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Hybrid Real-Time Life Cycle Assessment for Performance Monitoring in Mineral Extraction and Processing Facilities

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Introduction

The DINAMINE project seeks to integrate digital technologies to enhance the environmental performance and sustainability of mining operations, particularly for small and medium-sized mines, using a real-time LCA framework. LCA is gaining traction in the mining sector as a tool for monitoring environmental impacts. However, current LCA approaches often lack the timeliness necessary for operational decision-making. The DINAMINE project addresses this by implementing real-time monitoring. Real-time LCA, supported by hybrid input-output frameworks, can improve environmental performance monitoring and management in the mining sector, leading to more sustainable operations.

Objectives

- Develop and apply a **hybrid input-output LCA framework** that leverages both process-based and EEIO databases for dynamic, real-time assessment.
- Integrate **EXIOBASE data** for socio-environmental impact tracking, with a focus on **hotspot identification** and rapid response capabilities.
- Incorporate **LCA Analytics** into the **Integrated Smart Mine Planning and Managing (ISMPM)** system

Method

Hybrid I-O LCA Framework:

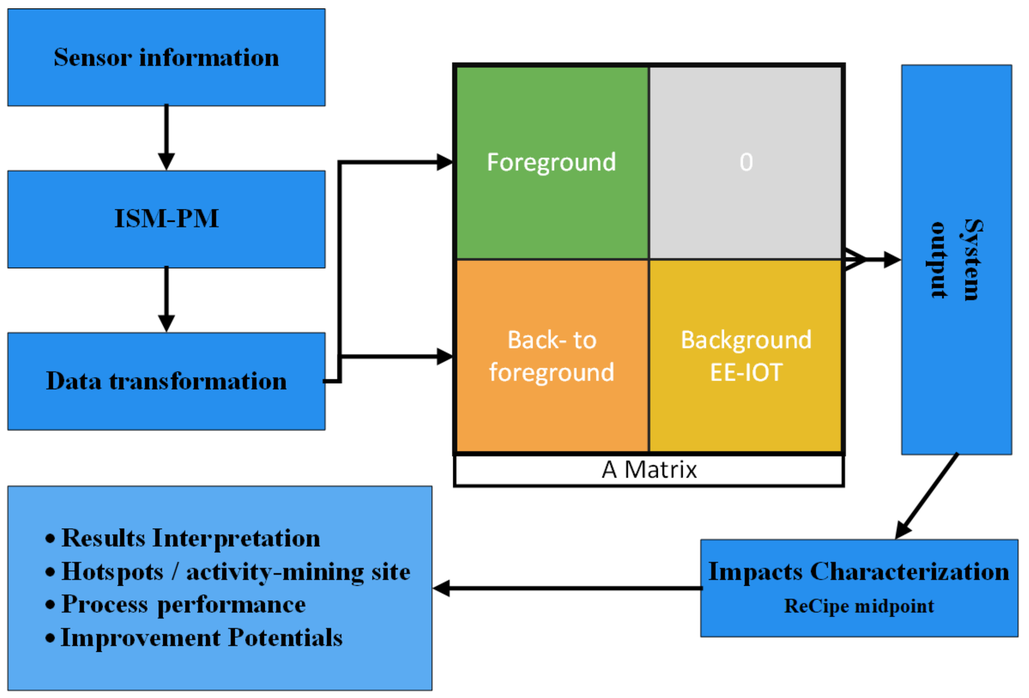
- Combines **process-based LCA** for asset evaluation and **EEIO LCA** for tracking ongoing operational emissions.
- Incorporates **EXIOBASE data** to provide sectoral and geographic specificity.
- Uses the **MARIO Python package** to manage background data aggregation (e.g., sector or geographic granularity).

Data Integration:

- The **Integrated Smart Mine Planning and Managing (ISMPM) system** gathers real-time data on key mining parameters.
- Collaboration with mine operators to determine **sensor selection** and key measurement points.

Real-Time Monitoring: The ISMP platform integrates environmental and operational data, using a **traffic light system** for easy-to-understand visualization.

Gamification: Gamified performance metrics encourage plant operators to engage with the LCA data by tracking their progress on various LCIA indicators.



Results

Faster Decision Making: The hybrid framework allows for rapid identification of **environmental impact hotspots** in real time, outperforming traditional LCA methods.

Targeted Interventions: Real-time data enables operators to implement immediate corrective actions in response to adverse environmental metrics.

Social Impact Integration: Indicators from EXIOBASE integrate social aspects into the LCA, providing a holistic view of mining operations' sustainability.

Discussion

Advantages:

- The combination of **real-time data** and LCA allows for **proactive decision-making** in dynamic mining environments.
- The use of **MARIO and EXIOBASE** enables detailed and accurate environmental assessments, accounting for both short and long-term impacts.

Challenges:

- Difficulty in aligning process-based LCA data with EEIO databases, especially in terms of data resolution.
- **Asset management complexities**: accounting for irregular usage patterns and early retirement can skew results.
- **Mismatched temporal resolution** of LCIA between background and foreground activities.

Conclusion

- The hybrid I-O LCA framework demonstrates that real-time LCA can provide **timely, actionable insights** for enhancing the sustainability of mining operations.
- The integration of **gamification**, **sensor data**, and **dynamic assessments** represents a significant advancement for small and medium-sized mines.
- While challenges remain in terms of **database integration** and data resolution, the potential for continuous improvement and responsive environmental management makes this approach highly promising.

DINAMINE

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