UKRI Interdisciplinary Centre for Circular Metals

Brunel University London

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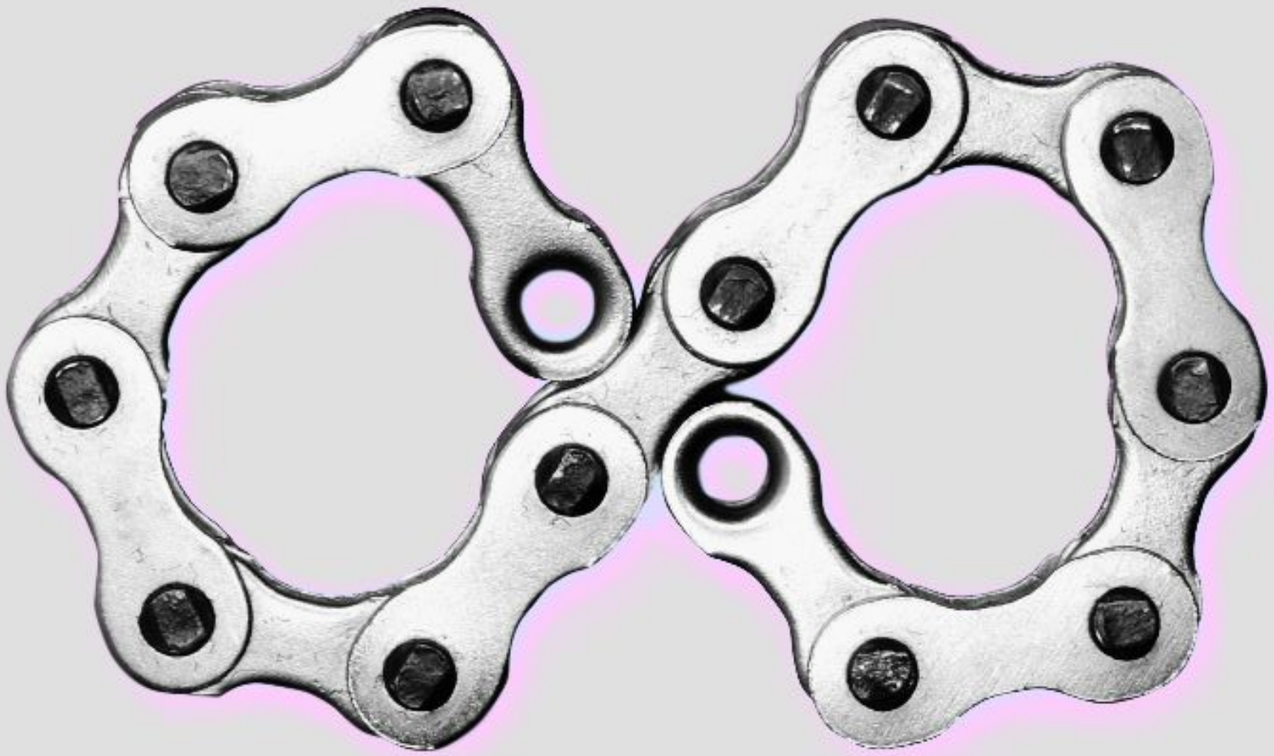
NICER PROGRAMME

UKRI UK Research and Innovation

Navigating the Transition: Pathways to a Circular Metal Economy in the UK



About this progress report

This progress report presents some initial findings of the WP3 'Circular Business' of the UKRI Interdisciplinary Centre for the Circular Metals. The aim of the centre is to transform the metals industry and make the UK the first country in the world to have a fully circular metals system.
The purpose of this progress report is to present a set of visions of how circular economy can transform the metal value chain in the long-term. progress report presents 12 visions for 2050 and discusses the most significant challenges and opportunities that might respectively hinder and support the shift to those visions.
The progress report is the result of research activities that brought together leading experts from academia, industry, and government to explore how the UK could transition to a circular metal economy.

For environmental reasons, this progress report should not be printed because it contains numerous photographs and was originally meant to be a digital edition.

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2050 - Circular Metal Visions

In our initial report in this series, we have outlined 12 preferable visions that reflect the objectives of stakeholders in achieving a complete circular metal economy by the year 2050. These concepts have served as the basis for our collaborative endeavours and are enhanced by over sixty "snapshots from the future." Visions and "snapshots from the future" are conveyed through narratives and visual depictions that illustrate the methods by which we can attain the desired future. Furthermore, our analysis discusses the opportunities and obstacles linked to each vision, as identified by experts. These activities were essential for enabling stakeholders to envision and conceptualise the future we are striving for, and to generate alternative strategies for achieving that future. This report aims to identify shared goals for achieving a circular metal economy by 2050, taking into account the perspectives of many stakeholders in the UK.

Navigating the Transition: Pathways to a Circular Metal Economy in the UK

In our second report in this series, we have carefully presented a collection of essential roadmaps, each aligned with the visions initially outlined in our first report. These roadmaps function as strategic blueprints, outlining the trajectory towards the achievement of each vision. Each roadmap contains comprehensive information on at least three significant milestones, carefully developed through collaboration with various stakeholders integrated into the UK metal supply chain. These milestones resulted from a in-person co-design session, where stakeholders provided useful input. Furthermore, our research provides a thorough collection of activities and sub-objectives within each milestone, precisely formulated to guide the complex path towards realising the preferable circular metal future by 2050. Although these milestones do not cover all possible activities, they provide a comprehensive overview of the diverse actions that stretch both upstream and downstream within the metal supply chain, as well as across crucial points in the broader supply chain ecosystem.

Circular Business Models for Metals

In our third report, we have carefully collected a list of over sixty circular business models tailored for the different sectors across the whole circular metal supply chain. By drawing inspiration from the previously defined 12 visions and doing desk research on potential circular business models, we categorised several business models for each single vision. We conduct a comprehensive analysis that goes beyond simply identifying these models. We thoroughly examine their internal operations, clarifying the complexities of how value is created and delivered. In addition, we identify the primary parties involved, including solution providers and the various client segments involved in these circular initiatives. To demonstrate how business models are put into practice, we offer concrete examples from real-life situations. In addition, our report presents a thorough framework that classifies these models according to ecosystem levels (macro, meso, micro), circular strategy levels (narrow, slow, close, mitigate, inform), stakeholder engagement levels (institutional, socio/cultural, organisational, technological), and technological readiness levels (emerging, niche, growth, mainstream innovation). This research aims to create a practical manual for businesses looking to transform their operating models and take advantage of the possibilities of circularity in different sectors of the metal supply chain.

CONTENTS

INTRODUCTION

UK government's climate goals and the metal industry's role - The UK Government's ambitious climate target, aims for a 78% emissions reduction by 2035 to achieve net-zero by 2050[1, 2]. This goal is not just aspirational but necessitates a paradigm shift across various sectors, most notably in industry, innovation, and infrastructure[3]. In this context, the metals industry, comprising predominantly of steel and aluminium sectors, emerges as both a critical player and a challenge in this transition. While these industries are indispensable for the development and implementation of green technologies, their operations are also major contributors to global warming[3]. Future projections indicate a staggering increase in demand for these metals, with aluminium expected to rise by 215% and steel by 86% by 2050[4]. This report presents different strategies that the UK government and stakeholders in the metal supply chain, specifically in the steel and aluminium sectors, could employ to effectively achieve the climate target of the UK.

Circular Economy as a Strategic Approach - In response to these challenges, our report introduces the circular economy (CE) model as a strategic and sustainable approach to ensure the future availability of metals, critical for meeting the UK's net-zero ambitions. The concept of CE advocates for the elimination of waste and pollution, and encourages a regenerative approach throughout all stages of the materials lifetime. Implementing CE principles in the metals business necessitates an in-depth understanding of the complete supply chain, which includes the metal and product manufacture, logistics, usage, recovery, and recycling stages[5, 6]. Nevertheless, adopting this paradigm is not without of its difficulties. It requires changing a number of previously established linear social, economic, environmental, and legal parameters.

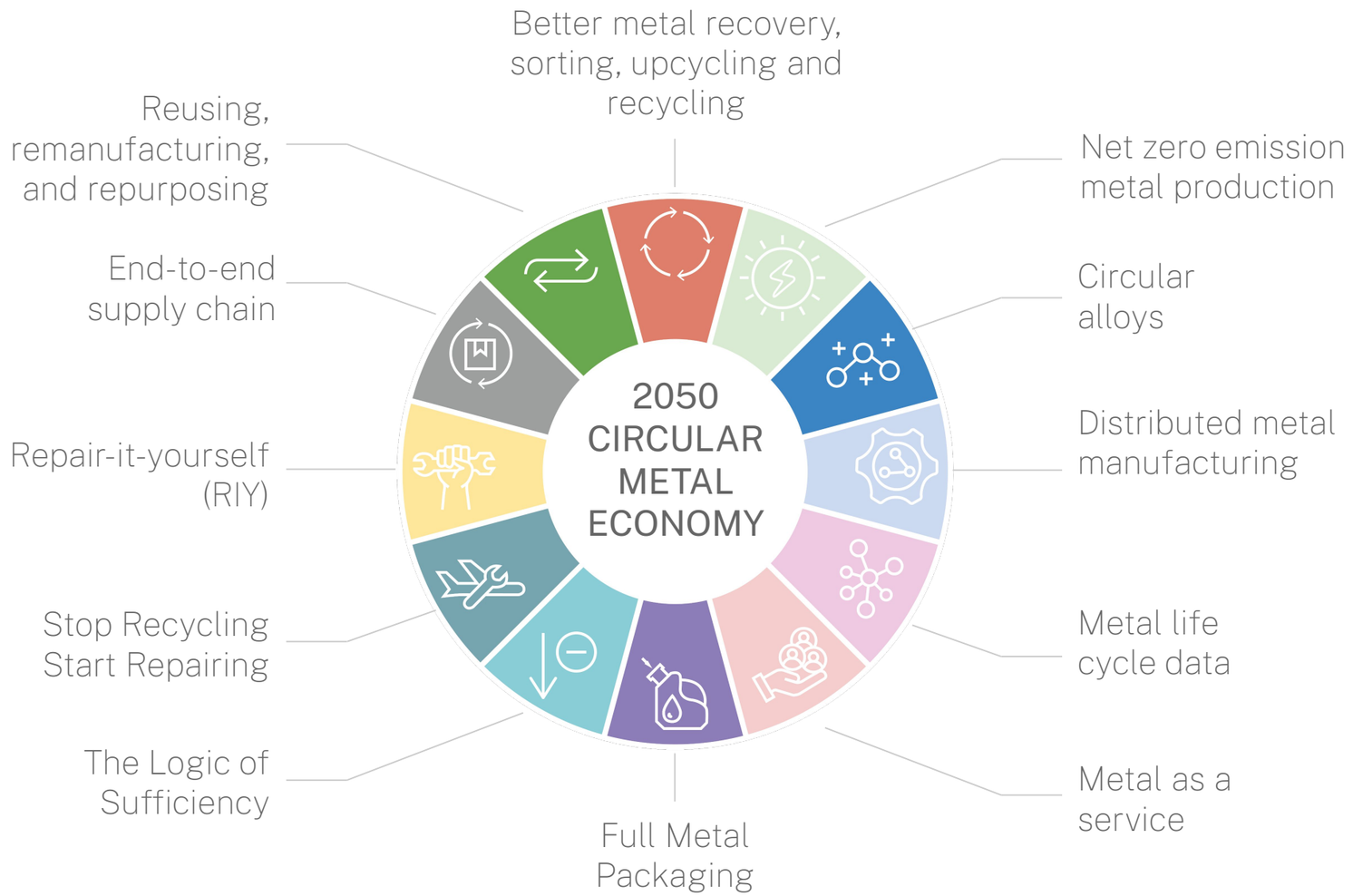
Research Methodology and Co-Design Workshops - The foundation of this report lies in the extensive research conducted throughout 2022/23, which involved collaborations with a broad spectrum of stakeholders in the metal supply chain. Central to our research methodology were two co-design workshops. The first, conducted online on 9th February 2022, brought together 29 experts to discuss the barriers and opportunities in transitioning to a circular metal economy. The second workshop, held in-person on 24th November 2022 in Westminster, London, expanded the discussion with 32 participants, focusing on detailed action planning and implementation pathway strategies. These workshops were instrumental in understanding the diverse perspectives and challenges in the industry, fostering collaboration, and co-ideating on effective solutions for the transition challenges.

Findings and Strategic Recommendations - The insights garnered from these workshops were deep and significant. They highlighted the need for a cohesive and comprehensive approach to address the challenges and leverage the opportunities in the metal industry. The workshops, based on 12 visions[7] we previously defined (see framework on page 5), not only provided a platform for stakeholders from various sectors to collaborate but also helped in identifying key interventions and actionable steps necessary for a transition towards a fully circular model. Each of the 12 visions, representing a broad spectrum of the metal supply chain, played a pivotal role in guiding the discussions and formulating strategic plans. This report details the pathway strategies for each vision, with a thorough analysis covering technological, economic, regulatory, and social factors, thus providing an initial roadmap for the industry's transition.

Synthesis and Future Directions - This report synthesises the outcomes of the co-design workshops into a coherent framework, outlining various milestones and corresponding actions based on the 12 preferable visions. Recognising the overlap in some milestones, we have highlighted the most relevant and frequently mentioned ones that are crucial to achieve by 2050. The overarching aim of this work is to present a comprehensive overview of the progress and findings to date. By offering an in-depth analysis and a holistic view of the sector's transition challenges and opportunities, the report aims to be a guiding document for

policymakers, industry leaders, and stakeholders in their journey towards a sustainable and circular metal economy in line with the UK's climate goals.

Guidance on interpreting the twelve pathway strategies - In the upcoming sections of this report, each of the 12 visions is outlined through a detailed pathway strategy, developed based on expert inputs during our co-design workshops. These strategies encompass specific milestones and actions. The milestones are shown by an arrow that is color-coded to match its related vision. The precise action associated with each milestone is displayed underneath the arrow. Milestones are categorised by four different lenses, that are economic, political/regulatory, technological, or social changes at the beginning of the arrow. The lens colour can be singular or a combination of two colours, indicating milestones that require a combined approach, like economic-regulative. The milestones and actions are further organised into short-, medium-, and long-term timeframes, with some spanning across multiple periods. Typically, short-term timeframes encompass more immediate, actionable changes, while long-term timeframes are reserved for larger infrastructural changes. For an in-depth understanding of each milestone, we included a short context explanation. Also, to connect this work with our previous one, we insert the "snapshots from the future" that illustrate the practical implications of each specific vision. To know more about our previous work, please check out our report “2050 - Circular Metal Visions”.



LENSES OF ANALYSIS

- Economic
- Political/regulative
- Technological
- Social

PROGRESSION HORIZON AND ICONS

Short-term (2024~2029)

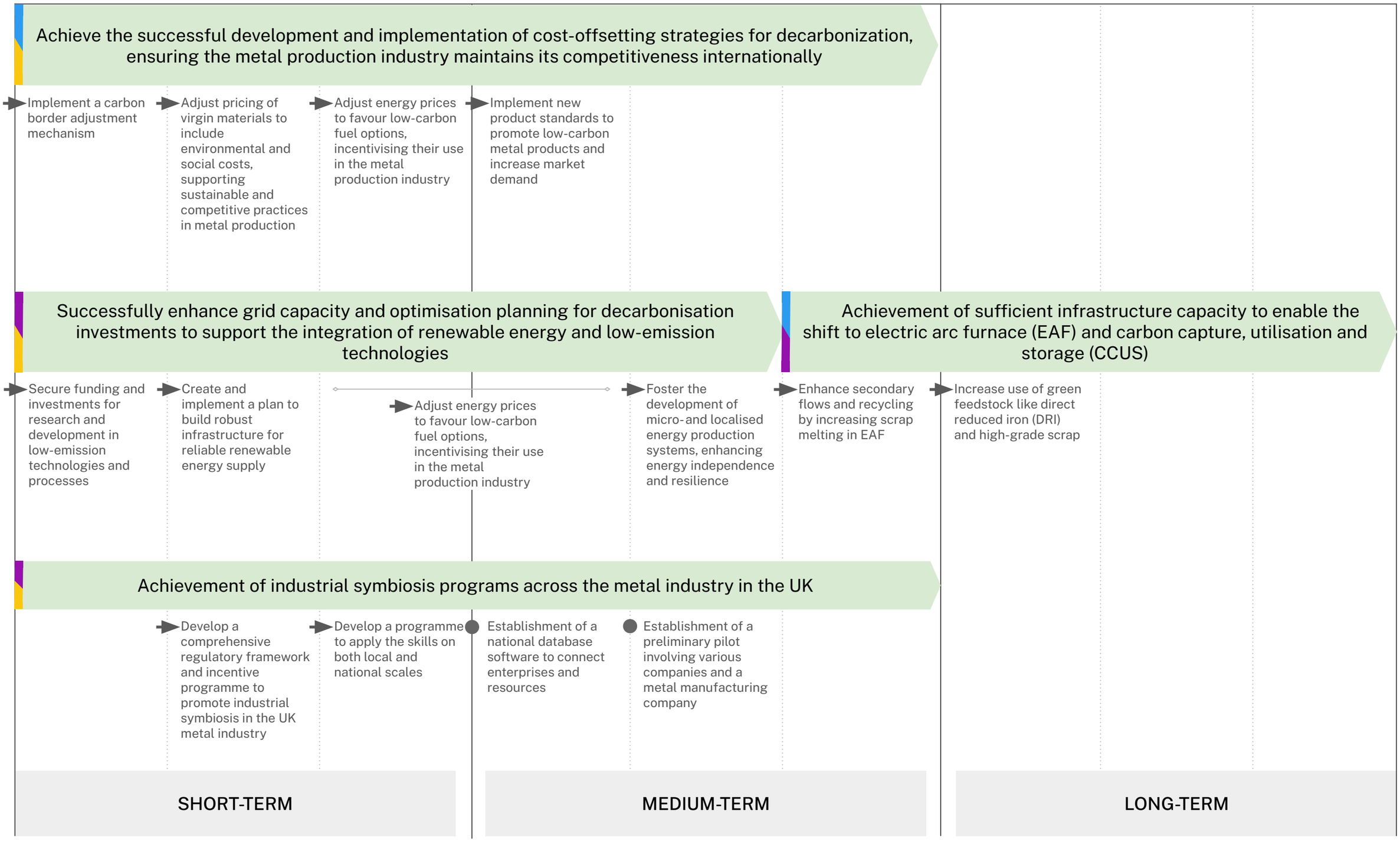
Medium-term (2030~2040)

Long-term (2041~2050)

- Action indicator
- Objective point
- Cross-term action line

VISION 01

Net zero-emission metal production



Keywords: Industrial Symbiosis; Green Metal Production; Closed Loop Systems; Resource Sharing; Waste Reduction; Energy Conservation.

Context Setting - This vision targets transforming the UK's metal production sector into a net-zero emission industry, emphasising decarbonisation to maintain global competitiveness amidst sustainable transitions. The steel and aluminium sectors, characterised by high emissions and investment demand, are notably challenging to decarbonise. They require the adoption of various emerging technologies, such as green hydrogen and carbon capture, which are still largely in developmental stages. Implementing these low-carbon technologies necessitates a robust climate transition finance strategy by the government, supported by a conducive ecosystem and de-risking measures for substantial investments.

Snapshots from the future related to this vision - 1. Green Energy Metal Making; 2. Hydrogen-powered metal manufacturing; 3. CO2 capture and reuse; 4. Industrial Symbiosis.

Pathway strategy - The first milestone is about achieving the successful development and implementation of cost-offsetting strategies for decarbonization, ensuring the metal production industry maintains its competitiveness internationally. Failing to address this challenge through the adoption of innovative practices could very well precipitate a trajectory where direct industrial emissions stemming from metal production serve as a catalyst for an upward surge in CO2 emissions. The impetus for embarking on this journey toward decarbonisation in the metal industry derives from a confluence of factors, including the diminishing costs associated with cleaner technologies, heightened environmental regulations, and the proactive engagement of industry stakeholders in voluntary climate mitigation initiatives. However, this transformative process can be further stimulated and accelerated by the proactive implementation of targeted regulatory measures and collaborative efforts across the metal production sector and its regulatory bodies. Recommendations put forth by experts in our co-design workshops as viable solutions for the short, medium, and long-term include carbon pricing implementation, promotion of sustainable practices, and establishment of energy incentives.

The second milestone involves the successful enhancement of grid capacity and the optimisation of strategic planning for decarbonisation investments. This initiative is pivotal in facilitating the seamless integration of renewable energy sources (e.g., wind and solar PV) and storage (e.g., lithium-ion batteries, green hydrogen, etc.) and low-emission technologies into the metal production sector (e.g. electric arc furnace (EAF), hydrogen-fueled production, and carbon capture, utilization, and storage (CCUS)). To achieve this milestone effectively, there is a pressing need to foster the development of micro-and localised energy production systems. This approach not only bolsters energy independence but also enhances resilience, which is indispensable for supporting the broader goals of decarbonising the energy system and establishing a robust metal production sector in the UK.

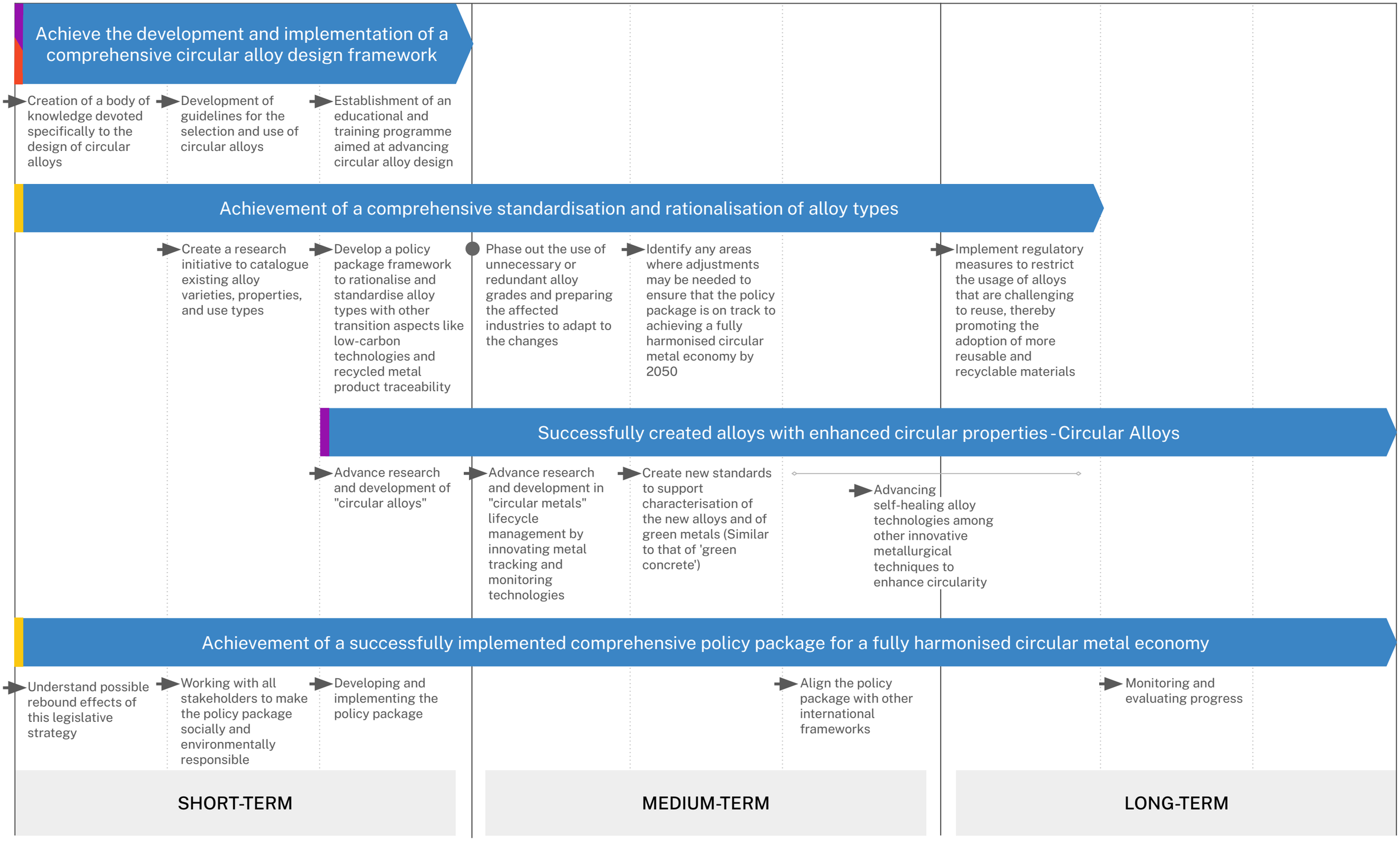
Having the necessary infrastructure in place is crucial to achieve the third milestone, that is centred in shift to EAF technology and the implementation of CCUS systems. This critical phase entails establishing the essential infrastructure to enable the use of EAFs for steel production and the capture, utilization, and storage of carbon emissions generated during these processes. Key components of this infrastructure may include the construction of pipelines for transporting captured carbon, storage facilities to securely store it, and the development of power generation and transmission systems capable of supplying the necessary energy to operate EAFs and CCUS equipment effectively.

The fourth and final milestone is a crucial step in building a more linked and sustainable ecosystems within the sector by establishing and widening industrial symbiosis practices. Industrial symbiosis involves the cooperation and exchange of by-products (e.g., slags, dusts, mill-scales and sludges) between various industrial organisations, resulting in synergistic effects that result in waste reduction, improved resource efficiency, and reduced environmental impact. Within the metal business, this entails establishing collaborations among metal manufacturers, suppliers, and end-users to enhance material efficiency, reduce waste production, and advocate for circular methodologies. The achievement of this significant milestone will be driven not only by the advancement of specialised programmes, but also by the implementation of national database software that facilitates the connection between businesses and resources, as well as collaborative initiatives where companies can collaborate.

This pathway approach focuses primarily on harnessing the transformative capabilities of advanced technologies in the metal production industry. The ultimate goal is to enable the industry to function with minimum or zero CO2 emissions. It is important to mention that most of these innovative technologies are now in the experimental stage and are not yet easily accessible in the market. In order to close the gap between experimentation and practical implementation, significant innovation efforts must be done in the next decade. It is essential to acknowledge that the successful advancement and commercialisation of these state-of-the-art technologies are key factors in attaining substantial reductions in industrial CO2 emissions.

VISION 02

Circular alloys and manufacturing



Context Setting - This vision targets a profound re-evaluation of prevailing norms in alloy design and manufacturing within the field of metallurgy. Despite its extensive history, metallurgy has generally followed a well-established developmental trajectory, often characterised as "mature" and lacking substantial innovation. However, the imperative shift towards a sustainable and circular economy necessitates innovation not solely along the supply chain but also at the molecular level. This new way of thinking about alloy development is fundamental to this paradigm shift. Materials with improved characteristics allow for more effective maintenance, reuse, and endless recycling, which is the first step towards a molecular level circular economy. This transformation carries particular significance for the UK, which heavily relies on metal imports. It underscores the urgency of adopting innovative strategies to secure a more sustainable and self-reliant future in metal production, aligning with the nation's broader sustainability objectives.

Snapshots from the future related to this vision - 1. Rationalisation of alloy grades and use; 2. Closed metal loops enabled by multi-principal elements alloys; 3. Metal nanomanufacturing for multipurpose alloys; 4. AI-driven metal material optimisation; 5. Self-disassembly metal components; 6. Zero Defect: Computer vision to predict quality defects.

Pathway strategy - The initial milestone revolves around the establishment of a comprehensive circular alloy design framework within the short-term horizon, under the purview of governmental authorities. This framework aims to provide clarity to all branches of government and relevant stakeholders, enabling strategic planning and facilitating a structured transition process. In the short-term, such a framework can serve as the foundation for a cohesive national vision encompassing all stakeholders within the metal supply chain. It plays a pivotal role in defining the objectives that will steer the long-term transition. These long-term objectives must be meticulously aligned with quantifiable targets and policy measures defined in the fourth milestone to ensure effective implementation. Moreover, the framework should also encompass the short-term social dimension of this transition, particularly with regards to educational aspects, fostering a holistic approach to sustainable change.

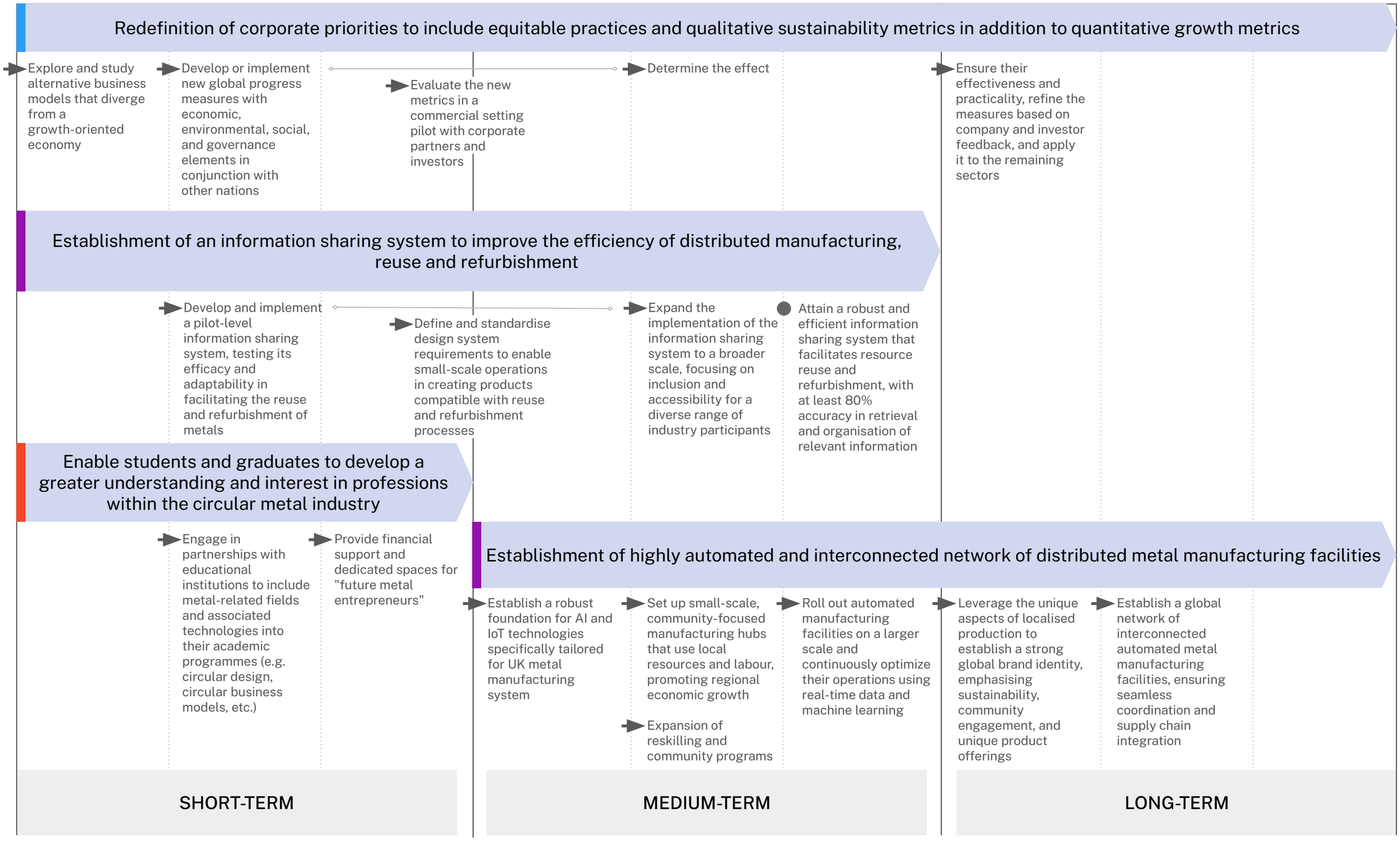
The second milestone focus on pursuit of a comprehensive standardisation and rationalisation of alloy types. Industries operating across multiple nations necessitate standardisation measures to ensure seamless interoperability. The lack of globally accepted standards can hinder the broad use of circular and rationalised alloys, especially in downstream processes (e.g. recycling). The formulation of these standards in the short-term has the potential to expedite the reduction in the variety of alloy types available in the market. This, in turn, can incentivise the use and application of more circular alloy solutions in the long-term. Also, in the long-term, the government should regulate and oversee the utilisation of alloys that possess limited reusability and recyclability.

The third milestone takes a more practical approach, focusing on the production of alloys that have enhanced circularity characteristics. Due to the complex and extensive nature of research, development, and implementation, this milestone spans a significant period of time and involves a diverse path towards its ultimate goal. Investing strategically in research and development has the potential to accelerate the advancement of circular alloys. These alloys are not only suitable for easier recycling processes, but they also demonstrate improved repairability, which is in line with the overall objective of Vision 8, "Stop Recycling, Start Repairing." Long-term integration of such alloys requires both technological improvements and the implementation of relevant legislation. Gaining knowledge on how to handle and control alloys that already exist in the ecosystem, as well as creating efficient methods to differentiate alloys at the end of their lifespan, will be crucial in achieving this important goal.

The fourth milestone is focused on the achievement of a successfully implemented comprehensive policy package for a fully harmonized circular metal economy. Such policy would need to be designed to respect the regulatory frameworks defined in the first milestone. This is essential to ensure that all stakeholders are effectively guided and that the established circular principles and practices are consistently adhered to throughout the metal production sector in the short-term. Furthermore, it is imperative to align the policies of other international trade frameworks, such as those established by the World Trade Organisation, in order to ensure the smooth integration of a global circular metal economy. The harmonisation will promote international collaboration, commerce, and the implementation of circular practices across nations, guaranteeing a smooth shift towards a sustainable and circular metal production industry.

This approach primarily aims to establish favourable conditions for the metal sector to promote innovation through metallurgical science and policy. This will ultimately drive change through investments in research and development, as well as the establishment of regulatory frameworks to facilitate the implementation of new infrastructure and technologies.

Distributed metal manufacturing



Context Setting - This vision seeks to transform the manufacturing of metal products sector in the UK into a technologically advanced, decentralised network that enhances system interoperability. The approach interconnects technological and local economic, social and cultural transformation by integrating distributed production systems with the Internet of Things, Big Data and Artificial Intelligence. This integration facilitates advanced variant configuration, giving the industry the agility to produce customised products close to the consumer with optimal efficiency. Furthermore, such a distributed network promotes a solid local economy, characterised by resilience and self-sufficiency. It catalyses a series of cascading actions, including digital engagement and decentralization of service delivery. An ever-widening range of digital-based services could lead to the territorial servitization of local production systems, making them robust and independent from large-scale oligopolistic service providers.

Snapshots from the future related to this vision - 1. Resilient local economies; 2. Fablabs for metal products and components; 3. Distributed additive manufacturing services; 4. Make to order/on-demand; 5. Mobile additive manufacturing repair labs; 6. Local fixing delivery.

Pathway strategy - The first milestone focuses on redefining company priorities to include fair practices and qualitative sustainability in addition to conventional quantitative growth indicators. Corporations, shareholders, and stakeholders all have important roles in redefining and evaluating company aims and strategies. Moreover, governments have a crucial role in assisting the attainment of this momentous milestone. They have the ability to offer financial support for research aimed at investigating alternative business models that deviate from economies focused on expansion. Governments can also generate immediate market demand for enterprises that prioritise these principles in the short and medium timeframes. Effective collaboration among governments, corporations, and civil society organisations is crucial for promoting sustainable and equitable objectives, with the possibility of targeting particular sectors or industries. In the long run, governments can oversee the advancement of these novel measurements and contemplate expanding or modifying them for other industries as well.

The second milestone is centred around developing a strong information exchange system to improve the efficiency of the distributed reuse and refurbishing processes. This milestone focuses on the development and implementation of a cutting-edge information exchange architecture, in line with Vision 11 - 'Reusing, remanufacturing, and repurposing'. In the short and medium-terms, government entities are tasked with crafting a strategy to define and regulate design system criteria for reuse and refurbishment, offering crucial support for these practices. This system undergoes rigorous testing to assess its effectiveness in promoting metal reuse and refurbishment within specific industries, serving as a crucial pilot phase. In the medium-term, there may be plans to broaden the system's scope, with a focus on making it more inclusive and accessible to a wide range of industry stakeholders. The main goal in the medium-term is to create a strong and effective information sharing system, aiming for a minimum of 80% accuracy rate in finding and organising relevant information. This achievement sets the stage for a future where the circular metal economy prioritises resource reuse and refurbishment within the local economies.

The third milestone focuses on fostering students' and graduates' increased awareness and enthusiasm for sustainable and varied professions within the circular metal sector. The main objective of this milestone is to establish collaborations with educational institutions in order to integrate metal-related subjects and associated technologies into their academic curricula, with a primary emphasis on short-term goals. Moreover, it entails the government offering financial support and designated facilities for potential "future metal entrepreneurs." This milestone is a crucial initial phase that establishes the foundation for the next milestone.

The fourth and final milestone centers on the development of a highly automated and interconnected network of distributed metal manufacturing facilities. This achievement is focused on industrial stakeholders and focuses on the creation of a consolidated infrastructure that can accelerate and facilitate the reuse and refurbish of used resources in the medium-term. To achieve this, it is essential to build a strong foundation for AI and IoT technologies specifically designed for the UK metal production system. It would be useful to create small-scale production hubs that give priority to the local community, using nearby resources and labour. This approach would stimulate regional economic growth and encourage reskilling and upskilling programs. Once the necessary infrastructure has been established, it is important to shift the focus from the local to the global. In this way, the UK has the potential to become a key player in the reuse and remanufacturing sectors.

In this strategy, it is crucial to emphasise the interconnectedness of technological progress with the essential responsibility of enhancing the skills and knowledge of the workforce to enable a smooth transition. This strategy is crucial because it forms the foundation for the implementation of other pathway strategies.

VISION 04

End-to-end supply chain

Realisation of a global circular metal economy supply chain sustainability reporting standard for enhanced transparency and industry-wide sustainability

- Developing a sustainability reporting standard and certification system
- Establish an international consensus concerning industry reporting
- Encouraging industry participation and rising awareness
- Implementing regulations and continuously monitoring and updating the standard
- Develop and implement a policy for VAT adjustments based on the sustainability rating, aligning economic incentives with environmental performance

Achievement of enhanced extended producer responsibility (EPR) through mandated manufacturer accountability for product life cycles

- Conduct a pilot project in a selected product segment to test and validate the sustainability rating system
- Optimise the rating system to ensure it is effective and suitable for different product types
- Implement the sustainability rating system across multiple sectors, aligning with the extended producer responsibility framework

Establishment of global regulations to prioritize local metal supply chains and reduce reliance on international trade

- Collaborate with international organisations and governments to promote policy changes that support the growth of domestic metal production and facilitate trade
- Research and development of localised supply chain models
- Establish incentives for businesses to develop local supply chain networks
- Invest in infrastructure that supports local metal repair, reuse and recycling and manufacturing facilities
- Implementation of economic incentives and penalties

Realisation of comprehensive data systems across worldwide metal supply networks

- Conduct extensive study to uncover technology gaps, evaluate tracking systems, and discover new data integration solutions for the metal sector supply chain
- Create a unified, centralised data platform that enables suppliers, manufacturers, distributors and recovery actors to exchange and collaborate on real-time data
- Establishment of an industry-wide standards for data collection, formatting, and sharing
- Develop and deliver training programs for metal sector employees
- Realisation of advanced technology integration, including blockchain, IoT sensors, and AI-driven analytics, to enable end-to-end tracking of materials and products across the supply chain

SHORT-TERM | MEDIUM-TERM | LONG-TERM

Context Setting - This vision aims at transforming the current linear supply chain into a circular end-to-end supply chain. A circular end-to-end supply chain entails the smooth incorporation of sustainable practices across the entire supply chain, encompassing activities such as raw secondary material reuse, manufacture, distribution, consumption, remanufacture. reuse and/or final recycling. Its primary objective is to eliminate inefficiency, minimise ecological footprint, and guarantee the conscientious utilisation of resources throughout all phases. Successful implementation of this transition necessitates the cooperation of all participants involved in the supply chain, adoption of advanced technologies, and a change in perspective towards sustainability and circularity. The ultimate objective is to establish a supply chain that is both economically effective and environmentally and socially responsible.

Snapshots from the future related to this vision - 1. Intelligent inventory management; 2. Supply chain sustainability reporting adopted by all businesses; 3. Service-oriented supply chain.

Pathway strategy - The initial milestone focuses on developing a global reporting standard for the metal industry to improve transparency and sustainability across the supply chain. This milestone is essential for conveying the impacts of businesses on the economy, environment, and people to an array of internal and external stakeholders. To progress in this direction, experts recommend that, in the short-term, an industry association or consortium should define a sustainability reporting standard and certification system. This involves establishing an international consensus on industry reporting and actively encouraging industry participation while raising awareness. Governmental entities and other relevant bodies should be engaged from the outset to implement actions in the medium-term. Experts recommend implementing regulations, continuously monitoring and updating standards, and developing policies for VAT adjustments based on sustainability ratings. This ensures economic incentives are aligned with environmental performance.

The second milestone emphasises the achievement of enhanced Extended Producer Responsibility (EPR) by holding manufacturers accountable for the entire life cycle of their products. While there is some disparity among experts regarding the timeline for this milestone in different visions (visions 5 and 12), it consistently emerges as a crucial aspect of the transition. Experts suggest that this milestone should occur in the short-term, with a focus on conducting a pilot project in a selected product segment to test and validate the sustainability rating system. Additionally, efforts should be made to optimise the rating system to ensure its effectiveness and suitability for various product types. Lastly, implementing the sustainability rating system across multiple sectors should align with the Extended Producer Responsibility framework, thus contributing to the overarching goal of enhanced producer accountability throughout the supply chain. This milestone is crucial to the realisation of the third milestone.

The third milestone entails implementing global regulations to prioritise local metal supply networks and reduce reliance on international trade. By decreasing dependence on global trade, the UK can enhance its resilience to economic fluctuations and geopolitical tensions. Additionally, supporting local supply networks stimulates regional economies, creates job opportunities, and strengthens domestic industries. Proposed medium-term initiatives by experts include collaborating with international organisations and governments to advocate for policy changes supporting domestic metal production and trade facilitation, as well as researching and developing localised supply chain models. To foster local supply chains, the government should provide incentives and invest in infrastructure improvements such as transportation networks, manufacturing facilities, and distribution systems. Furthermore, nurturing innovation and technology within local supply chains can bolster their competitiveness and resilience. Long-term strategies should include reinforcing these efforts and implementing economic incentives and penalties to sustain the transition.

Although the focus is on localisation and implementation of local supply chains, this is not always possible or desirable. For this reason, the final milestone entails the establishment of comprehensive data systems spanning global metal supply networks. While this milestone shares similarities with the first milestone of this vision and the second milestone of Vision 6, it distinguishes itself by focusing on short-term actions to address technological gaps, evaluate tracking systems, and explore new data integration solutions within the metal sector supply chain. Initially, extensive studies will be conducted to identify these gaps and inform the creation of a unified, centralized data platform. This platform will facilitate real-time data exchange and collaboration among suppliers, manufacturers, distributors, and recovery actors. Standardization of data collection, formatting, and sharing practices across the industry will be crucial for the success of this initiative, requiring workforce readiness to adopt such systems. In the medium-term, experts recommend the integration of advanced technologies such as blockchain, IoT sensors, and AI-driven analytics to enable end-to-end tracking of materials and products throughout the supply chain.

VISION 05
Metal as a service

VISION 07
Full Metal Packaging

Establishment of standardised metal grades, and design & manufacturing principles, to promote service-oriented economies by enhancing compatibility

- Conduct rigorous research and analysis to align metal grades and products with circular / sustainable principles to support strategic planning and resource usage optimisation to reduce environmental impacts
- Create standardised product design and manufacturing principles for part/component compatibility across different product categories

Realisation of enhanced compatibility and service-oriented economies through the standardisation of metal grades, design, and manufacturing principles

- Regulate early-adopting industry data. Use this data to improve standards and expand them to more industry players
- Develop a robust framework for extended producer responsibility (EPR) that incorporates servitization in the metal sector
- Advocate for policies and regulations that support EPR and servitization in the metal industry at both national and international levels
- Establish clear metrics to measure the effectiveness of EPR and servitization initiatives
- Plan for the scalability of successful servitization models and expand them to various sectors within the metal industry

Implementation of policies and regulations to incentivise and reward companies for shifting to service-based business models

- Establish financial incentives for companies transitioning to service-based models, such as tax breaks, grants, or subsidies
- Introduce legislation that specifically supports service-based business models, ensuring a favourable legal framework for such operations
- Regularly revise and update regulatory frameworks to align with evolving service-based business models and to remove barriers to their implementation

Establishment of comprehensive data management system with end-to-end traceability of molecules, materials, components, and products for improved lifecycle management and service delivery optimisation

- Promote government-private sector traceability and servitization technology research and development
- Standardise data exchange and traceability across industries and sectors
- Develop and adopt standard protocols for data sharing and traceability across different industries and sectors
- Reach complete integration of traceability systems in major industrial sectors, showcasing a significant enhancement in lifecycle management
- Realise a transition towards servitization in industry operations, as service-base models, take-back, and reuse of commodities grow

Mainstreaming leasing, renting, and sharing in the UK economy by transforming attitudes and usage patterns of goods

- Launch comprehensive campaigns to educate the public and the industry on the benefits of leasing, renting, and sharing
- Collaborate with key industries such as electronics and automotive to develop and promote sustainable business models focused on leasing, renting, and sharing, rather than ownership
- Connect product return and collection with the business model
- Support the development of infrastructure and platforms that facilitate the easy exchange, rental, and repair of goods.

SHORT-TERM | MEDIUM-TERM | LONG-TERM

Keywords: Service Oriented Economy; Service Ecosystem; Service-oriented Economies; Integrated traceability systems.

Context Setting - This vision aims to transform the current operational practices of businesses in the metal industry. The vision is around transitioning from the traditional business models based on make-sell-use-dispose, to a more effective and circular approach based on retaining the value of metal materials and products as long as possible. In other words, this approach focuses on selling the service provided by the product rather than the commodity itself. Given the numerous businesses in the United Kingdom and worldwide that engage in commercialisation and utilisation of metals in their products, this shift requires a significant and extensive transformation. Usually, when discussing this change, the attention is directed towards the technologies employed. To implement such alternative business models, however, companies often overlook the need to change their core operations. To achieve this goal, the government can play a significant role in encouraging enterprises to apply and users to adapt to this groundbreaking vision.

Snapshots from the future related to this vision - Vision 05: 1. Metals molecules as a service; 2. Metal components as a service; 3. Metal products as a service (B2B); 3. Metal products as a service (B2C); 4. Metal products shared; 5. Buildings and structural components as a service; 6. Social bubble collaborative economy. Vision 07: 1. Pure Metal; 2. Packaging deposit schemes; 3. Milkman model; 4. Refilling station; 5. Reusable packaging on-the-go; 6. Reverse vending schemes.

Pathway strategy - The primary goal of the first milestone is to establish standardized metal grades, manufacturing practices, and design principles to facilitate service-oriented economies and compatibility. Standardization is a critical aspect of enabling this transition, as it involves reshaping the product and system landscape to promote common roles, functions, and structures within a network, in contrast to the traditional linear approach where products compete with each other.

To achieve this transition, in the short-term, it is essential to explore how businesses can align on shared metal grades and products, incorporating circular and sustainable principles to enhance strategic planning and optimize resource utilization for every sector. After establishing standards for various sectors, it is crucial to promptly implement these standards and oversee the data of industries that adopt them early on. Utilise this data to enhance benchmarks and extend their use to a broader range of industry participants.

The second milestone, which is closely connected to the previous one, is to achieve greater compatibility and promote service-oriented economies through the standardisation of metal grades, design methods, and production principles. Essentially, this milestone aims to enhance the objectives established in the initial milestone by establishing a unified structure for companies related to metals. This framework incorporates uniform grading systems and product designs that conform to circular and sustainable concepts, enabling strategic planning and enhancing resource efficiency to minimise environmental footprints. The ultimate objective is to establish a conducive climate wherein enterprises can easily coordinate their efforts towards common standards, thereby facilitating collaboration and advancing sustainable practices across the metal industry.

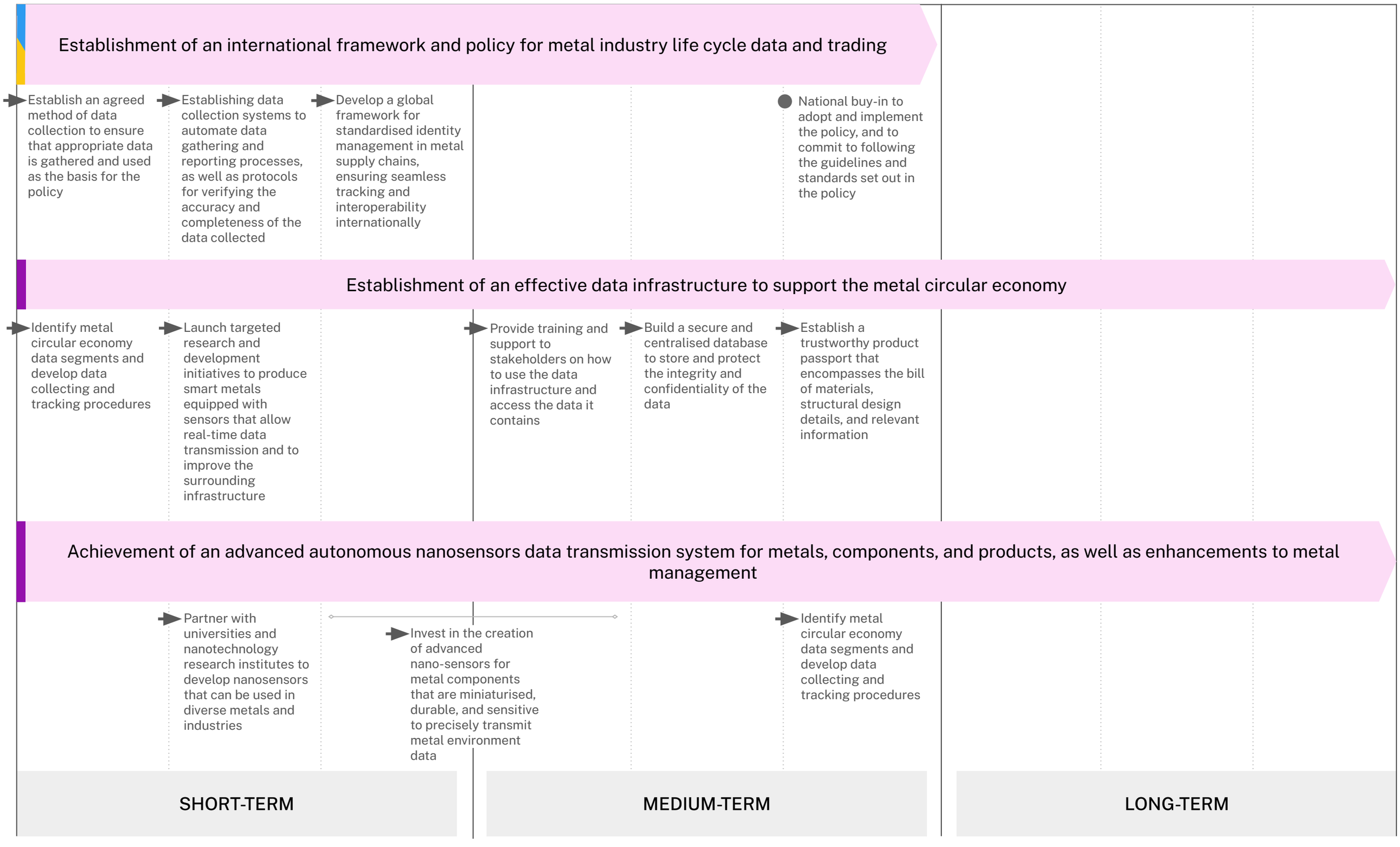
The third milestone involves creating a data management system that enables the tracking of molecules, materials, components, and products throughout their entire lifecycle. This can improve the management of products' lifecycles and optimise service delivery. While this milestone is comparable to Vision 6 - Metal Life Cycle Data, its main emphasis is on the servitization of products and the resulting data. It is necessary to standardise this data in a manner that is easily comprehensible and facilitates data sharing across all enterprises operating in the specific metal sector. Experts have proposed an initial understanding of the technology and requisite information for developing protocols, aiming to achieve full integration of traceability systems in key industrial sectors.

The fourth milestone aims to normalize the practice of leasing, renting, and sharing within the UK economy, reshaping consumer attitudes and usage behaviours toward goods. In the short-term, an awareness campaign will educate users about this servitization concept. In the medium-term, government collaboration with key industries will foster sustainable business models emphasizing leasing, renting, and sharing over ownership. Additionally, infrastructure and platforms will be developed to facilitate seamless exchange, rental, and repair of goods.

The fifth milestone focuses on the policy incentives for transitioning to service-based models. To accomplish this objective, a range of measures should be established. In the medium-term, this involves implementing financial incentives for companies shifting to service-based models, like tax breaks, grants, or subsidies. Furthermore, implement laws that incentivise service-based business models will establish a positive legal environment for these operations. In the long-term, regulatory frameworks should be revised and updated to stay relevant in relation to changing service-based business models for all sectors. This will help eliminate barriers to their implementation.

VISION 06

Metal life cycle data



Keywords: Metal Life Cycle Data; Metal Life Cycle Standards; Digitalization of Metal Supply Chain; Digitized Metal Ecosystem.

Context Setting - This vision seeks to transform the metal industry by implementing digital technology, thereby redefining how businesses generate and provide value within the metal ecosystem. This highlights the need for a strong digital infrastructure, a highly qualified workforce, and a supportive regulatory framework to promote innovation and facilitate circular transition. This transition is in line with optimising the management of resources to improve circular operational services, such as preventative maintenance and recovery. Today, the sector is facing difficulties in fully using digital technologies, such as establishing real-time connectivity with cloud-based and shop floor systems, while also ensuring cost-effectiveness. By making strategic investments and engaging in joint efforts, it is possible to create a metal ecosystem that is both more efficient and sustainable, resulting in mutual advantages for enterprises and the environment.

Snapshots from the future related to this vision - 1. Open-government metal data for the metal sector; 2. Digital passport on blockchain; 3. Remote maintenance and repairing with digital twins; 4. Components and materials banks; 5. Autonomous marketplace of components; 6. Autonomous household product; 7. Nanosensors embedded in metals to gather life cycle data.

Pathway strategy - In the first milestone, there is a strong focus on the need to establish or endorse an international framework and policy for life cycle data and trading in the metal industry. The primary objective of this milestone is to encourage sustainability, transparency, and responsible practices in the global metal sector. This approach aims to prevent the emergence of regulations that could impede international trade and collaboration. In addition, it helps maintain the UK's competitiveness in the metal market compared to unregulated competitors. Given the variety of data collection methods, the current priority is to establish a standardised approach that all stakeholders can agree on. Standardisation is crucial to ensure accurate and consistent data, which is vital for policy development. Furthermore, in the short-term, it is crucial to set up data collection systems. These systems will streamline data collection and reporting processes, ensuring the accuracy and completeness of the gathered data. These efforts help improve data quality, streamline operations, ensure compliance, and support informed decision-making in the metal industry. It is crucial to obtain widespread national support in the medium-term to approve and execute the policy, and to pledge to adhere to the rules and standards outlined in the policy.

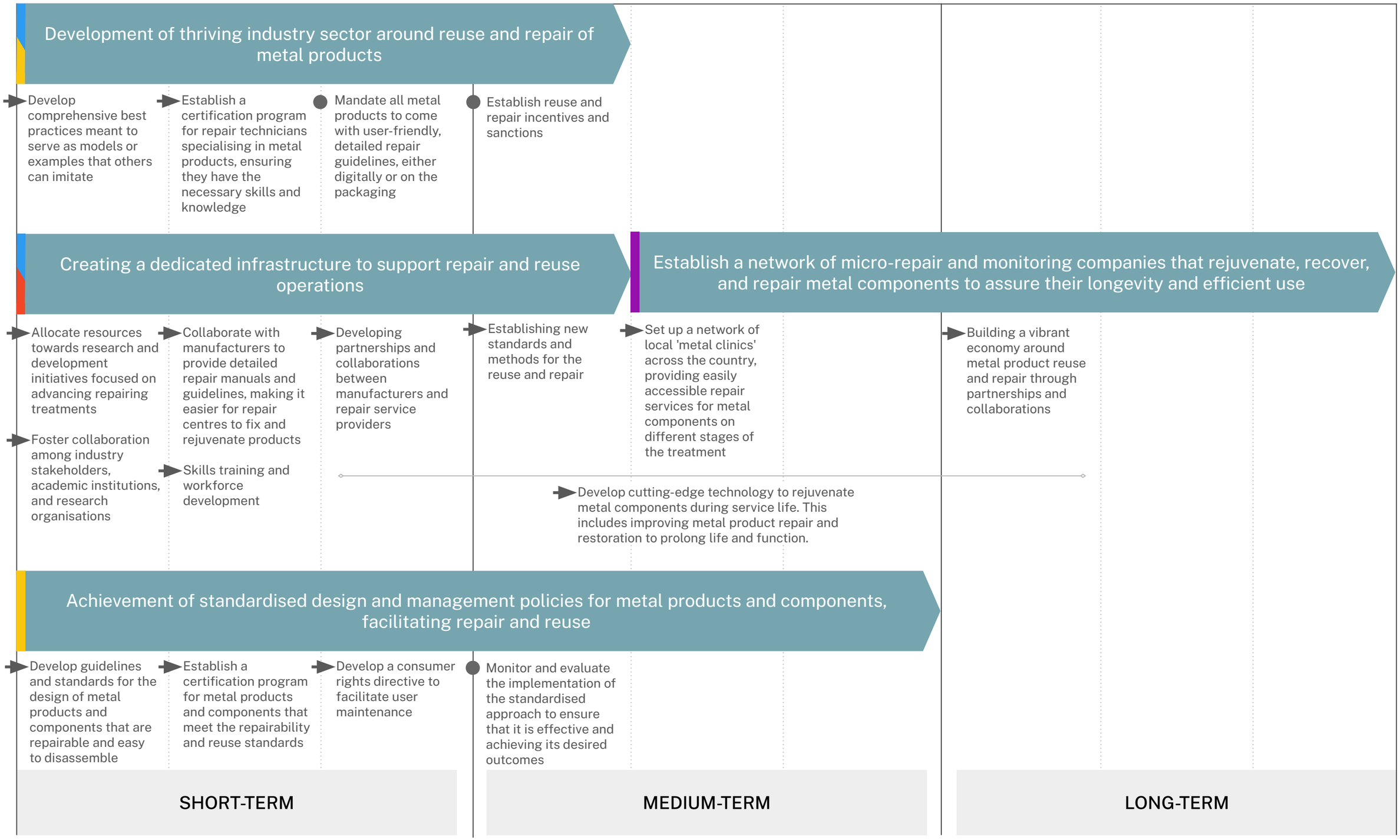
The second milestone focuses on the technical aspects of transitioning the metal sector towards a digitalized ecosystem. Establishing a strong data infrastructure is essential for effectively supporting the metal circular economy. Achieving this milestone is a long-term endeavour requiring a series of coordinated actions. One facet of this endeavour involves developing a centralised database and outfitting resources with sensors to track their movements. It is crucial to conduct more research and gain a better understanding of how companies can track their resources effectively in the near future. This requires cooperation in research between industry and the public sector, along with the implementation of initiatives to encourage the sharing of knowledge. In addition, it is important to have companies agree on a shared data set and framework to ensure smooth tracking and global interoperability. In the medium-term, the attention turns to creating a safe and centralised database. This action will be enhanced by the creation of a digital passport that is shared and used by all participants in the ecosystem. This passport will help track and verify data related to the lifecycle of resources. In order to support these efforts, it is crucial to train a competent workforce capable of effectively facilitating this transition.

The third and final milestone involves achieving an advanced autonomous data transmission system equipped with nanosensors for metals, components, and products. This milestone also focuses on improving metal management and integration across different applications. The approach to attaining this significant achievement shares resemblances with the second milestone, albeit with a more precise emphasis on advanced nano-sensors for the purpose of monitoring metal resources. Research is crucial in achieving this significant milestone, especially in developing standardised tracking systems. Moreover, it is advantageous for both firms and institutions to acquire knowledge about the practical application of these nano-sensors in many industries. After gaining a deeper understanding of this system, it is advisable to invest in the expansion and promotion of the general adoption of these nano-sensors. In the medium-term, the focus will be on identifying specific categories within the data landscape of the metal circular economy and establishing systems for collecting and tracking data.

This strategy is heavily technology-driven, with a primary focus on creating the conditions for companies and governments to attain a more efficient and sustainable metal ecosystem. The objective is to establish secure, trusted, and reliable practices within both local and global information architectures, thereby enabling circular opportunities for companies and simultaneously reducing their CO2 emissions.

VISION 08

Stop Recycling Start Repairing



Context Setting - This vision seeks to transform the metal industry by implementing innovative strategies aimed at prolonging the life cycle of metallic components and promoting their reuse. In order to move away from a linear or solely focused-recycling strategy of production and consumption, this vision intends to prioritise repair technologies like electro-pulsing treatment (EPT) and move towards a more reuse-oriented model. Central to this transformation is the recognition of the significant environmental and economic benefits associated with extending the service life of metal products and reducing waste. Repairing treatments like EPT offer a promising solution to address fatigue-related issues and other forms of degradation in metallic components, thereby minimising the need for new production and conserving valuable resources. Through the establishment of "metallic component clinics" and the integration of non-destructive testing and rejuvenation processes, the vision aims to create a sustainable ecosystem where products are maintained, repaired, and reused in a continuous loop. This holistic strategy promotes metal sector economic resilience and innovation.

Snapshots from the future related to this vision - 1. MHS - Components rejuvenation; 2. MHS - Structure rejuvenation; 3. MHS - Metal day hospital; 4. Micro repair entrepreneurs; 5. Self-healing metal.

Pathway strategy - The primary objective of the first milestone is to lay the groundwork for a thriving industry centred around the reuse and repair of metal products. While this milestone does not focus on technological advancements, it is essential to establish favourable conditions, particularly in the short-term, to incentivize businesses to transition towards metal repair and reuse practices. To achieve this, experts recommend the development of comprehensive best practices that can serve as benchmarks for others to follow. Clarity in how value is generated and delivered within these activities is paramount to providing businesses with a clear understanding of the overall landscape. Subsequently, industry associations and consortia, in collaboration with governmental bodies, can implement certification programs for repair technicians specialising in metal products, ensuring they possess the requisite skills and expertise. Additionally, governments can mandate the inclusion of user-friendly and detailed repair guidelines with all metal products, either digitally or on the packaging. In the medium-term, experts suggest that governments should introduce incentives and penalties to further encourage reuse and repair initiatives.

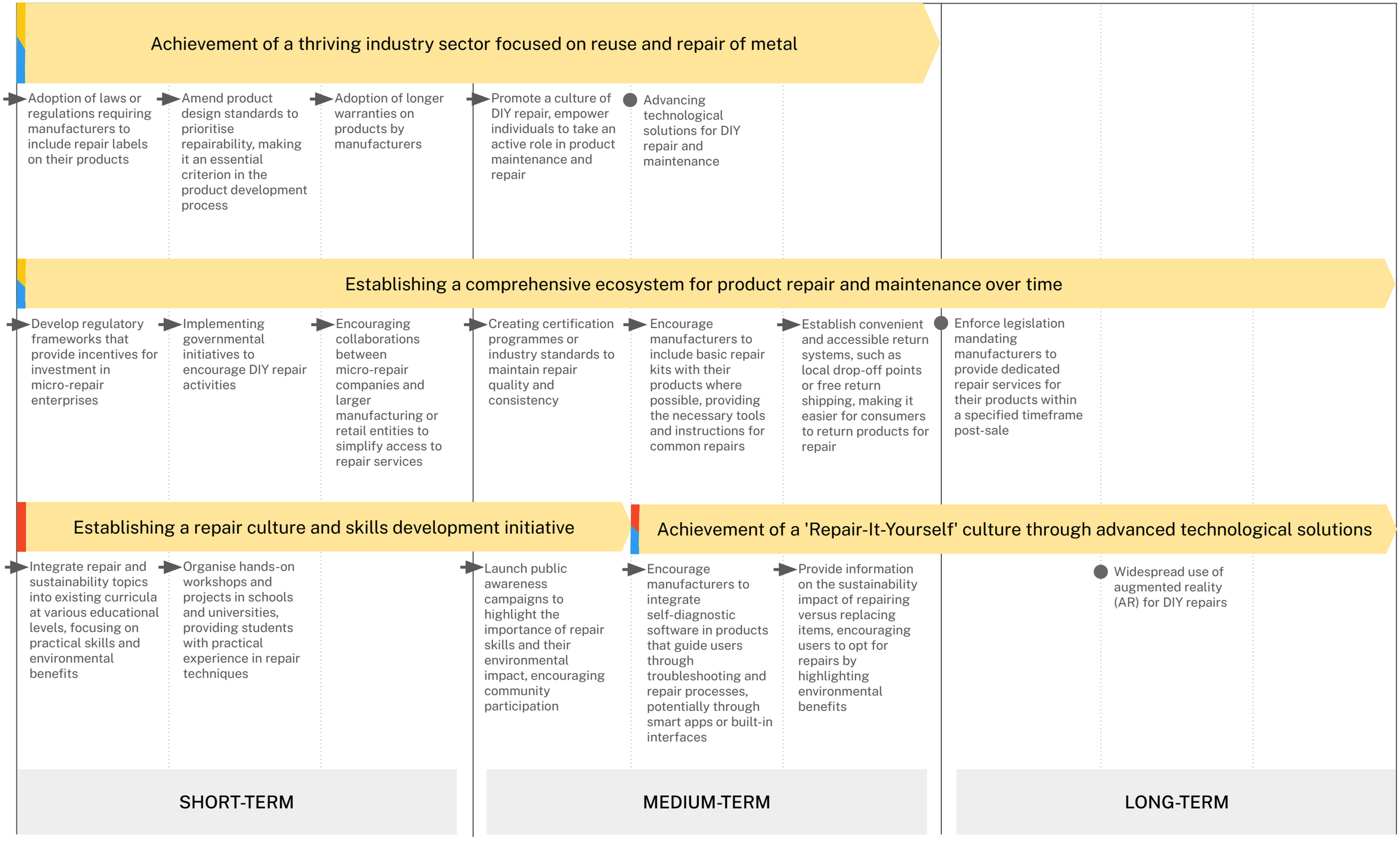
The second milestone aims to establish a comprehensive infrastructure to bolster repair and reuse endeavours, encompassing both physical facilities and the necessary knowledge and technological advancements. In the short-term, it is imperative to allocate resources from both public and private sectors towards research and development initiatives aimed at advancing repair treatments. Collaboration among stakeholders is essential to foster a conducive environment for innovation. Experts recommend the development of repair manuals and guidelines to streamline the process of repairing and rejuvenating products in repair centers. Looking ahead to the medium-term, government collaboration with industry associations or consortia is vital for establishing new standards and methodologies for repair and reuse, ensuring consistency and efficacy in these practices. These activities are essential to achieve also the third milestone.

The third milestone focuses on establishing a network of micro-repair and monitoring companies dedicated to rejuvenating, recovering, and repairing metal components to ensure their prolonged lifespan and efficient utilisation. This milestone is a direct outcome of the preceding second milestone and hinges on the development of essential knowledge and technologies crucial for advancing towards a repair-oriented society. However, the technological requirements to realize this vision are intricate, and experts anticipate that the development of such technologies will span the medium to long-term. To achieve this milestone, experts recommend collaboration between the government and companies to establish a network of local "metal clinics" nationwide, offering easily accessible repair services for metal components at various stages of treatment. These initiatives can commence as pilot projects in the medium-term and evolve into established industries in the long-term, underscoring the significance of partnerships and collaborations in driving this transition.

The final milestone centres on establishing standardised design and management policies for metal products and components to facilitate repair and reuse. A crucial initial step in the short-term involves developing guidelines and standards for designing metal products and components that are easily disassemblable and repairable. Additionally, initiating a certification program for metal products and components that meet these repairability and reuse standards is imperative. The government should also prioritise the development of a consumer rights directive aimed at facilitating user maintenance. Furthermore, monitoring and evaluating the implementation of the standardised approach is essential to ensure its effectiveness and achievement of desired outcomes.

VISION 09

Repair-it-yourself (RIY)



Context Setting - This vision aims to prolong the lifespan of metal products by empowering users to repair their own items through a concept known as Repair-it-yourself (RIY). RIY involves individuals modifying or fixing items independently, either with or without the support of professionals or certified experts. Achieving this vision requires companies to design products that are easily repairable by users or to provide services that enable users to repair the products themselves. While technological advancements such as platforms or virtual reality can facilitate this process, policy interventions are also essential to compel companies to offer customers the opportunity for self-repair, particularly in the initial stages of implementation.

Snapshots from the future related to this vision - 1. RIY-Repair digital platforms; 2. RIY-First-aid repair kit; 3. RIY-Repairs technologies; 4. School-based repair courses; 5. Repair community centres.

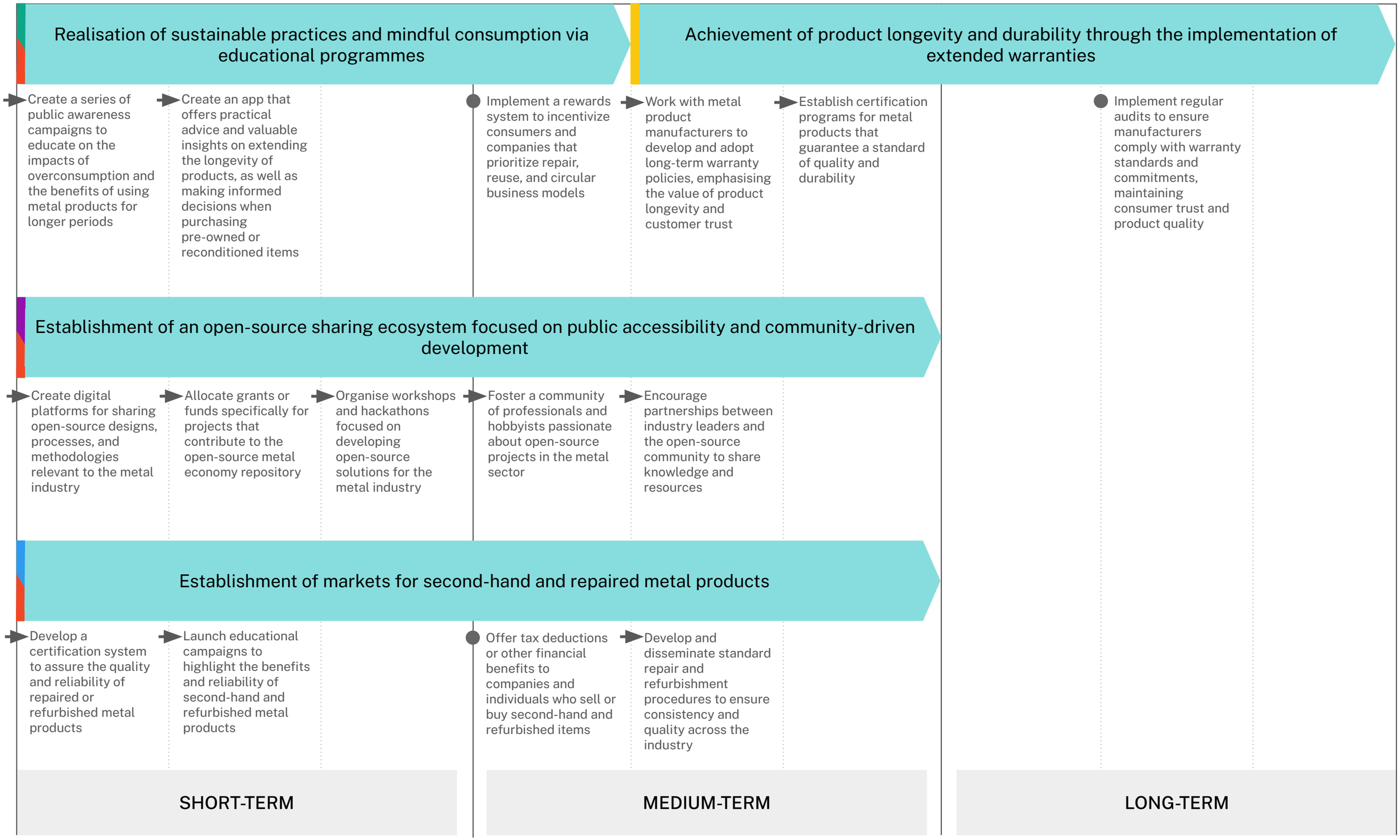
Pathway strategy - The initial milestone aims to support a robust industry sector focused on metal reuse and repair, necessitating streamlined legislative measures and support frameworks to seamlessly integrate these practices across sectors. Short-term strategies proposed by experts include enacting regulations mandating repair labels on products, revising design standards to prioritize repairability, and extending product warranties. In the medium-term, the focus shifts towards leveraging technological advancements to empower users in RIY repair endeavours. This may involve exploring interactive digital platforms and mobile apps offering guided repair instructions through augmented reality interfaces. Additionally, investments in modular, self-diagnosing components capable of autonomously detecting and addressing issues, coupled with the widespread dissemination of open-source repair manuals and repositories for 3D-printed spare parts, stand to revolutionise repair accessibility and reusability.

In tandem with fostering a robust industry sector dedicated to metal reuse and repair, governmental support is essential for establishing a comprehensive ecosystem for product repair and maintenance over time. This entails fostering collaborations between governmental bodies and private enterprises to develop regulatory frameworks that incentivise investment in micro-repair businesses. Financial assistance and technical support should be provided to facilitate their setup and operation. In the short-term, encouraging collaborations between micro-repair companies and larger manufacturing or retail entities can simplify access to repair services. In the medium-term, collaborative efforts involving government, industries, and consortiums can establish guidelines and protocols to ensure repair services meet predefined standards for quality, safety, and effectiveness. Concurrently, infrastructure enhancements, such as including basic repair kits with products or establishing convenient return systems like local drop-off points, should be implemented to streamline the repair process for consumers. In the long-term, experts advocate for legislation mandating manufacturers to offer dedicated repair services for their products within a specified timeframe post-sale.

Creating a repair culture and a programme to improve skills are essential for making this goal a reality. The experts agree that this can be accomplished by incorporating courses on sustainability and repair into current lesson plans at all grade levels. These lessons should highlight the importance of practical skills and the positive impact on the environment. Students can gain immediate practical experience in repair procedures through the organisation of workshops and projects in schools and universities. In the medium-term, experts suggested to hold public awareness programmes that highlight the importance of repair skills and their effect on the environment. This will encourage community involvement.

The fourth and final milestone aims to foster a 'Repair-It-Yourself' culture through advanced technological solutions. Here, the emphasis shifts towards integrating self-repair technologies into products. In the medium-term, it is recommended that governments incentivize manufacturers to incorporate self-diagnostic software in products, guiding users through troubleshooting and repair processes via smart apps or built-in interfaces. Concurrently, companies should disseminate information on the sustainability impact of repair versus replacement, encouraging users to choose repairs by emphasizing environmental benefits. Experts have proposed that widespread adoption of augmented reality (AR) for repair-it-yourself (RIY) repairs should be achievable in the long-term.

The Logic of Sufficiency



Context Setting - In this vision, the overarching goal is to cultivate a paradigm shift towards sufficiency-oriented consumption behaviors, wherein individuals are encouraged to prioritize durability, repairability, and longevity in their purchasing decisions. The approach relies on the ideas of moderation, prioritising high-quality items above low-quality alternatives, and promoting thoughtful consumption instead of impulsive buying. Its goal is to fundamentally change consumer attitudes and behaviours.

Snapshots from the future related to this vision - 1. Multigenerational products; 2. Open library of things; 3. Emotional attachment; 4. MyMetal; 5. Deliveries once a week.

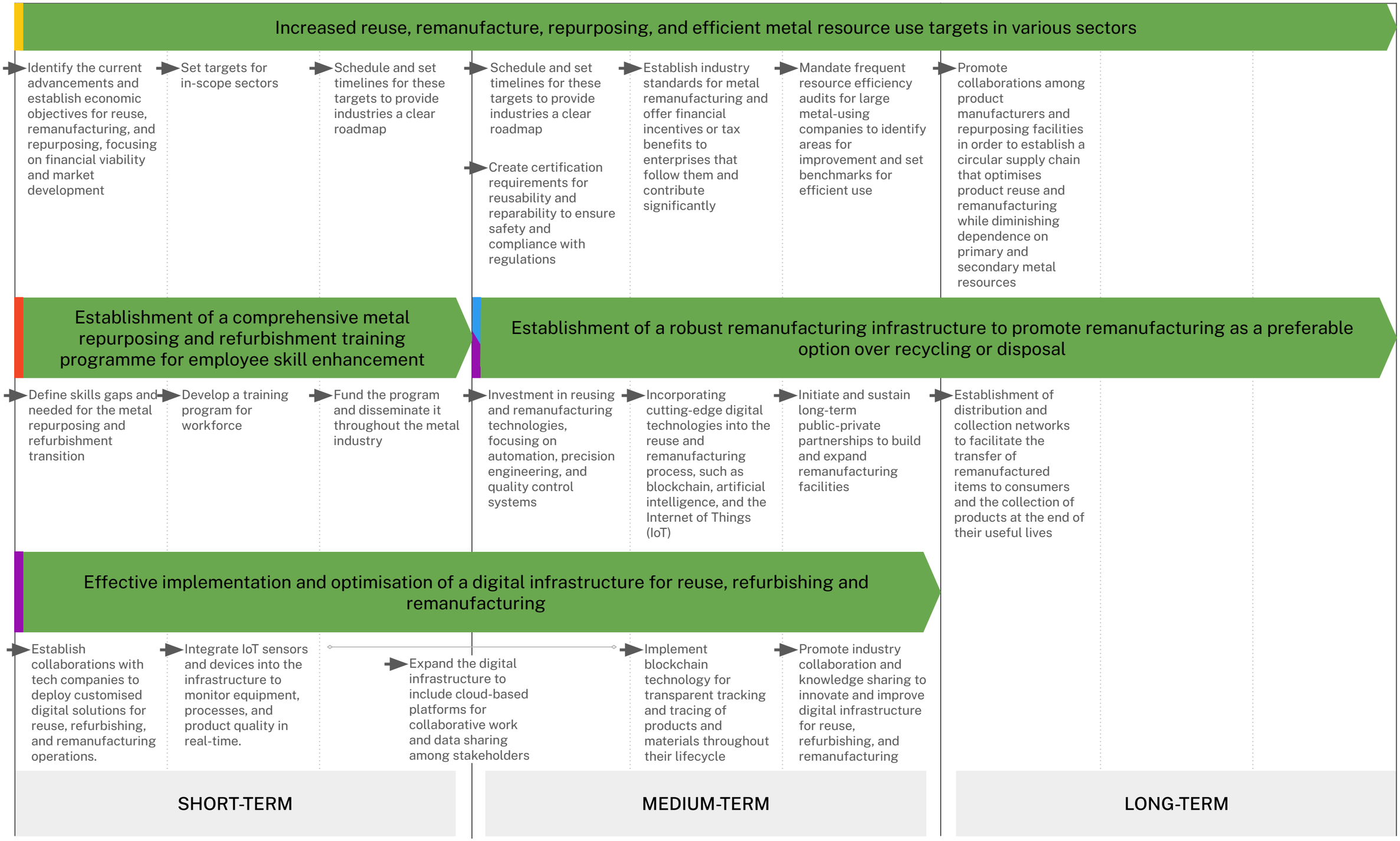
Pathway strategy - The initial milestone focuses on fostering sustainable practices and promoting mindful consumption through educational initiatives. In the short-term, this may involve launching public awareness campaigns to highlight the consequences of overconsumption and the advantages of prolonging the use of metal products. These efforts may encompass various activities such as workshops, seminars, and informational materials aimed at advocating for responsible consumption, and the significance of extending the lifespan of metal items through repair, reuse, and repurposing strategies. Additionally, the development of a mobile application can provide practical guidance and insights on enhancing product longevity and making informed choices when purchasing second-hand or refurbished goods. In the medium-term, experts propose the implementation of a rewards system to incentivise both consumers and businesses that prioritize repair, reuse, and circular business practices. This approach aims to gradually shift societal norms and consumer behaviour towards a more sustainable ethos, fostering a culture of conscious consumption and responsible management of resources.

The second milestone focuses on improving product longevity and durability by implementing strong warranty systems. Manufacturers or sellers provide warranties to assure consumers of a product's performance within a specified timeframe or conditions, serving as an important consumer protection measure. In order to reach this goal, in the medium-term, experts suggest that the government work together with metal product manufacturers to create and enforce extended warranty policies. This will emphasise the significance of product durability and instil trust in consumers. In addition, implementing certification programmes for metal products can help ensure that they meet high standards of quality and durability. These programmes often require rigorous testing to assess the durability of the product. In the long-term, regular audits should be conducted to ensure manufacturers comply with warranty standards, maintaining consumer trust and product quality.

The focus of the third milestone is to create a sharing ecosystem that is open-source, accessible to the public, and driven by the community. In the short-term, this may involve fostering collaborative platforms and initiatives for the free exchange of knowledge, resources, and innovations to collectively advance the goals of sustainability and circularity. Collaboration between different sectors can lead to the development of digital platforms for sharing open-source designs, processes, and methodologies related to the metal industry. This can be supported by grants or funds dedicated to projects that contribute to the open-source metal economy repository. In addition, workshops and hackathons can be arranged to develop open-source solutions that specifically address the requirements of the metal industry. In the medium-term, experts recommend building a community of dedicated professionals and enthusiasts who are passionate about open-source initiatives in the metal sector. Promoting collaborations between industry leaders and the open-source community can cultivate a spirit of camaraderie and shared purpose, sparking creativity and enabling the collaborative generation of fresh ideas and approaches.

The fourth and final milestone focuses on creating specialised marketplaces for pre-owned, used and refurbished metal products. Although this milestone partially aligns with Visions 09 and 11, experts recommend that the government take action in the short-term to creating a certification system to ensure the quality and reliability of repaired or refurbished metal products. These measures are crucial for boosting the credibility and trustworthiness of these marketplaces, which in turn will increase consumer confidence and demand for reused and refurbished metal goods. Furthermore, experts emphasise the significance of societal involvement, suggesting the implementation of educational campaigns to highlight the advantages and dependability of second-hand and refurbished metal products. In the medium-term, the government may consider providing tax deductions or financial incentives to companies and individuals involved in the sale or purchase of used and refurbished items. Moreover, specialists highlight the importance of implementing and sharing standardised repair and refurbishment procedures to maintain consistency and quality across the industry.

Reusing, remanufacturing, and repurposing



Context Setting - This vision aims to establish iterative lifecycles for metal products by coordinating the design of products, components, and materials to promote their continuous circulation within the economy. This, in turn, encourages opportunities for reuse, refurbishment, or remanufacturing. In this framework, the focus is on maximising resource utilisation over the lifespan of products by efficiently using embedded energy and resources, thus creating value. Metals are well-suited to this approach because they can be easily restored and used multiple times. The aim of this vision is to focus on improving product design rather than solely relying on recycling. Reuse, refurbishment, and remanufacture methods are not as well-established in the UK compared to waste-related concerns and metal recycling, which have garnered more attention. Nevertheless, they might promote improvements in product design that are less harmful, potentially benefiting both the environment and economy. Emerging technologies such as 3D printing of spare parts, automatic disassembling, and reversible assembly methods are showing promise in facilitating these operations. These technologies optimise the repair and refurbishment processes, resulting in improved resource utilisation and waste reduction. In addition, digital platforms and blockchain technology can increase product lifecycle traceability and transparency, supporting sustainable practices.

Snapshots from the future related to this vision - 1. The renaissance of second-hand markets; 2. Remanufacturing and refurbishment services become core offerings; 3. Cascade Reusing.

Pathway strategy - The primary focus of the first milestone is on achieving specific targets for increased reuse, remanufacturing, repurposing, and efficient utilisation of metal resources across various sectors. These targets serve as fundamental benchmarks for quantifying progress and facilitating the transition towards enabling multiple lifecycles. In the short-term, experts recommend to identify the current advancements and establish economic objectives for reuse, remanufacturing, and repurposing, focusing on financial viability and market development. This collaborative effort between public and private sectors sets timetables for implementation. In the medium-term, the government should establish certification standards for reusability and reparability, ensuring compliance and safety. Industry standards for metal remanufacturing should be set, with financial incentives or tax benefits provided to compliant enterprises. Additionally, mandatory resource efficiency audits for large metal-using companies can identify improvement areas and set benchmarks for efficient resource use. Long-term government initiatives should foster partnerships between product manufacturers and repurposing facilities, forming circular supply chains to enhance product reuse and remanufacturing, thereby reducing reliance on metal resources.

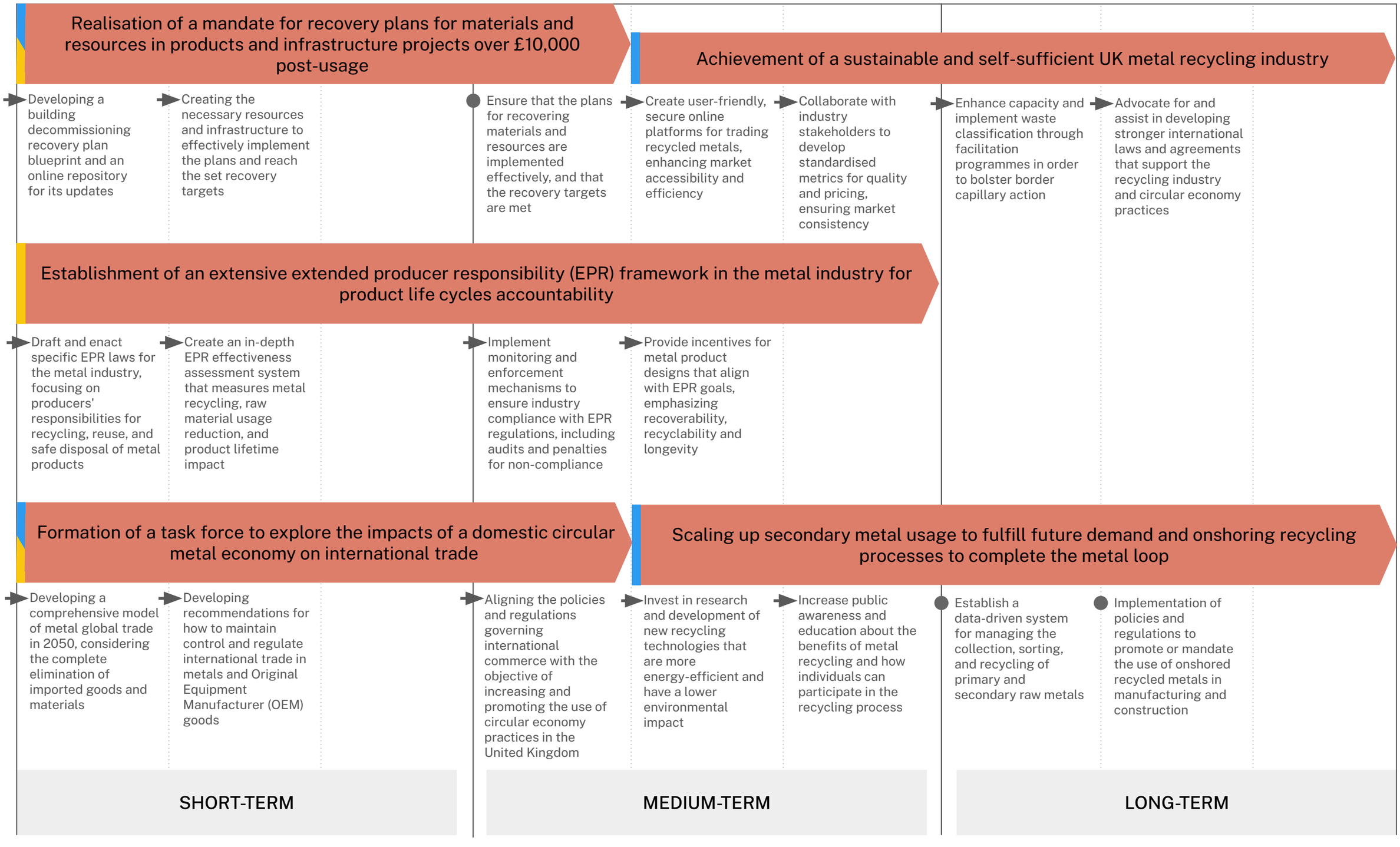
The second milestone involves creating a comprehensive training programme in the short-term with the goal of enhancing employees' expertise in metal repurposing and remanufacturing. This programme represents a significant step towards the progress of a highly advanced industry, where automation and human expertise come together in a mutually beneficial way. It also acts as key foundation to achieving the next milestone.

In the third milestone, the aim is to establish a robust remanufacturing infrastructure, positioning remanufacturing as the preferred option over recycling or disposal. The first step suggested by experts in the medium-term is for government and industry to invest in remanufacturing technologies, with a focus on automation, precision engineering, and quality control systems. Subsequently, integrating advanced digital technologies such as blockchain, artificial intelligence, and the Internet of Things (IoT) into the remanufacturing process is recommended. One potential approach to achieve this is by initiating and sustaining long-term public-private partnerships to build and expand remanufacturing facilities. In the long-term, this initiative will result in the creation of efficient distribution and collection networks, making it easier for consumers to access remanufactured items and ensuring the proper disposal of products at the end of their lifespan. Efficient networks are strategically designed to minimise environmental impact, ensuring smooth logistics from production to consumption and return.

The fourth and last milestone centres on the effective implementation and enhancement of a digital infrastructure to enable the reuse, refurbishment, and remanufacture of products. In the short-term, this involves setting up state-of-the-art facilities that are equipped with Internet of Things (IoT) solutions by industries. These solutions enable the real-time monitoring of equipment, processes, and product quality for a better circular logistics. Furthermore, in the near to intermediate future, industries, with the assistance of the government, should enhance the digital infrastructure by incorporating cloud-based platforms that facilitate collaborative work and data exchange across stakeholders. The expansion can be further improved in the near future by incorporating blockchain technology to ensure transparent monitoring and traceability of items and materials throughout their entire lifespan. To accomplish this aim, it is necessary for different industries to work together and exchange knowledge in order to stimulate innovation and ongoing enhancement in digital infrastructure, as recognised by experts.

VISION 12

Better metal recovery, sorting, upcycling, and recycling



Context Setting - This vision is dedicated to enhancing the end-of-life management of metal products by implementing more effective recovery, sorting, upcycling, and recycling methodologies. While previous discussions have shed light on the limitations of relying solely on recycling for achieving circularity, it remains a crucial aspect, especially after products have undergone multiple uses. However, it should be viewed as just one facet of a comprehensive circular approach aimed at maximizing material value retention. Despite considerable attention being directed towards end-of-life management, there is still ample opportunity for improvement in this domain. Various technologies, including those leveraging artificial intelligence (AI), stand poised to significantly enhance both the quality and quantity of recycled materials. Presently, a significant volume of metal scraps is exported for recycling, overlooking the inherent value these materials hold. Redirecting these resources for domestic reclamation and repurposing can contribute to the establishment of a more sustainable and self-reliant metal ecosystem.

Snapshots from the future related to this vision - 1. Open distributed demanufacturing; 2. Closed distributed demanufacturing; 3. Disassembling pods; 4. Industrial upcycling; 5. Urban Mining; 6. Smart waste management system; 7. Landfill scavenging; 8. Micro mobile foundry and upcycling workspaces.

Pathway strategy - The first milestone is focused on the realisation of a mandate for recovery plans for materials and resources in products and infrastructure projects over £10,000 post-usage. To achieve this goal, experts suggest creating a detailed plan for decommissioning recovery and setting up an online repository for regular updates. In order to successfully implement these plans and meet the recovery targets in the short-term, it is crucial to establish the necessary resources and infrastructure. In the medium-term, it is crucial for the government to focus on effectively implementing these recovery plans and achieving the set recovery goals. By taking a proactive approach, we can ensure that important projects follow sustainable practices, which will in turn contribute to the broader goals of conserving resources and being good stewards of the environment.

The second milestone aims to establish a sustainable and self-sufficient metal recycling industry in the UK. Experts suggest developing user-friendly and secure online platforms for trading recycled metals to enhance market accessibility and efficiency in the short-term. This objective can be accomplished by fostering collaboration among different stakeholders in the industry. In addition, working with industry stakeholders to create standardised metrics for quality and pricing would promote market consistency and increase confidence among participants. Implementing these measures would not only make the trading process more efficient, but also strengthen the metal recycling ecosystem in the long run. Improving capacity and implementing waste classification programmes can enhance the industry's resilience in the long-term. In addition, promoting stronger international laws and agreements that support recycling and circular economy practices would encourage long-term sustainability and growth.

The third milestone is centred around implementing a comprehensive extended producer responsibility (EPR) framework in the metal industry, which will ensure that there is accountability throughout the entire lifecycle of the products. Experts suggest that it would be beneficial to create and implement industry-specific EPR laws for the metal sector in the short-term. These laws would outline the obligations of producers regarding the recycling, reuse, and proper disposal of metal products. In the medium term, experts suggest effective monitoring and enforcement measures for EPR rules. This involves audits and fines. Also important are government incentives for EPR-compliant metal product designs. Promote recoverability, recyclability, and lifetime to encourage sustainable production and enable the EPR framework thrive.

The fourth milestone involves establishing a task force to analyse the implications of a domestic circular metal economy on international trade. In the short-term, in order to develop a comprehensive model of global metal trade by 2050, it is essential to have government support for research. This research should take into account the complete elimination of imported goods and materials. This research aims to provide recommendations for regulating and controlling international trade in metals and Original Equipment Manufacturer (OEM) goods. In the medium-term, it is crucial to harmonise policies and regulations for international commerce in the United Kingdom to promote circular economy practices.

The final milestone builds upon the previous one, aiming to scale up secondary metal usage and establish onshore recycling processes to close the metal loop. In collaboration with companies, the government should invest in researching and developing energy-efficient recycling technologies with reduced environmental impact. Increasing public awareness and education about metal recycling's benefits and individual participation is crucial. Establishing a data-driven system for managing collection, sorting, and recycling of primary and secondary metals is essential in the medium-term. Additionally, implementing policies and regulations by the government to promote or mandate the use of onshored recycled metals in manufacturing and construction will be vital.

The roadmaps in this report are part of a comprehensive plan to achieve a circular metal economy in the UK by 2050. This initial plan aims to raise awareness of the comprehensive approach that the government should adopt to address the transition to the Circular Economy in the metal sector, across the entire supply chain. The proposed changes will lead to a greater emphasis on product circularity, particularly through increased local resource reuse. The proposed strategies discussed in this report will have significant national impacts. They will support the health and growth of small and medium enterprises, help retain jobs, and create new jobs. Additionally, they will decrease the UK's reliance on materials sourced from foreign countries, address environmental challenges, and foster sustainable economic growth. The figure on page 29 presents a graphical depiction of the overarching priorities derived from the analysis of the roadmap strategies formulated by experts during the co-design workshops. These priorities are organised according to the four lenses employed during the workshop (Economic Political/regulative Technological Social) and categorised across three distinct time frames (short-, medium- and long-term). While these priorities mark substantial progress, the single roadmap strategies presented for each of our 12 visions offer a more actionable pathway forward. In the following paragraphs, we will give a brief explanation of the overall long-term priorities of each lens.

Economic: From an economic perspective, it is imperative for the government to include sustainability and equality into both corporate and government goals. This will facilitate the development of a more robust and inclusive economy. This alignment is crucial for fostering long-term prosperity, mitigating risks associated with fluctuating primary steel and aluminium prices, and fostering social cohesion in the face of evolving economic challenges. Transitioning from global to regional or localised systems for circular metal recovery is crucial to strengthen resource resilience and boost the UK manufacturing industry's competitive edge on a global scale. Adopting localised circular economies can enhance growth and resource efficiency in the UK circular metal industry, promoting innovative approach to creating value that support sustainable growth and competitiveness. This change will require stakeholders to work together to build local infrastructure, encourage regional cooperation, and use innovative cutting-edge technologies to improve material production, maintenance, recovery, and reprocessing.

Political/regulative: Continuing with the focus on regulatory and political priorities, it is essential to advocate for a unified global legislative framework governing the metal supply chain. This framework should be designed to streamline regulatory processes, harmonize standards, and facilitate collaboration among stakeholders worldwide. This overarching objective should be preceded by the establishment of robust national policies aligned with the overarching principles of the circular transition. Furthermore, the transition to a circular economy must be underpinned by legislation that not only incentivizes but also enforces compliance with circularity principles and practices in the metal sector. Such laws should provide clear guidelines, incentives, and penalties to ensure adherence to sustainable practices throughout the metal supply chain, promoting accountability and fostering a conducive environment for circularity initiatives to thrive.

Technological: Shifting towards technological priorities, it is crucial to ensure the development of strong infrastructure capable of supporting technological and digital advancements throughout the metal supply chain. UK Government should be committed to staying at the forefront of technological advancements, utilising IoT, AI, and blockchain to improve the efficiency, traceability, and transparency of metal production, maintenance, reuse, and recycling processes. In addition, it is essential to ensure a reliable and long-lasting electric capacity from renewable sources. Transitioning to renewable energy sources like solar, wind, and hydroelectric power can power steel and aluminium production facilities, thereby reducing the environmental impact of energy consumption in these sectors. By focusing on these technological advancements, the metal industry can enhance sustainability, resilience, and competitiveness in the shift towards a circular economy.

Social: Shifting focus to the social perspective, it is crucial to empower people for sustainable action. This entails promoting greater awareness, education, and engagement efforts to inspire individuals to embrace more sustainable behaviours and choices in their everyday lives. Communities can actively participate in the transition towards a circular metal economy by providing accessible information, resources, and incentives. Furthermore, it is crucial to prioritise the upskilling and reskilling of the current metal manufacturing and finished industry workforces. This involves putting in place policies and programmes to promote fair labour practices, equal opportunities, and social justice throughout the supply chain. By focusing on social empowerment and equity, UK can build a stronger, more informed, and sustainable society as we move towards a circular economy.

	SHORT-TERM	MEDIUM-TERM	LONG-TERM
ECONOMIC	Establish global lifecycle value/impact assessment methods	Ensure a shift in the economy towards greater emphasis on reusing resources and achieving sufficiency	Ensure that sustainability and equity are integrated into corporate and government objectives Ensure a complete transition from global to regional or localised systems for the circular metal recovery Ensure the UK recovering and reprocessing infrastructures are in place
REGULATIVE	Establish a legal framework to support transition from global to regional or localised governance and regulations	Establish circular certifications Ensure extended producer responsibility Establish circular standards	Ensure a unified global legislative framework across the metal supply chain Ensure that the transition to a CE is supported by laws that encourage and enforce compliance
TECHNOLOGICAL	Ensure innovation through R&D and industry collaborations Initiate diverse pilot projects throughout the metal supply chain for a thorough outcome analysis	Ensure open-data infrastructure is in place to enable secure and scalable data flow	Ensure a technological and digital adequate infrastructure capacity Ensure sufficient energy generation capacity derived from renewable sources
SOCIAL	Establish programmes to reskill and upskill workforce Establish educational programmes to teach the next generation about the CE	Establish open-source sharing ecosystem for public access and community-driven development Ensure public understanding and engagement in sustainable practices through education	Empower citizens for sustainable action

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