

Making Critical Mineral Recovery Bankable And Insurable

New York Climate Week

September 23, 2026



CLIMATE
WEEK **NYC**

ABOUT CCSI

Applied research center of Columbia Climate School
(since 2006)

Mission: To advance policies and practices that scale and shape investment contributing to sustainable development outcomes.



ABOUT CARBON TRUST

Mission Impact consultancy (since 2001)

Mission: To accelerate the move to a decarbonised future. Helping organisations worldwide reduce carbon emissions and achieve greater resource efficiency.



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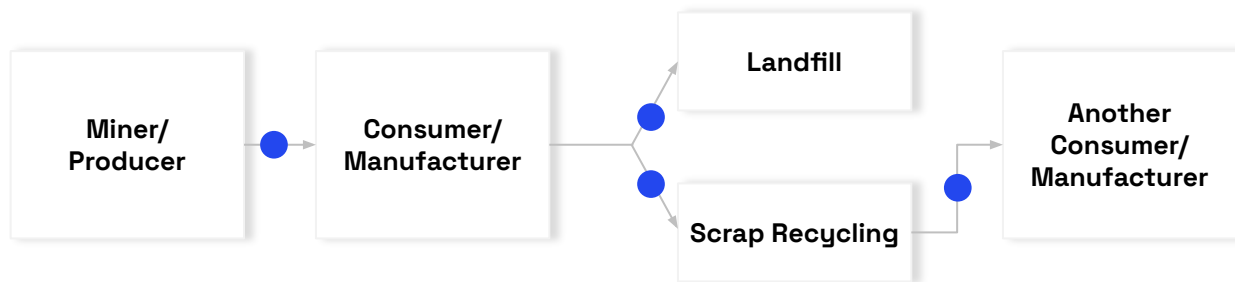
Part 1 - Introduction

What is Metals-as-a-Service?

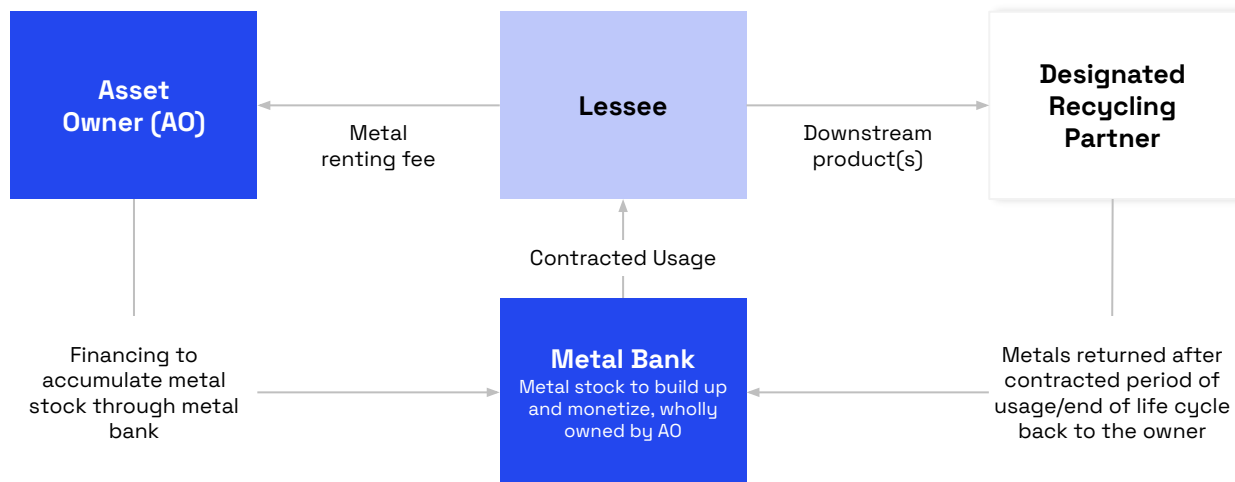
What is Metals-as-a-Service?

A model where metal ownership does not change. Only the right to use metal is transferred along with a contractual duty to ensure recoverability. Metal is leased and returned back in its original form at the end of a contract.

Traditional Model ● Indicates change in ownership



MaaS Model ● Owner ● Lessor ○ Contractor



Metals-as-a-Service: Turning Circularity into Capital

The Goal



Make MaaS operationally sound and commercially investable

The Motivation



Primary extraction is limited, circular models based solely on recycling don't close the loop → The Result: we don't meet the metal needs of the energy transition

The Loop Will Close Because



- The asset owner has an **incentive to recover** the metal → value chain around design and logistic for recoverability
- Financing is structured to **compete with the linear model**

The Immediate Benefits to Metal Users



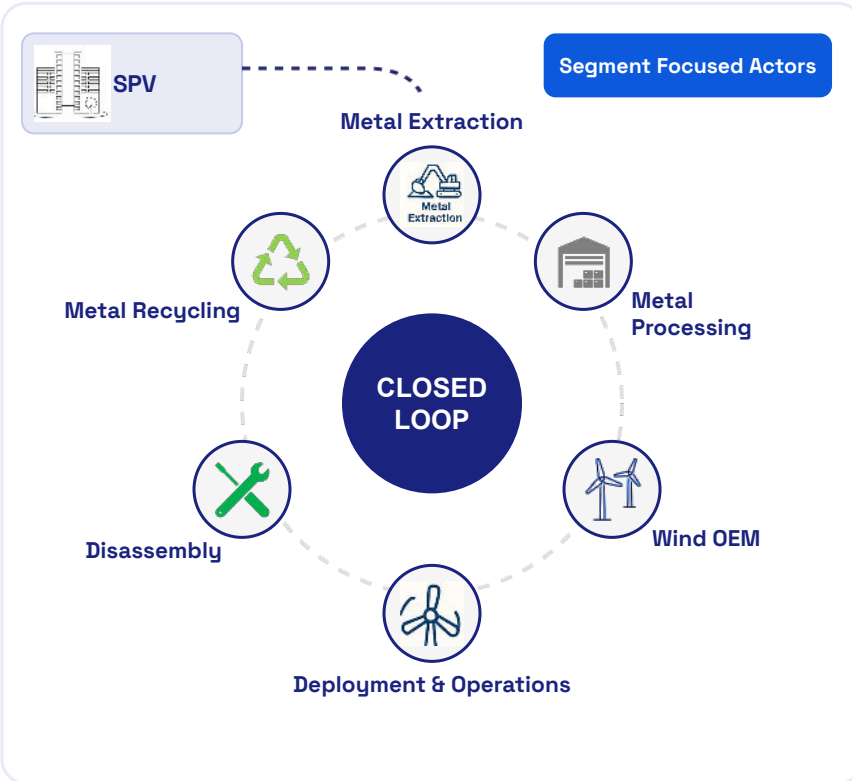
- Reduced upfront CAPEX and predictable OPEX
- Supply security
- Access to higher ore grade in the urban stock
- Lifecycle circularity

Part 2 - The SPV Story

The Backbone to Make Metals-as-a-Service Work

MaaS needs a backbone that is operationally and financially efficient

A “value chain business model” focused on retaining metal value along its length



Circular Value Chain Enablers

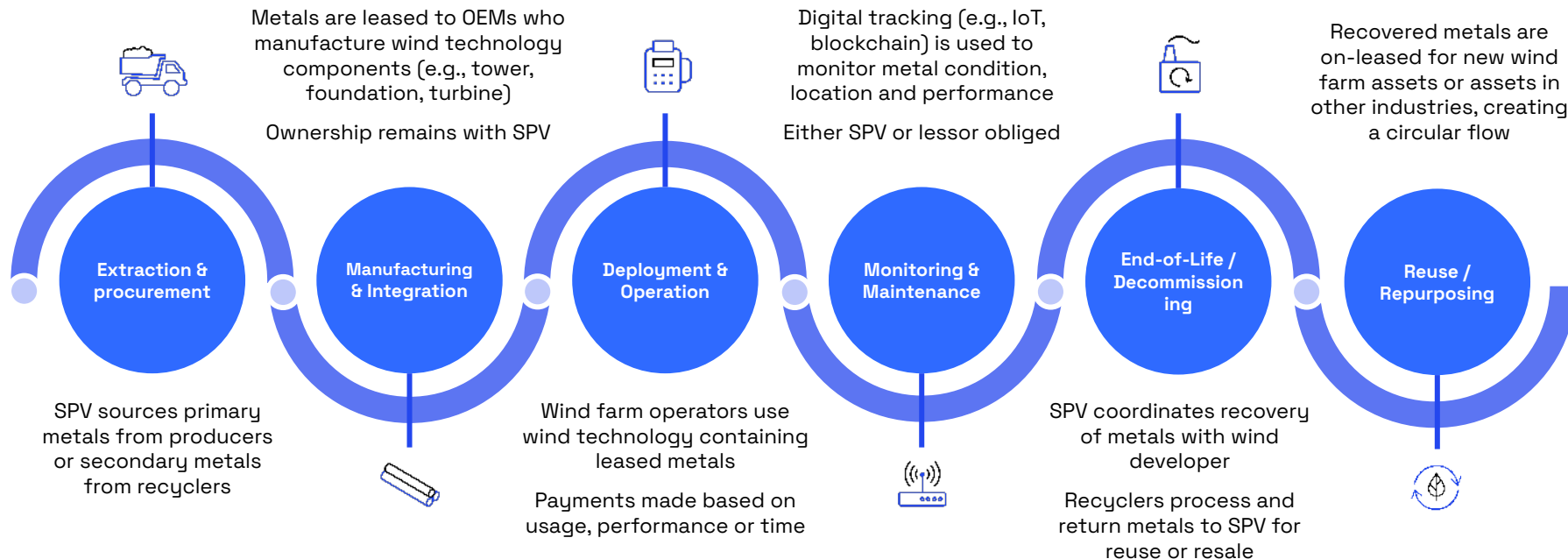
- **Business Leadership:** Drives circularity systematically within wind value chains.
- **De-risking Mechanisms:** Technologies, tools, and standardized contracts de-risk closed-loop metal use.
- **Metal Bank:** Secures reliable, long-term access to essential transition materials.
- **Financial Benefits:** Promotes revenue generation and balance sheet strengthening.

To This End: Core Operational Structure

- **Single SPV Entity:** Operationalizes the metal renting model and structures critical financial liquidity.
- **Entity-Owned Metals:** Retained by the provider, rented transparently to lessees, and systematically recovered for reuse.

A special purpose vehicle (SPV) is the backbone to execute this business model

Focus builds knowhow and operational efficiency



Part 3 - The Economics

**How do the Economics
of Metals-as-a-Service
work?**

How do the Economics of Metals-as-a-Service work?

To make MaaS economically viable, two key conditions must be met

1. Lower Levelized Cost (LCoM)

The levelized cost of MaaS (LCoM) must be lower than the levelized cost of buying and using the metal outright.

2. Zero Variable Yield

The variable yield must be lowered to 0% over time through structured metal accumulation cycles.

What is LCoM?

LCoM is a metric similar to **LCoE** used in the Energy Industry.

It calculates and compares the present values of the costs of pursuing MaaS against the revenues generated by MaaS.

Project Feasibility

Achieving a lower LCoM than the levelized cost of buying the metal outright creates a clear economic case to pursue MaaS on a particular project.

Path to Full Adoption

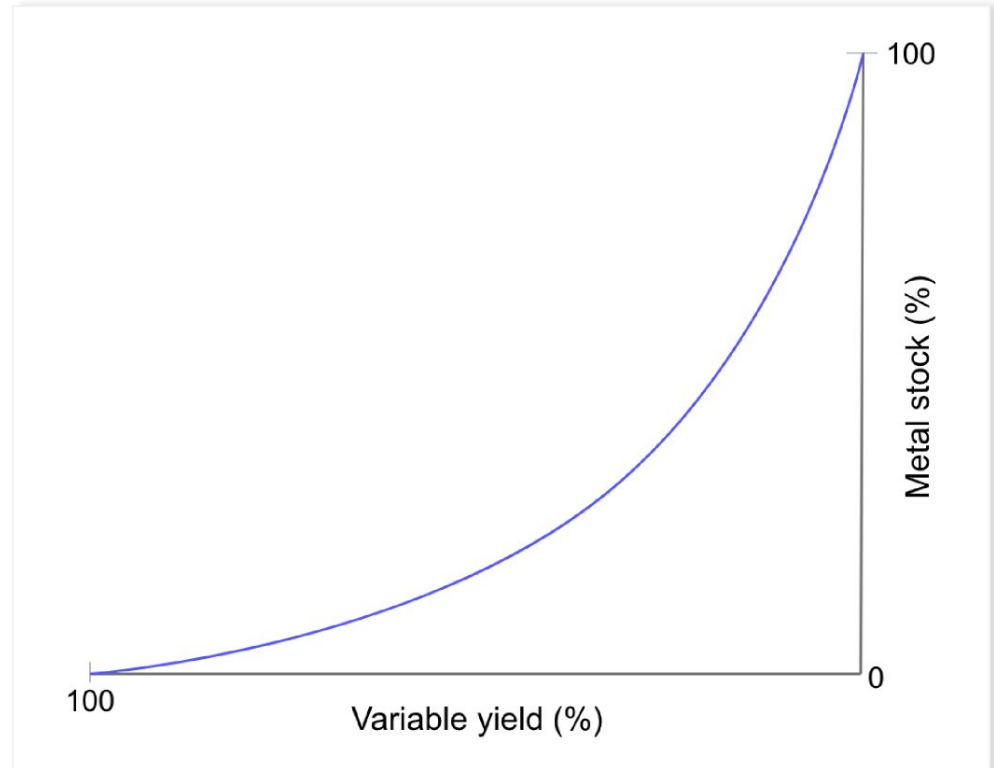
Multiple cycles of MaaS over time incentivize metal accumulation, directly lowering the variable yield, which is a key metric tracking progress toward complete adoption.

The Financial Incentive to Build a Metals Bank - Decreasing the Variable Yield

A stockpile of metal is needed to build the metals bank.

But the Asset Owner might not have the incentive to keep stockpiling metal. They may sell if the price of the metal increases.

A decrease in the variable yield will lead to a marginal incentive to accumulate metal stock for leasing but each asset owner has its “elasticity.”



Optimize the cost of MaaS with the Levelized Cost of MaaS

LCoM - A metric to make MaaS economically viable

The LCoM Equation

$$LCoM = (\sum [(I_{\square} + O_{\square} + M_{\square} + R_{\square}) / (1+r)^t]) / (\sum [S_{\square} / (1+r)^t])$$



Variable Definitions

- $I_{\square}$: Initial metal acquisition cost
- $O_{\square}$: Operations & monitoring
- $M_{\square}$: Maintenance & refurbishment
- $R_{\square}$: Recovery & logistics
- $S_{\square}$: Service utility delivered
- r : Discount rate / cost of capital



Optimization Levers via Stock & Flow

1. Minimize Idle Stock

Stock and Flow models enable just-in-time logistics, reducing excess buffer inventory and acquisition costs ($I_{\square}$).

2. Asset Velocity

Predictive retrieval increases the velocity ($S_{\square}$) of redeployment, diluting initial capital costs.

3. Managed Degradation

Sequencing high-grade to low-grade applications reduces Smelting/Refining costs ($M_{\square}$).

4. De-risking Capital

Predictable recovery schedules reduce investor risk, lowering the discount rate (r).

Pricing the Risk Transfer from CAPEX to OPEX

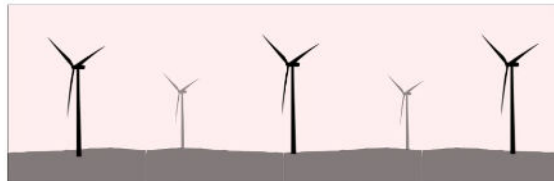
How would MaaS enabled wind look different under a CAPEX to OPEX transformation?



Risk Transfer CAPEX → OPEX

How would MaaS enabled wind look different under a CAPEX to OPEX transformation?

Non-MaaS-enabled Onshore Wind



Weighted Average Cost of Capital: **6%**

Average DSCR (31% capacity factor): **3.18**

Equity IRR: **15%**

MaaS-enabled Onshore Wind



Weighted Average Cost of Capital: **5.8%**

Average DSCR (31% capacity factor): **3.47**

Equity IRR: **17.12%**

*Lower equity hurdle rate was assumed for MaaS enabled onshore wind attributing to higher risk-adjusted return.

**SPV is responsible for HSLA steel recovery and the costs associated with reverse logistics.

Assumptions used:

Project type: **Onshore Wind**

Size of Project (MW): **400**

Electricity rate per kWh:
\$0.144 (arranged under a PPA)

P-50 Capacity Factor: **31%**

Debt-Equity Split: **70/30**

Renting fee: **7.6%**

Risk-free-rate: **4.16%**

Credit Spread: **3.5%**

Metal: **High Strength Low Alloy (HSLA) Steel**

HSLA Steel Quantity:
56,000 tons

HSLA Steel Spot price: **\$1,300**

MaaS Debt (HSLA + transportation costs):
\$187 Million

Recovery cost to OEM: **\$0****

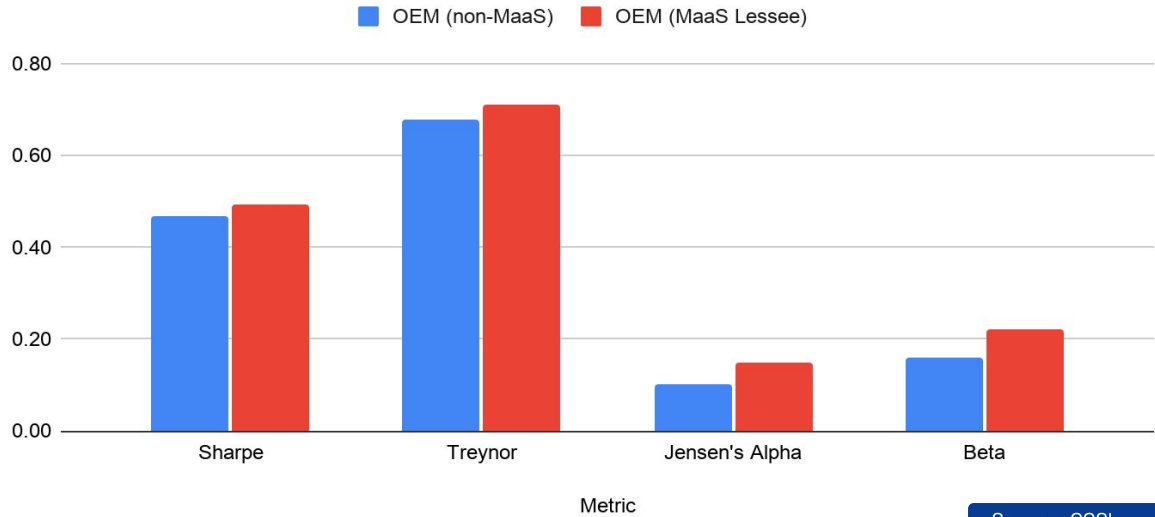
MaaS produces higher risk-adjusted returns



In our analysis comparing identical wind onshore projects, MaaS not only delivers higher returns for the lessee on an absolute basis, but also on a risk adjusted basis.

Risk-Return metrics comparison - Non-MaaS vs MaaS in Onshore Wind

Note: Sharpe is a measure of Total Risk, Treynor is a measure of systematic risk.



Source: CCSI

- **Sharpe:** MaaS generates slightly more excess return for every unit of *total* risk it takes on
- **Treynor:** MaaS earns a higher premium for every unit of *systematic* risk it assumes
- **Outperform the market benchmark more:** higher alpha delivered for MaaS-enabled
- **Beta:** MaaS is more volatile, but worth it, given higher risk adjusted returns

Note: Total risk = systematic risk (whole market) + unsystematic risk (stakeholder-specific)

The SPV-AO concern: Building the Metals Bank

How to incentivize

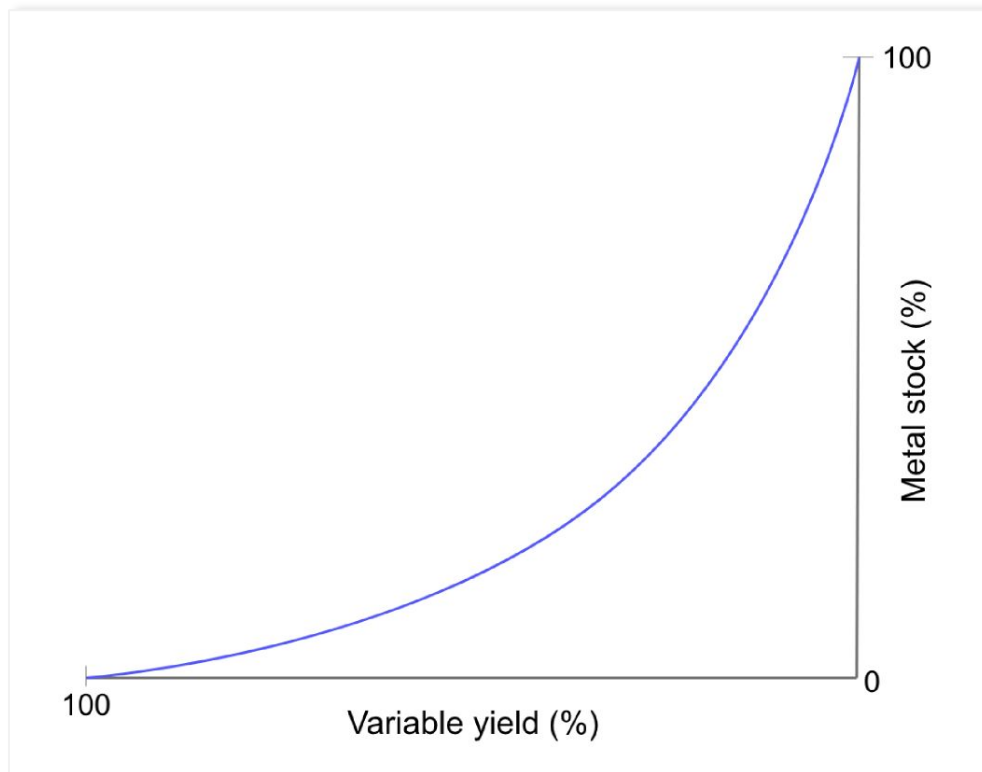
Metals Bank vision: Creates a predictable source of supply, generates recurring yield for the AO, and creates tradable exposure to circular metals.

Accumulation of Stock is necessary to realize this vision

However, the difference in revenues realized from sale of metal and leasing can be significant for the asset owner.

“Variable yield” represents this difference.

A decrease in the variable yield will lead to a marginal incentive to accumulate metal stock for leasing but each asset owner has its “elasticity”



From Rent Fees to Tradable Yields

Reimagining SPV-Asset Owner's Cash Flows under a bankable MaaS

The Problem

Reinvesting income + physical recovery **not enough** to accumulate the stock; model is **not scalable**



Fails to tap into **liquid markets**



Risk burden falls on the **Asset Owner (AO)** → results in **high fees for lessee**

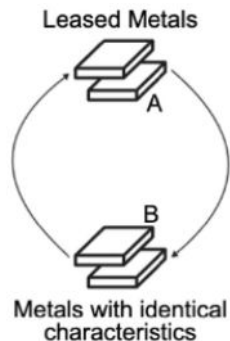


The Solution

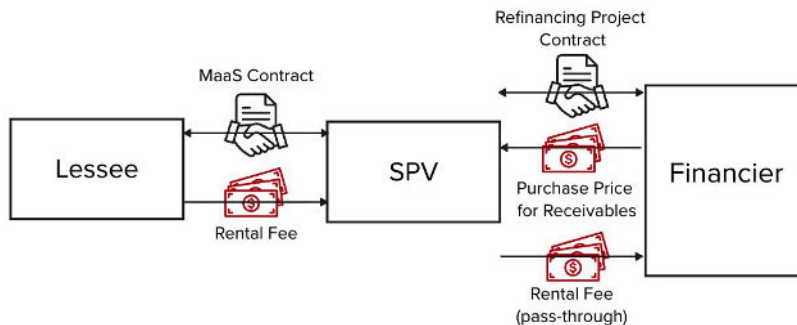
Fungibility

Durable metals of the same quality are interchangeable

- Shorter contracts
- Increased liquidity
- Reduced degradation risk



Monetize MaaS contracts and receivables



MaaS delivers Investors value

Investors & Lenders

Stable, Bond-Like Income

Long-term predictable cash flows with built-in inflation hedges.

Enhanced Tradable Liquidity

Access to standardized, liquid structures (ABS/MLP/CIT).

Optimized Risk-Adjusted Returns

Diversified portfolios backed by real, circular metal assets.

Strong Sustainable Finance Alignment

Direct eligibility for institutional sustainable finance mandates.

Producers & Sponsors

- Stable, recurring revenue
- Price risk mitigation
- Access to secondary streams

Special Purpose Vehicle (SPV)

- Circular economy positioning
- Control of material lifecycle
- New investable asset class

Recyclers

- Guaranteed material flows
- Premium circular supply
- Purity & asset traceability

OEMs & Wind Developers

- Shifted CAPEX to OPEX model
- Improved ROIC & deployment
- Reduced Scope 3 emissions

Policymakers & Regulators

- Secure critical-metal supply
- Accelerated carbon reduction
- Capture untapped local stock
- National industrial resilience



Part 4 - Risk Mitigation

How to Mitigate Risk for Each Stakeholder?

MaaS changes exposure to risks but mitigation strategies exist

For Metal Owners

Risk Category	Key Mitigation Strategy
Metal Price Volatility	Dynamic pricing, hedging, portfolio diversification, pass-through clauses
Interest Rate Risk	Fixed-rate financing, interest rate swaps, match lease/finance terms
Inflation Risk	Inflation adjustments in leases, real asset backing
Credit Risk (Lessee)	Credit screening, security deposits, insurance, lessee diversification
Residual Value Risk	Asset tracking, quality standards, predictive analytics, certified recyclers
Asset Recovery Risk	Blockchain/IoT tracking, strong legal frameworks, pre-negotiated recovery

For Lessees

Risk Category	Key Mitigation Strategy
Metal Price Volatility	Use MaaS to lease metal and avoid price exposure.
Economic Downturn	Build flexible lease terms and maintain working capital reserves.
Operational Cash Flow	Align payment schedules with revenue cycles and maintain credit facilities. Monitor liquidity ratios. Abide by the covenant.
Supply Disruption	Build buffer inventory and establish backup supply arrangements.
Quality and Product Risk	Establish clear quality specifications and implement inspection protocols. Use product liability insurance.
New Process Integration	Conduct technical due diligence and use a phased integration approach. Affects procurement and accounting function too

For Financiers

Risk Category	Key Mitigation Strategy
Metal Price Volatility	Use dynamic loan-to-value ratios and commodity-linked interest rates.
Interest Rate Risk	Use asset-liability matching and build rate sensitivity into loan pricing.
Counterparty Credit Risk	Implement enhanced due diligence and monitor real-time asset performance.
Asset Recovery Risk	Require asset tracking systems and pre-arrange relationships with recyclers.
Regulatory Requirements	Maintain strong capital ratios and use regulatory capital optimization strategies.
Due Diligence Risk	Develop MaaS-specific expertise and use comprehensive due diligence checklists.

MAAS REMAINS A BUSINESS MODEL
TRANSFORMATION JOURNEY

MaaS as a Journey

Financial structures for an Asset Owner evolve over time

Near term

Long term

Limited Liability Companies (LLC)

- Early-stage financing with *equity-only* capital structure; Funded by venture capital and sponsors
- For proof-of-concept MaaS ventures (0–3 Years)

Strength

- Flexible, low setup costs, simplified governance, VC alignment

Weakness

- Illiquidity, limited investor base
- Higher cost of capital (no debt)

Master Limited Partnership (MLP)

- GP runs SPVs; LPs fund for equity; sponsors contribute assets for shares
- MLP can securitize MaaS contracts to raise debt
- Best in growth-stage MaaS needing institutional capital and scalability (Years 3–5)

Strength

- Liquidity
- GP-LP alignment
- Flexible structuring

Weakness

- GP concentration risk
- Reliance on management expertise

Commodity Investment Trust (CIT)

- CIT raises capital by issuing publicly traded shares (ETF-like)
- CIT can securitize MaaS contracts to raise debt
- Best in mature MaaS markets with diversified portfolios (5+ Years)

Strength

- High liquidity, broad investor base
- Sophisticated risk management

Weakness

- Higher setup costs
- Concentration risk

THANK YOU

 COLUMBIA CLIMATE SCHOOL
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For more information on Metals-as-a-Service,
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