Longevity of Current Mines: Future Sustainable Mining

Liabilities to assets that further positive social, economic, and environmental outcomes

MANDELA MINING PRECINCT
MINDS FOR MINES

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Contents

1 Executive summary

Through its Longevity of Current Mines (LoCM) programme, The Mandela Mining Precinct has partnered with the Research Institute for Innovation and Sustainability (RIIS) to support the programme to develop a scope of work for future sustainable mining. The ultimate intention of which is to support the programme to explore a future outlook for sustainable mining in South Africa's PGM, Au, and Chrome mining industries, specifically looking at mechanisms to shift current liabilities into valuable assets and identify the relevant actors driving that process.

In line with the LoCM programme's expectations, three separate yet interdependent phases of work were envisaged to encompass the full scope of future sustainable mining project activities. RIIS has supported Phase 1, to 'Define the Problem Space' through conducting desktop research and a series of stakeholder engagements to outline the critical challenges faced in South Africa's PGM, AU, and Chrome mining industries in converting liabilities into assets while achieving positive social, economic, and environmental outcomes. Phase 2, which has just been completed, was intended to 'Define the Solution Space' to overcome challenges identified in Phase 1 as well as identify, define and build out implementation case studies for potential interventions based on strong impact pathways within the identified challenge areas. Phase 3 is intended to implement the conceptualised solutions and ensure strong feedback mechanisms are in place to enable response and adaptation where necessary.

The delivery of Phase 2 was conceptualised through five interdependent milestones, however, only Milestones 1, 2, and 3 are included in the current scope of work, while Milestones 4 and 5 will be completed when subsequent funding is available.

The details of the milestones and their key activities are as follows:

Milestone 1 Inception: The Inception milestone was intended to finalise a partnership agreement with the UP research panel and host a visioning workshop with MMP and the TSC to align on the activities of Phase 2 of the programme.

Milestone 2 Solutioning: We defined, evaluated, and prioritised solution areas and interventions for development and validation with the UP research panel.

Milestone 3 Design: The team developed comprehensive implementation case studies for the interventions identified in the Solutioning milestone.

2 Aim of Research

The primary aim of the Future Sustainable mining initiative under the Longevity of Current Mines Programme is to design and implement high potential interventions that are applicable to South Africa's PGM, Au, and Chrome industries and are able to successfully convert existing liabilities into assets whilst driving positive economic, social, and environmental impact. These interventions should address three critical challenge areas identified in the mining sector:

- Environmental custodianship and rehabilitation beyond life of mine;
- Energy optimization and management ensuring future sustainable operations;
- Water consumption and management ensuring future sustainable operations.

In order to design and implement meaningful interventions, RIIS conceptualised three primary phases of project activities to provide a framework for project implementation. The first phase being the "Define the Challenge Space" phase, intended to uncover and document key challenges and their root causes to ensure that solutions are able to effectively overcome these. The second phase being the "Define the Solution Space" phase, which currently under finalisation, has identified a broad range of potential solution areas and technologies, built up a series of case studies that inform implementation decision making, and developed a useful tool for industry for prioritising solution areas based on their potential to covert liabilities to assets and achieve social, environmental, and economic outcomes. The third phase being the "Implementation" Phase is intended to raise funding and activate partnerships to implement interventions at targeted mine sites and provide a demonstrated test case for further adoption in the industry.

With a solid grounding based on learnings from Phase 1 and 2, Phase 3 will focus on developing and supporting pathways to implementation.

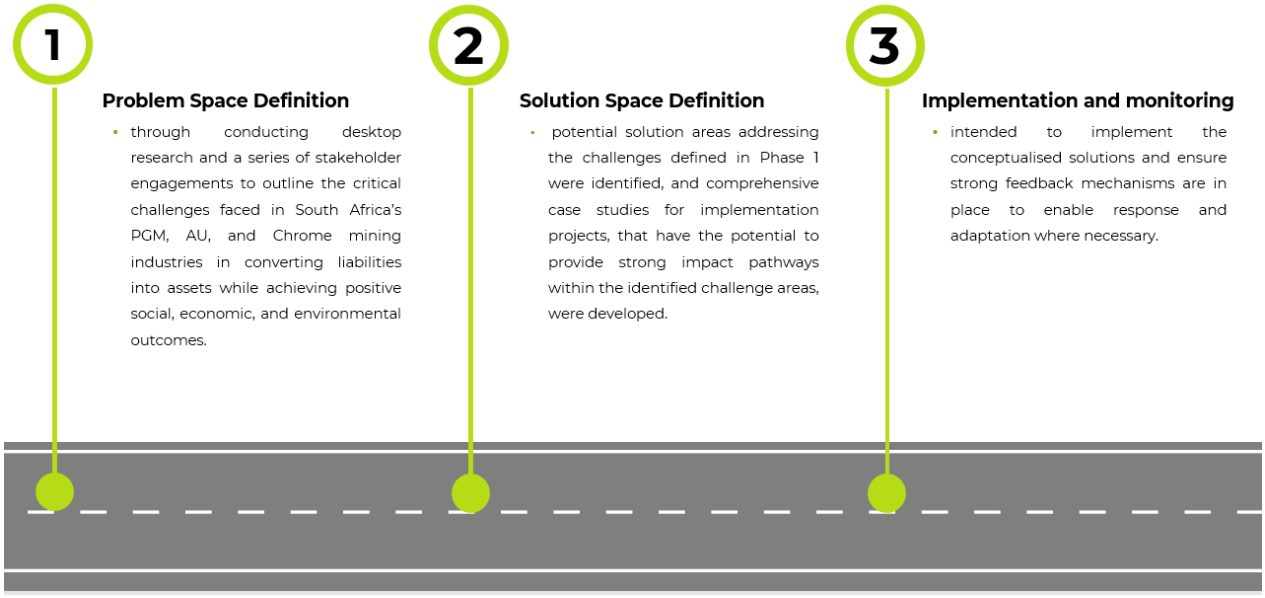


Figure 1. Overview of Approach to Programme

3 Methodology

RIIS proposed to deliver this project in 5 milestones. A flight plan of these phases is provided below with detailed approach and methodology provided following this.

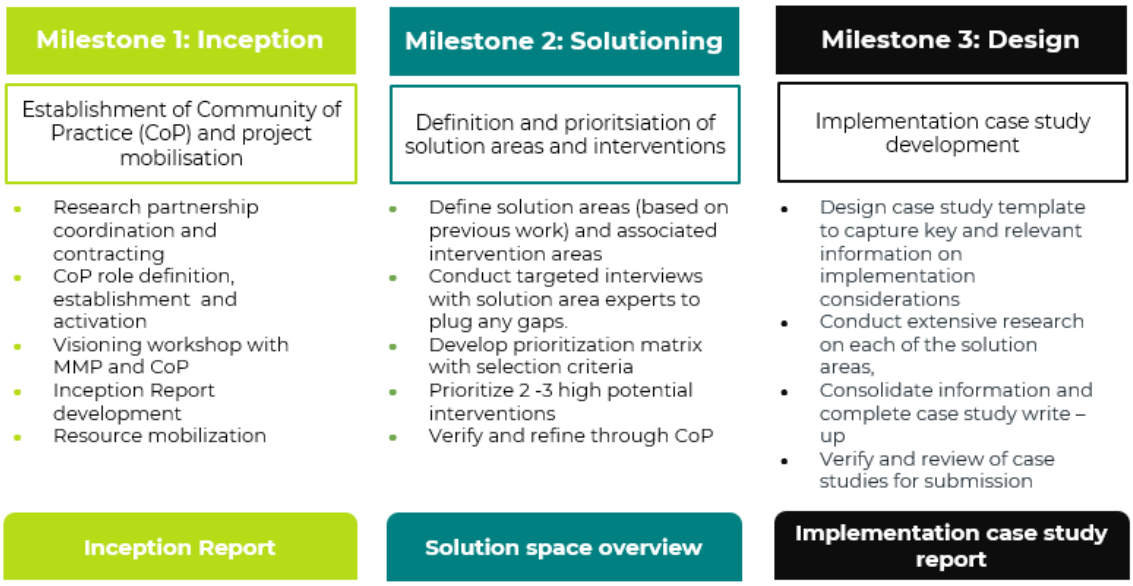


Figure 2. Overview of Phase 2

It is important to note that Milestones 4 and 5, have been included in this phase of work, but will only be completed in Phase 3.

Milestone 1: Inception

The Inception Milestone of this project focused on collectively building a pathway to success that will guide project activities. This included:

Establishing a research partnership: RIIS entered into a collaborative partnership with the University of Pretoria (UP), utilising their technical expertise and subject matter experts to support the solutioning and design components of the project. The UP experts together with Davis Cook from RIIS constituted an Internal Expert Panel that was tasked with providing expertise and guidance on project deliverables throughout the duration of the project.

Establishing stakeholder network: RIIS engaged extensively with key stakeholders during Phase 1 consultations and established a network of experts and practitioners within the major challenge areas. With an existing shared understanding of the challenges faced and the potential offered for this piece of work to deliver on shared value for the mining sector broadly, this group of stakeholders have a vested interest in the successful delivery of this project. This group of stakeholders was available for consultation during Phase 2 and will continue to be consulted and engaged at critical points in the development and execution of Phase 3, to provide strategic input, and direction and feedback on outputs.

Visioning workshop: Before mobilising resources, RIIS conducted a visioning workshop with the Mandela Mining Precinct Longevity of Current Mines Technical Steering Committee, and our research partner, UP Enterprise. The purpose of this visioning and kick-off workshop was to recap the findings on the challenge areas uncovered in Phase 1, define the envisaged future outlook for a mining sector characterised with sustainable businesses for collective value, explore high-level solution areas that would contribute to achieving the defined future outlook, and provide input to ensure our project approach was well-suited to allow for meaningful contribution and successful delivery.

Milestone 2: Solutioning

The Solutioning Milestone of this project was focused on defining solution areas and prioritising interventions for development based on key criteria.

Based on the problem definition completed by RIIS in Phase 1, solution areas were defined in response to the major challenges and themes with corresponding intervention areas. Where necessary, RIIS conducted interviews with key experts to ensure the universe of interventions identified comprehensively captures all potential interventions based on leading global and local trends and analysis. A number of interventions had already been identified during Phase 1 and the intention was to ensure comprehensiveness and refinement of this list.

While it is evident that there is a wide variety of solution areas and emerging technologies that are available for adoption by industry, not all solution areas have the potential to meaningfully convert assets to liabilities and drive positive social, environmental, and economic outcomes to the same extent. Part of the solutioning component was to develop a framework for the prioritisation of solution areas both for focusing our areas of study as well as providing a useful tool for industry to support decision making in pursuing solution areas for their own operations.

In order to ensure a rigorous prioritisation process RIIS developed and utilised a prioritisation matrix.

The prioritisation process included:

- Defining a list of criteria for assessing each intervention (e.g potential for accessing funding, potential for achieving shared benefit for mines and communities, potential for contributing to economic diversification beyond life of mine, potential for significant liability conversion, etc.)
- Defining high level interventions with enough detail to make a qualitative or quantitative assessment against each criterion.
- Qualitative or quantitative assessment of interventions against criteria utilising a high, medium, or low potential scoring system and assigning an aggregate final score for each intervention.
- Identifying high priority solution areas for focusing efforts and illustrating the prioritisation process for industry.

Milestone 3: Design

During the initial conceptualisation phases of this project, the team had envisaged that the key objective of Milestone 3 would be to design implementation plans for a few, high priority interventions at a granular level. However, based on discussion with MMP it was determined that it would be more valuable to build out case studies of all the interventions as examples of where mines have successfully implemented initiatives that successfully convert liabilities to assets.

Based on our consultation with MMP, a new approach was adopted for this milestone, which is outlined below:

- Workshop and design case study template: the case study template was designed collaboratively with our Internal Expert Panel after identifying which areas of information are necessary when determining which interventions are best suited for addressing current challenges sustainable mining and how feasible those interventions are to pursue. Based on our internal deliberations and after consultation with MMP, it was determined to include the following key research areas for each case study: project background; liability to asset conversion potential; commercial consideration; key enablers and constraints; environmental, economic, and social considerations.
- Case study prioritisation and research: In order to ensure that utility of case studies was maximised, our team undertook a prioritisation process to identify the most suitable case studies for further research and development. Our prioritisation approach considered the relevance and suitability of the intervention to the south African mining sector, the availability of key areas of information to inform the case study, and the degree to which the intervention was able to demonstrate traction in implementation.
- Consolidation and write-up: Based on our desktop research process, key information uncovered was then consolidated and presented in the form of a designed case study template, capturing the key and relevant implementation considerations.
- Verification and review: the completed case studies were submitted for verification and review, to ensure that the information provided is comprehensive enough and sufficient for driving adoption and implementation decision making.

At the completion of the Design Milestone a comprehensive implementation case study report was submitted to assist in the discussions and planning for the selection of interventions for implementation in the next phase.

4 Results

4.1 Milestone 1: Inception

This milestone deliverable was concluded with the following outcomes:

- Validation of the workplan;
- Overview of the solution areas being presented;
- Inception milestone deliverable completed.

The milestone deliverables have been reported in LoCM22WP4-1 milestone report.

The recommendations from the work concluded were made as follows:

- Refinement of solution focus areas – these were to include hydrogen, methane capture, land rehabilitation and tailings management - as areas that have high impact potential in South Africa;
- Need to explicitly draw out linkages to community benefit in proposed solutions;
- Research needs to be done to understand carbon offsetting potential of land rehabilitation-focused solutions.

4.2 Milestone 2: Solutioning

This milestone deliverable was concluded with the following outcomes:

- Clear definition of solution areas and identification of leading potential interventions for each;
- Development of an intervention evaluation framework;
- Evaluation and prioritisation of identified interventions.

The milestone deliverables have been reported in LoCM22WP4-2 milestone report.

The recommendations from the work concluded were made as follows:

- From the application of the evaluation framework and prioritsiation matrix, the following interventions were determined to be high priority: land rehabilitation and revegetation, reuse of mine-impacted water, solar and wind energy, artificial wetlands and mine infrastructure and land repurposing;
- Undertaking of further consultation with stakeholders before deciding on a final list of solution areas for inclusion in MS 3 will be key – verification workshops with industry actors (relevant mining houses and other organisations in the industry);
- Inclusion of evaluation framework and prioritisation matrix to allow and encourage industry actors to assess the information and evaluate and prioritise the interventions at their individual mine-levels.
- Identification and activation of key partners and contributors to the intervention design process based on prioritised solution areas for broad

buy-in and acceptance from a diverse group of stakeholders and higher chance of success for interventions chosen for design.

4.3 Milestone 3: Design

This milestone deliverable was concluded with the following outcomes:

- Development of comprehensive set of implementation case studies, covering all the identified interventions, across the four solution areas, energy, land, tailings management and water, that would assist in informing the decision on possible interventions for implementation in South Africa.
- The uncovering of information that assisted in understanding which technologies were more mature and had wider adoption and could offer many lessons vs those that were still novel and had little to no implementation examples, therefore requiring further research and development.

The milestone deliverables have been reported in LoCM22WP4-3 milestone report.

The recommendations from the work concluded were made as follows:

- There is a need to conduct a series of interviews to gather additional information and plug any identified gaps in the existing case studies.
- In order to ensure ease of access to the different outputs completed over the course of Phase 1 and phase 2 of this project, it will be essential to consolidate all learnings and outcomes into a single digestible document that can be shared broadly within the industry.
- This consolidated document should outline the key challenges faced in advancing future sustainable mining, outline the solution areas that directly address these challenges, highlight existing cases of successful implementation and provide an assistive prioritisation framework that supports mines to prioritise the adoption of solution areas based on their unique constraints and needs.
- This document will be beneficial in building industry interest in Phase 3 and facilitating the uptake of sustainable technologies and solutions.

5 Research findings

5.1 Milestone 1: Inception

While the Inception Milestone did not have any research objectives and intended findings, we were able to define key project requirements. These were:

- Establishment of Internal Expert Panel and relevant governance structure and meeting schedule.
- Stakeholder mapping and categorisation to ensure a consultative process is undertaken through to implementation.
- Refinement of the methodology and approach to be undertaken.
- Refinement of a high-level flight plan and detailed work plan with relevant expected deliverable timelines.

5.2 Milestone 2: Solutioning

The Solutioning Milestone is an integral milestone under phase 2 and had the following objectives:

- Define a universe of solution areas for consideration based on identified challenge areas in Phase 1, consultation and expert input, and additional desktop research.
- Develop and document a comprehensive overview of each solution area, identifying key opportunities, barriers, risks, and applications to the mining industry.
- Define a robust and defensible evaluation and prioritisation approach to enable focused intervention design in MS 3.
- Define a list of criteria on which to assess solution areas against to identify priority solution areas according to programme objectives.
- Evaluate each solution area to highlight those with the most potential for feasibly achieving program objectives.
- Based on prioritisation, recommend high potential solution areas to take forward to Phase 3 and drive industry adoption.
- Develop a prioritisation framework to support industry in deciding on solution areas to pursue.

From these objectives, the key research findings and outcomes were as follows:

- Four key solutions areas were defined; energy management and optimisation, land rehabilitation and infrastructure repurposing, tailings management, and water management and optimisation – with a total of 13 potential interventions identified and developed across these.
- Development of an evaluation framework to assess interventions. This consisted of a list of criteria which was based on the main objectives of the programme; 'liability to asset conversion potential' and 'impact and sustainability potential.' The evaluation framework is a tool that can be used by industry for solution evaluation and to gain insight on

- Development of a prioritisation matrix, which resulted in the ranking of the various interventions. The highest-ranking interventions were the following; Land Revegetation and Rehabilitation, Re-use of Mine-Impacted Water, Solar and Wind Energy, Artificial Wetland Construction, and Mine Infrastructure and Land Repurposing.

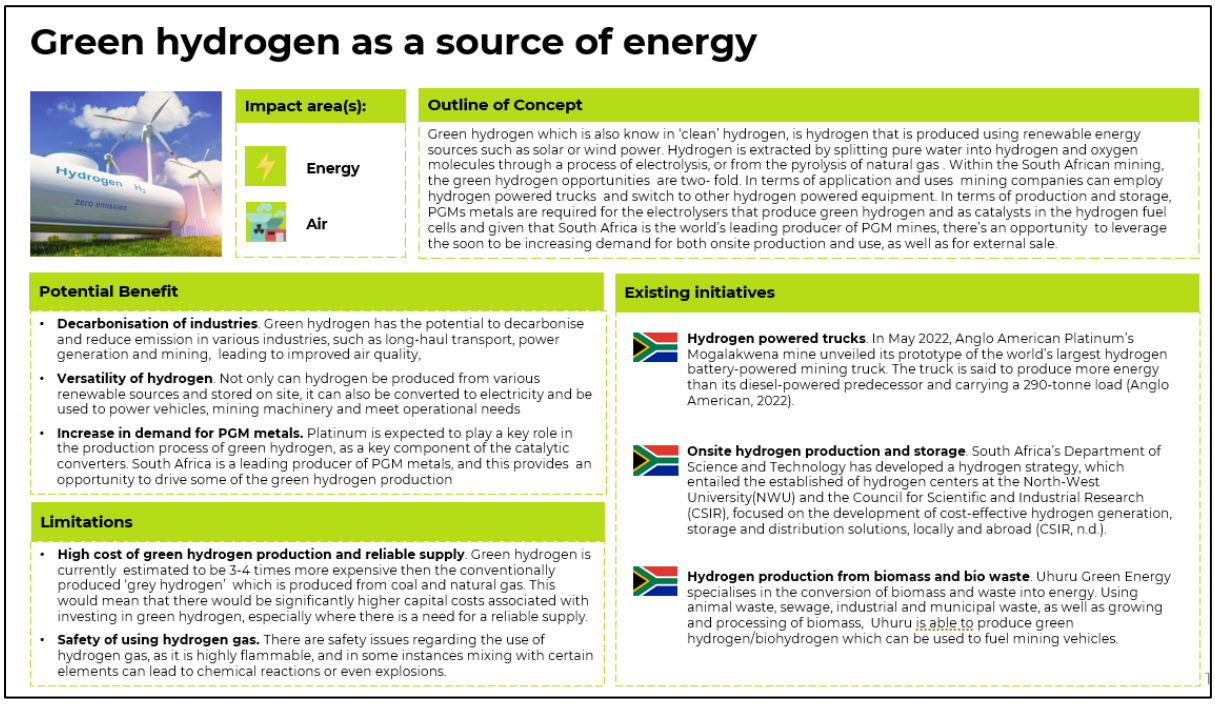
The details of each of the key research findings and outcomes, and the process followed has been outlined below:

Defining a universe of solution areas

When defining a universe of solution areas, it was necessary to categorise different solution areas according to the challenges they were addressing. Following an inductive approach to categorisation, RIIS established the following categories of solution areas and associated interventions;

- Energy management and optimisation:
  - Green hydrogen
  - Methane Capture
  - Solar and wind energy
  - Biomass
  - Electrification
  - Pumped- storage hydropower.
- Land rehabilitation and infrastructure repurposing:
  - Land rehabilitation and revegetation
  - Mine infrastructure and land repurposing
- Tailings management:
  - Repurposing of tailings
  - Tailings dewatering
- Water management and optimisation:
  - Reuse of mine-impacted water
  - Utilisation of artificial wetlands
  - Reverse osmosis.

In order to ensure that we were able to gather consistent information on each solution area that could be applied for evaluation and prioritisation purposes, RIIS designed an overview template to ensure consistency and comprehensiveness. An illustrative example of this has been provided below.

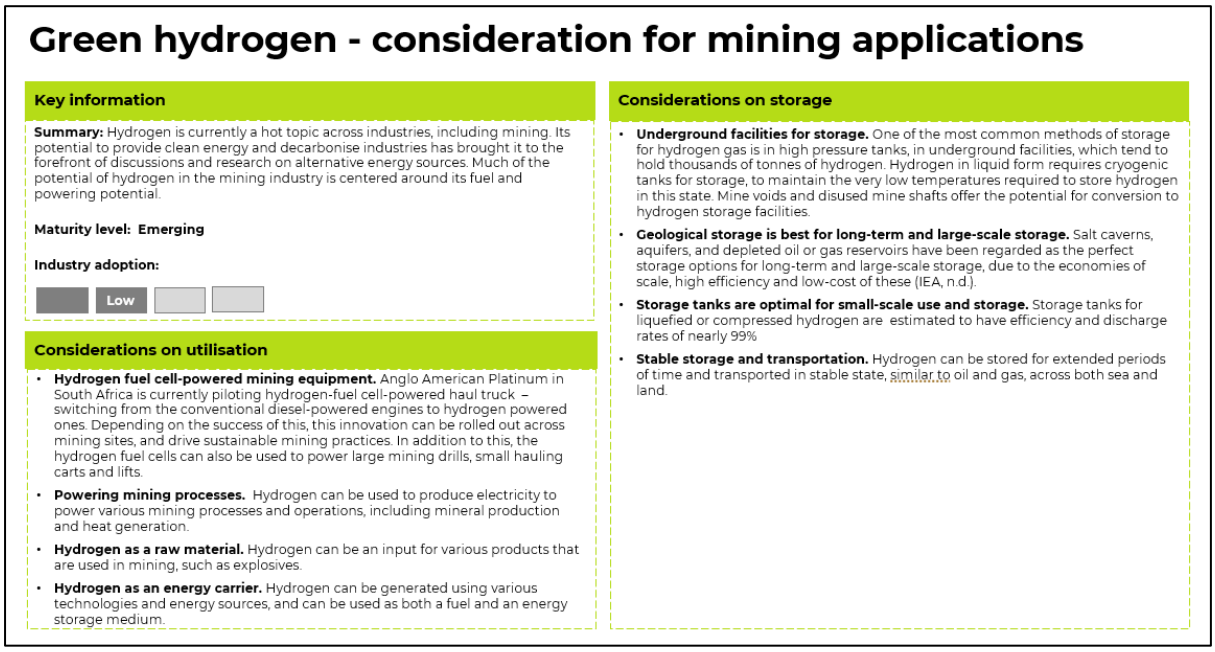


Each solution area was fully developed according to the above template providing an overview of critical information for decision making according to these aspects:

- **Impact area** – identifying which of the challenge areas defined in Phase 1 this solution would contribute towards addressing.
- **Outline of Concept** – providing an overview of the solution area and what it entails
- **Potential benefit** – that could be derived through adoption of this solution area (dependent on intervention design)
- **Potential limitations** – that may be faced through adoption of this solution area (dependent on intervention design)
- **Existing Initiatives** – outlining local or international examples where the interventions in this solutions area have been adopted (in relevant examples case studies of these interventions have also been developed)

In defining solution areas, it was also important to include an overview of the considerations of each solution area for mining applications to outline necessary consideration in applicability, these included:

- **Key information** – providing a summary of the envisaged technology for adoption, the level of maturity of this technology, and an assessment of how widespread adoption has been in industry to date.
- **Considerations on utilisation** - outline potential utility that could be derived by mines (dependent on intervention design)



Green hydrogen - consideration for mining applications

Key information

Summary: Hydrogen is currently a hot topic across industries, including mining. Its potential to provide clean energy and decarbonise industries has brought it to the forefront of discussions and research on alternative energy sources. Much of the potential of hydrogen in the mining industry is centered around its fuel and powering potential.

Maturity level: Emerging

Industry adoption:

Low

Considerations on utilisation

- **Hydrogen fuel cell-powered mining equipment.** Anglo American Platinum in South Africa is currently piloting hydrogen-fuel cell-powered haul truck – switching from the conventional diesel-powered engines to hydrogen powered ones. Depending on the success of this, this innovation can be rolled out across mining sites, and drive sustainable mining practices. In addition to this, the hydrogen fuel cells can also be used to power large mining drills, small hauling carts and lifts.
- **Powering mining processes.** Hydrogen can be used to produce electricity to power various mining processes and operations, including mineral production and heat generation.
- **Hydrogen as a raw material.** Hydrogen can be an input for various products that are used in mining, such as explosives.
- **Hydrogen as an energy carrier.** Hydrogen can be generated using various technologies and energy sources, and can be used as both a fuel and an energy storage medium.

Considerations on storage

- **Underground facilities for storage.** One of the most common methods of storage for hydrogen gas is in high pressure tanks, in underground facilities, which tend to hold thousands of tonnes of hydrogen. Hydrogen in liquid form requires cryogenic tanks for storage, to maintain the very low temperatures required to store hydrogen in this state. Mine voids and disused mine shafts offer the potential for conversion to hydrogen storage facilities.
- **Geological storage is best for long-term and large-scale storage.** Salt caverns, aquifers, and depleted oil or gas reservoirs have been regarded as the perfect storage options for long-term and large-scale storage, due to the economies of scale, high efficiency and low-cost of these (IEA, n.d.).
- **Storage tanks are optimal for small-scale use and storage.** Storage tanks for liquefied or compressed hydrogen are estimated to have efficiency and discharge rates of nearly 99%
- **Stable storage and transportation.** Hydrogen can be stored for extended periods of time and transported in stable state, similar to oil and gas, across both sea and land.

Defining Evaluation criteria

In order to navigate the complexity of a broad set of solution areas and identify those areas that offer the highest potential for achieving programme objectives, it was necessary to prioritise a number of solution areas for designing interventions that would most effectively deliver value for the mining industry. This is not an easy undertaking as it requires deprioritising solution areas that are often necessary and even offer the potential for being impactful. However, it is important to recognise the existence of a number of constraining factors that necessitate effort and resources are focused on the solution areas that offer the highest potential for achieving programme objectives and that not all avenues can feasibly be pursued. In order to guide this decision making, RIIS has developed a number of key criteria on which to evaluate solution areas and identify those that offer the highest potential. These criteria are outlined in the table below and consist of two primary objectives and supporting criteria.

Liability conversion potential	Impact and sustainability
Potential for revenue generation: ability and potential /LT forecasting for driving revenue streams for the mine that previously didn't exist	**Environmental impact**: this includes sustainable practices and other positive impacts on the environment - Impact on energy use; energy saving - Impact on carbon emissions - Impact on water utilisation and/or pollution - Impact on land pollution or rehabilitation
Potential to offset future debts/ liabilities: Potential to mitigate costs relating to future activities such as CO_2 emissions, land rehabilitation and restoration.	**Economic impact:** this includes factors such as job creation and other local economic empowerment - Job creation - Enterprise development opportunity - Economic diversification in the region - Innovative business model development
Ability to repurpose existing infrastructure and land: the use of already existing mine land, buildings and other assets.	**Social impact:** the proposed solution has community benefit and inclusion – directly or indirectly. - Community empowerment (skills development, etc.) - Community inclusion
Technological maturity: The current maturity of the technology i.e. its *readiness* for commercial application.	**Technical impact**: technology provides opportunity for broader uptake in the country
Commercial feasibility: Demonstrated and successful applications of the technology as well as accessible experts	
Expected significance of Capex and Opex: the magnitude of the new capital investment	
Ability to generate value beyond life of mine: potential for the asset to driver commercial value for the mine beyond its operational lifespan	

RIIS has identified two overarching objectives on which to base criteria. The first being the expected potential to convert existing liabilities into assets in a commercially feasible and effective manner; and the second being the expected potential to achieve impact and sustainability objectives including, environmental impact, economic impact, and social impact. Within these overarching objectives, supporting criteria have been developed and verified with our panel of experts.

Evaluating solution areas

It was critical to ensure a robust and defensible evaluation process in identifying priority solution areas, as this process would be recommended for use by the various industry players, as well as for advancing Phase 3, and therefore needed to stand up to scrutiny. In order to ensure procedural robustness, RIIS has conceptualised and designed an approach in collaboration with our expert panel that can stand up to any scrutiny.

The first step of this process is the development of an evaluation matrix to provide an evaluative framework and ensure consistency during assessment. The framework was based on the two overarching objectives of this project; liability to asset conversion potential, and sustainability.

For each developed solution area, a rational and justification slide developed to rationalise scoring against each criterion. Solution areas are assigned a score against each criterion from 0 -3 with a documented rational for this score. Scoring was conducted collectively between the RIIS team and the panel of experts using a knowledge-based evaluation approach to ensure consistency in application of

scoring and comprehensive consideration provided to each final score. The scoring rubric is provided below:

0 - Solution area does not offer any feasible potential for this criterion to be met.

1 - Solution area offers little potential for feasibly meeting this criterion

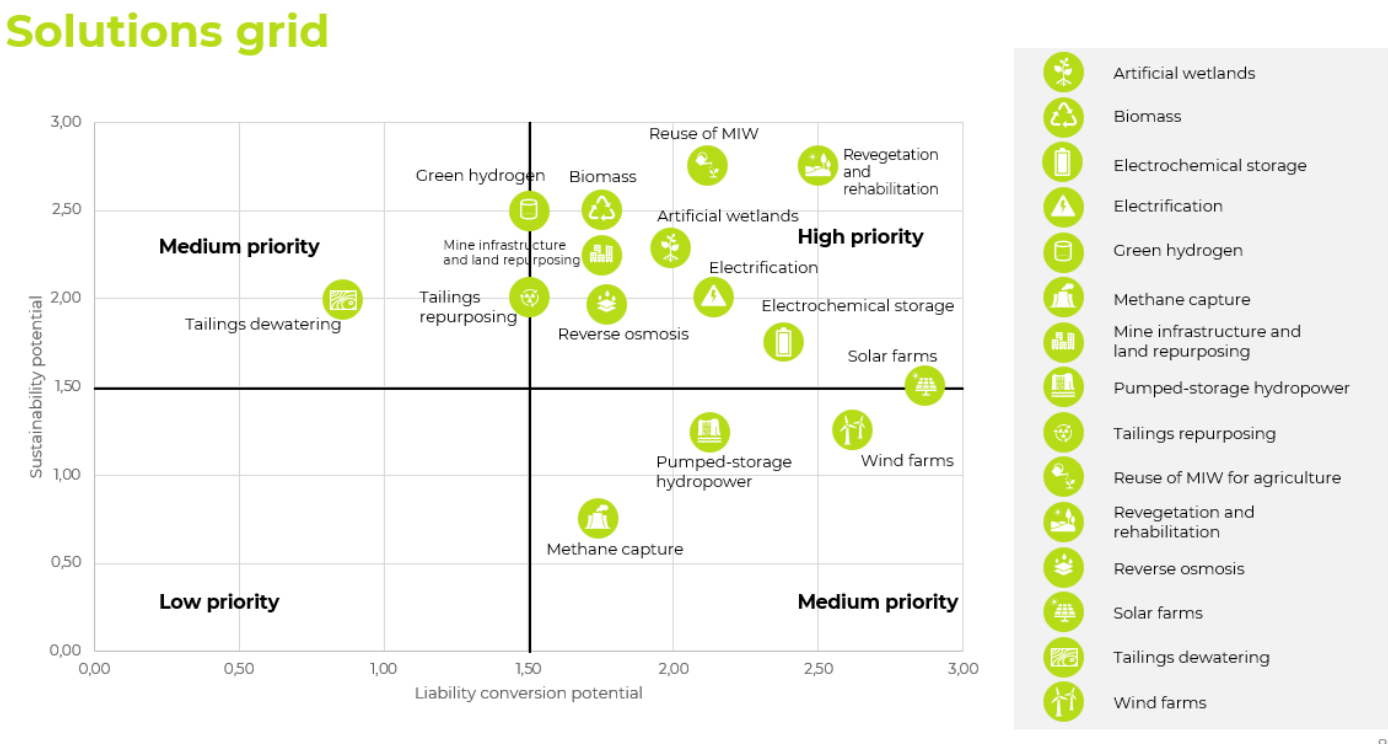
2 – Solution area offers notable potential for feasibly meeting this criterion

3 - Solution area offers significant potential for feasibly meeting this criterion

The evaluation process and framework has been extensively documented and can be found in Appendix 1: Prioritisation Overview Report.

Prioritising solution areas

With evaluation criteria and approach defined, it is necessary to ensure the outcomes are able to translate into clear and interpretable information on which to base prioritisation decision making. In order to do this RIIS has translated the scoring outcomes into an overarching final assessment of each solution areas against each overarching program objective. This required standardising the criteria into an aggregated score for each programme objective, ensuring that criteria score is provided equal weighting.



After scoring the different solution areas according to the prioritisation framework, each solution area had an aggregated score in terms of its liability conversion potential and sustainability potential. The scores on these two axes were then combined in order to rank the solution areas to see which were the most viable.

The results of the ranking process are indicated above. The scoring indicated that revegetation and rehabilitation, reuse of mine-impacted water and solar farms were the most promising and viable solutions for the mining sector to implement to become more sustainable. These final outcomes were documented, verified and rationalised through our expert panel, and shared with MMP for feedback and input.

We believe that the developed evaluation and prioritisation framework is a tool that can be used by industry in the programme and beyond, to assist in decision making processes that require an objective and robust approach.

5.3 Milestone 3: Design

The Design Milestone is critical for understanding implementation requirements of the various interventions, as well as their potential for liability to asset conversion. The objectives defined as follows:

- Workshop and design case study template to capture key and relevant information for implementation considerations.
- Conduct extensive research on prioritised case studies.
- Consolidate information and complete case study write-up.
- Review and verify case studies for submission.

The key objectives of Milestone 3 were therefore to:

- Develop comprehensive case studies, across all the solution areas and identified interventions, through extensive desktop research, and where possible interviews with the relevant stakeholders.
- Review and verify the case studies to ensure the relevance for the South African mining industry and context.

For each of these objectives, the following outcomes were achieved:

Workshop and design of case study template
Considering the constraints of publicly available information a first critical step was to design the case study template in a way that would capture key implementation information and considerations. Furthermore, it became important to demonstrate the ability of the prioritisation matrix (from milestone 2) to evaluate solution areas and highlight their potential.
The team proceeded with the following focus areas for the case study:

- **Liability to asset conversion** – identifying areas in which the interventions demonstrate potential for asset to liability conversion. These were based on the liability to asset criteria list used in the evaluation framework developed in Milestone 2: Solutioning included the following:
- **Enablers –** these include both project specific and broader technology-related enablers of successful adoption and rollout of the interventions, including legislative and economic advantages.
- **Constraints –** these include both project specific and broader technology-related constraints that would limit or hinder wider uptake of the

technology or adoption. This section also highlighted some of the barriers and challenges faced in adoption.

- **Commercial considerations –** these are the project-specific cost and income factors that are important to consider, such total project costs and sources of income or saving from the project. These provide a high-level overview of the financial considerations.
- **Environmental, economic and social impacts –** this includes both the project-specific and broader technology impacts for each of the three areas, benefits and challenges, during and post-mining.

The aim was to design a template that would provide a holistic view of what implementation of the interventions could possibly look like, based on actual examples that have been implemented.

An illustrative example of the case study template has been provided below.

REVERSE OSMOSIS AT EMALAHLENI WATER RECLAMATION PLANT

ANGLO COAL SA & BHP BILLITON ENERGY COAL SA, SOUTH AFRICA

The eMalahleni Water Reclamation Plant is an award-winning, private-public partnership led by Anglo Coal and BHP Billiton in partnership with the eMalahleni Local Municipality, to treat water from their Greenside, Kleinkopie and South Witbank Collieries, as well as surrounding areas.

Excess underground water from the coal mines is pumped to the reclamation plant and treated to produce potable water. This is done using a process of reverse-osmosis called Hi Recovery Precipitating Reverse Osmosis (Hi PRO), which efficiently maximises water recovery and reduces waste production. Over 70% of this is chlorinated and supplied to the eMalahleni local government, which has struggled to meet its potable water demands. The plant provides eMalahleni with 12% of its 120 megalitres daily potable water demand, which is expected to reach 180 megalitres by 2030. The rest of the water is used to meet the water needs of the Anglo Coal collieries in the area, namely, Greenside, Landau, and Kleinkopie Collieries, as well as the mines' service departments.

Commissioned in October 2007, the plant is currently undertaking its second phase of development, which is expected to increase potable water production to 33 megalitres daily.

25 ML — Daily production of potable water from the plant

12% — Of eMalahleni potable water demand is supplied

LIABILITY TO ASSEST CONVERSION

Revenue potential — Through the process of reverse osmosis (RO) enough water is produced at the eMalahleni water reclamation plant to make supplying the local community possible. More than 70% of the daily potable water produced at the plant is supplied to the local municipality, allowing for revenue generation.

Value generation — Plants such as the EWRP will be able to generate value even post mine closure, not only through the production and sale of potable water, but through the reuse of the waste products. For example, gypsum waste is processed and used as low-cost building material in house construction.

Capex/ Opex — RO is an energy intensive process, and is likely to require a significant capital investment. The EWRP is estimated to have required a USD 54 million investment from Anglo Coal. With continued developments in the technology however, the operating costs of RO are expected to offset the initial high capital investment in the long run

Feasibility — RO has been used as a water treatment method at the industrial and even domestic level. It is the most common desalination method and grown in application with an increasing scarcity of clean water worldwide. The proven success of the eMalahleni reclamation plant is a testament to this.

Enablers

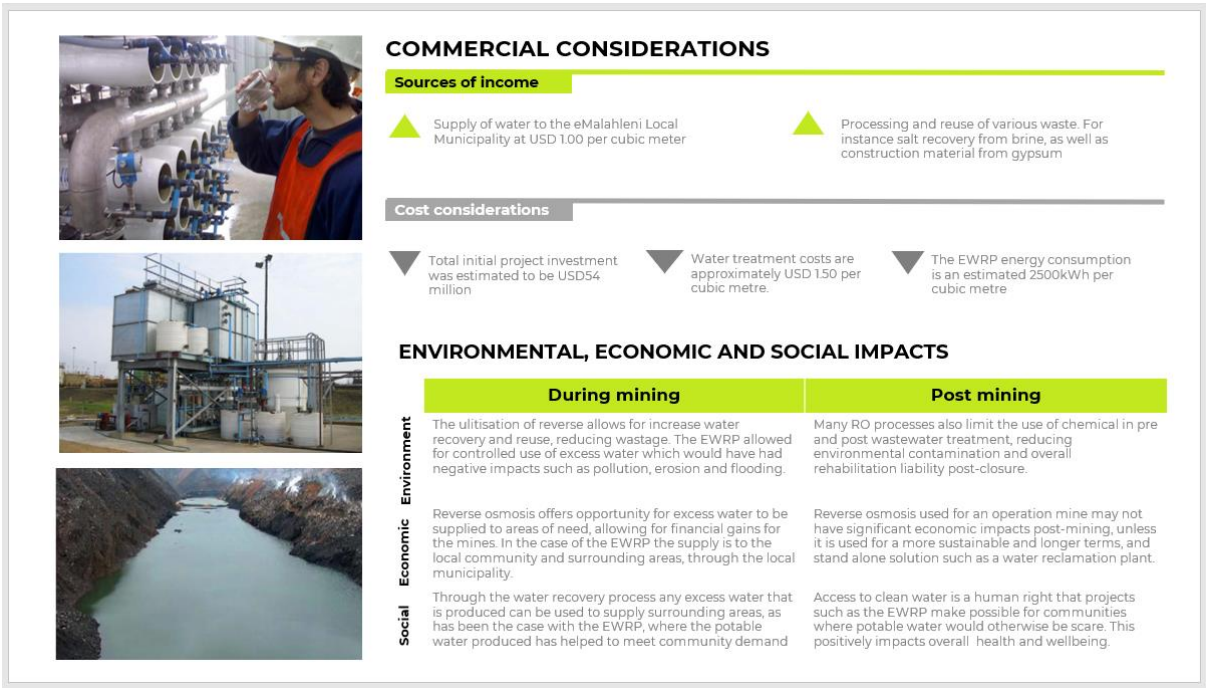
- The continued demand for additional potable water suppliers from the eMalahleni municipality will encourage sustainable water production by the plant, but also allows the mining companies to significantly impact the wellbeing of the local communities, through the consistent supply of a scare commodity.
- The significance of the environmental impact of the EWRP, through the prevention of possible damage due to excess underground water makes it a viable option not only for operational mines, but for mines that are closed as well. The automated plants allow for greater ease of operation and may reduce post-mine closure liability.
- RO is a mature technology, and further developments of it are leading to lower capital and operational costs, increasing possibility of adoption at the individual mine level, as a method of water recovery and recycling – with a 90% .recovery rate.

Constraints

- For profitable economic applications of RO, particularly in the mining industry where uptake is low, it is critical that water recovery rates are maximised, and waste production rates are minimised.

PROJECT PARTNER(S)

AngloAmerican BHP EMALAHLENI LOCAL MUNICIPALITY



Each of the case studies is preceded by an overview of the broader solution area, within which the intervention falls.

Case study prioritisation and research

Before the commencement of desktop research, the team ensured full coverage under each of the following solution areas:

- Energy and storage
- Land
- Tailings management
- Water

The prioritisation of the case studies was based on (i) the amount of accessible information available to inform key areas of each case study (ii) the relevance of the case study to the South African mining industry, and (iii) the extent of demonstrable successful implementation examples of a technology. This inherently applies a bias towards more established technologies while potentially excluding those that more nascent. We recognise this shortcoming and have attempted to mitigate for this by including those solution areas where we have a deficit of information and stipulated this in our reporting. Where the interventions had a strong case for relevance they were kept and a request for addition information sent out to the relevant parties for assistance.

The team undertook an extensive desktop research process and identified a number of key informant interviews to be undertaken to bolster areas within the case studies where information was not accessible. Due to time constraints and slow response to requests for interviews, the team were unable to update the case studies with uncovered insights from interview participants, however our team will conduct these interviews and uptake our case studies at the onset of Phase 3 of the project. The areas highlighted in the case study template were critical for guiding the research process.

Consolidation and write-up
All the key and relevant information from the research process was consolidated and then written up into comprehensive case studies.

Review and verification
Upon completion of the write up process, the case studies underwent a review and verification process, to ensure that indeed the information captured was relevant to the South African mining industry and would be sufficient for further discussions and deliberations on the possible interventions to proceed with into implementation.

Milestone findings
The purpose of this Milestone was to develop a comprehensive case for implementation that would assist in informing the decision on possible interventions for implementation in South Africa, through case study template workshopping and design; case study prioritisation and research; consolidation and write-up; and review and verification. Through this Milestone we were able to uncover information that assisted in understanding which technologies were more mature and had wider adoption and could offer many lessons vs those that were still novel and had little to no implementation examples, therefore requiring further research and development. Through demonstrating implementation case studies of high potential solutions, we are able to draw key insights and learnings that will inform solution selection and implementation decisions going forward.

The findings of this process are captured in a separate report which has been submitted to MMP and has been included as Appendix 2: Implementation Case Study Report.

6 Conclusion

In Milestone 1, a partnership with a team of experts from University of Pretoria Enterprise was established to ensure that the ultimate deliverable of this programme was able to effectively drive intended outcomes, and that the methodology and process followed is robust and defensible. The objectives of the internal expert panel were to provide technical guidance and expertise that would support the key outcomes of the subsequent phases of the programme including by helping define and prioritise solution areas, by aiding with the design of intervention research and by enabling the development of comprehensive reporting on solution areas and bankable models for future sustainable mining interventions.

Milestone 2 produced a methodology and approach to prioritising technological solution areas. This prioritisation framework enabled the development of a matrix showcasing the solution areas with the highest potential to i) convert a mine's liabilities into assets and ii) have positive environmental, social and economic impacts. The ultimate objective is for the prioritisation framework to serve as a decision-making tool that enables mining companies to map out the variables that need to be considered when implementing renewable technologies. The detailed

framework and its application to various solution areas can be found in Appendix 1: Prioritisation Overview Report.

In Milestone 3, the prioritisation framework was applied to various case studies to demonstrate how it can highlight the factors that contribute to successful implementation of renewable energy technologies in mining operations. This can enable mining companies to learn from the experiences of others and identify best practices for implementation. The outcome of the Milestone was a comprehensive document with key information on case studies that look into the conversion of liabilities into assets, as well as promote sustainable mining practices, essentially building a business case for the transition to more sustainable technologies in the mining industry. Although these are relevant to the South African mining industry, particular attention needs to be paid to how some of these would be rolled out in the gold, chrome and platinum group metals mines, which this project focuses on. There are also geographical considerations, as some of the interventions were implemented aboard, in countries such as Australia and the United States, where the geographic, political, economic and legislative contexts will differ from the South African one. However, key learnings have been derived and we are able to identify enabling and constraining factors to implementation is south Africa's mining sector.

The case studies can be found in Appendix 2: Implementation Case Studies.

7 Recommendations

Across Phase 2 of the programme RIIS has provided a number of recommendations specific to Milestones 1 to 3, and the summaries of these can be found in Section 4: Results. The detailed recommendations

The overarching and key recommendations coming out of Phase 2 are as follows:

- **Prioritisation tool:** in the Solutioning Milestone, the team developed a prioritisation framework that industry can employ for objective intervention evaluation. The tool can assist in the ranking of evaluated of solutions, provide guidance on interventions that should be considered for Implementations, as well as help individuals and teams think through some of the logic behind the ratings and the potential of impact of interventions. The employment of this tool is not limited to this programme. And Phase 3 of this programme should ensure broad dissemination of this tool for industry adoption.

- **Engagement with project implementors:** Although quite comprehensive, due to some of the limitations of desktop research and accessible information, the team highly recommends further, extensive engagement with the implementors of interventions of interest, to fill in some of the information gaps that may exist in some of the implementation case studies, as well as to get first-hand advice and direction. The developed case studies provide comprehensive overviews and illustrative examples, which are an excellent starting point, however further one-on-one engagement is necessary, particularly for those solutions that will be considered for implementation in Phase 3.

- **Stakeholder consultation:** As one of the first activities for Phase 3 of the programme, the team recommends verification workshops with key industry players, before a final decision is made on the interventions that will undergo trial implementation, for consultation and advisory purposes. We believe this is important for strengthening solutions through enabling input from implementing parties from various key stakeholders, across the mining industry, including research institutions and academia, NGOs, etc.

8 Way forward

The completion of phase 2 of this assignment provides a comprehensive foundation on which to prioritise solution areas based on extensive research into the applicability of those solution areas and inform implementation planning. With this footing, RIIS would like to turn our attention towards driving industry adoption and preparing for implementation of a suit of solutions that provide a test case for the South African mining industry.

Over the course of Phase 3 of LoCM, RIIS would like to accomplish the following:

Build stakeholder buy-in and interest in uptake. Through our stakeholder network we aim to build consensus on a feasible way forward with input from industry, academia, and civil society. Through presentation of the solution areas to our community of stakeholders, we aim to refine and prioritise these resulting in the prioritisation of 3 solutions to take forward.

Establishing a mine partnership – RIIS will consult with the various mine houses and determine the level of interest in adopting solution in their own mining operations. Based on this, a solution area will be prioritised for taking forward through a partner mine in South Africa.

Building a joint approach – Based on the priority solution area, RIIS will convene implementation partners through hosting a series of human centred design workshop to collaboratively build out and design an intervention for a partner mine. This will include input from technology providers, mine operators, targeted civil society organisations, and key experts.

Building a pathway to implementation – will a comprehensively designed intervention for a partner mine, RIIS will prepare for implementation through; securing commitment form relevant implementation partners, supporting the process to secure funding, and coordinating the definition of a joint implementation approach.

9 Lessons learned

This section highlights key takeaways from the efforts to identify renewable energy, water management, and land conservation technologies that can enable the mining sector to transition to a more sustainable mode of operation.

The value of interdisciplinary collaboration
The project required a diverse team with expertise in renewable energy, water management, land conservation, and mining operations. By bringing together individuals from different backgrounds, we were able to develop a holistic understanding of the challenges and opportunities associated with the transition to a cleaner mode of operation in the mining sector. Furthermore, various outputs such as the prioritisation framework were made more rigorous and useful by incorporating feedback from multiple perspectives.

The need for a structured approach to compare solution areas
It became clear during the project that, owing to the complex and multi-faceted nature of transitioning to renewable technologies, there was a need to develop a structured approach to evaluate the financial, environmental, social and socio-economic impacts of solution areas. This resulted in the development of the prioritisation framework, which is intended to serve as a decision-making tool that provides a means by which to evaluate the pros and cons of various technological solutions, both in isolation and in comparison to each other. Furthermore, the case studies complement the framework by providing concrete examples of reduced energy costs and carbon emissions, better water management and more effective land rehabilitation – all factors that are included in the framework, thus indicating its value as a standardised prioritisation tool.

The importance of augmenting qualitative information with quantitative analysis
The prioritisation matrix is a qualitative tool that provides a valuable starting point for mining companies to assess the potential of various solution areas. However, additional information that accounts for the companies unique operating environment as well as a detailed analysis of the economic feasibility of technologies will need to be conducted before a technological intervention is adopted.

10 Appendix

Appendix 1: Prioritisation Overview Report

Appendix 2: Implementation Case Studies