DINAMINE – Digital Intelligence for Europe's Critical Raw Materials Transition

Enabling strategic positioning in a data-driven and competitive mining landscape

The future of mining will be defined by intelligent integration—connecting data, operations, and strategy to drive performance, compliance, and long-term competitiveness.

PNO INNOVATION

Executive summary

Europe's mining industry is entering a decisive phase, driven by rising demand for critical raw materials, regulatory pressure under the European Green Deal and the Critical Raw Materials Act, and increasing expectations around safety and ESG performance. Digitalisation is now central to how mining systems are structured and managed, supported by strong market momentum—from approximately **€12 billion in 2021** to over **€29 billion by 2030 (≈10% CAGR)**, alongside a **€3.02 billion** mining drill rigs market.

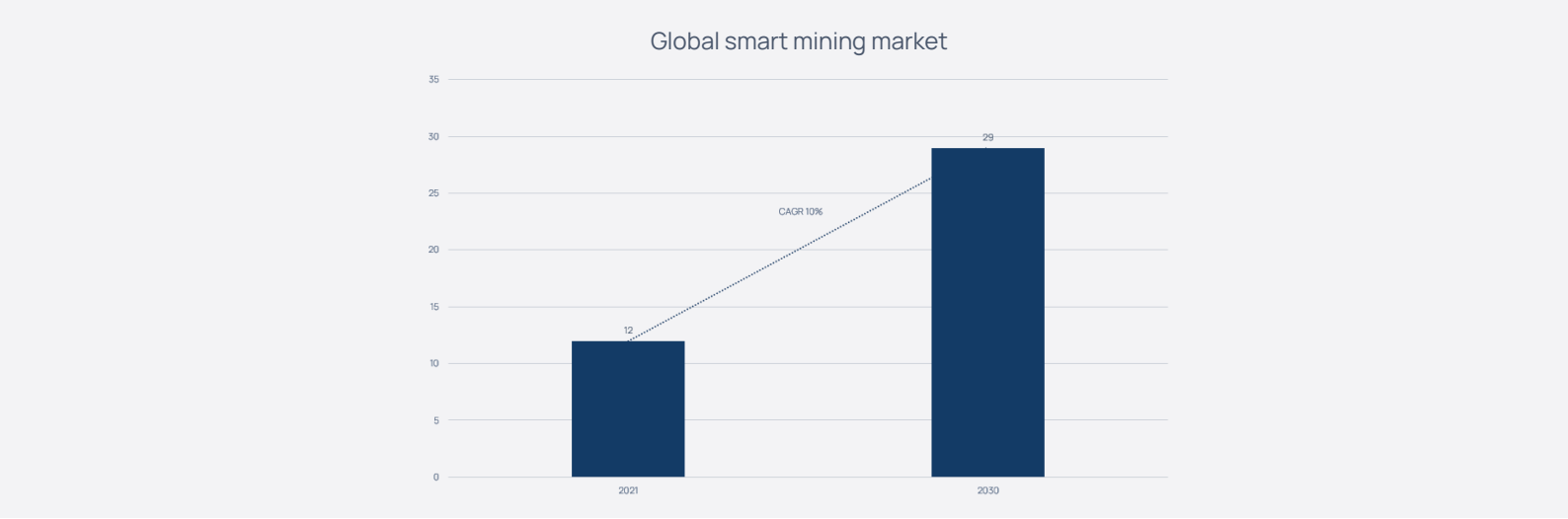


Figure 1: Smart mining market global growth

Within this context, DINAMINE—funded by the European Union under Horizon Europe Grant Agreement No. 101091541—supports the transition towards integrated and data-driven mining operations. PNO contributes by leading Technology Market Outlook analysis and stakeholder ecosystem mapping under WP7, aligning technological developments with regulatory frameworks, investment dynamics and evolving market conditions.

This transition is accelerating the shift towards data-driven mining systems, where operational performance, compliance requirements and strategic positioning are increasingly interconnected.

> "Digitalisation is no longer optional in modern mining—it is central to operational resilience, sustainability, and long-term competitiveness."

Critical Raw Materials and the Digital Mining Imperative

The European mining ecosystem faces intensifying structural pressure. Policy frameworks such as the Critical Raw Materials Act establish targets for domestic extraction, processing, and recycling capacities, while increasing environmental and social scrutiny requires operators to demonstrate alignment with ESG principles.
At the same time, digital maturity in mining remains comparatively low, with the sector lagging approximately **30–40%** behind comparable heavy industries. Despite this gap, adoption intentions are strong: approximately **90% of mining companies** plan to implement big data analytics, IoT, and automation technologies, while mine planning and management software already shows significant penetration, with nearly half of surveyed operations reporting full implementation.

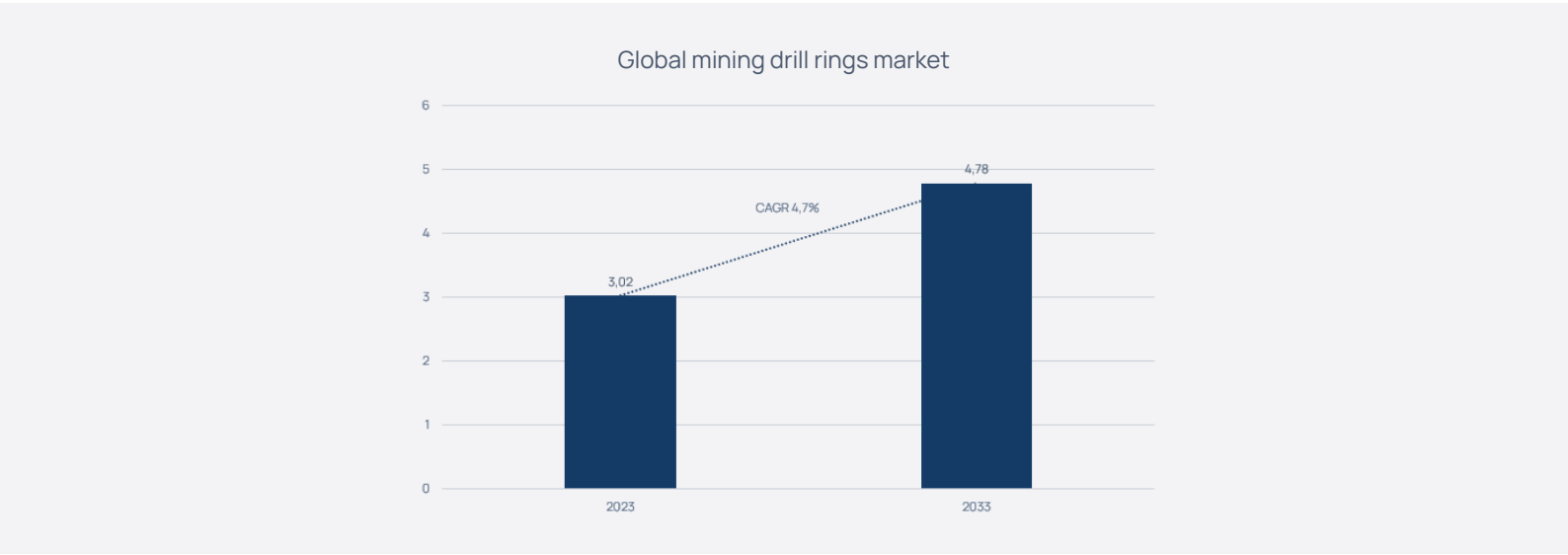


Figure 2: Mining drilling rigs global market growth

Market expansion across software and equipment segments reinforces this transition. The rock drilling jumbo segment, valued at approximately **€370 million in 2021**, and the autonomous mining equipment market, projected to grow from **€2.57 billion to €3.43 billion by 2033**, together illustrate the parallel advancement of digital integration and operational automation.

> "Europe's mining transition is driven by structural demand, regulatory pressure, and accelerating digital adoption."

From insight to implementation

Delivering digital mining transformation requires alignment across research, policy and funding stakeholders. A data-driven framework connects these dimensions, translating potential into performance.

Vision and Strategy

Set evidence-based priorities aligned with operational outcomes and policy direction.

Financing and Support

Mobilise public and private investment to accelerate responsible innovation.

Execution and Governance

Ensure transparent collaboration and compliance throughout deployment.

Digital Leverage

Use analytics and infrastructure to scale impact and measure results.

Together, these elements provide a pathway for transitioning towards integrated digital mining operations, linking technological development with regulatory and investment frameworks.

> "Transformation happens where evidence, investment, and execution converge."

Case examples in action

DINAMINE has actively pursued a structured approach to clustering activities, positioning itself within a broader ecosystem of EU and international initiatives. This effort aimed at fostering collaboration in key areas such as mining innovation, digitalisation, and sustainability, ensuring that project outcomes are not developed in isolation but rather contribute to a collective advancement of the sector.

DINAMINE has anchored itself within a dynamic network of complementary initiatives. These connections have enabled the project to both contribute to and benefit from a shared pool of expertise, reinforcing synergies across different R&I actions. Among sister projects and engaged clusters:

- MASTERMINE
- MINE.IO
- NETHELIX
- the SMART ECOMINE HUB
- the DIGIRAW Cluster

As a result, DINAMINE has been able to build a robust and well-connected network of related projects, facilitating continuous knowledge exchange and mutual learning for all relevant stakeholders. This collaborative environment has not only enhanced the quality and relevance of project outcomes but has also significantly increased DINAMINE's visibility at both European and international levels.

Beyond networking, these clustering activities have translated into tangible contributions to the wider ecosystem. DINAMINE has played a role in supporting standardisation efforts for the mining industry, promoting cross-project learning, able to further ease the penetration of digital technologies in the sector.

At the same time, joint dissemination actions have amplified the reach and impact of project results, contributing to a more coherent and interconnected European mining innovation landscape.

Collectively, these initiatives demonstrate how data transparency, shared infrastructure, and policy alignment convert research investment into measurable value.

> "When collaboration meets insight, innovation scales from pilot to system-level impact."

Ecosystem Positioning in a Concentrated Innovation Landscape

The mining innovation landscape reflects a concentration of activity in digitalisation and operational optimisation. Analysis of publicly funded R&D projects identified **59 relevant initiatives since 2017**, with approximately **42% focused on software solutions** and **59% addressing performance and productivity improvements.**

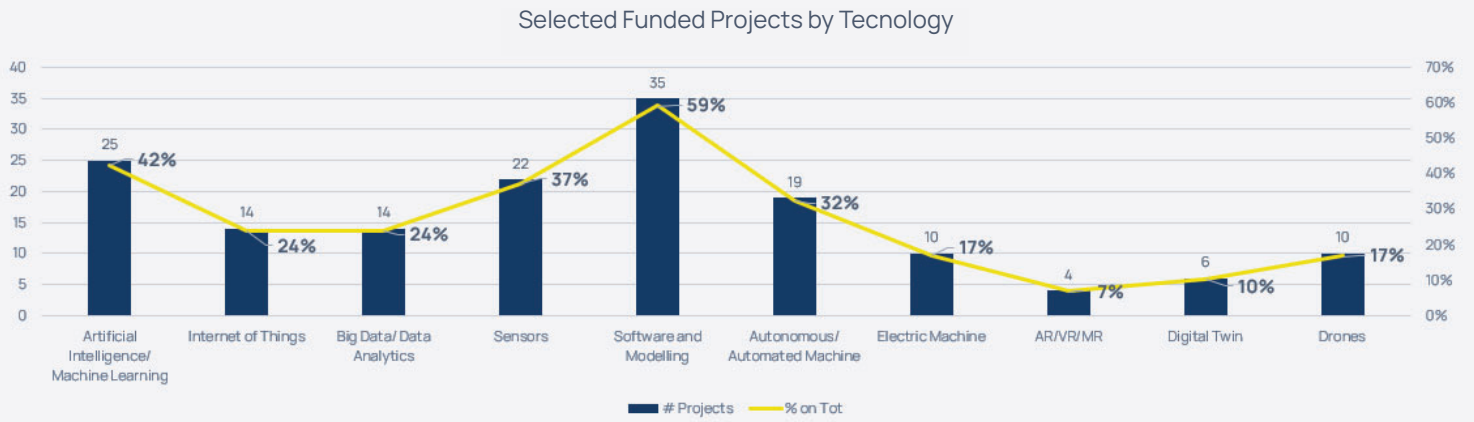


Figure 3: Technologies developed by selected projects

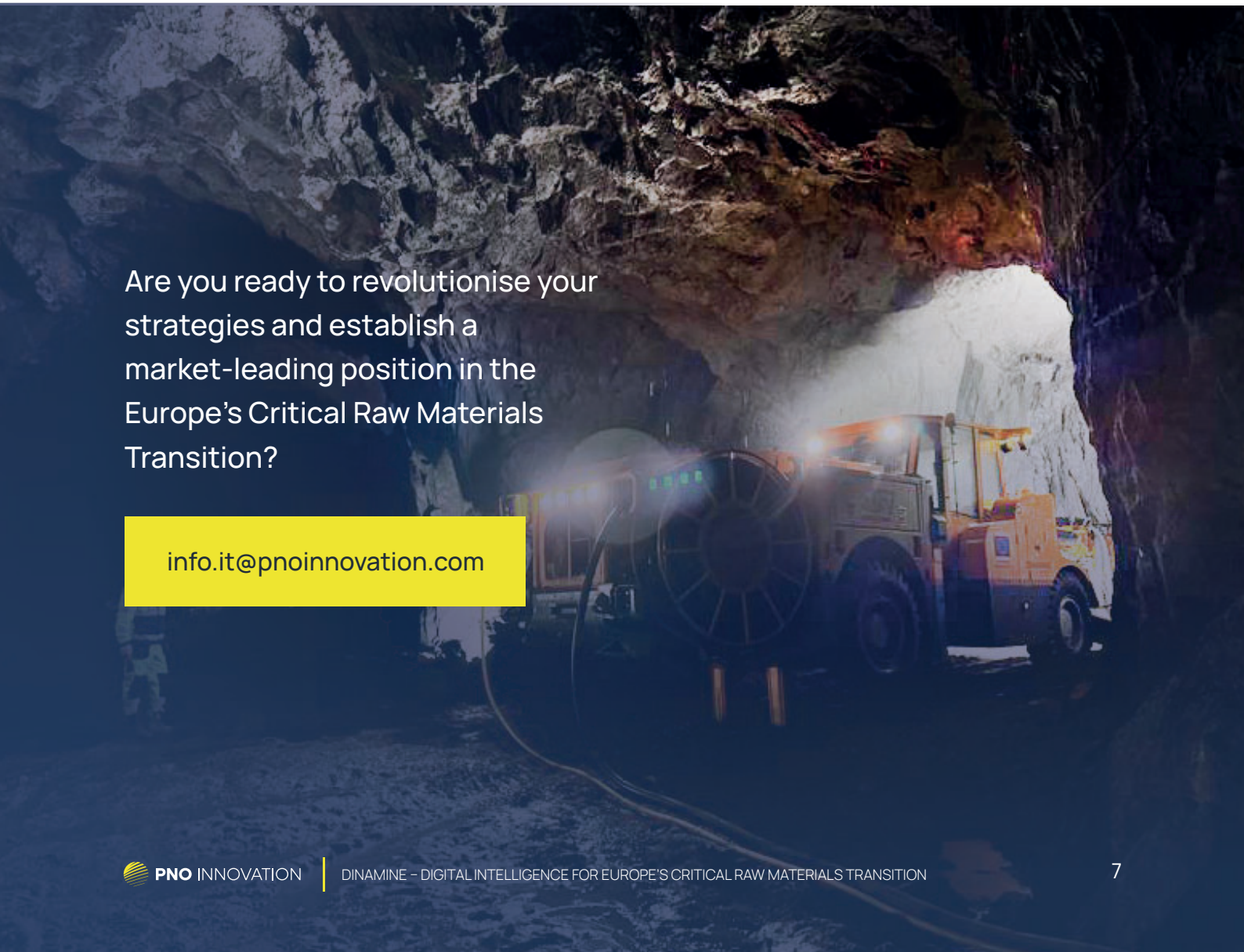
Private investment trends reinforce this direction, with approximately **16% of total mining investments** directed toward digitalisation and over **€16 billion invested** between 2017 and 2023. Software for mine planning and management captures the largest share.

Figure 4: Overview of private investments in the mining sector targeted towards digital transformation

Patent activity is concentrated among large equipment and software providers, particularly in mine planning software and autonomous drilling technologies, reflecting a competitive and hierarchical innovation landscape.

In such an environment, solutions that integrate fragmented systems or address underserved SME segments are particularly relevant. This highlights the importance of aligning technological development with clearly defined market needs, particularly in a landscape shaped by concentrated investment and technological specialisation.

> "Competitive advantage in mining is increasingly shaped by ecosystem positioning, investment concentration, and technological specialisation."



Are you ready to revolutionise your strategies and establish a market-leading position in the Europe's Critical Raw Materials Transition?

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Integrated mine intelligence and semi-autonomous precision

Addressing persistent industry challenges—including data fragmentation, operational inefficiencies, declining ore grades, rising energy costs, workforce safety risks and increasing ESG obligations—requires integrating digital intelligence with operational execution.

Integrated smart mine planning and management (ISMPM)

- The Integrated Smart Mine Planning and Management (ISMPM) system is a holistic platform integrating data across the mining value chain, from exploration to reclamation. It utilises real-time data analytics, artificial intelligence and predictive modelling to enable centralised performance monitoring and address data fragmentation across mine departments.

  Core capabilities include real-time performance monitoring across mine-to-port operations, predictive maintenance, environmental impact tracking (including CO_2 emissions and energy usage), and centralised data visibility across departments.

Semi-automated jumbo drill (JD)

- The semi-automated Jumbo Drill (JD) is designed for underground and open-pit mining environments and integrates 3D imaging and Measuring While Drilling (MWD) technologies to improve ore-body mapping and drilling precision. It enables semi-autonomous operation with real-time feedback and integrates with ISMPM for seamless data flow.

  Additional capabilities include enhanced safety through reduced human exposure, as well as support for selective extraction and blast optimisation.

A value chain integration model positions the ISMPM system across exploration, mine planning, operations and processing, acting as a digital backbone linking software layers, equipment, connectivity infrastructure and regulatory interfaces. The semi-automated Jumbo Drill is positioned as a bridge between manual drilling and fully autonomous systems.

> "Integrated digital platforms and semi-automated systems are bridging the gap between data intelligence and operational execution."

Assessing adoption momentum in European mining

Adoption patterns indicate that mine planning software has reached significant maturity, with **up to 48% of surveyed mines reporting full implementation**, while remote-controlled and robotic equipment adoption remains comparatively lower. Growth is strongest in digital integration, real-time analytics and automation, reflecting increasing demand for data-driven capabilities across mining operations.

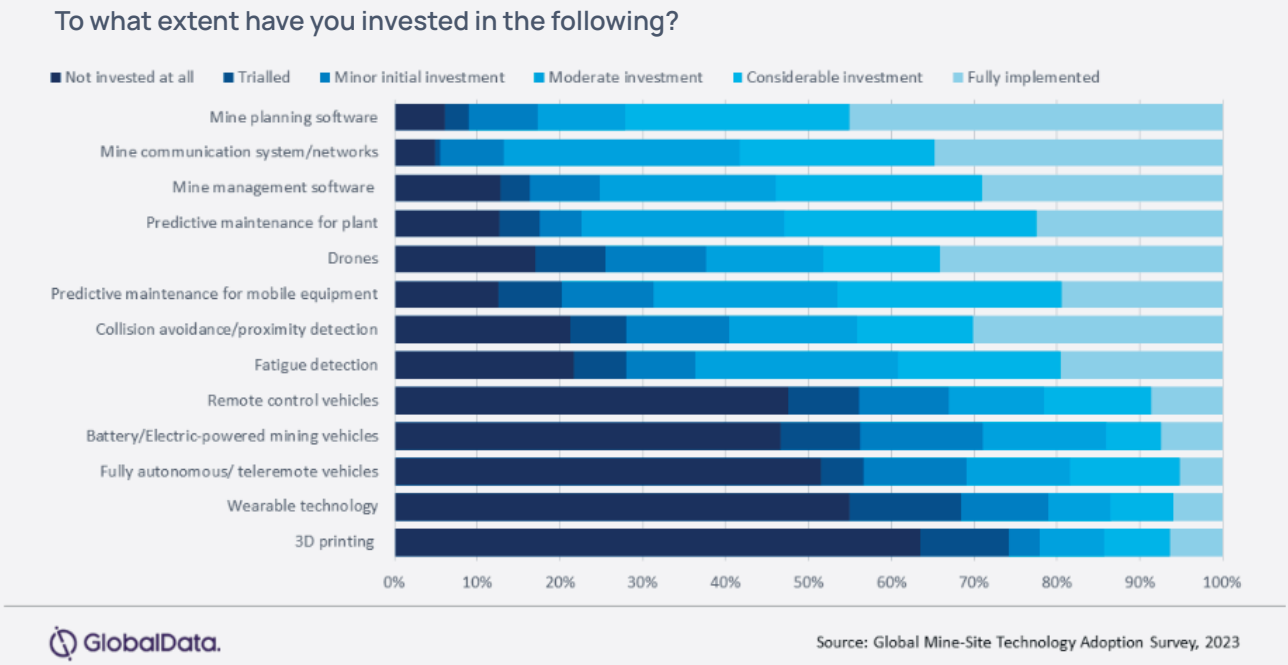

Figure 5: Level of implementation of digital technologies

Adoption is driven by rising operational costs, declining ore grades, ESG compliance requirements, workforce safety priorities, and demand for real-time data and predictive capabilities. Barriers such as high CAPEX and OPEX requirements, interoperability challenges, workforce reskilling needs, and cybersecurity risks continue to shape implementation pathways.

Effective market positioning depends on clear ROI articulation, modular deployment pathways, and alignment with regulatory and sustainability frameworks. Technology Market Outlook analysis and ecosystem mapping support informed decision-making in this environment.

> "Strategic positioning in mining now depends on aligning data, operations, and regulatory readiness."

Partnering for sustainable critical raw materials

Within DINAMINE, PNO contributes through Technology Market Outlook analysis and stakeholder ecosystem mapping under WP7, supporting the positioning and adoption of digital mining solutions in evolving market environments.

Mining operators seeking to strengthen operational intelligence, reduce environmental footprint and align with evolving European regulatory frameworks are invited to explore collaboration in integrated digital mine transformation.

For decision-makers, three priorities are clear:

1
Supporting ESG-compliant and data-transparent operations

2
Enabling SME-accessible digital transformation

3
Integrating mine planning and semi-autonomous execution layers

"The future of mining will be shaped by intelligent integration—aligning data, operations, and sustainability to deliver measurable and compliant outcomes.Strategic positioning in mining now depends on aligning data, operations, and regulatory readiness."

References

Allied Market Research, Smart Mining Market (2020–2027).
https://www.alliedmarketresearch.com/smart-mining-market

Boston Consulting Group (BCG), Racing Toward a Digital Future in Metals and Mining.
https://www.bcg.com/publications/2021/adopting-a-digital-strategy-in-the-metals-and-mining-industry

Coherent Market Insights, Smart Mining Market Analysis & Forecast: 2026–2033.
https://www.coherentmarketinsights.com/market-insight/smart-mining-market-4672

GlobalData, Mine site investment in safety-related technologies rising, says GlobalData.
https://www.globaldata.com/media/mining/mine-site-investment-safety-related-technologies-rising-says-globaldata/

Hitachi, The smart mine blueprint: A digital path to more productive, safer and greener mining.

Transparency Market Research, Smart Mining Market.
https://www.transparencymarketresearch.com/smart-mining-market.html

Zhironkin, S.; Gasanov, M.; Suslova, Y., Orderliness in Mining 4.0. Energies, 2022, 15, 8153.

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