Orchardman Pty Ltd

Whittle Consulting
Integrated Strategic Planning for the Mining Industry

LIFE OF MINE CONFERENCE 2023

Dynamic Influences of Optimisation on Emissions

Philip Bangerter & Jason Pan

4 Aug 2023 Session 9

Acknowledgements

Co-author : Jason Pan, Whittle Consulting

Whittle Consulting Pty Ltd

Mirco Nolte, Dundee Precious Metals

Ronne Hamerslag, Nordic Iron Ore

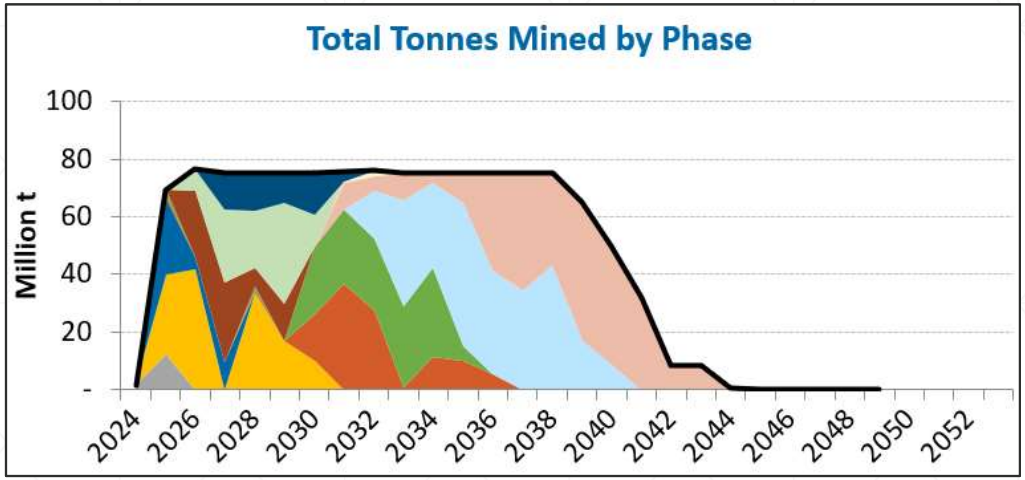
Whittle Consulting
Integrated Strategic Planning for the Mining Industry

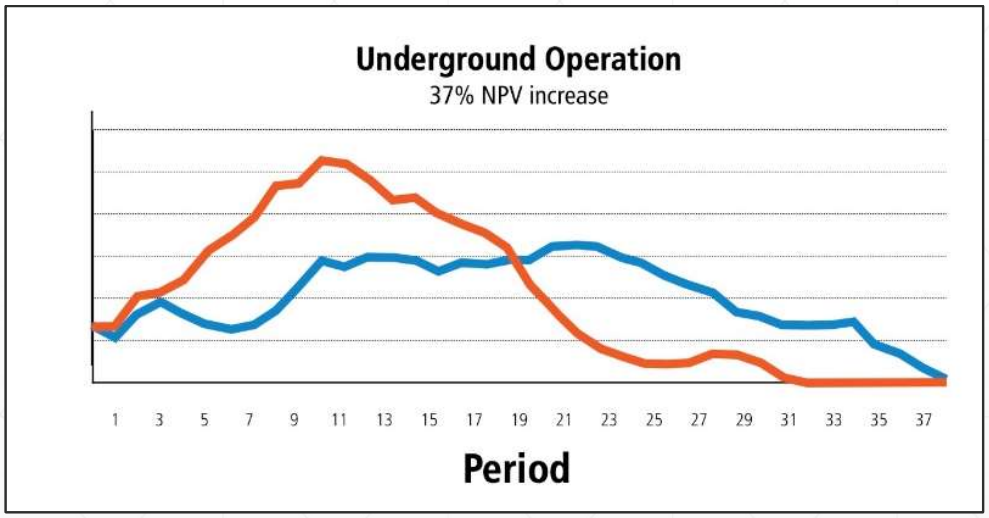
Dundee PRECIOUS METALS

Nordic Iron Ore™

Optimisation in LOM Planning

- Take a mining schedule
- Rearrange using a mathematical Optimiser
- Improve the NPV



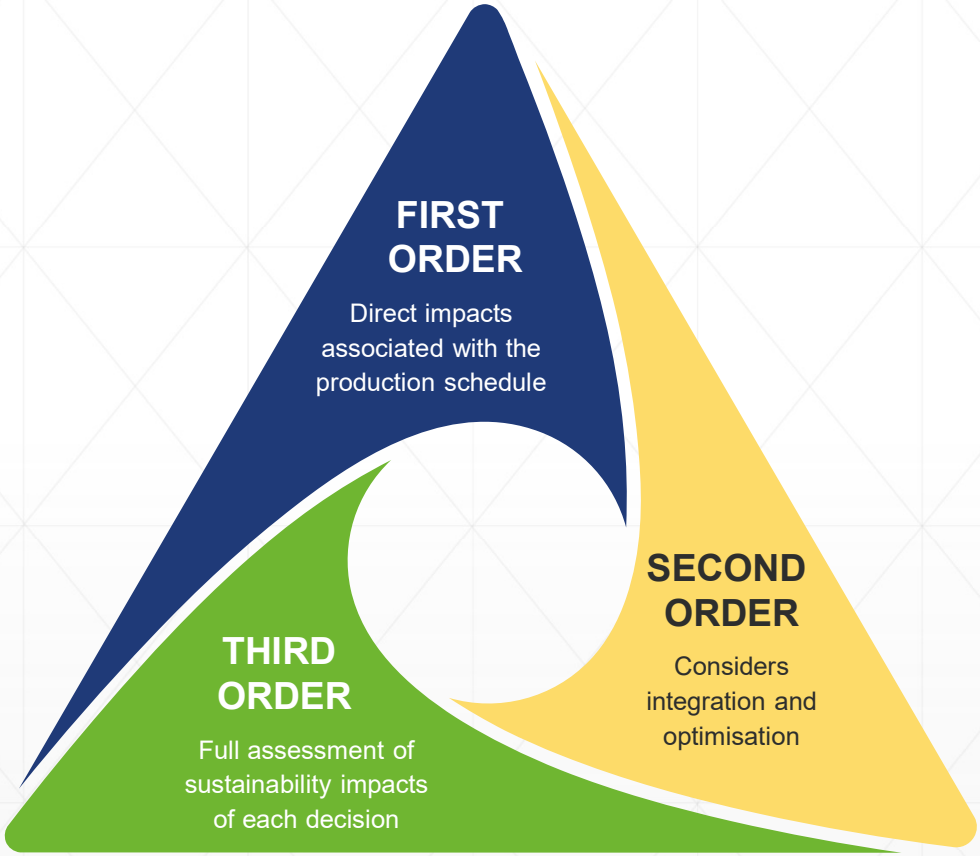


But what else?

Emissions & other sustainability criteria…

Effect on decision-making

Presentation Outline



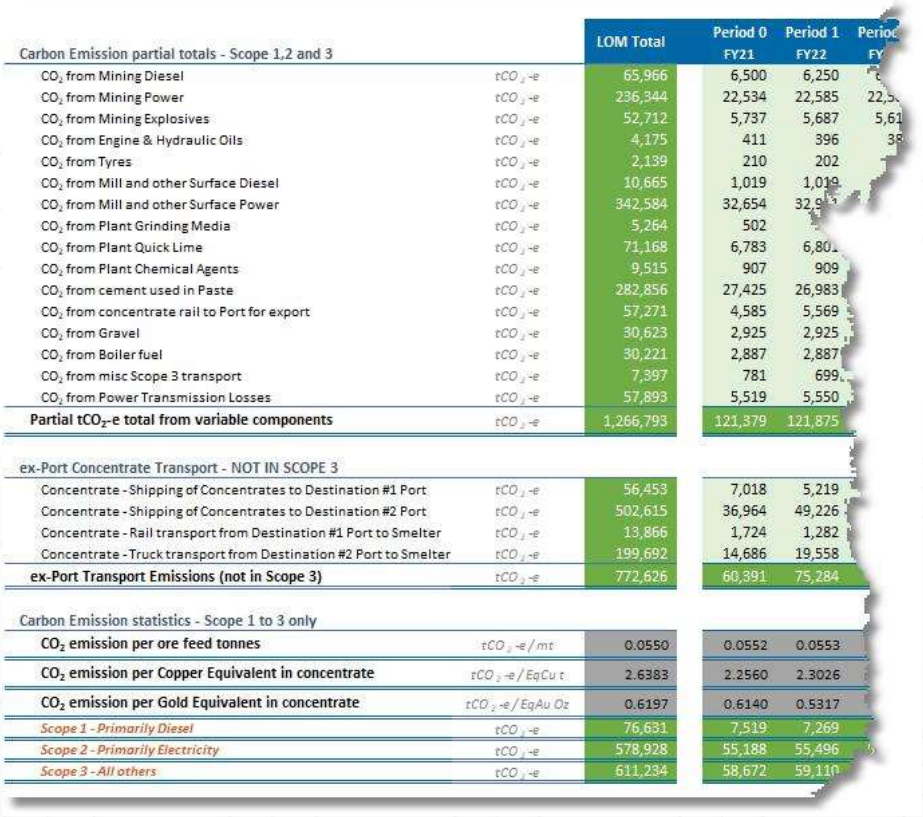
FIRST ORDER
Effects concerned with assembling capital and operating costs and calculating a net-present-cost for these

SECOND ORDER
Effects concerned with the orebody as an integrated whole and its optimisation

THIRD ORDER
Effects concerned with environmental and community value or impact

DECISION MAKING
How first, second and third-order effects must influence decisions

Enterprise Optimization - Carbon



Carbon Emission partial totals - Scope 1,2 and 3		LOM Total	Period 0 FY21	Period 1 FY22	Period
CO_2 from Mining Diesel	tCO_2-e	65,966	6,500	6,250	
CO_2 from Mining Power	tCO_2-e	236,344	22,534	22,585	22,5
CO_2 from Mining Explosives	tCO_2-e	52,712	5,737	5,687	5,61
CO_2 from Engine & Hydraulic Oils	tCO_2-e	4,175	411	396	38
CO_2 from Tyres	tCO_2-e	2,139	210	202	
CO_2 from Mill and other Surface Diesel	tCO_2-e	10,665	1,019	1,019	
CO_2 from Mill and other Surface Power	tCO_2-e	342,584	32,654	32,9	
CO_2 from Plant Grinding Media	tCO_2-e	5,264	502		
CO_2 from Plant Quick Lime	tCO_2-e	71,168	6,783	6,80	
CO_2 from Plant Chemical Agents	tCO_2-e	9,515	907	909	
CO_2 from cement used in Paste	tCO_2-e	282,856	27,425	26,983	
CO_2 from concentrate rail to Port for export	tCO_2-e	57,271	4,585	5,569	
CO_2 from Gravel	tCO_2-e	30,623	2,925	2,925	
CO_2 from Boiler fuel	tCO_2-e	30,221	2,887	2,887	
CO_2 from misc Scope 3 transport	tCO_2-e	7,397	781	699	
CO_2 from Power Transmission Losses	tCO_2-e	57,893	5,519	5,550	
Partial tCO_2-e total from variable components	tCO_2-e	1,266,793	121,379	121,875	
ex-Port Concentrate Transport - NOT IN SCOPE 3					
Concentrate - Shipping of Concentrates to Destination #1 Port	tCO_2-e	56,453	7,018	5,219	
Concentrate - Shipping of Concentrates to Destination #2 Port	tCO_2-e	502,615	36,964	49,226	
Concentrate - Rail transport from Destination #1 Port to Smelter	tCO_2-e	13,866	1,724	1,282	
Concentrate - Truck transport from Destination #2 Port to Smelter	tCO_2-e	199,692	14,686	19,558	
ex-Port Transport Emissions (not in Scope 3)	tCO_2-e	772,626	60,391	75,284	
Carbon Emission statistics - Scope 1 to 3 only					
CO_2 emission per ore feed tonnes	tCO_2-e / mt	0.0550	0.0552	0.0553	
CO_2 emission per Copper Equivalent in concentrate	tCO_2-e / EqCu t	2.6383	2.2560	2.3026	
CO_2 emission per Gold Equivalent in concentrate	tCO_2-e / EqAu Oz	0.6197	0.6140	0.5317	
Scope 1 - Primarily Diesel	tCO_2-e	76,631	7,519	7,269	
Scope 2 - Primarily Electricity	tCO_2-e	578,928	55,188	55,496	
Scope 3 - All others	tCO_2-e	611,234	58,672	59,110	

Scope 1 – Included from LOM plan.

Scope 2 – Included from LOM plan.

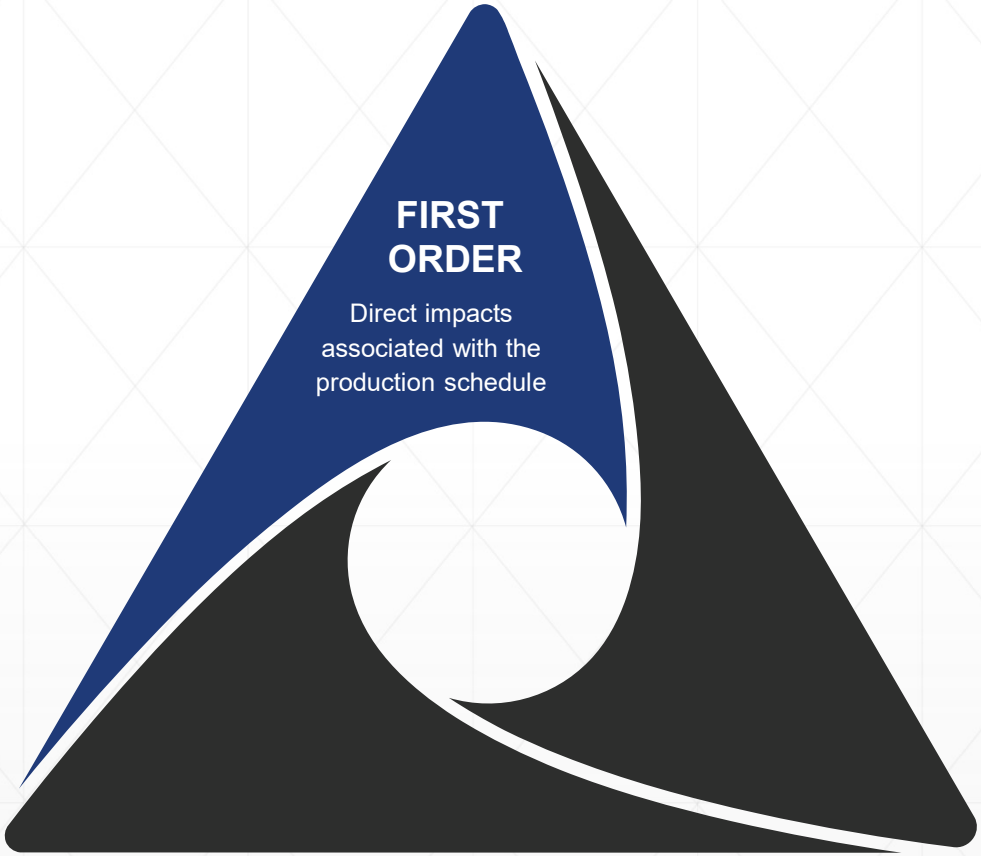
Scope 3 – Upstream. Included with estimates where LOM is deficient.

Scope 3 - Downstream. Included with estimates for transport to customer's gate.

Emissions expressed as tonnes of CO_2-e; as total by period and as intensity by period.

Scope 3 emissions need not be to LCA standards; merely to allow comparisons between options

First-order Effects

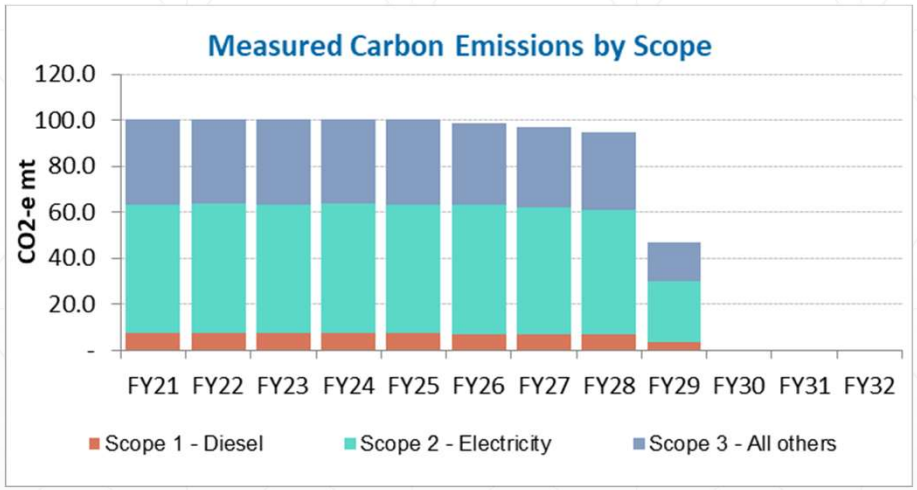


- Capex, Opex & Net Present Costs
- Compare options for their carbon footprint or water/tailings
- Typically: calculating annualised diesel and electrical energy consumptions from production outputs or abatement projects

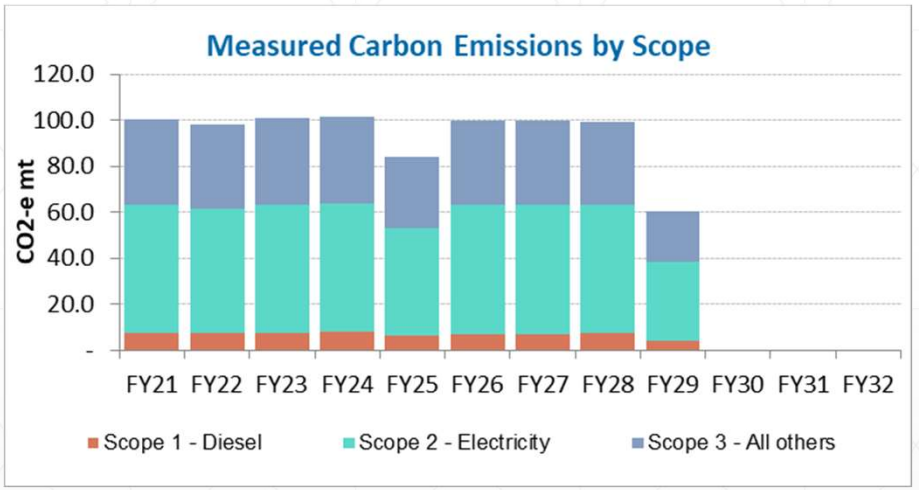
First-order Effects

Case Example - Dundee Precious Metals - Chelopech

Run 30A – LRF replica with ABC



Run 34B – latest 10% case with BMv021

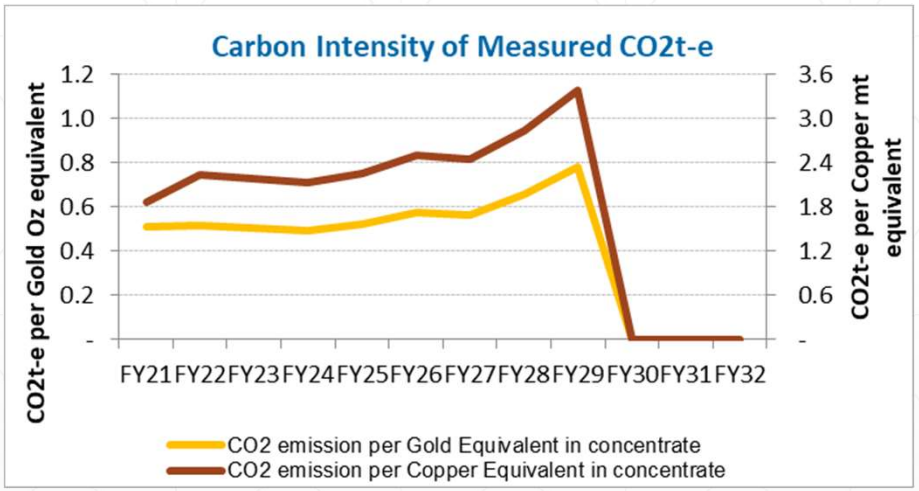


Total emissions comparison of two different mine schedules varying over time

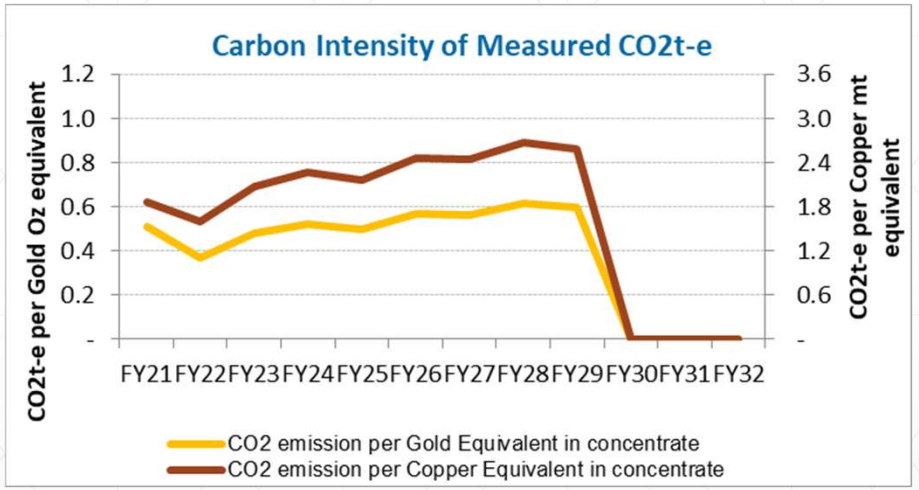
First-order Effects

Case Example - Dundee Precious Metals - Chelopech

Run 30A – LRF replica with ABC

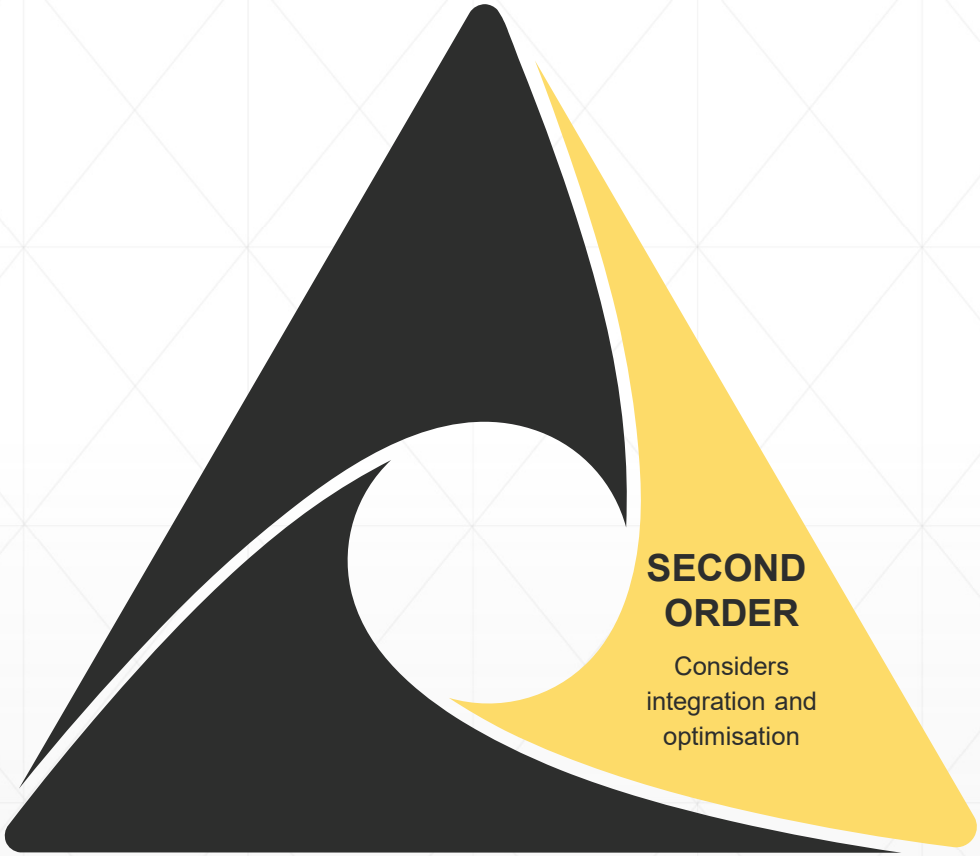


Run 34B – latest 10% case with BMv021



Intensity comparison of two different mine schedules varying over time

Second-order Effects



- The orebody as an integrated whole and its optimisation
- Optimiser enables:
  - Combination of financial and physicals
  - A new schedule
  - Changed cut-off policy
  - Revised design of pit shapes
- Project or operational outcomes that prompt a re-optimised configuration. E.g. comparison of electrified trucks

Second-order Effects

The planning processes, optimisation and methodology affects CO_2-e intensity and total output

Un-optimised Mine Schedule

Carbon intensity is fixed by the nature of the orebody, mine/plant design & methodology

Grades, geo-tech, spatial, process route

Optimised Mine Schedule (e.g. Prober)

Favours shallower, closer, higher-grade, low strip ratios and softer material

Material process unit cost reduction (or metal prices increase)

Favours better exploitation of existing pit-shells but brings marginal material (lower-grade, harder and more distant) to plant rather than waste.

Processing-dominated energy (e.g. Cu)

Material mining unit cost reduction

Cut-offs are lowered, LOM increased and pit-shapes expanded. Marginal material is brought into the schedule

mining-dominated energy (e.g. Fe Ore)

Introduction of process efficiencies

Favours higher throughputs per unit of energy

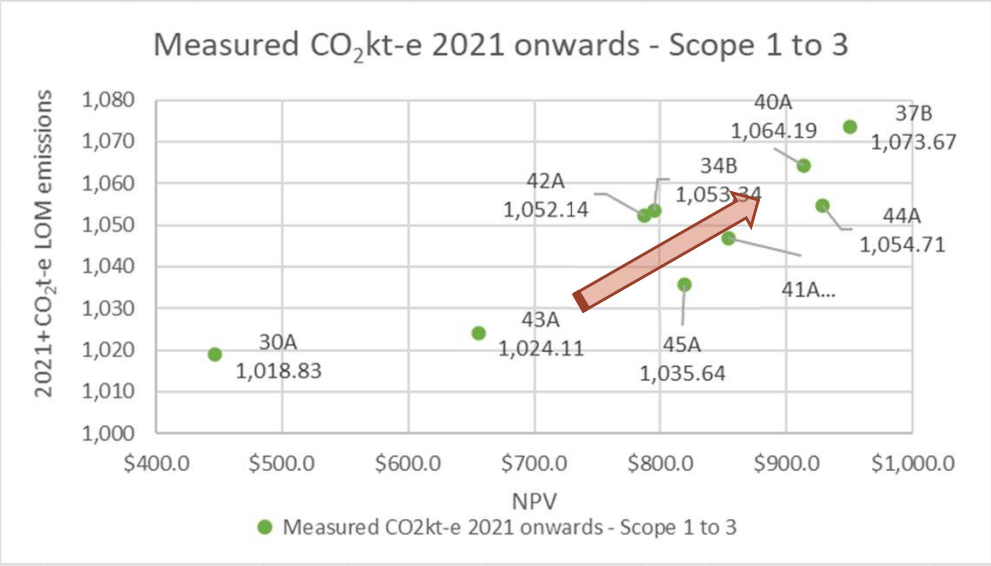
- E-trucks, dry-stack tailings, coarse-particle flotation and any technology choice has a potential effect here

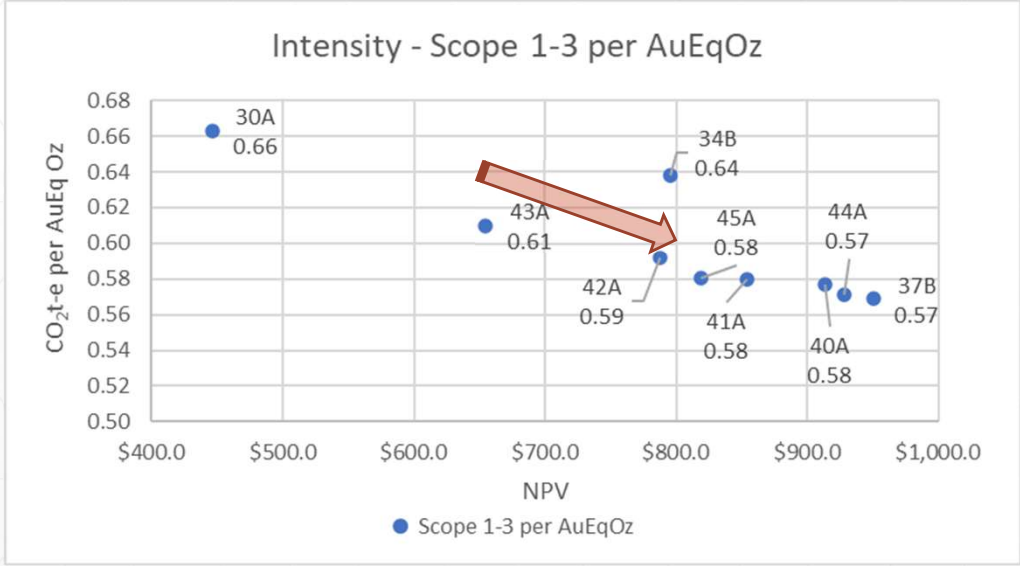
Second-order Effects

- **Plotting NPV of the optimized runs against:**
  - **LOM Carbon Inventory (t);**
  - **LOM Carbon Intensity (tCO_2 /oz)**

Insight

- **For Scope 1,2,3 inventories, CO_2 tracks upwards with NPV, but Intensity trends downwards**





Third-order Effects

- Environmental and community value or impact
- Evolving full assessment of sustainability impacts of each decision (case by case)
- Holistic view of Carbon Impact for each case e.g. as the NPV improves, does the carbon (or energy, land or water) impact rise or fall?

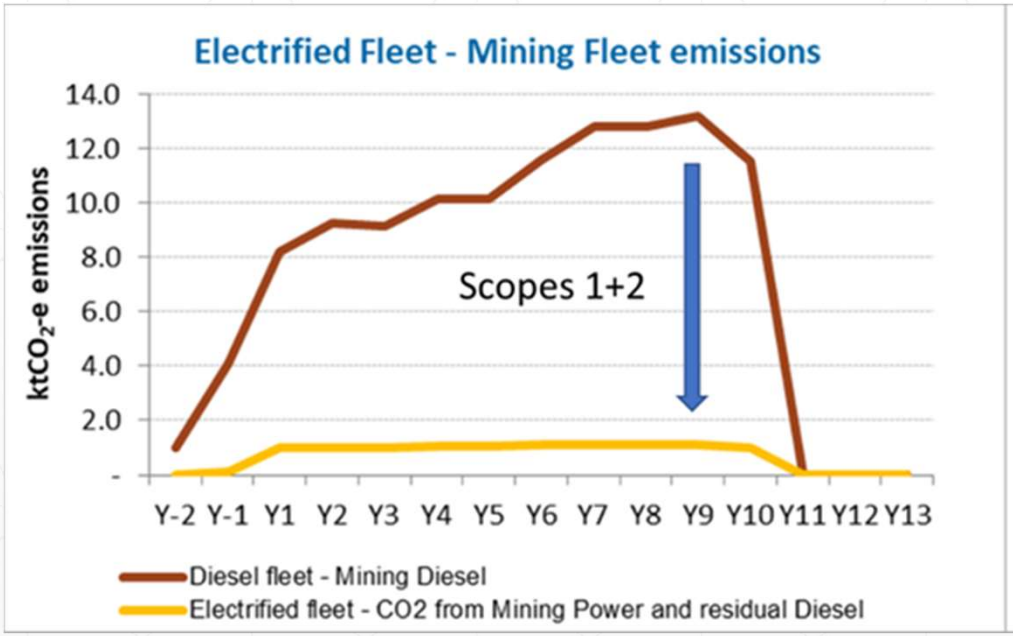
- Example: Hydrogen or Electric Truck solution as diesel abatement needs to consider the associated water, land and energy intensity impacts and social opportunity aligned with any Sustainable Mining Plan objectives

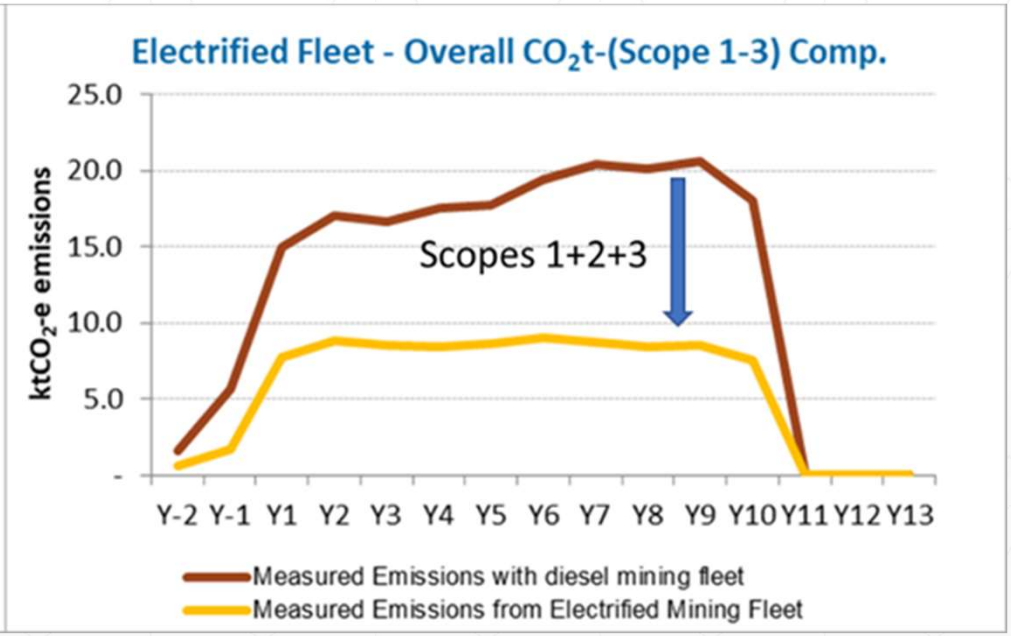
Decisions - Boundaries

- Plotting NPV of the optimized runs against:
  - LOM Carbon Inventory (t);
  - LOM Carbon Intensity (tCO2/oz)

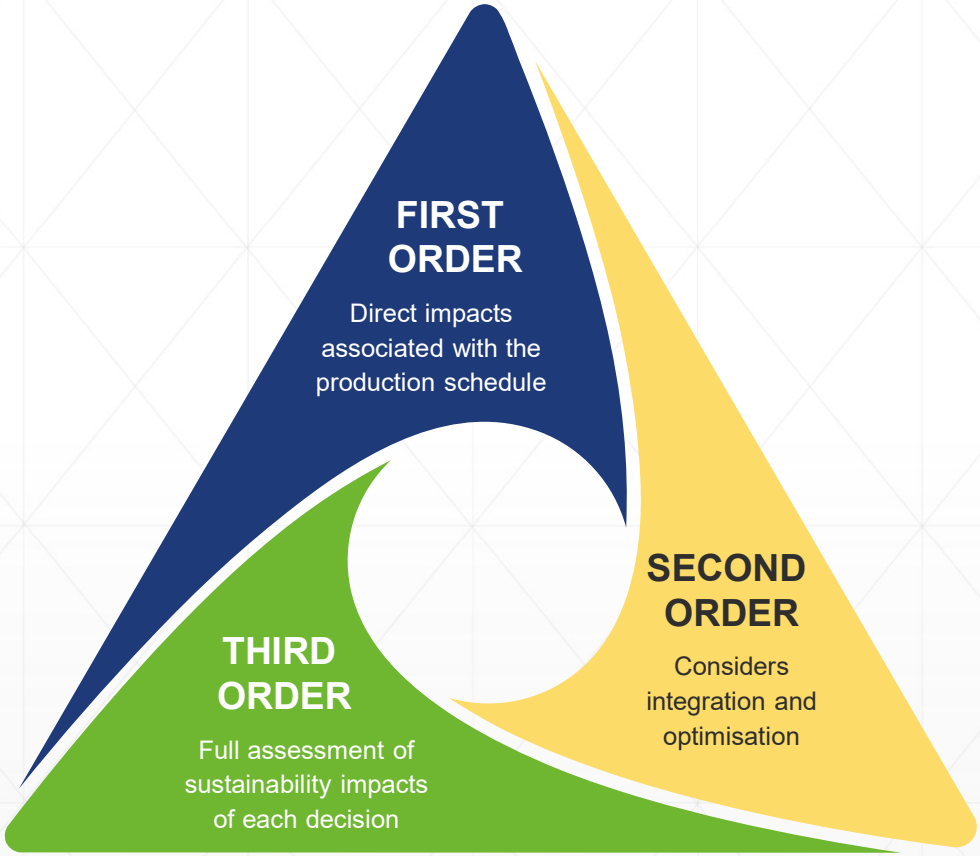
Insight

- **As on-site carbon emissions reduce, the off-site emissions become more prominent**





Recap



FIRST ORDER
Effects concerned with assembling capital and operating costs and calculating a net-present-cost for these

SECOND ORDER
Effects concerned with the orebody as an integrated whole and its optimisation

THIRD ORDER
Effects concerned with environmental and community value or impact

DECISION MAKING
How first, second and third-order effects must influence decisions

Final Thoughts

Other examples from recent studies

- Fleet electrification with trolley assist
- In-pit crush and convey vs truck haulage
- Renewables penetration vs traditional diesel at remote sites
- Dry-stack tailings vs conventional tailings storage

The traditional NPV-dominated assessment has become a multi-criteria evaluation as well.

A handful are dominant in the strategic sense:

- Carbon
- Water
- Tailings
- Employment

Which are the win-win-win vs trade-offs?
Have you considered the 1st, 2nd & 3rd-order effects?

Thankyou

Philip Bangerter, Orchardman Pty Ltd
E: philip@bangerter.net.au
T: +61 417 764 715

Jason Pan, Whittle Consulting Pty Ltd
E: Jason@whittleconsulting.com.au
T: +61 419 584 431