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Enabling Net-Zero GHG Emissions in the UK Metals and Transport Industries through a Circular Supply Chain Framework

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Abstract

The UK metals industry is indispensable in achieving the country's net-zero greenhouse gas (GHG) emissions target by 2050, especially considering the heavy reliance of the transport sector on metals. This paper proposes strategies based on recycling and refining locally sourced scrap metals to build a robust circular supply chain. Findings revealed that 16% of global crude steel is used in transport and this accounts for 8% of the world's GHG emissions. Domestically, iron and steel account for 14% of the UK industrial emissions, with over 8 million metric tons of scrap metals exported annually. Insights from stakeholders revealed export dependency and infrastructure gaps impeding circularity. Collaborative efforts between industry, government, and recyclers are vital. Investing in electric arc furnaces and storage can enable the processing of domestic metal scrap for high-quality yield. A closed-loop flow of battery-critical metals will also support sustainable manufacturing of electric vehicles. Ultimately, this paper advocates systemic efforts across policy, technology, infrastructure, and partnerships to realise a sustainable supply chain in the metals industry aligned with the decarbonisation and circular economy goals.

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Keywords: Circular Economy; Metals Industry; Transport Sector; Scrap Metal Recycling; Net-Zero Emissions.

1. Introduction

Metals are important for performing crucial enabling roles in manufacturing, power generation, construction and all other industrial sectors. Thus, the UK metals industry plays a pivotal role in achieving the country's net-zero greenhouse gas (GHG) emissions goal by 2050, particularly in the transport sector, which heavily relies on various metals for vehicle production, infrastructure, and components [1]. With a direct contribution of £10.7 billion to the UK's GDP [2], the industry is a key player in addressing the environmental impact of the transport sector. Globally, about 16% of crude steel, contributing to approximately 8% of GHG emissions, is utilised to meet the transport sector's needs [3,4]. Notably, the UK's iron and steel production alone accounts for 14% of the country's industrial emissions [5].

The transport sector in the UK is the largest emitter of GHG, contributing approximately 26% of emissions [6]. For instance, each vehicle manufactured in 2019 utilized around 900 kg of steel, with emissions exacerbated if sourced from primary materials [7]. Capacity development in recycling/refining locally sourced scrap metals offers a promising avenue to reduce net GHG emissions from these sectors. Currently, the UK exports over 8 million metric tons of scrap metals annually, with the volume increasing each year [8]. Particularly, in 2021, the UK imported 391,000 metric tons of scrap metals while exporting 8,067,000 metric tons in the same year [9]. The associated CO_2 emissions from logistics highlight the potential for developing a domestic market through circular loops for these metals, enhancing sustainability in the transport system. This, coupled with the rising demand for critical raw materials

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like lithium, aluminium, cobalt, nickel, copper, and manganese for electrifying the transport system, has led to significant reliance on imports, posing environmental and sustainability risks.

This paper provides insights into the current state of the UK metals industry's materials supply chain, considering barriers and untapped opportunities, aimed at supporting the transition towards circular and sustainable systems by achieving net-zero exports of scrap metals. The current difference between the import and export values of metal scraps [9] shows that not too much has been achieved in implementing the UK metals industry's 2030 strategic vision since its revelation in 2015. Thus, it is imperative to identify and address the challenges/barriers inhibiting its efficient/effective actualisation if the UK 2050 net-zero target is to be met. In addition, considering the emissions associated with the metals sector's activities coupled with the need to meet the SDG goals (particularly, goals 9 – industry, innovation, and infrastructure, 12 – responsible consumption and production, and 13 – climate action), all players in the UK metals industry including the transport sector must take actions aimed at reducing emissions across industries.

2. Methodology

Qualitative and quantitative approaches were adopted for the research methodology. Besides onsite visits to SMEs, industry experts, trade association representatives, policymakers and academics were interviewed through Teams call meetings and in-person conferences to gather insights into the barriers and opportunities regarding metals recycling and refining in the UK metals industry. Also, trade enquiry platforms and online databases were accessed to source virgin and scrap metals trade data to underpin the qualitative findings with quantitative analysis.

Note: The specific persons interviewed and their affiliations are not mentioned for confidentiality purposes and in compliance with GDPR

3. Results and discussions

3.1. Insights from stakeholder engagements/outreaches

The outcomes of engagements with stakeholders, including metals producers, industry and trade associations, and policymakers, along with information gathered from the trade enquiry system and certain databases, are outlined as follows.

International exports of iron waste and scrap reached a value of 56.6 billion U.S. dollars in 2021, surpassing the export value of any other type of scrap metal. Additionally, exports of copper waste and scrap approached 33 billion U.S. dollars during the same period. The United States holds the title of the largest global exporter of both iron and copper waste and scrap [10]. The UK is the second leading global exporter of ferrous waste and scrap in the last five years, exporting over 8 million metric tons annually. This export volume was surpassed only by the United States and significantly exceeded other major exporting countries i.e., Germany, Netherlands, France and Japan [11].

Meanwhile, according to the International Trade Centre [11], Turkey stands as the largest global importer of ferrous waste and scrap, importing nearly 21 million metric tons in 2022. This figure surpassed the combined total of the other top five importers (Italy, United States, South Korea, Belgium and Bangladesh). The United States ranked third, importing approximately 4.7 million tons. These huge export/import scrap data reveal the opportunity for resource efficiency and achieving net zero by embracing a circular supply chain and drastically reducing dependence on virgin materials.

Analysis of trade data from 2018 to 2022 confirms the UK annually exported approximately 8 million metric tons of scrap metal over this period (see Fig. 1). In contrast, the UK imported around 0.5 million metric tons of scrap per year during the same timeframe. The scrap metal types encompassed various categories including pig/cast iron, stainless steel, alloy steel, tinned iron/steel, new steel, old steel and remelting ingots. The significantly higher volume of scrap exports compared to imports indicates the UK ships a substantial portion of its domestically generated scrap overseas, exporting to approximately 80 countries worldwide. Fig. 2 presents the top recipient nations accounting for the largest shares of UK scrap exports. Conversely, the UK imports scrap metal from about 60 supplier countries globally. Fig. 3 provides an overview of the key exporting countries supplying metal scrap to the UK.

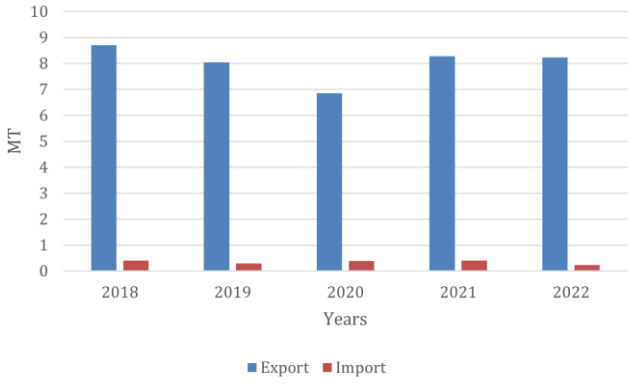

Fig. 1. Annual scrap export and import quantity from the UK (Source: ISSB)

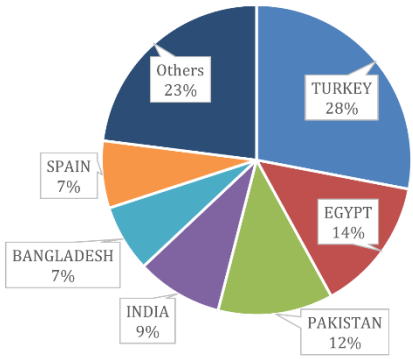

Fig. 2. Major export destinations – Top countries for UK metal scrap exports (Source: ISSB)

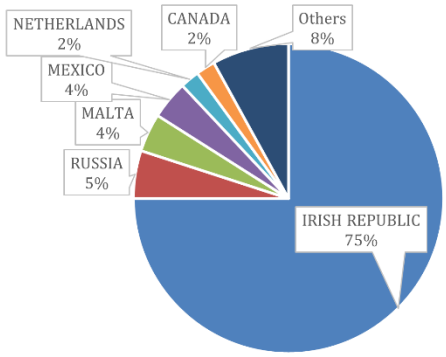

Fig. 3. Primary sources of imported metal scrap: An overview of key supplier countries for the UK (Source: ISSB)

Examining production data from the last five years reveals that 80% of the approximately 8 million metric tons of steel produced annually in the UK is sourced from blast furnace processes, with the remaining 20% coming from electric arc furnace methods [12].

Among the findings from stakeholder engagements, challenges at the upstream include difficulties related to the quality of materials available in the UK market, where scraps are sourced. These materials are often of inferior or low quality due to the existing infrastructure and a focus on quantity rather than quality. This has led to ongoing issues between steel producers in the UK and the local steel market. Meanwhile, contrary to the information that metal producers tend to source scrap metals for their EAF production from international markets due to the perceived low quality of UK-processed metal scraps, another reason discovered is that UK metals producers are hesitant to invest in higher-quality scrap materials from the domestic market, primarily because processing scrap in the UK is more expensive compared to countries like the United States, Germany, and France. However, it is worth noting that European Metal Recycling (EMR), a global scrap metal company, is collaborating with Tata Steel to address the cost issue through the RECTIFI project [13]. This initiative is focused on finding cost-effective methods for processing metal scraps in the UK to support the steel industry in reducing costs and advancing technology.

Furthermore, considering that the UK produces 6 – 7 million tonnes of steel yearly, reducing or substantially curbing the export of steel scrap from the UK presents challenges due to the lack of adequate infrastructure capable of handling the substantial annual volume. In addition to the £500 million government support package to Tata Steel for green steelmaking in Port Talbot [14], this is an opportunity for the UK government to play a significant role by enforcing the use of recycled materials among steelmakers and other metal producers. The government can achieve this by assisting in the establishment of storage facilities for bulk stocks and EAFs to enable the local processing of scrap metals to the required level of quality. Such an initiative can foster sustainability and circularity, a huge reduction in dependence on virgin materials, contributing effectively to supply chain resilience and achieving the goal of net-zero GHG emissions.

At the downstream, the challenges discovered are about controlling scope 3 emissions in delivering circularity solutions for customers, especially in the construction industry. It is essential to incorporate considerations for scope 3 emissions when implementing circular steel solutions. Another notable challenge is the traditional linear economy design which does not account for what happens to materials at the end of their life cycle. This calls for the need to recover critical resources from by-products, recognising that circularity is a facilitator of net zero, not the other way around. In terms of the challenge around collaboration, to achieve circularity and net-zero targets, OEMs (Original Equipment Manufacturers) need to collaborate more effectively, setting competition aside, and working together to find solutions to supply chain challenges.

In addition, the regulations mandating automakers to establish a closed-loop supply chain for battery materials, as illustrated in the timeline shown in Fig. 4 [15], present a significant opportunity for the UK metals industry to develop refining and recycling capabilities beyond the current level to support the emerging automotive EV supply chain. This development will help cater to the increasing domestic requirements for the envisioned UK batteries gigafactories in the near future, especially given the global surge in demand for EVs. This surge is resulting in a growing need for battery materials such as cobalt, lithium, nickel, manganese, and others. Projections indicate that demand will rise substantially, increasing from this year's 6 million tonnes (projected) to an estimated 17.5 million tonnes by 2030 [16].

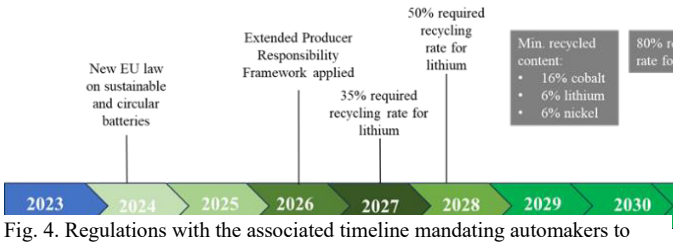

Fig. 4. Regulations with the associated timeline mandating automakers to close the battery materials loop (Source: [15])

From SMEs' perspective, some crucial challenges related to circularity and decarbonisation were highlighted. These include the absence of synergy among stakeholders in terms of information sharing which arises due to the economic sensitivity of the business environment. Moreover, SMEs are grappling with the heightened expenses associated with adopting environmentally friendly practices. The shift to renewable energy sources to power facilities, as well as the adoption of battery-powered vehicles for freight, incurs more significant costs compared to traditional systems. This additional financial strain is compounded by high corporation taxes, making it challenging to cover staffing and overhead expenses. Consequently, many SMEs find themselves with no alternative but to cease operations. The government could play a pivotal role in alleviating the cost burden on SMEs by reducing taxes and offering incentives. These measures would enhance the feasibility and efficiency of implementing circularity and net-zero goals within the business sector.

From the policy perspective on the heavy corporation tax burden faced by SMEs in the metals industry regarding supply chain decarbonisation, findings revealed that the government

cannot selectively provide a more favourable tax environment for a specific industry. The request for such consideration must be a collective effort from all industries; otherwise, it would be swiftly dismissed. The government's focus extends beyond metals, encompassing all industries, including addressing broader social issues. Consequently, decisions regarding tax environments are made in the broader context of all businesses. However, the metals industry has repeatedly urged the government to impose restrictions on the export of scrap metals from the UK. Yet, the government faces significant challenges in developing policies in this direction as outlined in the following two major points:

Resource Dependency and Protectionist Trade Policies:
The UK government, not being resource-rich and having depleted a bulk of resources during the Industrial Revolution, relies on the global market for its needs. Metal scrap is the UK government's primary resource, exceeding its domestic requirements by millions of tonnes, and is in high demand globally. Implementing restrictions on scrap exports would contradict the government's stance against protectionist trade policies, making it challenging to advocate for open trade while restricting a key resource. Navigating this complex political and policy framework makes deciding on scrap export restrictions an exceptionally challenging task.

Impact on Scrap Prices and Industry Dynamics:
Another challenge with export controls is the potential lowering of scrap prices in the UK. If scrap yards are unable to export, they will be compelled to sell domestically, leading to a competitive reduction in prices. This scenario forces the government to balance support for the primary metal production industry against the scrap industry, which employs more workers and plays a crucial role in the economy [17]. Determining which industry is more beneficial, considering their economic contributions, becomes a dilemma. The government is yet to reach a conclusion on this matter, exploring solutions to overcome the hurdles and challenges associated with controlling exports while still considering the interests of the scrap industry.

Meanwhile, the government is actively addressing scrap-related issues, particularly challenging steel producers on the type of scrap used and the tolerance level of residuals. To support Tata Steel UK's transition to EAFs for steel production, there is a push to increase the scrap ratio to DRI to up to 50%. This shift is essential for dismantling blast furnaces and aligning with the move towards a circular economy. There is a significant demand for prime scrap, particularly to fulfil the needs of EAFs charging a substantial annual steel production volume. This demand is crucial for specific applications that necessitate a low residual tolerance level. However, despite ongoing efforts, there is a need for further exploration of the connection between residual levels of prime scrap and the amount of virgin materials used in furnaces. Establishing this link and exploring options for enhancing prime scrap size through better sorting techniques or source separation are critical steps in advancing resource efficiency and circular economy goals.

3.2. Major barriers to closing the supply chain loop

Several barriers to metals recycling/refining capability development in the UK were identified in the course of this research with a good number of them mentioned in Section 3.1, however, the major ones requiring urgent attention are highlighted as follows:

- Export Dependency: The UK exports over 8 million metric tons of scrap metals annually, hindering the development of a domestic circular supply chain. Exporting scrap metals contributes to significant CO_2 emissions from logistics and poses challenges to achieving sustainability goals.
- Infrastructure and Technology Gaps: Insufficient infrastructure and technology hinder the storage and supply of prime scrap domestically. The lack of facilities for processing and storing prime scrap in the UK limits the transition to EAFs that rely more on scrap materials.
- Limited Circular Economy Adoption: Industries are slow to transition to circular material flows, and a significant percentage of generated scrap is exported due to the main focus on profitability rather than the net-zero goal. Circular economy practices, essential for net-zero goals, are not fully embraced due to factors such as a lack of infrastructure and technology.
- Information Sharing and Collaboration: Poor collaboration and information sharing among industry stakeholders, including Original Equipment Manufacturers (OEMs), to collectively address supply chain challenges and achieve circularity goals.

3.3. Opportunities for building a circular and resilient supply chain

Despite the barriers, there exist opportunities for enhancing the circularity and resilience of the metals supply chain in the UK. The attendant opportunities to the major barriers listed in Section 3.2 are highlighted as follows:

- Circular Supply Chain Development: Developing a circular supply chain for metals within the UK, reducing dependence on exports and enhancing domestic sustainability. This will lead to improved environmental sustainability, reduced CO_2 emissions from logistics, and increased resilience against global market fluctuations.
- Enhanced Scrap Quality and Sorting Techniques: Invest in technologies and practices to improve the quality of domestic scrap materials through better sorting techniques or source separation. Higher-quality scrap materials can meet industry standards, facilitating the transition to EAFs and supporting circular material flows.
- Government Support for Infrastructure: The government can invest in infrastructure, including

EAF plants and storage facilities, to support the transition to a scrap-based supply chain. This will improve capabilities for the domestic processing of scrap metals, fostering sustainability and circularity.

- Collaboration in the Industry: Encourage collaboration among Original Equipment Manufacturers (OEMs) and industry stakeholders to find solutions to supply chain challenges. Effective collaboration can lead to innovative solutions, addressing issues such as material quality, scope 3 emissions, and achieving circularity goals.
- Circularity in Battery Recycling: Support and incentivize companies, like Altilium, a pioneer in battery recycling to establish closed-loop supply chains for critical battery materials. This will lead to increased self-sufficiency in battery materials, reduced reliance on primary metals, and support for the growing demand in the electric vehicle sector.

3.4. Decarbonisation strategies and sustainable practices in steel production

The metals recycling sector plays a crucial role in assisting the steel industry and other metals smelted in the UK in their decarbonization efforts. The recycling of metal results in an 80% reduction in CO_2 emissions compared to production from raw materials [18]. Also, recycling steel consumes 70% less energy than mining and refining virgin ore, emphasising the environmental benefits of recycling practices [18]. As the demand for scrap is expected to surge with the global shift to green steel production, aligning domestic policies with circular material flows becomes imperative.

The environmental impact of steel production is a pressing concern, with every ton of steel produced in 2018 emitting an average of 1.85 tons of carbon dioxide, contributing to approximately 8% of global carbon dioxide emissions [18,19]. To mitigate this, the UK, as a developed economy, should focus on the role of scrap in reducing industry emissions and resource consumption. Notably, every tonne of scrap used for steel production avoids the emission of 1.5 tonnes of carbon dioxide and reduces the consumption of 1.4 tonnes of iron ore, 740 kg of coal, and 120 kg of limestone [20].

The recent introduction of the Carbon Border Adjustment Mechanism (CBAM) by the European Union in October 2023, with plans to phase in starting from 2026 [21], signals a significant step in penalising high carbon-intensive producers globally. While the UK's version is still in the consultation phase [22], it is clear that CBAM is just the beginning of addressing carbon leakage, and additional mechanisms are expected in the near future. The policy's expansion to cover other materials reinforces the idea that offshoring will be a short-term solution, emphasising the need for industries to adapt to a changing regulatory landscape [21]. Despite the complaints that the UK metals recycling sector is not adequately meeting domestic demands for scrap materials, about 80% of the generated scrap is exported. This has been attributed to a lack of infrastructure and technology to store and supply prime scrap. To support the UK steel industry's transition to net zero, the government should focus on policies that strengthen transitioning to EAFs that rely more on scrap materials.

In 2021, 71% of global steel production originated from blast furnaces, with only 29% derived from EAF [23]. The global trade of ferrous scrap in 2022 reached 97.6 million tonnes [24], with China being the world's largest consumer, consuming 215 million tonnes of scrap in the same year [24]. The adoption of carbon capture, utilisation and storage (CCUS) technology in the steel industry remains limited, with only one large-scale operational facility as of June 2022. This is an 800 kt per year CO_2 capture system at the DRI plant of Emirates Steel in the United Arab Emirates. The CO_2 from the DRI unit is compressed, dehydrated, and piped to an onshore oil field. It is then used for enhanced oil recovery through CO_2 injection [20]. While CCUS holds promise for emissions reduction, broader deployment in steelmaking has yet to materialise beyond this initial demonstration plant.

Additionally, the UK's target to transition to fully electric vehicles by 2035 brings attention to material security and circularity challenges. This would require a major proportion of global reserves of key battery metals like nickel, cobalt, manganese, and lithium, which are finite. Within 5 years post-2035, UK EV metals demand could exceed total EU demand [25]. Reliable EV supply chains will therefore necessitate extensive battery recycling and reuse domestically. If the UK can retain and recirculate EV battery materials in a closed loop, imports of primary metals could be balanced by 50% of secondary materials from recycling by 2045 [25]. This demonstrates the imperative and opportunity for the UK to lead in establishing circular material flows to enable the EV transition. The UK government has implemented various schemes to support British industries, including the Energy Bills Discount Scheme [26] and the Industrial Energy Transformation Fund [27].

Also, with the global vision to install approximately 12,000 offshore wind units by 2025, representing 3.5 million tonnes of steel in foundations [28], there is a growing need for sustainable practices in steel production. The concept of "green steel" becomes crucial, and the adoption of direct reduced iron (DRI) production utilizing hydrogen is seen as instrumental for manufacturing high-purity steel grades in a carbon-neutral fashion. This transition, however, is incremental, requiring customer acceptance and demand for low/zero-carbon steel products [29].

To facilitate the shift towards sustainable steel production, a strategic partnership between energy providers and the manufacturing sector is essential. The steel sector's significance in the UK underscores the need for proactive policymaking. Policymakers should guide the steel industry and investors toward a climate-aligned trajectory, utilizing technologies such as green hydrogen, biomass, electrification, and carbon capture, utilization, and storage (CCUS) [30]. However, such a transition demands substantial investment, with an estimated USD 2 trillion required over the next thirty years to ensure an adequate supply of zero-carbon electricity and green hydrogen for the steel sector [31].

The Mission Possible Partnership (MPP) and the International Energy Agency (IEA) have identified key

solutions to help meet steel demand while lowering associated greenhouse gas (GHG) emissions from production. Top priorities include transitioning suitable production to electric arc furnaces (EAF) using decarbonised electricity, integrating green hydrogen, and adopting carbon capture and storage (CCUS) technologies. EAF adoption has a relatively low risk and an estimated abatement potential of 1.7 $GtCO_2$ eq per year by 2050. By using renewable energy, EAF production can significantly reduce emissions compared to conventional blast furnace routes. However, scaling up high-quality steel recycling and scrap supply will be crucial to enable the transition to EAF methods. Green hydrogen and CCUS solutions face higher uncertainty but are critical complementary measures to cut emissions across primary and secondary steel production [32]. Pursuing these solutions concurrently in a strategic manner can enable the steel industry to achieve drastic decarbonization.

Fig. 5 presents a comparison of CO_2 emissions and energy intensity among three distinct global steel production methods: Blast Furnace-Basic Oxygen Furnace (BF-BOF), scrap-based Electric Arc Furnace (EAF), and Direct Reduced Iron (DRI)-based EAF [33]. The data clearly illustrates that the scrap-based EAF production route stands out as the superior method, displaying significantly lower CO_2 emissions and energy intensity values which are notably below the global average values.

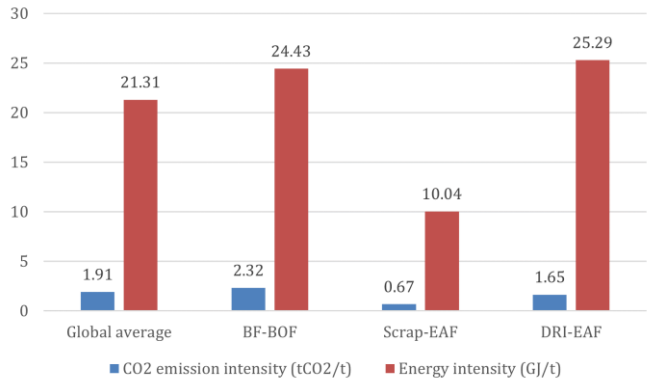

Fig. 5. CO_2 emissions and energy intensity values of global steel production routes vs. global average (Source: [33])

4. Conclusion

This research underscores the environmental benefits of transitioning from traditional metal production methods to circular material flows. By promoting the recycling and refining of metals, particularly through EAFs, there will be a substantial reduction in CO_2 emissions, aligning with the UK's net-zero greenhouse gas (GHG) emissions (96% emissions reduction) goal by 2050. Also, opportunities for domestic circular supply chains have been identified with the potential to enhance the economic resilience of the UK metals industry. By reducing the export dependency on scrap metals, this research envisions a more robust and sustainable industry that contributes positively to the country's GDP.

Through a comprehensive investigation of the current state of the UK metals industry and engagements with stakeholders, this research advocates for the adoption of circular economy principles. By emphasising the economic and environmental benefits of circular material flows, a paradigm shift towards more sustainable practices is encouraged. Additionally, the challenges related to the quality of domestic scrap, infrastructure gaps, and collaboration within the industry have been brought to the limelight. Advocating for government intervention, incentives, and collaborative efforts will contribute to the development of a resilient and efficient supply chain that can withstand global market fluctuations.

The focus on recycling critical battery metals for electric vehicles aligns with the UK's target to transition to fully electric vehicles. Promoting resource efficiency and security through extensive battery recycling and closed-loop supply is envisioned to yield a more sustainable and self-reliant approach to meeting the growing demand for EV materials.

Therefore, this research anticipates a transformative impact on the UK metals industry, fostering sustainability, circularity, and resilience. Influencing industry practices, policies, and innovation will contribute to the broader societal goal of achieving a net-zero carbon footprint while ensuring the long-term viability of the metals sector in the UK.

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