Which Way to Turn?

A Practical Guide to Evaluating Electrification Options in Mine Haulage

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Spectrum of Electrification

- Conventional (Truck & Shovel)
- Trolley Assist — Incremental Change
- Battery Electric Vehicles — Incremental Change
- Semi-fixed Ex-pit or In-Pit Crushing and Conveying (IPCC)
- Semi-mobile IPCC — Step Change
- Fully mobile IPCC — Step Change

- Evaluation Tools have not kept up with Electrification, particularly for Step Change

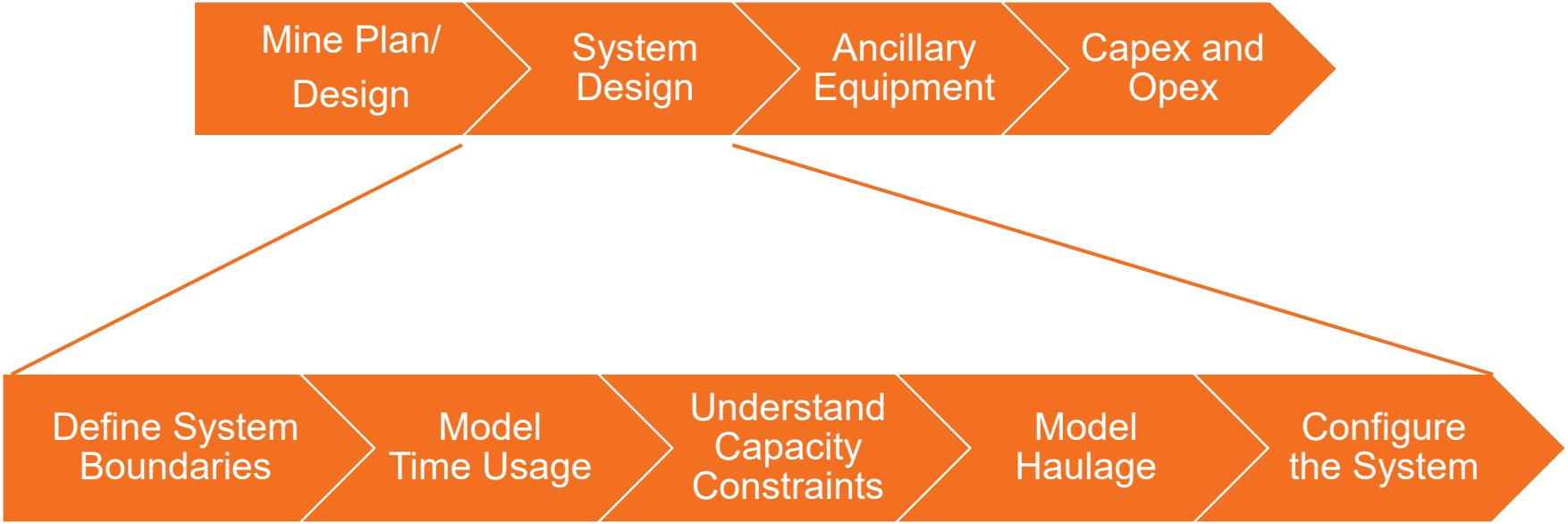
Where Traditional Methods Break

- Conventional Approach

- The gap for electrification:
  - No infrastructure
  - Missing system constraints
  - Different ancillary equipment requirements
  - Missing key operating cost centres (power, water, infrastructure maintenance, etc.)

So, What is the Alternative?

- Adopt a systems-based approach



Time & Availability

- System Availability:
  - **Availibility$_1$ X Availability$_2$ X Availability$_3$ …**

- Small losses compound quickly
- Model system to handle quantities in time available
- Quantify system downtime
  - Have contingency plans to keep equipment busy, but not at full production rates

Capacity Modeling

- Look for bottlenecks that govern throughput
  - For IPCC, align Crushing capacity to availability of IPCC targeted feed, including capacity of shovels supplying that feed
  - Ensure trucks can physically feed Crusher at required rates (i.e. multiple bays)
  - Model conveyors, with consideration of redundancy to accommodate different material types or downtime

Haulage Modeling

- Changes by technology
- Trolley Assist
  - Truck to Trolley
  - Truck on Trolley
- IPCC
  - Truck Only to Dump or ROM/Crusher
  - Truck to IPCC Crusher

Configure the System

- Trolley Assist
  - Catenary System
  - Substation Rectifiers
- IPCC
  - Crusher
  - In-pit Conveyor
  - Overland Conveyors
  - Dump Conveyors
- Site Power Supply

Evaluation Approaches - IPCC

IPCC	Scoping	Pre-feasibility	Feasibility
Compare to trucks only?	Yes	Maybe	No
Pit design	Truck pit designs/shells	Design for IPCC; phasing to use common wall if possible	Design for IPCC; phasing to use common wall if possible
Crusher selection	Assumed	Based on material testing	Based on material testing
Crusher stations	Conceptual, locations only; estimate extra excavation	Designed; consider blasting	Geotech investigated; engineered walls; detailed drill & blast
Pit exit strategy	Location only; estimate extra excavation	Part of pit design (shared or dedicated ramp)	Part of pit design; hazard risk analysis
Waste facility	Strategy selected; conceptual designs	Staging designs	Staging designs; including conveyor relocation planning
System operating hours	Time usage model	Time usage model	Time usage model; possible simulation
Costing	• Considers haulage and related support only • Benchmark, +/-40-50% • Opex elements: power, parts, ops+mtc labor, water	• Haulage and support only • Power estimated • OEM OTS pricing and performance checks • +/-25% accuracy	• Integrated into overall mine costing • OEM engineering to at least AACE Class 3

Evaluation Approaches – Trolley Assist

TROLLEY ASSIST	Scoping	Pre-feasibility	Feasibility
Compare to trucks only?	Yes	Maybe	No
Pit design	Truck pit designs/shells	Design for CS; phasing to use common wall if possible	Design for CS; phasing to use common wall if possible
In-pit CS* strategy	Two lane or three lane width CS ramp (+extra excavation)	Designed with pit design	Designed with pit design, hazard analysis on CS lines
Ex-pit CS strategy	Consider ramps in waste facilities	Consider ramps in waste facilities	Consider ramps in waste facilities.
System operating hours	Time usage model	Time usage model	Time usage model; possible simulation
Costing	• Considers haulage and related support only • Benchmark, +/-40-50% • Opex elements: power, parts, ops and mtc labour	• Haulage and support only • Power estimated • OEM OTS pricing and performance checks • +/-25% accuracy	• Integrated into overall mine costing • OEM engineering to at least AACE Class 3

* - CS = caternary system – either overhead or side rail (e.g. CAT DET or Liebherr Power Rail)

Evaluation Approaches – Tools

	Scoping	Pre-feasibility	Feasibility
Scope	Multiple technologies, including conventional, for TOS	Complete models per technology, possible integrated TOS	Complete detailed models for select technologies
Tool Type(s)	100% spreadsheet	Spreadsheet with inputs from specialty tools	Multiple specialty tools and sources, integrated in spreadsheet
Haulage	Distance and elevation tables for up and down hauls (e.g. down to lower crusher or trolley); Speed tables and fuel burn with gradient; contingency hauls	Definition of all hauls, with cycle times and fuel burn provided by specialty software; refine all hauls	Continued detailing of hauls in specialty software; possibly import into discrete simulation software along with other functions (e.g. crusher interaction, upset events)
Power Usage	High level assumptions for crushers and conveyor runs	Simple power modeling of conveyor runs	Advanced conveyor software or provided by OEMs
OEM Support	Performance specifications; Budgetary Capex and Maintenance Parts (Opex)	Performance specifications; Provides costing specific to project set-up	May takeover and take responsibility for all performance and costing

System Modeling

	IPCC	Trolley Assist
Crusher Station	Extra mining?	On-truck infrastructure
	Retaining wall or bench face?	Trolley infrastructure
	Hopper and Apron Feeder	
	Crusher and Discharge Conveyor	
Pit Exit	Ramp Conveyor	On-truck infrastructure
	Conveyor Crossings (overhead or underpass)	In-pit Trolley infrastructure
Ex-pit Conveyors	Dump Conveyors	Dump Trolley infrastructure
	Overland Conveyors	
Ancil. Equipment	Transporter, dozer, compactor, picker truck, belt reeler, splicer, etc.	

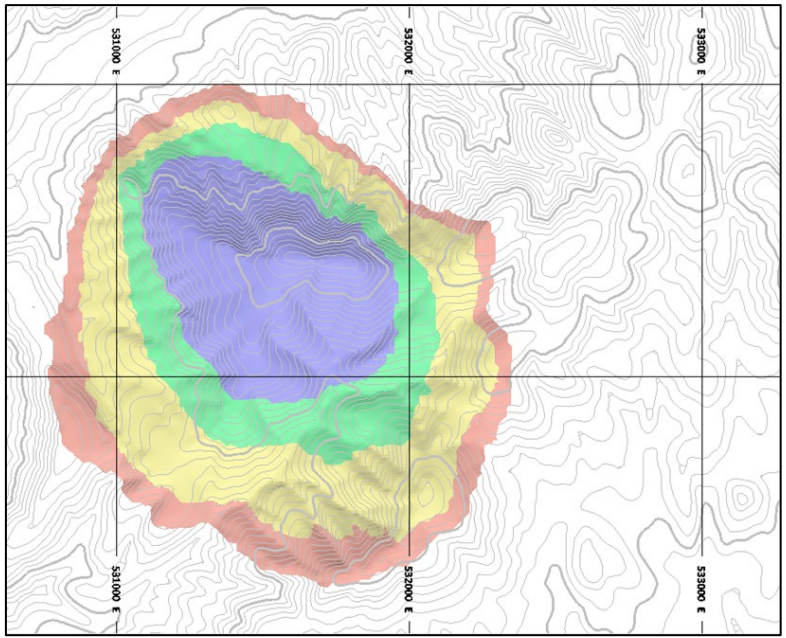
Case Study

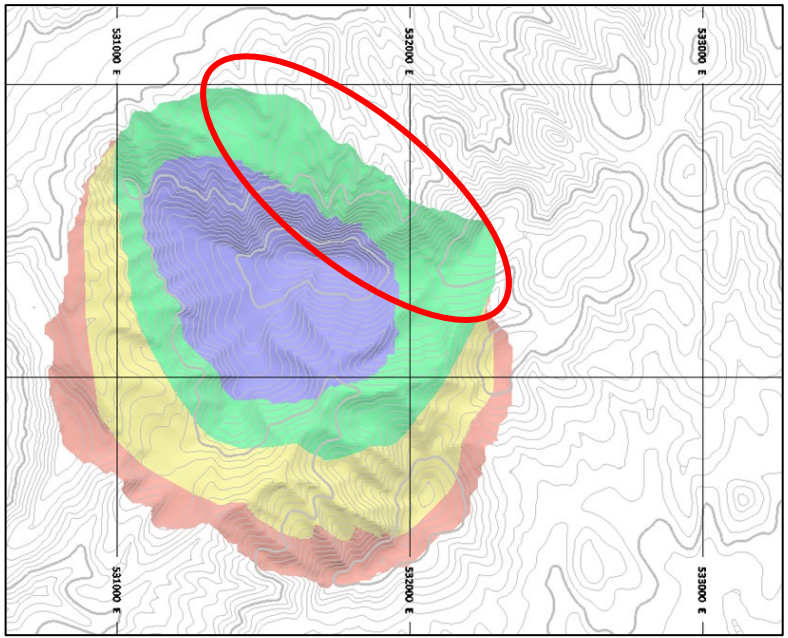
- AngloGold Ashanti, Silicon Project, Nevada
- 2023 Concept Study

  - Technologies investigated:
    - Conventional Truck
    - Trolley assist
    - IPCC
    - High Angle Conveying (HAC)

Case Study

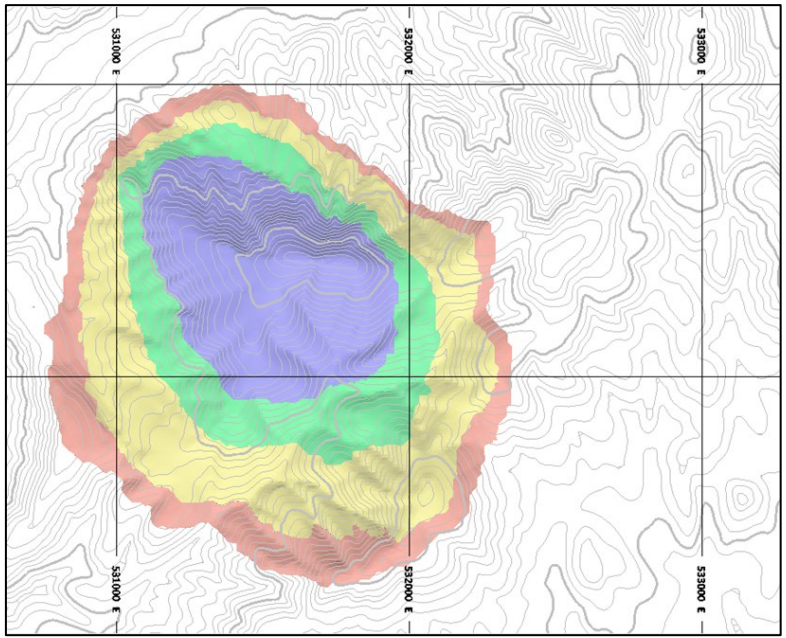
- Phase definition – for IPCC or Trolley Assist
  - Combine phases particularly along a straighter segment of wall

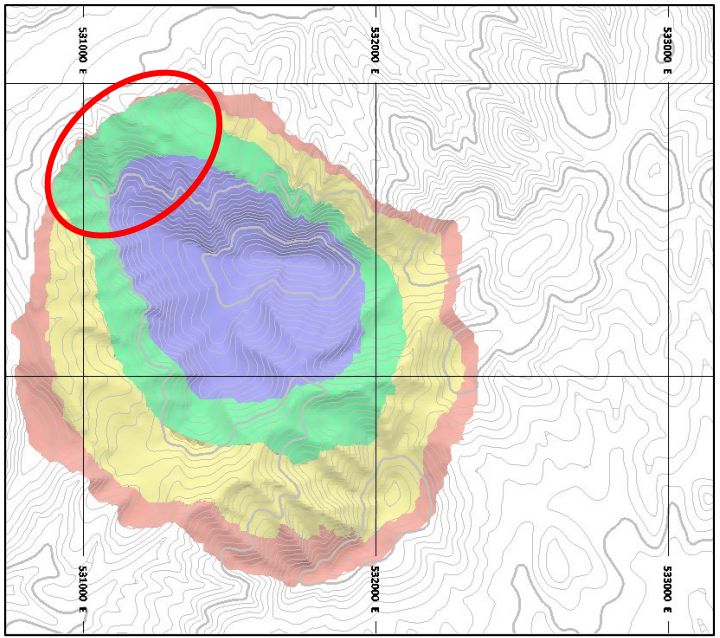




Case Study

- Phase definition – for High Angle Conveyor
  - Combine phases in small segment of wall where phases are closely spaced





Case Study

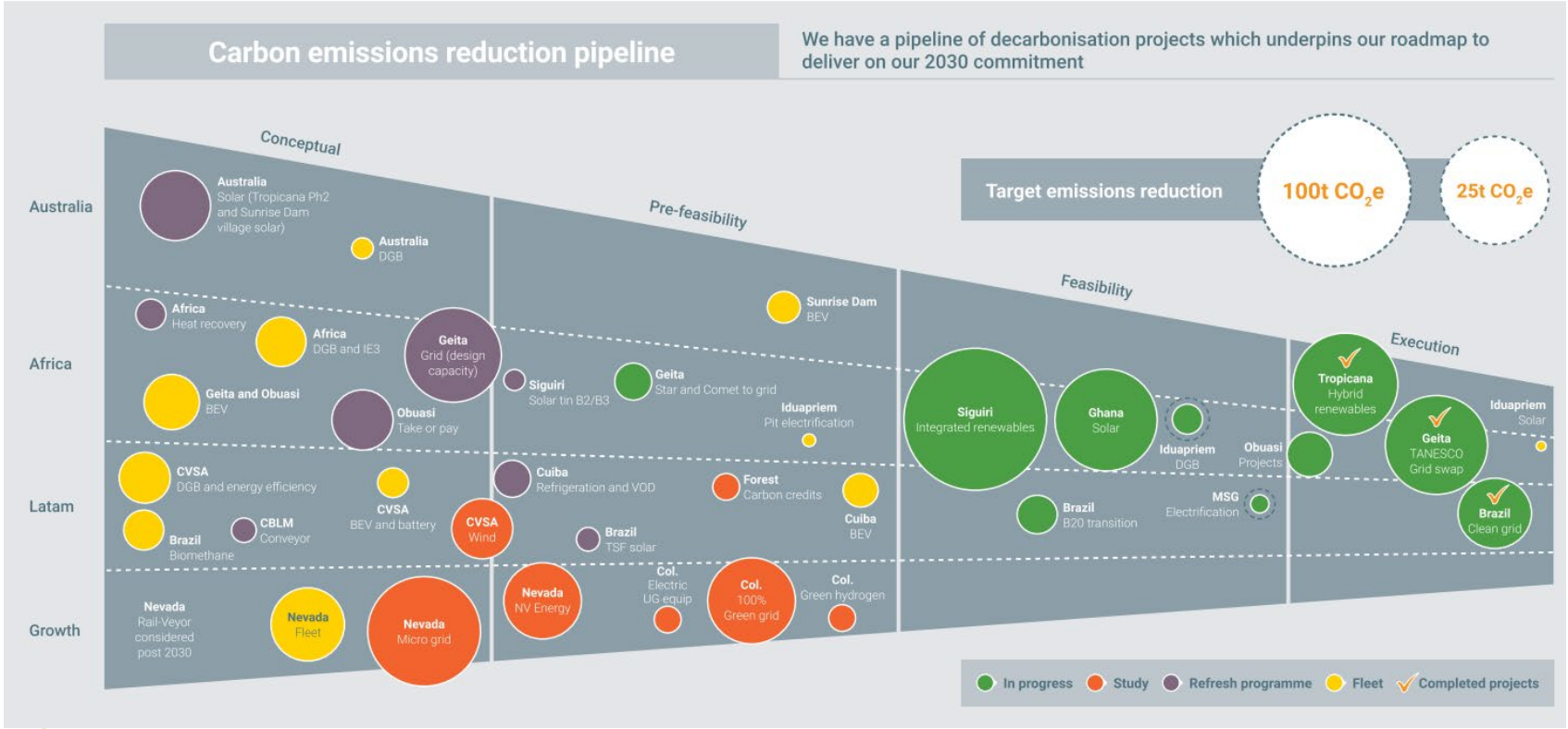
- Scenarios, ranked by NPV of cost savings (NPVc)

		NPVc Ranking
IPCC-1	Conventional Conveyor Waste Only Conveyed	9
IPCC-2	Conventional Conveyor Waste and Ore Conveyed - ROM not crushed/conveyed	5
IPCC-2b	Conventional Conveyor Waste and Ore Conveyed - ROM crushed at ex-pit crusher	6
IPCC-3	Conventional Conveyor Waste and Ore Conveyed - ROM crushed/conveyed	3
HAC-1	High Angle Conveyor Waste Only Conveyed	4
HAC-2	High Angle Conveyor Waste and Ore Conveyed - ROM not crushed/conveyed	2
HAC-3	High Angle Conveyor Waste and Ore Conveyed - ROM crushed/conveyed	1
TA-1	Trolley Assist - Waste and Ore (in-Pit) - Two lane	7
TA-2	Trolley Assist - Waste and Ore (in-Pit) - Three lane	8

Case Study

- Takeaways from this study:
  - Cost savings available from moving to electrification
  - IPCC generally more cost effective than Trolley Assist
  - The more material crushed and conveyed, the greater the savings
  - Where it works, HAC has clear potential

AGA Future Direction



Arthur Gold Project: Decarbonization & Development Path Forward

1. **Strategic Evolution: The District Range Project**

   – **Project Consolidation**: The Silicon project has transitioned to become part of the **District Range Project**, which is a component of the broader **Arthur Gold Project** (formerly known as the Expanded Silicon Project).

Arthur Gold Project: Decarbonization & Development Path Forward

2. Decarbonization & Operational Innovation

- **Autonomous Systems:** Enhances safety and utilization.
- **Trolley Assist:** Reduces diesel consumption and increases uphill cycle speeds.
- **Electrified Fleet:** Pairs Electric Rope Shovels with Ultra-Class Trucks to transition primary energy demand to the grid.

Thank-you

Questions?

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