MaaSiveTwin: Manufacturing as a service and Supply chain predictive Twin for critical raw materials

From dependency to resilience: reinventing critical raw material supply chains

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Critical raw materials (CRMs) such as lithium, cobalt, nickel, rare earth elements, vanadium and platinum are the backbone of **Europe's green and digital transition**. They are indispensable for **clean energy technologies** ranging from batteries and fuel cells to wind turbines and advanced electronics. However, Europe remains acutely dependent on imports, with more than 90% of many CRMs sourced from outside the European Union (EU) (European Commission, 2023a). This reliance exposes industries to market volatility, supply shortages and geopolitical risks. Recent global events, such as the COVID-19 pandemic and the Suez Canal blockage, have highlighted just how fragile these supply chains can be.

Recognising this vulnerability, the European Commission adopted the **Critical Raw Materials Act (CRMA)** in 2023, which sets ambitious targets for domestic sourcing, processing and recycling by 2030 to reduce dependency and increase resilience (European Commission, 2023b).

Against this backdrop, the Horizon Europe-funded **MaaSiveTwin** project is pioneering a new approach to strengthening CRM value chains. Through the integration of **digital twin technologies, predictive modelling, and manufacturing as a service (MaaS)**, MaaSiveTwin equips Europe with the tools to anticipate disruptions, optimise production and meet its sustainability and autonomy objectives.

A new era of data-driven CRM supply chains

Launched in April 2024, MaaSiveTwin is a 48-month, €5.2 million project funded under Horizon Europe's call *CL4-2023-TWIN-TRANSITION-01-07: Achieving resiliency in value networks through modelling and MaaS*.

The project revolves around the concept of **MaaS**—the flexible sharing of manufacturing resources across value chains. In the CRM context, this means not only **tracing material flows** but also enabling better **utilisation of expensive, infrequently used equipment** such as pilot battery production lines or advanced testing machinery.

The project's ambitious goal is to deliver a **demonstrator platform that combines MaaS with digital twin technologies**. This platform will give key players in CRM value chains the capacity to anticipate and respond rapidly to supply chain disruptions. It will be designed to **provide accurate predictions of price fluctuations, demand mismatches and supply risks**, while also supporting sustainability reporting and informed decision-making.

Through the **integration of diverse data sources and advanced modelling techniques**, MaaSiveTwin will enhance the accuracy of forecasting and strengthen resilience across CRM supply chains. The result is a dynamic, data-driven environment where policymakers, researchers and industry stakeholders can **monitor real-time developments, simulate disruption scenarios and explore alternative strategies** for more sustainable, efficient and secure supply networks.

Objectives that power a digital twin for Europe's CRM future

At its core, MaaSiveTwin seeks to **strengthen Europe's autonomy and resilience in CRMs** by creating a digital twin platform that integrates real-world supply chain data with advanced predictive modelling.

Project aims

- **Enhance transparency:** Provide stakeholders with a comprehensive, up-to-date overview of global CRM supply chains, from mining and refining to recycling and end-use applications.
- **Improve resilience:** Anticipate and mitigate the impact of disruptions such as transport blockages, geopolitical events or sudden demand surges.
- **Support sustainability:** Integrate environmental, social and ethical factors into supply chain models to ensure responsible sourcing and compliance with EU sustainability standards.
- **Optimise utilisation:** Enable MaaS by improving access to costly, underused manufacturing and testing equipment.
- **Empower decision-making:** Deliver actionable insights for policymakers, industry leaders, and researchers, ensuring alignment with EU strategic goals such as the Critical Raw Materials Act and the European Green Deal.

These objectives are realised through seven innovation pillars: event impact modelling, equipment optimisation, sustainability and ethics assessment, satellite-based mining monitoring, deterministic and stochastic supply chain models, and machine learning for pattern detection.

MaaSiveTwin's methodological approach

MaaSiveTwin follows a phased methodology that links data, modelling and validation into a single digital twin framework.

- **Data collection and integration:** A global CRM database is being developed, combining import/export statistics, annual reports, historic materials prices and satellite imagery. Automated crawlers ensure continuous updates.
- **Infrastructure development:** A scalable digital backbone, based on interconnected environments and orchestrated data pipelines, enables secure, reproducible and efficient handling of large, heterogeneous datasets.
- **Modelling:** Three complementary approaches are applied—deterministic (to quantify costs and delays), stochastic (to capture uncertainty), and machine learning (to detect patterns across complex datasets) after data pre-processing (statistics and imputation) and fusion.
- **Demonstrator development:** The integrated digital twin will be validated through two flagship use cases: (*i*) simulating transport blockages in CRM supply chains and (*ii*) assessing Europe's ability to meet the 2030 CRMA targets.
- **Validation and business modelling:** Results will be validated with stakeholders and translated into feasible business models for long-term exploitation.

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This structured approach ensures MaaSiveTwin evolves from raw data collection to actionable tools that directly serve European industry and policy.

Progress and early activities

Within its first year, MaaSiveTwin has already achieved important milestones that set a strong foundation for the demonstrator platform.

- **CRM price tracking:** A dedicated database now tracks spot prices for lithium, cobalt, nickel, vanadium, platinum, palladium, silicon and rare earths. Historical datasets of up to four years have been consolidated, providing the basis for forecasting algorithms. A Python scraper, introduced in project month nine, now automates this process, greatly reducing manual effort and improving reliability (Hess and Ortmann, 2024).
- **Infrastructure setup:** The technical backbone has been established with separate development, integration and demonstration environments. Docker containerisation ensures portability, while Prefect orchestrates data pipelines for real-time observability. This infrastructure supports smooth collaboration across partners and secures the scalability of future demonstrators (Pfahrer and Huch, 2024).
- **Product specification:** The project has refined its system architecture and defined two flagship use cases:

Use case 1

Transport Blockages

Simulation of shipping or logistics disruptions, such as port closures or route blockages, and the cascading effects across CRM supply chains. Early work includes compiling pilot datasets on LiFePO4 batteries and global trade routes.

Use Case 2

EU 2030 CRMA Targets

Scenario analysis to assess whether the EU's extraction, processing and recycling targets can realistically be achieved. Data on mining and refining projects worldwide is being collected, with models prepared to evaluate supply-demand mismatches (Battronics Sp.z.o.o *et al*., 2025).

Shaping Europe's raw materials future

The MaaSiveTwin digital twin platform will redefine how Europe approaches the management of CRMs. By bringing together real-time data, predictive modelling and MaaS, the project lays the groundwork for transparent, sustainable and resilient supply chains that can withstand disruption and support Europe's clean energy ambitions.

As the demonstrator advances, MaaSiveTwin will provide the European industry with tools to safeguard production, policymakers with foresight to anticipate risks, and researchers with insights to improve resource management. In doing so, the project transforms Europe's current dependency into an opportunity for leadership, ensuring that CRMs remain a secure foundation of the green and digital transition.

References

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MaaSiveTwin

PROJECT SUMMARY

MaaSiveTwin project develops a digital twin demonstrator for critical raw materials, integrating data-driven forecasting, simulation and manufacturing as a service. By predicting price volatility, demand–supply mismatches and disruption risks, it empowers industry and policymakers to make early, informed decisions. The platform enhances resilience, compliance and sustainability across Europe's CRM supply chains, supporting the green and digital transition.

PROJECT PARTNERS

MaaSiveTwin brings together a dynamic consortium of eight partners from six different countries across Europe. The consortium assembled for this project comprises three universities, five SMEs, and one industry leader, forming a multidisciplinary team with diverse expertise necessary to address the project's ambitious goals and to drive impactful results in the field of MaaS.

PROJECT LEAD PROFILE

Battronics (Batt), founded in 2017, operates in Switzerland, Germany and Poland, specialising in battery technologies and supply chains. With expertise spanning chemistry, modelling, ageing analysis and market intelligence, Batt delivers patent analyses and technology roadmaps. As MaaSiveTwin coordinator, Batt-DE leads management, IP protection and CRM database development, ensuring sustainable, resilient battery and raw material value chains.

PROJECT CONTACTS

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https://maasivetwinproject.eu/

/showcase/maasive-twin

https://cordis.europa.eu/project/id/101138334

FUNDING

Funded by the European Union

Funded by the European Union. Views and opinions expressed are, however, those of the author(s) only and do not necessarily reflect those of the European Union or the European Health and Digital Executive Agency (HADEA). Neither the European Union nor the granting authority can be held responsible for them.

Grant agreement No. 101138334.

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
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Swiss Confederation

Federal Department of Economic Affairs, Education and Research EAER
State Secretariat for Education, Research and Innovation SERI

This work has received funding from the Swiss State Secretariat for Education, Research and Innovation (SERI).

Contract No. 24.00047

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