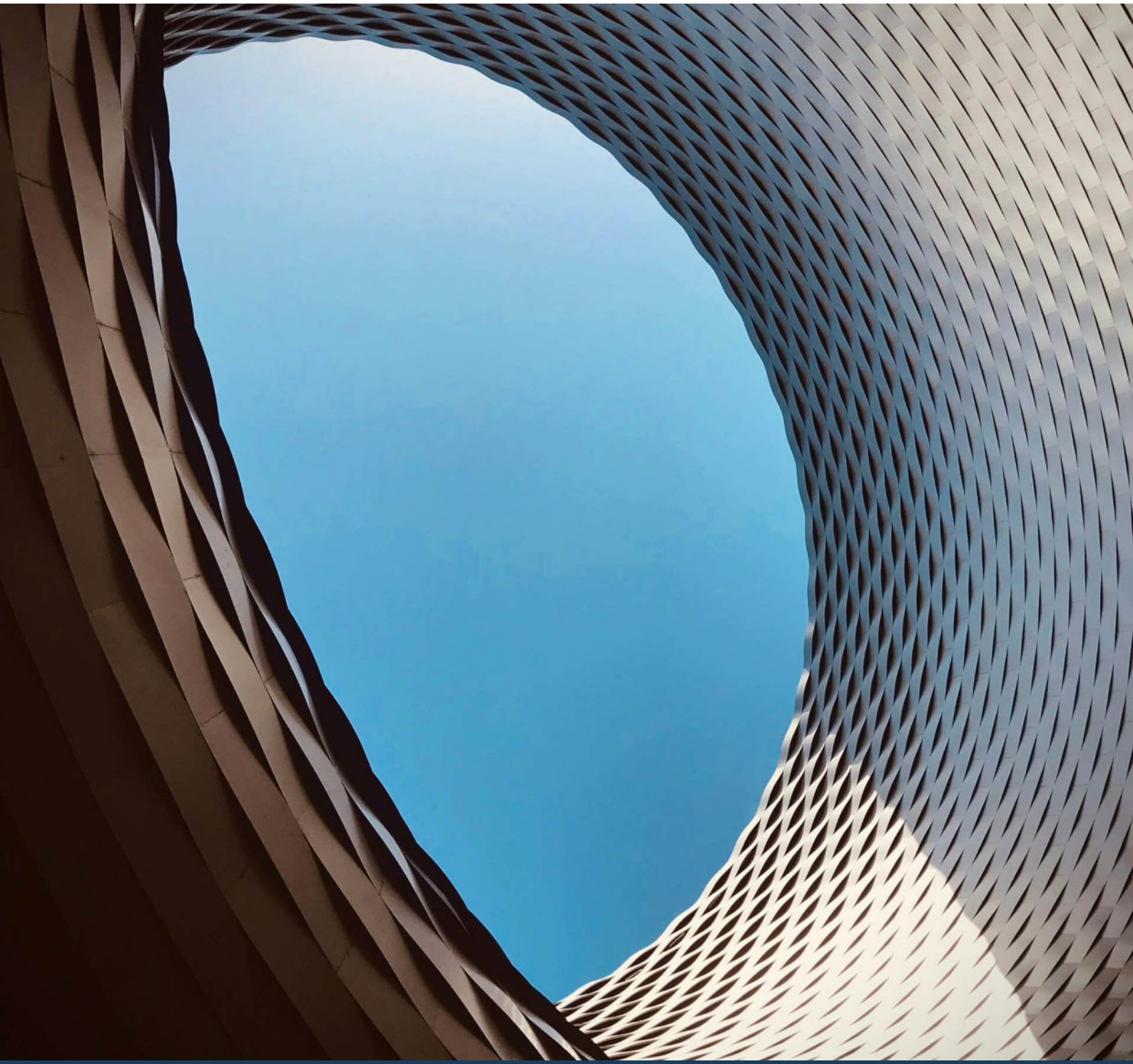
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MARKET DISCOVERY FRAMEWORK FOR METALS-AS-A-SERVICE:
IDENTIFYING WHERE CIRCULAR, SERVICE-BASED METALS MODELS MAY BE COMMERCIALLY VIABLE

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Foreword

This report forms part of a wider programme of work led by the Carbon Trust and the Columbia Center on Sustainable Investment (CCSI), with support from the Quadrature Climate Foundation. It examines whether Metals-as-a-Service (MaaS) could provide a commercially viable route to more circular and resilient metals value chains. The programme combines research, economic analysis, practical tools, and engagement with stakeholders across the metals ecosystem.

The work began by developing the conceptual and commercial foundations for MaaS. The report *Metals-as-a-Service: A Strategic and Investable Circular Business Model for the Wind Energy Industry and Beyond* explained the MaaS proposition and explored how retaining ownership of metals could strengthen incentives for their efficient use, recovery and reuse.[1] A companion economic analysis compared MaaS and linear business models in the context of an onshore wind project, providing quantitative support to the wider strategic analysis.[2]

The research has also considered the practical information and tools needed to translate the concept into implementable business models. Work on stock-and-flow and dynamic material flow analysis examined how data on the quantity, location, timing of return and residual value of metals could inform MaaS feasibility, metal-bank design, recovery planning and financial modelling. The Market Discovery Framework presented in this report complements that work by helping users identify and compare the value chains, assets and market contexts in which more detailed analysis may be justified.

Executive Summary

Metals are essential to the infrastructure and technologies that underpin the energy transition. Yet most metals value chains are long, fragmented and linear. Ownership changes hands several times, information on the location and condition of materials is limited, and those holding assets at end-of-use often have little incentive to recover the metal they contain. As a result, valuable material is lost from productive use, adding pressure on primary supply.

Metals-as-a-Service (MaaS) offers a potential response. Under MaaS, ownership of the metal is retained, and customers pay for access, use or performance, instead of buying the metal outright. Since the owner keeps an economic interest in the metal, they have a stronger reason to track it, preserve its value and recover it for future use cycles. However, MaaS is not a single standardised one-size-fits all model, and it won't suit every market, product or metal. Stakeholders also lack a consistent way to identify where it is most likely to work in practice.

This report, therefore, introduces the **Market Discovery Framework (MDF).** It is a high-level, pre-commercial tool that helps users identify, screen and compare potential MaaS opportunities across metals, assets, sectors and value chains. The MDF is built around seven core questions (layers), ordered from the broadest market signal to the most specific commercial conditions:

1. Is there a **market engine** to drive circularity?
2. Is there sufficient **economic value in the metal**?
3. Can the system be configured as a **closed loop**?
4. Can the **value chain structure** be clearly mapped?
5. How far has **circularity** already been adopted?
6. Is there a **business model entry point**?
7. Can MaaS **capture new value**?

These questions are assessed alongside three crosscutting enabling conditions: i) the **policy, regulatory and geopolitical setting,** ii) **community benefit,** and iii) **host-country benefit.** Together they ask whether an opportunity is commercially credible, and whether it can be implemented and deliver fair outcomes. The framework treats commercial viability and equitable outcomes as inseparable. It prompts users to consider from the outset who controls the metal, data and financial value that MaaS creates.

The MDF is designed for five main user groups:

- **Corporates**, to prioritise value chain segments.
- **Entrepreneurs and solution providers**, to see where their capabilities fit best.
- **Investors and financial institutions**, to decide where deeper due diligence may be justified.
- **Governments and host countries**, to find where MaaS could support domestic value creation, secure supply and a just transition.
- **Local communities**, to assess local benefit.

Users apply the framework through a four-stage process: **Discovery → Prioritisation → Analysis → Design and Testing.** Each assessment produces a readiness profile showing where an opportunity is strong, where the bottlenecks lie and where evidence is weak.

The MDF does not prove commercial viability or bankability. Instead, it makes visible the assumptions, drivers, risks and evidence gaps behind a potential opportunity. Users can then focus limited resources on the opportunities most worth pursuing. It complements the wider Carbon Trust–CCSI body of MaaS research, acting as a bridge between the MaaS concept and the detailed technical, commercial, financial, legal and stakeholder work needed to design and test credible MaaS models.

1. Introduction

1.1 The need for more circular metals value chains

Metals are essential to the infrastructure and technologies required for the energy transition. At the same time, rising demand is increasing pressure on primary metal supply and reinforcing the need to retain metals in productive use for longer. Expanding secondary supply through recovery, reuse, refurbishment and recycling can help reduce pressure on primary extraction, improve supply resilience and limit the loss of valuable materials from the economy.

However, increasing metals circularity is not solely a technical challenge. Metals often move through long, fragmented and internationally distributed value chains. Ownership may change several times, information on the location and condition of materials may be limited, and the party responsible for an asset at the end of its use may have little commercial incentive to recover its metal content. Existing linear business models can therefore separate decisions made at the point of sale from the long-term value, recoverability and subsequent use of the metal.

1.2 Metals-as-a-Service

MaaS offers a potential response to these challenges. Rather than treating metal as a one-off input that is permanently sold, MaaS explores models in which ownership is retained, and customers pay for access, use or performance. By maintaining a continuing economic interest in the metal, such models could create stronger incentives to track it, preserve its value and recover it for future use cycles.

MaaS is not a single standardised business model, nor will it be appropriate in every market. Its relevance will depend on factors such as the economic and residual value of the metal, the structure and traceability of the value chain, the maturity of recovery pathways, existing commercial relationships, and the surrounding policy, regulatory and governance environment. The potential distribution of value also matters. A credible MaaS opportunity should consider who owns and controls the metal, data and financial flows, as well as whether host countries and communities can participate meaningfully in the benefits created. These commercial, operational and wider enabling conditions need to be examined together to judge whether a MaaS opportunity is viable as a whole.

1.3 Purpose of this report

The Market Discovery Framework (MDF) provides a structured starting point for the assessment of MaaS opportunities. It is a high-level, pre-commercial tool designed to help corporates, solution providers, investors, financial institutions, governments and other stakeholders identify, screen and compare potential MaaS opportunities. It asks whether the conditions within a particular metal, asset, sector or value-chain context appear sufficiently promising to warrant further investigation.

The framework does not prove commercial viability, bankability or ability to implement. Instead, it helps users make the assumptions, opportunity drivers, risks, enabling conditions and evidence gaps associated with a potential MaaS opportunity more visible. Its outputs can support decisions about where to direct further research, stakeholder engagement, financial and legal analysis, stock-and-flow modelling, business-model development or pilot design.

In this way, the framework occupies a specific place within the wider MaaS body of work. The strategic and economic reports establish the rationale and potential commercial logic of MaaS.[1, 2] The feedback loop between MaaS, stock-and-flow models, and performance pricing report highlights how stock-and-flow analyses, producer ownership under MaaS, and performance-based pricing reinforce each other to bring the data that will support price discovery and business model formation.[3] The Market Discovery Framework helps determine where these more detailed forms of analysis should be applied first. It therefore acts as a bridge between the MaaS concept and the context-specific work required to design, test and implement credible opportunities.

2. Why a market discovery framework is needed

Despite growing interest in Metals-as-a-Service, stakeholders do not yet have a consistent way to identify where it may be most applicable in practice. The conditions that could support MaaS vary significantly across metals, products, assets, sectors and value-chain configurations. Some opportunities may combine strong market demand, durable metal residual value, clear recovery pathways and traceable commercial relationships. Others may be constrained by fragmented value chains, uncertain routes for recovery and subsequent use, limited data, weak enabling infrastructure or unclear commercial incentives.

This variation makes it difficult to move directly from the broad MaaS concept to the design of a credible MaaS opportunity. An opportunity may appear attractive when considered from one perspective, such as the residual value of the metal, but prove less promising when its wider value chain, technical requirements, ownership arrangements or regulatory environment are examined. Conversely, an opportunity that is not immediately obvious may merit further consideration because several favourable conditions align.

A structured discovery stage is therefore needed to test opportunities consistently before significant resources are committed to detailed analysis or business model solution design. This stage should consider three connected areas:

- **Market and metal conditions:** whether there is sufficient market demand and whether the metal is likely to retain meaningful economic or strategic value.
- **Value-chain and circularity conditions:** whether metal flows, actors and ownership arrangements can be understood, and whether credible pathways exist for recovery and subsequent productive use.
- **Commercial and enabling conditions:** whether a service-based commercial entry point can be identified and whether the surrounding policy, regulatory, governance, infrastructure and stakeholder environment could support it.

The MDF provides a structure for conducting this early-stage assessment. It helps users compare potential opportunities, document the evidence supporting an assessment and expose assumptions or knowledge gaps that require further investigation. The MDF is not intended to identify a single conclusive MaaS entry point or determine whether an opportunity is bankable. Instead, it helps users identify where MaaS appears most worth exploring, prioritise the most promising opportunities and determine where to focus additional research, stakeholder engagement and technical, commercial, financial, legal or policy analysis. Section 3 explains the seven discovery questions used to structure this assessment, while Section 5 describes how different user groups can apply the framework.

3. What the Market Discovery Framework assesses

The MDF can be applied to a metal, an asset or product, or a segment of a value chain that relies on metal. The logic is intentionally layered as depicted in Figure 1.

The MDF achieves features a sequence of seven core questions (see Table 1), which are explained in the subsequent subsections. These questions are deliberately ordered to move from the broadest market signal through to the more specific value chain, circularity and business model conditions that would need to be explored before a MaaS opportunity could be taken further. Beyond the seven core questions, there are crosscutting considerations that cover enabling conditions, safeguards, risks and evidence gaps (see Figure 1).

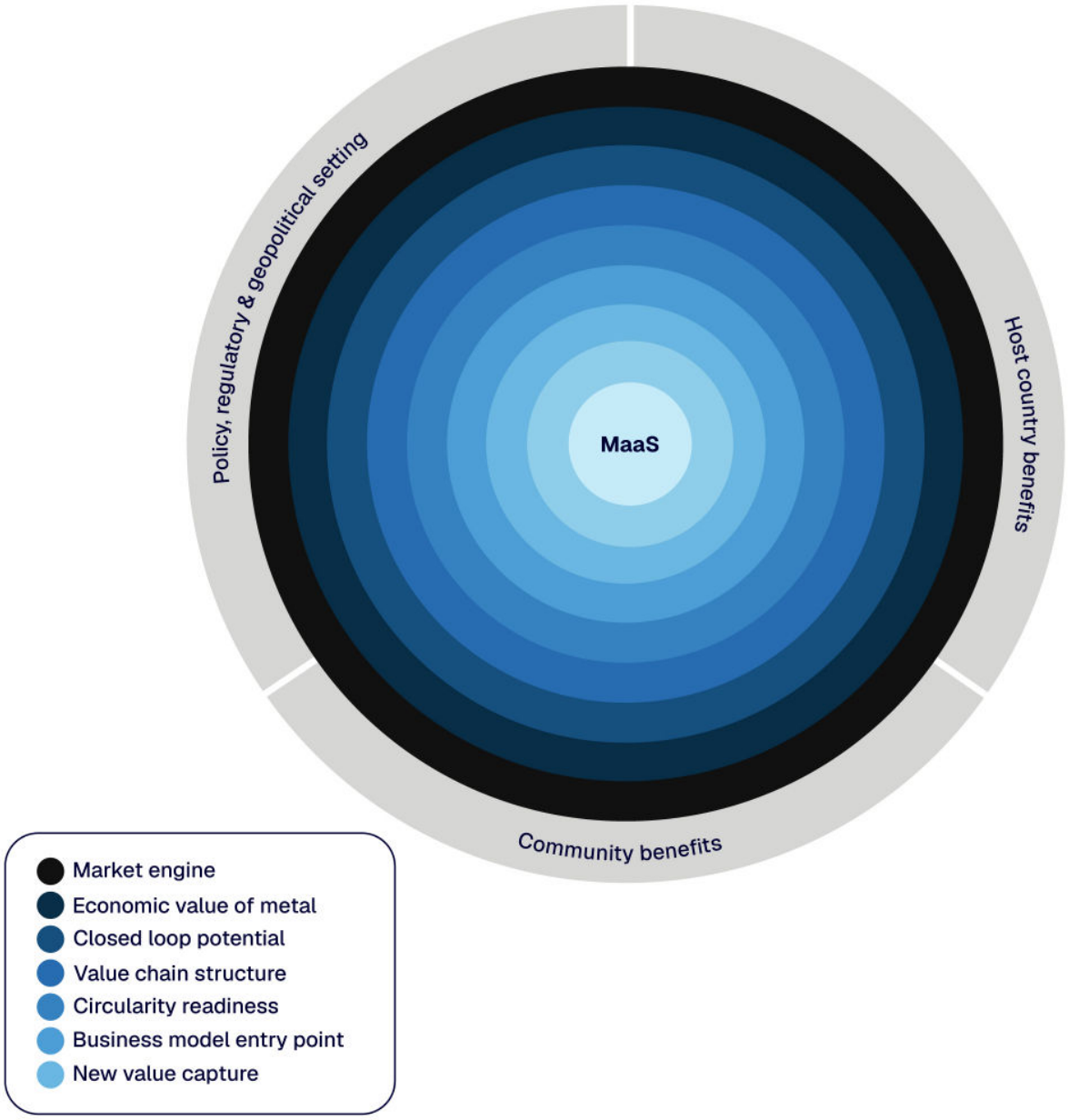


Figure 1: The seven layers of the MaaS Market Discovery Framework. The three outer segments apply across all seven layers as they are crosscutting enabling conditions.

Table 1: Seven core questions upon which the MaaS Market Discovery Framework is built.

#	Question	What it tests
1	Is there a market engine to drive circularity?	If there is a stable or growing market for the product or infrastructure that relies on the metal
2	Is there sufficient economic value in the metal?	If the metal has durable current and future economic value
3	Can the system be configured as a closed loop?	If the metal can physically and economically be returned to productive use
4	Can the value chain structure be clearly mapped?	The business logic of actors, ownership points, contracts and data flows
5	How far has circularity already been adopted?	Whether recovery capabilities and enabling technologies are already in place
6	Where is there a business model entry point?	If payment mechanisms exist that can carry 'metal-as-a-service' rental
7	Can MaaS capture new value?	If MaaS can capture forms of value that the current model does not fully capture

The MDF is intended to be used by different user groups, which are explained in section 5. This multi-user framing supports different personas while remaining a single, coherent framework rather than separate tools for each audience.

3.1 Is there a market engine to drive circularity?

The first question identifies whether there is a stable or growing commercial market for the product, infrastructure or service that depends on the metal or metals. This matters because even a technically interesting MaaS concept is unlikely to progress without a credible market driver behind it. The MDF therefore begins by asking whether there is a recognised long-term growth opportunity linked to the relevant product or infrastructure, such as the clean energy transition, buildings and transport infrastructure, shipping, electricity networks, data centres or other metal-intensive markets.

This "market engine" is the outer layer of the MDF. It helps users establish whether there is sufficient demand-side momentum to warrant further exploration. If the wider market is not growing, or if there is no clear commercial pressure to reuse, repair, refurbish, recycle, and recover the metal, then MaaS may have limited market opportunity. Both are needed: growth provides the demand, while supply, cost, resilience and sustainability pressure provide the reason to keep metal in use. Taking onshore wind as an example, the first question is not yet about the steel itself, but about whether the market the steel serves is growing. Since wind energy deployment is expected to expand significantly as part of the energy transition, the underlying market engine is strong. According to the International Energy Agency (IEA), global onshore wind capacity additions are expected to increase by 45% between 2025 and 2030 compared with 2019-2024, reaching 732 GW of new capacity.[4] This indicates strong and sustained growth in demand for wind generation assets, suggesting that the market for metals used in turbine towers, nacelles and other components is likely to remain robust. Such demand-side momentum makes the wind energy industry a plausible candidate for exploring MaaS approaches. Alongside this growth, the sector faces commercial pressure on the metal itself, including the need to manage end-of-life turbines and to reduce the embodied emission of the steel it uses. Taken together, these conditions make the wind energy industry a plausible candidate for exploring MaaS.

3.2 Is there sufficient economic value in the metal?

The second question is whether the metal itself has enough economic value to justify a service-based model. This includes considering the current market value of the metal and how it's secondary value may change over time. For example, copper is well suited to a model built on retaining access across multiple use cycles: its demand is crosscutting across electricity grids, EVs, solar PV, wind and data

centres, coupled with the fact that it can be recycled repeatedly without loss of performance, means clean copper scrap typically trades close to primary prices.[5, 6] By contrast, a metal such as nickel carries greater uncertainty over its secondary value, because its principal growth market is exposed to battery-chemistry shifts: nickel-free lithium iron phosphate (LFP) batteries rose from under 10% of the global EV market in 2020 to almost half by 2024, at the expense of nickel-based chemistries.[7, 8]

This question is important because MaaS depends on the idea that metal can remain valuable across multiple-use cycles. Metals with durable value, long-term demand, exposure to supply constraints, price volatility, or strategic importance may be more suitable candidates for MaaS than materials with low residual value or weak secondary markets. The MDF should therefore consider not only the primary value of the metal, but also its expected secondary relevance and the extent to which retaining ownership or access could create commercial advantage.

The MDF invites users to capture basic characteristics of the metal or asset, including its lifecycle duration, durability, recoverability and potential residual value. These factors shape whether the metal can realistically be treated as a long-term productive asset rather than a one-off input.

3.3 Can the system be configured as a closed loop?

The third question is whether the value chain is, or could become, a metal circularity closed loop system. In a MaaS model, value depends on the ability to keep metal visible, recoverable and capable of being used again. If the metal disperses into a highly fragmented system, or if it cannot be tracked or recovered at end-of-use, then the foundations for MaaS are weaker. For example, wind turbines lend themselves well to a closed-loop approach: they are large, high-value assets owned by a small number of operators and installed at known, documented locations, so the steel and other metals they contain can realistically be tracked, recovered and returned to productive use at end-of-life. Smartphones sit at the opposite end of the spectrum; dispersed across millions of individual users, frequently stored, discarded or sent to informal recyclers, and containing small quantities of many metals mixed. This makes the metal far harder to trace and recover, weakening the foundations for MaaS.

In short, this question tests whether the loop can close, both physically and economically. At the end of a use cycle, can the metal realistically be recovered and returned to productive use at a quality fit for that use, and would doing so make economic sense? Whether the capabilities and technologies to do this already exist is assessed separately under question 5 (section 3.5).

This question should also help identify possible “terminal points” in the value chain. A terminal point is where the MaaS logic may break down because recovery, reuse or recycling is not technically, commercially or logistically feasible. For example, a product may support circularity at the product level if it can be reused or redeployed but may not yet support full material circularity if recycling technologies, product design, quality requirements or economics prevent the metal from being recovered in a usable form. Equally, strong opportunities for product reuse do not necessarily translate into a viable MaaS model if the commercial and operational conditions for retaining ownership and stewarding the metal over time are not in place.

3.4 Can the value chain structure be clearly mapped?

The fourth question moves from the general idea of closed loop opportunities to the practical structure of the value chain. It asks whether the value chain in question can be mapped in enough detail to understand where MaaS might intervene. This includes identifying who the main actors are, where ownership and procurement decisions sit, and how contracts and data connect them, or fail to.

This is an important distinction from a generic value chain assessment. The purpose is not simply to describe a sequence of activities from production to end-use. Rather, the MDF should help users understand how metal, value, risk and ownership, contracts and data obligations might move through a circular MaaS system. In that sense, value chain mapping is where the opportunity begins to move from a broad concept into a structured opportunity.

This part of the MDF can also help users identify where existing structures already support MaaS and where gaps remain. For example, it may reveal that some actors are already connected through long-term contracts, that certain recovery or recycling points are already established, or that lifecycle visibility is weak and would need to be strengthened before MaaS could progress. Additionally, existing leasing, rental, pay-per-use or service-based arrangements can indicate whether a market already has commercial structures that could be adapted for MaaS.

This dimension assesses whether the value chain is sufficiently knowable, traceable and structured for a MaaS model to be considered. It covers questions such as where the metal sits in and moves through the value chain, how ownership and procurement currently work; whether the value chain is highly fragmented or not; whether lifecycle visibility is possible; current ownership and procurement model; and end-of-life pathways.

Mapping also matters because MaaS cannot be delivered by the metal or asset owner alone. It typically depends on an ecosystem of actors (technology providers, recyclers, traceability companies, logistics providers and others) whose combined capabilities allow metal to be tracked, recovered and returned to productive use. Mapping the value chain therefore shows not only where MaaS might intervene, but which actors would need to be brought together and where the commercial opportunity may sit for each of them.

3.5 How far has circularity already been adopted?

Where question 3 (section 3.3) asks whether the loop *can* close, this question asks how far the practical means to close it are already in place or emerging. It looks for existing take-back, refurbishment, reuse, or recycling activity in the value chain, or in similar value chains, and assesses the maturity of enabling capability such as design for disassembly, reverse logistics, collection and sorting, recycling technologies, and digital tracking and lifecycle data system. Strong existing activity should lower the barrier to MaaS. Where it is absent, it shows which capabilities would need to be developed.

This matters because MaaS would be easier to build on existing practice than to create from scratch. Where take-back or recycling already operates in the same or a similar value chain, a MaaS model may only need to formalise ownership and recovery obligations around activity that is already happening. Where it does not, the opportunity may still be worth pursuing, but the investment, partnerships and lead time needed to build recovery capability should be reflected in its readiness. Taking wind turbine steel as an example, steel recycling routes are well established, so the gap is less about whether the steel can be recycled and more about where towers are decommissioned, tracked and routed into those pathways in a way that preserves their value.

3.6 Is there a business model entry point?

The sixth question asks whether there is already a service-based, leasing, rental, pay-per-use or similar commercial model somewhere in the value chain that could provide an entry point for MaaS. Existing service-based arrangements may indicate that the market is already familiar with recurring payments, access-based models, performance-based contracts or long-term commercial relationships.

This matters because MaaS requires a shift away from one-off metal ownership and towards access-, usage- or performance-based arrangements. Where customers already pay for a service (e.g., through electricity consumption, vehicle leasing, equipment rental, building rental or other recurring payment model), it may be easier to imagine how metal access or metal stewardship could be integrated into the commercial structure. Where the value chain is dominated entirely by one-off sales and no recurring payment logic exists, the shift to MaaS may require more substantial business model innovation. This question therefore identifies whether there is a practical commercial "hook" that could make MaaS less of a disruptive leap and more of an extension or adaptation of existing market behaviour.

A well-established example is Rolls-Royce's "Power-by-the-Hour" model (now TotalCare), which has operated for over 60 years. Rather than treating the engine as a one-off sale, airlines pay a fixed fee per engine flying hour while Rolls-Royce retains responsibility for maintenance, performance and end-of-life management across the engine's lifecycle.[9] Since the value chain already operates on recurring, performance-based payments and lifecycle stewardship, the conceptual and commercial leap to retaining and monetising the *metal* in the engines is considerably smaller than in a market built purely on one-off sales. It is worth noting that under TotalCare®, the airline typically retains ownership of the engine. Rolls-Royce sells availability and maintenance, not access to the engine or its metal. The model is therefore not strictly MaaS, but it shows that the market already accepts recurring, performance-based payment and lifecycle stewardship, which are the building blocks a MaaS model would extend.

Another relevant example is NIO's Battery-as-a-Service (BaaS) model, launched in China in 2020. Customers can buy an electric vehicle without its battery and pay a monthly subscription for the battery pack instead. A dedicated batter asset company, established by NIO, a battery manufacturer, CATL, and two investment partners, purchases and owns the batteries and leases them to users.[10] This separates ownership of a metal-intensive component from ownership of the product and places it in a jointly owned entity that closely resembles the SPV structure proposed for MaaS.

3.7 Can MaaS capture new value?

The final question asks whether MaaS could unlock forms of value that are not fully captured in the existing linear or partially circular model. This is where the MDF brings together the previous layers: market growth, metal value, closed-loop potential, value chain structure, circularity readiness and business model entry points.

Crucially, this question should also test whether MaaS adds value beyond simpler circular alternatives, such as take-back or buy-back contracts, EPR schemes or conventional recycling agreements. Where these already capture most of the available value, a good recycling opportunity should not be mistaken for a good MaaS opportunity. MaaS is most compelling where retained ownership unlocks something these alternatives cannot, such as financing against the metal's future value, long-term supply security or stronger stewardship incentives across multiple use cycles.

Through a MaaS lens, value may be created or captured in several ways. These could include retaining residual value, improving supply security and ore quality, reducing exposure to price volatility or geopolitical risks, converting upfront capital costs into more predictable operating costs, creating recurring revenue streams, improving recovery incentives, enabling better risk allocation, or making circular material flows more measurable and financeable.

This question should also examine whether waste or end-of-life products are currently undervalued. In some cases, material that appears to be low-value or difficult to manage under the current model may hold greater economic potential if it can be recovered, tracked, reused, recycled or reintegrated into a managed metal pool or "metal bank". The MDF therefore helps users identify where value is currently leaking from the system and whether MaaS could provide a structure for capturing that value more effectively. For example, the steel embedded in a wind turbine could be treated as a stock of retained value rather than a sunk cost: because it can be recovered at decommissioning and reintroduced as secondary metal, that future value could be leveraged to help finance turbine deployment in the present. Once completing this section of the MDF, the user should see whether there is a credible value capture hypothesis that justifies deeper analysis, such as financial modelling, legal structuring, stakeholder engagement, pilot scoping or value chain test bed design.

4. Crosscutting enabling conditions

4.1 The need for a whole system view

The seven core questions test whether a MaaS opportunity holds together commercially. Three further conditions determine whether it can be implemented and whether it delivers fair outcomes. These are: the policy, regulatory and geopolitical setting; community benefits; and host-country benefits. They are treated as crosscutting because, unlike the core layers, they are not a further step in the sequence; they bear on every layer. Regulation, for example, can block recovery (question 3), shape whether ownership can be retained (question 6) and influence who captures new value (question 7). Governance is not treated as a separate condition but runs through all three, since who owns and controls the metal, data and financial value created by MaaS is at once a regulatory, community and host-country question.

These conditions may not determine the commercial logic of MaaS on their own, but they strongly influence whether an opportunity is appropriate to pursue and what further work would be needed. Assessing them helps identify where governance arrangements are unresolved, where community or host-country implications require further consideration, or where policy and regulatory conditions are not yet supportive.

4.2 Policy, regulatory and geopolitical setting

Users should also consider whether the surrounding policy, regulatory and governance environment can support a MaaS model. A MaaS model may appear viable on commercial, economic, and circular grounds, yet remain unimplementable if the legal and regulatory foundations are not in place. Therefore, the MDF asks whether such foundations exist, or could plausibly develop. This matters as ownership retention, circularity clauses, return and recovery obligations, traceability requirements and cross-border recovery loops each depend on legal and regulatory support that varies between markets.

The maturity of relevant policy levers varies significantly between markets and can either enable or obstruct a MaaS model. On the enabling side, the EU's Critical Raw Materials Act (2024) sets a non-binding benchmark for EU recycling capacity to supply at least 25% of annual consumption of each strategic raw material by 2030, and offers faster permitting for designated strategic projects, including recycling points.[11] The EU Batteries Regulation (2023) goes further, combining Extended Producer Responsibility (EPR), mandatory recycled-content targets and a Digital Battery Passport. These are mechanisms that, despite their practical shortcomings, align closely with the MaaS principle of retaining lifecycle responsibility for the metal.[12] The Ecodesign for Sustainable Products Regulation (ESPR) establishes the framework for the Digital Product Passport (DPP) and for requirements on durability, recyclability and recycled content, which can be applied to almost all physical goods through product-specific delegate acts (with iron, steel and aluminium named as priority intermediate products). Traceability infrastructure like the DPP is precisely what MaaS models need to keep metal visible, valued and recoverable.[13] Conversely, some regulatory frameworks can act as unintended barriers. Metal-bearing products classified as hazardous waste are subject to strict controls on handling, treatment and cross-border movement: under the Basel Convention, exports for recycling or recovery require the prior written consent of importing and transit states. Amendments effective from January 2025 extended this requirement to all e-waste, hazardous and non-hazardous. This can slow, restrict or prevent the return of material into productive use even where recovery is technically and commercially attractive.[14]

Assessing this policy maturity early therefore helps users distinguish opportunities that are genuinely implementable from those that would first require regulatory or governance change. The MDF can prompt users to assess the maturity of relevant policy levers, including: EPR; circular economy regulation; the treatment of ownership within an SPV; rules on cross-border movement of

materials and end-of-life assets; and tax, royalty and procurement regimes that determine whether the MaaS model can compete with linear procurement. A related threshold question is whether retained title can be legally enforced. Where metal is incorporated into another asset, property-law rules on accession and fixtures may transfer title to the asset owner, and enforceability may differ across jurisdictions. Users should flag this for the legal analysis undertaken in the 'Analysis' stage.

Finally, users should remain alert to the wider geopolitical context surrounding the MaaS opportunity in question. As metals value chains are increasingly shaped by supply security, a MaaS opportunity should be positioned as a stabilising model that supports supply security with secondary metals, rather than one that entrenches already dominant actors.

4.3 Community benefit

A MaaS opportunity must be structured to deliver genuine benefit to the communities in which metals are sourced, processed, or recovered, if socially equitable value chains are to be achieved. Communities should be considered from the beginning of the opportunity screening process, not as a downstream concern. For this reason, the MDF asks users to look beyond value creation alone. It encourages them to consider who benefits from that value and whether local communities have a meaningful role in shaping and sharing the outcomes.

This matters because the SPV and metal bank structure[15] proposed to make MaaS commercially operable, could, if left unexamined, concentrate ownership, data and financial value in a small number of actors, replicating inequities that exist in extractive industries today.[16] To guard against this, the MDF draws on the principle that no single actor should control all of the material, financial, information, and strategic value that MaaS creates. Rather, governance arrangements should be designed to balance value across all stakeholders. Since this condition cuts across the MDF, it should be tested wherever value and control are allocated, most directly when assessing new value capture and the design of any SPV: could the structure accommodate community ownership, participation in governance or other mechanisms that give affected communities a voice and a share of the benefits?

The MDF can also help users identify the specific forms of community benefit a given value chain could support. For example, local employment, revenue sharing, and environmental and social safeguards. Where such benefits appear feasible, the viability and durability of a MaaS opportunity would be strengthened. Conversely, where they appear difficult to secure, this signals an area requiring deeper design, partnership, or policy work before implementing the opportunity. Emerging research on relevant designs for community benefit provides a useful reference point for this deeper analysis.[17]

4.4 Host-country benefit

At the national level, mineral-rich nations have a legitimate interest in retaining value from metals that originate within their borders. A credible MaaS opportunity should therefore be assessed on whether it can support host-country priorities such as domestic processing and recovery capacity, revenue retention through royalties and taxes, and governance rights over how the country's metal is used over successive cycles. Where these can be designed in from the outset, MaaS can be positioned as a contributor to an equitable and just transition rather than a financial mechanism that leaves national benefit behind.

One example raised by the Community of Practice, which is coordinated by the Carbon Trust and the Columbia Center on Sustainable Investment (CCSI) throughout the duration of the MaaS project, is set out here. There could be a model in which mineral-rich nations accept reduced upfront royalties and taxes and retain a small, perpetual ownership claim on the value generated each time their metal is re-used under a MaaS agreement, in effect making the exported metal a traceable and enduring value creator. While such models are complex to implement and depend on strong governance, traceability and legal enforceability, their inclusion signals that host-country benefit can be structured in ways that materially improve on conventional linear models.

5. The Market Discovery Framework user groups

The MDF is intended to support different actors across the MaaS ecosystem. While each user group would approach the MDF with a different question, the underlying logic remains consistent: to identify where value chain conditions, circularity pathways, commercial drivers and enabling conditions suggest that MaaS may merit further exploration. Alongside corporates, solution providers and investors, this includes governments, host countries and communities, whose priorities shape whether an opportunity is not only commercially viable but also equitable. Table 2 captures the use of the MDF by the different actors.

As each user group approaches the MDF with a different question, the same opportunity can legitimately receive different scores. A corporate may rate new value capture highly because of supply security, while a host government may rate it lower if little value is retained domestically. This is intended: the framework's structure, questions and scoring rules stay the same, but the perspective shapes the evidence and priorities applied. Users should therefore record which perspective they are scoring from and compare opportunities within the same perspective. Where several perspectives are combined, for example in a multi-stakeholder test bed, differences in scores are themselves a useful output: they show where interests diverge and where governance and benefit-sharing arrangements will need to be negotiated.

Table 2: Questions the Market Discovery Framework can answer for key user groups

User group	Core question	Potential output
Corporates	Where could MaaS create strategic value in our value chain?	Priority value chain segments
Entrepreneurs / solution providers	Where are our capabilities most relevant?	Opportunity areas and capability fit
Investors / financial institutions	Where might deeper diligence be justified?	Comparative opportunity profile
Governments and host countries	Where could MaaS support domestic value creation, supply security and industrial policy goals?	Priority value chains for policy and regulatory support, and terms for national value retention
Local communities	Would a MaaS opportunity give us a meaningful voice and a fair share of the value created?	Assessment of local benefit, participation in governance and safeguards

5.1 Corporates: identifying strategic entry points

In the MaaS context, corporates are established companies that currently own, produce, use or manage significant volumes of metal within their existing value chains, such as metal producers and miners, Original Equipment Manufacturers (OEMs) and asset owners or operators. For corporates, the MDF can support strategic prioritisation. It can help companies compare where MaaS may be relevant across different assets, product groups or value chain segments. For example, a corporate user might use the MDF to assess whether a particular asset class has sufficient lifecycle visibility, end-of-life recoverability, residual value and commercial relevance to justify further internal investigation. Corporates could use the tool to prioritise value chains or segments, such as built environment, shipping or capital equipment, that may present stronger strategic entry points for MaaS.

5.2 Entrepreneurs and solution providers: locating opportunities

In the MaaS context, these actors are smaller, or more specialised, providing an enabling capability rather than owning metal. For entrepreneurs and solution providers, the MDF can help to gain an understanding of where their capabilities are most differentiated and commercially relevant within emerging MaaS ecosystems. This might include traceability, reverse logistics, asset management, product design, recycling, recovery or data infrastructure.

5.3 Investors and financial institutions: targeting due diligence

For investors, the MDF is positioned as a screening and comparison tool, not an investment decision tool. These actors would be capital providers who would finance MaaS structures, such as an SPV or metal bank. They include project and infrastructure financiers, institutional and venture investors, and development finance institutions. Therefore, MaaS could offer these capital providers a commercial opportunity in its own right. Metal held in these structures could generate recurring lease or service revenue while retaining residual value that be realised at the end of each use cycle. For these actors, the MDF can help identify which opportunity areas may warrant deeper diligence by comparing value chain attractiveness, commercial logic, residual value, potential cashflow structures, risk transfer and enabling conditions.

5.4 Governments and host-countries: aligning MaaS with national priorities

For governments and host countries, the MDF can help identify where MaaS could support domestic value creation, strengthen supply security and advance national industrial and transition goals. Rather than screening for commercial return alone, these users can ask where service-based models might retain more value within their borders, for example through domestic processing and recovery capacity, revenue retention or governance rights over how national metal is used over successive cycles. The framework can also help policymakers prioritise where to direct regulatory support and identify which policy levers would need to mature for an opportunity to be implemented.

5.5 Local communities: securing a voice and a fair share

For communities where metals are sourced, processed or recovered, the priorities are often more immediate and local than those of national governments: employment, environmental and social safeguards, and a genuine say in decisions affecting them. These interests do not always align with national priorities. The MDF can help communities, and organisations representing them, assess whether a proposed MaaS opportunity offers local benefit and participation in governance, or whether it risks replicating the inequities of conventional linear models.

6. From market discovery to deeper design

For the most promising opportunities, the next step may be to explore value chain test beds: structured collaborations that bring together relevant actors to examine whether closed-loop MaaS models could work in practice. The proposed structure has four stages: Discovery → Prioritisation → Analysis → Design and Testing as depicted in Figure 2.

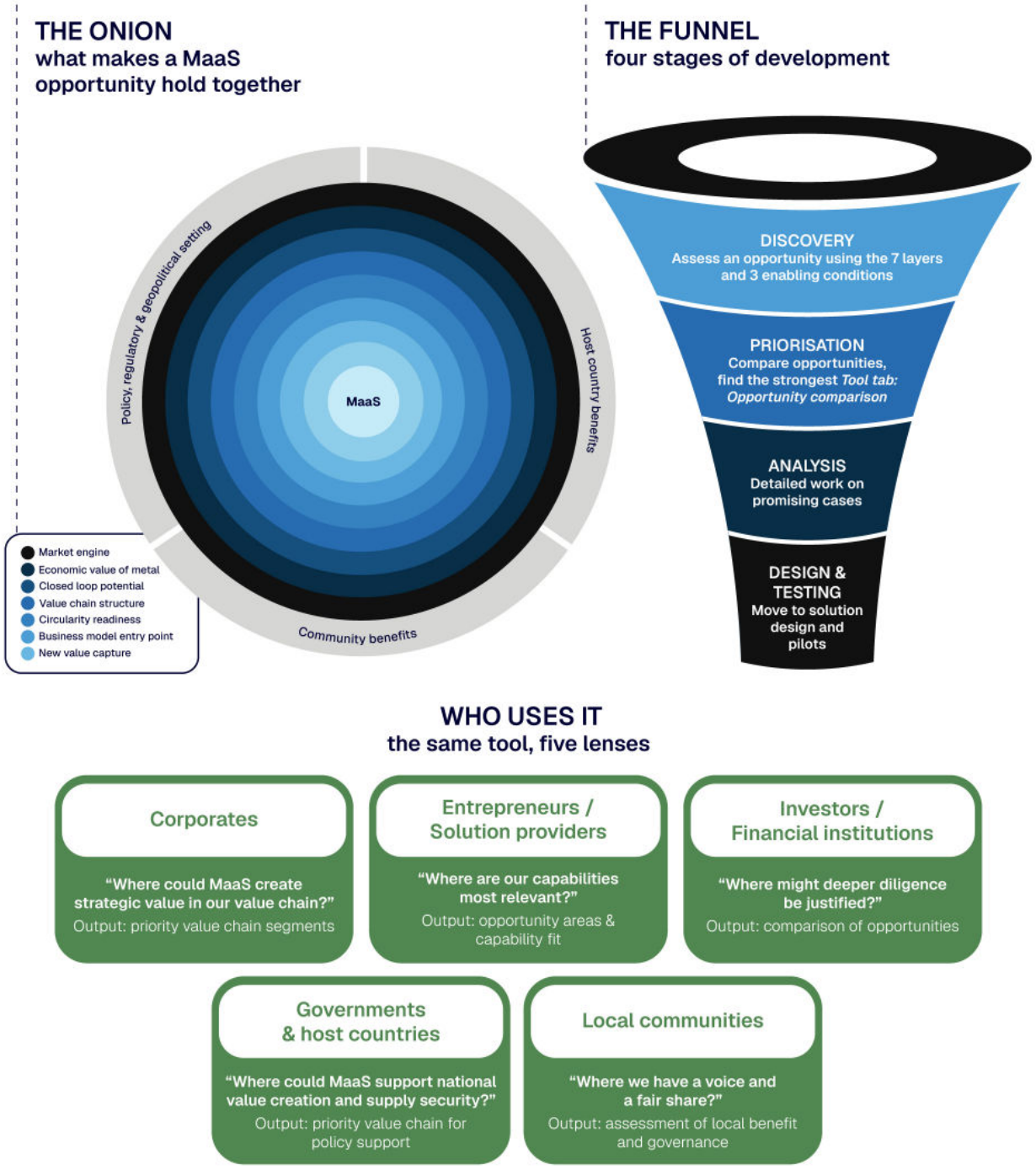


Figure 2: The MaaS Market Discovery Framework; what it assesses, how it is applied across four stages, and who it is for.

6.1 Discovery

At this stage, the MDF helps users assess whether a particular metal, asset or value chain segment has characteristics that may be relevant to a MaaS model. This includes considering whether the value chain is sufficiently traceable, whether the asset has recoverable or residual value, whether reuse or recycling pathways exist, and whether ownership could realistically be retained, transferred or structured differently over the asset lifecycle. The aim is not to prove viability at this point, but to establish whether the opportunity has enough MaaS-relevant features to warrant further consideration.

6.2 Prioritisation

Once potential opportunities have been identified, the MDF can help users compare them and understand which appear most promising. Outputs could include a shortlist of high-potential value chains, a readiness heatmap, or a narrative profile setting out the relative attractiveness of an opportunity, the key drivers of value, the principal risks and the most important evidence gaps. This stage is especially useful where users are considering multiple sectors, asset classes or value chain segments and need a structured basis for deciding where to focus time, resources or further investigation.

6.3 Analysis

For opportunities that appear promising, users would then need to undertake more detailed assessment. This could include business model development, stakeholder engagement, legal and contractual analysis, financial modelling, stock-and-flow analysis, policy assessment, or early pilot scoping. Its role is to help identify the questions that need to be answered next and the conditions that would need to be in place for MaaS to progress.

6.4 Design and testing

At this point, the focus shifts from opportunity identification to solution development. More detailed tools, such as a reference architecture, pilot design process or business model development exercise, may be needed to guide how a specific MaaS model could be structured and implemented. The MDF can help inform this stage by clarifying where the strongest opportunities, risks and knowledge gaps sit. However, the design and testing of specific MaaS solutions would require more detailed, context-specific work with relevant value chain actors.

Beyond discovery and prioritisation, promising opportunities would need to be convened around relevant value chain actors, de-risked through further analysis, and tested through pilots or demonstration activities before they could scale. Taken together, these stages position the MDF as a bridge between concept and implementation. It helps stakeholders identify where MaaS may be worth exploring, prioritise the most promising opportunities, and determine what further analysis is needed before moving toward detailed solution design or piloting.

7. How the Market Discovery Framework can be applied

7.1 Guiding questions

Building on Table 1, Table 3 provides the sub-questions that support the assessment of a MaaS opportunity. In total, users answer 25 questions: 19 across the seven core layers and six across the three crosscutting conditions. The full framework, which includes guidance on how to use it, is available as an accompanying Excel tool on request (contact at the end of this document).

Table 3: The MDF's seven core layers and three crosscutting enabling conditions, with the guiding questions used to assess each.

Layer	Core question	What it tests (guiding sub-questions)
1. Market engine	Is there a market engine to drive circularity?	Is there a recognised long-term growth market for the product or infrastructure relying on the metal? Is there clear commercial pressure to secure, recover or reuse it? Both are needed
2. Economic value of the metal	Is there sufficient economic value in the metal?	Does the metal hold durable primary and secondary value? Is it exposed to supply constraints, declining ore quality, price volatility or scarcity? Can it be treated as a long-term productive asset?
3. Closed-loop potential	Can the system be configured as a closed loop?	Can the metal be recovered and returned to productive use at a quality fit for that use? Are those pathways economically feasible? Where are the 'terminal points' at both material and business-model level?
4. Value chain structure	Can the value chain structure be clearly mapped?	Can segments, actors, ownership and procurement models be mapped? Is the chain concentrated or fragmented and is lifecycle visibility possible? Which ecosystem actors would need to be brought together?
5. Circularity readiness	How far has circularity already been adopted?	Is circular activity already happening in this or similar value chains? Are enabling technologies mature? Are recovery capabilities in place at the scale and location needed?
6. Business model entry point	Is there a business model entry point?	Is there an existing leasing, rental or pay-per-use model? How familiar is the market with access- or performance-based and long-term contracts?
7. New value capture	Can MaaS capture new value?	Can MaaS capture value the linear model does not? Does it add value beyond take-back, EPR or recycling contracts? Is end-of-life metal undervalued, and is there a credible value-capture hypothesis?
Crosscutting enabling condition: Policy, regulatory & geopolitical	Can the legal and geopolitical environment support MaaS?	Are policy levers (EPR, circular-economy rules, SPV treatment, cross-border movement) mature? Is the opportunity well positioned on supply security? Can retained title be enforced?
Crosscutting enabling condition: Community benefit	Do communities have a meaningful stake?	Who captures the value? What forms of community benefit could the value chain support?
Crosscutting enabling condition: Host-country benefit	Has host-country benefit been designed in from the outset?	Can governance rights, revenue retention and safeguards be built in? Is a perpetual-claim / 'urban mine' arrangement feasible?

7.2 Scoring

Each question is scored from 1 to 5, using whole numbers only, according to how favourable the condition is (Table 4). To help different users score consistently, Table 5 gives anchored descriptions of what a 1, 3 and 5 look like for each layer; scores of 2 and 4 sit between these anchors. Each score is accompanied by a High, Medium or Low confidence rating reflecting the strength of the supporting evidence, so that weak evidence is visible rather than hidden within a score.

Scores also reflect the perspective of the person scoring. As Section 5 explains, a corporate and a host government may legitimately score the same opportunity differently. Users therefore record their scoring perspective at the start of each assessment, and opportunities should be compared within the same perspective.

Table 4: The 1–5 scoring scale applied to each question in the MDF. Low-confidence areas flag evidence gaps for deeper work.

Score	Meaning
1	Absent / very weak — condition does not hold; likely a blocker
2	Limited — early or partial; major gaps
3	Moderate — some conditions present; mixed evidence
4	Strong — conditions largely in place
5	Very strong — well established and clearly favourable

Table 5: The MDF scoring rubric for each of the seven core layers and the three cross cutting enabling conditions. Scores of 2 and 4 sit between the anchors of 1, 3, and 5

Layer / condition	Guiding questions	1 — Absent	3 — Moderate	5 — Very strong
Layer 1 — Market engine	Is there a recognised long-term growth market for the product / infrastructure / service that relies on this metal? Is there clear commercial pressure to secure, recover or reuse the metal?	Market flat or declining; no pressure to retain the metal	Steady market, or growth without clear pressure on the metal	Strong forecast growth AND clear supply, cost or sustainability pressure
Layer 2 — Economic value of the metal	Does the metal have enough current and future economic value? Is the metal exposed to supply constraints, price volatility or scarcity? Can the metal be treated as a long-term productive asset?	Low or uncertain secondary value; weak scrap markets	Moderate value; secondary prices volatile or below primary	Durable value; secondary trades close to primary
Layer 3 — Closed-loop potential	At the end of a use cycle, can the metal realistically be recovered and returned to productive use at a quality fit for that use? Is recovery and return to productive use economically feasible? Where are the 'terminal points' — at material level and at business-model level?	Metal dispersed or unrecoverable; terminal point reached early	Recoverable with quality loss or marginal economics	Recoverable at usable quality and economically viable
Layer 4 — Value chain structure	Can key segments, actors, ownership points and procurement models be mapped? Is the chain concentrated or highly fragmented, and is lifecycle visibility possible? Which ecosystem actors would need to be brought together to deliver MaaS, and where would the commercial opportunity sit for each?	Fragmented; ownership and data flows unknown	Main actors known; gaps in ownership or data visibility	Few, known actors; ownership, contracts and data flows mapped
Layer 5 — Circularity readiness	Is circular activity already happening in this value chain or in similar value chains? Are enabling technologies sufficiently mature? Are recovery capabilities in place at the scale and location needed?	No recovery activity; enabling technologies immature	Some take-back or recycling; technologies partly mature	Established recovery pathways and mature enabling technologies
Layer 6 — Business model entry point	Is there an existing service / leasing / rental / pay-per-use or performance-based model in the value chain? How familiar is the market with access- or performance-based payment and long-term contracts?	Only one-off sales	Some leasing, service or long-term contracts	Established access- or performance-based payment
Layer 7 — New value capture	Can MaaS create or capture value the current linear model does not? Does MaaS add value beyond simpler circular alternatives? Is end-of-life metal currently undervalued, and is there a credible value-capture hypothesis to test?	No value beyond linear or simpler circular models	Plausible but unquantified added value	Clear value that take-back, EPR or recycling cannot capture
Crosscutting — Policy, regulatory & geopolitical	Are relevant policy levers mature or plausibly developing, and can retained title be legally enforced? Is the opportunity well positioned in the geopolitical / supply-security context?	Legal barriers prevent retained ownership or recovery	Mixed: some enabling policy, some barriers	Supportive policy; retained title enforceable
Crosscutting — Community benefit	Who captures the value, and do communities have a meaningful stake? What forms of community benefit could the value chain support?	No identifiable local benefit or voice	Some local benefit possible; no governance role	Local benefit and participation in governance designed in
Crosscutting — Host-country benefit	Can host-country benefit be structured into the model? Is an 'urban mine' / perpetual-claim style arrangement feasible?	No national value retention	Some value retention, e.g. processing or revenue	Value retention and governance rights designed in

7.3. From scores to a readiness profile (three rules)

Each layer's score is the average of its question scores, and averages are converted to labels using the same scale as Table 4: 1.0–1.4 Absent, 1.5–2.4 Limited, 2.5–3.4 Moderate, 3.5–4.4 Strong and 4.5–5.0 Very strong. The MDF deliberately does not combine these into a single overall score, because a simple average can hide a condition that would stop MaaS altogether. Instead, three rules apply:

1. Gating: Layers 1, 2, 3 and 6, and the policy, regulatory and geopolitical setting, are treated as gates. If any question in a gated layer scores 1, the opportunity is marked Blocked, whatever its average, and the blocking layer is named. Without a market engine, recoverable value, a closed loop, a commercial entry point or a legal basis for retained ownership, MaaS cannot progress.
2. Separate reporting: core readiness (the average of the seven-layer scores) and enabling conditions (the average of the three crosscutting conditions) are reported side by side, never blended.
3. Design flags: a score of 1 on community or host-country benefit does not block an opportunity. Instead, it is flagged as a design requirement that must be resolved before the Design/Test stage.

The readiness profile also counts the answers rated Low confidence for each layer, showing where further evidence is needed before conclusions are drawn. The resulting status reads, for example, "Strong core readiness / Moderate enabling conditions", or "Blocked (Layer 3)".

7.4 Illustrative example

Table 6 applies the framework to the two contrasting cases used in Section 3: steel in wind turbines and metals in smartphones, The former is scored from a corporate perspective and latter from an entrepreneur/solution provider perspective. Table 6 is the final output of the MDF, and the scores are illustrative and show how the method works; they are not a formal assessment of either value chain.

Table 6: An illustrative readiness profile comparing wind turbine steel and smartphone metals. Blocked layers and low-confidence scores show where design, investment, partnership or policy work, or further evidence, is needed.

Framework layer	Opportunity 1	Opportunity 2
Opportunity name	*Wind turbine steel (illustrative)*	*Smartphone metals (illustrative)*
1. Market engine	5.0	3.0
2. Economic value	3.0	2.0
3. Closed-loop potential	4.0	1.0
4. Value chain structure	4.0	2.0
5. Circularity readiness	3.0	2.0
6. Business model entry point	3.0	3.0
7. New value capture	3.0	1.0
Policy, regulatory & geopolitical	3.0	2.0
Community benefit	3.0	2.0
Host-country benefit	3.0	2.0
Scoring perspective	**Corporates**	**Entrepreneurs / solution providers**
Core readiness (L1–7)	**3.6**	**2.0**
Core rating	**Strong**	**Limited**
Enabling conditions	**3.0**	**2.0**
Enabling rating	**Moderate**	**Limited**
Blocking layer(s)	**None**	**Layer 3**
Design flags	**None**	**None**
OVERALL STATUS	**Strong core readiness / Moderate enabling conditions**	**BLOCKED (Layer 3)**

The comparison shows why gating matters. Smartphones score Moderate on market engine and business model entry point, which device leasing and contracts provide. However, the metal cannot realistically be recovered in a closed loop, so the opportunity is blocked at Layer 3. Here, simpler options such as take-back schemes or improved recycling are likely to be more appropriate than MaaS. Wind turbine steel shows strong core readiness.

7.5 The accompanying Excel tool

The Excel tool mirrors the four-stage process described in Section 6. In the Discover stage, users complete an Assessment tab for each opportunity (up to five), recording evidence, scores, confidence and scoring perspective. A Readiness Profile is generated automatically, highlighting blockers and design requirements. In the Prioritise stage, the Opportunity Comparison tab sets opportunities side by side. A Scoring Rules tab documents the gates, flags and rating bands, which users can adjust where their context justifies it, and a Scoring Rubric tab provides the anchored descriptions in Table 5.

8. Conclusion

The MDF is a MaaS opportunity identification tool. It offers stakeholders a structured, repeatable way to move from broad interest in MaaS to a practical, early-stage view of where the concept may be worth exploring. Rather than delivering a single verdict on viability, it surfaces whether the conditions for MaaS appear sufficiently promising to justify deeper analysis. It does this by asking the user to assess whether there is a strong market engine, durable metal value, closed-loop potential, a mappable value chain, circularity readiness, a business model entry point and scope for new value capture.

Its main objective is to make the assumptions, drivers, risks and evidence gaps behind a potential opportunity visible and comparable. By scoring each layer and highlighting where confidence is low, the MDF helps users distinguish opportunities that are genuinely worth pursuing from those that would first require design, investment, partnership or policy work. In doing so, it acts as a bridge between the MaaS concept and the more detailed technical, commercial, financial, legal and stakeholder analysis that credible implementation demands.

Importantly, the MDF treats commercial viability and equitable outcomes as inseparable. Since the structures proposed to make MaaS work, such as an SPV holding metal in a managed metal bank, could, if left unexamined, concentrate ownership, data and financial value in a few actors, the framework prompts users to test community and host-country benefit from the outset. Where such benefit cannot yet be evidenced, the scoring treats this not as a barrier but as a flagged design requirement, to be resolved through further governance, actor-mapping and policy work before an opportunity moves to design and testing.

Used this way across its different user groups, each scoring from their own perspective, the MDF supports better early-stage decision-making: helping stakeholders identify whether MaaS may be worth exploring, where the strongest opportunities appear to sit, and what questions must be answered next. It is the starting point of the MaaS journey and is most powerful when paired with the wider body of MaaS research, tools and stakeholder engagement of which it forms part.

Endnotes

1 Perrine Toledano, Laura Garcia Cancino, Aniruddha Pravin Jaydeokar, Shunta Ofusa, Paul Huggins, Charlotte Bucke, and Matthew Willis, *Metals-as-a-Service: A Strategic and Investable Circular Business Model for the Wind Energy Industry and Beyond* (New York: Columbia Center on Sustainable Investment (CCSI) and Carbon Trust, May 2026), https://ccsi.columbia.edu/metals-service-maas.

2 Aniruddha Pravin Jaydeokar, Perrine Toledano, Shunta Ofusa, and Laura Garcia Cancino, *Metals-as-a-Service. Economic Analysis: Comparing the MaaS and Linear Business Models in the Context of a Wind Project. A Companion Report* (New York: CCSI, May 2026), https://ccsi.columbia.edu/metals-service-maas.

3 Aniruddha Pravin Jaydeokar, Perrine Toledano, Laura Garcia Cancino, and Shunta Ofusa, *The Feedback Loop between MaaS, Stock-and-Flow Models, and Performance Pricing* (New York: CCSI, September 2026), https://ccsi.columbia.edu/metals-service-maas.

4 International Energy Agency (IEA), *Renewables 2025: Analysis and Forecasts to 2030* (Paris: IEA, October 2025), https://www.iea.org/reports/renewables-2025.

5 IEA, "Copper," in *Global Critical Minerals Outlook 2024* (Paris: IEA, May 2024), 101–113, https://www.iea.org/reports/copper.

6 "Critical Minerals Data Explorer," IEA, July 27, 2026, https://www.iea.org/data-and-statistics/data-tools/critical-minerals-data-explorer.

7 IEA, "Beyond NMC batteries: Supply chain issues for emerging battery technologies," in *Global Critical Minerals Outlook 2024* (Paris: IEA, May 2024), 207–227, https://www.iea.org/reports/copper.

8 "Infographic: Battery Material Production Expansion Since 2020 Driven by Shifting Chemistry," *BenchmarkSource*, April 30, 2026, https://source.benchmarkminerals.com/article/infographic-battery-material-production-expansion-since-2020-driven-by-shifting-chemistry.

9 "TotalCare® Power by the Hour," Rolls-Royce plc, https://www.rolls-royce.com/media/our-stories/discover/2017/totalcare.aspx.

10 NIO, "NIO Launches Battery as a Service," press release, August 20, 2020, https://www.nio.com/news/nio-launches-battery-service.

11 European Union (EU), European Parliament and Council, Regulation (EU) 2024/1252 of the European Parliament and of the Council of 11 April 2024 establishing a framework for ensuring a secure and sustainable supply of critical raw materials and amending Regulations (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1724 and (EU) 2019/1020, April 11, 2024, Regulation (EU) 2024/1252, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:L_202401252.

12 EU, European Parliament and Council, Regulation (EU) 2023/1542 of the European Parliament and of the Council of 12 July 2023 concerning batteries and waste batteries, amending Directive 2008/98/EC and Regulation (EU) 2019/1020 and repealing Directive 2006/66/EC, July 12, 2023 (EU Battery Regulation), https://eur-lex.europa.eu/eli/reg/2023/1542/oj/eng.

13 EU, European Parliament and Council, Regulation (EU) 2024/1781 of the European Parliament and of the Council of 13 June 2024 establishing a framework for the setting of ecodesign requirements for sustainable products, amending Directive (EU) 2020/1828 and Regulation (EU) 2023/1542 and repealing Directive 2009/125/EC, June 13, 2024 (Ecodesign for Sustainable Products Regulation (ESPR)), https://eur-lex.europa.eu/eli/reg/2024/1781/oj/eng.

14 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, May 5, 1992, revised in 2025, (Basel Convention), https://www.basel.int/TheConvention/Overview/TextoftheConvention/tabid/1275/Default.aspx.

15 A Special Purpose Vehicle (SPV) is a dedicated legal entity that owns, finances, and manages the metal so that its value, risks, and obligations sit separately from the metal users. The metal bank is the pooled, managed stock of metal that users draw on and return material to over successive use cycles. Both are explained in detail in the earlier CCSI–Carbon Trust reports on MaaS and are referenced here only at a high level. For more detail: https://ccsi.columbia.edu/metals-service-maas/.

16 Deanna Kemp and John R. Owen, "Global Mining and the Production of Inequality: A Case for Continued Inquiry," *World Development Perspectives* 39, no. 100708 (September 2025), https://doi.org/10.1016/j.wdp.2025.100708.

17 "Materials as a Service in the Minerals and Metals Sector: Event Takeaways," *World Resources Forum*, August 8, 2023, https://wrf2025.org/materials-as-a-service-in-the-minerals-and-metals-sector-event-takeaways.

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