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I4 MINING

Solving the ESG Conundrum: Industry 4.0 Technologies' Role in Enabling Miners to Achieve their Strategic Zero Harm, Zero Waste & Zero Carbon Objectives.

How Industry 4.0 technology enables miners to achieve their strategic environmental & community sustainable development goals.

ESG takes center stage.

The lifecycle of a mine is a multi-faceted, complicated thing.

At all stages, the environment and the community that exists around sites are affected and impacted in multiple, evolving ways - and the sector's footprint is significant.

Mines cover 57,277km2 of the earth's surface*, consume 3% of the world's water †, and account for 4% - 7% of greenhouse gas emissions globally ‡. Every year, 61.1bn tons of metal ores, fossil energy, and non-metallic minerals are extracted, up 55% in 20 years, with an additional 20.5bn tons of biomass removed Ω.

Regulatory limits, industry standards and judicial intervention have, therefore, been used to shape miners' environmental approach over the last century. The Environment Protection and Biodiversity Conservation Act 1999 in Australia and National Environmental Policy Act of 1969 in the US - to name just a two pieces of federal legislation (international, state and local legislation, as well as individual site agreements have all played a role, too) - have impacted miners' policies and ensured that the environment is considered across operations.

Continued overleaf.

* Source: Maus, V., Giljum, S., Gutschlhofer, J. et al. A global-scale data set of mining areas. Sci Data 7, 289 (2020)
† Source: Australian Bureau of Statistics, 1301.0 - Year Book Australia, 2003
‡ Source: McKinsey: Climate risk and decarbonization - January 28, 2020
Ω Source: https://www.theworldcounts.com/challenges/planet-earth/mining/environmental-impacts-of-mining/story

Contents.

Adhering to these rules is expensive. Compliance with environmental regulation costs the industry AU$1.5bn per year in Australia alone* and whilst many countries' regimes vary in strictness, as well as whether they adopt a 'polluters pay' approach, the cost to miners is significant.

In past decades, compliance with national regulatory frameworks has been enough and the sector - despite the many detractors - has actually been at the vanguard of promoting ESG and sustainable development, but compliance and old approaches are no longer sufficient: miners and the businesses that serve them need to do more - and they know it.

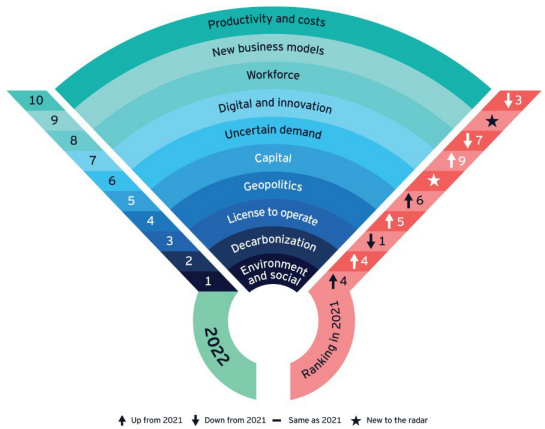
In the most recent report of its nature by EY, 'Top 10 Business Risks and Opportunities for Mining and Metals in 2022', global mining executives ranked Environment, Social and Governance (ESG); Decarbonization; and License to Operate (LTO) as the top three risks/opportunities facing their organizations over the next 12 months - above challenges related to capital, uncertain demand, workforce, productivity and digital/innovation. White & Cases' 2021 report 'Mining & Metals Market Sentiment Survey' said much the same thing.

Why?

There are many answers to this. Outside of medium-to-long-term zero carbon arrangements (such as the Paris Agreement and individual state/national targets), the societal and political zeitgeist has evolved to a point where, although the sector's role in achieving energy transition is undeniable, it needs to do more. The consequences of missteps have grown significantly at both a corporate and individual executive level (see Rio Tinto's experience at Juukan Gorge or Vale's at Córrego do Feijão) and miners' ability to expand or open new sites are now subject to stricter LTO and capital requirements that factor in short, medium and long-term ESG risks.

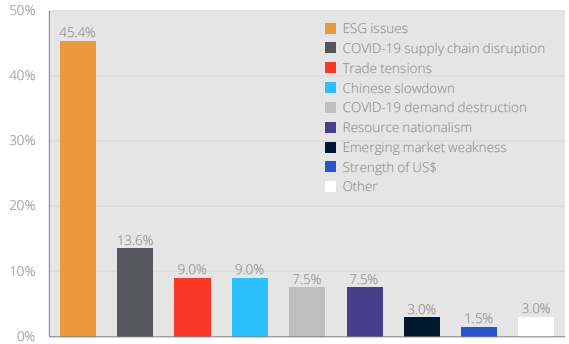
The sustainability of the sector and success of the people that work within it are now even more directly tied to the environment and the community that surrounds their operations.

"Our success as an industry is not only measured by the ounces, carats, or tons we mine, it is also measured by whether we improve people's lives."
Mark Cutifani, CEO,
Anglo American



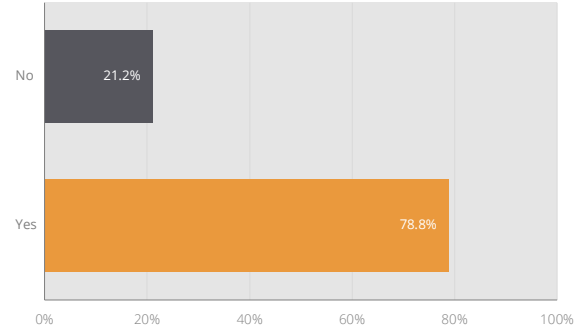
Source: EY Top 10 Business Risks and Opportunities for Mining and Metals in 2022.

What is the key risk for mining & metals in 2021?



Source: White & Case2021 Mining & Metals market sentiment survey.

Following COVID-19, do you expect ESG issues to play a greater part in investors' deal-making?



Source: White & Case2021 Mining & Metals market sentiment survey.

* Source: CSIRO https://www.csiro.au/en/work-with-us/industries/mining-resources/social-and-enviromental-performance/minesite-environmental-management

The challenge (and benefits) of an enhanced ESG focus.

Much of the world's easily mineable sites have already been tapped and new locations with minerals of sufficient volume and quality to warrant investment are generally in either more environmentally sensitive areas, may be in direct conflict with the needs of the local population, or are in parts of the world considered difficult to do business.

Nearly all of the world's major miners have committed to net-zero carbon targets by 2050 (or sooner), have a raft of ESG strategic initiatives (including zero harm goals), and are ploughing significant amounts of time and expense into transforming (and ensuring that they are being seen to do so).

Whilst there is a real risk that if miners don't start moving the needle themselves that someone else might start setting targets which are somewhat more challenging (and costly) to achieve - or that they may leave themselves open to new 'disruptive' technologies, such as scrap utilization - there are significant benefits to adopting an enhanced ESG footing beyond decreasing risk and avoiding interference from investors and governments.

Data is beginning to emerge that suggests that businesses with an ESG focus are outperforming those without it - and did so even throughout the global pandemic (see chart to the right).

The bottom-line, quite literally, when it comes to ESG initiatives is that operations that are more efficient are more productive - a fact that...

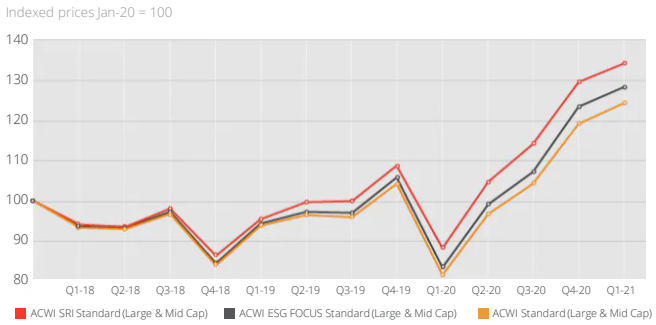
...shouldn't be a surprise given we were all taught The Second Law of Thermodynamics at school. In achieving efficiency, you reduce the volume of unwanted byproducts, find new ways of operating, and increase output - i.e. you lessen the negative impact on the environment and increase profits.

For miners, there are many benefits:

- Reduce inputs - water, chemicals and everything else that goes into day-to-day operations comes at a cost. If efficiency is improved, you lessen the amount used or find ways of recycling, directly impacting the bottom-line and profitability of an operation.
- New outputs - new technologies and techniques are making it possible to find value in previous waste products, such as tailings, which reduces environmental impact and increases outputs.
- Extend LTOs - by proving green credentials and making mining operations more transparent, miners can find it easier to get new or extended LTOs, meaning that output, lifespan and productivity rates of existing operations can be extended.
- Cheaper energy - initial CAPEX to set-up on-site energy generation via renewables comes at a cost, but on sites that have a long or even medium-term future, this can pay itself back multiple times.
- Reduced workforce - people are a significant OPEX. By leveraging automation technologies and robotics, you make environments safer and reduce the need for in-field personnel.
- Enhanced production - production processes that are geared towards efficient, maximum-yields inevitably reduce the number of unwanted byproducts that could be environmentally detrimental and increase productivity rates.
- Longer asset lifespans + reduced maintenance costs - modern electric plant, machinery and equipment have fewer moving parts. This means they'll operate for longer with fewer interventions and produce the new lifeblood for the sector: accurate, real-time data.

Poor ESG performance adds risk. Industry 4.0 technology can mitigate this and will play a growing role in enabling miners to seize on new benefits; achieve their zero carbon, zero harm and zero waste goals; and evolve to be ready for the ever-more environmentally conscious future that awaits us.

Relative performance of companies with an ESG focus.



Source: S&P Capital IQ, MSCI.

Industry 4.0 and its role in ESG: it's not about a single solution.

The fourth industrial revolution - where businesses build upon their use of computing power and automation with the adoption of intelligent, autonomous systems that can leverage complex data sets and machine learning to deliver AI-driven enhancements in real-time - is critical if miners are to achieve their strategic and operational ESG goals.

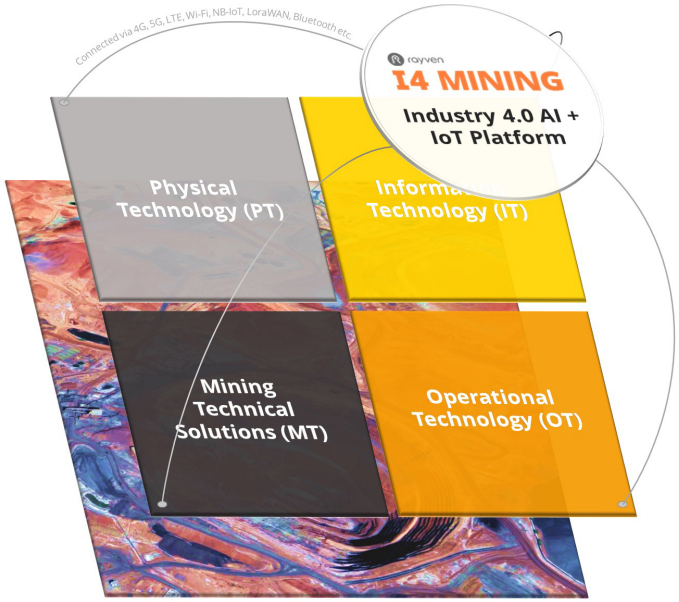
There is a vast array of 'Industry 4.0 ESG solutions' available. From new forms of IT and Mining Technical solutions (MT), to Physical Technology (PT) and Operational Technology (OT); all boast outcomes that deliver on efficiency, real-time monitoring, productivity and other business goals.

What these individual solutions and technologies cannot do on their own, though, is deliver holistic change, enhance the ESG footing of every part of your operations, or fuel the attainment of strategic zero harm, zero carbon and zero waste goals. This is because they are either too siloed, too narrowly focused, or cannot access and process all of the necessary data to do so.

What these individual solutions do deliver, though, is the additional functionality that's needed to either deliver on Industry 4.0 transformation or deliver on the changes that have been identified by it. For example, real-time environmental monitoring systems are great to track compliance on multiple measures, but it's not capable of analyzing current performance, upcoming weather and work patterns, and then predicting when there is going to be a breach of these limits.

In order to improve operationally and meet strategic goals, it's necessary to analyze 'Big Data' sets that look at *all* the variables that go into particular targets, compare it with other events and historical data sets, analyze work and personnel schedules, third party data (such as weather conditions), planned future usage, and much more to uncover commonalities and trends, and predict risks and direct optimizations.

To do this, miners need to adopt a new piece of technology that can sit in the middle of every Industry 4.0 business and/or operation to analyze and orchestrate: an integrated AI + IoT platform.



An integrated AI + IoT Industry 4.0 platform sits in the middle of your technology and operations. It integrates with all your other systems, platforms and data stores, offering extreme interoperability and creating a single source of truth through which you can analyze data, apply machine learning, seize optimizations either manually or via AI-led control, and much more.

An integrated AI + IoT platform is capable of a supremely high-level of interoperability, connecting to every possible system and data source, before then analyzing all of the data that's coming from them (plus other systems or data sources inside and outside your organization) to identify trends, relationships and insights hidden in the 'Big Data' that you're accumulating in real-time. The platform can also be programmed to take direct action based on pre-programmed business logic or via AI-led intervention to prevent harm or identify where and how a business (or individual employee) needs to improve, optimizing on an ongoing basis based on changing variables and performance.

The AI + IoT platform is critical because it's the one place in an organization where all of its data (both historical and real-time, from any system, sensor or data lake) can flow and be standardized for analysis, where machine learning algorithms can be leveraged, and where cross-functional decisions - made by human or AI - can be orchestrated and executed: it's an Industry 4.0 organization's brain.

You don't give an AI + IoT platform a specific job to do - you give it a business or ESG objective that you want to achieve and let it uncover (and action) the way to achieve it.

This makes the path to achieving Industry 4.0 status one that involves a suite of use case-specific solutions that can be deployed and then integrated with one another piece-by-piece, function-by-function. It's not about a single technology in isolation, but the amalgamation of multiple solutions which are integrated together (along with legacy technology) via an integrated AI + IoT platform to share data, analyze it to deliver predictive insights, and then enable real-time action to be taken to improve or prevent harm via human or AI-led intervention.

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Why Industry 4.0 is about AI and IoT.

IoT and AI technology are distinct sets of interrelated technologies in the context of Industry 4.0 technology. To simply delineate the two:

IoT: Collecting the right data. ✚ **AI:** Using machine learning to do something with it.

IoT: IoT or IIoT (Industrial Internet of Things) technology enables miners to collect real-time data about their operations via infield sensors; through links from OT, MT, PT and IT; as well as via third party resources (such as weather forecasting). This data then enters a platform through which it is combined and can be examined via dashboards to assess performance in real-time, and sometimes even execute simple automations based on 'if this then that' business logic.

On its own, IoT presents miners with opportunities for transformation and improvement, removing the need for people to enter hazardous environments to take measurements or enabling all-new environmental data sets to be recorded, but it cannot deliver true Industry 4.0 transformation on its own as it lacks the critical decision-making and predictive analysis required to meet the definition.

AI: The AI element of an Industry 4.0 solution is about the applications and subsequent actions taken as a result of the use of machine learning algorithms being applied to the data sets collated using IoT technology and the platform's other integrations.

To operate, you need to have in place a way to record and compare the interactions of all of the potential variables that go into an operation - which could be hundreds of terabytes of data everyday - so that machine learning algorithms can be applied to the data sets to spot trends, relationships and uncover optimizations.

For Industry 4.0-status and strategic goals to be reached, this needs to be done in real-time, with interventions executed through automation before they're lost or before they occur, e.g. preventing accidents etc. Over time (and with growing data sets) machine learning algorithms find new and more effective ways to operate - they get better - and multiple ones can be applied to the same data to experiment with new use cases or to test alternative approaches (via digital twins).

It is with the combination of AI + IoT that we get to the heart of what people mean by Industry 4.0 status: having operations that utilize machine learning-led automated interventions in real-time that self-optimize over time on an ongoing, incremental basis.

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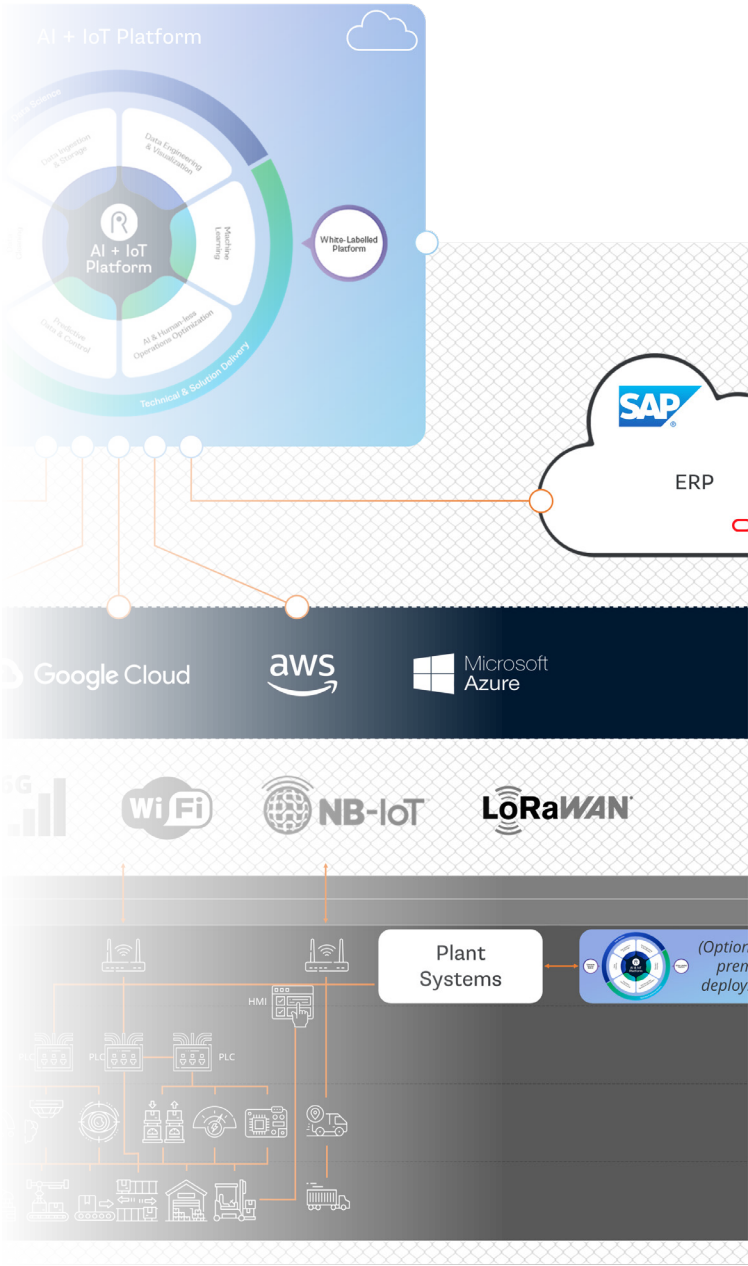


ESG Industry 4.0 AI + IoT platform use cases.

The modern approach to mining using best practices when it comes to ESG* involves:

a) The establishment of a pre-mining baseline from which to monitor environmental effects (and their impact on people) during mining and help establish geologically reasonable closure goals;
b) The identification of environmental risks related to mining through standardized approaches; and
c) The formulation of an environmental closure plan before the start of mining.

Whilst analyzing Industry 4.0 AI + IoT use cases, it would be easy to segment and silo them into each stage, however that undermines the full-cycle role that the technology has.

Environmental harm can occur at any point from multiple sources, and whilst there may be a novel (or old) technology that can solve these individual occurrences, when talking about Industry 4.0 AI + IoT technology, what we're really trying to do is provide new ways to analyze risk holistically (using machine learning) and then improve functions to achieve a strategic business objective (not a technology one) based on that analysis.

Therefore, to explore the application of Industry 4.0 technology in mining, it's important to focus on operational areas where the application of an AI + IoT platform can have significant impacts, rather than the analysis of a particular technology (such as drone usage or driverless technologies).

* Source: Environmental Considerations Related to Mining of Nonfuel Minerals, US Department of the Interior and the US Geological Survey, 2017.

Enhanced operational performance:

Production improvements. The use of Industry 4.0 AI + IoT technology in the manufacturing sector has been widespread and many of the optimizations and efficiencies that it provides can be directly adopted by the mining sector during refinement, processing and production. From finding energy efficiencies, improving yields, OEE optimization, all the way through to predictive maintenance and downtime prevention, the technology can help miners to increase efficiencies and adopt optimal processes that reduce waste and the environmental impact of activities.

Reduce waste. Through the use of an AI + IoT platform, it's possible to identify where further resources can be extracted from waste materials, reducing environmental impact and improving productivity. For example, it can direct miners to tailings where valuable resources exist in quantities that make it cost-effective to extract or identify where in situ leaching or recovery (ISL / ISR) opportunities exist.

Recycling. The circular economy is a growing narrative and the mining sector, like many others, can take advantage of it - fueled by Industry 4.0 technology. From using advanced analytics to review and revisit waste material from historical operations with a view to reprocessing them with modern techniques, identifying what removed material can be used safely for construction and other purposes, and working with the wider value chain, in particular with metal reprocessing facilities, mining companies can find more value with minimal additional inputs and reduce waste.

Better waste management. Mining creates a lot of spill, tailings and other waste which, if improperly handled, can have serious environmental impacts. Industry 4.0 AI + IoT technology can enable miners to monitor how it is being handled in real-time, scrutinizing process adherence, plant and personnel performance, and ensuring that the tonnage of waste expected arrives where it should (reconciliation), whether it's being treated/incinerated/stored properly, and assess whether there are potentially alternative ways of utilizing byproducts to reduce waste.

Immediate, automated mitigation + remediation. Industry 4.0 AI + IoT technology that utilizes real-time data can provide miners with rapid, effective direction (as well as automated interventions) should the worst occur and an unexpected environmental event happen (or be about to). Learning from modelling and previous learned performance, the platform can leverage situational data and find better ways to mitigate unwanted outcomes, as well as monitor critical environmental measures in real-time to prevent breaches and harm from occurring via manual or AI-led automated interventions.

Manage shared infrastructure. One way of reducing costs associated with mining and investing in the community is to leverage shared infrastructure. Industry 4.0 AI + IoT platform technology makes this possible at a practical level, allowing for the better scheduling of usage, monitoring of maintenance needs, as well as uncovering the most efficient (and effective)...

...way of running it. In some places, it will be possible for the renewable energy infrastructure created to supply a mine with electricity to feed into the local grid and/or subsidize the local community's energy usage, for example.

Resource discovery. The use of drones to better map topographical (as well as underground) sites, leveraging of third party data, as well as in-field sensors and collected geological data; make it possible to leverage AI + IoT technology to identify where on a site the best (and most profitable) material is, explore the different ways of extracting it, and predict the potential environmental impacts of each of them to find the best, most long-term cost-effective locations and methods of extraction.

Energy efficiency. Ventilation represents a huge cost in underground mines, but are critical in ensuring a safe working environment by removing fumes, gases and smoke, as well as in controlling temperature. An AI + IoT platform can be used to forecast peaks, automatically adjust ventilation systems and find improved operational schedules. The result is that systems don't necessarily need to run around-the-clock everywhere and can save up to 40% of energy costs*.

Industry 4.0 AI + IoT technology that utilizes real-time data can provide miners with rapid, effective direction.

* Source: Natural Resources Canada, 2016 via the OECD's 'Mining and Green Growth' report.

Plant electrification + hydrogen fuel cells.
The benefits of electrifying assets or moving to Hydrogen technology have been widely discussed. Whilst not a panacea to achieving ESG initiatives, it will go a long way in reducing carbon and other harmful gas emissions, creating safer working environments and adding to efficiencies - as long as the power that's being used to drive it is from renewable or zero carbon sources. Goldcorp's Borden mine in Ontario, Canada has been completely electrified. This demands a 25-30% premium on the cost of equipment (although this will reduce in time), but the savings over the long term are significant with Goldcorp expecting to save CA$9m annually in operational costs from lower diesel use as well as a 70% reduction in greenhouse gas emissions.

Autonomous plant + automation.
Autonomous vehicles have been operating in mines for many years and have demonstrated fuel and efficiency savings, kept people out of harm's way, and made a positive impact on measurable ESG goals. There are numerous assets and plant that are yet to be transformed, as well as new use cases to be explored, such as with predictive maintenance. At Vale's Brucutu site in Brazil, the company estimates that automation is increasing plant lifespan by 15%, whilst fuel and maintenance costs are decreasing by 10%*. The growth of the technology, coupled with an AI + IoT platform will enable new optimal processes to be modelled and implemented – in real-time – as well as provide predictive insights that will offer new productivity, safety and efficiency benefits that enhance bottom-line results and environmental measures.

Optimal plant configuration. An Industry 4.0 AI + IoT platform can be leveraged to provide real-time, ongoing plant optimization based on real-time data being collected from it and the wider environment. For example, should a piece of machinery be expelling excessive amounts of fumes or vibrating too much, configurations can be adjusted to run the machinery more efficiently, resulting in reduced risk of a failure, environmental harm, and improving efficiency.

Real-time catastrophic failure prevention.
Real-time monitoring of assets and plant, even with the use of predictive machine learning algorithms, need time and large data sets to be able to predict things 100% accurately (and it's arguable whether it can go beyond 99.9%). Therefore, using an AI + IoT platform, it's possible to analyze the real-time data measures and implement fail-safe plant shutdowns should a catastrophic failure be impending by understanding operational norms, the outcome of previous breaches of them, and by being able to identify from real-time measures where recovery won't be possible; directing machinery to shut down immediately via automated intervention. This can stop major environmental (and safety) events before they happen.

* Source: OECD Green Growth Studies: Minin and Green Growth in the EECCA Region 2019. ISSN: 22229523.

Real-time employee, environment & plant monitoring:

Real-time environmental monitoring.
Perhaps the most obvious use of the technology, an Industry 4.0 AI + IoT platform enables you to unite real-time data feeds from sensors on-site, with internal systems and third-party data sources to provide miners with accurate, real-time environmental measures that enable them to more accurately gauge baseline values prior to opening a site, as well as during operation and post-closure. Leveraging the data, the platform can additionally provide predictive insights based on current operational models so that miners can judge future environmental performance. It also unlocks the potential for many other benefits, such as: fault and leak detection, geo fencing, reduced energy consumption, operator environmental and safety scoring, proximity real-time alerts, compliance guidance, remote tracking, plant class comparisons, pinpoint environmental areas of concern, improve maintenance regimes, and much more.

Better conversations with community + regulators. With real-time environmental monitoring in place, it's possible to have better conversations with the people that are or will be impacted by operations. From providing real-time data feeds that demonstrate conservatorship through to accurately forecasting impacts and how post-closure remediation efforts are performing, conversations with community and regulators can be realigned and occur around actual current data and the accurate forecasts being provided from the AI + IoT platform.

Accurately monitor + measure entire global mining supply chain. An Industry 4.0 AI + IoT platform enables miners to get a complete, holistic view of their entire global supply chain in real-time. Via extreme interoperability, the platform can leverage any data source, no matter where it sits. This means that real-time data feeds from the wider supply chain can be leveraged, including real-time data from assets retrofitted with cheap IoT sensors, to provide miners with complete visibility of their supply chain and environmental performance.

Time to failure + predictive maintenance. There are many things that go into the failure of plant, machinery and equipment, but the environmental (and safety) impact of them can be severe. Poor operation, different terrains, as well as the failure of individual parts all have a role to play. With real-time monitoring of plant and the use of predictive algorithms that can utilize data from multiple sources, such as real-time temperature and vibration measurements coupled with forthcoming usage and operator schedules, it's possible to predict when an asset is going to fail, why and what the remedy is. This not only makes it possible to predict when plant needs to be serviced (versus when it's scheduled to be, simply because it's been 6 months since its last check), but also identifies what the fix is (reducing maintenance crews time in the field) and prevents the development of problems that could cause hazardous failures. This means fewer interventions, greater efficiencies and a lower environmental impact.

Standard operating procedure adherence + safety margins. Putting in place all of the safeguards and procedures needed to achieve zero harm is always going to be ineffective if incidents aren't reported, standards aren't followed or if the safety margins that they are based upon are insufficient. Through real-time monitoring of operations, including plant and people, it's possible to identify where deviations are occurring, where margins are insufficiently strict (or even where they're too constraining), as well as pick up on the small incidents that may never make it onto incident reports but which, occurring repeatedly over time, may be a key lead indicator of a problem that could have potentially more catastrophic consequences.

Deliver proximity alerts + real-time Permit To Work. Many injuries and environmental harm occurs on site due to people being in the wrong place at the wrong time, doing something that they shouldn't be, or through an unforeseen failure resulting in an action, such as inundation, gas explosion or rock fall. An AI + IoT platform enables miners to, via the use of wearables and the real-time monitoring of environmental and mine conditions, aggregate data in real-time and identify when something is going to occur, sending alerts to personnel or automatically stopping plant.

Inventory & waste monitoring + reconciliation. Mining uses many potentially harmful chemicals (some of which are controlled) and creates hazardous waste which, if released or stored in the incorrect circumstances, can cause huge amounts of environmental harm. An advanced AI + IoT...

...platform enables miners to accurately track their usage, how it is being handled across supply chains, monitor storage conditions, and reconcile its use across sites.

Water treatment monitoring. Large amounts of water is utilized at different points of the mining lifecycle, as well as with certain extraction techniques. Modern mines process and treat water on-site before reusing it and/or discharging it into the environment. Through the use of an Industry 4.0 AI + IoT platform you can monitor performance in real-time, identify process optimizations, and identify where further treatment may be necessary before discharge, avoiding harm.

Fill data gaps in ecological + hydrological knowledge. Much of the impact that mining may have on the environment isn't definitively known. What's more, different geologies, topographies, fauna, flora, weather patterns etc. all have a unique impact on a particular operation. Through the use of Industry 4.0 technology and an AI + IoT platform, it is possible to measure much more accurately data from in-field sensors, business systems, as well as third party data to establish new, accurate measures which will enable miners to better predict the impact of operations, measure operations in real-time, and then monitor the effect of remediation efforts long after closure. An example of this in action is with Glencore's drone usage to monitor NO2 fumes from blasting In real-time; not only are they learning more about the dynamic nature of blasts so that they can predict future outcomes from further activity, but it has removed much of the uncertainty around NO2 creation...

...which was previously based on visual inspection of blast footage*.

Establish real-time employee safety + environmental scores. Through the analysis of real-time data monitoring via wearables, comparing it with environmental measures and operational understanding, it's possible to monitor employee performance based on the individual aspects of their role, such as how safe they're being. This could help identify when, for example, an employee is tired or beginning to make small mistakes and could be about to come to harm, whether they're consistently following required compliance norms at any given moment, or if they have a 'heavy foot' and are using more energy than other operators. In one trial, by providing operators with direct feedback based on how they were driving their trucks, they were able to limit peak speed, reduce short stops and restarts, and avoid abrupt braking and strong acceleration - in just eight weeks, fuel consumption dropped by 7%†.

Enhanced safety walks + environmental inspections. The real-time, remote monitoring of environmental and mine measures is a more accurate, safer way of conducting critical safety and environmental procedures. Taking this a step further, you can use machine learning to predict how these variables are affected by third party data (such as weather) or your operations, providing you with real-time analysis that identifies problems in the afternoon that weren't there in the morning, or that can predict the development of risks.

* Source: Safe to Work Magazine, https://safetowork.com.au/glencore-receives-recognition-for-safety-and-environment-initiatives.
† Source: BCG: Mining Value in AU, 2017.

Holistic operational analysis:

Complete environmental performance transparency + accurate carbon accounting. Through the use of an Industry 4.0 AI + IoT platform, mining companies are able to more accurately monitor and track their carbon (and any other material's) environmental footprint through leveraging data from in-field devices, advanced plant, and business systems. This can be enabled to provide real-time insights, compared to benchmarks, and through the use of machine learning, future performance predicted across assets, personnel, sites and entire operations.

Improved Environmental + Social Impact Assessments (EIAs & SIAs). The collection of accurate data from multiple sites and the monitoring of environmental performance over time based on different operational factors enables miners to leverage historical data to better establish baselines for future EIAs and SIAs. Not only this, by leveraging exploration data and modelling, as well as future operational plans, an AI + IoT platform can provide miners more accurate predictive insights…

…that allow them to better plan their operations and post-closure remediation efforts.

Process optimization (Digital Twins). Current best practices in mining are reliant on doing the same thing, day after day; with every individual following the same steps, processes, and patterns. This makes the analysis of deviations in current practice in an attempt to find better ways of operating difficult because those are the very behaviors which are trying to be avoided. With digital twinning, it is possible to test new models or set algorithms with the task of analyzing all the current variables and finding better ways of functioning without risking harm, efficiency or productivity. This enables miners to explore low-impact mining techniques and impact of different rehabilitation efforts risk-free - as long as there is a way of measuring success, then any scenario can be tested.

Plant, mine, country + cross organizational analysis. The aggregation of data from multiple sources across an entire organization makes it possible to uncover best practices, identify…

…superior assets and plant (e.g. by brand, age, model etc.), as well as identify areas for improvement based on much larger data sets. This works at the short-term, site level, but also will improve the environmental results being made via longer-term optimizations (e.g. better staff training) and takes away the barriers that sometimes exist between departments and business units.

Remote operations + superior skill set identification. The application of industry 4.0 technologies to achieve the ability to operate machinery remotely and leverage superior skill sets is an obvious one. Through the use of detailed data analysis, it is also possible to examine individuals' performance who conduct similar functions in a business. By doing this, organizations can understand what it is that makes them better so that they can upskill a wider workforce, or even set-up remote control and operations rooms that enable top performers to conduct their highly-skilled roles across multiple sites without ever having to visit sites, again reducing secondary and schedule three environmental impacts.

Aggregated risk profiling. The operation of certain mining techniques might not be an immediate environmental hazard in itself, but it could be if the external temperature rises beyond norms or wind speed reaches a certain measurement. Using an AI + IoT platform you can create algorithms that can explore the impact of certain activities and provides the ability to create accurate, aggregated risk scores that can't and mightn't be foreseeable.

Improved emergency performance. Using an AI + IoT platform, it is possible to analyze how previous incidents occurred and the effectiveness of previous responses. By creating a score for each individual aspect, businesses can analyze where improvements can be made and decrease the likelihood of a spill becoming a major environmental event in the future.

Long-term performance pattern analysis. An Industry 4.0 AI + IoT platform makes it possible to analyze data sets across sites to identify and predict environmental performance. Through identifying patterns (such as how long it takes for an asset to start or whether it does better at a certain time of day), you can use these insights to further enhance environmental outcomes by changing shift patterns and ensuring that the correct personnel or skills are on-site at the right time.

Improved training. It's possible with an AI + IoT platform to monitor the impact of workforce training initiatives, identify what does and doesn't work, as well as spot individuals who need further support with environmental compliance by comparing the performance of employees both before and after training via the use of real-time monitoring and the aggregation of data from other sources, such as productivity and output measures.

Energy & fuel tracking + enhanced operational schedules. With large real-time data sets coupled with pertinent other data (such as outside temperature, operator action, maintenance regimes etc.) it is possible to utilize machine learning within an integrated AI + IoT platform to spot patterns and uncover the most efficient ways of operating individual pieces of machinery and entire operations. Taking this a step further, the insights delivered can be directly inputted into automated plant to seize benefits, via instructions and alerts to operators (in real-time) to slow down, for example, as well as other potential applications including rescheduling of usage to prevent restarts and short stops.

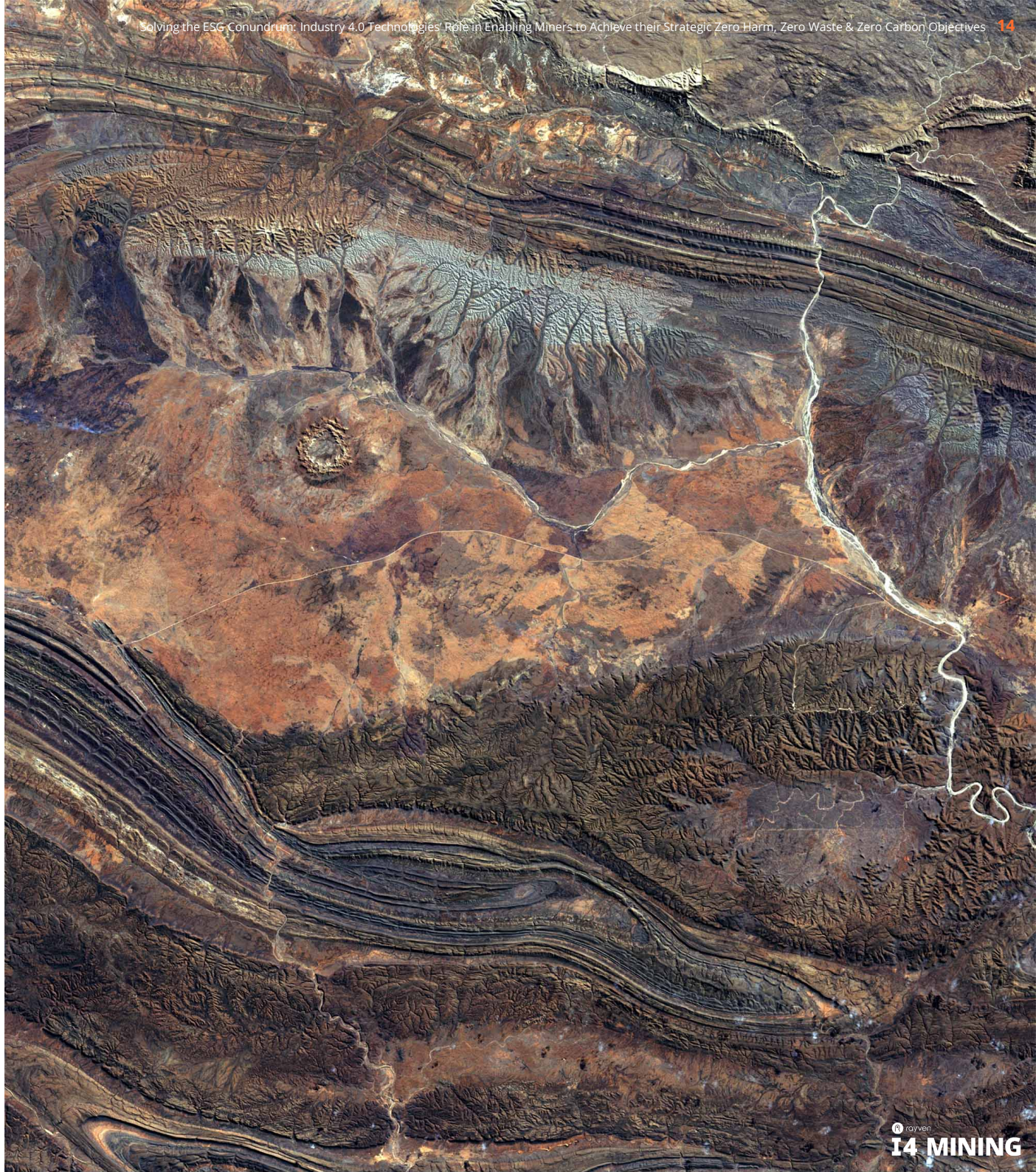
An Industry 4.0 AI + IoT platform makes it possible to analyze data sets across sites to identify and predict environmental performance.

Added advantage.

As the trend to mine lower grade, larger tonnage deposits continues, the application of these and other Industry 4.0 AI + IoT platform use cases will be critical in enabling the mining sector to achieve their ESG and sustainable development goals.

There are numerous other applications and potential benefits that can be derived from the use of Industry 4.0 technology, such as reducing the manual and error-prone reporting burden, the retention of knowledge and freeing team members from repetitive work to focus on other aspects of their role - making it easier for employees to consider environmental risks and apply best practice correctly. It also makes it easier for management to adopt competency-based risk management practices, ensure that they have the full picture when it comes to real-time environmental performance and make better decisions that will enable them to achieve zero harm, zero waste and zero carbon goals.

As the trend to mine lower grade, larger tonnage deposits continues, the application of these and other Industry 4.0 AI + IoT platform use cases will be critical.



Where to start and how to implement.

The first step is to Identify a particular objective or function that needs improving which can be used to test efficacy, as well as an individual (or small multi-disciplined team) who will be capable of championing and running the project.

For example, a common place within the mining sector to start with Industry 4.0 technologies in ESG is with real-time environmental monitoring and predictive analytics. The reason for this is that it can prevent the breaches that can turn into long-term stewardship difficulties, plus enables miners to start collecting the complete, authoritative data sets that are needed to model future optimizations, compare outcomes from different activities, enhance EIAs and SIAs, as well as plan better for the future.

From there, it's important to explore the use case for Industry 4.0 technology. With real-time environmental monitoring and predictive analytics, it would be best to pick a particular activity and site, before then identifying all of the potential variables that impact the use case and where the real-time data gaps are, such as with the real-time collection of noise, dust, smell, subsidence, vibrations, gas release, light (etc.) data. Is there certain data that cannot be collected at this stage? Is all the data needed readily accessible in real-time? What's the internal skills gap when it comes to the necessary technology, implementation or data analysis and use of AI?

At this point, if it's not already occurred, it is prudent to look for the right suppliers. Critical to developing an Industry 4.0 footing is an AI + IoT platform, so this should be the starting point. Utilizing someone that has an understanding of mining operations and good cross-functional technology and data science expertise is going to be critical, as many providers are industry agnostic or lack the in-depth understanding of a sector to add value during solution development.

The next step would be to further explore the technology stack that is going to be needed. Central to this will be the in-field devices needed, integrations with systems (both internal and external), as well as the networks and comms necessary to transmit data to the AI + IoT platform and then carry back to the Edge the instructions that are directed as a result of its real-time analysis (if Edge processing is not being leveraged). What's more, it's also important to begin developing (or buying) the machine learning algorithms that are going to be used to predict environmental performance - there will be multiple options.

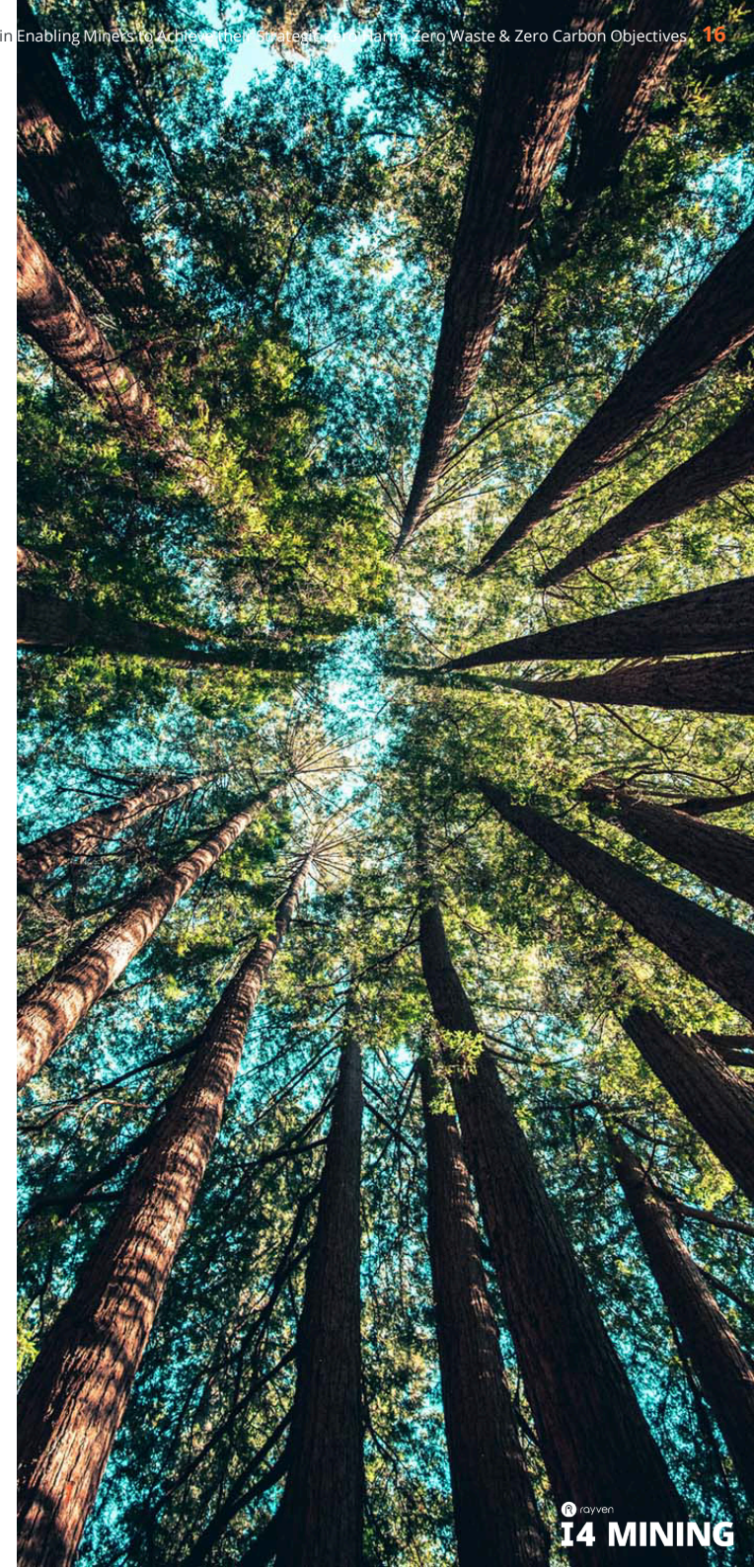
Once the full technology stack is identified, it's about the deployment, roll-out and internal communication/transition plan. Every site and piece of plant is unique, but there are commonalities across classes, mines and operations that can be applied to every situation and across projects.

The best approach is to start small and scale. Pick an easy-to-monitor use case without too many variables, where improvement can be clearly measured, and look to apply it to a single site. This enables the rapid deployment of technology (sometimes in weeks), reduces costs and risks, and provides a pilot program through which data is beginning to be collected (bigger data sets = faster optimizations and quicker success).

Once making a measurable impact, it's time to scale across other on-site activities and multiple sites to capture bigger data sets from across operations. By scaling at this point, it will be possible to utilize the learnings from the pilot to find efficiencies and enhance the optimization loop almost instantly. What's more, by working with a partner that can work over the longer-term and, critically, knows how to scale will reduce costs, speed-up the deployment process, and reduce further development cycles.

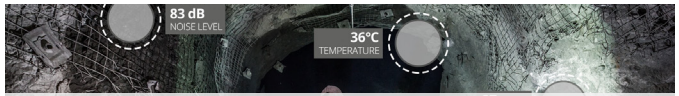
Work with someone who is a digital native, can explore your operations in relation to your business objectives, who understands the sector, knows the current technology, and has a global network of best-in-class partners who can provide you with the future-proofed technologies that you need to create complete Industry 4.0 solutions: talk to Rayven about I4 Mining.

The best approach is to start small and scale.



Ready-to-go digital mining solutions.

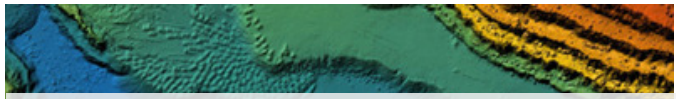
I4 Mining is a specialist set of digital mining solutions built especially for the Mining sector by Rayven.
Discover our pre-built Industry 4.0 AI + IoT solutions or speak to us about your bespoke needs.



Health + Safety

Achieve zero harm to workforce, simply.

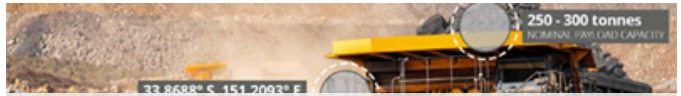
I4 Mining's Health + Safety digital mining solution enables you to connect all of your people, plant and systems to utilize historical and real-time data; preventing workforce harm across your operations and enabling you to achieve your zero harm objectives.



Environment + Community

Making zero harm to environment easy.

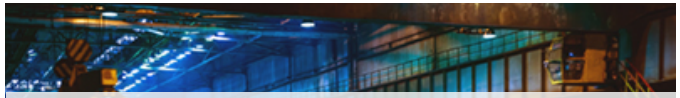
I4 Mining's Environment + Community digital mining solution is a complete environmental monitoring, management and compliance solution that enables you to monitor your operations in real-time and use AI to predict, prevent and remediate breaches, fast.



Asset Monitor + Maintenance

Achieve 100% scheduled uptime & increase tonnage.

I4 Mining's Asset Monitor + Maintenance solution is a real-time asset monitoring, utilization optimization & predictive maintenance solution all-in-one. It enables you to improve plant performance across your operations, from drill rigs and motor graders, to pumps and HVAC equipment.



Yield + Production

Increase yield, prevent breakdowns and find efficiencies.

I4 Mining's Yield + Production digital mining solution enables you to monitor and analyze all of the variables that go into material extraction, screening and processing to uncover improvements and then seize upon them. It Increases yields, prevents breakdowns and finds efficiencies using the platform's IoT, AI and adaptive real-time data analysis.

Energy + Resources

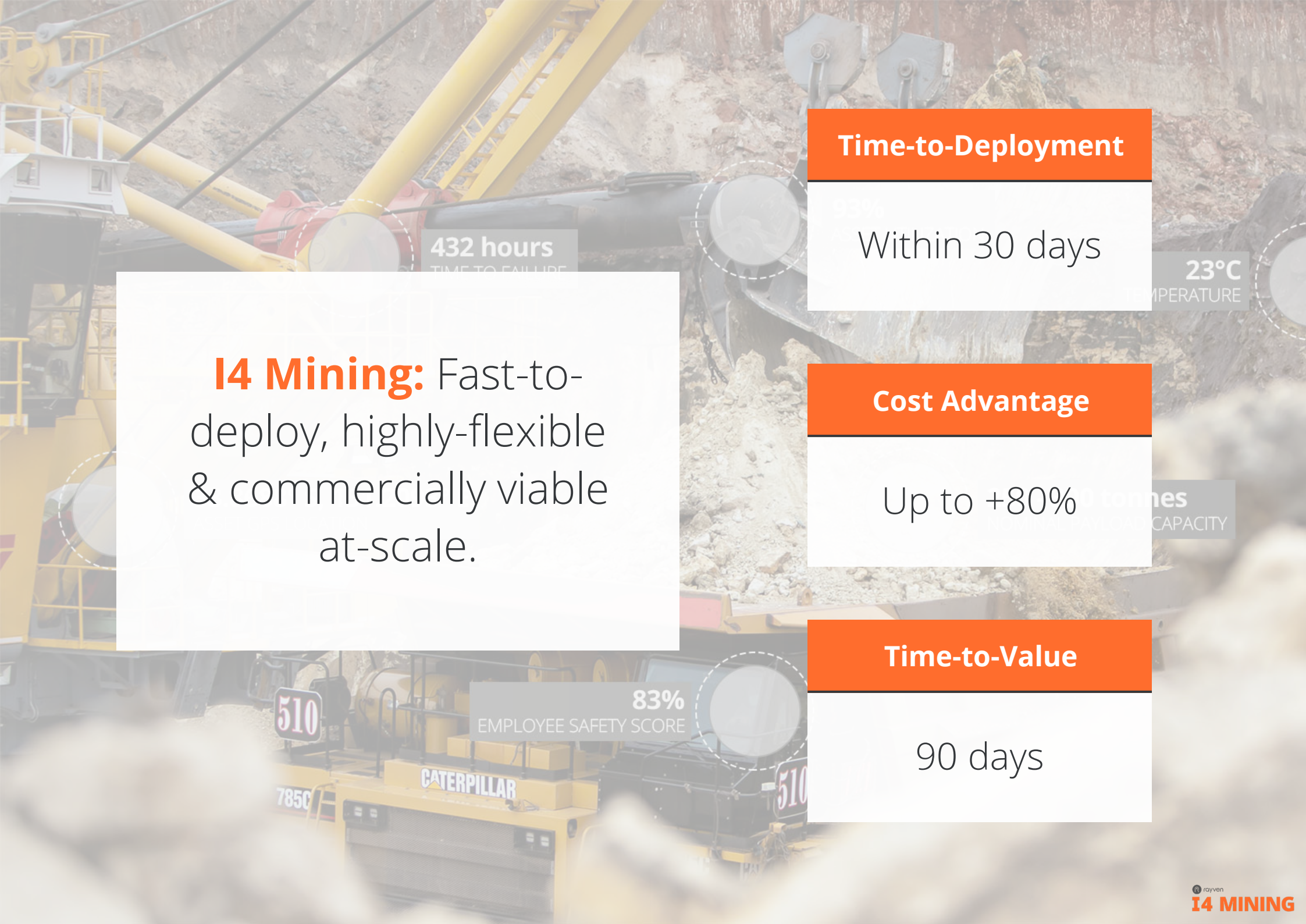
Turn real-time energy + resource data into tangible cost and carbon savings.

I4 Mining's Energy + Resources digital mining solution enables you to optimize the usage of the costly inputs that go into your operations and reduce waste; delivering you immediate efficiencies and dramatically improving profitability, fast.

Oversight

Get a single source of truth and advanced analytics to reduce risk & solve compliance challenges.

Our solution improves real-time strategic decision-making, enhances risk assessment and reduces the reporting burden by providing up-to-date, accurate data in an easy-to-use predictive analytics engine. Beyond that, it gives you the ability to execute those decisions, both manually and via AI-led automation.



I4 Mining: Fast-to-deploy, highly-flexible & commercially viable at-scale.

Time-to-Deployment

Within 30 days

Cost Advantage

Up to +80%

Time-to-Value

90 days

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Want to see how an advanced AI + IoT platform is used in the real-world?

Watch the **Discover Rayven** video.

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Next generation Industry 4.0 digital mining solutions.