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# Smart Mining: Leveraging Data & Technology to Transform Ghana's Gold Sector

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# Foreward

We hope this white paper, *Smart Mining: Leveraging Data & Technology to Transform Ghana's Gold Sector*, captures that ethos and demonstrates the importance of working together to understand the challenges and opportunities at play in the industry.

Data-driven strategies and new technologies are required for sustainable growth and development in an ever-changing mining world.

Mining industry technology has experienced a major shift in innovation not only from basic tools to hi-tech machinery but also from the implementation of automated, digital, and geospatial tracking technologies that have changed exploration, and especially fieldwork since their start. Modern times have brought new unexpected data to the forefront, data is now the driver for sustainable development, cost-effective production, and future growth of mining companies.

Hiedberg believes in enabling stakeholders to harness advanced technologies efficiently. We hope this white paper, *Smart Mining: Leveraging Data & Technology to Transform Ghana's Gold Sector*, captures that ethos and demonstrates the importance of working together to understand the challenges and opportunities at play in the industry.

Therefore, we published this white paper to share actionable insights and tactics applicable to mining. We hope this document helps you achieve your goals, whether it is maximizing productivity, improving sustainability, or targeting new market segments.

We appreciate you taking time to look into our findings. We are excited about the potential of collaborating with you in your pursuit of innovation and success in the gold mining industry.

Best Regards,

**Miriam MacCarthy**

CEO, Hiedberg



# Background

Today Ghana is Africa's largest gold producer and a top gold exporter in the world.

Ghana is steeped in gold mining history, and this industry is crucial for the economy. Today Ghana is Africa's largest gold producer and a top gold exporter in the world. Ghana's stiff links to gold mining stretch to the colonial age when Europeans such as the Portuguese, Dutch, and British, took advantage of the nation's huge gold reserves.

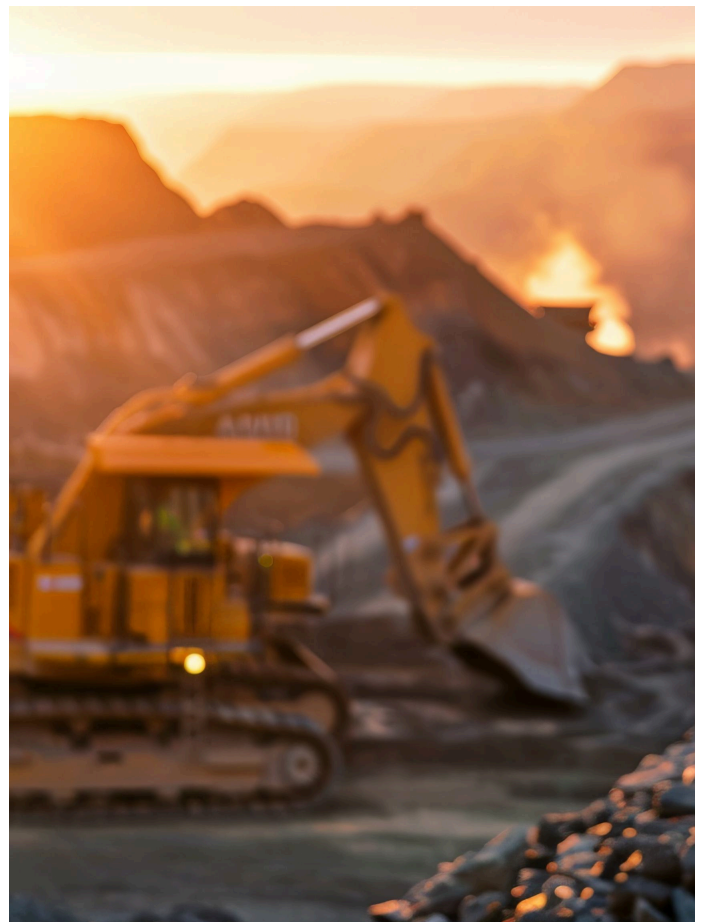
When Ghana became independent, the government initiated a process to nationalize the mining sector, but mismanagement and limited resources led to a drop in gold production. The government later pushed through legal changes and new mechanisms to draw in foreign investments. Some of the key reforms included the Minerals and Mining Law, 1986 (PNDC Law 153), which liberalized the sector and introduced tax incentives. This was strengthened by the Minerals and Mining Act, 2006 (Act 703), allowing 100% foreign ownership and establishing the Minerals Commission for sector oversight. These efforts contributed to restoring Ghana's status over the years as a leading gold-producing country, positioning the sector as a significant driver of economic growth.

Ghana's key gold-producing regions are Ashanti, Western, Eastern, and Northern regions with major mines in Obuasi (AngloGold Ashanti), Tarkwa (Gold Fields), Ahafo and Akyem (Newmont).

The gold sector has negative effects on communities. To manage these, the government must regulate, monitor, and promote the industry through bodies like the Minerals Commission and Ghana Gold Board. These institutions ensure transparency in production, exports, and revenue collection while combating gold smuggling and illegal trade.

Despite efforts by the government to modernize the gold sector to enhance efficiency, transparency, and sustainability, the sector still faces challenges including the following :

- > **Dependence on informal and unregulated mining**
- > **Limited digital infrastructure**
- > **Gold smuggling and illicit trade**
- > **Environmental degradation**
- > **Inconsistent enforcement of mining policies**



## Objectives

This paper aims to highlight the gold sector's economic contributions, current gaps, and inefficiencies such as illegal mining, smuggling, and regulatory challenges. It also explores new government initiatives: Gold Board Initiative, designed to address these challenges and enhance the sector's efficiency.

Additionally, it proposes Hiedberg-inspired policy interventions, focusing on data driven governance, transparency, value addition, and sustainable mining practices to ensure long-term growth and resilience in the sector.





# Current State

In 2023, the gold sector itself produced almost 4 million ounces of gold which was almost 7% of G.D.P

The gold sector is a dominant branch of Ghana's economy. It has had a significant impact on GDP and on the country's foreign exchange earnings. In 2023, the gold sector itself produced almost 4 million ounces of gold which was almost 7% of G.D.P<sup>1</sup>. As at 2024, Ghana reported total gold export earnings of approximately \$11.64 billion, representing a 53.3% increase from the previous year. The considerable growth in the export revenues from gold in 2024 has made Ghana's foreign exchange reserves become more solid and has strengthened its trade balance with other countries.<sup>2</sup>

Despite the significant contributions of the Gold sector, it still faces some challenges and inefficiencies, including:

- **Illegal Mining (Galamsey):** The unforeseen growth of small-scale mining without any regulations, otherwise known as 'galamsey' in Ghana, has resulted in land degradation, deforestation, water pollution, and state revenues were no longer collected.
- **Gold Smuggling:** Despite significant gold bar and jewelry exports from Ghana, there is a notable discrepancy between the volume of these exports and the corresponding revenue accrued to the nation. The UK government reported that Ghana is in the region of losing about bi-annual revenue worth of US\$2 billion to galamsey and gold smuggling according to the African Mining Market.
- **Regulatory Challenges:** Inconsistency in the enforcement of regulations and the inability of the government to monitor the sector properly fosters the aforementioned problems. Even though the country has a functioning legal system, the authorities are short on resources. As a result, the officials fail to enforce the rules.

<sup>1</sup> MiningSee (2025) – Ghana's gold mining dilemma

<sup>2</sup> Reuters (2025) – Ghana plans Gold Board to boost earnings and curb smuggling

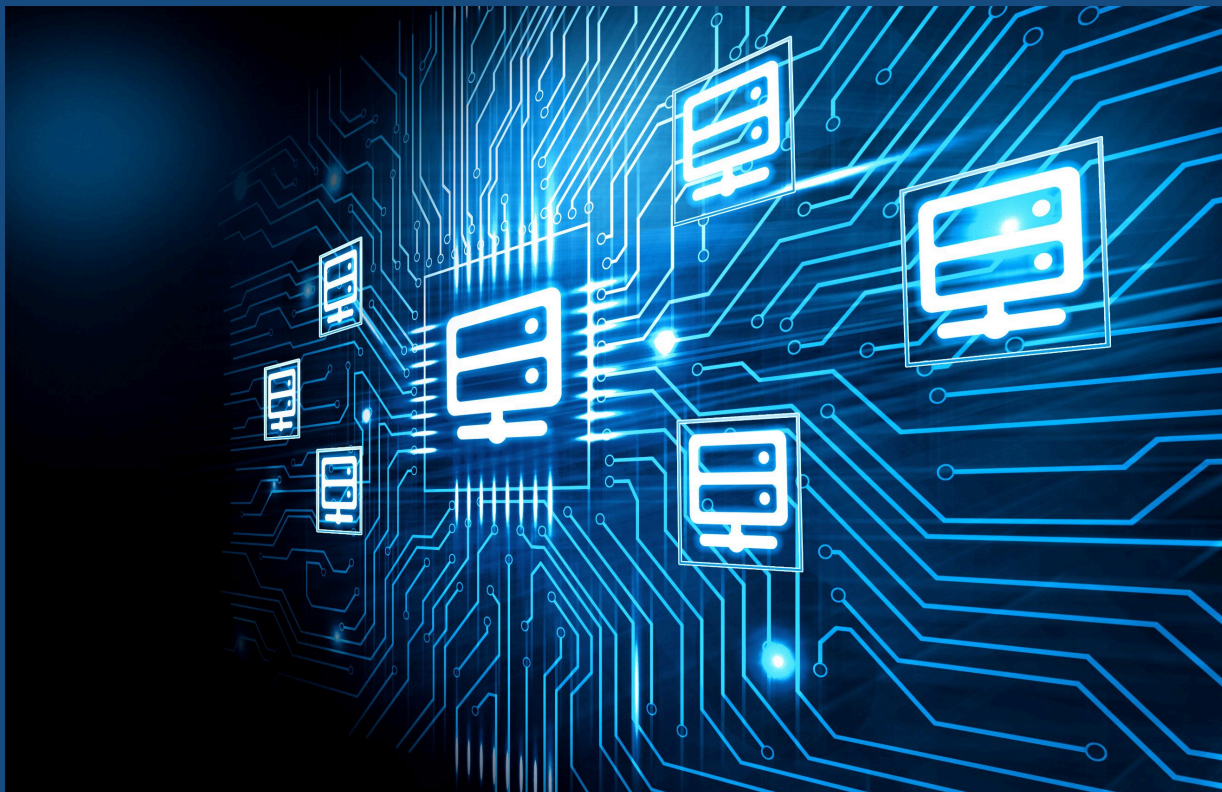
gold trading, smuggling, and lost revenue. The Ghana Board members of the Technical Committee consists of officers in the Ministry of finance, Ministry of Lands and Natural Resources, the Bank of Ghana, the Minerals Commission, Ghana Revenue Authority (GRA), Environmental Protection Agency (EPA), security agencies and academia, and the mining industry.



## Key Components of the PFJ Program

- > **Serve as the sole buyer of gold from small-scale miners to curb smuggling**
- > **Formalize small-scale mining to increase government revenue and tax compliance**
- > **Establish a centralized system for transparent tracking of gold production and trade**
- > **Strengthen regulatory oversight and improve inter-agency collaboration**
- > **Promote responsible and sustainable mining practices**
- > **Use Gold to stabilize foreign reserves and strengthen the national currency**

The board will also implement a data-driven governance structure to enable a real-time monitoring of gold transactions and production volumes. This will address underreporting and tax evasion, allowing the state to benefit the most from its gold resources.



# Gap Analysis

In Ghana, the mining sector is faced with various challenges that affect efficacy, transparency and sustainability.

The gaps arise mainly from poor data collection, ineffective regulations, environmental issues, and financial transparency problems. Tackling these is key to not only better governance, but improved use of resources, and ensuring that both large and small scale mining for human consumption is done according to best practices.

## Data Collection and Aggregation

The lack of comprehensive and real-time data collection systems for gold production in Ghana affects and creates inconsistency in data collection and aggregation. Licensing records, reserves, and market trends are not accurately collected, analyzed and stored. The existing data in the gold sector is often fragmented and inconsistent, resulting in inefficiencies in monitoring of the gold sector. Also, the lack of a unified system hinders transparency and provides avenues for illegal activities such as smuggling and unregulated trade.difficult.

## Gold Production Data

Gold production data is often incorrect and impossible to compare, thus the discrepancies between the mining volumes cannot be easily traced. It is not unusual for most small-scale miners to bypass accurate information about their work, and, in the long run, underreporting becomes a major problem for the country. Moreover, there is no real-time tracking system, making it difficult to optimize resource management and make sure that the rules of mining are followed.

## Demographic and Operational Data

There is limited information on the number of small-scale miners, their operational capacity, and economic contributions to the gold sector. Many artisanal and small-scale miners operate informally, making it difficult to assess their impact, provide adequate support, or enforce regulations. Furthermore, the lack of a centralized registry is a problem in identifying which mining operations are legal and which ones are illegal.

## Environmental and Land Impact Data

The absence of the necessary monitoring and documentation makes it a challenge to comprehend the environmental degradation which is caused by mining including deforestation, water pollution, and land destruction. A considerable number of mining operations, particularly those that are illegal, go on without undergoing proper environmental impact assessments, thereby leading to serious ecological damage. The lack of established technologies with reliable operational capacity, especially their inability to detect very small quantities in the field, makes it difficult for environmental authorities to develop the necessary infrastructure for mitigation and enforce sustainable mining practices.



## Financial and Market data

Gold pricing, taxation, and export revenues tracking are not transparent enough. Gold transactions are mostly commonly made through informal markets, which are mostly owned by small scale miners, making it difficult to determine the actual price of Gold that is being exported.

## Regulatory and Compliance Data

The mining sector faces bureaucratic inefficiencies in the licensing process, tax payments, and environmental compliance monitoring. Most mining companies and small-scale miners are unable to afford the long and complex requirements which are causing them to take up extra time and risk non-compliance. Moreover, the non-existence of a monitoring system in real-time also complicates the situation since it is difficult for the regulators to locate the forbidden activities, enforce laws, and make the companies in compliance with the mining standards set by both the national and international organizations.

## Technology-Driven Insights for Policy and Decision-Making

AI, big data analytics, and blockchain technology are not widely employed in policy formulation and enforcement in the mining sector. In the absence of these advanced technologies authorities can hardly identify the risks by prediction, diminish the resource allocation by optimization and improve governance. Besides, the lack of a centralized dashboard or a digital reporting system affects the efficiency of the government work of monitoring the operations and executing the regulations.

TASK	KPI
<p><b>Data Parameters and Scope</b></p> <p>Description: Identify and define the types of data to be collected, methods of collection, and standard procedures. This includes geological data, mining activities, gold production, environmental impact, and financial transactions</p>	<p>Comprehensive list of data sources, established data collection framework, and data acquisition procedures.</p>
<p><b>Data Audit and Assessment</b></p> <p>Conduct a thorough audit of existing records, assessing their quality, completeness, and consistency across different departments. Identify gaps, missing data, and outdated storage methods.</p>	<p>Completed audit report with recommendations for improving data accuracy, optimization, and standardization.</p>
<p><b>Data Optimization and Preprocessing</b></p> <p>Description: Clean data by removing inconsistencies, duplicates, and missing values to ensure accuracy for analysis. This includes refining production figures, tracking gold smuggling, and optimizing regulatory compliance data.</p>	<p>Optimized data set with improved accuracy and completeness.</p>
<p><b>Data Standardization</b></p> <p>Description: Implement uniform naming conventions, formats, and units for collected data, ensuring consistency. Use descriptive analytics to analyze gold production trends, illegal mining activities, and regulatory compliance levels.</p>	<p>Consolidated database with streamlined access to gold sector information.</p>
<p><b>Data Consolidation</b></p> <p>Description: Merge multiple data sources, including government databases, mining companies' reports, environmental assessments, and market trends, eliminating redundancies</p>	<p>Consolidated database with streamlined access to gold sector information.</p>

TASK	KPI
<p><b>Data Modeling</b></p> <p>Description: Develop models to recognize trends in gold production, market pricing, smuggling routes, and the impact of government interventions.</p>	<p>A functional data model that enhances predictive analytics and strategic decision-making.</p>
<p><b>Data Validation</b></p> <p>Description: Test the data models with sample datasets to ensure accuracy and alignment with gold sector needs.</p>	<p>Validated data models that meet analytical and policy development requirements.</p>

# Visualization and Reporting




Data insights can be the most influential if they are shown in an easy way. We will use the visualization of the data in the reports and dashboards so that we can have the clear and legible documents and tables. Logic in visual data will aid stakeholders to interrelate with the data, bookmarking multiple factors and situations. The uniqueness of the reports is the result of their adaptation to the specific purpose of the project.

This visual software is capable of improving effectiveness in data analysis and decision making, hence, it supports not only strategic policymaking, but it also assists in running the day-to-day operational processes and the oversight of the company's regulation, thereby ensuring the transparency and effective resource management.

	<h3>Gold Production Trends</h3>	<p>Heat maps are going to show how gold is being mined and where those mines are located or how they occur over time. These maps will not only assist regulators and investors in recognizing high-yield areas and seasonal differences but will also help to determine the production levels in different mining regions over time. Furthermore, real-time dashboards will be available for both the large and the small scale miners, providing a clear roadmap of gold output and serving as a key tool for monitoring gold flow and production efficiency. This is possible through the integration of basic and smart technologies</p>
	<h3>Mining Operations Optimization</h3>	<p>lowcharts and simulations are going to be applied in order to examine mining activities and to find inefficiencies at the stage of extraction, transportation, and the processing stage. Through data-driven findings, the ability to make mining layouts better, allocate resources, and distribute the workforce will be given.</p>
	<h3>Regulatory Compliance &amp; Governance</h3>	<p>Interactive reports will establish the difference between authorized and unauthorized mining, bringing special attention to regions that are hot spots for illegal activities and smuggling. Dashboards will be required for reporting compliance with environmental and safety regulations, so as to enable the monitoring authorities to do their job more effectively.</p>
	<h3>Revenue &amp; Trade Monitoring</h3>	<p>Data visualizations will illustrate gold exports, internal sales, and revenue ebbing away due to smuggling. Furthermore, the dashboards will measure the value of the gold against Ghana's production, which allows policymakers to set the prices right for the gold and also come up with the necessary trade policies.</p>
	<h3>Environmental &amp; Social Impact Analysis</h3>	<p>Analytical mapping of climate and environmental risk will illustrate the detrimental influence of gold mining on water bodies, deforestation, and the earth's surface. The social aspect will be focused on employment figures, community activities, and the resettlement from the mining area.</p>

# Insights Generation

The aim of data analysis is to provide understandable insights that will help decision-makers, layouts, and the refinement of Ghana's gold sector to be developed. Our way to insights generation requires the next steps are:

	<h3>Segmentation Analysis</h3>	<p>Descriptive data mining of mining activities including size, production, the status of compliance, may also be used along with the three types that are large-scale, small-scale, and illegal mining. Research provides information on the following demographics: identification of job trends, popular locations of investment, and estimates of operational efficiency.</p>
	<h3>Pattern Recognition</h3>	<p>Identifying the changes such as spikes in the gold mining stocks, periods of low production, and fluctuations in the gold prices due to gold smuggling. Evaluating how traffic spikes, online orders, and policies affect the price and quantity of gold over time.</p>
	<h3>Correlation Analysis</h3>	<p>Investigating the connection between mining regulations and the compliance, assisting in the modification of the policy to enhance adherence. Appraising the link between gold prices and export volumes which will help the government to take the right action for its revenues.</p>
	<h3>Predictive Insights</h3>	<p>Anticipating what the future gold extraction will look like without forgetting the fact that the resources will be available or viable. Creating models for which the citizenry and government should work to come up with the best possible outcome for all the citizens. Predicting the future of gold production looking at the availability of resources, growth in investment, and regulatory changes.</p>

## Risk Mitigation

<b>Risk</b>	<b>Solution</b>	<b>Risk Level</b>	<b>Category</b>
Failure in project coordination, especially among non-state actors and private mining companies	Develop and implement standardized project management frameworks aligned with mining regulations and investment agreements	Medium	Operational
Inaccurate or incomplete data on gold production, trade, and compliance	Establish data validation mechanisms and enforce mandatory reporting standards for all mining entities	High	Technical / Operational
Resistance from stakeholders (miners, traders, regulators) to data-sharing initiatives	Develop formal agreements outlining the benefits, terms, and compliance requirements for data sharing	Medium	Operational
Mining operations may not meet legal and environmental standards	Strengthen regulatory oversight, conduct regular inspections, and enforce strict penalties for non-compliance	High	Compliance
Data security breaches exposing sensitive gold trade and mining information	Implement encryption, multi-layer security protocols, and regular cybersecurity audits	High	Security
Difficulty integrating digital mining data with existing regulatory and financial systems	Conduct compatibility tests and invest in flexible data integration solutions	Medium	Technical
Use of predictive analytics in gold production may lead to misleading projections	Regularly refine models with updated industry data and validate assumptions before decision-making	Medium	Analytical
Environmental data analysis may not align with sustainability goals	Regularly refine models with updated industry data and validate assumptions before decision-making	Medium	Analytical
Environmental data analysis may not align with sustainability goals	Ensure continuous stakeholder engagement and integrate sustainability-focused KPIs in analytics	Medium	Analytical / Operational
Smuggling and unregulated gold trade may distort data-driven insights	Strengthen border controls, improve digital tracking systems, and enhance enforcement measures	High	Analytical
Predictive models for gold market trends may be overfitted to past data, affecting decision-making	Use advanced modeling techniques and update with real-time market data to improve accuracy	Medium	Analytical



# Case Study: Technological Innovation in Australia's Gold Industry

Australia has a rich history of gold mining that has greatly influenced the country in many ways. In 2022-23, Australia gold exports generated \$ 24.4 billion in revenue. The country has one of the most advanced gold sectors in the world, using advanced technology, automation, and data analytics to maximize production and sustainability. It is one of the largest gold producers globally, with major mining operations in Western Australia, Queensland, and New South Wales.

## Background

Australia's gold sector, which has a glorious history in the field of gold mining that goes back to the mid-19th century gold rush, played a great role in facilitating the country's industrialization and population growth. The exploration of gold in Bathurst, Ballarat, Bendigo, and Kalgoorlie caused a huge leap forward and considerable wealth increase.

During the last years, it has acted to be the backbone of the economy not only in the country but also worldwide. It has brought in about \$2.4 trillion of export revenue, made up of wages, and company taxes of up to \$252 billion and \$206 billion and \$ 150 billion royalties, respectively. These earned revenues covered the everyday needs of people including healthcare, schools, and infrastructure, which are the reasons for 21% of the country's growth and development. In 2020, Australia was placed as the second-largest gold producer in the world just after China, and one of the leading gold exporters in the world. The country is also the world's largest holder of gold known gold reserves, with above 10,000 tons of backing that will ensure the long-term viability of the sector.<sup>5</sup>

<sup>3</sup><https://minerals.org.au/about/mining-facts/mineral-gold/>

<sup>4</sup> <https://minerals.org.au/policies/economic-policy/>

<sup>5</sup> <https://www.proactiveinvestors.com.au/companies/news/944978/australia-ranks-top-with-highest-gold-reserves-in-2020-followed-by-russia-and-the-us-a-distant-third-944978>

## Government Initiatives

The priority of the government is the investment in Australia's gold sector. Australia is a globally renowned minerals development center and exploration road lord. It offers endless commercial and operational benefits to investors. To ensure the long-term sustainability of the business, the government has introduced measures that reduce risks and encourage mineral exploration. These efforts are set out to help and develop the gold industry with a focus on investment attraction, technological advancement and sustainable development

Some Initiatives by the Australian government :

> **Junior Minerals Exploration Incentives (JMEI)**  
Offers tax incentives to encourage investment in mineral exploration, including gold. It provides investors with refundable tax offsets for eligible greenfields mineral exploration expenditure. This incentive is also known as the Exploration Development Incentive.

> **METS Innovation Program**  
The Minerals research institute of western Australia launched this program in December 2023 to support the mining equipment, technology, and services (METS) sector innovation. It sets out to promote technological innovations which can be tried out on gold mining operations to get them to be more profitable

> **Australian Critical Minerals Research and Development Hub**  
This center concentrates on unlocking the critical minerals of Australia through research and innovation. Although the center is made of critical minerals, its activities also support the gold sector through the use of technological advances and sustainability practices.

> **Scalability & Future-Proofing:** The cloud-based document management systems associated with DBS made it possible to fast track the scaling of operations. Greater mobility had the power to create a new tools for any additional branches, services, and regulatory modifications without the burden of the physical expansion and manual labor wellbeing incurred

> **Leading Practice Sustainable Development Program in Mining**  
The program aims at providing a series of handbooks that will explain the best practices for environmental management, community engagement, and mine closure. The purpose of this program is to be the leading one in promoting sustainable development within the mining sector.

> **Environmental, Social, and Government (ESG) Initiatives**  
The Australian government is pushing forward its mining sector ESG principles that are aimed at responsible operations to ensure strong achievements . Utilizing these methods is the reason mining companies are focusing on their social license to operate and getting "best in" global markets having peak profits.

> **Climate Change Policies**  
The adherence of the policies by Australia to diminish the greenhouse gas is through the renouncing of the mining sector. The encouragement of mining companies to introduce energy efficient technologies and promote a transition to renewables is the predominant pro-green policy of Australia which has seen a shift of the demand for coal and other non-renewable energy.

## Technological Integration

The Australian government has attempted several strategies for the further advancement in technology and application of data. The uses of advanced technologies and data analytics to integrate Australia's gold mining sector have greatly improved operations in the sector and have made them more sustainable. In general, we can say that the integrations of advanced technologies have really altered the sector of gold mining in Australia. Through continuously developing and adopting technological advancements, Australia is a leader in mining innovation.

Key Technological advancement include :



### **Digital Twins and Process Simulations**

It uses data from physical assets and 3D models to simulate processes, improving productivity and safety by enabling virtual testing and optimization before implementing changes in the physical environment.



### **Artificial Intelligence (AI) and Robotics**

The introduction of AI and robotics of mining in Australia is a notable case of the modern technological adaptation that has helped to boost the efficiency of operations. Instances are the autonomous vehicles and robotics systems that have been ordered to conduct routine tasks, which has mitigated human errors and increased efficiency. Through AI algorithms analyzing large data sets, the drilling plus blasting operations are better optimized, benefiting the company cost and resource extraction.



### **Autonomous and Remote-Controlled Equipment**

The introduction of autonomous trains, haul trucks, and drills has led to a sea change in the mining sector. The use of these technologies in decreasing the human presence in very hazardous areas is the contributing factor to operation's preciseness and overall productivity gains.



### **Data-Driven Decision Making**

In the process of decision making in Australia, mining companies are becoming bigger in their use of data analytics as a tool for examining data sources to inform on business decisions. By monitoring and analyzing operating data, companies may spot the main Performance indicators by tracking the KPI of the company, find losses, and execute targeted amendments. This approach leads to optimized resources utilization, cost reduction, and enhanced sustainability practices.



### **Fleet Management Systems (FMS)**

At the Granny Smith Gold Mine, Gold fields recently installed a digital fleet management system which is the first of its kind in the point. This system combines real-time data to control and maintain mining fleets, hence it has thus increased the efficiency of operations, minimized downtime, and made the mining process safer by posting the information of the equipment's performance and location timely.

Australia carries on to be the leader in the world market of gold mining, marked by the growth of advanced technologies and data integration resulting in high efficiency, safety assurances as well as sustainability. New technologies that include machines, AI programs, IoT equipment, and real-time analytics have advanced, such automation has streamlined exploration, extraction, and processing, thus cutting costs and reducing the environmental impact. These technologies have also made Australia one of the top producers of gold, thus resulting in ensuring industry growth, which is the industry's way to keep up its global competitiveness.

# Conclusion

The gold mining industry has undergone significant transformation, with data emerging as a critical driver of strategic decisions. Robust data mining which was previously considered a luxury is now a necessity for competitive advantage. This white paper examines the dissidents and the supporters of data-driven innovation and also provides recommendations that are practical and useful for the Ghanaian government.

A collaboration with Hiedberg will introduce new levels of efficiency, sustainability, and competitiveness to Ghana's gold sector. By leveraging data analytics, the mining sector can achieve superior operational standards, optimize resource utilization, and drive sustained development.

# Authors

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