UKRI Interdisciplinary Centre for Circular Metals

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NICER PROGRAMME

UK Research and Innovation

Circular Business Models for Metals

About this progress report

This progress report provides the second report on the preliminary findings of Work Package 3 (WP3) titled "Circular Business" inside the UKRI Interdisciplinary Centre for the Circular Metals. The objective of this study is to present a variety of circular business models that are specifically tailored to foster innovation within the metals industry. Expanding upon the 12 possible visions defined in our preliminary report, we have meticulously assembled a compendium of more than sixty distinct business models of a different kind. These findings will serve as the foundation for future research endeavours, with the objective of providing guidance to enterprises operating in the metals sector, facilitating their transition towards the adoption of more circular business practises.

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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Introduction to the report

The Circular Economy (CE) aims to achieve sustainable development by separating economic growth from the negative effects on resources and the environment. This is particularly relevant in the steel and aluminium industries, as they account for approximately 10% of global emissions (Holappa, L. 2020; Cousins S., 2021; IEA 2022). This report focuses on the adoption of CE through alternative business models that maximising material retention and minimising waste. The emphasis is to present a range of Circular Business Models (CBM) opportunities that can be adopted by organisations operating in the metal sector. This set of 61 CBM opportunities provide valuable insights for companies in the metal sector on how to generate and capture value.
Our work has classified these CBM opportunities according to the 12 visions that were previously formulated by our research team (Franconi et al., 2022), and the 20 circular business model archetypes defined by Pieroni et Al. (2020). For each CBM opportunity, we provide a comprehensive analysis of its relevance to the metal sector, its value delivery and capture mechanisms, the responsible actors for value delivery, and the intended customer/user. Furthermore, each CBM opportunity is accompanied by a practical example that provides specific instances of implementation in diverse sectors. Each CBM opportunity description is coupled by a right column that offers additional information on the (1) Ecosystem Level, (2) Circular Strategies Level, (3) Stakeholder Level, and (4) Technology Readiness Level. This column was designed to provide a framework for understanding the unique characteristics of each CBM opportunity. The column allows users to compare and analyse different circular business model strategies, identifying their distinct characteristics and variations. In the following section, we will examine the different levels encompassed in the description of each CBM opportunity.

1. ECOSYSTEM LEVEL
To fully comprehend how contextual factors can either facilitate or constrain organisations in generating circular solutions, it is important to understand the interconnections among the various Ecosystem Level dimensions: Micro, Meso, and Macro (Urbinati et al., 2021; Kühl et al., 2023). While businesses typically develop circular and eco-efficient solutions at the Micro Level, this level is intrinsically linked with both the Meso and Macro Levels (Lonca et al., 2019). Studies have indicated that resource circulation within a single company is often less eco-efficient compared to a systemic approach that involves resource sharing and collaboration among multiple stakeholders (Figge et al., 2021). Therefore, it is crucial to have a thorough understanding of the intricate dynamics and mechanisms at various levels in order to effectively examine the factors that facilitate the establishment of a CBM. Presented below is a concise overview of the ecosystem's three main hierarchical levels: (1) Micro Level, (2) Meso Level, and (3) Macro Level.

1. **Micro Level - Business Model Level** refers to the company-related factors.
2. **Meso Level - Collaborative Level** refers to supply chain/customer-related factors.
3. **Macro Level - Societal level** refers to the socio-technical and political factors related to the context where the business model is supposed to be implemented.

To assess the ecosystem aspects of each CBM opportunity, we address the following question: How the CBM is enabled in the micro-, meso-, and/or macro-level(s)?

2. CIRCULAR STRATEGY LEVEL
The circular strategy level dimension aims to provide an indication of the overarching circular focus of each of CBM opportunity. These strategies aim to promote circularity in the economy and reduce emissions related to metal production.
We used the five circular strategy levels as defined by Konietzko et al., 2020:

1. **Narrow - Use Less**: This strategy focuses on minimising resource consumption by using fewer materials and resources throughout the product lifecycle, as well as using those resources that have a lower environmental impact.
2. **Slow - Use Longer**: This strategy aims to extend to using products, components and materials longer. This includes aspects such as durability, promoting maintenance and repair, facilitating upgrade. Longer product life cycles mean fewer product replacements overall, which saves money, energy, and material.
3. **Close - Use Again**: This strategy emphasises

the importance of recycling, remanufacturing, and reusing materials and components. It promotes the development of circular supply chains and encourages the reintegration of products and materials back into the production cycle, reducing the reliance on virgin resources.
4. **Mitigate - Make Clean**: This strategy emphasises using clean, renewable energy, decreasing emissions, and minimising environmental impacts throughout the product lifecycle.
5. **Inform**: This strategy highlights the significance of raising awareness and providing information to stakeholders about circular economy principles. It aims to educate and engage individuals, organisations, and communities, fostering a shared understanding and commitment to circular practices.

In relation to the overarching circular strategies, we address the following question: Which overarching circular strategy is associated with the business model?

3. STAKEHOLDER LEVEL

In the context of business models aimed at system innovations, understanding stakeholders and their interactions within broader socio-technical systems is crucial. These stakeholders co-evolve in response to various factors including social, legislative, ecological, technological, and economic changes. Drawing on the framework by Gaziulusoy et al., 2015, we categorize stakeholders involved in specific business models into four social system types:

1. **Institutional:** Actors that influence laws, rules, regulations and standards.
2. **Socio/Cultural**: Actors influencing social norms and cultural practices.
3. **Organisational**: Businesses or organisations directly involved in the business model.
4. **Technological**: Actors related to the technological aspects of the business model.

To understand the essential interactions between stakeholders in wider socio-technical systems for the purpose of facilitating CBM, we aim to answer the following question: Who are the key stakeholders involved in the implementation of the CBM and what are their roles in facilitating its success?

4. TECHNOLOGY READINESS LEVEL

The concept of Technology Readiness Level (TRL) serves as an evaluative metric for gauging the maturity of technologies that either contribute to value creation or facilitate the circularity of steel and aluminum. Given that TRL estimations are intrinsically context-dependent, especially in relation to the business models in which they are deployed, it should be noted that the assessment is specifically tailored to the United Kingdom context. While traditional TRL metrics consist of nine levels, this work condenses them into four overarching levels to provide directional guidance for future business models in these sectors.

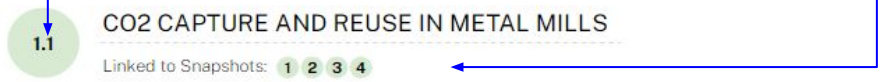
1. **Emerging Innovations**: These are early-stage technologies with the potential to contribute to circularity but have not yet been validated.
2. **Niche Innovations**: These technologies have been validated and are operational within specific market segments, but have not yet achieved broader market penetration.
3. **Growth Innovations**: These are technologies that are in the scaling phase, having passed the validation stage and are in the process of broader market adoption.
4. **Mainstream Innovations**: These technologies have achieved wide market adoption and are considered industry standards.

To identify the TRL, we address the following question: In relation to the technologies needed to implement the CBM opportunity, what is their current technology readiness level?

VISION NUMBER + BUSINESS MODEL OPPORTUNITY NUMBER

BUSINESS MODEL OPPORTUNITY TITLE

LINKED SNAPSHOTS



WHY we need this BM

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? The steel and aluminium sector accounts respectively for around 7% (Holappa, L. 2020) and 3% (Cousins S., 2021; IEA 2022) of direct CO2 emissions, making metal production's environmental impact critical. Metal mills can minimize emissions by using CO2 capture systems such as Carbon Capture Utilisation and Storage (CCUS), supporting climate change initiatives. Compliance is crucial, as mills without such technologies may face penalties or restrictions in the future. By integrating CCUS, mills can ensure compliance, maintain operations, and benefit economically. Reusing captured CO2 reduces fossil fuel use and energy costs. Additionally, meeting market demand for sustainability enhances reputation and attracts environmentally conscious clients and investments. Overall, adopting CO2 capture and reuse technologies in metal mills is essential for environmental, regulatory, and economic reasons.

HOW value is delivered

HOW value is captured

BUSINESS MODEL ASPECTS

Value is delivered by sequestration of CO2 emissions in the atmosphere and store carbon dioxide emissions through a variety of mechanisms, including incentivising emissions reductions, creating transparent pricing structures, providing a market for low-carbon products, and encouraging investment in carbon capture and storage (Muslemani et al., 2020). This can mitigate climate change by reducing carbon dioxide emissions.

Value is captured for now mostly by monetising emissions reductions or other low-carbon practices through the sale of tax credits, certificates, or other financial instruments (Desnz & Beis 2020). However there is potential for CO2 exchange, particularly in its utilisation as a raw material for the synthesis of chemicals, and construction materials.

POTENTIALLY RELEVANT TO

Solution providers: In general, the solution providers could include technological providers, companies, government bodies, and financial institutions.

Customers/users: The customers could include metal mills and/or metal-related companies that want to reduce their carbon emissions.

s is a ongoing project in which CO2 from industry in the Port of Rotterdam is transported and stored in empty gas North Sea. Porthos will transport and store CO2 captured by several companies. The companies will send their n port pipeline. CO2 will be compressed in a compressor station. CO2 will be piped to a North Sea platform 20 km n offshore pipeline. From this platform, CO2 will be pumped into an empty gas field. More than 3 km below the pty gas fields are in a sealed reservoir of permeable sandstone. Porthos will store 37 Mton CO2 for 15 years, 2.5

EXAMPLE OF THE BUSINESS MODEL OPPORTUNITY

WHO create and utilise the BM

ECOSYSTEM LEVEL - focus

CIRCULAR STRATEGY LEVEL

STAKEHOLDER LEVEL

TECHNOLOGY READINESS LEVEL

ECOSYSTEM LEVEL

How the CBM is enabled in the micro-, meso-, and/or macro-level(s)?

MICRO LEVEL
Focusing on the company level - inter-firm circularity, CBMs, cleaner production, waste reduction.

MESO LEVEL
Focusing on group of firms - emphasising the interactions and dynamics of materials and energy that flow between them.

MACRO LEVEL
Focusing on economy system - Optimise cross-organizational interactions for socio-economic and ecological impact.

CIRCULAR STRATEGY LEVEL

Which overarching circular strategy/ies is/are associated with the business model?

NARROW
Minimising resource consumption or waste

SLOW
Extending product lifespan or durability

CLOSE
Facilitating product or resource recycling, repurposing, or reuse

MITIGATE
Ensuring environmentally friendly processes and outputs

INFORM
Emphasizing awareness, communication, or education about sustainability practices

STAKEHOLDER LEVEL

Who are the key stakeholders involved in the implementation of the CBM and what are their roles in facilitating its success?

INSTITUTIONAL
Shaping or being influenced by institutional rules, norms, and conventions

SOCIO/CULTURAL
Interacting with or being impacted by socio-cultural norms, beliefs, and values

ORGANIZATIONAL
Functioning within or influencing organizational structures, processes, or practices

TECHNOLOGICAL
Engaging with or determining technological developments, tools, or platforms

TECHNOLOGY READINESS LEVEL

What is the current level of technology readiness level?

EMERGING INNOVATION
It is still in its early conceptual or developmental phases with potential for the future

NICHE INNOVATION
It is functioning in specific, limited scenarios or markets but not yet widely adopted

GROWTH INNOVATION
It is rapidly expanding, being adopted by a wider user base, and demonstrating increased market potential

MAINSTREAM INNOVATION
It is widely recognised, adopted, and integrated into mainstream applications or markets

The 61 CBM opportunities for the metal sector

This study expands on the twelve desirable visions outlined in Franconi et al., 2022, along with corresponding 'Snapshots from the future' (listed on the right) that depict practical exemplifications of these visions. We contrast these visions and snapshots with the circular business model archetypes described in Pieroni et al., 2020 to suggest potential CBM opportunities for steel and aluminium companies. This investigation resulted in the comprehensive set of 61 CBM opportunities, which are outlined in Table 1.
The CBM opportunities are categorised according to the twelve visions and the 20 archetypal circular business models.

VISION 01
Net-zero emission metal production

1. Green Energy Metal Making
2. Hydrogen-powered metal manufacturing
3. CO2 capture and reuse
4. Industrial Symbiosis

VISION 02
Circular alloys and manufacturing

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

VISION 03
Distributed metal manufacturing

1. Mitigate 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

VISION 04
End-to-end supply chain

1. Intelligent inventory management
2. Supply chain sustainability reporting adopted by all businesses
3. Service-oriented supply chain

VISION 05
Metal as a service

1. Metals molecules as a service
2. Metal components as a service
3. Metal products as a service (B2B)
4. Metal products as a service (B2C)
5. Metal products shared
6. Buildings and structural components as a service
7. Social bubble collaborative economy

VISION 06
Metal life cycle data

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

VISION 07
Full metal packaging

1 Pure Metal

2 Packaging deposit schemes

3 Milkman model

4 Refilling station

5 Reusable packaging on-the-go

6 Reverse vending schemes

VISION 08
Stop Recycling Start Repairing

1 MHS - Components rejuvenation

2 MHS - Structure rejuvenation

3 MHS - Metal day hospital

4 Micro repair entrepreneurs

5 Self-healing metal

VISION 09
Repair-it-yourself (RIY)

1 RIY- Repair digital platforms

2 RIY- First-aid repair kit

3 RIY- Repairs technologies

4 School-based repair courses

5 Repair community centres

VISION 10
The logic of sufficiency

1 Multigenerational products

2 Open library of things

3 Emotional attachment

4 MyMetal

5 Deliveries once a week

VISION 11
Reusing, remanufacturing, and repurposing

1 The renaissance of secondhand markets

2 Remanufacturing and refurbishment services become core offerings

3 Cascade Reusing

VISION 12
Better metal recovery, sorting, upcycling and recycling

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

2050 Visions for the metal sector	Circular Business Archetypes																		
	Dematerialised or efficiency			Collaborative consumption		Product-service systems		Long life			Next life				Circular sourcing			Circular production and distribution		
	A01	A02	A03	A04	A05	A06	A07	A08	A09	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20
01																(1.2)			(1.1) (1.3) (1.4) (1.5)	
02														(2.3)	(2.2)		(2.1)	(2.4)	(2.5)	
03							(3.17)	(3.1) (3.2) (3.3) (3.4)	(3.5) (3.6)			(3.8)	(3.9)		(3.12)			(3.7) (3.10) (3.11)		
04		(4.1)																		(4.2)
05			(5.1)			(5.2) (5.3)	(5.4) (5.5)			(5.7)										
06								(6.1) (6.3)							(6.4) (6.5)					(6.2) (6.6)
07						(7.1) (7.2) (7.3)														
08									(8.1) (8.2) (8.3)											
09		(9.3)							(9.1) (9.2)											
10		(10.1)		(10.3)				(10.2)												(10.4)
11											(11.1)	(11.2) (11.3)	(11.4)							
12											(12.2) (12.3) (12.4)			(12.5) (12.6)			(12.1)			

Tab 1. Cross-Referencing Preferable Visions by Franconi et al., 2022 (column) with Business Model Archetypes by Pieroni et al., 2020 (row) for Steel and Aluminum Sectors.
Please refer to the following list of circular business models archetypes situated in the table row on the left-hand side.

Dematerialised or efficiency

A01 Dematerialised services
A02 Demand reduction services
A03 Encourage sufficiency

Collaborative consumption

A04 Sharing economy
A05 Sharing or pooling systems/platforms

Product-service systems

A06 Access model
A07 Performance or result model

Long life

A08 Lifetime products
A09 Premium products with life extension services
A10 Hybrid model

Next life

A11 Direct reuse
A12 Next life sales
A13 Product transformation
A14 Extending resource value

Circular sourcing

A15 Asset management
A16 Industrial Symbiosis
A17 Circular supplies

Circular production and distribution

A18 On demand
A19 Cleaner production and eco-efficiency
A20 Collection, take back, and reprocessing of used products

Vision 01

Net zero emission metal production

In 2050, the UK's metal production has shifted to net zero emissions. This means that all processes related to metal production, from recycling to smelting to manufacturing, have been redesigned to release no greenhouse emissions. This has been made possible by a combination of advances in renewable energy, energy storage, and process efficiency. The majority of the UK's electric arc furnaces (EAFs) are now placed near by or within large, solar-powered factories and wind farms. This has made metal production much cleaner and more efficient than in the past. Renewable energy sources are also used to generate the hydrogen to power EAFs. Hydrogen-oxygen fuel cells are used to power EAFs by supplying the electrical energy needed to operate the furnace. This has led to a cleaner and more efficient process, as well as a reduction in emissions. The process is now so efficient that it is able to produce large quantities of metal without almost any negative environmental impact. This is due also to the carbon capture, utilisation and storage (CCUS) technologies that allow capture and either reuse or storage of carbon dioxide from metal manufacturing. Furthermore, today the UK's metal system is one of the world's most advanced industrial symbiotic networks, which allows businesses to pool resources and knowledge to maximise waste product reuse, reduce waste sent to landfill, and decrease the carbon footprint of the steel sector. This shift to net zero emissions has had a major impact on the UK's economy. Metal production is now one of the most important industries in the UK, and it is responsible for thousands of jobs. The shift to cleaner production has also helped to reduce global warming, as metal production was one of the biggest sources of greenhouse gas emissions.

Related ‘Snapshots from the future’

1 Green Energy Metal Making

2 Hydrogen-powered metal manufacturing

3 CO2 capture and reuse

4 Industrial Symbiosis

1.1 CO2 CAPTURE AND REUSE IN METAL MILLS

Linked to Snapshots: 3

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? The steel and aluminium sector accounts respectively for around 7% (Holappa, L. 2020) and 3% (Cousins S., 2021; IEA 2022) of direct CO2 emissions, making metal production's environmental impact critical. Metal mills can minimize emissions by using CO2 capture systems such as Carbon Capture Utilisation and Storage (CCUS), supporting climate change initiatives. Compliance is crucial, as mills without such technologies may face penalties or restrictions in the future. By integrating CCUS, mills can ensure compliance, maintain operations, and benefit economically. Reusing captured CO2 reduces fossil fuel use and energy costs. Additionally, meeting market demand for sustainability enhances reputation and attracts environmentally conscious clients and investments. Overall, adopting CO2 capture and reuse technologies in metal mills is essential for environmental, regulatory, and economic reasons.

BUSINESS MODEL ASPECTS

Value is delivered by sequestration of CO2 emissions and storing carbon dioxide emissions through state-of-the-art carbon capture technologies.

Value is captured by monetizing emissions reductions or other low-carbon practises through the sale of CO2. This is especially true in its use as a raw material for chemical synthesis and construction materials.

POTENTIALLY RELEVANT TO

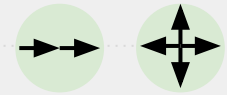
Solution providers: In general, the solution providers could include technology providers, mills, government bodies, and financial institutions.

Customers/users: The potential customer include metal mills and other metal-centric enterprises seeking to mitigate their carbon footprint. The effective execution of this approach should additionally incorporate the communities living in close proximity to the mills.

EXAMPLE Porthos is a ongoing project in which CO2 from industry in the Port of Rotterdam is transported and stored in empty gas fields beneath the North Sea. Porthos will transport and store CO2 captured by several companies. The companies will send their CO2 to a Rotterdam port pipeline. CO2 will be compressed in a compressor station. CO2 will be piped to a North Sea platform 20 km offshore through an offshore pipeline. From this platform, CO2 will be pumped into an empty gas field. More than 3 km below the North Sea, the empty gas fields are in a sealed reservoir of permeable sandstone. Porthos will store 37 Mton CO2 for 15 years, 2.5 Mton per year.

MESO LEVEL

ECOSYSTEM LEVEL: This model operates at the meso level, as it requires the cooperation of several companies that exchange CO2.



CLOSE - USE AGAIN & MITIGATE - MAKE CLEAN

CIRCULAR STRATEGY LEVEL: This model primarily enhances the CO2 mitigation and resilience of the metals ecosystem. By reusing captured CO2 in other sectors, resource closing is also promoted.

INSTITUTIONAL , SOCIO/CULTURAL, ORGANIZATIONAL & TECHNOLOGICAL

STAKEHOLDER LEVEL: In this model multiple stakeholders work together to capture and utilise CO2. Government bodies are usually involved in researching and funding these initiatives.

NICHE INNOVATION

TECHNOLOGY READINESS LEVEL: Multiple rapidly emerging and evolving technologies are used in this model. However, despite the existence of CO2 capture and reuse facilities, these technologies have not yet achieved widespread adoption.

1.2 INDUSTRIAL SYMBIOSIS IN METAL-RELATED DISTRICTS

Linked to Snapshots: 4

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? In the past 50 years, the steel industry has reduced its energy consumption per tonne of steel produced by 60% (WSA a, 2016). Although waste energies are effectively captured and utilised, there is little space for technological advancement. Today, the average energy intensity of steel manufacturing is 20 GJ/t crude steel, with a 15-20% improvement potential (WSA a, 2016). Therefore, it is worthwhile to explore alternative non-technological approaches in order to mitigate emissions. Industrial symbiosis in metal-related districts bolsters resource efficiency — increasing it worldwide by an average of 36% (IEA, 2020) for steel — and environmental sustainability, given the potential for a 30% reduction in CO2 emissions. By pooling resources and exchanging heat, gaseous and solid waste/byproducts (such as slug which makes up 90% of the byproducts of steel manufacturing, according to Branca et al., 2020), businesses decrease costs, increase profitability, and drive innovation. This collaborative approach aligns with circular economy principles, reduces waste generation, and improves environmental sustainability. Overall, industrial symbiosis fosters a more efficient and mitigate metal industry.

BUSINESS MODEL ASPECTS

Value is delivered by reusing production byproduct or residuals by nearby businesses that will turn them into new resources in other production processes. Through the establishment of a network encompassing private and public entities, steel and aluminium companies can optimize the utilisation of byproducts, mitigate the need for byproduct disposal, and effectively minimise CO2 emissions within the industry.

Value is captured mainly through sale of these byproducts between industries and the reduction of waste management.

POTENTIALLY RELEVANT TO

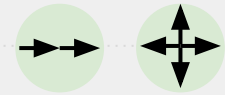
Solution providers: Potential solution providers encompass various entities from both the private and public sectors. They can be government companies, large corporations, conglomerates, manufacturing companies, recycling plants, universities, municipalities, utilities, and corporate partnerships. These diverse actors work together to establish local business networks and devise strategies for exchanging and reusing one another's byproducts.

Customers/users: In industrial symbiosis, customers can act as solution providers within local business networks, and vice versa.

EXAMPLE ArcelorMittal Ghent is using gas fermentation technology from LanzaTech in an effort to lower CO2e emissions. Carbon-rich waste gases are captured by the technology and converted into sustainable fuels and compounds. The plant seeks to reduce carbon emissions by 125,000 tonnes per year while producing 80 million litres of bio-ethanol. LanzaTech is also investigating the conversion of captured emissions into chemical building elements for textiles, rubber, and packaging.

MESO LEVEL

ECOSYSTEM LEVEL: This model operates at the meso level as it requires the cooperation of several companies to exchange different kind of resources (e.g., heat, gaseous byproducts, and solid waste).



CLOSE - USE AGAIN & MITIGATE - MAKE CLEAN

CIRCULAR STRATEGY LEVEL: This model facilitates the closure of the loop through the exchange of heat, gaseous byproducts, and solid waste. By engaging in this practise, it also guarantees the implementation of an environmentally sustainable process.

INSTITUTIONAL , SOCIO/CULTURAL, ORGANIZATIONAL & TECHNOLOGICAL

STAKEHOLDER LEVEL: This model exploits spatial and social relationships. When combined, these elements allow enterprises to share assets, knowledge, and infrastructures in an economically and environmentally advantageous way.

NICHE INNOVATION

TECHNOLOGY READINESS LEVEL: Although this model does not rely much on cutting-edge technology, its maximum potential is limited without a sufficiently robust supporting infrastructure and network. Therefore, this model is classified as nich innovation.

1.3 ECO-EFFICIENT METAL PRODUCTION

Linked to Snapshots: 1

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? Given the substantial role played by the metal industry in global greenhouse gas emissions, it is imperative that this sector undergoes a transition from fossil-carbon materials to sustainable alternatives within the near to medium term (Mousa et al., 2016). This transition is crucial in order to effectively mitigate CO2 emissions originating from the metal industry (WSA b, 2021). Biomass, a renewable and carbon-neutral source, is promising; studies suggest replacing fossil fuels with sustainable biomass in electric arc furnace (EAF) could cut CO2 emissions by up to 12% (Echterhof, 2021). Additionally, waste-based energy options could facilitate material value recapture while reducing CO2 emissions; for instance, utilising waste plastics (plasmix or mixed plastics that cannot be recycled through traditional circuits) in steelmaking could substantially lower CO2 emissions (IREN, 2022). These changes aren't just environmentally motivated; they're a strategic move towards innovation and resilience in the industry.

BUSINESS MODEL ASPECTS

Value is delivered by enabling a shift towards sustainable and efficient metal production techniques. Traditional blast furnace-basic oxygen furnace (BF-BOF) and electric arc furnace (EAF) processes have historically depended on fossil fuels like coal and natural gas. This model aims to promote alternatives, such as biomass, waste-based fuels, and other low-carbon energy sources, to replace fossil fuels in metal production. The benefits include cost savings, new revenue streams, and an enhanced corporate reputation for sustainability.

Value is captured through cost savings, revenue generation, and enhanced reputation resulting from the adoption of sustainable and efficient metal production methods.

POTENTIALLY RELEVANT TO

Solution providers: Bioenergy or waste companies developing and applying new technology may be solution suppliers. These solution providers can explore synergistic cooperation with the aluminium and steel sectors to generate innovative and sustainable solutions. These solution suppliers can develop environmentally friendly aluminium and steel practises by using their experience and technologies.

Customers/users: Customers encompasse metal producers, steel mills or companies in the aluminium and steel industry that traditionally rely on coal for their operations.

EXAMPLE The I.Blu plant in San Giorgio di Nogaro, Italy, converts mixed plastics that cannot be recycled into the Bluair® polymer, a circular secondary raw material. This polymer can replace coal in the iron and steel sector, acting as a reducing agent and optimizing the steel production process. By using Bluair® polymer instead of coal, the decarbonization process in the iron and steel industry is facilitated, resulting in a reduction of CO2 emissions by over 30% and improved environmental performance. The I.Blu plant has the capacity to process 115,000 tonnes of non-traditional plastic waste annually, producing 70,000 tonnes of Bluair® polymer. This innovative approach showcases the transformation of waste into valuable resources and contributes to the ecological transition process pursued by Iren.

MICRO LEVEL

ECOSYSTEM LEVEL: This model mostly operates at the micro level as it enables a more efficient production process at the individual firm level.

MITIGATE - MAKE CLEAN

CIRCULAR STRATEGY LEVEL: This model enables the reduction of carbon dioxide emissions by implementing different sustainable and efficient methods for metal production.

INSTITUTIONAL, ORGANIZATIONAL & TECHNOLOGICAL

STAKEHOLDER LEVEL: This model is frequently implemented by private enterprises, although it often requires government funding to decarbonize the industry and incentivize it.

GROWTH INNOVATION

TECHNOLOGY READINESS LEVEL: In general, technologies associated with this model, such as the EAF, have been in use for several decades and are well-established, particularly in the steelmaking industry; however, this model is not widespread.

1.4 RENEWABLE-POWERED METAL PRODUCTION

Linked to Snapshots: 1 2

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? Renewable-powered metal production is essential for the metal economy to address its environmental impact. By adopting cleaner production methods, the industry can reduce emissions, comply with regulations, and meet consumer demands for sustainable products. Among the various available options, the transition towards hydrogen-based processes emerges as a crucial approach, replacing carbon-intensive fossil fuels. This transition not only improves the industry's competitiveness and reputation but also holds the potential for significant cost reductions, particularly beyond the year 2030 (McKinsey & Company, 2020). Other initiatives may include for example, blast furnace (BF)/basic oxygen furnace (BOF) efficiency programs, the increased utilization of scrap-based electric arc furnaces (EAF), and the optimization of direct reduced iron (DRI) and EAF processes.

BUSINESS MODEL ASPECTS

Value is delivered through the adoption of cleaner production methods and the utilisation of renewable energy sources. This results in reduced environmental impact, lower emissions, and compliance with sustainability goals. By transitioning to renewable energy sources, such as solar, wind power, or hydrogen the industry can enhance its reputation, attract environmentally conscious customers, and meet regulatory requirements.

Value is captured through cost savings from utilising renewable energy sources, improved operational efficiency through emission reduction, market differentiation with sustainable products, and alignment with evolving consumer preferences and regulatory frameworks.

POTENTIALLY RELEVANT TO

Solution providers: The potential solution providers consist of technology providers, research institutions, and government/regulatory bodies that develop and offer renewable-powered metal production solutions.

Customers/users: Customers encompasse metal producers, who implement these solutions, as well as manufacturers and end users who demand and utilize renewable-powered metal products.

EXAMPLE HYBRIT, an initiative by Swedish steel manufacturer SSAB, stands at the forefront of revolutionizing the steel industry through sustainable practices. HYBRIT, an acronym for Hydrogen Breakthrough Ironmaking Technology, is a unique project that aims to replace coking coal, traditionally required for ore-based steel making, with hydrogen. The result is an innovative process that emits water instead of carbon dioxide, making it a groundbreaking attempt to produce 'fossil-free' steel. The pilot phase of the HYBRIT project started in 2018, and by 2021, it had begun testing operations to use hydrogen in the direct reduction of iron ore. The aim is to have a solution for fossil-free steel in place by 2035.

MACRO LEVEL

ECOSYSTEM LEVEL: This model is considered on a macro level due to its significant interdependence with the development of renewable infrastructure.

MITIGATE - MAKE CLEAN

CIRCULAR STRATEGY LEVEL: This model is critical for decarbonizing metal production and mitigating the effects of metal production across the circular metal supply chain.

INSTITUTIONAL, ORGANIZATIONAL & TECHNOLOGICAL

STAKEHOLDER LEVEL: The success of this approach relies on the comprehensive development of the renewable infrastructure establishing, which necessitates the collaboration of both private and governmental partners.

NICHE INNOVATION

TECHNOLOGY READINESS LEVEL: There are renewable energy-powered metal production systems, but their utilisation is limited. Furthermore, several innovations in this field are still in development.

1.5 CLEANER METAL PRODUCTION

Linked to Snapshots: 1

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? Due to the high energy consumption involved in the production and assembly of metal products, cleaner product production is crucial to the metal economy. By employing a cleaner approach to production and substituting or modifying less environmentally friendly practises, the metal industry can effectively mitigate environmental harm. These methods include the conservation of raw materials, water and energy, the reduction of toxic raw materials (toxicity and quantity), emissions and waste, which go to water, into the atmosphere and the environment.

BUSINESS MODEL ASPECTS

Value is delivered by reducing the environmental impact of product manufacturing. This can be achieved through a variety of means, including total quality management, recycling of waste, substitution of environmentally hazardous products, improved product design, efficient component manufacturing and maximising renewable energy generation at the facility.

Value is captured through reduced environmental impact of product manufacturing, reduced operational costs, and reduced investment demands associated to rising carbon dioxide pricing.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers are typically the companies operating cleaner production in their facilities.

Customers/users: Customers encompasse both direct and indirect users of the items.

EXAMPLE The REALITY aluminium project is a key part of Jaguar Land Rover's Destination Zero strategy, which aims to reduce carbon emissions and create safer, cleaner society via innovation. In pursuit of this mission, Jaguar Land Rover is dedicated to the redesign of its vehicles, aiming to enhance vehicle stiffness by 30 percent and achieve a weight reduction of 35 kilograms. The reduction in vehicle body weight not only enhances performance during product usage but also leads to decreased material consumption during production processes. Jaguar Land Rover has already achieved a commendable 50.7 percent reduction in global operating CO2 emissions per vehicle since 2007 and remains resolute in its commitment to an ongoing decarbonization trajectory.

MICRO LEVEL

ECOSYSTEM LEVEL: This model mostly operates at the micro level as it enables a more efficient production process at the individual firm level.

MITIGATE - MAKE CLEAN

CIRCULAR STRATEGY LEVEL: This model enables the reduction of carbon dioxide emissions by implementing different sustainable and efficient methods for product metal production.

ORGANIZATIONAL

STAKEHOLDER LEVEL: Typically, this model is implemented through the partnership between individual companies and their respective providers.

MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: The technologies used in this model (e.g. waste minimization in product manufacturing) are commonly adopted and utilised by numerous manufacturers.

Vision 02

Circular alloys and manufacturing

In 2050, the UK has one of the most efficient metal closed loop systems worldwide. This has been made possible by research and innovation in the development, manufacture, regulation, and application of metals. In the early 2030s, the UK government successfully conducted a rationalisation of alloys grades and use, drastically lowering their number and application. This prompted the market to invest in high-quality metals and the development of highly efficient and recyclable alloys. For this reason, alloys with high temperature, fatigue, corrosion, and oxidation resistance, such as multi-principal alloys, became widely used. Technology innovation has also been critical in improving efficiency and productivity compared to the past. For example, nanotechnology, robotics, and computation have enabled the development of metal nanomanufacturing centres capable of producing micro-scale alloys with precise qualities for various applications. Artificial intelligence (AI) is used to optimise the manufacturing of metal components, enabling the creation of metal structural components that require significantly less material and are substantially more robust. Through automated image recognition, AI can also locate and label any potential faults in the metal while it is being made. This technology cuts down on production waste and gives the producer useful information about the materials. 4D printing technology has enabled the development of self-disassembling metals for improved recyclability. All of this significantly aided the management and repurposing of metals across several loops.

Related ‘Snapshots from the future’

1 Rationalisation of alloy grades and use

2 Closed metal loops enabled by multi-principal elements alloys

3 Metal nano-manufacturing for multi-principal alloys

4 AI-driven metal material optimisation

5 Self-disassembly metal components

6 Zero defect: computer vision to predict quality defects

2.1 STANDARDS FOR ALLOY USE IN METAL SUPPLY CHAIN

Linked to Snapshots: 1 2

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? The excessive variety in commercial metallic materials poses sustainability and recycling challenges. Unnecessary alloying and strict alloy specifications escalate costs, impact resource productivity, harm the environment, and complicate recycling. Simplifying materials and designing for reusability and recyclability can greatly improve this situation. For instance, the current catalogue of over 400 grades of aluminium (Al) alloys can feasibly be reduced to 10-15 without compromising their application (LiME Project). Strategies to achieve this include designing high-performance alloys (e.g., Multicomponent Metal Alloys), classifying alloy systems by composition, thermomechanical history, performance, and application; standardising alloy compositions using commonly available elements; optimising thermomechanical treatments; and developing new, sustainability-focused alloy specifications.

BUSINESS MODEL ASPECTS

Value is delivered by utilising recyclable alloys in product design, leading to cost reduction in the recovery process, enhanced resource reuse, and reduced company CO2 emissions.

Value is captured through the implementation of a closed loop system, wherein the manufacturer company recaptures the value of the material.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers are typically companies specialising in material engineering, alloy development, and manufacturing processes.

Customers/users: The customers in this business model are typically industries or companies that rely on metallic materials, specifically alloys, for their manufacturing processes.

EXAMPLE Alcoa's Micromill technology offers significant advancements in the production of aluminium sheets, providing greater formability, strength, and lighter weight. The process involves changing the microstructure of the metal, resulting in alloy sheets with superior characteristics compared to traditional rolling mills. The Micromill technology reduces production time drastically, from 20 days to just 20 minutes, making it the fastest and most productive aluminium casting and rolling system. The Ford F-150 pickup truck from Ford Motor Co. is an example of a product that employs this alloy.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level, as it focused on the circular implementation of the molecular scale alloys.

NARROW - USE LESS, SLOW - USE LONGER & CLOSE - USE AGAIN

CIRCULAR STRATEGY LEVEL: This model, through the design of higher performance allies, can use less energy for production, last longer due to straight properties, and be more recyclable, thereby closing the cycle.

ORGANIZATIONAL

STAKEHOLDER LEVEL: Typically, this model is implemented through the partnership between individual companies and their respective providers.

EMERGING INNOVATION

TECHNOLOGY READINESS LEVEL: This model requires significant innovation in R&D and the implementation of novel alloys, but the viability of these endeavours is still in its early stages.

2.2 INTEGRATED DISASSEMBLING SYSTEM

Linked to Snapshots: 5

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? As advancements continue to be made in the sphere of circular alloys, maintenance, and recovery technologies, the implementation of an Integrated Disassembling System (IDS) is becoming essential within the metal economy. This system plays a crucial role in synchronising and integrating these innovations, facilitating the transition to a model that optimises product disassembly and reuse to maximise profitability. For instance, when applied within the automotive industry, an IDS utilises a strategic approach to implementing self-disassembly components in vehicle assembly. Consequently, if a specialised disassembly equipment is utilised during the product's end-of-life disassembly, the vehicle can be disassembled without the need for employees capable of performing more complex disassembling tasks. This optimised approach enables faster, safer, and more efficient disassembly processes, leading to increased resource recovery. IDS, with its integrative design, facilitates coordination across the metal supply chain, bridging the gap between different parties involved upstream and downstream.

BUSINESS MODEL ASPECTS

Value is delivered through the seamless integration throughout the metal supply chain of innovations that maximise disassembly and reuse (e.g. self-disassembly metal components, automated disassembly line, etc.). This model enhances coordination and collaboration across the metal supply chain by bridging the gap between different stakeholders involved upstream and downstream. This coordination improves communication, reduces inefficiencies, and creates opportunities for synergistic partnerships and value chain optimization.

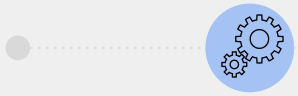
Value is captured by designing closed-loop systems that make efficient use of resources and allow for optimal product and material value retention.

POTENTIALLY RELEVANT TO

Solution providers: The main solution providers are manufacturing working in a closed-loop system or material or component recovery companies that recover and disassemble products in order to reuse or resell them.

Customers/users: The customers of this business model can be diverse and include industries that reuse or recycle products and materials or original equipment manufacturers that intend to refurbish or remanufacture their products.

EXAMPLE Oak Ridge National Laboratory (ORNL) has developed a robotic disassembly system specifically designed for spent electric vehicle battery packs. This technology improves safety and throughput, making cobalt, lithium, and metal foil recycling and reuse efficient. This disassembly line reduces human intervention, harmful chemical exposure, and errors, maximising product and material value. Advanced metrology and AI allow the system to adapt to different battery pack configurations. ORNL connects recyclers, manufacturers, and supply chain providers. The system reduces inefficiencies and fosters synergies by enhancing cooperation and communication. This project is crucial to commercial scalability and wasted battery supply chain integrity.



MESO LEVEL

ECOSYSTEM LEVEL: This model primarily operates at the meso level because it enables manufacturers to disassemble products and components for reuse or recycling efficiently.

CLOSE - USE AGAIN

CIRCULAR STRATEGY LEVEL: This model facilitates the closing-loop operation and enhances product reuse and recycling.

ORGANIZATIONAL

STAKEHOLDER LEVEL: Typically, this model is implemented through the partnership between individual companies and their respective providers.

EMERGING/NICHE INNOVATION

TECHNOLOGY READINESS LEVEL: This model incorporates a number of technologies, although the most groundbreaking ones, such self-disassembling products, are yet emerging or in the nich innovation level.

2.3 METAL NANOMANUFACTURING

Linked to Snapshots: 3

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This business model presents a transformative opportunity for the metal industry (Pokrajac et al., 2021). By manipulating metal structure at the nanoscale, metal noano-manufacturing enhances physical properties like strength and durability, potentially increasing tensile strength by up to 50% (Sun et al., 2020). Furthermore, this model leads to prolonged product lifespan, reduced maintenance costs, and allows for distinct product offerings (Lloyd et al., 2005; Chee et al., 2022).

BUSINESS MODEL ASPECTS

Value is delivered by manipulating and controlling the structure of alloys (using atom-by-atom deposition techniques) to design high-quality, lightweight, strong, safe, and sustainable alloys. It involves precise control and manipulation of metal atoms and their interactions to engineer materials and products with improved performance.

Value is captured through the sale of the engineered materials and products. By offering superior materials with enhanced properties, companies can charge a premium price for their products and capture additional value.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers include nanotechnology and materials science companies, research institutions and laboratories developing nanomanufacturing technologies, equipment manufacturers making nanoscale fabrication machinery and tools, material suppliers offering nanomaterials and nanoparticles, and engineering and consulting firms specialising in nanomanufacturing processes and design.

Customers/users: Customers span various industries and sectors such as aerospace, automotive, electronics, healthcare, and energy, which require advanced materials with tailored properties.

EXAMPLE Seattle-based startup Modumetal is revolutionizing metal nano-manufacturing with its advanced electroplating process. By controlling the structure of metals at the nanoscale, they create corrosion-resistant parts for oil fields and other applications. The process involves precise deposition of multiple metal ions to form layered structures with unique properties. Modumetal's production capacity is expanding, and further validation and standardized testing are underway. Their breakthrough technology has significant potential across industries.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level, as it focused on the nanomanufacturing of alloys.

SLOW - USE LONGER

CIRCULAR STRATEGY LEVEL: This model increases the lifespan and durability of nanomanufactured alloys and their products.

ORGANIZATIONAL

STAKEHOLDER LEVEL: Typically, this model is implemented through the partnership between individual companies and their respective providers.

EMERGING INNOVATION

TECHNOLOGY READINESS LEVEL: This model requires significant innovation in R&D and the implementation of novel alloys and manufacturing processes, but the viability of these endeavours is still in its early stages.

2.4 ON-DEMAND METAL CASTING

Linked to Snapshots: 1 2 3

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model is rooted in the principles of reducing lead times and enabling the rapid use of products through the use of cutting-edge technologies. Utilising increased dependability and availability results in decreased operational expenses. In addition, it enables the reduction of logistical and warehousing costs, as products are obtained and delivered only when required.

BUSINESS MODEL ASPECTS

Value is delivered from the provision of an agile and flexible manufacturing system that is cost-effective, efficient, and environmentally sustainable. This system enables the production of high-quality, customised metal components without the need for initial capital investment. This can lead to increased customer satisfaction, loyalty, and a competitive advantage in the market.

Value is captured by offering a premium service that is tailored to the needs of their customers, while at the same time reducing their own operating costs and enhancing their brand value.

POTENTIALLY RELEVANT TO

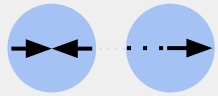
Solution providers: The solution providers may include metal casting service providers, 3D printing companies, digital platforms, and software providers.

Customers/users: This business model serves individuals, corporations, and organisations who need custom products and services on demand.

EXAMPLE CastLab utilises the capabilities of digitisation and 3D-printing to significantly enhance the efficiency of on-demand metal casting. Through 3D printing, the company can quickly generate precise patterns or moulds for metal casting. The advantage lies in the reduced lead times, where spare parts, obsolete parts, and prototypes can be obtained within a matter of days instead of months. Reduce operational expenses by leveraging enhanced uptime and availability. Additionally, it enables the reduction of costly logistics and warehousing endeavours. The process of ordering prototypes or replacement parts is expedited and simplified by exclusively acquiring the necessary items at the time they are required.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level as it enables a more efficient custom metal casting process at the individual firm level.



NARROW - USE LESS, &
SLOW - USE LONGER

CIRCULAR STRATEGY LEVEL: This model supports the principles of narrow and slow resource consumption by promoting the efficient use of metals, reducing waste, and extending the lifespan of products.

ORGANIZATIONAL

STAKEHOLDER LEVEL: Typically, this model is implemented through the partnership between individual companies and their respective providers.

GROWTH
INNOVATION

TECHNOLOGY READINESS LEVEL: This model primarily utilises 3D printing, which is a rapidly advancing technology.

2.5 INTELLIGENT MANUFACTURING AUTOMATION

Linked to Snapshots: 5 6

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? A metal economy that prioritises efficiency, resource conservation, waste reduction, cost reduction, data-driven decision making, higher-quality materials and production processes requires an Intelligent Manufacturing Automation (IMA) business model. The IMA is an emerging set of new technologies that combines fundamental process redesign both in material and product manufacturing with robotic process automation, advanced equipment and machine learning. The IMA model simplifies operations, maximises resource utilisation, cuts costs, allows for informed decision making, and promotes innovation and competitiveness through the use of intelligent automation and cutting-edge monitoring systems. For instance, real-time computer vision may detect quality problems during production, saving costly recalls and improving product quality. Applying computer vision technology in manufacturing settings has the potential to streamline processes, cut costs, and improve quality all at the same time.

BUSINESS MODEL ASPECTS

Value is delivered through the implementation of advanced technologies such as Internet of Things (IoT), Artificial Intelligence (AI), Machine Learning, Digital Twin Technology, and Robotics, along with process redesign. These technologies enable real-time monitoring, predictive maintenance, and automated quality control, resulting in increased efficiency, resource conservation, waste reduction, cost reduction, and higher-quality materials and production processes.

Value is captured through cost savings, improved product quality, informed decision-making enabled by data analytics, competitive advantage through automation and customisation, and optimised resource utilisation facilitated by intelligent systems.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers can include technology companies specialising in automation, robotics, advanced equipment, computer vision systems, and machine learning. These solution providers develop and offer the necessary technologies, software, and systems to enable intelligent automation and process optimisation in the metal economy.

Customers/users: Customers can range from various industries within the metal economy, such as metal manufacturers, metal fabricators, metal processing companies, and metal product manufacturers. Intelligent automation and modern production technology help these customers boost efficiency, quality, cost, and market competitiveness.

EXAMPLE Batch.Works is a circular manufacturing company that employs smart technology and sustainable methodology to develop practical manufacturing solutions. Batch.Works specialises in circular product design, 3D printing, innovative materials, and re-manufacturing. They have the capability to rapidly prototype, test, and refine new designs. Additionally, they can produce products on demand, localise production and material sourcing, and enhance supply chain security. These practises contribute to waste reduction, lower emissions, and shorter lead times for customers.

MICRO LEVEL

ECOSYSTEM LEVEL: This model mostly operates at the micro level as it enables a more efficient production process at the individual firm level.

NARROW-USE LESS

CIRCULAR STRATEGY LEVEL: This model reduces the amount of resources used, making manufacturing processes more efficient and minimising waste.

ORGANIZATIONAL

STAKEHOLDER LEVEL: Typically, this model is implemented through the partnership between individual companies and their respective providers.

GROWTH INNOVATION

TECHNOLOGY READINESS LEVEL: This model integrates several advanced technologies, often powered by artificial intelligence (AI), and its level of readiness is relatively high, despite their uneven prevalence across industries.

Vision 03

Distributed metal manufacturing

In 2050, the UK has a thriving CE in which factories of today are more varied, and more distributed than those of the past. Many small and medium-sized firms, both in urban and rural areas, use innovative technologies to establish circular businesses and connect to intensive super factories for the creation of complex products. As a result, there is a proliferation of locally-based manufacturing networks and related supply chains, giving rise to MITIGATE local economies that are developed around metal production, processing, maintenance, and recycling with a stronger emphasis on repair and regeneration.

Fablabs support these new local economies by providing spaces (to businesses, schools, community groups and individuals) to manufacture, repair, or customise products.

Today's distributed production makes it easier to deploy and adapt new on-demand sales models. In addition, specialised companies offer distributed manufacturing services, enabling manufacturers to produce their products locally.

Flexibility is not only related to production, but also to repairs; innovative on-demand repair models, such as mobile additive manufacturing repair workshops and local repair delivery, make repairs easier by enabling on-site replacement component manufacture.

Electric vehicles, fuel cells, and solar-powered ships all play a role in the new green logistics supporting this new way of conducting business.

Related ‘Snapshots from the future’

1 Regenerative 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

3.1 FAB LAB ENABLING PERSONAL (METAL) MANUFACTURING

Linked to Snapshots: 1 2 3

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? The Fabrication Laboratory (Fab Lab) is instrumental in democratising manufacturing by providing individuals access to digital fabrication tools (Schneider et al., 2019). Furthermore, it fosters innovation, customisation, and rapid prototyping (Prendeville et al, 2017), while encouraging collaboration and knowledge sharing in an open-source platforms (Fleischmann et al., 2016). Notably, by reducing financial and logistical barriers, it improves accessibility to metal manufacturing.

BUSINESS MODEL ASPECTS

Value is delivered by empowering and assisting individuals to design, manufacture and customise their own products (including products with metal components).

Value is captured through the sale of services that provide access to the physical assets (such as buildings, manufacturing facilities, and materials) and intellectual capital (such as technologies knowledge).

POTENTIALLY RELEVANT TO

Solution providers: The Fab Labs that offer the services and resources needed to enable individuals to design, manufacture, and customize their own products. Government departments frequently contract with and strategically locate these facilities (see example).

Customers/users: Individuals who use these services to create their own products or prototypes, such as non-specialists, hobbyists, amateurs, students, start-ups, small businesses, and creative individuals.

EXAMPLE Fab Lab Nepal, the first community-focused, world-class digital manufacturing/training facility in Nepal, enables local capacity-building projects in digital and mechanical manufacturing skills. It has generated significant interest from a wide range of potential partners, including NGOs, government entities, educational institutions, businesses, entrepreneurs, and individuals. The facility has already made a positive impact on the local community, such as the redesign and rebuilding of a food cart, which resulted in a six-fold increase in income for the owner. Fab Lab Nepal collaborates with organizations like Field Ready and Space A to train community members in steel fabrication and support local businesses affected by the COVID-19 pandemic.

MICRO LEVEL

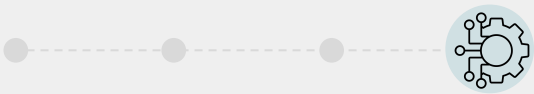
ECOSYSTEM LEVEL: This model operates at the micro level, as it enables users to engage in local manufacturing activities at the level of individual firms.

NARROW-USE LESS

CIRCULAR STRATEGY LEVEL: This model reduces the amount of resources needed by enabling local manufacturing.

INSTITUTIONAL, ORGANIZATIONAL & TECHNOLOGICAL

STAKEHOLDER LEVEL: This model is often implemented through joint venture betweens different stakeholders in community spaces.



MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model incorporates a wide variety of diffused computer-controlled tools, including 3D printers, laser cutters, and more conventional metal working tools.

3.2 FAB LAB PROVIDING EDUCATIONAL SERVICES

Linked to Snapshots: 1 2 3

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? In light of the emerging circular metal economy, there is a crucial necessity to equip individuals with relevant technological skills and knowledge. Fabrication laboratories (Fab Labs) serve this need by offering an educational model oriented towards fostering innovation, collaboration, and sustainability in the industry. These maker-spaces, equipped with modern tools and technologies, facilitate learning through doing, thus accelerating the diffusion of new technological paradigms within the metal economy.

BUSINESS MODEL ASPECTS

Value is delivered by providing opportunities for students, academic institutions, and businesses to learn about and experiment with emerging technology related to the circular metal economy.

Value is captured through the delivery of courses and educational activities and the establishment of joint partnerships between Fab Labs and academic institutions and businesses.

POTENTIALLY RELEVANT TO

Solution providers: The Fab Labs that work in tandem with a university or multiple universities to provide students with the services and resources they need to develop their skills and knowledge.

Customers/users: The users are the students, faculty, and staff at academic institutions, as well as businesses.

EXAMPLE The Fabrication Laboratory Westminster provides an innovative learning environment and advanced digital fabrication facilities to empower students in the field of digital fabrication. The lab offers access to flexible computer-controlled tools for various design and fabrication processes, including 3D printing, CNC cutting, routing, metal milling, and robot fabrication. It serves as a platform for students to explore new design possibilities and produce high-quality work. Additionally, the lab offers specialised training courses and research support for students and researchers.

MACRO LEVEL

ECOSYSTEM LEVEL: This model operates at the macro level due to the focuses on broader socioeconomic long-term dynamics, which includes systemic changes in educational patterns.

INFORM

CIRCULAR STRATEGY LEVEL: This model raises student awareness and educates them about circular and sustainable practises.

INSTITUTIONAL , SOCIO/CULTURAL, ORGANIZATIONAL & TECHNOLOGICAL

STAKEHOLDER LEVEL: This model involves the cooperation of various stakeholders who collaborate to enhance student learning.

MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model incorporates a wide variety of diffused computer-controlled tools, including 3D printers, laser cutters, and more conventional metal working tools.

3.3 MANUFACTURING & PRODUCT CARE FAB LAB NETWORK

Linked to Snapshots: 1 2 3 5 6

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? Fab Labs, while beneficial individually, show significant promise as a global, collaborative network, with capabilities extending beyond local impact. These labs facilitate circular economy initiatives which, once initiated at one site, can be replicated and refined across the network. These initiatives may encompass many strategies such as the production of tailor-made goods, enhancing resource efficiency through targeted endeavours, and prolonging the longevity of products through retrofitting solutions. Crucially, they also promote knowledge exchange necessary for a circular metal economy.

BUSINESS MODEL ASPECTS

Value is delivered by guaranteeing the longevity and performance of metal products via a network of fab labs. Fab labs in the network can provide on-site disassembly, cleaning, repair, maintenance, and re-assembly depending on the client's location. These services optimise metal product integrity throughout their lifespan. The network ensures access to specialised advice, the rapid dissemination of information, and the collaborative use of capabilities.

Value is captured through the revenues generated by the provided maintenance service to original equipment manufacturers' products and clients. These network of fab labs become industry leaders and secure their market position by continually providing high-quality metal products and services.

POTENTIALLY RELEVANT TO

Solution providers: The Fab Labs, which serve as collaborative spaces for innovation and knowledge exchange, as well as the Fab Lab Networks, which provide a platform for the sharing of ideas and data.

Customers/users: The model serves individuals, communities, and organisations who want to participate in circular economy projects, access resources and skills, and promote sustainability by doing.

EXAMPLE Castelan's Furniture Care Services offers many services to extend and improve furniture. They prepare products for sale, manage pre- and post-delivery concerns, and offer in-guarantee fabric and leather upholstery care, recliner and cabinet furniture maintenance, bed and mattress care, and more. Their independent assessments include kitchen furniture and worktops. Castelan excels at pre-delivery resolution, quality assurance, manufacturing fault resolution, transportation damage, and product alterations with management information. Their UK-wide flat box assembly services reduce product returns and offer fantastic retail add-ons or inclusive services. Castelan's Furniture Care Network, with qualified technicians, provides nationwide furniture care, while its Furniture Care Centre provides commercial and warranty services to meet SLAs and avoid client service disruption.

MICRO LEVEL

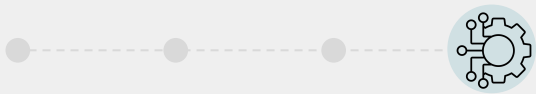
ECOSYSTEM LEVEL: This model operates at the micro level, as it enables users to engage in local manufacturing activities at the level of individual firms.

NARROW - USE LESS, SLOW - USE LONGER, CLOSE - USE AGAIN & INFORM

CIRCULAR STRATEGY LEVEL: This model has significant capacity and its effectiveness is contingent upon the specific projects undertaken. Digital communication systems can narrow, slow, or closed resource flow in these projects.

INSTITUTIONAL, ORGANIZATIONAL & TECHNOLOGICAL

STAKEHOLDER LEVEL: Typically, this model is implemented through the partnership between individual companies and their respective providers.



MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model incorporates a wide variety of diffused computer-controlled tools, including 3D printers, laser cutters, and more conventional metal working tools.

3.4 MOBILE MAINTENANCE LABS

Linked to Snapshots: 1 2 5

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model addresses the unique requirements of rural and underserved communities, as well as large infrastructure necessitating maintenance and upgrade services such as bridges, communication towers, wind farms, and industrial facilities. With restricted access to specialised services, maintaining metal assets in these areas is sometimes challenging. Services of this nature typically run on a timetable, with unplanned maintenance operations available 24/7, to ensure that critical actions are taken to ensure the proper operation of infrastructure.

BUSINESS MODEL ASPECTS

Value is delivered by providing maintenance, repair, and upgrading services, through mobile labs, to rural and underserved communities or in relation to large structures that cannot be transported.

Value is captured through the revenues from the service provided.

POTENTIALLY RELEVANT TO

Solution providers: The solution providers are specialised companies able to travel rapidly to rural regions to provide maintenance or repair services.

Customers/users: The customers are the rural and underserved communities, as well as the owners and operators of large infrastructures.

EXAMPLE Green energy maintenance company Natural Generation provides scheduled and unscheduled maintenance to maximise wind turbine generation and return on investment. Wind engineers at the organisation are trained to work in difficult situations and provide world-class service. Maintenance is organised and monitored by a Cornwall-based office team for field engineers around the UK. Scheduled servicing, reactive maintenance, refurbishing, remote online monitoring, spare parts, and a dedicated problem-solving team are offered by the organisation.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level, as it enables customers, usually B2B customers, to maintenance, repair, and upgrade underserved communities and structures.

SLOW - USE LONGER

CIRCULAR STRATEGY LEVEL: This model slows the flow of resources by extending the lifespan of remote infrastructures via maintenance, repair, and upgrade.

ORGANIZATIONAL

STAKEHOLDER LEVEL: Typically, this model is implemented through the partnership between individual companies and their respective providers.

MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model incorporates a wide variety of diffused and mainstream technologies.

3.5 URBAN MINI MOBILE MAINTENANCE LABS

Linked to Snapshots: 1 2 6

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? Densely populated urban ecosystems depend on infrastructure, high-rise structures, furnishings, and fittings. However, maintenance and repair materials are highly fragmented due to specific parts for varied equipment. For urgently needed spare parts or tools, wait times can be long. By leveraging on state-of-the-art technologies like 3D printing, or rejuvenation impulse, this model can decrease unscheduled failures and increase equipment efficiency. In urban contexts, where wear and tear and environmental exposure create distinct maintenance needs, this maintenance method must be adaptable and flexible. Electric service and maintenance transportation is fundamental to this model. Electrified transport contributes to sustainable city planning objectives and reduces the carbon footprint of maintenance.

BUSINESS MODEL ASPECTS

Value is delivered in urban areas through the offering of on-the-go maintenance services using mobile labs. These services make use of advanced technologies including 3D printing, portable CNC machines, laser cutters, and advanced diagnostic tools, reducing downtime and prolonging product lifespan.

Value is captured through the charge of a fee for the maintenance services.

POTENTIALLY RELEVANT TO

Solution providers: The solution providers are companies that offer state-of-the-art technologies in urban contexts.

Customers/users: The customers of this business model are the urban ecosystems themselves, including infrastructure owners, high-rise structures, and entities responsible for furnishings and fittings.

EXAMPLE NipNip Mobile provides a handy bicycle maintenance service catering to both individuals and organisations. The company has a group of proficient bicycle technicians capable of conducting repairs on customers' bicycles at their residences, workplaces, or by arranging designated maintenance sessions for various organisations. The mechanics of NipNip are supplied with high-quality tools as well as all essential parts and accessories.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level, as it enables users to maintenance, repair, and upgrade their products in urban areas.

SLOW - USE LONGER

CIRCULAR STRATEGY LEVEL: This model slows the flow of resources by extending the lifespan of product via maintenance, repair, and upgrade.

ORGANIZATIONAL

STAKEHOLDER LEVEL: Typically, this model is implemented through the partnership between individual companies and their respective providers.

EMERGING INNOVATION

TECHNOLOGY READINESS LEVEL: This model may incorporates a variety of classic and cutting/age technologies for maintain products such as portable 3D printing, portable CNC machines, laser cutters, and advanced diagnostic tools.

3.6 SPARE PARTS DIGITAL INVENTORY AND CUSTOMISATION

Linked to Snapshots: 1 2 3 4

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model presents an innovative approach to inventory management and customisation with significant implications for cost efficiency, machine downtime minimisation, and resource optimisation. By maintaining a digital inventory of spare part designs or redesigning customised ones, manufacturers can not only mitigate the capital expenditure associated with physical inventory, obsolete parts, or long-tail performance but also facilitate rapid replacement of faulty components and improvements, thereby enhancing the efficiency of resource allocation. Integrating additive manufacturing techniques such as 3D printing into this model allows for on-demand production of components. This can substantially reduce lead times and mitigate the impact of supply chain disruptions.

BUSINESS MODEL ASPECTS

Value is delivered through the provision of spare parts supply or rapid production services to clients, which result in cost reduction, minimised downtime, optimised asset utilisation, facilitated agile maintenance and customization, and faster delivery.

Value is captured through the production of parts on demand, eliminating the need for large warehouses and potentially producing the spare part in close proximity to the user who requests it.

POTENTIALLY RELEVANT TO

Solution providers: The solution providers are companies that offer digital inventory management platforms, 3D printing technology, and associated services. These solution providers can include technology firms specializing in inventory management software, 3D printing companies, and digital design providers.

Customers/users: The customers in this business model are typically manufacturing companies operating in maintenance, repair and overhaul operations.

EXAMPLE Shell is utilizing 3D printing to reduce costs, delivery time, and carbon footprint of spare parts in the energy sector. They collaborate with OEMs, reverse engineer parts when needed, and print in-house for emergencies. Successes include rapid replacements in Nigeria and reducing supply chain reliance. Shell aims to develop a digital warehouse for on-demand printing. Cross-industry collaboration is crucial for establishing technical standards in the energy sector.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level, as it enables users to maintain, restore, upgrade, and customise their product or assets using spare parts and custom components.

SLOW - USE LONGER

CIRCULAR STRATEGY LEVEL: This model slows the flow of resources by extending the lifespan of product via maintenance, repair, and upgrade.

ORGANIZATIONAL & TECHNOLOGICAL

STAKEHOLDER LEVEL: Typically, this model is implemented through the partnership between individual companies and their respective providers. The usage of digital platforms may also involve several technological stakeholders.

GROWTH INNOVATION

TECHNOLOGY READINESS LEVEL: This model uses digital platforms for monitoring spare part inventory and 3D printing, laser cutters, and CNC equipment to rapidly manufacture spare parts and custom components.

3.7 DISTRIBUTED ADDITIVE MANUFACTURING

Linked to Snapshots: 1 3

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? Distributed additive manufacturing (AM), or 3D printing, offers many benefits for the metal industry, including amplified mass customisation, localised manufacturing, swift on-demand manufacturing, fortified supply chain resilience, and heightened sustainability. Although the AM metals market is still in its infancy, this revolution in manufacturing processes offers potential advantages concerning energy efficiency and raw material consumption (Dustman et al., 2019). For instance, AM's optimised designs save energy in various industries. The U.S. fleet's lightweight AM aeroplane components might save 1.2 to 2.8 billion gigajoules by 2050 (Huang et al. 2015). Additionally, technologies like Wire Arc Additive Manufacturing could curtail raw materials by as much as 78% (Williams, et al., 2015) and manufacturing time can be significantly reduced by 40–60% compared to conventional processes such as machining (Welding, 2021).

BUSINESS MODEL ASPECTS

Value is delivered by local, on-demand and high-quality manufacturing services. Also businesses can ensure a better standard of quality in production, tailor products to meet individual demands, and provide spare components on demand.

Value is captured through the charge of a fee for the manufacturing, the charge of extra services such as texturing, coating or the use of special alloys.

POTENTIALLY RELEVANT TO

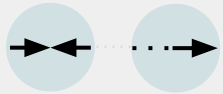
Solution providers: Solution providers are businesses that provide the necessary additive manufacturing technologies, equipment, and software. They offer 3D printers, materials, design software, and related services to facilitate distributed additive manufacturing.

Customers/users: This business model targets manufacturers, metal suppliers and original equipment manufacturers.

EXAMPLE Using the distributed additive manufacturing model, Alstom, a railway equipment manufacturer, partners with Replique, a 3D printing provider, to produce small batches of parts. By leveraging the decentralized network of Replique, Alstom can minimize lead times, enabling faster and more cost-effective responses to customer requirements. This approach also simplifies procurement and production processes. Alstom benefits from outsourcing to Replique, as it allows them to access these advantages without making significant investments in technology and materials. Resource BCG.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level by facilitating the decentralisation of maintenance, repair, and asset upgrades for B2B clients.



NARROW-USE LESS,
SLOW-USE LONGER

CIRCULAR STRATEGY LEVEL: This model uses low-energy technology to produce only the necessary commodities near their need, narrowing resource utilisation. It slows resource depletion by giving services that extend equipment's lifespan.

ORGANIZATIONAL

STAKEHOLDER LEVEL: Typically, this model is implemented through the partnership between individual companies and their respective providers.

GROWTH
INNOVATION

TECHNOLOGY READINESS LEVEL: This model primarily utilises 3D printing, which is a rapidly advancing technology.

3.8 DISTRIBUTED REMANUFACTURING

Linked to Snapshots: 1 2 3 4 2

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? Remanufacturing, or restoring a used product to its original condition, is essential to the success of the circular economy. This practise is needed for recovering the inherent value of a product for repurposing, offers cost savings, enables customised production, facilitates partnerships with specialised remanufacturers, and stimulates employment and economic opportunities, thereby encouraging the establishment of additional profitable cycles. In a best-case scenario, Parker et al. (2020) estimate that remanufacturing could generate an annual turnover of approximately €100 billion in Europe, along with employment opportunities for approximately 600,000 people. The complexity of remanufacturing systems, however, accentuates the need for specialised third-party remanufacturers. These entities are ideally decentralised and located close to both the product's end-of-life and the beginning of its secondary life cycle in order to maximise efficiency.

BUSINESS MODEL ASPECTS

Value is delivered through the collaboration of Original Equipment Manufacturers (OEMs) with local third-party remanufacturers, either by outsourcing the remanufacturing operations while retaining sales or by licensing the entire remanufacturing business to a third-party remanufacturers. The decision between these strategies is influenced by the manner in which new and remanufactured products are sold — directly by the OEM or third-party remanufacturers, or indirectly through a retailer.

Value is captured by outsourcing particular activities and keeping sales in-house or licencing the entire remanufacturing business to a third-party remanufacturers, the OEM secures income stability. This lets the OEM profit from remanufactured items without lowering brand value or operational costs (Wu.et al., 2021)

POTENTIALLY RELEVANT TO

Solution providers: Solutions suppliers are businesses that supply technology, resources, and knowledge to help with the remanufacturing process. These companies provide solutions such as specialised machinery, software, testing equipment, and remanufacturing consulting services.

Customers/users: The customers in this business model are the typically original equipment manufacturers.

EXAMPLE Dell licenses remanufacturing operations and sales of desktop, notebook, server, and storage systems at its Lebanon, TN facility to GENCO ATC. In this licensing model, the Dell decides on the licensing fee and retains control over the wholesale price. This allows Dell to capture value by setting the terms of the license, thereby benefiting from the remanufacturing process carried out by GENCO ATC.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level by facilitating the remanufacturing of products or equipments for other B2B clients, usually manufacturers.

NARROW - USE LESS, SLOW - USE LONGER & CLOSE - USE AGAIN

CIRCULAR STRATEGY LEVEL: This model narrow, slow, and close resource consumption by promoting the efficient use of materials, extending the life of products and components, and minimising transportation needs.

ORGANIZATIONAL

STAKEHOLDER LEVEL: Typically, this model is implemented through the partnership between individual companies and their respective providers.

MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs well-established, mainstream technologies for disassembly, cleaning, inspection, repair, refurbishment, and reassembly such as robots, X-ray, ultrasound, or laser scanning

3.9 UPGRADABILITY SERVICE FOR PRODUCT LIFE EXTENSION

Linked to Snapshots: 1 5 3

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? Typically, metal products and infrastructure are engineered for durability, but this is not always the case due to the lack of design measures that ensure extended lifespans and minimise waste and resources. Upgrade support services not only extend the product's life, reduce waste and resource consumption, and support the servitation system, but also enable businesses to perform at its maximum effectiveness and efficiency. Products, infrastructures, and buildings could see significant lifespan extensions if upgrades were implemented in iterative cycles of progressively improved functionality, and if solution providers had a digital platform to communicate with customers and offer the best advice and most accurate information on which upgrade best suited their needs (Pialot et al., 2017).

BUSINESS MODEL ASPECTS

Value is delivered through the ability of a company to locally improve, personalise, and customise used products. By updating the technology, modules, or including new features or performances, businesses can raise the economic value of a product and extend its value. In addition, the company can enhance the service by incorporating a new service element into the primary offering or by enhancing both the product and the associated services (Khan, et al., 2018).

Value is captured through the selling of updates, customisations, and reconfiguration services.

POTENTIALLY RELEVANT TO

Solution providers: The solution providers are service companies that provides consumers with upgrade services and related solutions. This service provider upgrades, updates, and modifies products and systems according to their specific sector.

Customers/users: Customers may be private or public organisations that own or manage specific products or systems requiring an upgrade.

EXAMPLE Google's "Project Ara" is an effort to create a modular smartphone that can be upgraded and repaired individually rather than as a whole. The modular design of the product allows for the replacement of individual components, such as the camera or battery, rather than the complete device.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level by facilitating the upgradability of products or equipment through specialised services tailored to their client.

SLOW - USE LONGER

CIRCULAR STRATEGY LEVEL: This model extends the lifespan of products by allowing them to be updated or improved without the need for complete replacement.

ORGANIZATIONAL

STAKEHOLDER LEVEL: Typically, this model is implemented through the partnership between individual companies and their respective providers.

MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs well-established, mainstream technologies for upgrading, such as diagnostic tools, hardware and software testing tools as well as simulation and modeling tools.

3.10 MAKE-TO-ORDER METAL MANUFACTURING

Linked to Snapshots: 1 2 3 4

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? The Make-to-Order (MTO) manufacturing business model offers customised metal products without the need for extensive stock, allowing businesses to meet the varying needs of their customers while reducing inventory costs. In an industry with limited storage space and resources, MTO enables the metal economy to offer a wide range of options to consumers, thereby enhancing competitiveness and customer satisfaction. In addition, by manufacturing products based on actual customer demand and optimising resource utilisation, MTO reduces storage needs, minimises wastage, and lowers financial risks. Profitability and adaptability of the metal economy are enhanced by the efficient allocation of resources and adaptability in scaling operations to meet seasonal demands. Overall, the MTO business model correlates with the changing demands of the metal industry by providing customised solutions, minimising waste, and maximising resource efficiency.

BUSINESS MODEL ASPECTS

Value is delivered by producing products only once a customer order has been received. This means that there is no inventory of products, and each product is made specifically for each customer. This type of business model is often used for custom products or products that are made in small batches.

Value is captured by creating a product or service that is tailored to the specific needs of the customer. This allows the company to charge a premium for the product or service, as the customer is willing to pay more for a product or service that is specifically designed for their needs.

POTENTIALLY RELEVANT TO

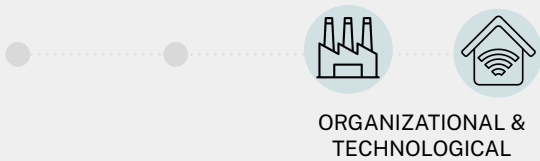
Solution providers: Metal manufacturers, fabricators, custom product makers, and MTO specialists are examples of solution suppliers. They may fulfil special requests depending on customer specifications.

Customers/users: This business strategy targets aircraft manufacturers, car businesses, construction organisations, and other industries that need customised metal parts. Solution providers provide metrics, materials, finishes, and design aspects. Customization ensures a perfect fit for customers' applications.

EXAMPLE Notebooks manufactured by Dell uses MTO production to allow customers to order fully customised laptops online and have them delivered in two weeks. Their website provides a variety of processor, hard disc, RAM, operating system, and other component options. After the customer selects and submits their selected components, Dell will provide a quotation for the customised product. After the quote is approved, production begins. Manufacturers receive and assemble parts required by the consumer. The customer receives a personalised computer. Dell must have supplies and components on-site or arrive "Just-in-Time" in order to keep on track and deliver the product on time.

ECOSYSTEM LEVEL: This model operates at the micro level by tailoring production processes to individual customer demands.

CIRCULAR STRATEGY LEVEL: This model narrows the use of resources by preventing the production of surplus.



STAKEHOLDER LEVEL: Typically, this model is implemented through the partnership between individual companies and their respective providers. The usage of digital platforms may also involve several technological stakeholders.

TECHNOLOGY READINESS LEVEL: This model employs well-established, mainstream technologies for manufacturing. Digital platforms allow product ordering and customisation using well-established technologies.

3.11 DESIGN AND MANUFACTURING OUTSOURCING

Linked to Snapshots: 3 4

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? Outsourcing design and manufacture in the metal economy has many benefits, such as gaining access to external expertise, increasing innovation, lowering prices through economies of scale, and improving operational efficiencies. Metal sector organisations can gain efficiencies, speed in product development, lower investment risks, and a competitive edge in a dynamic market by contracting with specialised providers. Local logistics and technical efficiency enhancements can reduce CO2 emissions in the metal sector by 20% in heavy transport and 35%-40% in technical efficiency (Amory, et al., 2021). This model works well for complex products and production processes.

BUSINESS MODEL ASPECTS

Value is delivered when a product or component is designed, sold digitally, and then built by a group of independent manufacturers. While the design can be created anywhere in the world, production is often handled by a provider in close proximity to the end user.

Value is captured by selling the design of (custom) items or components, as well as the rights to manufacture the design.

POTENTIALLY RELEVANT TO

Solution providers: The solution providers may consist of engineering firms, contract manufacturers, design studios, or product development firms. They have the knowledge, skills, and resources to manage various aspects of the design and manufacturing process, from concept development and prototyping to production and quality assurance.

Customers/users: Customers may include original equipment manufacturers (OEMs), startups, small and medium-sized enterprises (SMEs), and even sole proprietors. They rely on the solution providers to realise their product concepts, assure manufacturing efficiency, and deliver high-quality end products.

EXAMPLE Opendesk, a London-based startup, functions as an intermediary portal connecting customers with local furniture manufacturers. Customers peruse designs, place orders, and digital design files are transmitted to local fabricators for local fabrication. This decentralised method allows for customization, reduces costs, supports local economies, and creates a collaborative ecosystem for designers and producers.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level by utilising specialised external expertise and localised manufacturing in order to generate value through design and operational efficiencies.

NARROW-USE LESS

CIRCULAR STRATEGY LEVEL: This model narrows the use of resources by strategically selecting manufacturers in close proximity to users, hence reducing emissions associated with logistical operations.

ORGANIZATIONAL & TECHNOLOGICAL

STAKEHOLDER LEVEL: This model is implemented through the partnership between individual companies and their respective providers. Typically, the provision of this service is facilitated by a digital platform.

MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs well-established, mainstream technologies for manufacturing, such as CNC machining, laser cutting, and 3D printing.

3.12 EQUIPMENT-AS-A-SERVICE MODEL

Linked to Snapshots: 1 3

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model enables carbon footprint reduction by reducing equipment production, transportation, and disposal. Additionally, it promotes increased efficiency through outsourcing and energy-efficient options. Equipment-as-a-Service (EaaS) improves resource utilisation by matching equipment usage to demand and promoting shared equipment. It also reduces waste by minimizing equipment ownership and offering energy-efficient alternatives. EaaS delivers cost reduction, access to valuable data, promotes circular economy, and strengthens customer connections through optimized equipment performance.

BUSINESS MODEL ASPECTS

Value is delivered through subscription-based access to specialised manufacturing equipment, complete with maintenance and technology-driven insights for optimised performance. In addition, the provider may offer remote manufacturing services for high-tech equipment that requires expert labour when there is a shortage of such experts.

Value is captured through flexible subscription fees and potential revenue-sharing models, along with the monetisation of machine-generated data for research and predictive maintenance.

POTENTIALLY RELEVANT TO

Solution providers: The solution providers are manufacturers offering EaaS solutions.

Customers/users: B2B firms with fluctuating needs, as well as organisations facing a scarcity of highly qualified employees.

EXAMPLE Trumpf's innovative pay-per-part business model is revolutionising the industry of sheet metal processing. Trumpf offers clients the option to use the machine on a pay-per-part basis in response to the challenges posed by skilled labour shortages and the need to promote sustainability and resource efficiency. This can maximise production capacity, minimise waste, and lessen their environmental impact. Utilising the machine's spare capacity, customers are only charged for the manufactured parts. Trumpf provides the machine and remote monitoring, as well as additional services such as programming and maintenance, thereby optimising machine performance and reducing energy waste.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level by optimising the use of equipment between providers and users.

NARROW-USE LESS

CIRCULAR STRATEGY LEVEL: This model narrows resource utilisation by employing shared machinery among numerous enterprises.

ORGANIZATIONAL

STAKEHOLDER LEVEL: Typically, this model is implemented through the partnership between individual companies and their respective providers.

MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs well-established, manufacturing technologies for metal production, such as remote monitoring and control systems.

3.13 MICRO-FACTORY RETAILING

Linked to Snapshots: 1 2 6

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model reduces dependency on high capital intensity production technology and improves prospects for improved profit margins at greatly reduced output levels. It also facilitates many components of Product-Service Systems (PSS), such as upgrading, repair, and end-of-life management, which are crucial for a sustainable metal econom. The small-scale and locally-based nature of a typical micro-factoring retailing site means that it would not be limited solely to carrying out manufacturing activities. Proximity to the market means that facilities could also perform a retail function. It is possible that consumers could visit a site and, together with qualified manufacturing or design staff, specify the exact nature of the product they require. They could then collect the product from the site when it is finished. Such a set up offers much more choice for consumers over product design and specification (Williams, 2005).

BUSINESS MODEL ASPECTS

Value is delivered through a focus on small, localised and distributed networks that incorporate assembly, retail, and aftercare services. This approach allows companies make smaller numbers of long-lasting, customised products that are usually offered as a service rather than for outright purchase. This method offers incremental expansion, risk reduction, and closer customer relationships.

Value is captured by optimising revenue while minimising resource utilisation, thereby maximising earnings. Increasing the lifespan of a product has the potential to enhance profitability by enabling the sale of a greater number of functional units.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers are the manufacturers who adopt the micro-factory retailing approach. They are responsible for designing, producing, and maintaining the products, as well as managing their end-of-life.

Customers/users: Customers are individuals or entities who engage in the act of acquiring goods or services in exchange for monetary compensation. Nevertheless, in this particular model, manufacturers set up a more direct and distinct connection with consumers, thereby deviating from conventional models where the onus of product utilisation and disposal typically rests with the consumer.

EXAMPLE Riversimple, a UK-based car manufacturer specialising in hydrogen-powered fuel cell electric vehicles (FCEVs), operates on a "sale of service" model. The customers of Riversimple are individuals or entities that pay a monthly fee for accessing vehicles. The fee includes tax, insurance, energy required to power the vehicle, and required maintenance and repair. This model enables zero-emission transportation with increased fuel efficiency, contributing to the establishment of a robust hydrogen refueling infrastructure and supporting the transition to a more sustainable and circular metal economy.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level by placing emphasis on localised, small-scale micro-factoring retail outlets that provide consumers with direct engagement in product design and specification.

NARROW - USE LESS, SLOW - USE LONGER & CLOSE - USE AGAIN

CIRCULAR STRATEGY LEVEL: This model narrow, slow, and close resource consumption by promoting the efficient use of materials, extending the life of products and components, and implementing localised production..

ORGANIZATIONAL

STAKEHOLDER LEVEL: This model is implemented through the partnership between individual companies and their respective providers.

MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs well-established, mainstream technologies for manufacturing, such as CNC machining, laser cutting, and 3D printing.

Vision 04

End-to-end supply chain

With the use of intelligent assets, the circular supply chain has radically altered the traditional constrained and silos system. The modern end-to-end supply chain encompasses all the aspects of a product lifetime. This is a fully integrated and automated system that allows for real-time monitoring and execution of all supply chain processes. In this system transparency and standardisation play a key role as they can enable intelligent inventory management. To encourage corporations to adapt to this new working paradigm, sustainability reporting is now required by all businesses. Businesses that collaborate based on data sharing are able to provide high-quality customer-centric services across the supply chain, such as predictive or remote services.

Related ‘Snapshots from the future’

1

Intelligent inventory management

2

Supply chain sustainability reporting adopted by all businesses

3

Metal nanomanufacturing for multi-principal alloys

4.1 INTELLIGENT INVENTORY MANAGEMENT

Linked to Snapshots: 1

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? The incorporation of this model presents opportunities for optimal inventory levels, improved supply chain transparency, advanced traceability and quality control. A study conducted by Dias et al., (2017) revealed that efficient inventory management could lead to cost reductions of up to 10%. Moreover, supply chain visibility, traceability, and quality control could enhance overall operational performance. Adopting this model could facilitate businesses in more effectively reducing expenses, meeting customer requirements and adapting to a rapidly evolving market. For instance, according to Alicke et al., (2021) analysis, organisations who employ AI in their procurement process enhance inventory and service levels by 35% to 65% and reduce logistics expenses by 15%.

BUSINESS MODEL ASPECTS

Value is delivered by using advanced technologies such as machine learning, real-time data analytics, and IoT to optimise inventory levels and ensure timely product availability. These technologies support sustainable practises by improving resource allocation, minimising waste, and enhancing traceability throughout the production and consumption process. This enhances customer satisfaction and builds trust, as products are always in stock and delivered on time.

Value is captured by reducing operational costs through smart, data-driven inventory management. The system minimises stock holding costs and prevents stockouts, thereby maximising profitability and resource efficiency. This minimises holding costs and warehousing and transportation carbon emissions.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers may consist of software companies specialising in inventory management, data analytics firms, supply chain consulting firms, and technology companies offering inventory monitoring and management solutions. These solution providers provide the tools, technologies, and expertise necessary for implementing and optimising intelligent inventory management systems.

Customers/users: This business model serves metal industry manufacturers, distributors, and suppliers who use inventory management to optimise operations, increase supply chain performance, and satisfy client expectations.

EXAMPLE Circularise, a leading blockchain platform for industrial supply chain digital product passports, worked with Porsche and material suppliers to improve automotive supply chain transparency. They established a secure, end-to-end traceability system for automotive manufacturing materials using blockchain and Smart Questioning. The technology helps manufacturers and customers make better informed decisions, supporting sustainability and environmental compliance. The pilot research showed that complete openness without compromising private information is possible in complex, multi-tiered automotive supply chains.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level by facilitating the optimisation of inventory management at the individual firm level.

NARROW - USE LESS

CIRCULAR STRATEGY LEVEL: This model narrows the use of resources by optimising inventory levels.

ORGANIZATIONAL

STAKEHOLDER LEVEL: This model is implemented through the partnership between individual companies and their respective providers.

GROWTH INNOVATION & MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs growthing innovation such as AI or Blockchain, alongside established and widely adopted technologies such as real-time tracking systems and data analytics platforms.

4.2 SERVICE-ORIENTED SUPPLY CHAIN

Linked to Snapshots: 3

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? The objective of this model is to address the challenge of ensuring the prompt and efficient availability of essential components, resources, personnel, and services for product repairs and maintenance. Its purpose is to establish a service supply chain that caters to after-sales service and support, encompassing activities like scheduled maintenance and warranty repairs. Leveraging digital technologies, the implementation of a service-oriented supply chain model becomes crucial for fostering service-centric and network-driven businesses. By building a robust business network, companies can unlock opportunities for increased profitability and foster collaboration within the industry, leading to reduced emissions and enhanced product and service circularity. Through effective data and information sharing, businesses can exchange critical insights to better cater to their customers' service-centric needs.

BUSINESS MODEL ASPECTS

Value is delivered by a third party or the manufacturing company itself by assisting customers (typically other businesses) in maintaining, reusing, and recycling products or using resources more efficiently. The service-oriented providers of the supply chain facilitate the interchange of information and resources in order to make the supply chain more efficient and responsive to consumer demands. This partnership can result in cost and resource savings as well as enhanced customer service.

Value is captured by the solution provider through the revenue generated from the service.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers can be third-party companies specialising in after-sales service and support, or they can be the manufacturing companies themselves. Service-oriented supply chain providers help solution providers and clients share information and resources. They improve supply chain efficiency and responsiveness to fulfil consumer needs. Solution providers and service-oriented providers collaborate to save clients money and improve service.

Customers/users: Customers are usually other businesses or organisations who need help repairing, reusing, and recycling products or optimising resource use. These clients depend on solution providers for product reliability and lifespan.

EXAMPLE The New York Power Authority (NYPA) is the largest state-owned electric utility in the United States. As part of its VISION2030 strategic plan to combat climate change, NYPA seeks to become the first fully digital public power utility in the country. To accomplish this, the NYPA implemented IBM Maximo, an industry-leading enterprise asset management system, to unify its asset management processes. In addition, NYPA established the Integrated Smart Operations Centre (iSOC), a digital power asset monitoring and diagnostics centre, and was the first electric utility in North America to receive ISO 55001 certification for superior asset management. By integrating Maximo solutions with SAP ERP and other core applications, NYPA obtained a comprehensive view of its 60,000 power generation and transmission assets, thereby optimising planning, control, and compliance.

MICRO LEVEL

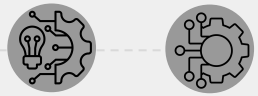
ECOSYSTEM LEVEL: This model operates at the micro level by providing services to extend the product lifetime of products at the individual firm level.

NARROW - USE LESS, SLOW - USE LONGER & CLOSE - USE AGAIN

CIRCULAR STRATEGY LEVEL: This model narrows and slows down the use of resources by providing repair and maintenance services. When products are beyond repair, this model ensures that the materials undergo recycling processes.

ORGANIZATIONAL

STAKEHOLDER LEVEL: This model is implemented through the partnership between individual companies and their respective providers.



GROWTH INNOVATION & MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs growthing innovation such as AI or Digital Twins, alongside established and widely adopted technologies such as real-time tracking systems and data analytics platforms.

Vision 05

Metal as a Service

In 2050, the UK is a world leader in metal as a service. As a result, the majority of firms are held accountable for their products throughout their entire life cycle (including usage and disposal). The UK was one of the first governments to create a "Department for Metal Services" to lease metals molecules from metals and mining corporations to UK materials industries. Also, different business models such as metal components as a service and metal products as a service are increasingly used by companies, for both B2B and B2C markets. These performance-related services are now prevalent offer models and account for the majority of business revenues. Another business model that became widely adopted by businesses, particularly for B2C, is product sharing. This has been aided by tracking technologies and product automation, allowing firms to fully monitor and control their products.
On an urban scale, cities have become more dynamic and community-driven. Today, many buildings and structural components are envisioned as community assets. In addition, a sharing economy has now widely permeated into society. In this respect, businesses and communities have partnered to make numerous 'product-sharing' services available to specific social bubbles (e.g. community car sharing).

Related ‘Snapshots from the future’

1 Metals molecules as a service

2 Metal components as a service

3 Metal products as a service (B2B)

4 Metal components as a service (B2C)

5 Metal products shared

6 Buildings and structural components as a service

7 Social bubble collaborative economy

5.1 SOCIAL BUBBLE COLLABORATIVE SOLUTIONS

Linked to Snapshots: 7 2

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model represents a local, member-centric approach offering accessibility to self-service, utilisation-based, low-carbon commodities. It is typically spearheaded by local assemblies aiming to bolster their communities, with commodities being reserved via digital platforms. It leverages digital technologies for remote control and data extraction, and transitions from a 'ownership' to a 'pay-per-use' approach, reducing environmental impact and costs. Despite facing challenges such as lack of technical know-how and inadequate investment (Rizos et al., 2016), it represents a sustainable solution that benefits both the community and the environment. However, successful implementation requires supportive policies and a shift in consumer preferences towards greener products (Rizos et al., 2016).

BUSINESS MODEL ASPECTS

Value is delivered by offering a platform for local communities to connect and utilise shared goods and services. This allows individuals to avoid purchasing their own products and foster the sharing of knowledge, skill, and information. This can enable the development of relationships and the creation of new values within the community.

Value is captured through the fees charged by the platform, which are typically a percentage of each transaction, as well as any advertising or other revenue generated by the platform.

POTENTIALLY RELEVANT TO

Solution providers: The solution providers are public or private entities or sometimes national charities that provide community-wide asset sharing via a bespoke platform. They lay the groundwork for the digital infrastructure required for low-carbon, self-service goods. Working with community leaders helps keep operations running smoothly while also providing opportunities to earn money through transaction fees and other means.

Customers/users: Customers in this business model are local community members who use the platform to access shared goods and services.

EXAMPLE Located in Wiltshire, England, the Tisbury Electric Car Club (TECC) is a collaborative effort by Nadder Community Energy (NCE) and local residents to bring together the power grid and the transport sector. Members access cars through a technology platform on their phones. TECC benefits from low staffing needs, volunteer support, and shared resources with NCE. As part of The Mobility Factory, a European network of car clubs, TECC offers interoperability and pricing autonomy. Cooperative ownership aligns with community values and attracts local sponsorships and council support. Core volunteers consist of NCE board members and car club users.

MICRO LEVEL

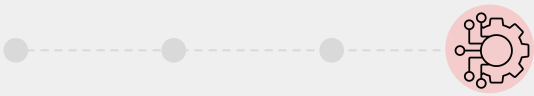
ECOSYSTEM LEVEL: This model operates at the micro level, emphasising localised, community-driven initiatives.

NARROW - USE LESS

CIRCULAR STRATEGY LEVEL: This model narrows resource use, promoting a shift from ownership to a community utilisation-based-approach, thereby minimising waste and environmental impact.

INSTITUTIONAL , SOCIO/CULTURAL, ORGANIZATIONAL & TECHNOLOGICAL

STAKEHOLDER LEVEL: This model encompasses various stakeholders, such as institutional bodies, social/cultural groups, organisations, and technological entities, which collectively contribute to the functioning and effectiveness of the model.



MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model employes mainstream technologies, including digital platforms for reservation and remote control, to gather data that supports the implementation of a 'pay-per-use' structure.

5.2 SHARING METAL PRODUCTS

Linked to Snapshots: 5

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model enables products to have more customers, be used for longer, and have multiple lifetimes within a closed-loop system if the design is executed properly (Bocken et al., 2016). When metal products reach their end of useful life, businesses can refurbish and improve them to keep them in use for longer and use less raw materials (Tukker, 2015). This approach holds particular relevance within the context of uncertainty surrounding supply and demand dynamics and the market's volatility. Successful adoption of the model requires government support initiatives and customer willingness to embrace the new business model. Additionally, technological advancements and infrastructure improvements, such as dedicated bike lanes for a bike-sharing system, may be necessary for its effective implementation.

BUSINESS MODEL ASPECTS

Value is delivered through offering customers with a quick, flexible, and affordable means of accessing goods, typically via online platforms and/or from other customers. This reduces the need for owning a personal products, resulting in savings on product purchases, insurance, and maintenance.

Value is captured through membership fees or usage fees. Customers may pay a monthly or annual fee to join the service or charged on a pay-per-time basis. Advertising offers an additional means of extracting value.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers include metal manufacturers, sharing platform providers, and technology/infrastructure providers. These entities contribute to the design, and technological support necessary for the model's success.

Customers/users: Customers in this business model consist of businesses/enterprises, individuals/consumers, and government agencies. Businesses and individuals benefit from the flexibility and cost-efficiency of accessing metal products through sharing or rental instead of ownership. Government agencies can adopt the model for their operations or infrastructure projects, promoting sustainability and optimising resource utilisation.

EXAMPLE BMW and Daimler have collaborated to create a joint venture focused on urban mobility solutions. With a combined investment of €1 billion, they have established ReachNow, ChargeNow, FreeNow, ParkNow, and ShareNow. These initiatives encompass multimodal travel, electric car charging, ride-hailing, ticket-free parking, and car sharing. The aim is to address the challenges posed by increasing urban congestion and pollution while competing with emerging players like Uber. BMW and Daimler's ability to form a joint venture in response to the dynamic nature of the automotive industry is indicative of their drive to pioneer environmentally responsible transportation solutions.

MICRO LEVEL

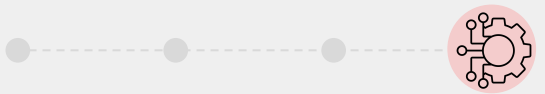
ECOSYSTEM LEVEL: This model operates at the micro level by focusing on a closed-loop system at the firm level.

NARROW - USE LESS, SLOW - USE LONGER & CLOSE - USE AGAIN

CIRCULAR STRATEGY LEVEL: This model narrows, slows and closes material consumption by fostering shared consumption of products, prolonging their lifespan through maintenance, and emphasising a closed-loop system with multiple lifecycles.

ORGANIZATIONAL & TECHNOLOGICAL

STAKEHOLDER LEVEL: This model is implemented through the partnership between individual companies and their respective providers. Sharing platforms and technology providers play a crucial role in facilitating the operational activities of businesses.



MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs well-established, mainstream technologies for sharing metal products such as digital platforms, tracking systems and GPS.

5.3 RENTING OF METAL PRODUCTS

Linked to Snapshots: 4 5 2

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model presents several promising avenues for enhancing resource optimisation, cost-effectiveness, increasing flexibility, and reinforcing market resilience within the metal economy. This model offers advantages such as avoiding initial acquisition costs and preserving financial flexibility for customers. It also provides businesses with greater sales potential and increased revenue by offering rental options that generate consistent income over time. However, challenges such as uncertain profitability, customer acquisition, equipment maintenance, and customer default risk exist (Urbinati et al., 2017).

BUSINESS MODEL ASPECTS

Value is delivered by providing customers with access to a wide variety of products that they would not otherwise have access to. Customers are able to use these products for a short period of time and then return them to the business when they no longer need the products. The business cleans and maintains the products before making them available to other customers.

Value is captured by charging customers a rental fee for the use of the products or charging a membership fee that allows customers unlimited access to the products. Also, value can be captured by selling additional services or products related to the product's use, advertising space on its products, website, or app, and partnering with other businesses to give customers discounts or other benefits for using the product.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers include metal manufacturers, sharing platform providers, and technology/infrastructure providers. These entities contribute to the design, and technological support necessary for the model's success.

Customers/users: Customers in this business model consist of businesses/enterprises, individuals/consumers, and government agencies. Businesses and individuals benefit from the flexibility and cost-efficiency of accessing metal products through sharing or rental instead of ownership. Government agencies can adopt the model for their operations or infrastructure projects, promoting sustainability and optimising resource utilisation.

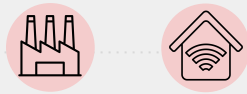
EXAMPLE WeWork is a provider of co-working spaces that offers individuals the opportunity to rent office space with a high degree of flexibility. Rather than engaging in the purchase or lease of a physical office space, individuals have the option to rent a desk or private office on a flexible and temporary basis. This model is especially preferred among individuals who work as freelancers or own small businesses and do not require a dedicated office space on a full-time basis, yet desire a professional environment for their work activities.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at micro level as it places emphasis on individual firms and their direct relationships with customers.

NARROW - USE LESS, SLOW - USE LONGER & CLOSE - USE AGAIN

CIRCULAR STRATEGY LEVEL: This model narrows, slows and closes material consumption by fostering shared consumption of products, prolonging their lifespan through maintenance, and emphasising a closed-loop system with multiple lifecycles.



ORGANIZATIONAL & TECHNOLOGICAL

STAKEHOLDER LEVEL: This model is implemented through the partnership between individual companies and their respective providers. Sharing platforms and technology providers play a crucial role in facilitating the operational activities of businesses.

MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs well-established, mainstream technologies for sharing metal products such as digital platforms, tracking systems and GPS.

5.4 LEASING OF METAL PRODUCTS

Linked to Snapshots: 4 5 2

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? In this model the solution provider retain ownership of the product and charge customers a periodic fee for continuous access and service. It provides affordability, equipment upgrades, and increased sales, but involves risks such as loss of control over the product and the potential for decreased profitability and default on payments. Transitioning to this model requires building relationships and considering financing costs. When metal products reach their end of useful life, businesses can refurbish and improve them to keep them in use for longer and use less raw materials (Tukker, 2015).

BUSINESS MODEL ASPECTS

Value is delivered by providing the customer with the use of an asset for a extended period of time, in exchange for regular payments. The payments are typically made over the term of the lease, and the customer has the option to purchase the asset at the end of the lease. This can save customers money on the upfront cost of the pushing of the products, as well as the ongoing costs associated with maintaining and storing the products.

Value is captured by periodic payments made by customers to use the metal product. This can provide a consistent and predictable stream of revenue for the business.

POTENTIALLY RELEVANT TO

Solution providers: The companies or organisations that retain ownership of the metal product and offer it to customers under a leasing or access arrangement.

Customers/users: Individuals or businesses that pay a periodic fee to the solution provider for continuous access to the metal product and accompanying services, rather than owning it outright.

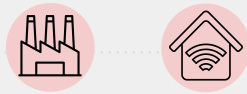
EXAMPLE Tesla's leasing program offers affordable terms and convenient monthly payments, making electric vehicles (EVs) accessible to a broader customer base. By simplifying ownership and reducing financial barriers, Tesla promotes eco-friendly mobility. Tesla's utilisation of pre-owned cars in its business model has the potential to extend the lifespan of vehicles, decrease environmental impact, and promote the adoption of electric vehicles, thereby facilitating the transition to a more environmentally friendly transportation system.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at micro level as it places emphasis on individual firms and their direct relationships with customers.

NARROW - USE LESS, SLOW - USE LONGER & CLOSE - USE AGAIN

CIRCULAR STRATEGY LEVEL: This model narrows, slows and closes material consumption by fostering shared consumption of products, prolonging their lifespan through maintenance, and emphasising a closed-loop system with multiple lifecycles.



ORGANIZATIONAL & TECHNOLOGICAL

STAKEHOLDER LEVEL: This model is implemented through the partnership between individual companies and their respective providers. Sharing platforms and technology providers play a crucial role in facilitating the operational activities of businesses.

MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs well-established, mainstream technologies for sharing metal products such as digital platforms, tracking systems and GPS.

5.5 METAL MOLECULES AS A SERVICE

Linked to Snapshots: 1

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? Embracing the principles of a circular economy, a new business model is emerging that promotes leasing of metal resources rather than outright sale. This 'Metal-as-a-Service' model allows companies to utilise metals without owning them, with the expectation that the resources will be returned in their original or processed form. This model encourages resource efficiency, reuse, and recycling, and requires collaboration among local and international stakeholders. However, transitioning to such a model involves challenges such as redesigning products, developing infrastructure, and changing mindsets (Aurisicchio et al., 2021). Government support and active participation in reuse activities are crucial for a successful transition. Other challenges include redesigning products, developing infrastructure, and changing mindsets.

BUSINESS MODEL ASPECTS

Value is delivered by providing the business-to-business leasing of metal molecules. As this is an on-demand service, molecule stocks might be characterised based on the customer's requirements. When a metal product has reached the end of its useful life, the service provider with the right expertise in the field and access to the relevant information about the alloy (such as the type of alloy and its characterization) can do the necessary industrial recycling to recover pure metal molecules for leasing again.

Value is captured by the long-term lease of molecules and the provision of related services.

POTENTIALLY RELEVANT TO

Solution providers: The solution providers may include metal leasing companies, recycling firms, or specialised service providers with knowledge in the field of metal alloys and their characterization.

Customers/users: Customers are companies and industries that require metal resources for their operations but prefer not to own the metals outright. Customers may come from various sectors such as manufacturing, construction, electronics, automotive, and any other industry that relies on metal resources.

EXAMPLE MetalClean Solutions is a pioneer in the metal industry, offering sustainable chemicals management through Chemical Leasing. They provide performance-based leasing services for chemicals used in metal cleaning and protection. By focusing on function instead of quantity, MetalClean Solutions optimizes resource efficiency, reduces risks to health and the environment, and enhances business performance. Their innovative approach has earned them recognition, including the Global Chemical Leasing Award.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at micro level as it places emphasis on individual firms and their direct relationships with customers.

NARROW - USE LESS, SLOW - USE LONGER & CLOSE - USE AGAIN

CIRCULAR STRATEGY LEVEL: This model narrows, slows and closes material consumption by fostering shared consumption of alloys, prolonging their lifespan through reuse, and emphasising a closed-loop system with multiple lifecycles.

INSTITUTIONAL , SOCIO/CULTURAL, ORGANIZATIONAL & TECHNOLOGICAL

STAKEHOLDER LEVEL: This model encompasses various stakeholders, such as institutional bodies, social/cultural groups, organisations, and technological entities, which collectively contribute to the functioning and effectiveness of the model.

EMERGING INNOVATION

TECHNOLOGY READINESS LEVEL: This model requires significant innovation in R&D and the implementation of novel alloys servitization systems.

5.6 FUNCTIONAL RESULT OF METAL PRODUCTS

Linked to Snapshots: 3 4 6

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model places customers at its core, unlocking new untapped solutions, fostering satisfaction and long-term relationships between the solution provider and the users (Bocken et al., 2016). This model stresses on integrating intangible elements such as improved comfort, lighting, and mobility (Bocken et al., 2016) in order to enhance the overall value delivery. In this context, the solution provider has the ability to determine the most efficient methods for achieving desired outcomes, without any predetermined constraints on the product or technology employed. Through optimising operational efficiency, expenses can be cut, resource allocation can be improved, and profits can be boosted (Tukker, 2015).

BUSINESS MODEL ASPECTS

Value is delivered by providing a specific performance that fully meet the customer needs. The delivery of this performance might require a combination of products and services. The customer is relieved from the responsibilities associated with the maintenance, repair and end-of-life of all products that are part of the offer. The provider owns and is responsible for all products, maintenance, repair, take-back, and end-of-life, and performance costs.

Value is captured by the payments of a recurrent fee. Fee-based contracts give the organisation predictable revenue over time. Additionally, the model allows the organisation to adopt new technologies or innovations that can improve performance savings, giving value to the client and improving the long-term relationship.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers are manufacturers or organisations that provide a service or product associated with metal products. These solution providers may be metal product producers, distributors, or service providers.

Customers/users: Customers of this business model are individuals or organisations in need of the functional outcomes provided by metal products.

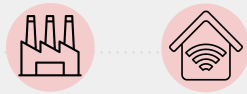
EXAMPLE The National Union of Students (NUS), a registered charity promoting sustainability, partnered with Philips to create a pioneering "Pay Per Lux" lighting solution for their new sustainable office at Macadam House in London. Instead of owning the lighting, NUS adopted a functional result scheme, allowing Philips to retain responsibility for lighting performance over a 15-year period, with NUS paying for energy consumed through a quarterly fee. This model provided NUS with predictable costs, expert monitoring, maintenance, and access to the latest LED lighting technologies, ensuring ongoing energy savings and aligning with NUS's commitment to sustainability.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level, as it focused on the servitization of products and the comprehensive management of their care.

NARROW - USE LESS, SLOW - USE LONGER & CLOSE - USE AGAIN

CIRCULAR STRATEGY LEVEL: This model narrows, slows and closes material consumption by fostering shared consumption of products, prolonging their lifespan through maintenance, and emphasising a closed-loop system with multiple lifecycles.



ORGANIZATIONAL & TECHNOLOGICAL

STAKEHOLDER LEVEL: This model is implemented through the partnership between individual companies and their respective providers. Sharing platforms and technology providers play a crucial role in facilitating the operational activities of businesses.

MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs well-established, mainstream technologies for sharing metal products such as digital platforms, tracking systems and GPS.

5.7 SUBSCRIPTION-BASED CONSUMABLES

Linked to Snapshots: 2 1

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model facilitates the manufacturing of long-lasting primary goods that depend on replaceable components, hence mitigating the necessity for wholly new items when a single element reaches the end of its operational lifespan.

BUSINESS MODEL ASPECTS

Value is delivered from the delivery of products to consumers, which necessitate the use of consumables or replaceable components. These primary products are frequently offered at a reduced initial cost, which serves as an incentive for users to make investments. Replaceable components provide optimal functionality and performance, providing a long-term, cost-effective solution.

Value is captured by regularly selling consumables or replaceable parts. After buying the primary product, users buy the necessary replacement parts to maintain it working. These components' continual purchase cycle produces revenue and brand loyalty among users who participate in the product and replacement part ecosystem.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers are commonly manufacturers of durable goods. These companies engage in the design and production of durable main products and their corresponding replaceable components. They prioritise quality and compatibility, and offer customer support and warranties for their products.

Customers/users: The customer consists of end-users or consumers who are in search of affordable, dependable, and environmentally-friendly products for their everyday requirements. These individuals are willing to invest in durable products and recognise the need to occasionally purchase replaceable components for optimal functionality.

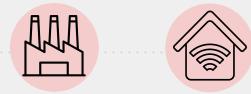
EXAMPLE Examples of this model include shaving systems, printers, and coffee machines. In such instances, the primary product is intentionally designed to possess durability and longevity, while relying on replaceable components that have finite lifespans. Examples of products that require additional components include razors, which necessitate replacement blades, printers, which rely on ink cartridges, and coffee machines, which utilise pods or cups. The main product has a low initial investment, which incentivizes consumers to make a purchase and subsequently buy the necessary replacements to maintain product functionality. This model generates revenue for companies and promotes sustainability through waste reduction and efficient resource utilisation (Bakker et al., 2014).

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level, as it focused on the selling of a long-lasting product and the servitization of replaceable component (e.i. cartridges).

NARROW - USE LESS, SLOW - USE LONGER & CLOSE - USE AGAIN

CIRCULAR STRATEGY LEVEL: This model narrows, slows and closes material consumption by fostering the selling of high quality products and the servitization of replaceable components that can be refilled, reuse or recycled within a closed loop system.



ORGANIZATIONAL & TECHNOLOGICAL

STAKEHOLDER LEVEL: This model is implemented through the partnership between individual companies and their respective providers.

MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs well-established, mainstream technologies for swap of replaceable components, such as mobile applications.

Vision 06

Metal life cycle data

Midway through the 2020s, the UK government built an open metal data infrastructure to make data available to companies along the supply chain in order to maximise metals' circularity. This was also made possible by the spread of asset-monitoring technologies such as Digital passport on Metal Blockchain. These technologies have increased openness and data responsibility among all stakeholders.
Data collecting via increasingly implanted intelligent sensors in physical equipment has also facilitated the development of metal digital twins. This technology revolutionised equipment control, allowing for real-time monitoring of environmental and economic performance. Smart sensors have also enabled material banks, which employ disused facilities and products as material supplies for new applications.
Cognitive computing and machine-to-machine communication have accelerated the development of autonomous marketplaces for selling/exchange of metal components. Even household products are becoming autonomous, gathering data and providing insights on energy optimisation and utilisation. Metals are also embedded with nanosensors, allowing for the collection of data that can inform humans or non-human systems in planning maintenance, repairs, and advising the user on best practices.

Related ‘Snapshots from the future’

1 Open-government metal data for the metal sector

2 Digital passport on Metal Blockchain

3 Remote maintenance and repairing with digital twins

4 Components and materials banks

5 Autonomous marketplace of components

6 Autonomous household products

7 Nanosensors embedded in metals to gather life cycle data

6.1 AUTONOMOUS SMART PRODUCTS IN A CONNECTED ECOSYSTEM

Linked to Snapshots: 5 6 7

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? By implementing this model, the sector has the potential to optimise resource allocation by utilising up-to-date data, resulting in increased efficiency and reduced inefficiency. The extensive collection of data not only enhances operational efficiency but also provides opportunities for novel insights that have the potential to revolutionise metal use, recycling, and innovation (Usama et al., 2023). For customers, this implies the availability of more intelligent and adaptable products that can effectively respond to their changing requirements. The sector has the potential to diversify its revenue streams by venturing into additional avenues, such as data services and consultation, rather than solely relying on metal sales. This connected approach promises streamlined operations, spurs collaboration across the supply chain, and ensures the industry remains nimble in the face of global market changes (Attias, 2017). As Rizos et al. (2016) highlight, SMEs often face barriers such as a lack of support from the supply and demand network, limited capital, lack of technical know-how, and insufficient government support.

BUSINESS MODEL ASPECTS

Value is delivered through the provision of interconnected products within a shared ecosystem that can adapt and cater to the unique needs and preferences of users, hence ensuring a seamless and effective operating process in real-time. Access to current operations data helps companies make informed decisions and provide additional services.

Value is captured through multiple channels, such as cost-saving operations, dynamic pricing for the use of products in the ecosystem, monetising data by sharing anonymised, selling and providing additional services, and product usage fees.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers include manufacturers who engage in the production of products, as well as organisations that employ data collection and management methods to generate supplementary sources of income beyond the sale of products and services.

Customers/users: Customers could be end-users who benefit from these smart products or organisations that want to increase energy and material efficiency, decrease waste, and optimise operations.

EXAMPLE Future smart cities in the linked and autonomous car ecosystem will transform urban mobility and planning. These vehicles will optimise traffic flow with advanced traffic lights and other infrastructures, boosting road capacity and lowering congestion. Connected and driverless vehicles will free up city centre parking spaces for leisure or green places. This transformation will follow the "15-min city," where all critical services are within a 15-minute walk or bike ride, decreasing the demand for private cars. Residents' quality of life will improve as cities become digital hubs that combine safety, sustainability, and efficiency.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level, as it is centred on the maintenance of products or assets that occur inside inter-firm relationships.

NARROW - USE LESS, SLOW - USE LONGER, CLOSE - USE AGAIN, MITIGATE - MAKE CLEAN & INFORM

CIRCULAR STRATEGY LEVEL: This model has the potential to reduce CO2 emissions and product impact by increasing product longevity, facilitating circularity more effectively, and educating consumers on how to reduce their consumption.

ORGANIZATIONAL & TECHNOLOGICAL

STAKEHOLDER LEVEL: This model is implemented through the partnership between individual companies and their respective providers. Enabling platforms for IoT are essential for this new model to be develop.

NICHE INNOVATION, GROWTH INNOVATION & MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model incorporates a diverse array of technologies, encompassing both mature and emerging ones. Self-driving automobiles for instance are in niche level.

6.2 DIGITAL MONITORING AND DIAGNOSIS SYSTEM

Linked to Snapshots: 2 3 4 5 6 7

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model can facilitate the transition of businesses from traditional product-centric models to service-oriented models that leverage digital technologies. This transition is driven by the need to achieve sustainable growth, strengthen customer relationships, and develop new revenue streams. Digital servitization enables companies in the metal economy to provide value-added services, such as predictive maintenance and performance optimisation, which can result in enhanced customer loyalty and market differentiation.

BUSINESS MODEL ASPECTS

Value is delivered by implementing comprehensive lifecycle digital solutions that monitor, control, optimise, and enhance autonomous capabilities of products. The incorporation of digital technologies enables organisations to provide advanced services, such as remote diagnostics and preventive maintenance, thus potentially improving operational efficiency and reducing client inaction.

Value is captured through various pricing models, including performance-based pricing, where customers pay based on the outcomes or performance achieved. Companies also harness insights into customers and partner equipment to provide tailored solutions, enhancing value capture.

POTENTIALLY RELEVANT TO

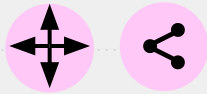
Solution providers: Solution providers include companies that offer integrated product-service solutions with a focus on digitalization. They are capable of monitoring, controlling, optimising, and operating autonomous products. Their organisational identity is comprised of engineering and customer orientations, and they prioritise knowledge integration in order to create and capture value.

Customers/users: Customers are organisations in seeking integrated solutions with performance guarantees and accessibility. They may prefer these integrated solutions over pure outcomes, and they value the solution providers' sophisticated services and digital capabilities.

EXAMPLE Airbnb disrupted the travel industry by leveraging the sharing economy and digital innovations when it was founded in 2008. Airbnb connected travellers with local residents, offering more than just a place to stay, with a focus on authentic experiences. Their platform ensured user safety through verification and reviews, and was subsequently expanded to include Airbnb Experiences for one-of-a-kind local activities. Airbnb's proactive approach and emphasis on trust have propelled it to the forefront of modern travel, highlighting the importance of customer-centric innovation and digital servitization.

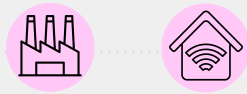
MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level, focusing on individual firms transitioning from traditional product-centric models to service-oriented models that leverage digital technologies.



MITIGATE - MAKE CLEAN & INFORM

CIRCULAR STRATEGY LEVEL: This model emphasizes the mitigate and inform levels, ensuring that digital technologies are integrated seamlessly into product-service solutions to optimize performance and reduce waste.



ORGANIZATIONAL & TECHNOLOGICAL

STAKEHOLDER LEVEL: This model prioritises organisations seeking integrated solutions at the organisational level and digital solution providers and their technology skills at the technological level.

GROWTH INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs technologies like remote diagnostics and preventive maintenance at the growth innovation level to enhance the delivery and optimization of integrated product-service solutions.

6.3 CIRCULAR AUTONOMOUS MARKETPLACE

Linked to Snapshots: 4 5 1

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? Circular e-commerce faces information overload in a crowded market with many consumer options. Different from linear e-commerce, circular models use pre-owned, unsold, surplus, or underused resources to reduce waste. The limited availability of these resources and competition from traditional e-commerce face significant hurdles. Organisations especially in the B2B sector can use technology to establish demand and availability mechanisms for effective exchange of resources. Using intelligent software agents to improve search optimisation and e-commerce is promising. These complex digital entities use advanced algorithms and machine learning to understand customer preferences, analyse large datasets, and make intelligent recommendations, negotiate, or autonomously complete purchases or sales (Wang et al., 2005).

BUSINESS MODEL ASPECTS

Value is delivered by increasing market efficiency of used, unsold, surplus or unused resources through machine-to-machine trading. Autonomous marketplaces enable direct connections between buyers and sellers, eliminating the need for human intermediaries and streamlining the selling process.

Value is captured by efficiently allocating resources and reducing transaction costs, improving inventory management, optimising the availability of unsold, surplus, or underused resources, and eliminating unsold inventory that could be valuable to others.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers are companies that leverage technological advancements and intelligent software agents to enable efficient asset exchange and enhance the overall e-commerce experience. They develop and deploy the necessary infrastructure, algorithms, and machine learning capabilities to facilitate machine-to-machine trading, increase market efficiency, and streamline the selling process.

Customers/users: Customers include buyers and sellers of used, unwanted, surplus, or underutilised resources. Sellers can better allocate resources, minimise transaction costs, improve inventory management, and connect with potential buyers to eliminate unsold inventory and earn value, while buyers benefit from enhanced search optimisation and intelligent recommendations.

EXAMPLE In the future, the practise of selling components of used and surplus items, even in small quantities, will be commercially lucrative due to the implementation of machine learning-based autonomous decision-making processes. Through machine-to-machine communication, computers will offer, negotiate, and purchase components, materials, and services.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level, since its primary focus lies in optimising the sale of previously owned, unsold, surplus, or underutilised resources within the B2B market.

NARROW - USE LESS, SLOW - USE LONGER & CLOSE - USE AGAIN

CIRCULAR STRATEGY LEVEL: This model helps to narrow, slow down, and ultimately close the resource loop by facilitating the sale and purchase of resources amongst autonomous agents.

TECHNOLOGICAL

STAKEHOLDER LEVEL: This model mostly revolves around technology, as it relies on the utilisation of data for resource prediction and trading.

GROWTH INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs technologies such as the Internet of Things (IoT) and intelligent software agents, which are rapidly growing technologies.

6.4 COMPONENTS AND MATERIALS BANK

Linked to Snapshots: 4 5 1 3 5 7

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? The Components and Materials Bank business model is essential for the metal economy to achieve efficient component reuse, material reuse and recycling. By treating products and buildings as material banks, for instance, their value and materials can be retained, leading to cost savings and improved ownership models. For example, a building could be significantly cheaper to build if materials like steel are owned by external investors. In this model, the focus is on buying the service of using materials rather than purchasing them outright (Hansen et al., 2020). Material banks would ensure the design retains value, promoting the use of high-quality coatings and facilitating robot-assisted disassembly to avoid toxic materials. By closing gaps in product and building component reuse, this business model can create high-quality jobs and enable the use of the best components and materials, transforming product and building design.

BUSINESS MODEL ASPECTS

Value is delivered by providing a solution that helps companies save money and time on sourcing components and materials through a central repository. This reduce the amount of time spent buying and selling materials and products and increase space-saving storage.

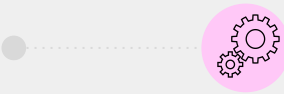
Value is captured through the charging of a fee for the service.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers are businesses or organisations that create and manage material banks. These entities are responsible for administering the inventory of reusable materials and components, facilitating their reuse and recycling, and ensuring that the design retains its value.

Customers/users: Industrial companies and builders in need of product parts and construction supplies are two examples of the types of consumers this model might attract. Customers like these can save money while gaining access to high-quality components and materials by using the material banks.

EXAMPLE BAMB (Buildings As Material Banks) aimed to transform the building sector by introducing material banks and promoting circular solutions. Traditionally, building materials end up as waste, contributing to environmental damage and resource scarcity. BAMB created material banks to retain and reuse valuable materials, reducing waste and reliance on virgin resources. Through innovative tools like Materials Passports and Reversible Building Design, BAMB enabled dynamic and sustainable building practices. The project successfully demonstrated the viability of material banks in pilot projects, paving the way for a circular economy in the building sector. BAMB was an EU-funded initiative under Horizon 2020, spanning three and a half years.

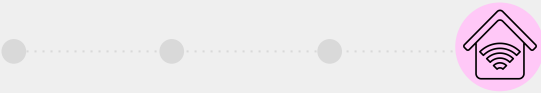


MESO LEVEL

ECOSYSTEM LEVEL: This model operates at the Meso level, as it focuses on sectoral and value chain interactions, especially in the metal and construction industries, to promote efficient component and material reuse.

NARROW-USE LESS, CLOSE-USE AGAIN, & INFORM

CIRCULAR STRATEGY LEVEL: This model aims to narrow and close resource use by ensuring efficient reuse and recycling. It also affects the "inform level" by informing stakeholders about material availability.



TECHNOLOGICAL

STAKEHOLDER LEVEL: This model mostly revolves around technology, as it relies on the utilisation of available data to comprehend the materials available for use, as well as when and how much can be used in the short-to medium-term.

NICHE INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs emerging technologies such as digital twins, which are still in the early stages of development, to monitor the state and gather information about structures or products.

6.5 OPEN GOVERNMENT METAL DATA

Linked to Snapshots: 1 2 3 4 5 6 7

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model enables informed decision-making, promotes transparency and accountability, fosters research and innovation, and supports the circularity of the metal sector. Access to this data empowers businesses to optimize operations, anticipate market shifts, and drive sustainability in the industry. Policy, technology, funding, organisational, cultural, and legal issues prevent this business model's adoption. These issues make data difficult to identify and reuse. Opening government data requires capital, needs new skills and equipment, and requires a mindset transformation in public sector organisations. However, opportunities include the potential for economic benefits, the stimulation of a competitive marketplace, and the creation of innovative value-added services. Additionally, the transition to this business model can lead to a cultural shift in the public sector, fostering greater collaboration and participation (Ubaldi, 2013).

BUSINESS MODEL ASPECTS

Value is delivered by providing access to data that would otherwise be unavailable or difficult to obtain. This data is then used by governments, private sector entities, and individuals to develop new applications, services, and insights. This can lead to increased transparency, improved public services, and new economic opportunities.

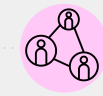
Value is captured through the development of applications and services based on the Open Government Metal Data (OGMD). These applications and services can generate economic benefits, stimulate innovation, and create jobs. Also, the government can use information about the users that accessed the data and by surveying them to enhance the government's policy on metal industries.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers includes governments, private sector corporations, and individuals. These entities utilise OGMD to create new applications and services to meet specific requirements.

Customers/users: Customers in this model can be anyone who uses the applications and services developed based on OGMD. This can include individuals, businesses, and other government entities.

EXAMPLE The municipality of São Paulo, in Brazil, has successfully established an open data portal named ObservaSampa. This platform serves as a repository for government data, which is made available to the public in an open data format. The platform has provided people with the ability to scrutinise, engage, and suggest public policies, thereby advancing the city's progress towards attaining the characteristics of a smart city (Takiya et al., 2022).

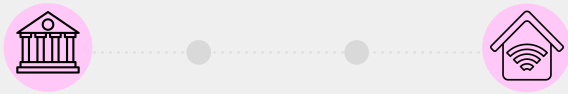


MACRO LEVEL

ECOSYSTEM LEVEL: This model operates at the macro level, given its overarching influence on the broad metal industry sector and its implications for national or even international policy-making and industry standards.

INFORM

CIRCULAR STRATEGY LEVEL: This model promotes the "Inform" strategy by facilitating transparency and providing essential data that can be used to make decisions in favor of a circular economy within the metal sector.



INSTITUTIONAL & TECHNOLOGICAL

STAKEHOLDER LEVEL: This model involves institutional stakeholders, given the role of policy and public sector organizations and technological stakeholders, considering the innovation and value-added services stemming from the data.

NICHE INNOVATION

TECHNOLOGY READINESS LEVEL: This model uses "Niche innovation" technology. Open government data isn't new, but its application to the metal sector is limited.

Vision 07

Full metal packaging

Single-use packaging is used only when strictly necessary, and metal is the most used material in the packaging sector, for its quality in preserving food quality, prolonging shelf life, and safeguarding food from contamination. The majority of packaging is intended to be reused numerous times before being recycled to complete the resource cycle.
Multiple reusable packaging models, with different degrees of user responsibility, are available in 2050, including packaging deposit schemes, reverse vending schemes, milkman model and reusable packaging on-the-go.

Related ‘Snapshots from the future’

1 Pure Metal

2 Packaging deposit schemes

3 Milkman Model

4 Refilling station

5 Reusable packaging on-the-go

6 Reverse vending schemes

7.1 REFILL-BASED MODEL

Linked to Snapshots: 2 3 4 5

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model encourages reuse and minimises the consumption of new materials by transitioning from single-use to refillable products. Refill-based models provide incentives for consumers to return containers or products for replenishing, thereby decreasing the demand for virgin resources and minimising environmental impact. Bashir et al., (2020) defined five different refill-based models: (1) a big-bag in the household for refilling containers; (2) a refill station in the store that requires consumers to bring back empty containers; (3) a home delivery solution with refill at home, bundled with online grocery delivery; (4) a home delivery solution based on smart-lock solutions that allows delivery when the consumer is not home; and (5) a home cleaning service with refill in the home included.

BUSINESS MODEL ASPECTS

Value is delivered through a combination of factors such as ease of use, perceived quality, effective communication and a convenient and environmentally friendly alternative to traditional disposable packaging. Customer preferences can be used to personalise service delivery. Customers appreciate the quality aspects of these solutions if additional product value is perceived.

Value is captured by charging for each refill or a monthly or annual cost for a set number of refills. Additionally, revenue can be generated by providing complimentary packaging for the consumption of particular food/beverage items. Value is also captured through the savings made from reduced production and waste management costs.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers in this model are the entities that offer the refill services and infrastructure. These companies are responsible for providing the infrastructure and services necessary for customers to refill their metal containers.

Customers/users: The customers in this business model are the consumers who choose to use the refilling stations to replenish their metal containers. These consumers are likely to be those who are environmentally conscious and interested in reducing their personal impact on the environment.

EXAMPLE The Body Shop, a British cosmetics, skin care and perfume company, has successfully implemented refill stations as part of its sustainability efforts. By allowing customers to refill their own containers, the company significantly reduces plastic waste, promotes the circular economy, and provides convenience and affordability. Customers actively contribute to waste reduction and receive an extra 50ml of product per refill. This initiative exemplifies The Body Shop's commitment to sustainability and serves as an industry-leading example.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level, focusing on direct interactions between service providers and individual consumers.

NARROW - USE LESS, SLOW - USE LONGER & CLOSE - USE AGAIN

CIRCULAR STRATEGY LEVEL: This model narrows, slows and closes the flow of resources by create a loop of usage, refilling, and reuse facilitated by the production of superior goods, hence reducing the need for raw materials.

SOCIO/CULTURAL, & ORGANIZATIONAL

STAKEHOLDER LEVEL: This model requires organisational stakeholders to implement and manage refill stations and delivery systems and socio/cultural stakeholders to promote sustainable consumer behaviour and incentives.

MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs various technologies, which varies based on the specific refill model implemented. In general, however, the level of technology is considered mainstream.

7.2 DEPOSIT REFUND SCHEMES

Linked to Snapshots: 2 6

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model provides incentives for consumers to engage in the return of their used products, particularly containers but not only, thereby fostering the practises of reusing and recycling and ultimately leading to a reduction in environmental impact. This model uses monetary incentives that are in line with sustainable behaviours to encourage people to participate in the circular economy, whether they do so voluntarily or because they are required to. The obstacles to the adoption of this model encompass the viability of its implementation, the allocation of costs, and the possibility of unintended consequences, such as a consumer migration towards different product groups. The potential opportunities encompass enhanced collaboration among businesses, augmented financial resources allocated to collection systems, and potential advancements in reutilization and recycling rates (Hogg et al., 2011).

BUSINESS MODEL ASPECTS

Value is delivered through increased reusing and recycling rates, along with the revenue generated from the reuse of products and the sale of recycled materials. Moreover, consumers are rewarded monetarily for returning products, delivering additional value. In addition to returning collected products, the service provider may also offer sorting and cleaning services to other businesses or utilise the products within its own operations.

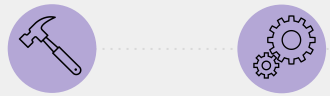
Value is captured through the operational costs of the deposit refund systems, cost reduction of the reusable product, revenue from the sale of material for recycling, and revenue from unredeemed deposits.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers are the producers who place packaging items on the market, and the organisations that manage the deposit refund systems.

Customers/users: Customers are who purchase beverages or food in cans or containers and participate in the deposit refund scheme.

EXAMPLE collection systems differ by country in small or large details. Metal cans are collected by most countries, however not all include glass in their Deposit Refund Systems. Return-to-retail models, where drink retailers and producers are legally liable for empty container collection, are used in most European DRS models. North America has return-to-depot, where consumers bring empty containers to collection centres. Iceland is the only European country with this concept. Most models are centrally controlled, therefore the DRS administrator is a non-profit that represents stakeholders, manages deposits, and reports to the government.



MICRO LEVEL & MESO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level, focusing on individual consumer behaviors and their direct interactions with businesses, and at the meso level, promoting business collaboration to improve reuse and recycling.

NARROW - USE LESS, SLOW - USE LONGER & CLOSE - USE AGAIN

CIRCULAR STRATEGY LEVEL: This model narrows, slows and closes the flow of resources by implementing a closed cycle of product return, reuse, and recycling at the end of a product's life.

SOCIO/CULTURAL, & ORGANIZATIONAL

STAKEHOLDER LEVEL: This model involves organizational stakeholders for effective system collaboration and socio-cultural stakeholders, using monetary incentives to influence consumer behavior towards the circular economy.

GROWTH INNOVATION & MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model uses growth Innovation level technologies, with deposit-refund schemes gaining traction but facing challenges for mainstream adoption due to viability concerns and potential unintended consequences.

7.3 MILKMAN MODEL

Linked to Snapshots: 3

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? By adopting this model, service providers can provide customers with individualised, high-quality options at reduced prices. The emphasis is on developing a cost-effective and efficient logistical infrastructure. This model also emphasises the use of technology to meet the requirements of retailers and consumers, while incorporating packaging designs, particularly for metal packaging, that prioritise durability, repairability, and reusability.

BUSINESS MODEL ASPECTS

Value is delivered by delivering products in reusable containers to the customer's doorstep and then retrieving the empty containers. The containers are then sanitised and reused. Deliveries create a competitive advantage.

Value is captured through a monthly or annual fee for the service.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers are those who adopt and implement the model. These may include logistics companies, packaging manufacturers, technology providers, and other parties engaged in providing customised, high-quality options and constructing an effective logistical infrastructure.

Customers/users: Retailers and customers who use the services.

EXAMPLE Loop, like Milkman, delivers brand-name goods in reusable containers without single-use packaging. Loop, designed by TerraCycle, lets clients borrow or hire containers that are returned, rinsed, and reused, like a milkman. This revolutionary concept reduces single-use plastics to reduce waste and enhance circularity. Online grocery orders and returnable containers cost money. The products are delivered in an insulated box in reusable containers without wrappers or plastics. Washing and reusing empty containers reduces waste, energy, and raw materials. The Milkman business model, supported by big brands and merchants, eliminates single-use plastic and changes consumer behaviour.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level, focusing on direct interactions between service providers and individual consumers.

NARROW - USE LESS, SLOW - USE LONGER & CLOSE - USE AGAIN

CIRCULAR STRATEGY LEVEL: This model narrows, slows and closes the flow of resources by implementing a closed cycle of product return, reuse, and recycling at the end of a product's life.

ORGANIZATIONAL & TECHNOLOGICAL

STAKEHOLDER LEVEL: This model involves organizational stakeholders level by emphasising efficient logistical infrastructure and collaborating with retailers and integrating technology level to meet both retailer and consumer needs.

GROWTH INNOVATION & MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model uses growth Innovation level technologies, with deposit-refund schemes gaining traction but facing challenges for mainstream adoption due to viability concerns and potential unintended consequences.

7.4 SECURE-TRACE MODEL

Linked to Snapshots: 2 3 6 2

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model enable the delivery of customised, reusable, high-quality offerings to consumers at competitive pricing points. The packaging is designed to be durable and equipped with digital locking and monitoring capabilities. It incorporates a range of sensors and gadgets, similar to those found in smartphones, to enable tracking and enhance its adaptability. Additionally, the packaging may feature an E-Ink screen that allows for easy updates of its destination or contents as desired. The primary emphasis is placed on the establishment of a logistical framework that is both cost-effective and operationally effective. Moreover, the model incorporates cutting-edge technology to successfully cater to the unique requirements of shops and consumers alike. In the specific domain of metal packaging, it encompasses design solutions that inherently prioritise durability, foldability to take it back and repairability.

BUSINESS MODEL ASPECTS

Value is delivered from the provision of a secure, traceable, and long-lasting alternative to conventional packaging. Businesses gain advantages from streamlined tracking and insurance procedures, while consumers benefit from convenient return policies. For logistics companies, standardised and robust packaging that can be folded and returned reduces handling time and costs.

Value is captured by charging a fee on customers for the use of packaging, while the business retains ownership. This strategy streamlines company tracking, insurance, and eco-friendly, cost-effective packaging for users, benefiting all stakeholders. This approach promotes continued package usage, capturing value through its durability and recyclability at the end of its lifespan.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers refer to the entities within the business sector that offer reusable packaging solutions that can be digitally tracked.

Customers/users: Customers include all stakeholders who are engaged in the process of online transactions and product delivery.

EXAMPLE LivingPackets has introduced a reusable and trackable package called "The Box," which incorporates digital features with the intention of revolutionising the delivery industry. The product was created as a sustainable and user-friendly alternative to disposable boxes. "The Box" provides a versatile solution to delivery logistics challenges through the incorporation of features such as E-Ink screens for real-time updates and digital locks for enhanced security. Preliminary trials conducted by carriers and retailers in France and Germany have effectively showcased the advantages of "The Box". These benefits encompass notable reductions in waste and carbon emissions, alongside enhanced efficiency in logistics and delivery operations. The company's business model and funding strategy, which involves a combination of bootstrapping and crowdsourced equity, demonstrate its dedication to creating shared value and promoting sustainability.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level, focusing on direct interactions between businesses and individual consumers.

SLOW - USE LONGER &
CLOSE - USE AGAIN

CIRCULAR STRATEGY LEVEL: This model slows and closes the flow of resources by creating a loop of reuse made possible by the manufacture of superior products and the recycle of metals at the end of their lives, hence reducing the demand for raw materials.

ORGANIZATIONAL

STAKEHOLDER LEVEL: This model requires organisational stakeholders to adopt this model by using a standardized packaging that will be filled up and reuse multiple times.

MAINSTREAM
INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs standardised technologies such as digital security, monitoring, E-ink, and smartphone applications for packaging monitoring.

Vision 08

Stop Recycling Start Repairing

Today's economy is built on the principle of repair, while recycling is used less and less. It is now possible to easily extend the life of metal products and components thanks to cutting-edge technologies. Specialised companies provide new services for the maintenance/repair of metal products and components, known as the Metal Health Service (MHS). This includes services such as component rejuvenation, structure rejuvenation and day hospital.
Due to the presence of several repair entrepreneurs, repairing is not only accomplished on a large scale, but also on a micro and local level.
In addition, due to achievements in research and technical innovations, materials have improved in terms of performance and ability to self-heal. Metals' components can now self-heal microscopic cracks, greatly prolonging the life of goods.

Related 'Snapshots from the future'

1 MHS - Components rejuvenation

2 MHS - Structure rejuvenation

3 MHS - Metal day hospital

4 Micro repair entrepreneurs

5 Self-healing metal

8.1 METAL REJUVENATION SERVICES

Linked to Snapshots: 1 2 3

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model relates to the inherent occurrence of micro-cracks and defects on the surface of metallic components throughout their manufacturing and operational lifespan. The presence of these defects has the potential to negatively impact the mechanical properties of the materials Zhang et al., (2021). Preventive rejuvenation procedures are applied prior to or during the initial stages of corrosion, aiming to mitigate the formation of micro-cracks. The implementation of a proactive approach successfully extends the durability of the material, thereby reducing the necessity for intrusive interventions or replacement, resulting in cost savings.

BUSINESS MODEL ASPECTS

Value is delivered through the provision of rejuvenation services for metal components and infrastructures, aimed at mitigating fatigue and preserving the mechanical properties of damaged materials.

Value is captured through various means, including revenue generated from one-time rejuvenation services or revenue generated from ongoing or recurring rejuvenation services, such as an annual fee. Another potential situation involves the collection of revenue through a rejuvenation service that is integrated into a broader offering, such as a service incorporated within an access or performance/results business model. This integration aims to enhance the durability and reliability of the product, thereby extending its lifespan and reducing the necessity for replacement, ultimately resulting in cost savings.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers are the entities that offer rejuvenation treatments. These could be companies or research institutions that have developed technologies for the rejuvenation of metallic materials.

Customers/users: The customers are industries that manufacture and use metallic components. These could include sectors such as aerospace, automotive, construction, and any other industry that relies heavily on the use of metallic materials and components.

EXAMPLE In Zhang et al., (2021), the application of Ultrasonic Nanocrystal Surface Modification (UNSM) is explored as a method to enhance the fatigue performance of pre-corroded 7075-T651 aluminium alloy. The study found that specimens that underwent pre-corrosion and UNSM treatment demonstrated a remarkable twenty-fold increase in fatigue life compared to specimens solely subjected to corrosion. This highlights the effectiveness of UNSM in improving the durability and longevity of the aluminium alloy, even after pre-corrosion.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level as it focuses on specific defects and micro-cracks on the surface of individual metallic components, ensuring that each component reaches its maximum potential lifespan.

SLOW-USE LONGER

CIRCULAR STRATEGY LEVEL: This model prioritises the slow resource flow level strategy by proactively rejuvenating metal components to extend their lifespan and minimise their requirement for replacement.

ORGANIZATIONAL & TECHNOLOGICAL

STAKEHOLDER LEVEL: This model involves organisational stakeholders, who benefit from longer product lifespans, and technological ones essential for rejuvenation processes and overall success.

NICHE INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs niche innovation technologies, such as electro-pulsation, which are primarily employed for rejuvenation purposes and are not widely used in larger applications.

8.2 REPAIR MICRO-ENTERPRISES

Linked to Snapshots: 4 1

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model has the potential to reduce metal consumption by prolonging the lifespan of products within a specific and localised context. By adopting this approach, it becomes feasible to not only prolong the lifespan of products and assets, but also foster a thriving local economy centred around repair rather than consumption. One of the main barriers for this model is the lack of customer demand for environmental behavior. This lack of demand means that there is little incentive for firms to comply with environmental regulations unless they are strictly enforced or required by insurance companies. Another barrier is the high cost of environmental compliance, which small and medium enterprises (SMEs) often find difficult to bear. These costs are not easily transferable to customers and provide few benefits without a competitive advantage. However, government intervention, market forces, and social pressures and opportunities can all influence environmental awareness and action (Mir, 2006).

BUSINESS MODEL ASPECTS

Value is delivered to customers by offering a wide range of services, including repairs for consumer products and assets.

Value is captured through delivering a low-cost, convenient, and reliable service to clients and working with other companies to repair their customers' products. Original Brand Manufacturers (OBMs) and Original Equipment Manufacturers (OEMs) may partner with local enterprises to offer repair services for their own products. This allows them to comply with environmental regulations and gives them a competitive advantage when consumers demand environmental compliance.

POTENTIALLY RELEVANT TO

Solution providers: There are potential options for both internal and external solution providers. Internally, an individual may assume the role of a sole repair professional who establishes and operates her own local repair enterprise. Externally, various entities such as franchisees, dealerships, and trade organisations play a significant role in advocating for environmental and professional standards.

Customers/users: Customers are predominantly individual product owners in need of repair and maintenance services. These consumers may be regular clients or walk-ins. In some instances, the customers of these small enterprises can be larger organisations, such as franchises or auto dealerships, that subcontract work to them.

EXAMPLE Local automotive technicians represent a distinct segment within this particular operational framework. They work in the field of automotive repair and maintenance services. Customers have the ability to make specific and personalised requests for various forms of repair services.

MICRO LEVEL

ECOSYSTEM LEVEL: https://docs.google.com/forms/d/e/1FAIpQLSfmixuylJZCNr3gdt-xlMKCbVy0-OCGzx6SK8mGWA_YnhRhpA/viewform?usp=sf_link

SLOW-USE LONGER

CIRCULAR STRATEGY LEVEL: This model promotes the Slow Resource Flow strategy by emphasising the extension of product lifetimes, thereby slowing the consumption and processing of metals.

INSTITUTIONAL & ORGANIZATIONAL

STAKEHOLDER LEVEL: The primary focus of this model mostly encompasses organisational stakeholders, while the influence of the government can significantly impact its establishment.

NICHE INNOVATION

TECHNOLOGY READINESS LEVEL: This mode may employ technologies with varying levels of growth, but the majority can be categorised as mainstream innovation levels such as laser welding, ultrasonic testing, etc.

8.3 SELF-HEALING METAL

Linked to Snapshots: 5

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? The main aim of this model is to significantly prolong the lifespan of metal products and assets, resulting in improved sustainability and operational efficiency. Fatigue damage occurs when the metal is subjected to repeated stress or motion, leading to the formation of microscopic cracks. These cracks gradually propagate and extend until the metal eventually breaks. This approach offers innovative solutions for asset management and utilisation in the metal industries through the integration of advanced self-healing technologies with a service-oriented approach. It encourages the use of self-healing materials in the design and production of products, which reduces the frequency of expensive repairs. By adopting a strategic shift in their business approach, companies can enhance customer loyalty and operational efficiency by transitioning from a product-centric sales model to a service-oriented provision model, facilitated by the implementation of performance-based contracts. Strategic alliances play a crucial role in surmounting various challenges, such as securing financial resources for initial research and development (R&D) endeavours, as well as facilitating the integration of digital technologies.

BUSINESS MODEL ASPECTS

Value is delivered through the provision of metal products and assets that possess the capability to self-repair, thereby enhancing operational efficiency.

Value is captured through the collection of premium prices for high-end products, or by minimising the expenses associated with product maintenance in the case of products provided as part of a product-service solution.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers can vary, encompassing researchers and organisations engaged in the development of such materials, as well as companies involved in the production and sale of these metals or related products. Additionally, there may be entities that offer servitization of self-healing metals. These organisations are engaged in the scientific investigation and advancement of self-repairing metallic materials.

Customers/users: The customer of this model primarily consists of industrial entities that incorporate metals into their operational processes. These sectors encompass areas such as energy, transportation, healthcare, safety, and infrastructure.

EXAMPLE In a groundbreaking investigation conducted at Sandia National Laboratories, Brad Boyce and his research team have identified a remarkable self-healing characteristic in platinum sheets. This property enables the metal to autonomously repair any cracks that may develop. The experiment, conducted under vacuum conditions, demonstrated that the cracks not only healed but also resulted in increased resistance to future fractures. The potential of this "self-healing metal" to transform industries that rely on resilient materials, such as construction and automotive, is significant. However, further research is necessary to validate its practicality in real-world applications (Barr et al., 2023).

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level, with a focus on individual businesses, collaborations, and strategic alliances across the metal industry.

SLOW-USE LONGER

CIRCULAR STRATEGY LEVEL: This model aims to slow resource use by prolonging the lifespan of metal products and assets, leveraging advanced self-healing technologies and performance-based contracts to achieve this goal

INSTITUTIONAL, ORGANIZATIONAL & TECHNOLOGICAL

STAKEHOLDER LEVEL: This model incorporates various organisational stakeholders. However, technological and institutional stakeholders are also essential for the coordination of R&D funds and activities.

NICHE INNOVATION

TECHNOLOGY READINESS LEVEL: This model incorporates advanced technologies, such as self-healing materials, which can be considered as a niche innovation due to the limited use of this technology beyond academic settings.

Vision 09

Repair-it-yourself (RIY)

People nowadays own fewer but higher-quality products. They are used to looking after their items and perform maintenance and repair tasks. The reuse and repair economy has outgrown the old throwaway approach, making it quicker and more convenient for customers to repair broken or damaged things rather than throwing them away and purchasing new ones. Thanks to courses provided in schools, maintaining and repairing products has become common knowledge. People can also learn and share practices in repair community centres.
Repair kits are becoming increasingly widely available. Customers use them to fix simple metal components on their own, which saves them money and time. In addition, repair technologies such as augmented reality are being used by people to fix more sophisticated items.
Companies, on the other hand, are keen, for competitive and regulatory reasons, to facilitate these activities. Repairability is a key criterion for users when selecting products and brands. Users can obtain this type of information from any digital platform available today, in addition to instructions on how to do maintenance and repairs.

Related ‘Snapshots from the future’

1 RIY- Repair digital platforms

2 RIY- First-aid repair kit

3 RIY- Repairs technologies

4 School-based repair courses

5 Repair community centres

9.1 ENABLING REPAIR-IT-YOURSELF AND UPGRADE-IT-YOURSELF

Linked to Snapshots: 2 3

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model improves the accessibility of product repair and upgrades through the implementation of a user-centric approach. As a result, it not only prolongs the lifespan of products but also empowers users to independently perform these tasks.

BUSINESS MODEL ASPECTS

Value is delivered by providing an easy-to-use kit or spare parts for repairing or upgrading metal products and materials. These kits can be used to repair minor aesthetic flaws in metal sheets and chassis, as well as more prominent flaws like rust and metal corrosion, or to upgrade new components. Metal repair kits and upgrade kits can be tailored to the needs of customers by companies who supply them.

Value is captured by sales of different types of kits. Providers of repair and upgrade kits can establish partnerships with other businesses by including a free repair kit with metal products, thereby enhancing the brand image of the company. While upgrade kits can be sold separately to enhance or customise the product.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers are the companies offering metal repair and upgrade kits, providing easy-to-use solutions to extend product lifespan and empower users to independently perform repairs and upgrades.

Customers/users: Individuals and organisations in search of metal product repair, customization, and improvement options. They purchase the kits to address aesthetic defects, rust, or corrosion, or to improve the performance of the product.

EXAMPLE Fairphone, a Dutch electronics manufacturer and social enterprise, has made significant advancements in the electronics industry through the introduction of their Fairphone 3+ model. This particular device stands out due to its innovative modular design, which allows users to engage in Repair-It-Yourself (RIY) and Upgrade-It-Yourself (UIY) activities. By purchasing spare parts from the company, individuals can easily repair and upgrade various modules, thereby extending the lifecycle of their mobile devices and reducing the production of electronic waste. Fairphone grants users the freedom to possess and maintain their own devices.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level, focusing on user behaviour and activities connected to repair and upgrade.

SLOW-USE LONGER

CIRCULAR STRATEGY LEVEL: This model focuses on the slow resource flow rate, with the goal of extending the lifespan of metal products by enabling and encouraging repairs and upgrades.

INSTITUTIONAL, ORGANIZATIONAL & TECHNOLOGICAL

STAKEHOLDER LEVEL: This model facilitates collaborations between suppliers of kits and producers of metal products, whilst empowering customers by offering them opportunities for self-repair and customisation.

MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs technologies that are considered mainstream in terms of innovation, as the components employed for repairing and upgrading items are often mainstream in nature.

9.2 ENABLING REPAIR-IT-YOURSELF THROUGH DIGITAL PLATFORMS

Linked to Snapshots: 1

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model encourages the repair and reuse of metal products, reducing the need for new production and the associated environmental impact. It also fosters skill development among individuals, who can learn to repair items themselves, further promoting a circular economy.

BUSINESS MODEL ASPECTS

Value is delivered by providing end-users with knowledge pertaining to the repair and maintenance of their metal products. Furthermore, these platforms can serve as a medium for users to identify and establish connections with individuals facing similar repair issues. Additionally, they can also operate as a marketplace where users can engage in the exchange of goods (e.g. repair kits) and services (e.g. repair workshops) related to product repair. Also, these platforms can function as product ratings and reviews.

Value is captured by charging a commission on subscriptions or getting sponsorships and partnerships from companies whose main business is repairs. If the user can't fix the product on their own, the platform suggests a paid professional repair service.

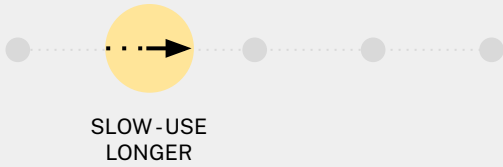
POTENTIALLY RELEVANT TO

Solution providers: Solution providers are the digital platform operators who provide the infrastructure for connecting repairers with customers.

Customers/users: The users encompass both individuals and businesses seeking repair instructions or looking for knowledge of repair methodologies to effectively address product repairs.

EXAMPLE iFixit, a California-based company, partners with schools and community centers worldwide to promote a culture of repair through hands-on workshops and educational resources. By empowering individuals with repair skills, iFixit advocates for the right to repair, reduces electronic waste, and fosters a sustainable circular economy.

ECOSYSTEM LEVEL: This model operates at the micro level, focusing on individual actions and behaviors.



CIRCULAR STRATEGY LEVEL: This model seeks to slow resource use by prolonging the lifespan of metal products through repair and maintenance, facilitating the reuse of products and reducing the demand for new production.

STAKEHOLDER LEVEL: This model engages socio-cultural groups through skill training, forms partnerships with repair businesses for organisational support, and employs digital platforms for knowledge and transactions.

TECHNOLOGY READINESS LEVEL: This model employs technologies at the mainstream innovation level, such as digital platforms, to connect users with knowledge, resources, and services for product repair and maintenance.

9.3 REPAIR EDUCATIONAL PROGRAMMES

Linked to Snapshots: 4 5

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? Given the significant societal shift towards resource utilisation and consumption patterns, it is becoming increasingly important to recognise the central role of repair practises in combating and mitigating consumerism. As knowledge-based institutions, schools can provide education that meets the requirements of particular times, contexts, and societies by expanding knowledge and cultivating approaches based on the broader society's interests. These practises can be tailored based on the specific interests of students and seamlessly integrated into the regular process of acquiring knowledge.

BUSINESS MODEL ASPECTS

Value is delivered through the provision of knowledge and skills to individuals, enabling them to effectively extend the lifespan of their products and reduce their consumption of new goods and services. This contributes significantly to the creation of essential value for society.

Value is captured through revenue streams like course fees, subscriptions, or licensing of educational materials. Additionally, partnerships with local repair-oriented businesses could offer a source of income through referral fees or co-promotion opportunities.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers are primarily public schools for different grades, which are seen as specialist knowledge providers.

Customers/users: Students who can apply their skills in real life are the primary users of this model.

EXAMPLE Repair Café International's model aims to cultivate a repair and sustainability mindset in young children. Their digital starter kit equips volunteers with engaging teaching materials to organize repair lessons in primary schools. By showing kids that repairing is fun and accessible, they challenge the notion of immediate replacement for broken items. The program's hands-on repair sessions, guided by volunteers, encourage critical thinking and problem-solving skills while promoting environmental responsibility. Ultimately, Repair Café International seeks to create a lasting impact on consumption patterns, waste reduction, and community involvement, contributing to a greener and more sustainable metal economy.

MACRO LEVEL

ECOSYSTEM LEVEL: This model operates at the macro level by engaging educational institutions and local repair-oriented companies to transform the public's perspective on consumption through education.

SLOW-USE LONGER

CIRCULAR STRATEGY LEVEL: This model promotes the slow resource flow level by equipping individuals with knowledge and skills to extend the lifespan of their products, thereby delaying the need for new products.

INSTITUTIONAL, SOCIO/CULTURAL, & ORGANIZATIONAL

STAKEHOLDER LEVEL: This model involves the institutional and organisational levels by incorporating schools and educational institutions, as well as the socio/cultural level by leveraging society values and consumer behaviours.

NICHE INNOVATION

TECHNOLOGY READINESS LEVEL: This model is not using specific technologies, but instead emphasises distinct repair-oriented abilities and approaches that have not yet been broadly incorporated into standard school curricula.

Vision 10

The logic of sufficiency

In 2050, people are becoming more aware of the ethical implications of overconsumption and are beginning to adopt a more sustainable approach to consumption. People tend to possess fewer, higher-quality products, which reduces material usage and can be passed down through generations (Multigenerational products).
The trend towards sustainable consumption is being pushed by initiatives such as MyMetal, which limits the amount of metal each person can own, and by the popularity of open libraries of things, which are locally owned stores that allow people to borrow items instead of buying them.
However, individual ownership is still important for certain products, as people form emotional attachments to these items and want to keep them for as long as possible.
To reduce emissions associated with product transportation, large and small retail companies now deliver and pick up products only once a week, depending on the postcode area in which the client lives.

Related ‘Snapshots from the future’

1 Multigenerational products

2 Open library of things

3 Emotional Attachment

4 Deliveries Once a Week

5 MyMetal

10.1 LOGISTICS OPTIMISATION

Linked to Snapshots: 5

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? In 2020, 24% of the UK's total emissions came from the transportation sector, largely due to the heavy consumption of fuel in transportation, making it the largest emitting sector (UK Department for Transportation, 2022), To mitigate global emissions, scientists are investigating new energy sources, even if their use is limited at present due to technological advancement. Transitioning to renewable energy fleets or alternative options, such as cycle vehicles, is one of the most prevalent strategies for reducing CO2 emissions from transportation, especially in large cities. Additionally, optimising the delivery and exchange of products during low-traffic periods or in specific locations can contribute to the reduction of CO2 emissions associated with transportation, particularly when replacing traditional petrol or petroleum fleets. This model can effectively and economically reduce emissions by decreasing the frequency of shipments, modifying inventory control decisions (Tang et al., 2015), and upgrading ageing fleet systems. This approach is particularly advantageous for metal wholesalers and distributors, whose emissions are predominantly a result of transportation.

BUSINESS MODEL ASPECTS

Value is delivered through the reduction of carbon emissions and the optimisation of inventory control. By upgrading ageing fleets, reducing shipment frequency and modifying inventory control decisions within the framework of periodic review systems, a company can meet emission reduction target with minimal total cost impact.

Value is captured through cost savings and increased efficiency. Reducing shipment frequency and updating fleets reduces fuel consumption and carbon emissions. This can result in savings with respect to fuel costs and prospective carbon taxes. Moreover, adjusting inventory control decisions can improve resource efficiency and save costs.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers are firms that are interested in reducing emissions and are willing to modify their operational decisions to achieve this objective. These businesses can be from a variety of industries, but wholesalers and distributors whose emissions are primarily from transportation may find this model particularly useful.

Customers/users: Customers may include a variety of types, including local and online retailers and end end users.

EXAMPLE Abel & Cole's logistics business strategy successfully integrates sustainability into the food system. Combining strategic delivery approaches, real-time route optimisation, environmentally-designed vehicles, and a dedication to circular practises, the company demonstrates how businesses can create and deliver value while minimising their environmental impact. Through this innovative model, Abel & Cole maintains its leadership position in the circular economy, paving the way for other companies in the metal economy to follow suit and create a more sustainable future.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at both the meso level, focusing on individual sectors such as transport within bigger economies, and the macro level, addressing wider environmental and socioeconomic consequences, particularly in relation to nationwide emissions.

NARROW-USE LESS

CIRCULAR STRATEGY LEVEL: This model reduces shipping frequency and optimises inventory control to narrow resource flow and cutting carbon emissions through fleet upgrades and other transport optimisation measures.

ORGANIZATIONAL

STAKEHOLDER LEVEL: This model involves organisational stakeholders, specifically metal wholesalers and distributors who are directly affected by transportation emissions.

NICHE INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs technologies like renewable energy fleets and alternative transportation methods, which currently might be at the niche innovation level, given their limited use.

10.2 LONG-LASTING PRODUCTS

Linked to Snapshots: 1 3 4

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? In recent decades, as product lifetimes have decreased, material throughputs have become unsustainable. This pattern contributes to resource waste and has a developing negative impact on the environment. Moreover, in today's ever-changing markets, where limited resources are driving up production costs, it is wise to extend the useful life of a product in order to preserve its value (Bakker et al., 2014). This model reduces environmental impact by decreasing primary material consumption. However, not all products should be designed to last decades. The emergence of newer technologies and enterprises with rapid product turnover rates presents a challenge for the implementation of this longevity paradigm. To overcome this obstacle, products in such contexts should be thoughtfully constructed, ensuring that repairs and enhancements can be carried out with ease, thus promoting a circular approach to resource management.

BUSINESS MODEL ASPECTS

Value is delivered by selling long-lasting products (potentially coupled with product lifespan extension services) and by eliminating the need for the customer to purchase new products.

Value is captured from premium prices from the sale of high-quality products and by offering life-extension and tailor-made services (e.g., repair, maintenance, and/or upgrade services). Value is also captured by linking brand names with superior quality and by improving brand loyalty.

POTENTIALLY RELEVANT TO

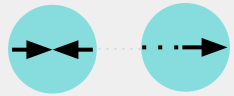
Solution providers: Solution providers are primarily the companies that design and manufacture the products.

Customers/users: Customers are both businesses the end-users of the products, who have certain expectations regarding the lifespan and performance of the products they purchase.

EXAMPLE Patek Philippe's business model relies on exclusivity, craftsmanship, and generational appeal. By manufacturing a restricted quantity of premium timepieces annually, the brand effectively creates scarcity and sustains elevated resale prices. The company's dedication to post-purchase services, such as maintenance and restoration, enhances the longevity and worth of every watch. Patek Philippe has maintained its prestigious market position over generations by strategically choosing sales channels and investing in innovation, exemplifying a durable business model.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level, focusing on individual products and their extended lifetimes.



NARROW - USE LESS
& SLOW - USE LONGER

CIRCULAR STRATEGY LEVEL: This model extends product lifetimes, slowing resource consumption and waste, while also fostering resource conservation through repairs and upgrades.

ORGANIZATIONAL

STAKEHOLDER LEVEL: This model engages organisational stakeholders by promoting industry standards for durable products and encouraging businesses to employ life-extension services.

MAINSTREAM
INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs technologies at the mainstream level of innovation, where concepts such as modularity, upgradability, and repairability are already prevalent.

10.3 LIBRARY OF THINGS

Linked to Snapshots: 2

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model facilitates the optimisation of resource utilisation and minimises wastage. The Library of Things model promotes the principles of a circular economy by fostering the sharing and reuse of items. One beneficial outcome is the reduction in demand for new products, thereby mitigating the extraction of new metals and subsequently lessening the environmental repercussions (Ameli et al, 2017).

BUSINESS MODEL ASPECTS

Value is delivered by providing access to a variety of items that can be rented or borrowed for a set period of time. This model allows for the efficient use of items by multiple individuals, reducing the need for each person to own a copy. It also fosters community interaction and cooperation, creating social value. Furthermore, it contributes to environmental sustainability by reducing waste and the demand for new products.

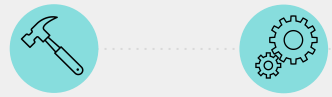
Value is captured by charging a rental fee or a monthly membership fee for renting products. This model allows for the efficient use of items by multiple individuals, reducing the need for each person to own a copy. It also fosters community interaction and cooperation, creating social value. Furthermore, it contributes to environmental sustainability by reducing waste and the demand for new products.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers are the founders and operators of the Library of Things. They provide the platform for sharing and manage the operations of the library. They also engage with the community to promote the concept and benefits of sharing.

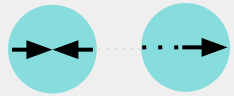
Customers/users: Customers in this model are the members of the Library of Things. They are individuals or entities that borrow items from the library.

EXAMPLE Library of Things in London operates on a membership basis, where members can borrow items for a fee. The library offers a wide range of items, including kitchen appliances, gardening tools, camping gear, and more



MICRO LEVEL & MESO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level by directly engaging consumers and promoting community involvement, and at the meso level by encouraging local entities and groups to collaborate on resource sharing.

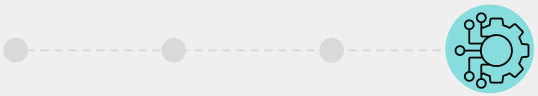


NARROW - USE LESS
& SLOW - USE LONGER

CIRCULAR STRATEGY LEVEL: This approach promotes sharing and reuse to narrow the resource flow and slow it by extending the lifespan of items because they are used by many different people.

SOCIO/CULTURAL, & ORGANIZATIONAL

STAKEHOLDER LEVEL: This model involves organisational stakeholders by engaging companies that rent or borrow these products and socio/cultural stakeholders by promoting community connection, cooperation, and sharing consumption.



MAINSTREAM
INNOVATION

TECHNOLOGY READINESS LEVEL: This model does not rely on any particular technologies for its operation, thus placing it under the category of mainstream innovation level.

Vision 11

Reusing, remanufacturing, and repurposing

In 2050, the UK is a world leader in reusing, remanufacturing, and repurposing products. UK waste management systems were originally built to handle the 'take-use-dispose' economy, but this has changed. Single-use items are a thing of the past, as more and more products are intended to be reusable, remanufacturable, or repurposed. The UK government has supported a radical shift in pace, encouraging the reuse of goods rather than the production of raw resources, via a vast infrastructure adjustment. Consumers were educated on the benefits of buying products that are made to last or repurposed.
Currently, products are designed with repairability and upgradeability in mind, and manufacturers offer extensive repair and replacement options. As a result, the product recovery business is well-established and well-connected. Stable employment in remanufacturing and repurposing is a major source of economic growth.

Related ‘Snapshots from the future’

1 The renaissance of second-hand markets

2 Remanufacturing and refurbishment services become core offerings

3 Cascade Reusing

11.1 REUSE-ORIENTED MODEL

Linked to Snapshots: 1

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model increases resource utilisation, decreases environmental impact, facilitates diverse interactions between parties, and promotes sustainable and circular economic practises. The transition to this model may be limited by growth objectives, target customer segments, critical mass of users, first-mover advantage, platform development costs, and value creation and capture. These factors must be evaluated by marketing managers in order to assess their current business models or contemplate entry into secondary markets. Nonetheless, businesses can optimise their current models, collaborate with secondhand businesses, and integrate elements of such models into their operations. Developing and coordinating a user network can also generate value (Yrjölä et al., 2021).

BUSINESS MODEL ASPECTS

Value is delivered through the redistribution of product ownership to customers, typically at a lower price than the purchase of new products.

Value is captured by selling used products, services and products to restore used products, and platform services to connect U2U, U2B, or B2B. Other possible revenue can come from listing fees, third-party advertisements on websites, additional services offered to sellers, or commissions on second-hand sales (Yrjölä et al., 2021).

POTENTIALLY RELEVANT TO

Solution providers: Solution providers can be categorised into platforms that facilitate the connection between consumer-driven supply and demand, such as the online platform for second-hand cars. Physical retail establishments that offer pre-owned items for sale, such as car dealers. An original equipment manufacturer (OEM) engages in the practise of recovering their products and subsequently reselling them through their own websites or physical retail establishments.

Customers/users: In general, this model's consumers are individuals who purchase used goods.

EXAMPLE eBay's second-hand market business model centers on providing a user-friendly, secure, and expansive platform that facilitates the buying and selling of pre-owned products. The combination of auction-style listings, fixed-price options, global reach, and community engagement has contributed to its success as a leading online marketplace for second-hand goods.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level by placing emphasis on the direct reuse of metal products within a network of firms that share similar levels of operation.

CLOSE - USE AGAIN

CIRCULAR STRATEGY LEVEL: This model prioritises the close resource flow level as it emphasises the redistribution of product ownership, thereby closing the cycle through the resell and reuse of metal products.

ORGANIZATIONAL & TECHNOLOGICAL

STAKEHOLDER LEVEL: This model engages organisational stakeholders through business operations and partnerships with secondhand businesses, and emphasises the technological stakeholders due to key role of platforms in connecting parties.

MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs mainly the use of technologies like platform services to resell the products which can be considered mainstream technologies.

11.2 MODULAR STRUCTURE REUSE

Linked to Snapshots: 1 2 3

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? Adopting a modular, reusable, and recyclable models offers numerous advantages to the metal industry. It improves resource efficiency, adapts to market shifts, and adheres to evolving regulations. Moreover, the model promotes business resilience by generating consistent revenue through service contracts encompassing design, maintenance, as well as assembly and disassembly. Customizable structures of superior quality enhance value by adapting to user-specific requirements and facilitating diverse applications for a single product.

BUSINESS MODEL ASPECTS

Value is delivered through the provision of tailored modular solutions which can be assembled and disassembled to meet the specific requirements of customers. These structures are commonly servitized, allowing for various configurations and designs, which ultimately enhances their adaptability and reusability.

Value is captured through rental fees and extra services including design, setup, maintenance, and deconstruction. Service contracts for long-term leases or seasonal use can generate reliable, ongoing revenue.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers sell reusable and modular structures and services. These firms design, build, disassemble, and maintain metal structures. They may also develop technology and methods to improve assembly and disassembly efficiency, recycling.

Customers/users: The customers range from construction firms and manufacturers to governments and individual consumers.

EXAMPLE Marquee hire firms supply temporary structures for weddings, parties, and corporate events. These firms offer a variety of marquee sizes, types, furniture, and themed decor to meet consumer needs. Pricing depends on event kind, location, duration, and luxury. Larger firms may specialise in certain markets and give expert guidance and frameworks for specific event sizes and complexities. Geolocation and specialised knowledge offer value to this company strategy, which emphasises customization and flexibility.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level by placing emphasis on the direct reuse of metal structures within a network of firms that share similar levels of operation.

NARROW - USE LESS, SLOW - USE LONGER & CLOSE - USE AGAIN

CIRCULAR STRATEGY LEVEL: This model narrows, slows and closes the flow of resources by implementing a closed cycle of product return, reuse, and recycling at the end of a product's life.

ORGANIZATIONAL

STAKEHOLDER LEVEL: This model engages organisational stakeholders by requiring coordination throughout various segments of a company's supply chain.

MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs mainly the use of technologies like platform services to renting, designing structures and communicating with customers, which can be considered mainstream technologies.

11.3 REMANUFACTURING

Linked to Snapshots: 2

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model not only extends the product's life cycle but also reduces the need for new raw materials and energy for production, thus creating environmental and economic value. Remanufacturing closes the loop of the supply chain, reducing waste and energy consumption. It also offers opportunities for reducing adverse environmental impacts, influenced by market competition, environmental concerns, high product disposal costs, and End-of-Life product regulations. The barriers to the transition to such a business model include intellectual property rights restrictions, lack of training in remanufacturing, and the need for a robust framework that includes all business components to capture the overall business to a single sheet. The opportunities to the transition of such a business model include the potential for reducing adverse environmental impacts, the ability to meet market demand for sustainable products, and the potential for cost savings through the use of remanufactured rather than new products. Additionally, the development of effective business models for remanufacturing is essential and offers significant opportunities for innovation and growth (Gunasekara et al., 2021).

BUSINESS MODEL ASPECTS

Value is delivered through the recondition of products in as-new or better conditions, which can often be sold at a lower price than new products and with the same warranty coverage.

Value is captured through the sale of the remanufactured products and related services and contracts, as well as decreasing operational costs. Additionally, increased customer satisfaction and loyalty if remanufacturing is offered as a service.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers are typically the remanufacturers. These can be Original Equipment Manufacturers (OEMs) themselves or contract remanufacturers working under license to the OEMs. They are responsible for the process of remanufacturing, which includes collection, inspection, disassembly, cleaning, repair, reassembly, and testing of used products.

Customers/users: Customers can vary widely, but they are typically those who are interested in purchasing remanufactured products. This can include both individual consumers and businesses.

EXAMPLE Caterpillar Inc., a prominent manufacturer of heavy equipment, adopted the practise of remanufacturing in 1972, initially expressing uncertainty regarding its viability and potential environmental consequences. At present, Caterpillar holds a firm belief in its economic sustainability and the significant contribution it makes to its brand. The company engages in the remanufacturing process wherein it retrieves previously utilised diesel engines, restores essential parts to a state like their original condition, and subsequently reassembles them into engines that are then distributed through its established network.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level by emphasising the remanufacturing of metal products within a network of firms that share similar levels of operation.

CLOSE - USE AGAIN

CIRCULAR STRATEGY LEVEL: This model prioritises the close resource flow level as it places significant focus on the practises of remanufacturing and reusing.

ORGANIZATIONAL

STAKEHOLDER LEVEL: This model engages organisational stakeholders by requiring coordination throughout various segments of a company's supply chain.

MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model uses mostly mainstream technologies like cleaning or surface treatment technologies.

11.4 REFURBISHING

Linked to Snapshots: 2

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model, which conserves value within a restorative and regenerative circular loop, can also , increased market competition, constantly changing customer needs, and the emergence of new regulations concerning end-of-product-life. This model is particularly relevant in sectors like automotive, aerospace, ICT equipment, ink, and toner cartridges, and the rail industry due to its strategic importance for economic and sustainable benefits and reduction in environmental impacts (Page 3). Finally, refurbishment can contribute to material savings of between 82% and 99% on average, and reduction in Greenhouse Gases emissions by between 79% and 99% in appropriate sectors (Okechukwu et al., 2021).

BUSINESS MODEL ASPECTS

Value is delivered primarily through refurbishing products, which involves basic repairs and cleaning as opposed to more extensive remanufacturing. These refurbished products are sold at a lower price than brand-new or remanufactured items and often come with a limited warranty.

Value is captured by refurbishing and reselling products that would otherwise be thrown away and by providing a service that extends the life of a product and saves the customer money. Providing an assurance or warranty on products enhances value capture.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers are typically the refurbishers. These can be Original Equipment Manufacturers (OEMs) themselves or contract remanufacturers working under license to the OEMs. They are responsible for the process of refurbishing, which includes collection, exchange of components, renewal, repair, and resell.

Customers/users: Customers can vary widely, but they are typically those who are interested in purchasing refurbished products. This can include both individual consumers and businesses.

EXAMPLE GreenPower Solutions is a pioneering company operating in the emerging electric vehicle market. They have established a circular business model that focuses on refurbishing used electric vehicle batteries for energy storage. Collaborating with automotive manufacturers, fleet operators, and battery recycling facilities, GreenPower Solutions collects used batteries and thoroughly assesses their remaining capacity. Through an extensive refurbishment process, faulty cells are replaced, and the battery management system is upgraded to ensure optimal performance. The refurbished batteries are then offered to utility companies, renewable energy projects, and commercial entities for cost-effective and sustainable energy storage solutions. By reusing these batteries, GreenPower Solutions reduces electronic waste, conserves valuable raw materials, and contributes to a more environmentally responsible metal economy.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level by emphasising the refurbishing of metal products within a network of firms that share similar levels of operation.

CLOSE - USE AGAIN

CIRCULAR STRATEGY LEVEL: This model prioritises the close resource flow level as it places significant focus on the practises of refurbishing and reusing.

ORGANIZATIONAL

STAKEHOLDER LEVEL: This model engages organisational stakeholders by requiring coordination throughout various segments of a company's supply chain.

MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model uses mostly mainstream technologies like cleaning or surface treatment technologies.

11.5 CASCADING

Linked to Snapshots: 3

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model has the potential to mitigate competition risks among diverse end-users and enhance natural resource efficiency throughout the entire material lifecycle. This approach aims to maximise the longevity of the "added value" of materials throughout their lifecycle, encompassing resource extraction, product consumption, and disposal stages. A comprehensive understanding of the cascading process necessitates a dual perspective, encompassing both the physical dynamics associated with sequential material utilisation and the socio-organizational requirements inherent in a circular economy-cascading system (Campbell-Johnston et al., 2020).

BUSINESS MODEL ASPECTS

Value is delivered by creating a product that can be used by multiple downstream businesses or users. The product may be altered to become something different, or it may retain its original form. Value can also be derived from engaging the local community in the practise of reusing materials within the same context in which they are utilised.

Value is captured by engaging in the repetitive process of selling a particular product through direct sales or by adopting a product servitization approach.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers in this model are businesses, or sometimes users, that interchange products, components, or materials with other stakeholders who play integral roles throughout the various stages of the product lifecycle. Products can be exchanged or transferred between individual actors within a value chain as well as between various actor configurations. These transactions may be between businesses (B2B), between businesses and consumers (B2C), or between consumers (C2C).

Customers/users: Customers can vary widely, but they are typically those who are interested in purchasing a cascading value. This can include both individual consumers and businesses.

EXAMPLE Wood from the demolition of buildings can be recovered in relatively good condition and has potential for cascading in different ways such as being used for other building components, furniture, or wood products. The cascading use of wood contributes to the mitigation of climate change, including the reduction in greenhouse gas emissions. The cascading of solid wood and materials requires demand from the construction sector or other customers, or incentives/legal requirements (Husgafvel, et al., 2023).

MESO LEVEL

ECOSYSTEM LEVEL: This model operates at the meso level and promotes the reuse of products through functional changes, enabling the direct reuse of metal resources by collaborating with companies involved in different downstream levels.

CLOSE - USE AGAIN

CIRCULAR STRATEGY LEVEL: This model emphasises the close resource flow level by promoting the transformation and reuse of metal products, thus completing the cycle through resale and repurposing.

SOCIO/CULTURAL, & ORGANIZATIONAL

STAKEHOLDER LEVEL: This model engages organisational stakeholders by providing value to multiple downstream businesses or users, and socio/cultural stakeholders by involving the local community in reuse practises.

MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model predominantly employs mechanical processes that can be classified as mainstream technologies.

Vision 12

Better metal recovery, sorting, upcycling and recycling

The reuse of material lies at the heart of today's most successful businesses. Open distributed disassembly (allowing for metal reuse by third parties) or closed distributed disassembly (components can be reused for the same initial function in closed loops) are common and cost-effective industrial practices used by the majority of businesses to disassemble small and medium-sized products, components and materials. Also, effective and quick disassembling pods are utilised for large structures, especially in remote locations.
Recovering underutilised value has never been more critical than it is today. Intelligent waste management systems facilitate collection and transport, through vacuum tube systems, to waste transfer stations. When reusing metal products is not practicable, industrial upcycling is the best option for recovering the material's value. Urban mines are another way to recover material value quickly and economically, especially in urban areas. This is possible by modern technological and design methods that make the disassembly process much simpler. In addition, even old landfills may be safely and sustainably mined for metal today (landfill scavenging), making it viable to reclaim metal from them. This is a significant advancement in recycling processes since it improves the quality and purity of the material recovered. Finally, micro mobile foundry and upcycling workspaces have become widespread. But technological advancement did not end with the recycling of current materials.

Related ‘Snapshots from the future’

1 Open distributed demanufacturing

2 Industrial upcycling

3 Closed distributed demanufacturing

4 Landfill scavenging

5 Urban Mining

6 Smart waste management system

7 Disassembling pods

8 Micro mobile foundry and upcycling workspaces

12.1 OPEN-LOOP PRODUCT MANAGEMENT

Linked to Snapshots: 1

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model seeks to capitalise on the potential benefits of non-recovered products by parent companies. By recovering these products or acquiring their components, the objective is to generate a profit while simultaneously satisfying the demand for reconditioned goods and recycled materials.

BUSINESS MODEL ASPECTS

Value is delivered by disassembling third-party products and selling or reusing their components or metals to customers, partners, or external entities. This allows for the utilisation of inexpensive resources that are not reclaimed from the original manufacturer.

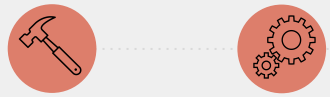
Value is captured by reusing or reselling components or raw materials, which is not obtained from the original manufacturer.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers are primarily the firms that are involved in the recovery phase of the value. These firms are responsible for reusing materials and reducing energy use, thereby minimising the environmental impact of industry. They are also responsible for managing reverse supply chain activities.

Customers/users: Customers are the end-users of the products. These end-users return their products to the firm when they no longer receive utility from the product.

EXAMPLE ReCellular, Inc., trades in new, used, and remanufactured cellular handsets. The company has a large network of sellers from whom they purchase their cell phones. Each seller that ReCellular purchases cellular phones from is paid a certain price based on a nominal quality metric that ReCellular has maintained for grading mobile telephones.



MICRO LEVEL & MESO LEVEL

ECOSYSTEM LEVEL: This model operates at both the micro level, affecting operations between companies on the same level and the meso level, underlining system-wide value exchanges and interrelations among various entities in the metal industry.

CLOSE - USE AGAIN

CIRCULAR STRATEGY LEVEL: This model promotes a close resource flow level strategy that aims to close material cycles by recovering, disassembling, and reusing metal components and materials that would otherwise have been wasted.

ORGANIZATIONAL

STAKEHOLDER LEVEL: This model integrates various organisational stakeholders who reclaim the value of discarded items, either for reuse or recycling.

MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model predominantly employs mechanical processes that can be classified as mainstream technologies.

12.2 CLOSED-LOOP PRODUCT MANAGEMENT

Linked to Snapshots: 2

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model ensures the recovery of value through reverse logistics managed by the parent company, which ensures the efficient reutilisation or recycling of resources, thereby mitigating adverse environmental impacts. The field of reverse supply chain management may present significant variations from conventional supply chain management practises. When internal closed-loop product management is not feasible, the company can work with business partners to facilitate the reuse or recycling of products by end users. The challenges in production planning, replacement material procurement, costing, and resource planning arise from the variability in system input. Therefore, it is imperative for a closed-loop system to effectively handle the intricacies and uncertainties associated with it.

BUSINESS MODEL ASPECTS

Value is delivered through the process of taking back products, disassembling them in-house, and then repurposing or selling the individual components or metals within the parent company or to external entities.

Value is captured through the reuse or resale of components or materials. Additionally, value can be captured by creating databases of disassembled components for use in new or remanufactured products (e.g., through materials banks).

POTENTIALLY RELEVANT TO

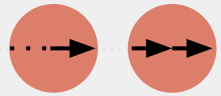
Solution providers: Solution providers are primarily the parent company that is involved in the closed-loop product management. They are responsible for reusing components and materials and reducing energy use, thereby minimising the environmental impact of industry. They are also responsible for managing supply chain activities which can differ greatly from management activities in traditional supply chains.

Customers/users: Customers are the end-users of the products. These end-users return their products to the firm when they no longer receive utility from the product.

EXAMPLE The Japanese business Fuji Xerox is known for innovation thanks to its closed-loop technology that incorporates recycling and an inverse production strategy. They introduced in 2017 the “Go Beyond” programme to take back all Fuji Xerox printers, parts and print consumables such as toner bottles, cartridges and parts for reuse and recycling. Printers are recycled into approximately 40 categories, including copper, glass, steel, and plastic. The materials are sold abroad for use in other goods. Waste toner from toner cartridges is mixed with waste engine oil and other components. This produces TonerPave™, a low-carbon asphalt. Using TonerPave™ for road resurfacing in Australia has reduced carbon footprints by up to 23% over the lifespan of over 1,000km of roadways.

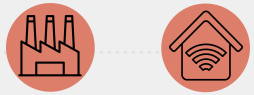
MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level and emphasises the close connections between a network of companies that collaborate to reuse resources at the same operational levels.



SLOW-USE LONGER &
CLOSE-USE AGAIN

CIRCULAR STRATEGY LEVEL: This model enables efficient resource reuse by implementing optimised reverse logistics processes, which effectively slow down and close the flow of resources through a series of comprehensive procedures.



ORGANIZATIONAL
& TECHNOLOGICAL

STAKEHOLDER LEVEL: This model encompasses both organisational stakeholders, such as the parent company and its business partners, as well as technological stakeholders who are essential in database management for the reverse supply chain.

NICHE INNOVATION &
GROWTH INNOVATION

TECHNOLOGY READINESS LEVEL: This model uses advanced reverse logistics and materials bank databases, spanning from niche to growth innovations.

12.3 URBAN METAL MINING

Linked to Snapshots: 5

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model offers a sustainable solution to the increasing demand for metals. Urban mining focuses on the recovery of valuable materials from waste streams, reducing the need for virgin material extraction and mitigating environmental impacts.

BUSINESS MODEL ASPECTS

Value is delivered through the recovery of valuable materials from waste streams. This process mitigates environmental impacts and generates new business opportunities. The recovered materials can be reintroduced into production cycles, extending their useful life and creating economic and environmental value.

Value is captured through the sale of recovered materials. Although steel and aluminium are not as valuable as precious metals like gold and silver, their abundance lends validity to the business plan.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers are organisations that engage with the practise of urban mining. These may encompass enterprises that specialise in the collection, sorting, and processing of waste, as well as those engaged in the development and implementation of technology aimed at enhancing material recovery efficiency.

Customers/users: Customers can be entities that purchase the recovered materials for reuse in production cycles. These can include manufacturers of various products, especially those that require the metals recovered through urban mining.

EXAMPLE Dell has introduced an innovative urban metal mining business model by creating a line of jewelry crafted from reclaimed gold sourced from recycled computer motherboards. Partnering with actress Nikki Reed, the company has transformed excess gold material — generated through its efficient recycling processes — into stylish rings, earrings, and cufflinks.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level due to its focus on individual urban environments.

CLOSE - USE AGAIN

CIRCULAR STRATEGY LEVEL: This model promotes the close resource flow level by ensuring that recovered materials from waste streams are reintroduced into production cycles.

ORGANIZATIONAL & TECHNOLOGICAL

STAKEHOLDER LEVEL: This model engages organisational stakeholders through businesses handling reclaimed materials and addresses the technological level with the equipment used for metal extraction and processing.

GROWTH INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs technologies like advanced material recovery processes, which currently stand at the growth innovation level.

12.4 UPCYCLING

Linked to Snapshots: 4

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? This model is essential for enhancing the efficacy of metal high-recycling processes, also known as upcycling, and ensuring the preservation of high-quality recycled resources. This measure effectively mitigates the potential combination of recycled metal with other metallic components, thereby maintaining the integrity and quality of the upcycled material. This model simultaneously prevents the extraction of new resources and provides economic benefits. By utilising high-quality upcycled materials, which are comparable in performance to virgin materials, they can be employed in the production of high-performance products. This model relies on new sorting technologies that are capable of sorting various metal compositions precisely and accurately. These sophisticated sorting technologies ensure that only metals with compatible properties are combined during the upcycling process. The successful implementation of these cutting-edge sorting technologies represents a significant step towards obtaining a more effective and environmentally friendly high-recycling process for metals.

BUSINESS MODEL ASPECTS

Value is delivered through enhanced metal recycling (upcycling) processes, preserving high-quality recycled resources and ensuring material integrity.

Value is captured through the utilisation or the sele of upcycled metals for the production of high-performance goods.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers are companies offering advanced sorting technologies for precise and accurate metal composition and upcycling. Also, manufacturers and these businesses can work together to upcycle metals.

Customers/users: Customers are manufacturers and businesses seeking to reduce their reliance on virgin resources by incorporating upcycled metals into high-quality products.

EXAMPLE The REALITY aluminium project is an integral component of Jaguar Land Rover's overarching objective known as Destination Zero, which seeks to mitigate carbon emissions, enhance community safety, and foster cleaner environments by means of continuous innovation. The engineers employed upcycled aluminium components along with a reduced amount of primary aluminium in order to develop a novel prototype alloy. This alloy underwent rigorous testing and demonstrated comparable grade and quality to that of Jaguar Land Rover. The examination of the upcycling and manufacturing procedure revealed the potential to reduce CO_2 emissions in alloy production by approximately 26% in comparison to the current automotive grade. This outcome presents an opportunity for Jaguar Land Rover to achieve a closed-loop system in its manufacturing operations and raw material utilisation.

MACRO LEVEL

ECOSYSTEM LEVEL: This model operates at the macro level, considering the broader context of metal upcycling in interconnected geographical contexts.

CLOSE - USE AGAIN

CIRCULAR STRATEGY LEVEL: This model emphasises the close resource flow by ensuring effective sorting while preserving the quality of recycled metals.

INSTITUTIONAL

STAKEHOLDER LEVEL: This model incorporates institutional stakeholders at the public level to ensure the efficient operation and upkeep of a system that aims to maintain the quality of materials.

GROWTH INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs advanced sorting and analytical systems at the growth innovation level, showing fast adoption and increasing relevance in the field of metal recycling.

12.5 RECYCLING

Linked to Snapshots: 4 5

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? The utilisation of this model is crucial in the context of mitigating greenhouse gas emissions, preserving finite resources, and mitigating waste generation. This model advocates for the utilisation of scrap metal as a valuable resource, hence mitigating the demand for primary raw materials and energy-intensive procedures. The transition described is of utmost importance for the metal sector to effectively align itself with worldwide sustainability objectives and endeavours to mitigate climate change.

BUSINESS MODEL ASPECTS

Value is delivered through the efficient use of resources. By reusing and recycling materials, the industry can reduce costs associated with raw material extraction and waste disposal. Additionally, the development and implementation of innovative technologies for recycling and waste reduction can lead to operational efficiencies and new business opportunities.

Value is captured through the utilisation or the sele of recycled metals for the production of goods.

POTENTIALLY RELEVANT TO

Solution providers: Solution providers are companies offering sorting technologies and recycling. Also, manufacturers and these businesses can work together to recycle metals.

Customers/users: Customers are manufacturers and businesses seeking to reduce their reliance on virgin resources by incorporating recycled metals into products.

EXAMPLE Aluminium has the potential to be recycled into a wide range of products, including tractor trailer and car bodies. However, it is worth noting that aluminium cans often find their way back into the production of new aluminium cans.

MACRO LEVEL

ECOSYSTEM LEVEL: This model operates at the macro level, considering the broader context of metal recycling in interconnected geographical contexts.

CLOSE - USE AGAIN

CIRCULAR STRATEGY LEVEL: This model emphasises the close resource flow by ensuring effective sorting while preserving the quality of recycled metals.

INSTITUTIONAL

STAKEHOLDER LEVEL: This model incorporates institutional stakeholders at the public level to ensure the efficient operation and upkeep of a system that aims to maintain the quality of materials.

GROWTH INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs advanced sorting and analytical systems at the growth innovation level, showing fast adoption and increasing relevance in the field of metal recycling.

12.6 MICRO MOBILE FOUNDRY AND UPCYCLING WORKSPACES

Linked to Snapshots: 4 5

WHY DOES THE METAL ECONOMY NEED THIS BUSINESS MODEL? Micro mobile foundries can be used to improve the synergy between customers, communities, and local enterprises. This model is useful for creating business hubs around shared interests. Metal scraps can be melted on the spot and reused immediately, making these workshops useful in both urban and remote settings. Re-use and repair centres, urban innovation districts and community hub in making locations are just a few of the numerous possible applications for these kinds of workspaces.

BUSINESS MODEL ASPECTS

Value is delivered by implementing improved metal upcycling and recycling methods in micro workshops located in urban areas and/or small, isolated regions. The workshops efficiently recycle small amounts of metal, which are either utilised for local product manufacturing or sent to larger factories for metal utilisation.

Value is captured by selling metals or metal products and by collaborating with waste management companies, as they assist in the execution of their tasks.

POTENTIALLY RELEVANT TO

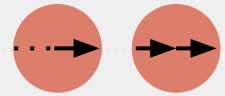
Solution providers: Solution providers are typically micro companies that relocate their foundry workspace to various locations in order to meet the specific needs of customers, communities, and local businesses.

Customers/users: The customer base of a foundry can vary significantly depending on its location, encompassing user communities, business communities, urban centres, and remote areas with a viable metal supply that ensures profitability.

EXAMPLE Precious Plastics is an open-source digital commons project that focuses on open hardware plastic recycling. In order to assess the feasibility of tackling local ocean plastic pollution, a plastic recycling facility within a shipping container was established and transported to the Maldives, equipped with all the necessary open hardware plastic recycling tools. This approach facilitates the utilisation and conversion of local resources to support the local community, particularly in economically disadvantaged and geographically remote areas where there aren't recycling facilities. One objective of this project was to involve local schools and communities to inspire aspiring entrepreneurs in the field of recycling.

MICRO LEVEL

ECOSYSTEM LEVEL: This model operates at the micro level due to its focus on individual urban environments.



SLOW-USE LONGER & CLOSE-USE AGAIN

CIRCULAR STRATEGY LEVEL: This model enables efficient resource reuse by implementing optimised reverse logistics processes, which effectively slow down and close the flow of resources through a series of comprehensive procedures.

SOCIO/CULTURAL, & ORGANIZATIONAL

STAKEHOLDER LEVEL: This model incorporates organisational stakeholders who have the ability to establish the necessary conditions for communities to recycle their metals.

MAINSTREAM INNOVATION

TECHNOLOGY READINESS LEVEL: This model employs conventional mechanical methods, such as disassembly and the use of small metal melting equipment or tools, to dismantle and reshape metal into novel goods.

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