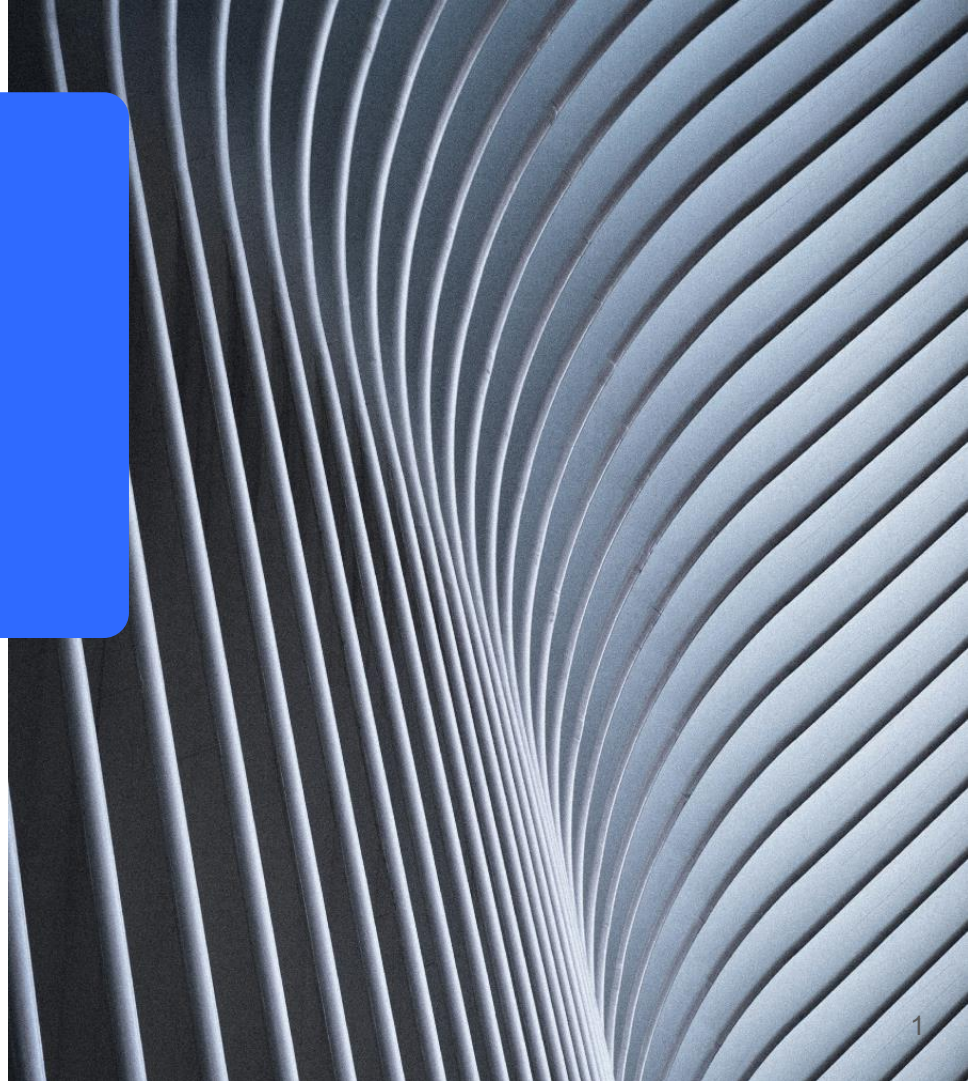
# Metals-as-a-service: A Bankable Circular Business Model

**December 4, 2025**



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## 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.

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Quadrature Climate Foundation

# 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

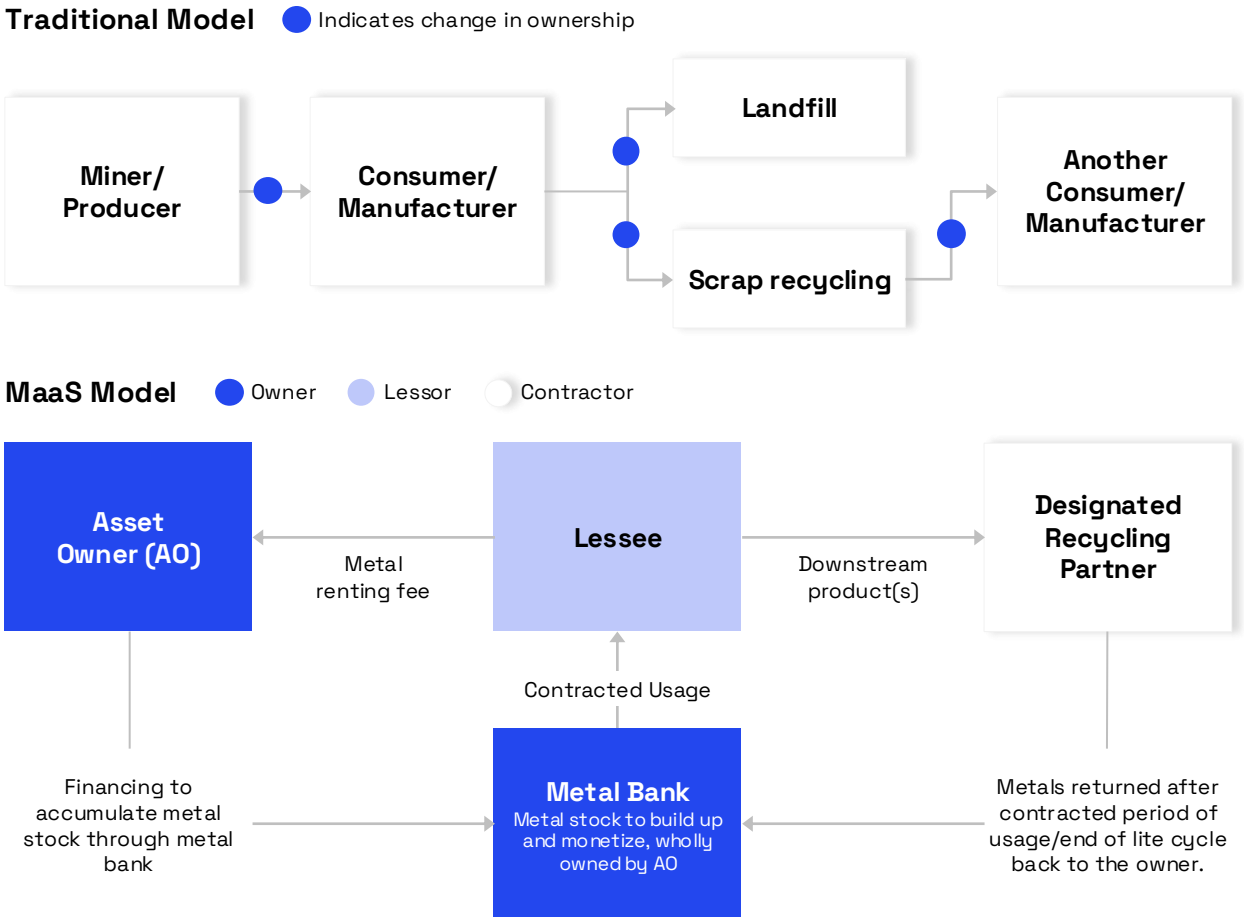
- The asset owner has an **incentive to recover** the metal → value chain around design and logistic for recoverability
- Financing is structured to **compete with the linear model**

## 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

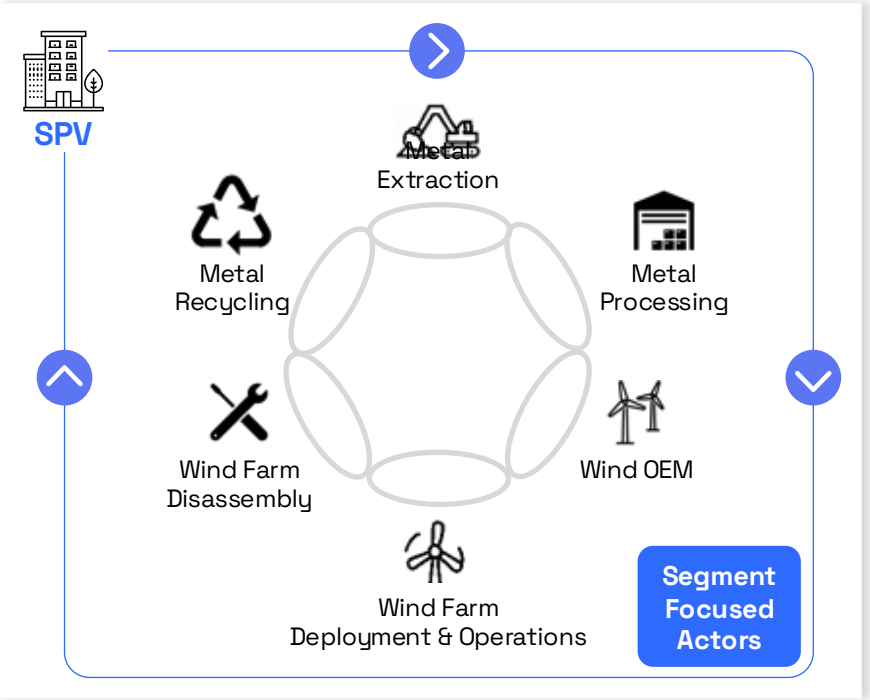
# Reminder: What is MaaS?

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



# 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:

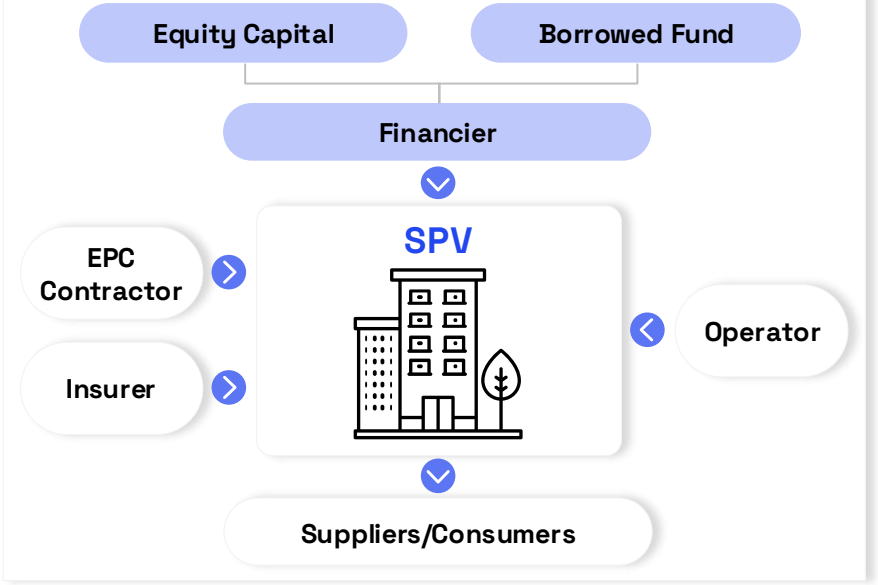
A **single entity, an SPV**, operationalizes metal renting and structures financial liquidity

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

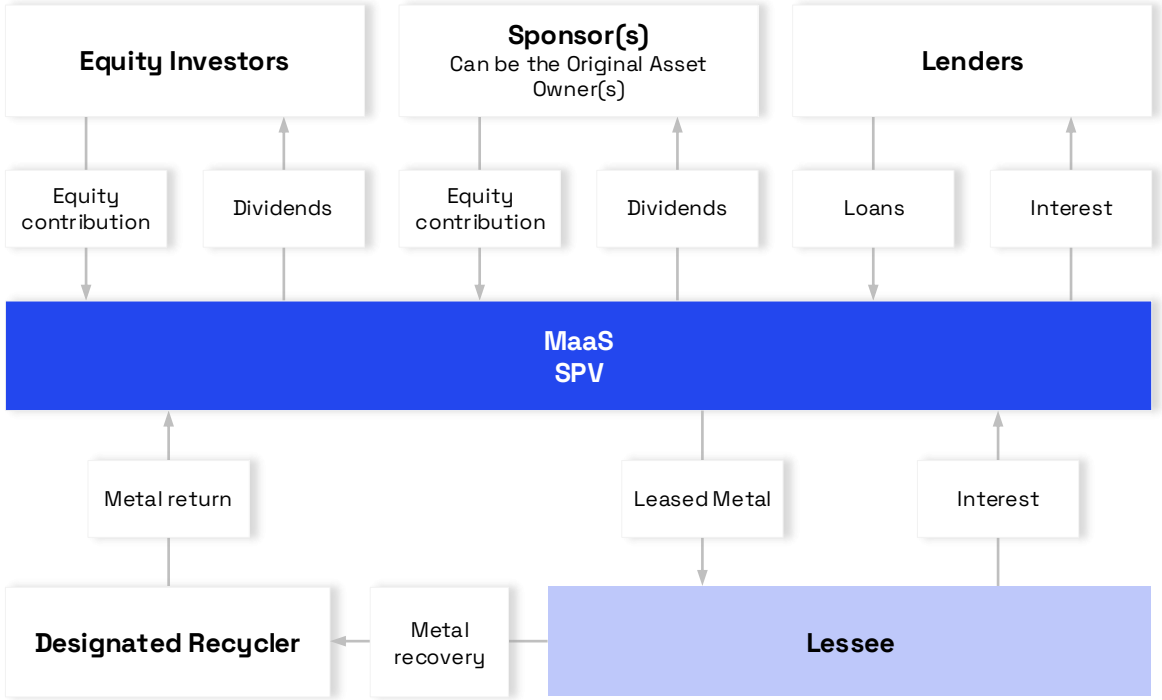
**Therefore, SPV-based project finance models can directly support effective MaaS financing, using financial products & metal procurement**

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

## Sponsored by the AO

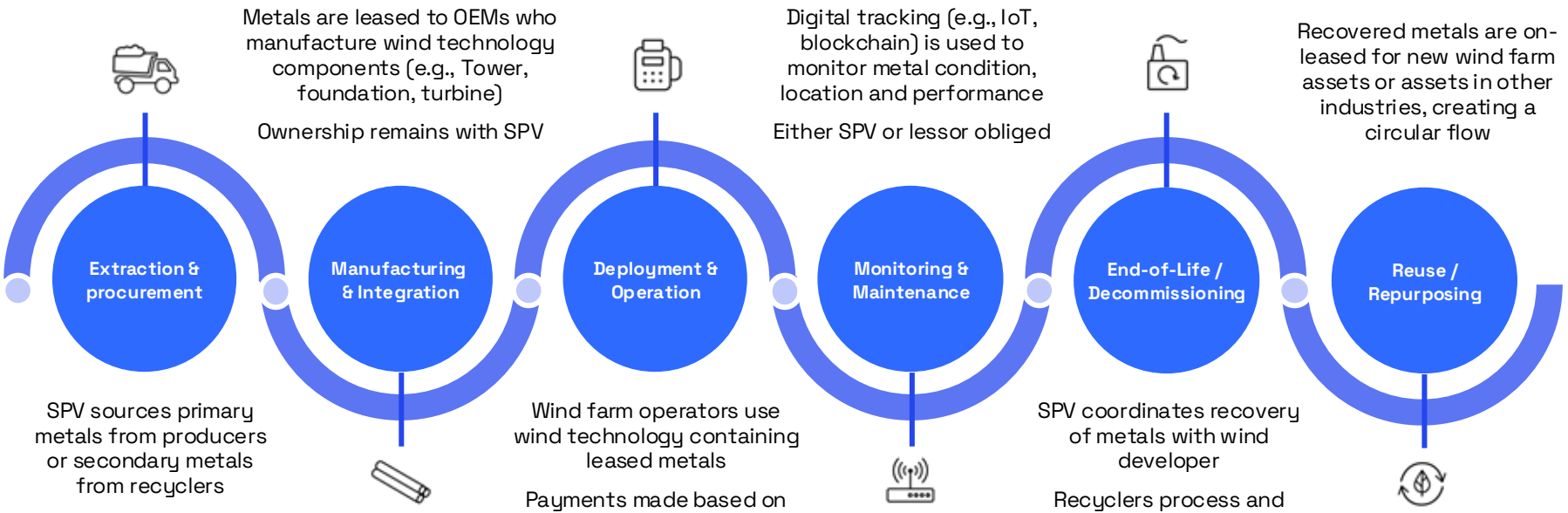
**The Sponsor(s) can be the original asset owners** who either transfer the ownership of the metal to the SPV or let the SPV procure metal

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



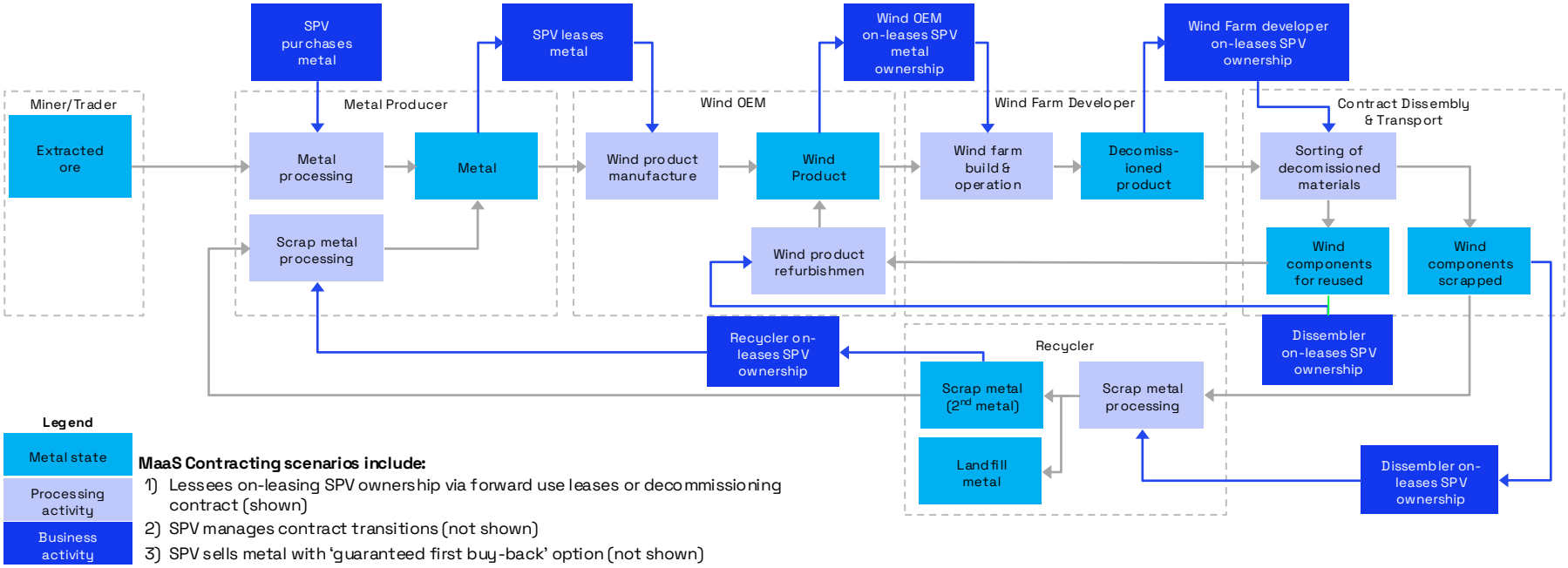
# A special purpose vehicle (SPV) is the backbone to execute this business model

## Focus builds knowhow and operationally efficiency



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

## Illustration in the wind industry




**MaaS Contracting scenarios include:**

1) Lessees on-leasing SPV ownership via forward use leases or decommissioning contract (shown)
2) SPV manages contract transitions (not shown)
3) SPV sells metal with 'guaranteed first buy-back' option (not shown)

Sources: Carbon Trust/CCSI analysis. Modelling approach taken from Engelmann, 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

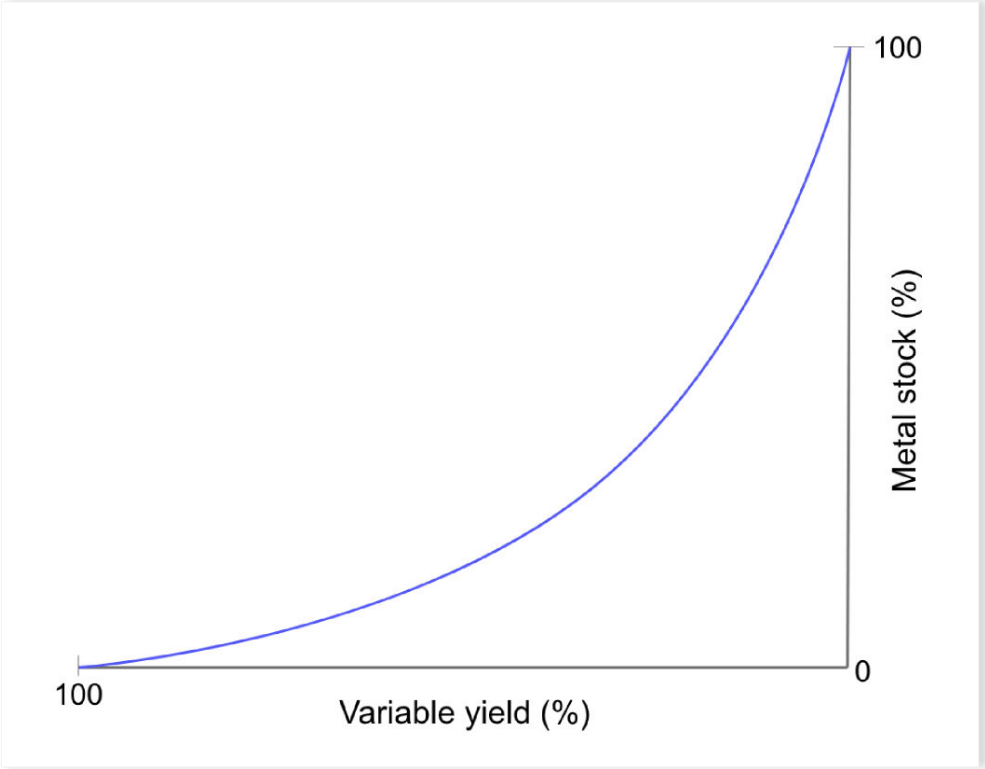
**Metals Bank vision:** Creates a predictable source of supply, generates recurring yield for the AO, and creates tradable exposure to circular metals.

**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" .....

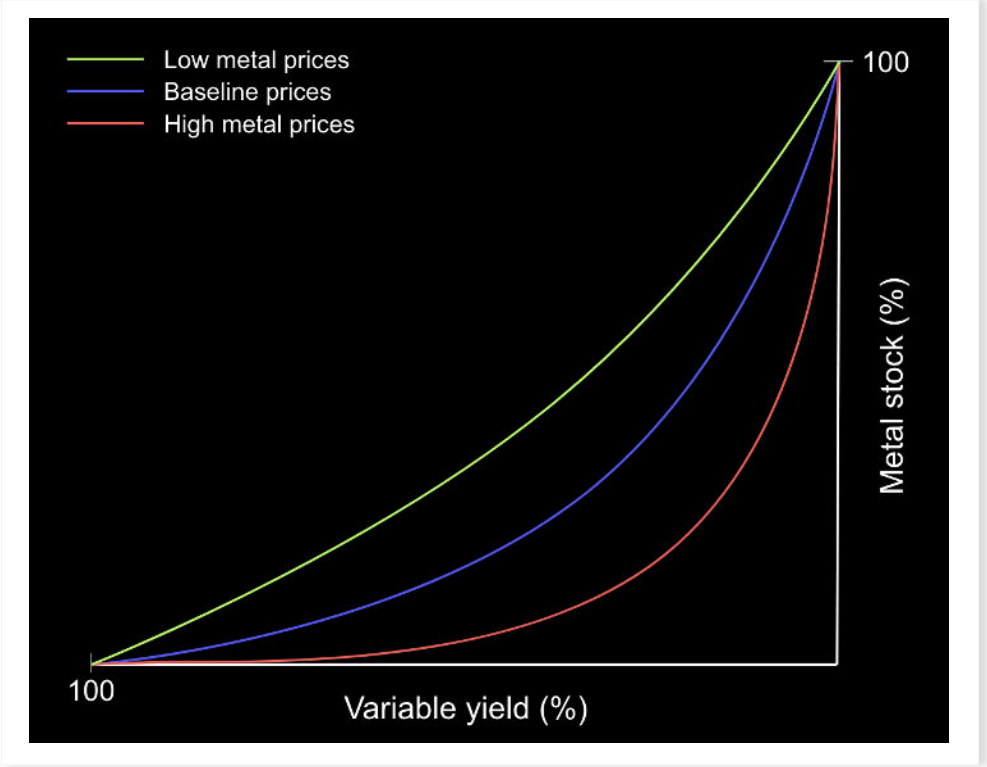


# The SPV-AO concern: Building the Metals Bank

**....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):** Fee = BaseRate (£/MW/yr) × TurbineRatedMW × 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**

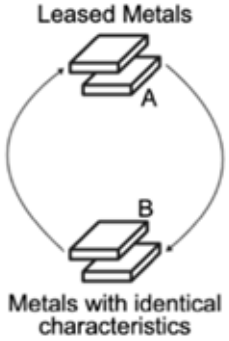
Risk burden falls on the **Asset Owner (AO)** → results in **high fees for lessee**

## Solution: AO's Cash Flows to be Reimagined

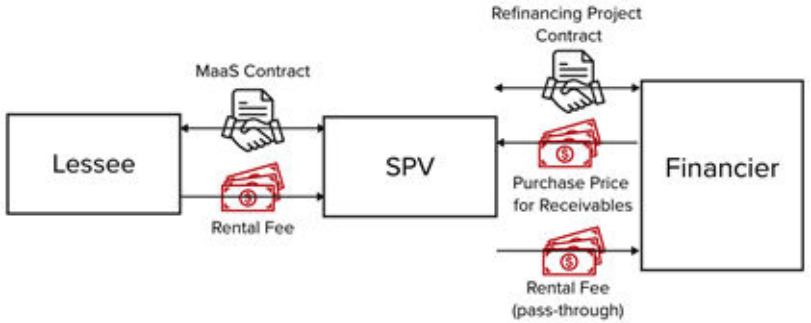
### Fungibility

**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

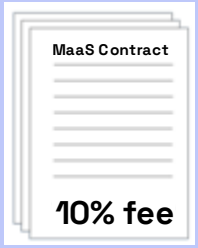
Converting operating cash flows into investable securities

**MaaS-enabled Onshore Wind**

SPV

Investors

MaaS Contract of Steel to Onshore Wind represents claim on future cash




This claim can be turned into fixed income securities


The IRR difference between the MaaS contract and the fixed income contract is the excess spread that the SPV can use to cover its operating expenses

# 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

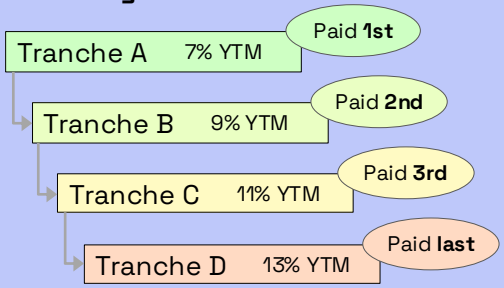
SPV

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/


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 Pte Ltd ("Trafigura"), has successfully priced a new series of notes ("TSF 2024-1") on the 144A/RegS Asset-Backed Securities ("ABS") market.


pv magazine

Residential solar installer Palmetto closes $420 million asset backed securitization

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

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


BROOKINGS

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

# 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?

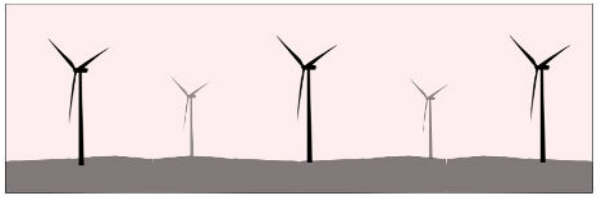
### Risk Transfer - CAPEX -> OPEX

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

**Assumptions used:**

- Project type: **Onshore Wind**
- Size of Project (MW): **400**
- Metal: **High Strength Low Alloy (HSLA) Steel**
- Electricity rate per kWh: **$0.144** (arranged under a PPA)
- Debt-Equity Split: **70/30**
- P-50 Capacity Factor: **31%**
- Renting fee: **7.66%**
  - Risk-free-rate: **4.16%**
  - Credit Spread: **3.50%**

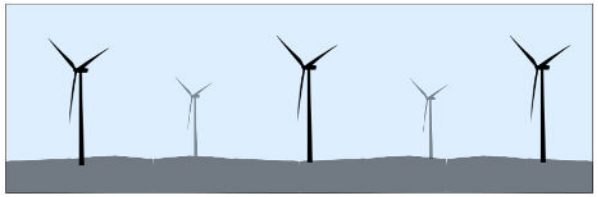
**Non-MaaS-enabled Onshore Wind**



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

Equity IRR: **15%**

**MaaS-enabled Onshore Wind**

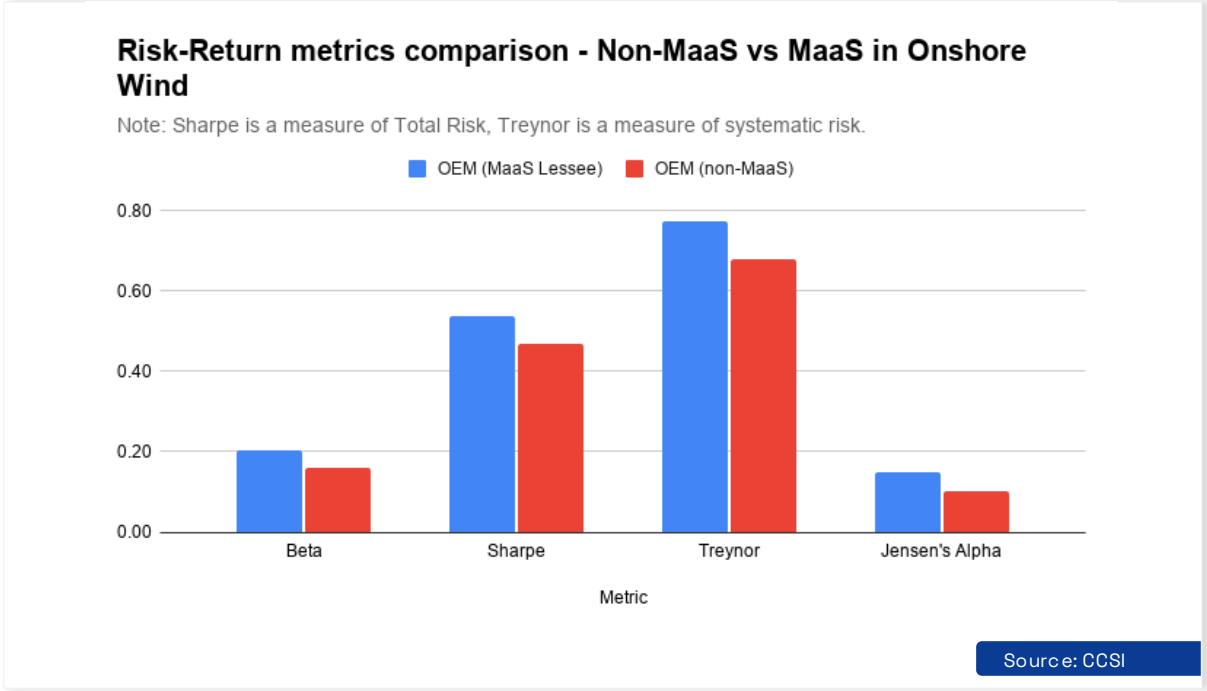


Average DSCR (31% capacity factor): **4.02**

Equity IRR: **19.94%**

# 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.




- **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 fo 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.** | Circulor'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, & Circulor | 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

| Investment / Market Segment | | | Business Model | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Function-as-a-Service | Metal-as-a-Service | Product-as-a-Service | Component-as-a-Service | Recovery-as-a-Service | Shared-as-a-Service | Opportunity Space |
| Asset-Centric MaaS Models | Long-term leasing of metal for large infrastructure or products | Infrastructure-as-a-Metal Bank | | | | | | | |
| | | 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 | | | | | | | |

# MaaS as a journey

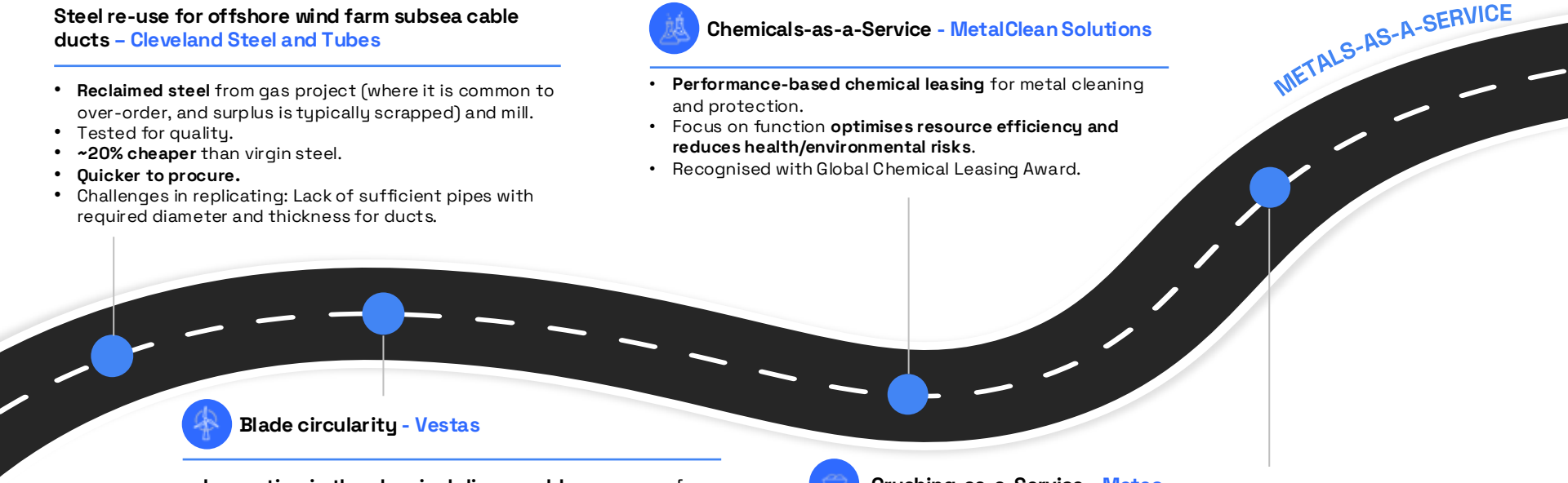
## Business Models operationally evolve

**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.

**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.




**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.

**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).

Sources: 1 Steel reuse for offshore wind farm – The Alliance for Sustainable Building Products 2 Blade Circularity 3 Metal CDM archetypes presentation.pptx
4 Metso introduces a groundbreaking Life Cycle Services model for minerals processing - Industry Europe

# 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 | Weakness |
|---|---|
| Flexible, low setup costs, simplified governance, VC alignment. | 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 | Weakness |
|---|---|
| Liquidity<br>GP-LP alignment<br>Flexible structuring | GP concen- tration risk<br>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 | Weakness |
|---|---|
| High liquidity, broad investor base,<br>Sophis- ticated risk management | Higher setup costs<br>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

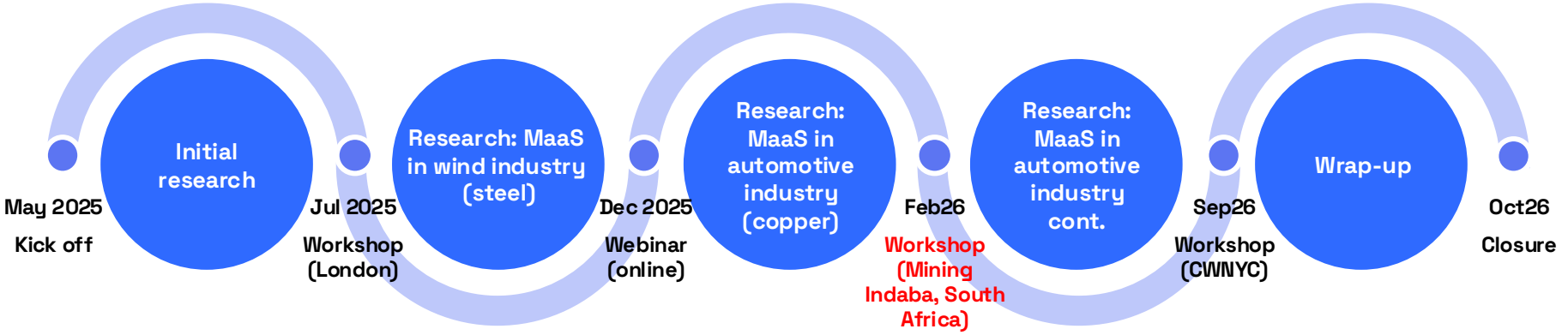
- Predictable long-term cash flows attractive to investors
- Design for disassembly ensures component reuse and end-of-life value recovery
- Investment metrics are integrated into asset valuation

# MaaS: A systemic answer to systemic bottlenecks

## Linear business models underservice supply of needed metals

| Key Challenges Faced with the Linear Model | MaaS Closed Loop Advantages |
| --- | --- |
| Continued dependence on inelastic primary production | MaaS with maintained ownership incentivizes metal circulation |
| Geopolitically driven supply risks | MaaS structures mitigate exposure to a single producer and political instability |
| Volatility of metal prices disrupts the market and downstream players | MaaS transfers the price risk for the lessee to the financiers |
| Fragmented supply chain: less efficient metal uses and product design as well as waste of durable metals | MaaS enables progress towards true circular economy |

# Research journey



# THANK YOU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