

Application of large language models to develop an ESG digital twin for mining operations

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Project Highlights:

- Development of an LLM-enabled ESG digital twin framework for mining projects that converts mine plans, technical reports and production schedules into standardised estimates of carbon emissions, energy demand, water consumption and environmental performance.

Overview:

Investors, regulators and mining companies increasingly require robust environmental, social and governance (ESG) assessments prior to project development. Current ESG assessments are typically bespoke, consultant-led exercises that are difficult to compare across projects and often rely on inconsistent reporting standards.

This project will develop an large language model (LLM)-enabled ESG Digital Twin platform that transforms mine designs, technical reports and production plans into standardised estimates of carbon emissions, energy demand, water consumption and environmental performance. By combining knowledge of mining engineering, geoscience with LLMs, the system will create a scalable benchmark engine capable of comparing projects across different commodities, jurisdictions and mining methods.

The long-term vision is to establish a new industry standard for ESG-adjusted project valuation, enabling investors and developers to quantify environmental performance and ESG-related risks before construction.

Methodology:

Stage 1: Build a standardized taxonomy of mines – with each archetype having: a typical range of emissions, water intensity, energy profile, etc. This would allow high-level benchmarking of ESG predictions for a new mine against commodity, mining method, etc. industry ranges.

Stage 2: Develop a mine ESG digital twin that takes the physical design of a mine (ore type, production, mining method) and breaks it into processes like extraction, hauling, and processing. It applies engineering-based intensity factors (energy and water use per tonne) to each step to estimate outputs such as CO₂ emissions, water use, and waste. The model is then used to simulate and benchmark environmental performance across alternative design and operating scenarios. It is subsequently calibrated and validated using real operational data (e.g., reported emissions and water use) to improve predictive accuracy over time.

Possible Timeline

Year 1: Literature review; Development of mine taxonomy; Collection of technical reports and ESG disclosures; Initial LLM extraction workflows; and Construction of ESG knowledge graph.

Year 2: Development of digital twin architecture; Engineering process models; Benchmark database development; Initial validation exercises.

Year 3: Integration of LLM-powered scenario generation; Calibration using operational mine datasets; Development of ESG risk metrics.

Training and skills:

The candidate will develop expertise at the intersection of mining engineering, computer science, AI, programming, sustainability analytics and investment decision-making, creating a highly transferable skill set for industry, consulting, investment and research careers.

TARGET researchers will also participate in a minimum of 40 days training over the 3.5 years of study composed of:

- an annual one-week workshop dedicated to their year group, and tailored to that cohort's needs in terms of skills development – *for the first three years of their study*;
- an annual all-TARGET workshop with cross-year interactions, advanced training and opportunities to specialise in particular areas – *all years of study*;
- a number of one-day workshops;
- additional online events and in-person workshops attached to relevant conferences.

Partners and collaboration (including CASE):

CASE support for this project will be provided by KMO Fleet who are an innovative mining technology company specialising in the optimisation of mobile mining fleets. The student will benefit from 3 months placement with the KMO fleet team to learn a wide range of skill related to coding, LLM application for mine site data collection and compilation and to understand the market for commercialisation of findings.

Further details:

Please visit <https://target.le.ac.uk/> for additional details on how to apply. Please contact r.crane@exeter.ac.uk with any questions.