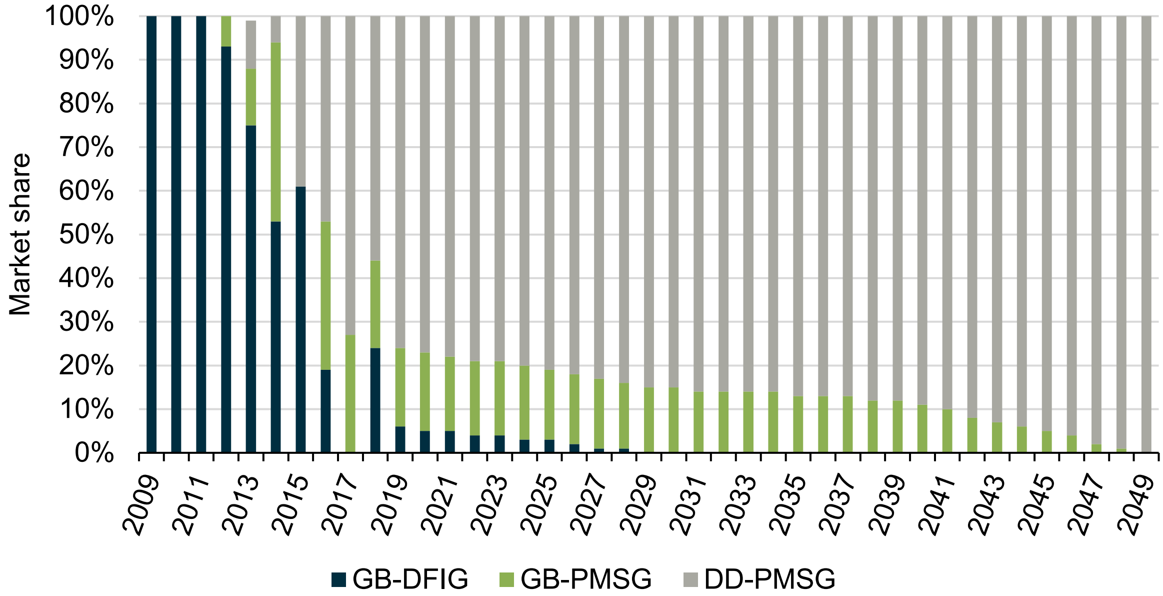
A resilient reverse supply chain requires robust logistics, workforce capability, infrastructure readiness and processing capacity. Future work should map the movement of critical raw material-rich components through EoL stages, supporting planning for regional dismantling hubs, decommissioning facilities and scaling up of domestic recycling and refining infrastructure.

6.6 IMPROVING DATA, TRANSPARENCY AND MATERIAL TRACKING

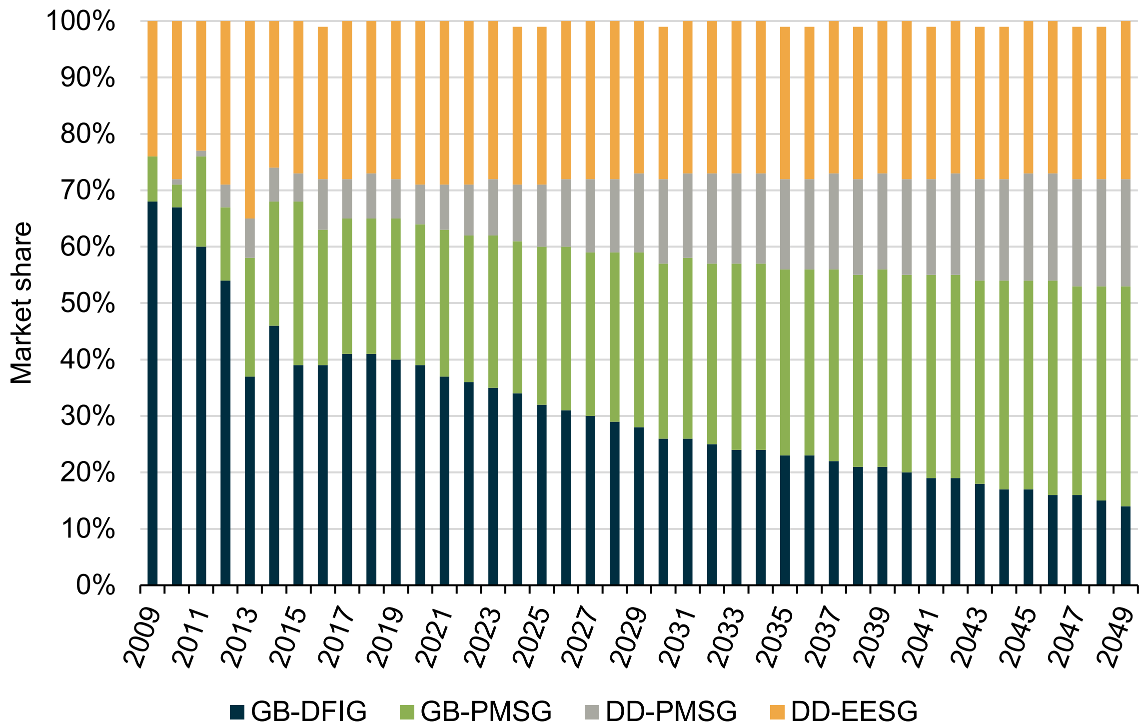
Finally, future work should integrate techno-economic and environmental assessments of recycling pathways and enhance national data systems. This includes establishing consistent reporting standards, improving transparency around material content in products and supporting the development of digital product passports. Strengthening data systems is essential to refining material-flow modelling and monitoring progress toward national circularity and critical minerals goals.

Appendix 1 Understanding technology evolution

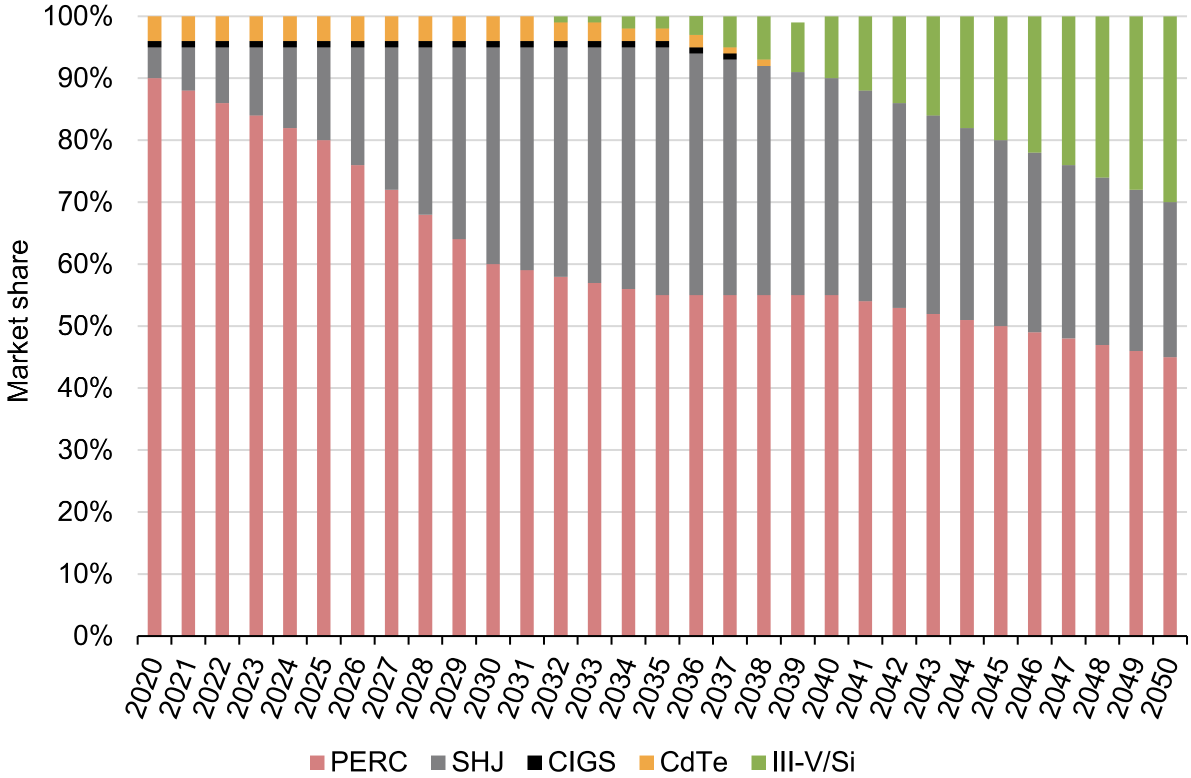
OFFSHORE WIND TURBINES



ONSHORE WIND TURBINES



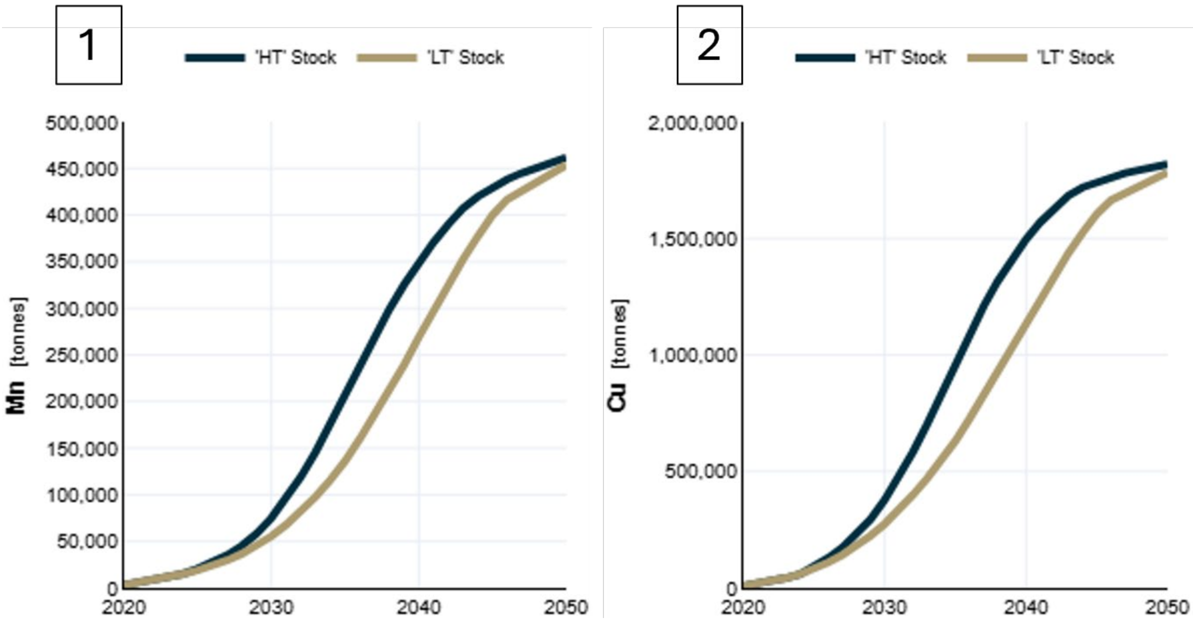
PV CELLS



Evolution of the PV cells market between 2020 and 2050 showing the technology transformation that is likely to take place (data from Gervais et al. (2021) and Fraunhofer ISE (2023)). The market shares shown were used in the material demand calculations. BGS © UKRI 2024.

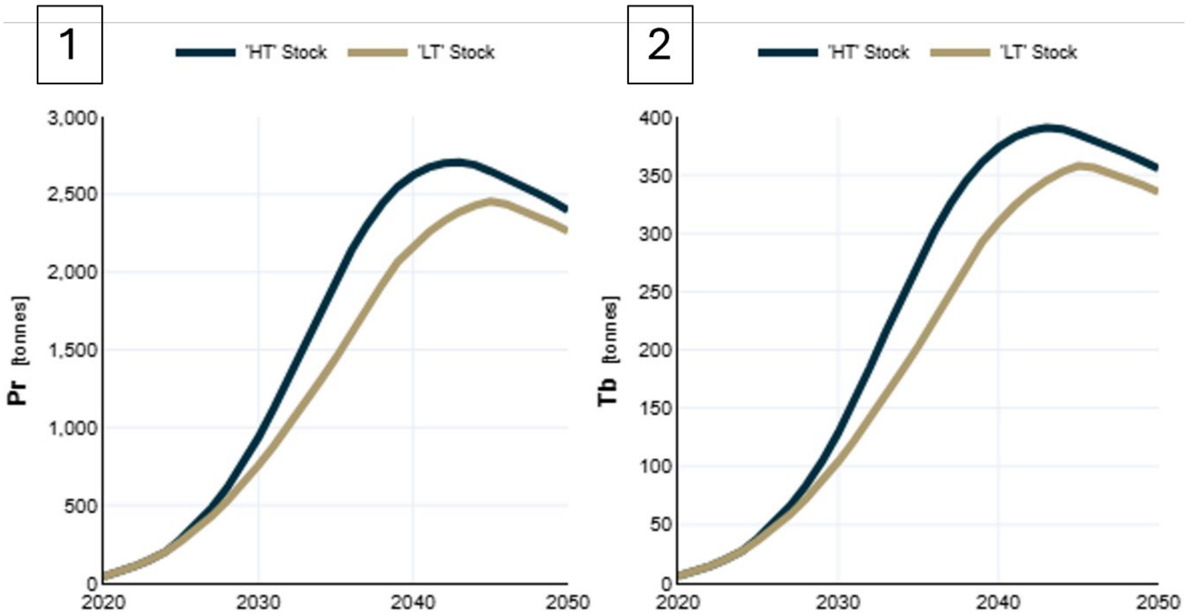
Appendix 2 Stocks, demand and availability

BATTERY STOCK



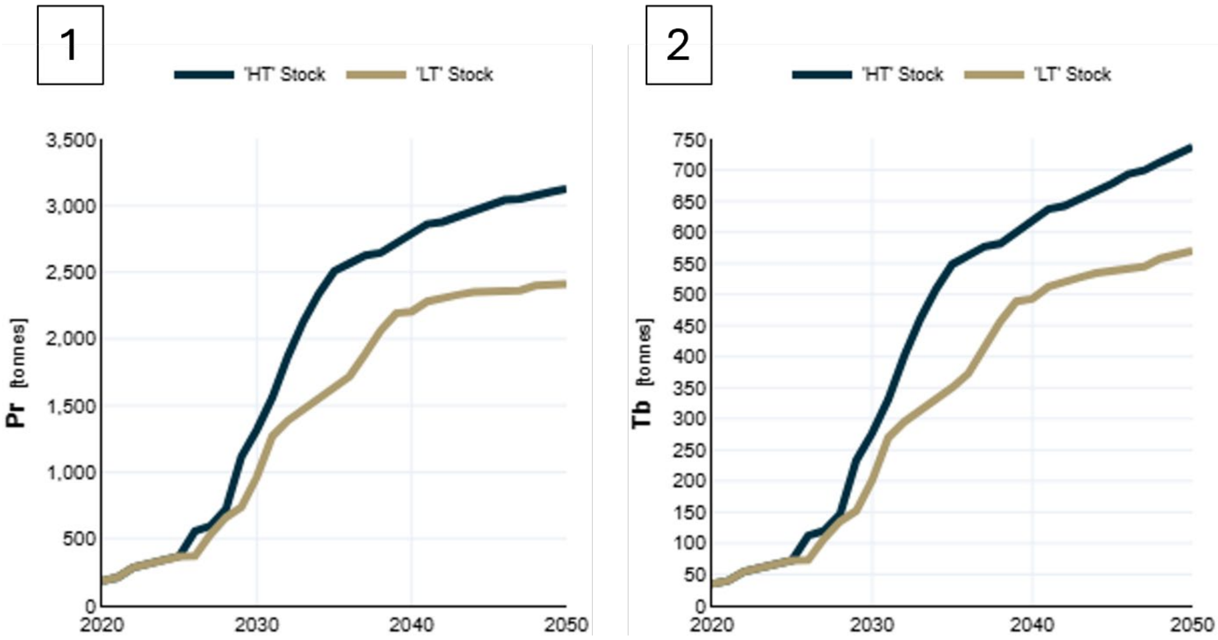
Stock evolution of (1) Mn; (2) Cu in batteries between 2020 and 2050. The graphs estimate stocks under two different pathways: HT and LT. The unit is tonnes. BGS © URI 2026.

TRACTION MOTOR STOCK



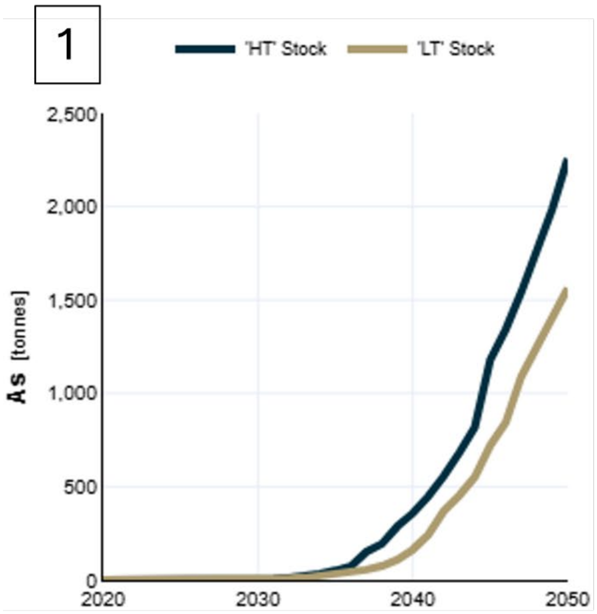
Stock evolution of (1) Pr; (2) Tb in traction motors between 2020 and 2050. The graphs estimate stocks under two different pathways: HT and LT. The unit is tonnes. BGS © UKRI 2026.

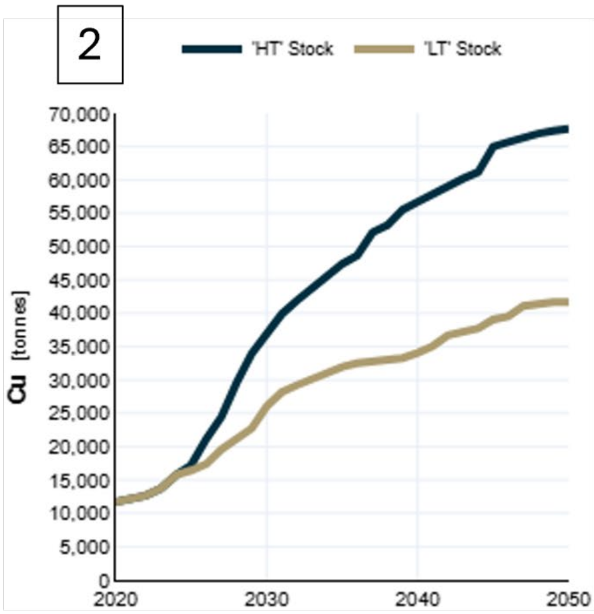
WIND TURBINE STOCK

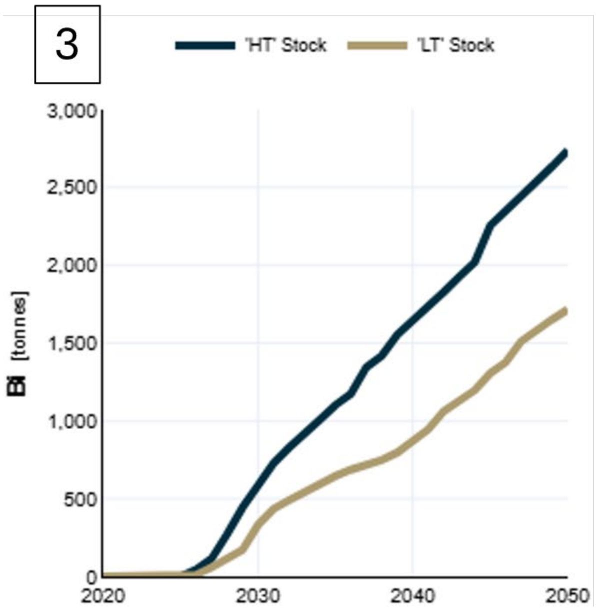


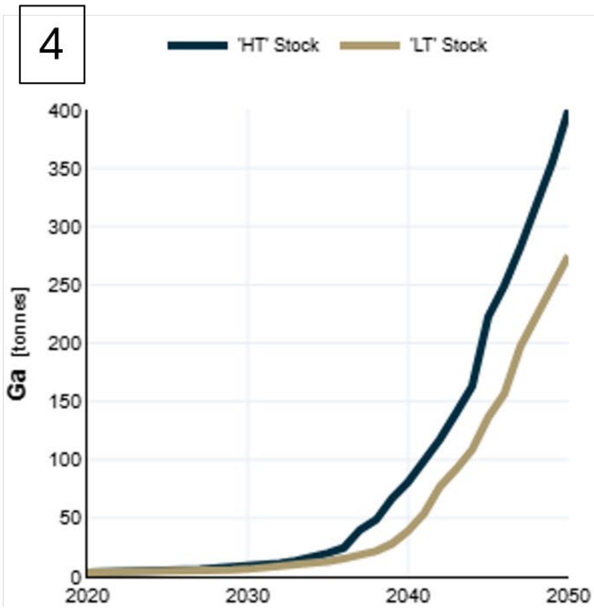
Stock evolution of (1) Pr; (2) Tb in wind turbines between 2020 and 2050. The graphs estimate stocks under two different pathways: HT and LT. The unit is tonnes. BGS © UKRI 2026.

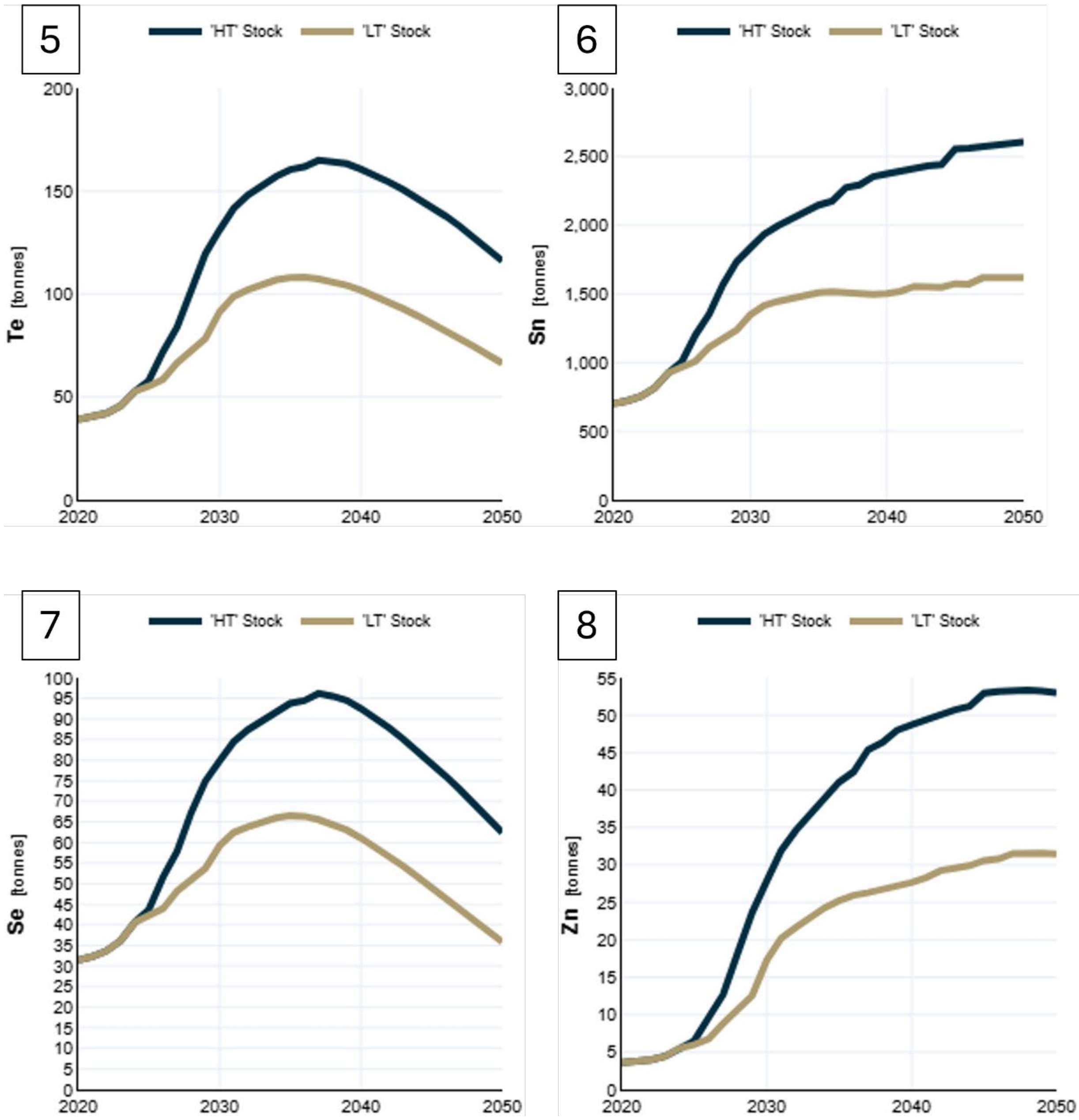
PHOTOVOLTAIC STOCK





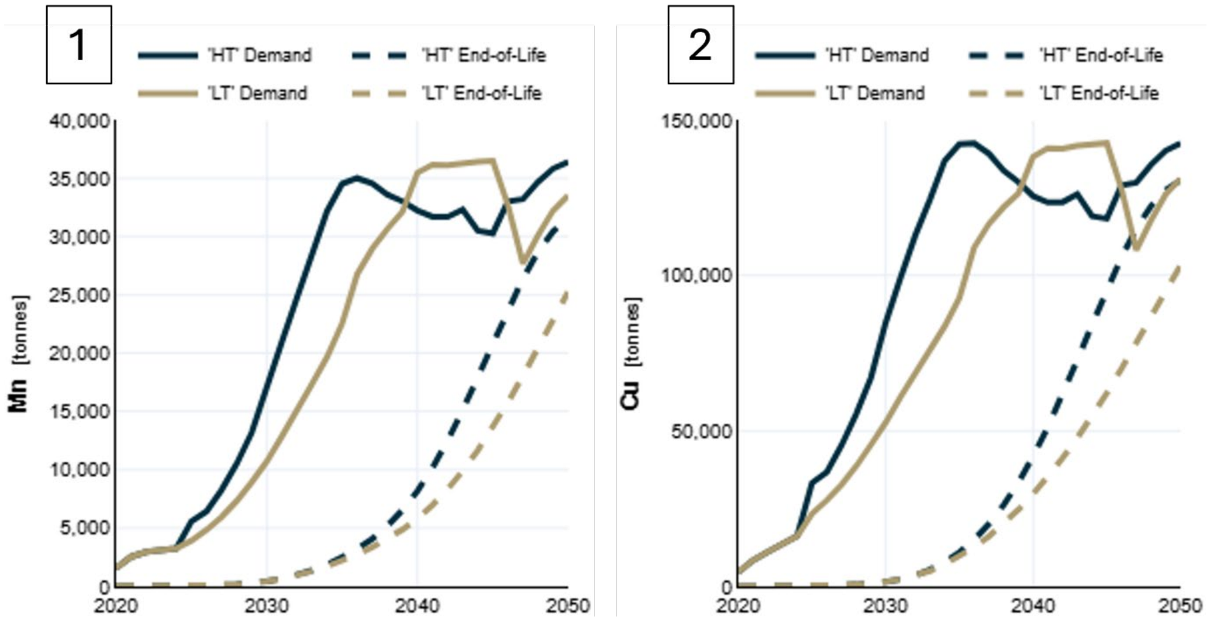






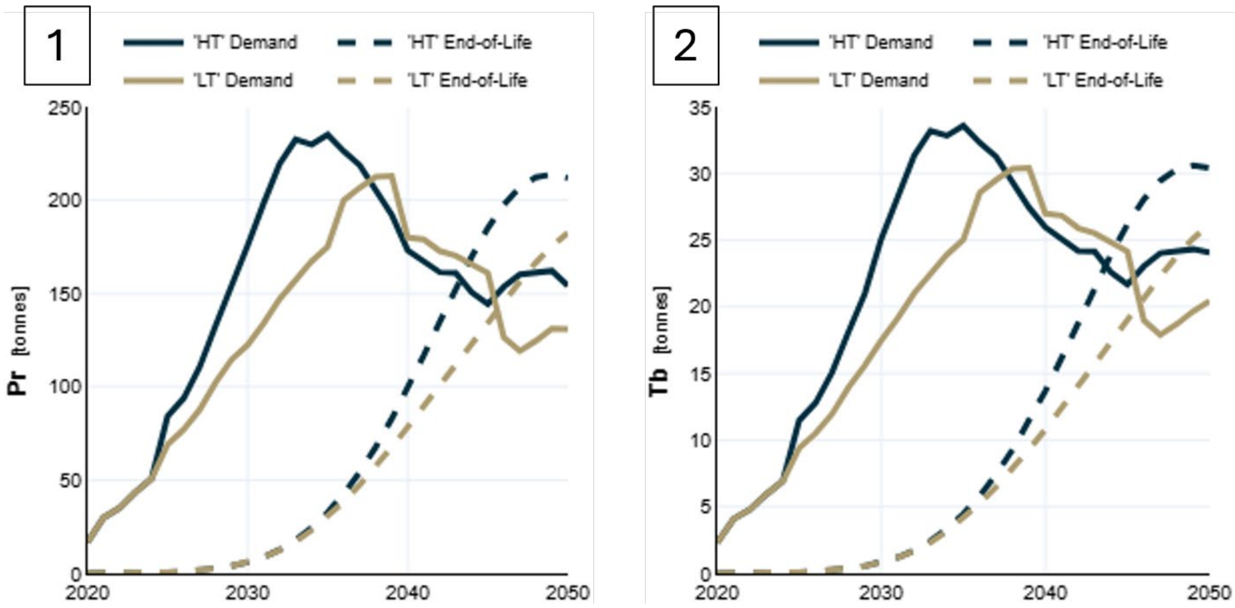
Stock evolution of (1) As; (2) Cu; (3) Bi; (4) Ga; (5) Te; (6) Sn; (7) Se; (8) Zn in PVs between 2020 and 2050. The graphs estimate stocks under two different pathways: HT and LT. The unit is tonnes. BGS © UKRI 2026.

BATTERIES DEMAND VS. EOL MATERIAL AVAILABILITY



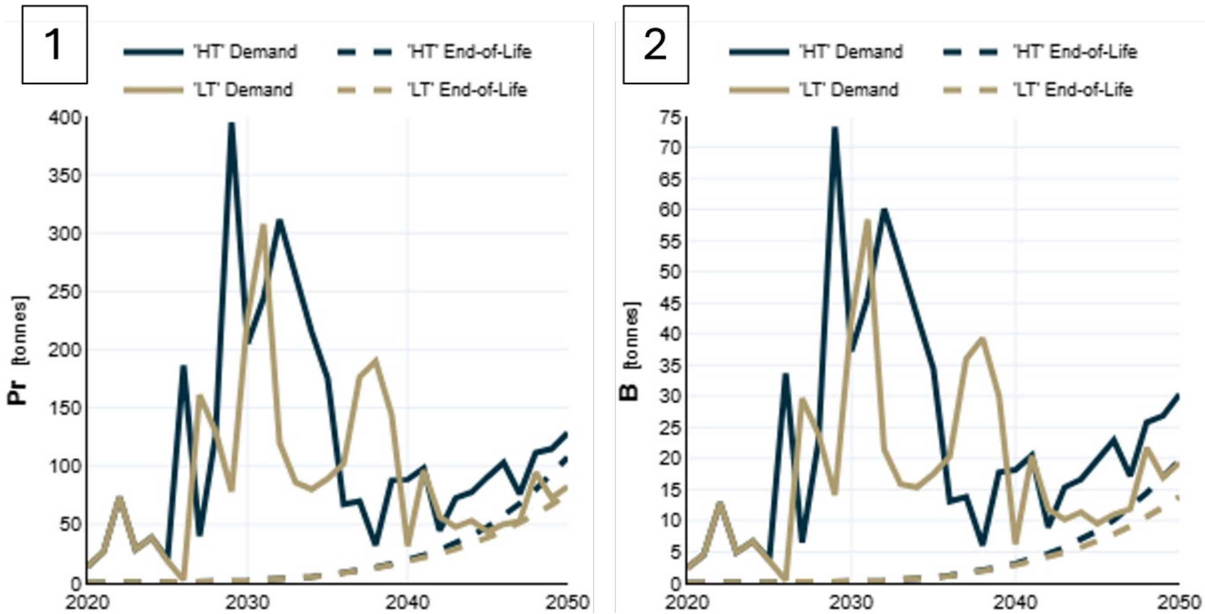
Annual demand and EoL quantities for (1) Mn; (2) Cu in batteries between 2020 and 2050 under the HT and LT pathways. The unit is tonnes. BGS © UKRI 2026.

TRACTION MOTORS DEMAND VS. EOL MATERIAL AVAILABILITY



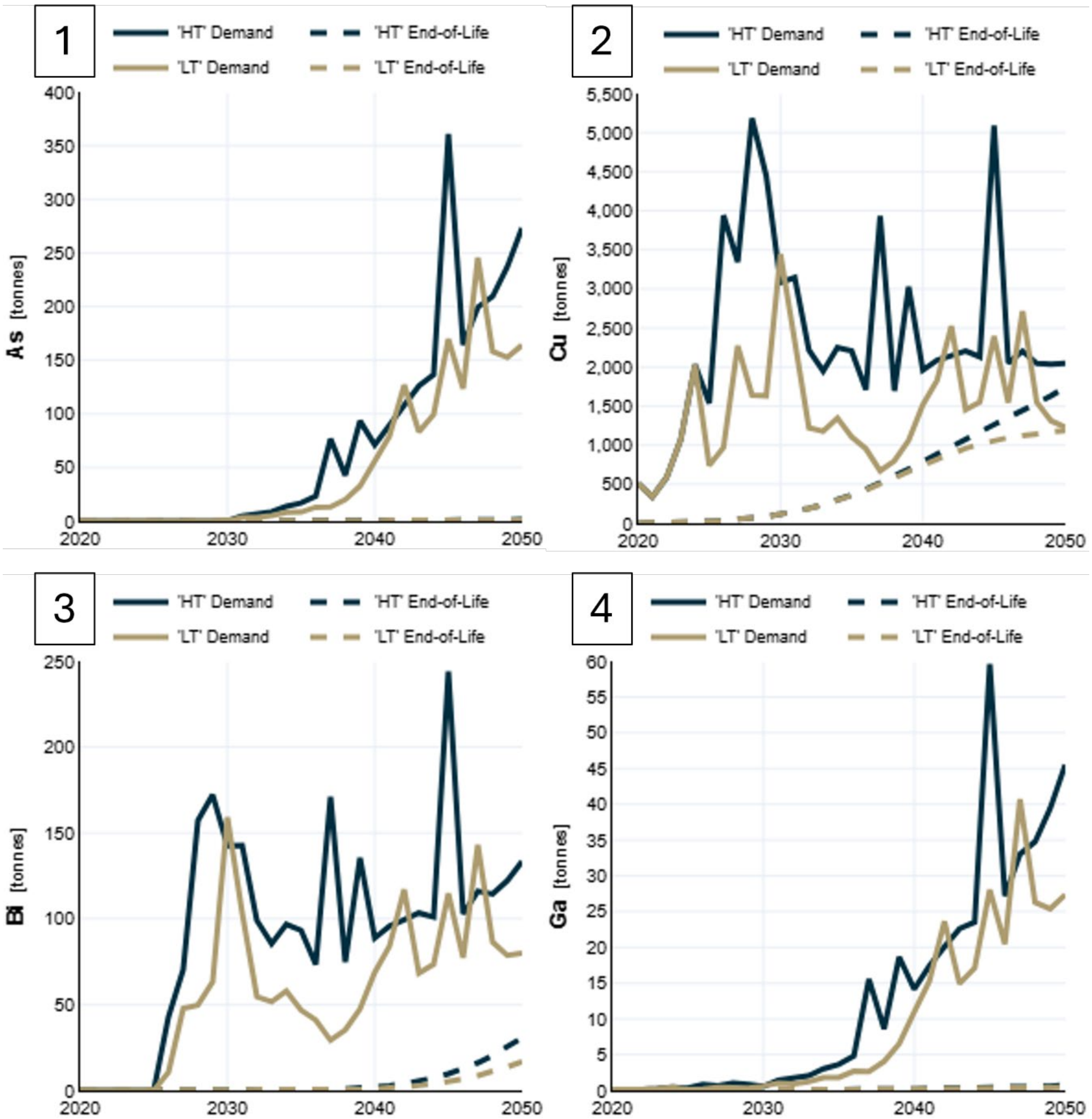
Annual demand and EoL quantities for (1) Pr; (2) Tb in traction motors between 2020 and 2050 under the HT and LT pathways. The unit is tonnes. BGS © UKRI.

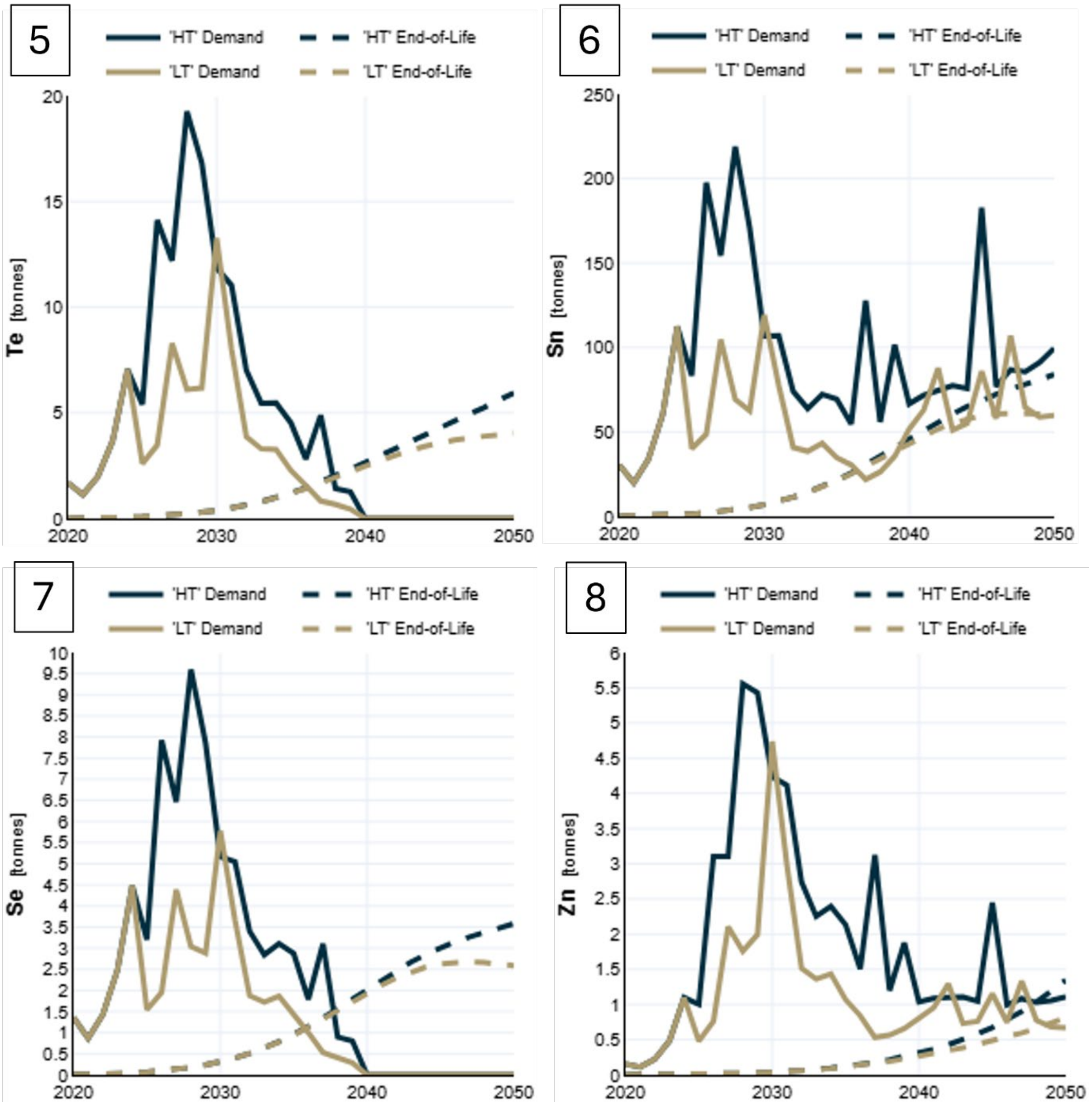
WIND TURBINE DEMAND VS. EOL MATERIAL AVAILABILITY



Annual demand and EoL quantities for (1) Pr; (2) B in wind turbines between 2020 and 2050 under the HT and LT pathways. The unit is tonnes. BGS © UKRI 2026.

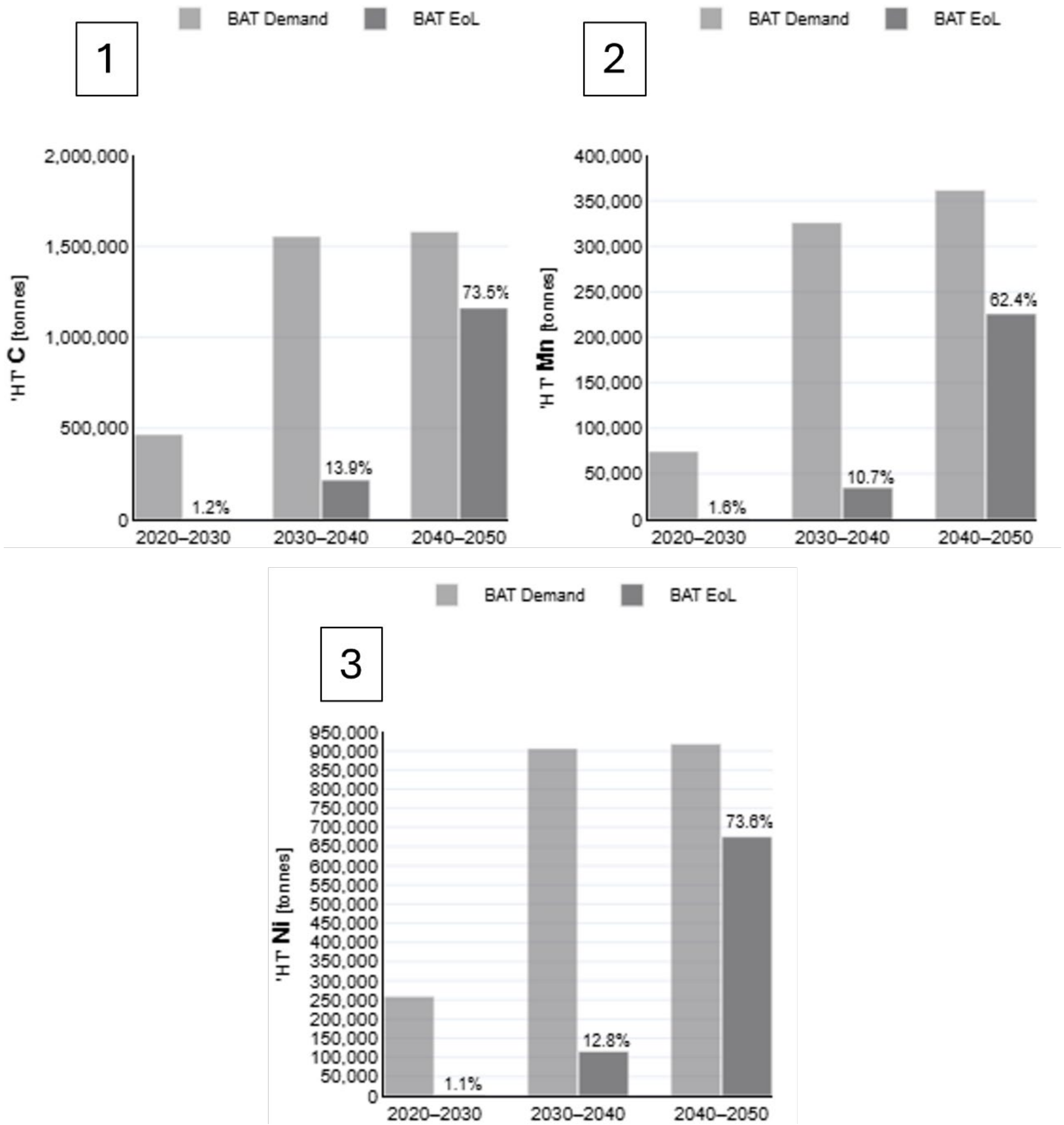
PHOTOVOLTAIC DEMAND VS. EOL MATERIAL AVAILABILITY





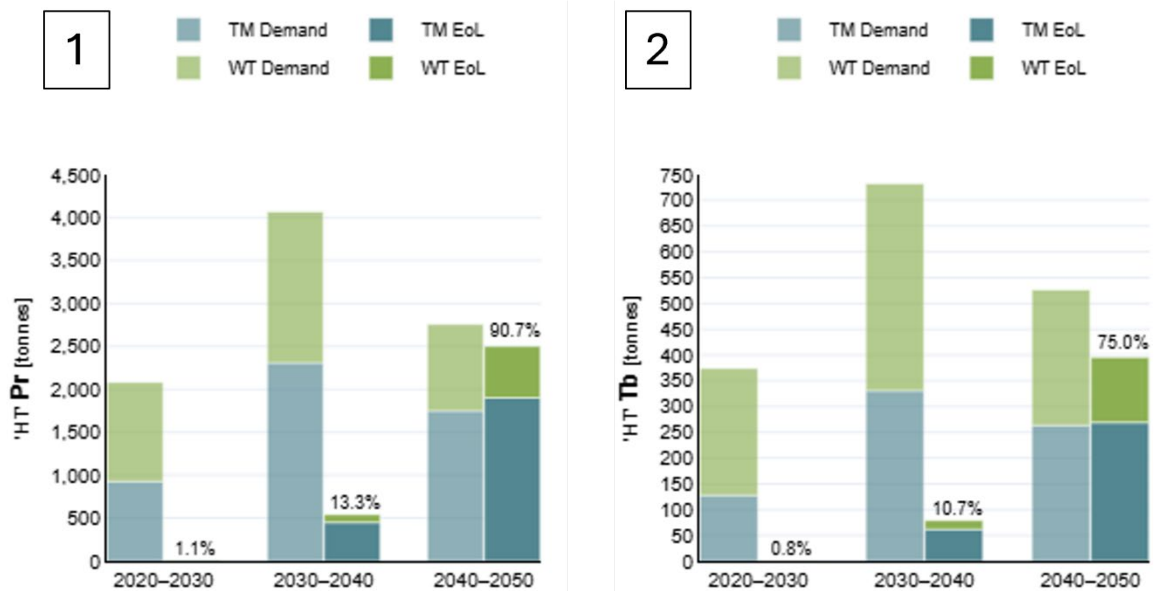
Annual demand and EoL quantities for (1) As; (2) Cu; (3) Bi; (4) Ga; (5) Te; (6) Sn; (7) Se; (8) Zn in PVs between 2020 and 2050 under the HR and LT pathways. The unit is tonnes. BGS © UKRI 2026.

BATTERIES CUMULATIVE DEMAND PER DECADE



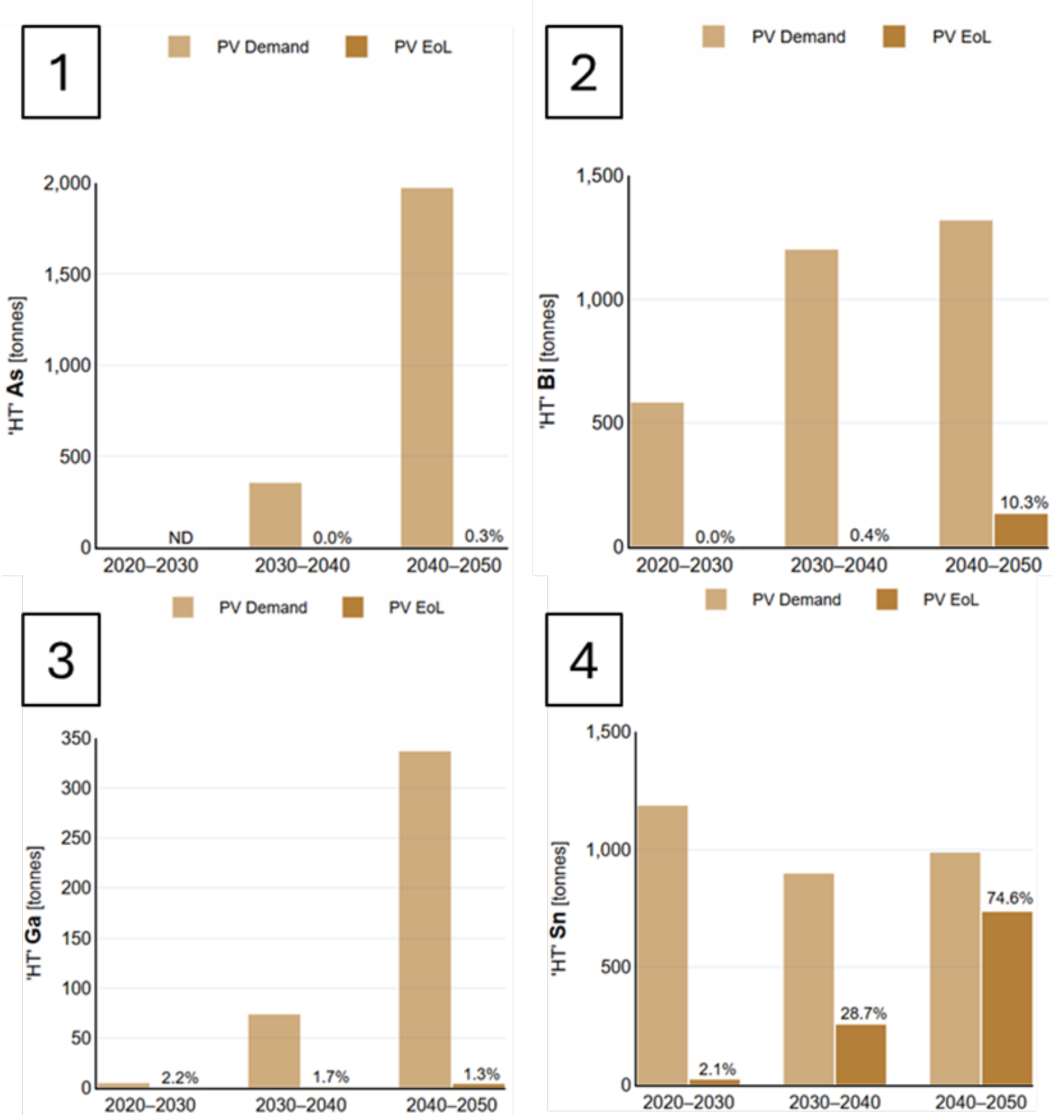
Cumulative demand and EoL quantities under the HT pathway for (1) C; (2) Mn; (3) Ni in EV batteries for the decades 2020 to 2030, 2030 to 2040 and 2040 to 2050. The unit is tonnes. BGS © UKRI 2026.

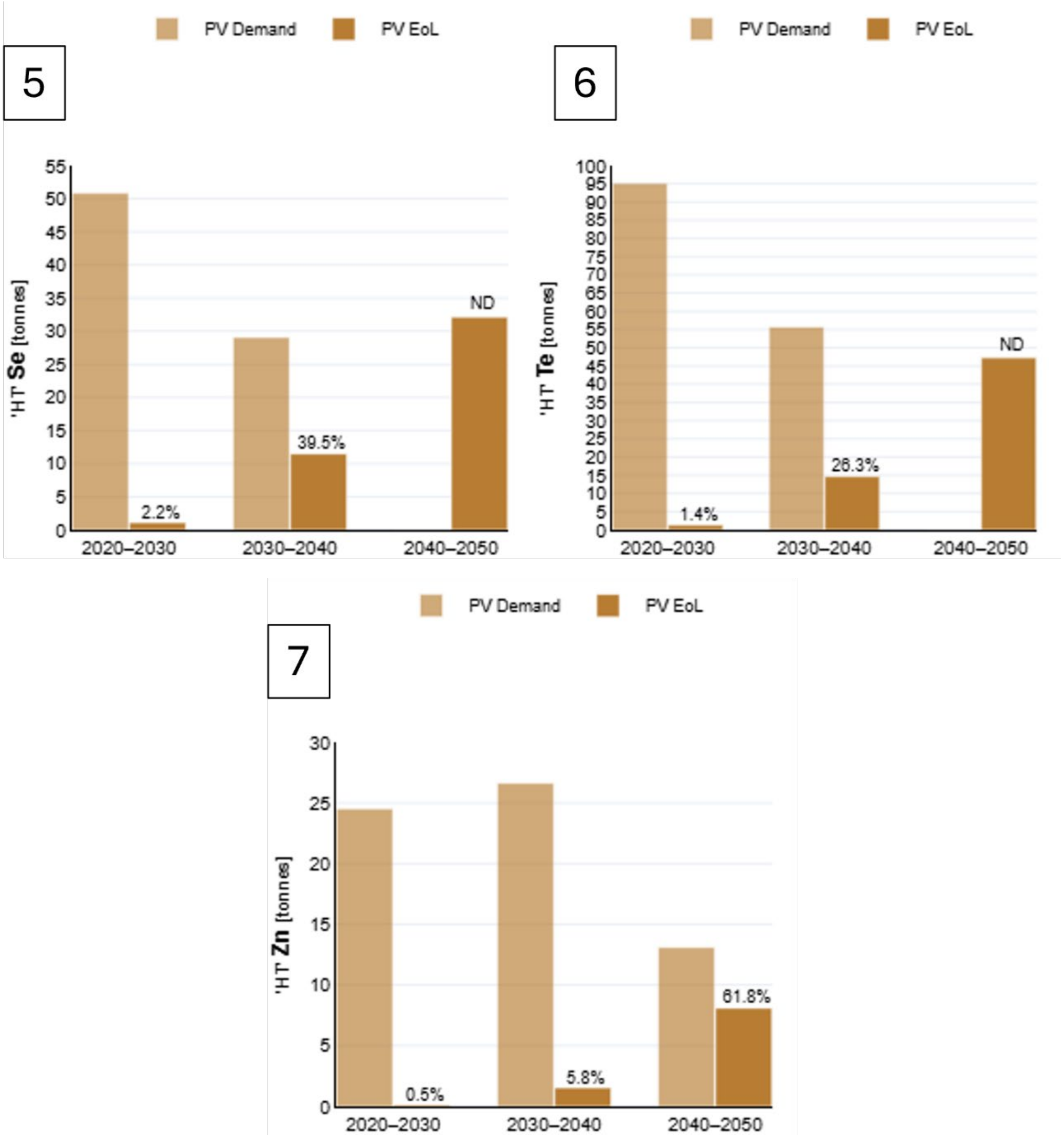
TRACTION MOTOR AND WIND TURBINE CUMULATIVE DEMAND PER DECADE



Cumulative demand and EoL quantities under the HT pathway for (1) Pr; (2) Tb in traction motors and wind turbines for the decades 2020 to 2030, 2030 to 2040 and 2040 to 2050. The unit is tonnes. BGS © UKRI 2026.

PHOTOVOLTAIC CUMULATIVE DEMAND PER DECADE





Cumulative demand and EoL quantities under the HT pathway for (1) As; (2) Bi; (3) Ga; (4) Sn; (5) Se; (6) Te; (7) Zn in PVs for the decades 2020 to 2030, 2030 to 2040 and 2040 to 2050. The unit is tonnes. BGS © UKRI 2026.

Glossary

AC	Alternating current
As	Arsenic (element)
B	Boron (element)
BEV	Battery electric vehicle
Black mass	A fine, black powder generated by shredding EoL lithium-ion batteries that contains lithium, cobalt, nickel, manganese and graphite
C	Carbon (element)
Cd	Cadmium (element)
c-Si	Crystalline silicon
CdTe	Cadmium telluride
CIGS	Copper-indium-gallium selenide
Co	Cobalt (element)
Cu	Copper (element)
DC	Direct current
DD-EESG	Direct drive electrically excited synchronous generator
DD-PMSG	Direct drive permanent magnet synchronous generator
dMFA	Dynamic material flow analysis
Dy	Dysprosium (element; REE)
EESM	Externally excited synchronous motor
EoL	End-of-life
EV	Electric vehicle
FES	Future Energy Scenarios (from the National Grid)
Ga	Gallium (element)
GB-DFIG	Gearbox double-fed induction generator
GB-PMSG	Gearbox permanent magnet synchronous generator
GW	Gigawatt
HT	High transition scenario (based on National Grid FES)
III-V/Si	Thin-film tandem solar cells
IM	Induction motor
In	Indium (element)
kg/kWh	Kilogram per kilowatt-hour
kg/MW	Kilogram per megawatt
kt	Kilotonne
Li	Lithium (element)
LIB	Lithium-ion battery
LFP	Lithium-iron phosphate

LMFP	Lithium-manganese-iron phosphate
LMO	Lithium-manganese oxide
LT	Low transition scenario (based on National Grid FES)
MFA	Material flow analysis
Mn	Manganese (element)
NCA	Nickel-cobalt-aluminium oxide
Nd	Neodymium (element; REE)
NdFeB	Neodymium-iron-boron
NG	National Grid
Ni	Nickel (element)
NMC	Nickel-manganese-cobalt
OEM	Original equipment manufacturer
PERC	Passivated emitter and rear cell
PHEV	Plug-in hybrid electric vehicle
PMSM	Permanent magnet synchronous motor
Pr	Praseodymium (element; REE)
PV	Photovoltaic
R&D	Research and development
REE	Rare earth elements: the 15 lanthanides plus scandium and yttrium
Se	Selenium (element)
SHJ	Silicon heterojunction
Si	Silicon (element)
SIB	Sodium-ion battery
Sn	Tin (element)
Stdev	Standard deviation
t	tonne
Zn	Zinc (element)

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