

Metals-as-a-service: A Bankable Circular Business Model

December 4, 2025



 COLUMBIA CLIMATE SCHOOL
COLUMBIA CENTER ON SUSTAINABLE INVESTMENT

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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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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



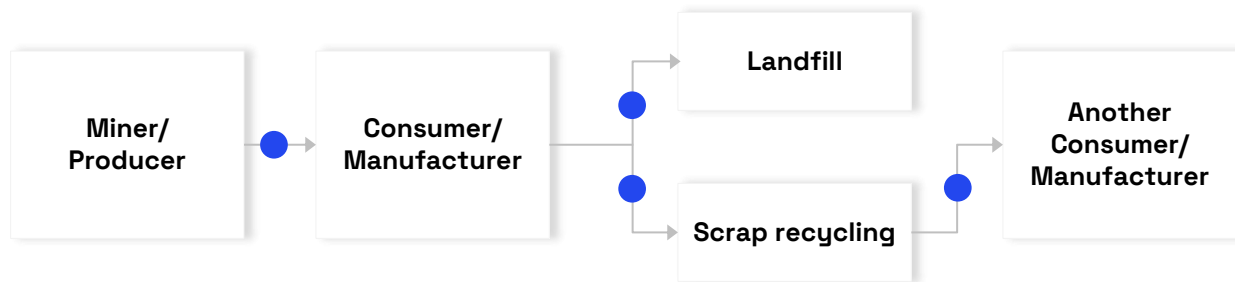
- Reduced upfront CAPEX and predictable OPEX
- Supply security
- Access to higher ore grade in the urban stock
- Lifecycle circularity

Reminder: What is MaaS?

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

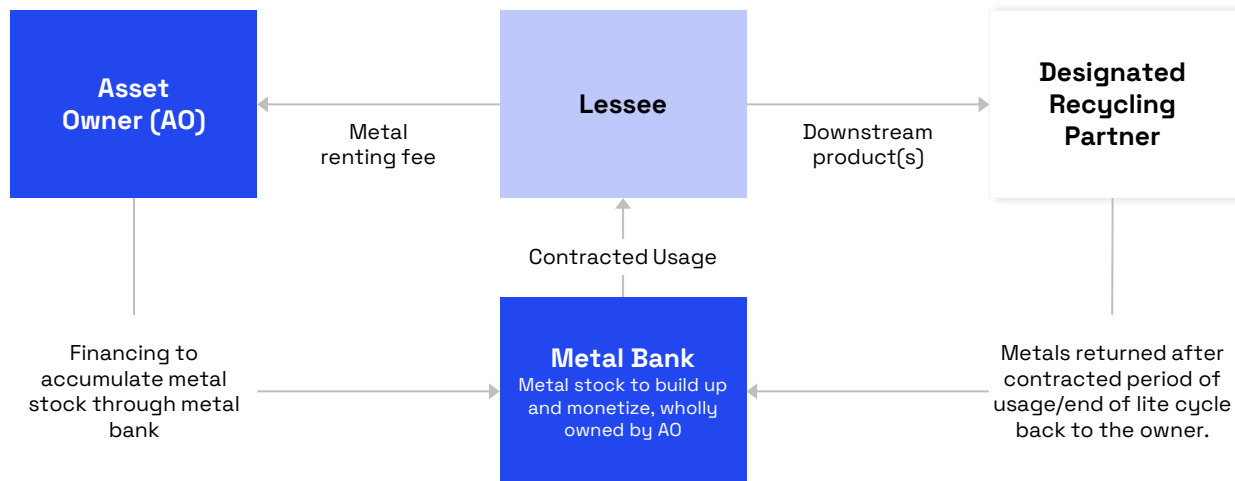
Traditional Model

● Indicates change in ownership



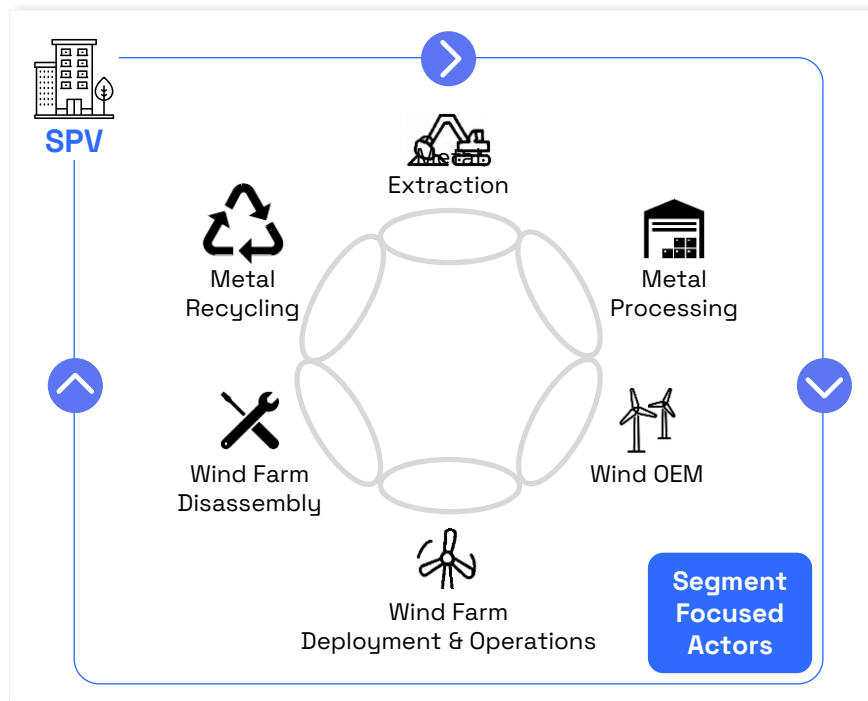
MaaS Model

● Owner ● Lessor ○ Contractor



MaaS needs a backbone that is operationally and financially efficient

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



- Business leadership drives circularity in MaaS value chains (e.g., wind)
- Technologies, processes, tools, and standardized contracts and agreements de-risk closed loop metal use
- Establishing and growing a Metal Bank ensures long-term access to metals
- Revenue generation, balance sheet strengthening, and market development

To this end:



A **single entity, an SPV**, operationalizes metal renting and structures financial liquidity

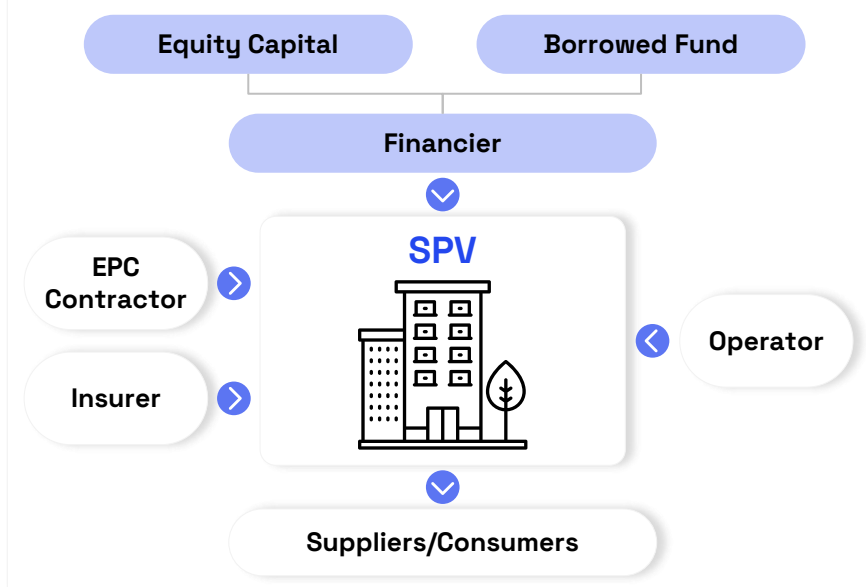


Metals remain **entity-owned**, rented to lessees (developers/OEMs), then recovered and reused

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

Proven way to raise capital while isolating project risk

Project Finance Model in typical wind power project



Proven way to raise capital while isolating project risk

- Common in mining, metals, and energy with large financing & long-lived assets
- Risks are transferred to financiers, not born by operators.
- Uses SPV to ring-fence assets & risks, and finance on a **project basis**, not corporate.



MaaS business model needs to;

- Handle cyclical metal prices through hedging and structured risk allocation
- Address supply shortage risks



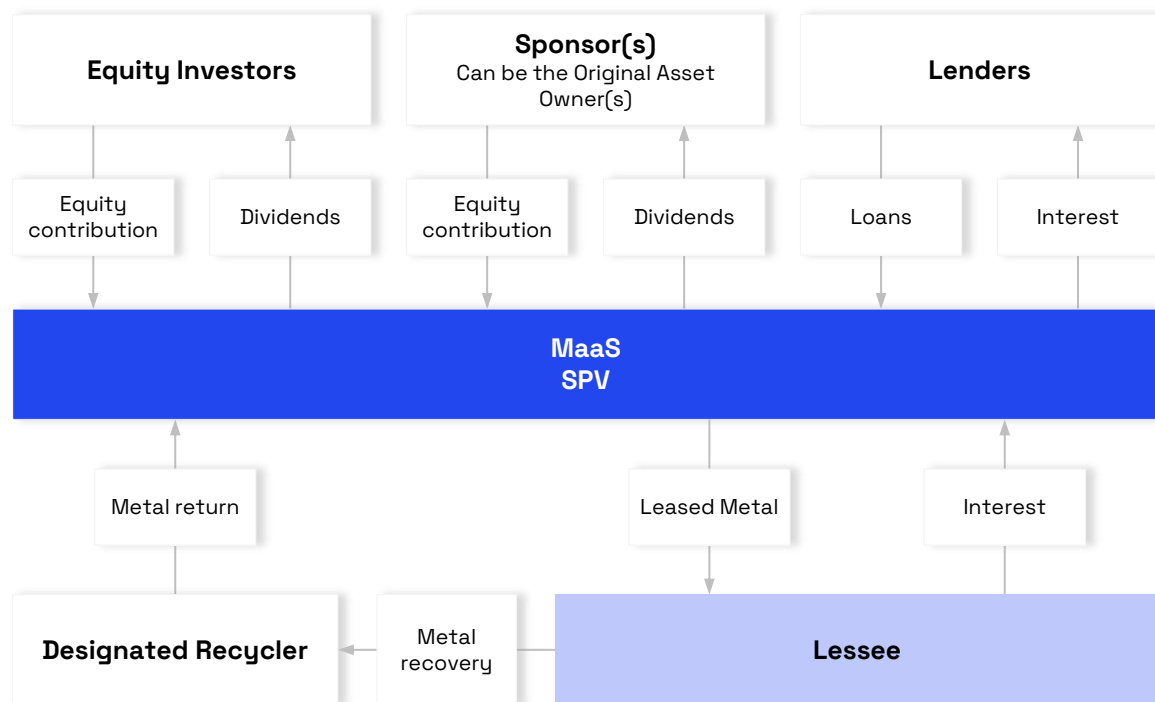
Therefore, SPV-based project finance models can directly support effective MaaS financing, using financial products & metal procurement

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

Sponsored by the AO

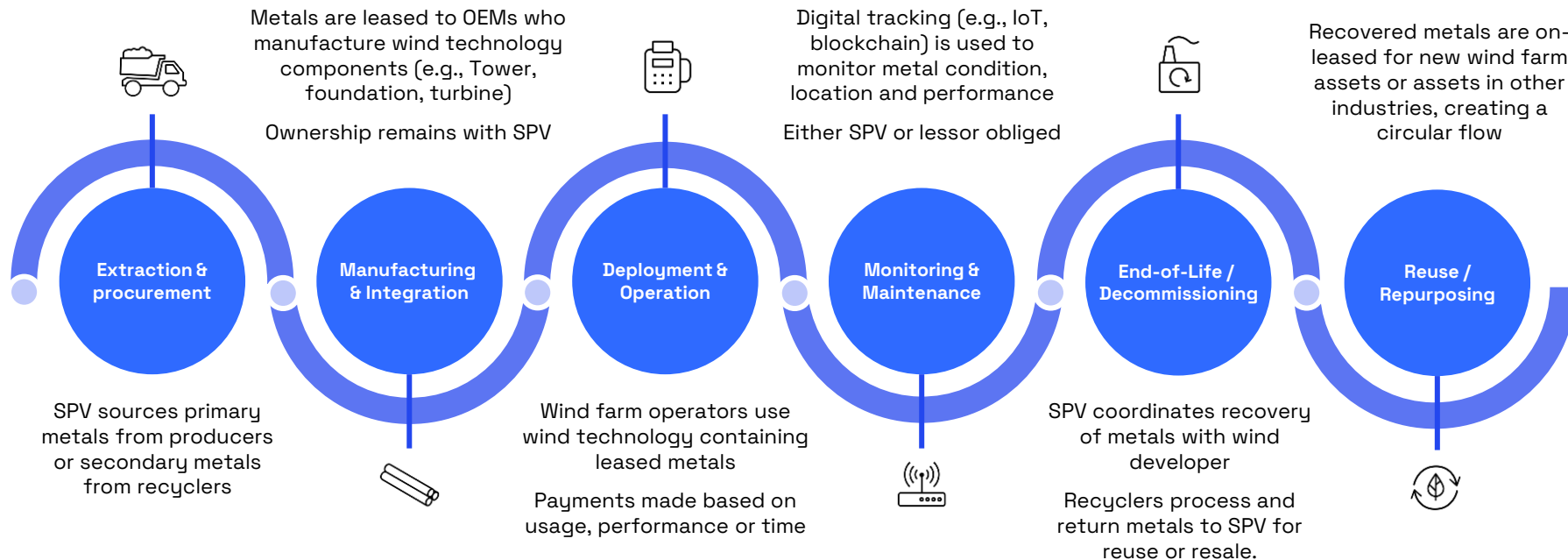
The Sponsor(s) can be the original asset owners who either transfer the ownership of the metal to the SPV or let the SPV procure metal

> It anchors the governance of the metal while alleviating the AO from non-core business functions



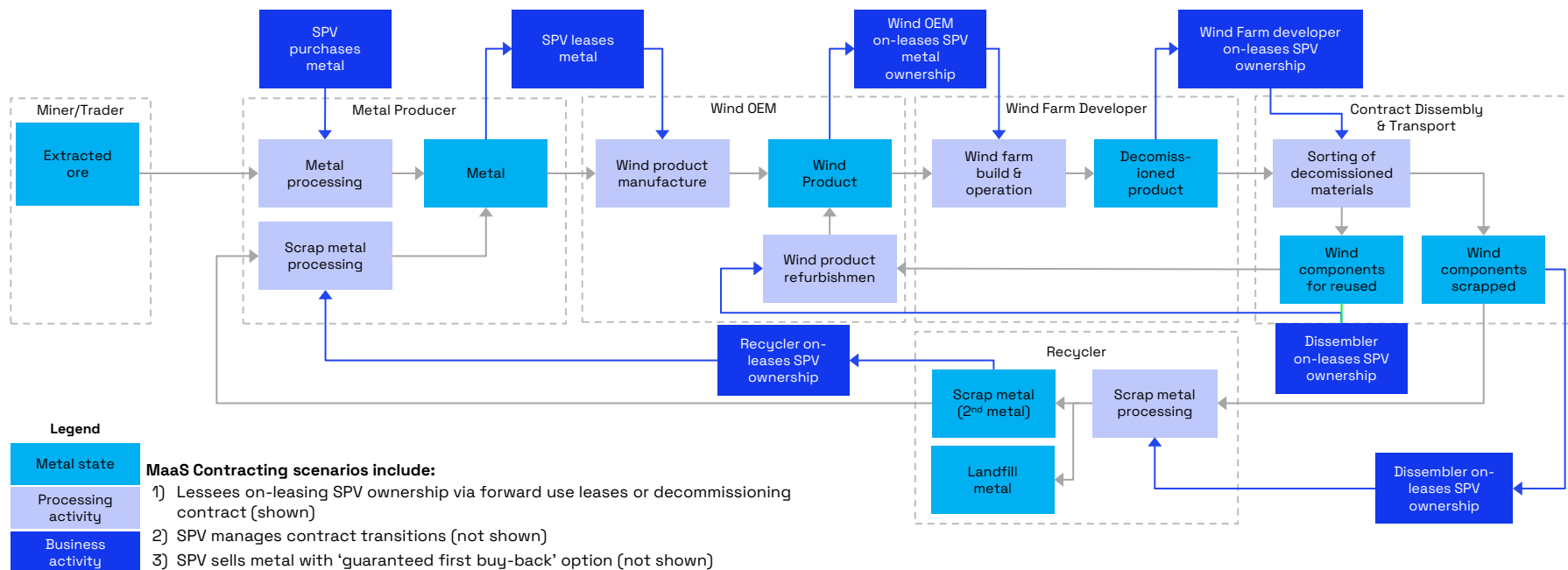
A special purpose vehicle (SPV) is the backbone to execute this business model

Focus builds knowhow and operational efficiency



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

Illustration in the wind industry



Sources: Carbon Trust/CCSI analysis. Modelling approach taken from Engemann, A., Zeeuw van der Laan, A., Aid, G., Nybom, L., Aurisicchio, M. (2021) 'Developing the Material-Service System Concept: A Case Study of Steel Industrial Drums', in Proceedings of the International Conference on Engineering Design (ICED21), Gothenburg, Sweden, 16-20 August 2021. DOI:10.1017/pds.2021.122.

The SPV-AO concern: Building the Metals Bank

How to incentivize

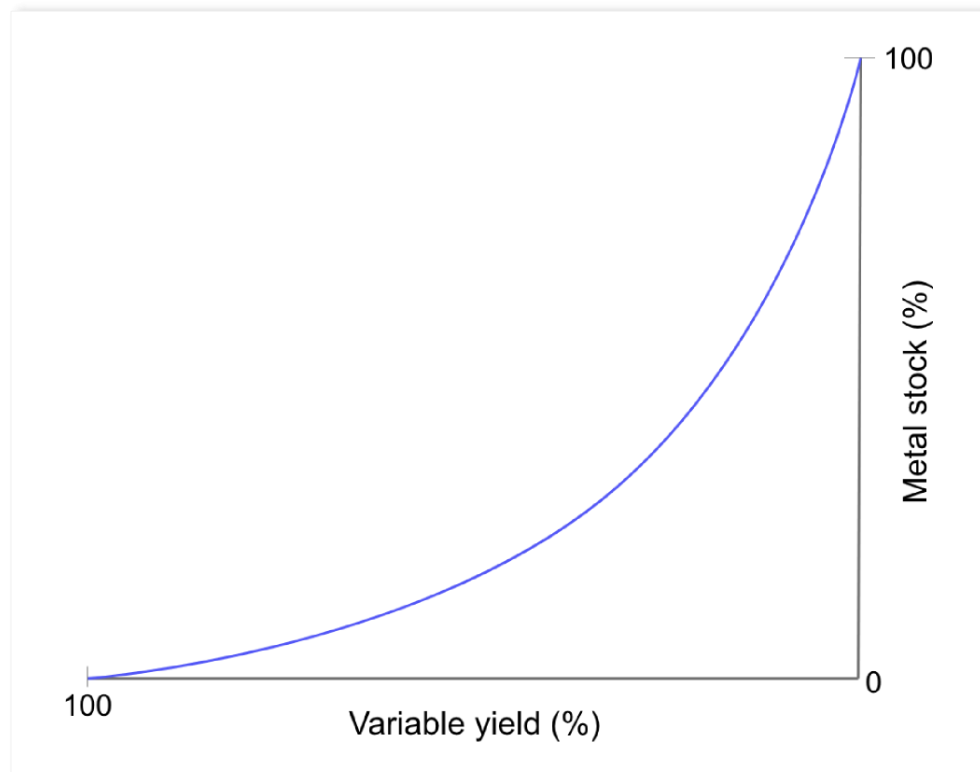
Metals Bank vision: Creates a predictable source of supply, generates recurring yield for the AO, and creates tradable exposure to circular metals.

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”

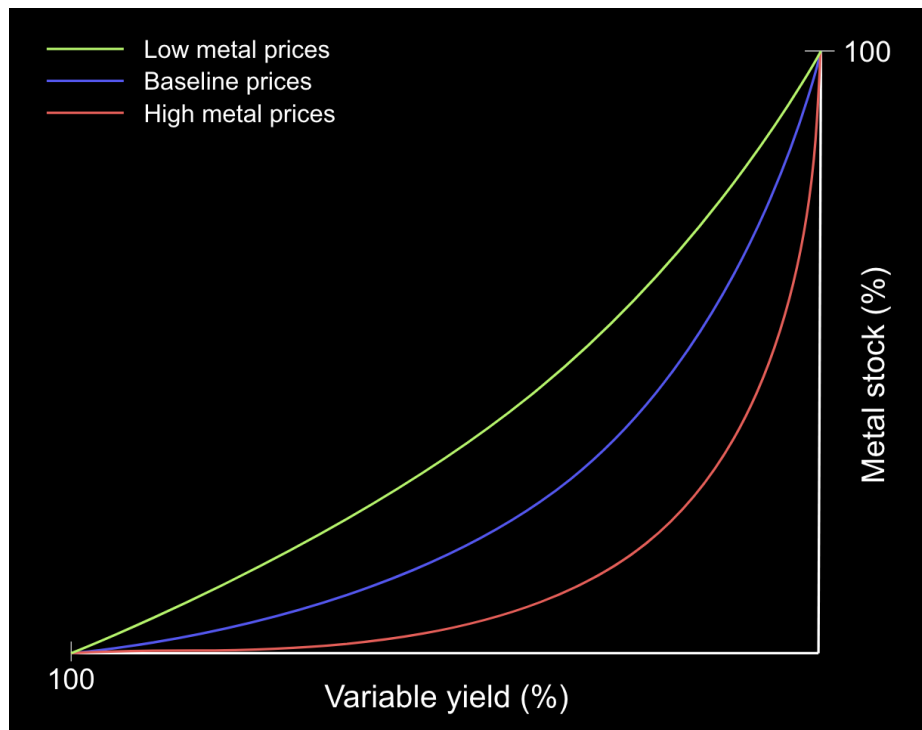


The SPV-AO concern: Building the Metals Bank

...Each asset owner reacts differently to variable yield reduction (ie: with a different “elasticity”), depending on:

1. Type of metal
2. Cost of Capital
3. Lessee’s credit-bearing capacity
4. Debt terms
5. Metal prices
6. Contextual factors (inflation, interest rates, etc..)

Example: When metal prices are low, falling yields of the linear business model encourage stockpiling. At high prices the effect weakens. The choice between the two business models depends - in large part - on whether the lessee values secure supply enough to justify higher leasing fees.



The SPV-AO concern: Building the Metals Bank

Reinvest rent income to build the inventory

Payment types

#	Payment type	Payment type description
1	Availability Service (Predictable)	Fixed periodic payment for guaranteed availability/function
2	Usage-Based (Variable)	Payment per unit of output (MWh, operating hour)
3	Performance-linked (Contingent)	Bonuses/penalties tied to measured performance/KPIs
4	Upfront/Capital	Mobilisation/lease deposits, financing
5	Terminal/Recovery	Revenue share or credits at decommissioning for material recovery or reuse.



For each service and payment pairing, the following information can be provided (examples provided here):

- **Name:** Structural Availability Lease
- **Service provided:** Load-bearing, structural integrity for towers & foundations (steel) — supplier guarantees usable capacity.
- **Payment forms:** Fixed periodic fee (quarterly/annual) — e.g., £/MW/year or £/tonne steel/year.
- **Payment formula (example):** $\text{Fee} = \text{BaseRate (£/MW/yr)} \times \text{TurbineRatedMW} \times \text{AvailabilityFactor}$
- **KPIs & monitoring:** Structural inspections annually; sensor data for tilt/vibrations, corrosion rate thresholds.
- **Risk allocation:** Supplier retains ownership and long-term corrosion risk; developer pays fixed fee but can claim service level agreement (SLA) penalties if KPIs breach.
- **Contract clauses to include:** guaranteed service life, inspection schedule, SLA credits, insurance for catastrophic failure, replacement lead time.
- **Sample pricing heuristic:** 2–5% of equivalent CapEx per year (highly dependent on expected life and corrosion environment).
- **Best for components:** Towers, foundations, large structural steel sections.

SPV-AO's Cash Flows to be Reimagined: From Rent Fees to Tradable Yields

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**

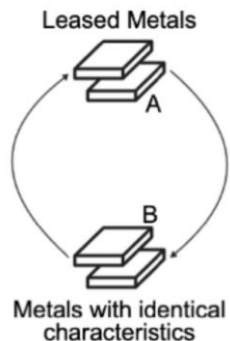


Solution: AO's Cash Flows to be Reimagined

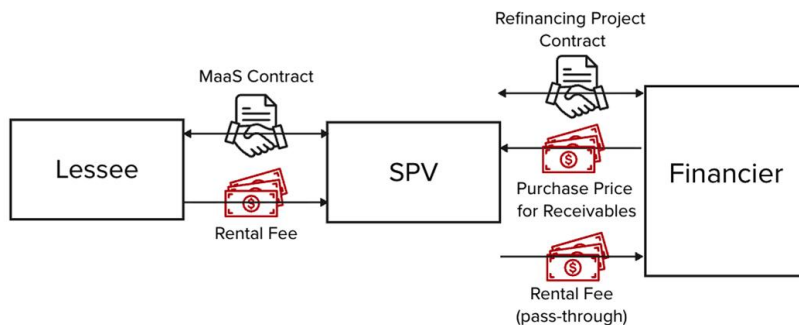
Fungibility

Durable metals of the same quality are interchangeable

- Shorter contracts
- Increased liquidity
- Reduced degradation risk



Monetize MaaS contracts and receivables



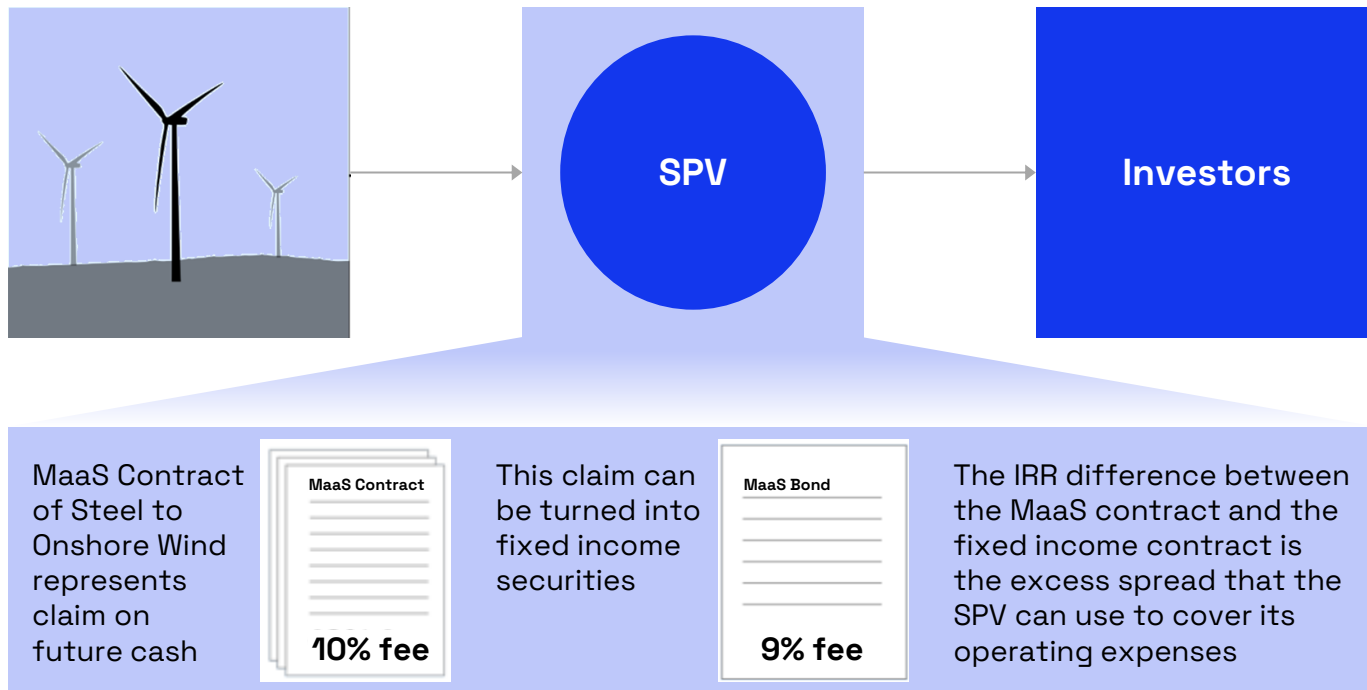
SPV-AO's Cash Flows to be Reimagined: From Rent Fees to Tradable Yields (cont'd)



Securitizing MaaS

Converting operating cash flows into investable securities

MaaS-enabled Onshore Wind



SPV-AO's Cash Flows to be Reimagined: From Rent Fees to Tradable Yields (cont'd)



Features of Securitization

Over-collateralization and Tranching are risk management tools for investors

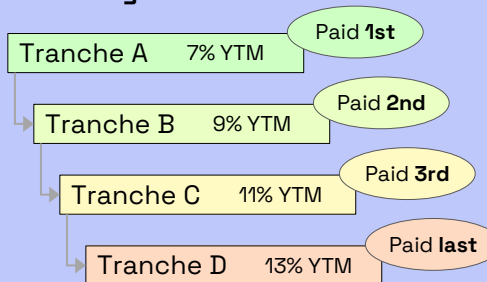


Overcollateralization



If the MaaS contract is worth \$11 million, \$10 million worth of bonds can be raised. The extra \$1 million serves as a buffer

Tranching



Lower risk, lower reward.
Higher risk, higher reward

Tranching helps create securitized products with different risk-return profiles, appealing to a broader range of investors and allowing the SPV to raise varying amount of capital for each tranche, which effectively will help reduce its net cost of capital

SPV-AO's Cash Flows to be Reimagined: From Rent Fees to Tradable Yields (cont'd)

Source:
<https://www.trafigura.com/news-and-insights/press-releases/2024/trafigura-securitisation-finance-raises-usd500-million-in-asset-backed-securities-market/>

Home > News and Insights > Trafigura Securitisation Finance raises USD500 million in Asset-Backed Securities market

Press release

Trafigura Securitisation Finance raises USD500 million in Asset-Backed Securities market

Published on 9 May 2024

Geneva, 9 May 2024 - Trafigura Securitisation Finance Plc ("TSF"), a receivables securitisation vehicle of Trafigura Group Plc Ltd ("Trafigura"), has successfully priced a new series of notes ("TSF 2024-1") on the 144A/RegS Asset-Backed Securities ("ABS") market.

Source:
<https://www.brookings.edu/articles/from-bottom-billion-to-top-trillion-using-commodity-backed-securities-to-support-the-future-of-africas-resource-economies/>

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From Bottom Billion to Top Trillion: Using Commodity-Backed Securities to Support the Future of Africa's Resource Economies

Nava Samuels
June 11, 2013



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Residential solar installer Palmetto closes \$420 million asset backed securitization

The transaction is backed by over 22,000 residential solar leases and power purchase agreements and marks the second major ABS deal in 2025 for Palmetto.

OCTOBER 7, 2025 BY AN KENNEDY

NEWS ANALYSIS OP-ED



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Source: <https://pv-magazine-usa.com/2025/10/07/residential-solar-installer-palmetto-closes-420-million-asset-backed-securitization/>

The Lessee's Concern: Risks are Transferred Profitably



Risk Transfer CAPEX → OPEX

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

Assumptions used:

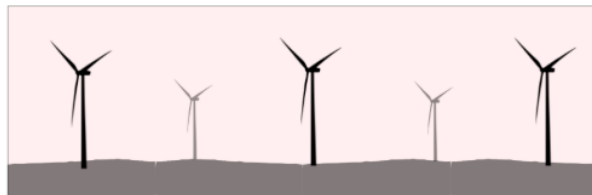
Project type: **Onshore Wind**
Size of Project (MW): **400**
Electricity rate per kWh: **\$0.144** (arranged under a PPA)

P-50 Capacity Factor: **31%**
Debt-Equity Split: **70/30**
Renting fee: **6.6%**
Risk-free-rate: **4.16%**
Credit Spread: **2.5%**

Metal: **High Strength Low Alloy (HSLA) Steel**
HSLA Steel Quantity: **56,000 tons**

HSLA Steel Spot price: **\$3,300**
MaaS Debt (HSLA + transportation costs): **\$187 Million**
Recovery cost to OEM: **\$0****

Non-MaaS-enabled Onshore Wind



Equity hurdle rate: **15%**
Weighted Average Cost of Capital: **6%**
Average DSCR (31% capacity factor): **3.18**
Equity IRR: **15.74%**

MaaS-enabled Onshore Wind



Equity hurdle rate: **13%***
Weighted Average Cost of Capital: **5.8%**
Average DSCR (31% capacity factor): **4.19**
Equity IRR: **21.27%**

*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.

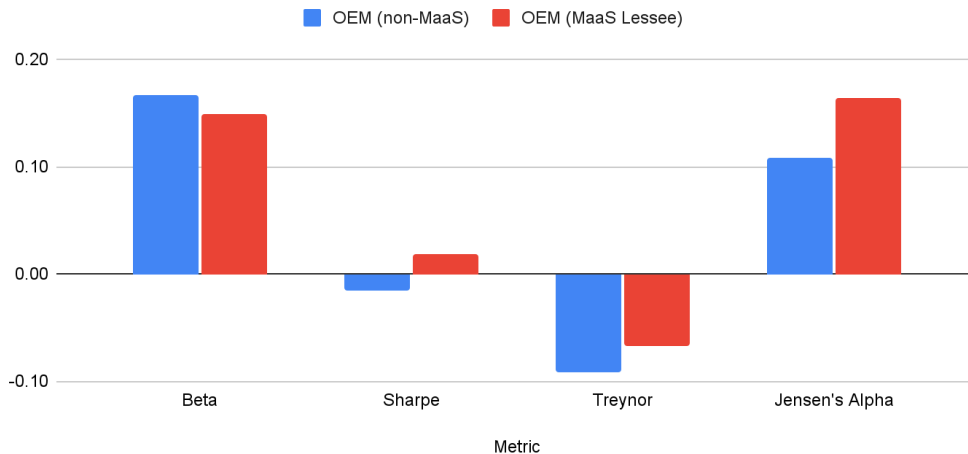
So, how do MaaS financials compare on a risk-adjusted basis for the lessee?



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

- **Total risk = systematic risk** (whole market) + **unsystematic risk** (stakeholder-specific)
- **More stable returns:** Sharpe turns positive
- **Less exposed to the market:** Beta drops ~11%, **reduced sensitivity to macro swings**
- **Better risk-adjusted performance:** Treynor improves ~26%, more return per unit of market risk
- **Outperform the market benchmark more:** higher alpha delivered for MaaS- enabled

MaaS entails changes exposure to risks but mitigation strategies exist

For Metal Owners

Risk	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.

Risk Made Transparent: Digital Traceability to Meet Investor Metrics



Operational risk controls



Design for disassembly enables asset recovery and reduces stranded value risk



Verified recovery under SPV ownership ensures accountability and compliance



Circularity clause embeds contractual obligation to return the metal equivalent in quality and quantity for reuse by the asset owner

Digital traceability for fungibility & securitization



Tagging & lifecycle verification (Digital Product Passports (DPPs)): unique identifiers for each asset to trace quality.



Digital ledger integration (e.g., blockchain): recorded data feeding SPV dashboards.



Real-time metal flow and credit performance reporting: Supports securitization and investor confidence.

Risk Made Transparent: Digital Traceability to Meet Investor Metrics

Examples of current applications of traceability in the wind industry

Application	How it works	Country	Leader	Benefits
End-to-end traceability of recycled turbine blades.	Blockchain + IoT track in real time every kg of RX polymer in recycled composite material from collection to reuse.	Northern Ireland	Plaswire (UK), Ubloquity, Ørsted	Estimated 2.7 tonnes CO2 for every ton of material processed.
Digital passports for turbine components & the Turbine Recycling and Circular Economy (TRACE) Tool	Radio Frequency Identification (RFID) and data standards ensure lifecycle tracking for reuse/recycling.	UK	Circular Economy for the Wind Sector (CEWS) Programme (ORE Catapult, Total Energies, RWE, Equinor, EDF, Scottish Power Renewables)	Provides a clear, traceable product history, allowing stakeholders to confidently choose the best end-of-life path (reuse, recycle, or disposal).
Full traceability of copper in turbine transformers.	Circular's blockchain-based traceability and emissions tracking platform to track copper from mines to installation. World's first for copper in turbine transformers.	Global	Ørsted + Siemens Gamesa, Siemens Energy Grid Technologies, & Circular	Supply chain collaboration and transparency.
Mandatory recovery clauses in Materials-as-a-Service contracts.	Contracts mandate OEMs to reclaiming metals at end-of-life.	Global	European Bank for Reconstruction and Development	Industry wide guidance created

Digital Product Passports (DPPs) for companies selling into EU will be mandatory from 2027

Sources: 1 [Plaswire partners with global wind giant to recycle onshore wind turbine farms – Plaswire](#); 2 [Lurgan recycling innovator pioneers world-first blockchain system to trace recycled wind turbine blades..](#) "For the first time, we can provide complete transparency"; 3 [Wind turbine blade Recycling with end-to-end traceability – RECYCLING magazine](#) 4 [Driving towards a sustainable Circular Economy for the wind sector](#) 5 [Turbine Recycling and Circular Economy \(TRACE\) Tool](#) 6 [Collaboration Powering the Future: World's First End-to-End Traceability for Wind Energy](#) 7 [Sector supply-chain guidance – wind energy](#) 8 [Smart steel: new paradigms for the reuse of steel enabled by digital tracking and modelling – ScienceDirect](#)

MaaS as a journey

Business Models operationally evolve

			Function-as-a-Service	Metal-as-a-Service	Product-as-a-Service	Component-as-a-Service	Recovery-as-a-Service	Shared-as-a-Service	
Asset-Centric MaaS Models	Long-term leasing of metal for large infrastructure or products	Infrastructure-as-a-Metal Bank							Opportunity Space
		Renewable Asset Circular Leasing							
		Mobility Metal Pools							
		Utility-Linked Metal Leading							
Product-Centric MaaS Models	Long-term leasing for component products	Component-as-a-Service							
		Battery-Metals-Stewardship							
		Remanufacturing-as-a-Service							
Recovery-Centric MaaS Models	End-of-life product reprocessed into metal for on-leasing	Urban Mining Models							
		Industrial Symbiosis Metal Networks							
		Community Based Models							
Investment / Market Segment			Business Model						

MaaS as a journey

Business Models operationally evolve

Steel re-use for offshore wind farm subsea cable ducts – Cleveland Steel and Tubes

- **Reclaimed steel** from gas project (where it is common to over-order, and surplus is typically scrapped) and mill.
- Tested for quality.
- **~20% cheaper** than virgin steel.
- **Quicker to procure.**
- Challenges in replicating: Lack of sufficient pipes with required diameter and thickness for ducts.



Blade circularity – Vestas

- **Innovation in the chemical disassembly process** of epoxy resin used in wind turbine blades, meaning blades can now be disassembled.
- Metal, resin and foam from end-of-life blades can be **re-used for future blade production.**
- Before, blades had to go to landfill.



Chemicals-as-a-Service – MetalClean Solutions

- **Performance-based chemical leasing** for metal cleaning and protection.
- Focus on function **optimises resource efficiency and reduces health/environmental risks.**
- Recognised with Global Chemical Leasing Award.



Crushing-as-a-Service – Metso

- **Mobile crushing plants leased and operated** by Metso, reducing client CAPEX.
- **Equipment reused** in new operations at contract end.
- Fixed cost model **lowers operational risk and price volatility.**
- **Avoids inefficiencies of traditional models** (long build times, high resource use).

METALS-AS-A-SERVICE

MaaS as a journey

Financial structures evolve

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

MaaS offers a value proposition for each stakeholder

Producers – Sponsor

- Stable, recurring revenue streams
- Strong customer lock-in
- Enhanced price risk management
- Brand differentiation through circularity
- Access to secondary materials streams
- Value-added service opportunities

SPV

- Strategic positioning in the circular economy
- Long-term stable cash flows
- Control of material lifecycle and Metal Bank
- Unique MaaS expertise and knowhow
- Creation of new asset class

Recyclers

- Guaranteed materials flows
- Integration into premium circular supply chains
- Higher purity and traceability
- Process and cost efficiencies
- Value-added service opportunities

OEMs & wind farm developer(s)

- Access to new commercial value streams: end of life, materials circularity & materials fungibility
- CAPEX burden shifted to SPV and predictable OPEX charges over the long term
- Improved ROIC which could accelerate wind farm deployment through efficient balance sheet management
- Reduced risks of metal price volatility, improved supply security, and improved decommissioning as SPV holds active supporting or driving role
- Reduced Scope 3 emissions

Investors & lenders

- Bond-like income
- Tradable liquidity (ABS/MLP/CIT)
- Attractive risk-adjusted returns
- Diversification
- ESG eligibility
- Inflation hedge
- Standardised due-diligence via SPVs

Policymakers & regulators

- Capture untapped local metal stock
- Improved critical-metal security
- Private capital mobilization
- Improved circular policy, taking a step beyond EPR
- Carbon/waste reduction
- National and industrial resilience

With MaaS, Circular Metals can become a New Asset Class

Circular metal a new asset class



Unified Platform

MaaS combines operational leasing and financial securitization in a single integrated product

- SPV retains ownership while leasing metals to operators
- Bundled circular metal streams are transformed into financial instruments
- Digital backbone ensures traceability, compliance, and investor confidence



Outcome

Physical metal stock is converted into yield-bearing, tradable assets

- Metals generate long-term recurring revenue through leasing
- Securitisation enables participation in secondary markets
- Circularity metrics embedded in contracts make sustainable metal uses measurable and reportable



Thesis

A commercially self-reinforcing system where performance, material recovery, and sustainability objectives are aligned

- Predictable long-term cash flows attractive to investors
- Design for disassembly ensures component reuse and end-of-life value recovery
- Investment metrics are integrated into asset valuation

MaaS: A systemic answer to systemic bottlenecks

Linear business models underservice supply of needed metals

Key Challenges Faced with the Linear Model

Continued dependence on
inelastic primary production

Geopolitically driven supply
risks

Volatility of metal prices
disrupts the market and
downstream players

Fragmented supply chain:
less efficient metal uses and
product design as well as
waste of durable metals

MaaS Closed Loop Advantages



MaaS with maintained ownership
incentivizes metal circulation



MaaS structures mitigate
exposure to a single producer
and political instability

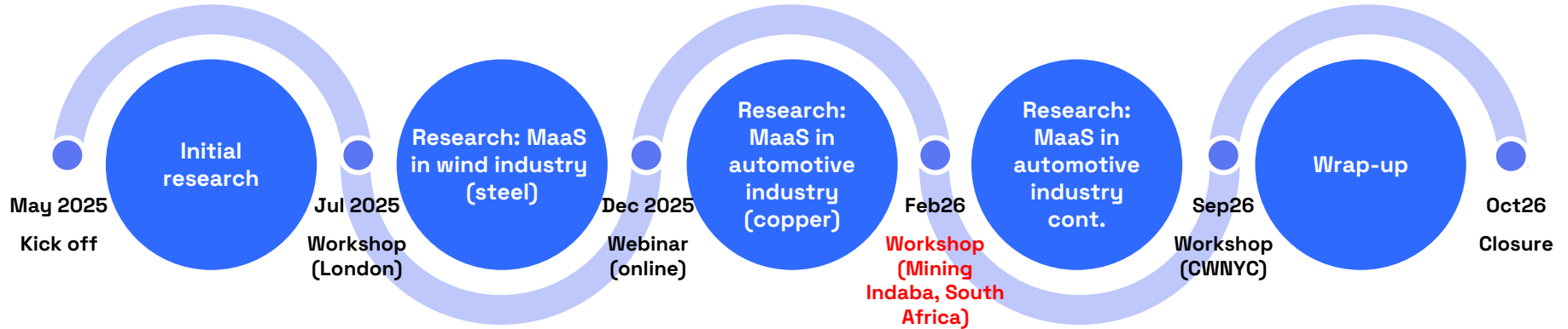


MaaS transfers the price risk for
the lessee to the financiers



MaaS enables progress towards
true circular economy

Research journey



THANK YOU

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