Resourceful Paths

Economic and sustainability drivers for copper-gold deposits

Presentation - CIM North Central BC Branch

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Introduction

Resourceful Paths

- Economic drivers
  - Revenue
  - Opex
- Process trade-offs and responding to varying metal prices
  - Consumables strategies
  - Production capacity strategies
- Sustainability metrics
  - Types of metrics
  - Energy and GHG emissions, tailings and water management

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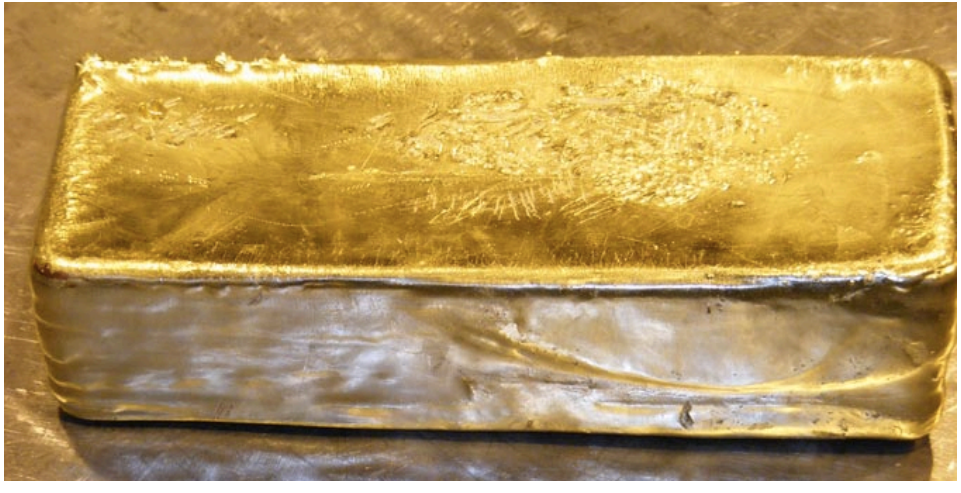
Revenue

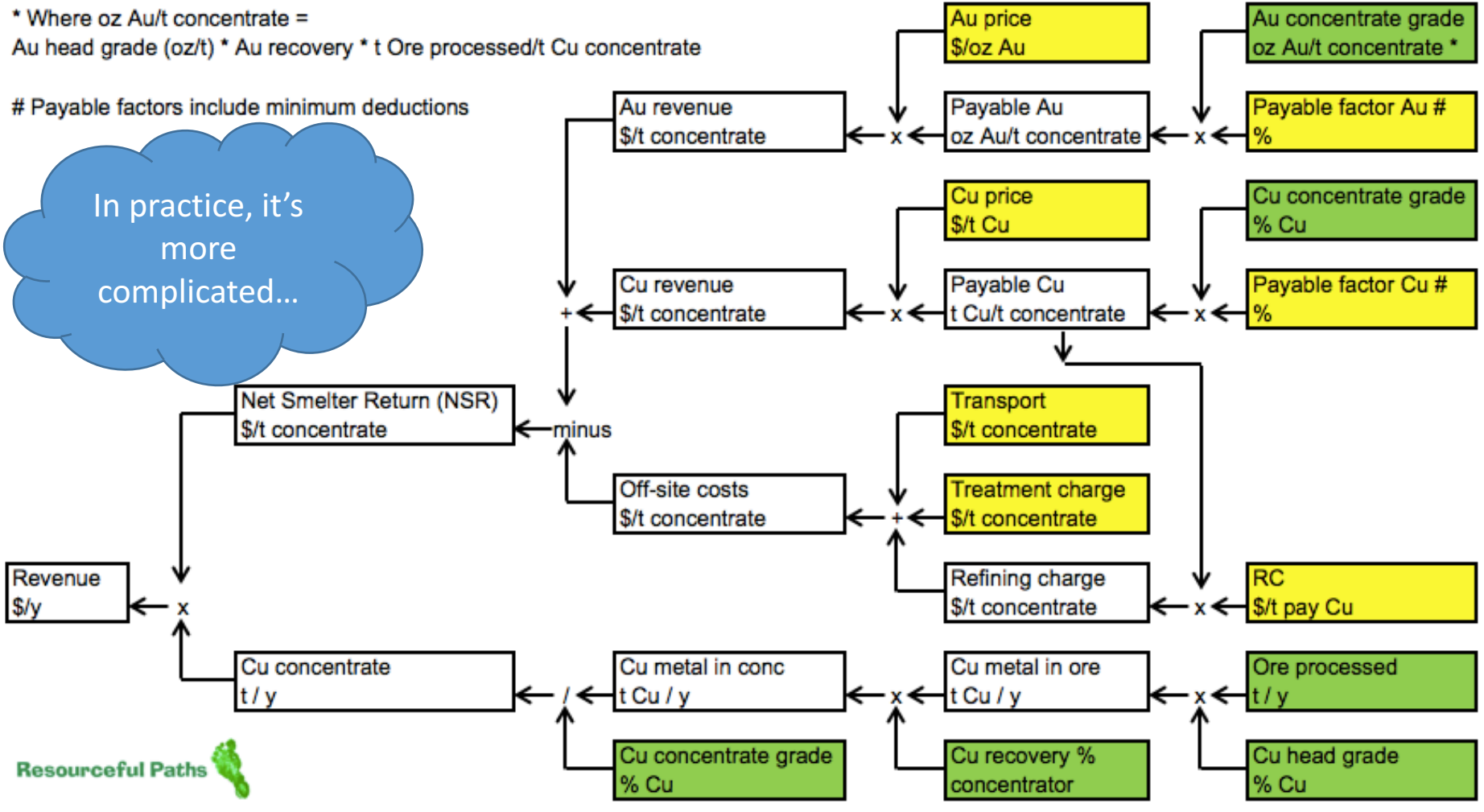
- Metal produced * Metal price?
- It depends…



* Where oz Au/t concentrate =
Au head grade (oz/t) * Au recovery * t Ore processed/t Cu concentrate

Payable factors include minimum deductions

In practice, it's more complicated…



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Keeping it simple

- Rules of thumb can help, e.g.:
  - ~80% net realizable Cu in concentrate accounts for payables, TC, RC, transport
  - ~95% net realizable Au in Cu concentrate accounts for payables, RC
  - Can calculate factors for a given mine, e.g. clean, high grade concentrates close to port have higher net realizable Cu
- Where possible, look at everything on a $/t ore or $/t metal basis, not $/t concentrate
- Check detailed revenue calcs against rules of thumb, sometimes the financial spreadsheets have errors

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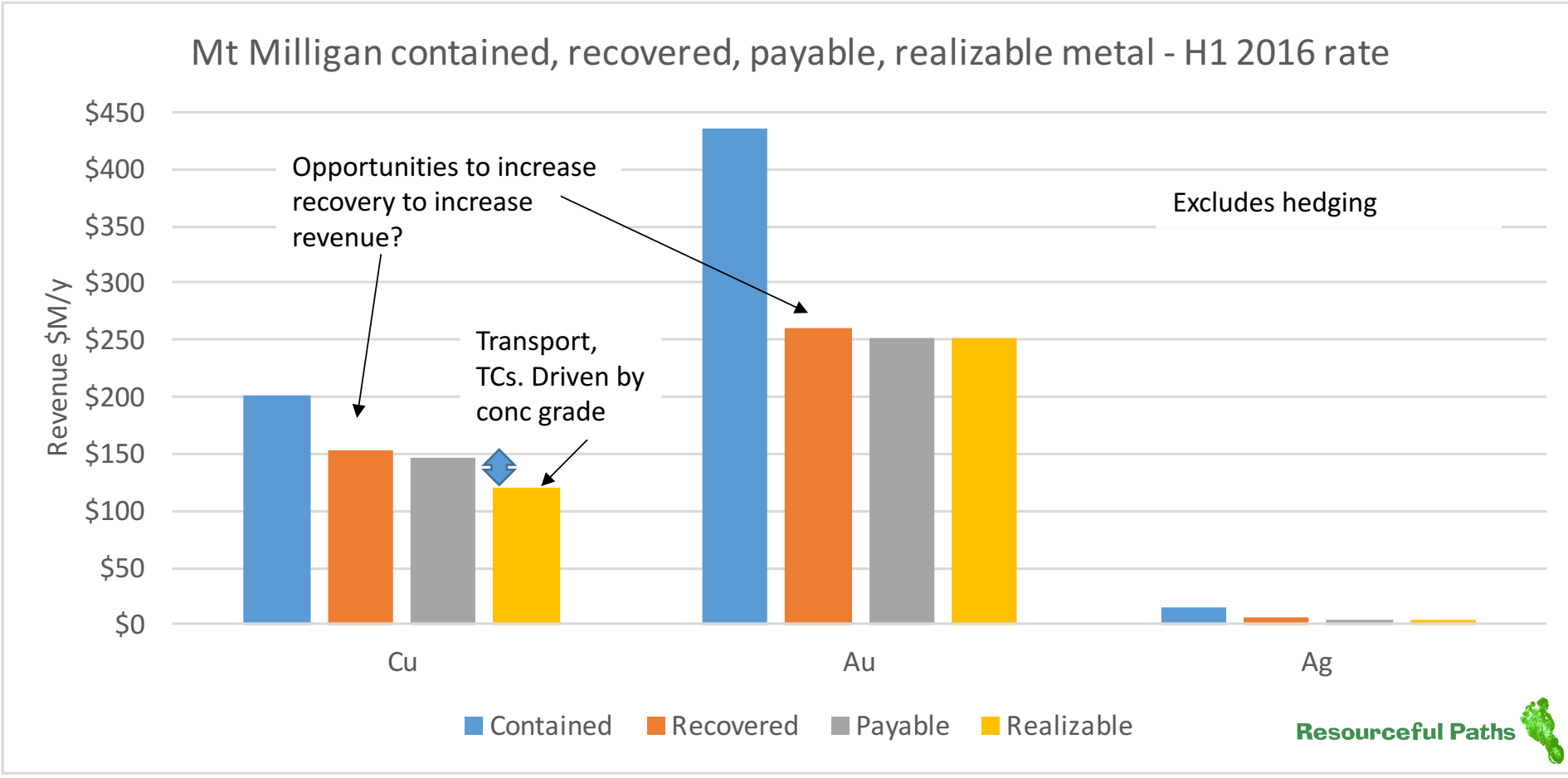
Simplified revenue model – Cu-Au

Net revenue estimate

		mt/y	Cu	Au	Ag	Total $/t	Total $M/y
			%	g/t	g/t		
Mill feed		20.0	0.35%	0.4	4		
Metal prices	US$/lb or oz		$2.50/lb	$1,250/oz	$18.00/oz		
	US$/t or g		$5,511	$40.19	$0.58		
Contained metal value (US$/t)			$19.29	$16.08	$2.31	$37.68	$754
Recovery (est)			90%	70%	50%		
Recovered metal value (US$/t)			$17.36	$11.25	$1.16	$29.77	$595
NSR content (est)			80%	95%	90%		
NSR value (US$/t)			$13.89	$10.69	$1.04	$25.62	$512

- What's 1% Cu recovery worth? About $0.20/t * 80% = $0.16/t
- What's 1% Au recovery worth? About $0.16/t * 95% = $0.15/t
- What's 1% Ag recovery worth? Not much…


Mt Milligan contained, recovered, payable, realizable metal - H1 2016 rate
Revenue $M/y
$450
$400
$350
$300
$250
$200
$150
$100
$50
$0
Opportunities to increase recovery to increase revenue?
Transport, TCs. Driven by conc grade
Excludes hedging
Cu
Au
Ag
Contained
Recovered
Payable
Realizable
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Net smelter return for Cu-Au-Ag-Mo deposits in BC, Canada

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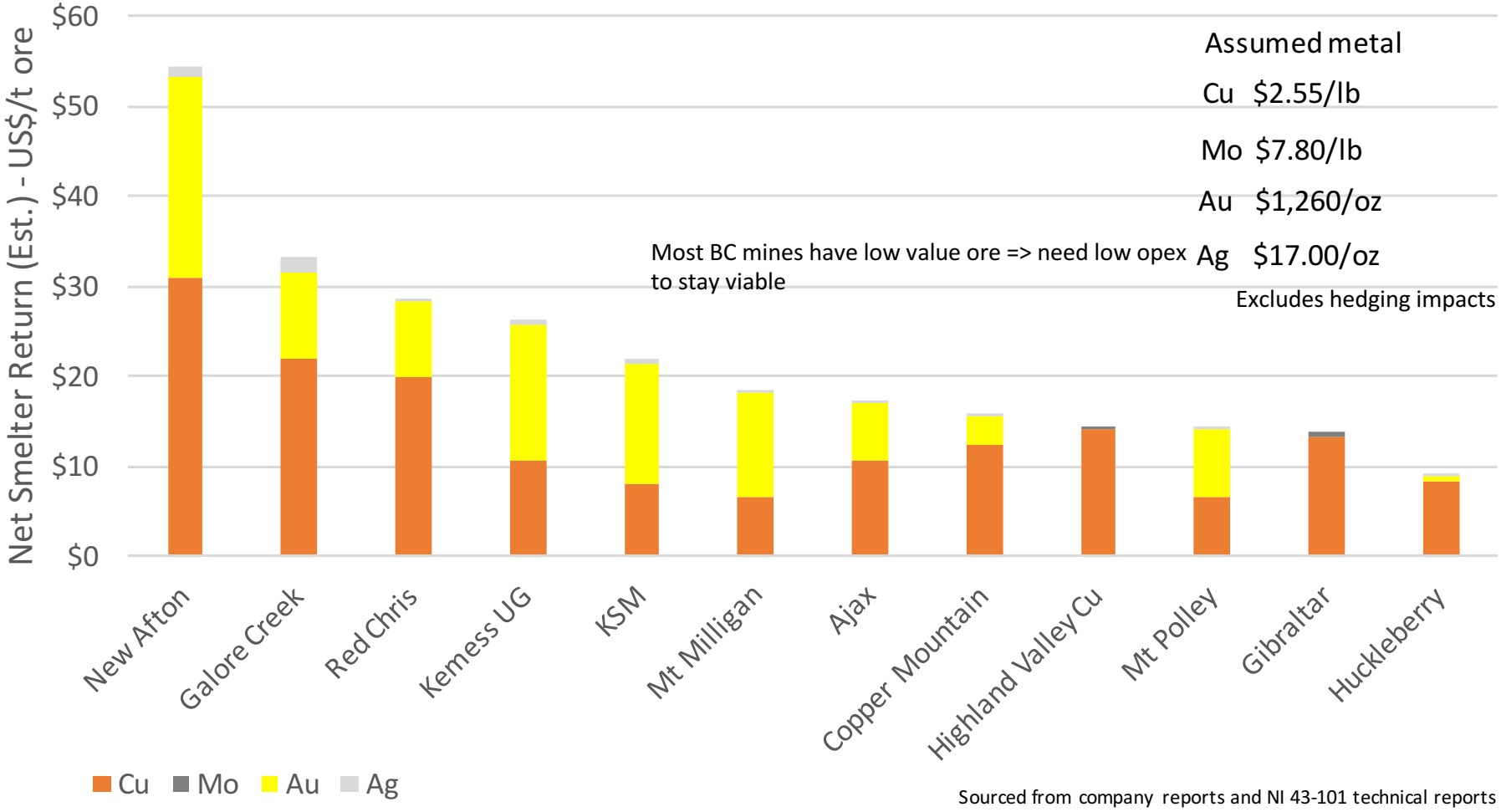

Sourced from company reports and NI 43-101 technical reports

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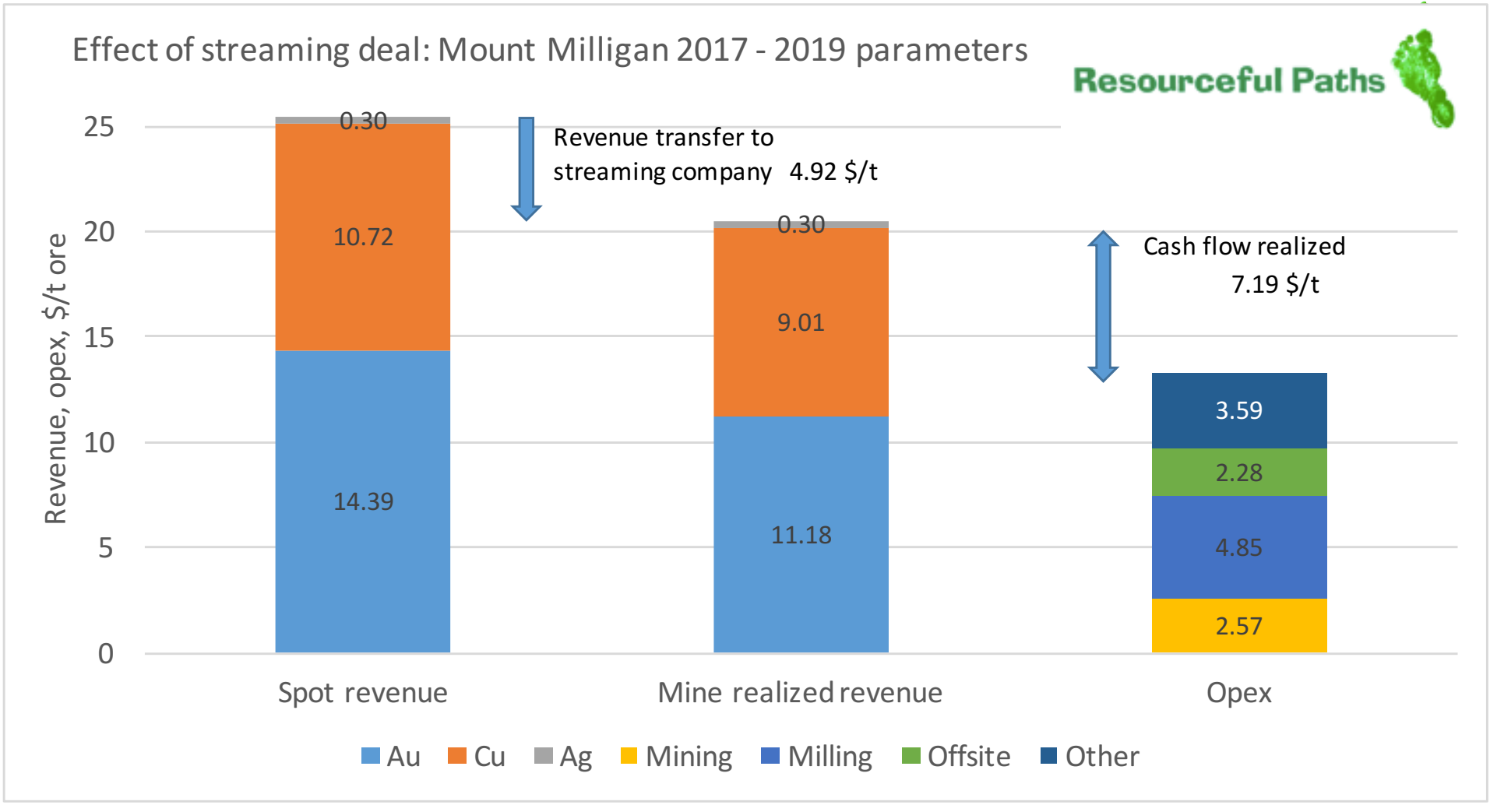
Effect of streaming

- Lowers metal price realized by mine hence lowers revenue
- Changes revenue vs. opex trade-offs – reducing opex becomes a stronger value driver than revenue increase
- Not all streaming deals are created equal – understand to determine how it affects marginal revenue and profit
- No free lunch


Effect of streaming deal: Mount Milligan 2017 - 2019 parameters
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Revenue, opex, $/t ore
25
20
15
10
5
0
0.30
10.72
14.39
Revenue transfer to
streaming company 4.92 $/t
0.30
9.01
11.18
Cash flow realized
7.19 $/t
3.59
2.28
4.85
2.57
Spot revenue
Mine realized revenue
Opex
Au
Cu
Ag
Mining
Milling
Offsite
Other

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Operating costs – where to focus?

- The big ones
- The ones you can do something about
- The ones that don’t hurt revenue

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Operating costs – where to focus?

- Pareto analysis can be useful to visualize costs
- Consider grouping of costs to best understand drivers
  - By department function
  - By input type
- For consumables, consider specific consumption and unit price, e.g.:
  - Power unit cost ($/t ore) = kWh/t ore * $/kWh
  - Grinding media unit cost ($/t ore) = kg media/t ore * $/kg media

Casino Concentrator Opex by plant and cost areas

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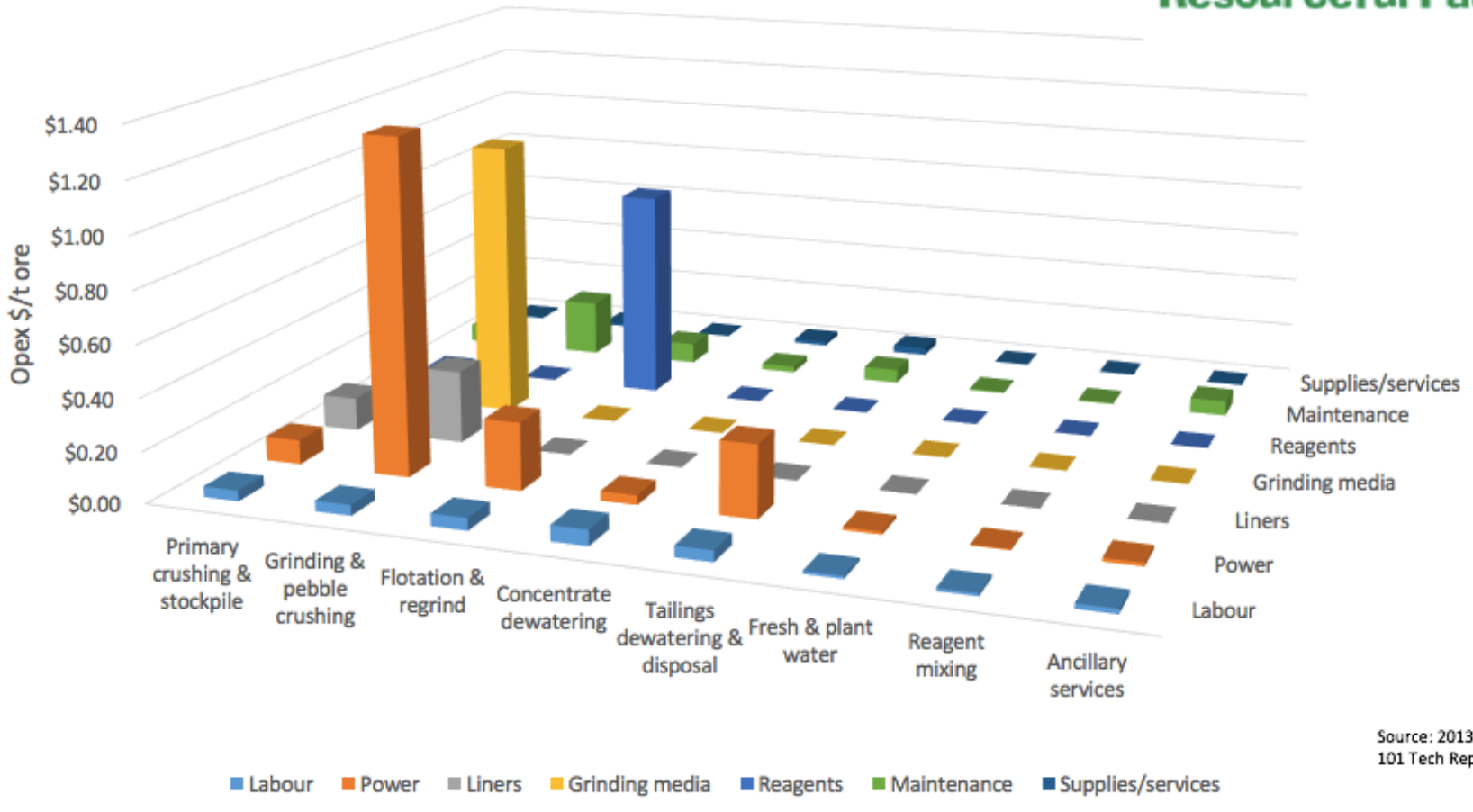

Source: 2013 Casino NI 43-101 Tech Report, M3

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Operating costs – where to focus?

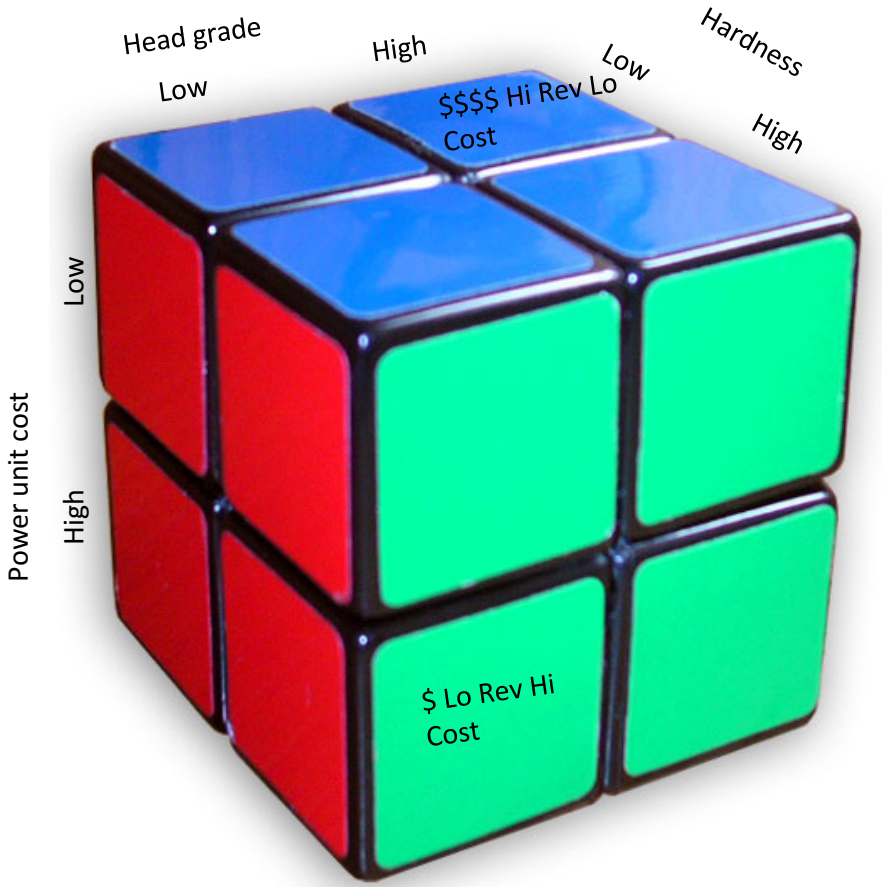
- Casino case – concentrator opex dominated by:
  - Power for grinding, plus flotation and tailings disposal
  - Grinding media
  - Reagents in flotation
  - Typical for low grade Cu-Au sulphide operation
- Other areas such as labour are relatively minor
- Ensure that focus is on the right areas
  - Understand production, metallurgical, cost trade-offs of any changes
  - Consider the management focus and time needed to make a change

Understanding trade-offs

- What does it mean to be on different blocks on the cube?
- E.g.: soft ore with cheap power =

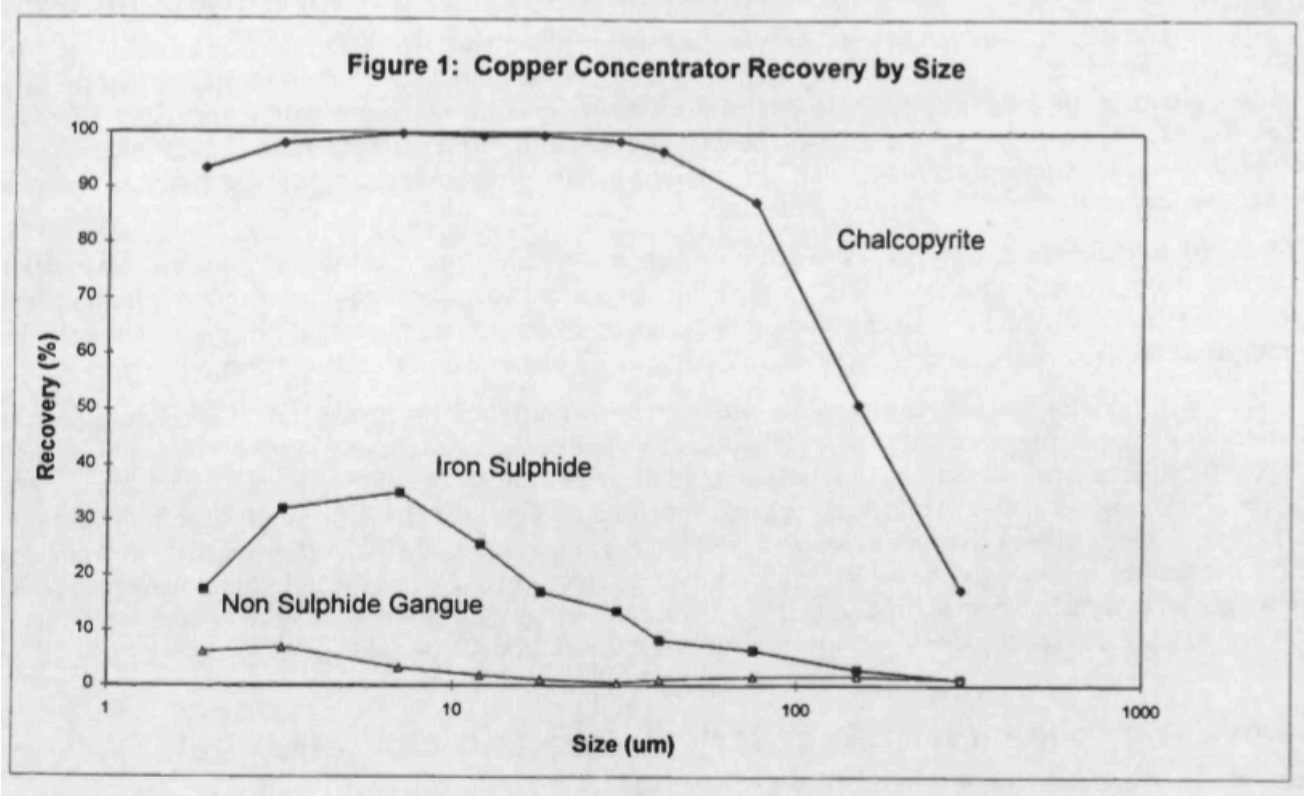
  10 kWh/t * $0.05/kWh = $0.50/t
- E.g.: hard ore with expensive power =

  20 kWh/t * $0.15/kWh = $3.00/t
- Can revenue sustain these costs?



Grind size – recovery trade-offs

- Recovery often falls at coarser grinds
- Should we cut power costs or maximize recovery?
- It depends...



Source: L Reemeyer, Analysis of Copper Concentrator Performance Using Sized and Liberation Data, 1995

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Understanding trade-offs

- Changes to consumable inputs may cause trade-offs, e.g.:
  - Less kWh/t = lower cost = coarser grind and potentially lower recovery
  - Switch to high quality media = less kg/t consumed but higher $/kg media
  - New reagent changes usage rate, unit price, metallurgical performance
- Small drop in recovery may negate opex saving, e.g.:
  - Reducing 1.5 kWh/t at $0.10/kWh saves $0.15/t
  - But if 1% Cu recovery ~$0.15/t, a 1% recovery loss would wipe out savings
- May need statistical analysis on plant performance to determine if change increases or decreases profit

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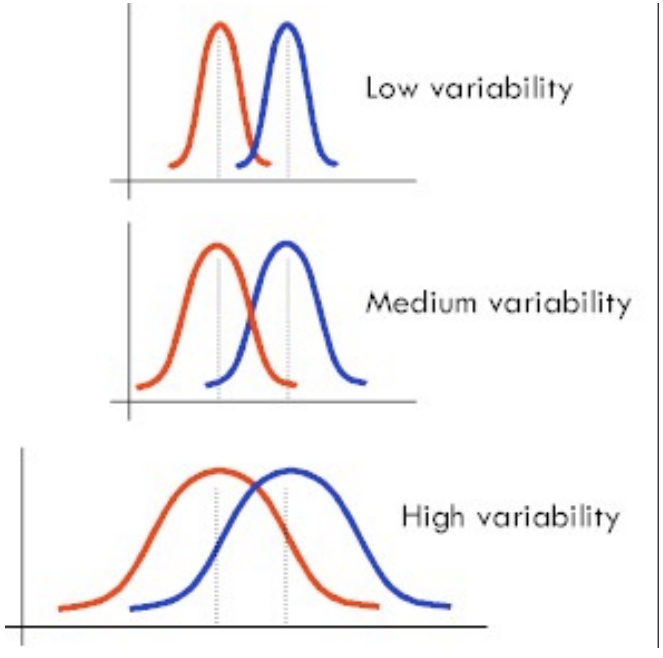
Statistics in opex-revenue trade-offs

- How do we know if we're improving?
  - Use statistics and a t-test
- If variability is high, takes longer to see a result
  - Need a larger sample number to be sure of difference in mean
- Trial cost savings/improvements when steady, otherwise will get lost in noise



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Make summer hay, survive bleak winter…

- How to maximize life of mine profit and survive cycles?
  - Save the most metal when prices are high rather than maximize production when prices are low
  - Low prices - can we drop opex more than we sacrifice revenue?
  - High prices - can we grow revenue more than we increase opex?
- What could this look like?
  - High prices - selective mining, segregation, ore sorting to boost head grade
  - Low prices - scale back production, shutdown sections of mine and plant - relies on turndown ability - ore and site specific
  - Low grade stockpiles campaign treated at end of mine life when profitable

Sustainability metrics

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- Focus on environmental metrics in this presentation – easier to quantify, but social metrics also must be considered
- Risk based metrics – e.g. probability and likelihood of a bad event occurring:
  - Tailings embankment failure
  - Water contamination event
- Impact and emissions metrics, e.g.:
  - Water consumption
  - GHG emissions

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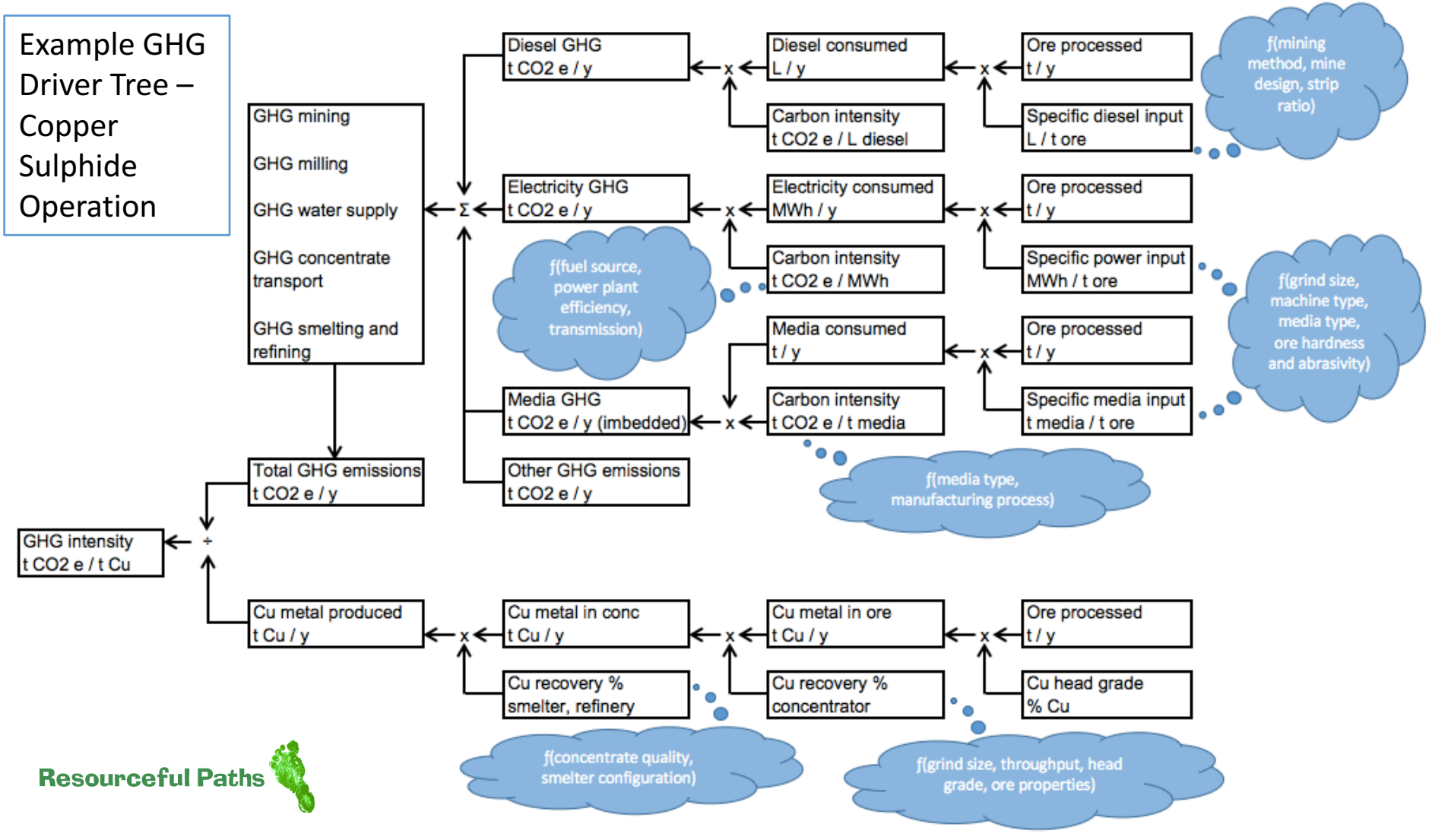
Sustainability metrics - examples

Category	Description	Metric type	Example units
Water consumption	Quantity of water consumed in operations	Temporal	ML/y
		Specific	m^3/t ore
		Specific	m^3/t Cu produced
Water recycled	Proportion of recycled water to total water consumed	Ratio	%
Energy consumption	Quantity of energy consumed in operations	Temporal	GJ/y
		Specific	kW/t ore milled
		Specific	GJ/t Cu produced
GHG emissions	GHG emissions produced from operations (Scope 1 and 2)	Temporal	t CO_2-e/y
		Specific	t CO_2-e/t Cu produced
Disturbance footprint	Land area disturbed by mining excavation and waste facilities, or area rehabilitated	Temporal	ha/y
Waste generated	Quantity of waste rock and tailings generated by operations	Temporal	t/y waste rock
		Specific	t tailings/t Cu produced

Source: L Reemeyer, 2017

Example GHG Driver Tree – Copper Sulphide Operation



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Reducing environmental impacts

- Reducing GHG emissions:
  - Mill less t
  - Use less energy (e.g. kWh/t) - efficient equipment/flowsheets, design parameters (e.g. coarser grind size)
  - Reduce GHG intensity of energy inputs (e.g. switch to low C power, fuel)
  - Less consumables use (e.g. 1 t grinding media, ~2 t CO_2 embedded emissions)
- Reducing water consumption
  - For low grade Cu-Au projects, mostly about reducing water loss to tailings
  - Make less tailings (i.e. increase head grade, reduce ore treated)
  - More intensive tailings dewatering (e.g. high density/paste thickening, filtration) - coarser streams easier to dewater

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Tailings affecting process design

- Mount Polley and Samarco tailings failures have increased scrutiny on tailings management
  - Increased consideration of/requirements for dry stack tailings
  - Filter performance heavily affected by grind size and fines content in tailings
  - If tailings dewatering becomes significant operating cost (e.g. >$2/t), will this influence process design? (Hint: it should).
- Interaction between tailings disposal and ARD management
  - Conflict between water covers and embankment failure risks
  - Consider flowsheets that segregate sulphides from tailings both for metallurgical recovery and environmental management

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Head grade is your friend

- Higher head grade = more metal production per t ore treated
- Costs ($/t payable metal) fall as head grade rises due to lower consumable inputs/t metal produced
- Less t ore treated means lower emissions, lower water consumption, less tailings, less risk
- Consider all options to boost head grade (e.g. selective mining, preconcentration, etc.) within limits of geology

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Reducing impacts and economics

- If reducing consumption of power, media, reagents, etc., need to consider economic trade-off – opex vs. revenue
- Mining operations can be risk averse, consider trials that are well monitored and reversible
- Calculate and report both cost and environmental metrics
- Often sustainable business is good business (e.g. by eliminating waste in all forms)

Conclusions

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- Basic techno-economic models help understand payable revenue by metal, opex and cash flow drivers
- Pareto analysis and driver trees shows production and cost parameters to focus on
- Reducing consumables can save $, reduce environmental impact, but check metallurgical and economic trade-offs
- Tailings risks will start driving changes in process
- Head grade is your friend