Update on Financial Payment Systems: Seabed Mining for Polymetallic Nodules

International Seabed Authority
Council Meeting – Kingston, Jamaica
July 16, 2018

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Agenda

- Decision Analysis Framework & Review of Cash Flow Approach
  - Review of seabed nodule mining
  - Outline the decisions facing the ISA
  - Cash flow approach
  - Goals for dividing up the revenues
  - Payment mechanisms (ad valorem, after-tax profit,…)
- Techno-economic modeling updates
  - Revenues: metals price estimation updates
  - Consideration of other metals
  - Cost modeling: collection/transport & metals processing
- Example Results: **NOT FINAL**
- Impact of Seabed Nodule Supply on Metals Prices
- Response to Comments from March Council Meeting
- Next Steps

Decision Analysis Framework & Review of Cash Flow Approach

Decision Classifications

Seabed Management Decisions

- Financial decisions
  - Levels of compensation
  - Mechanism of payments
  - Rates or other parameters
- Regulatory decisions
  - Which areas to be mined
  - Under what conditions?
    - Environmental and otherwise
- Monitoring & enforcement decisions
  - Monitoring requirements for operators
  - Independent monitoring by ISA or others
  - Remediation mechanism when out of compliance

System Evaluation Decisions

- Which analyses should be conducted?
- What additional information is needed
- Additional assumptions that might be needed

Today's focus

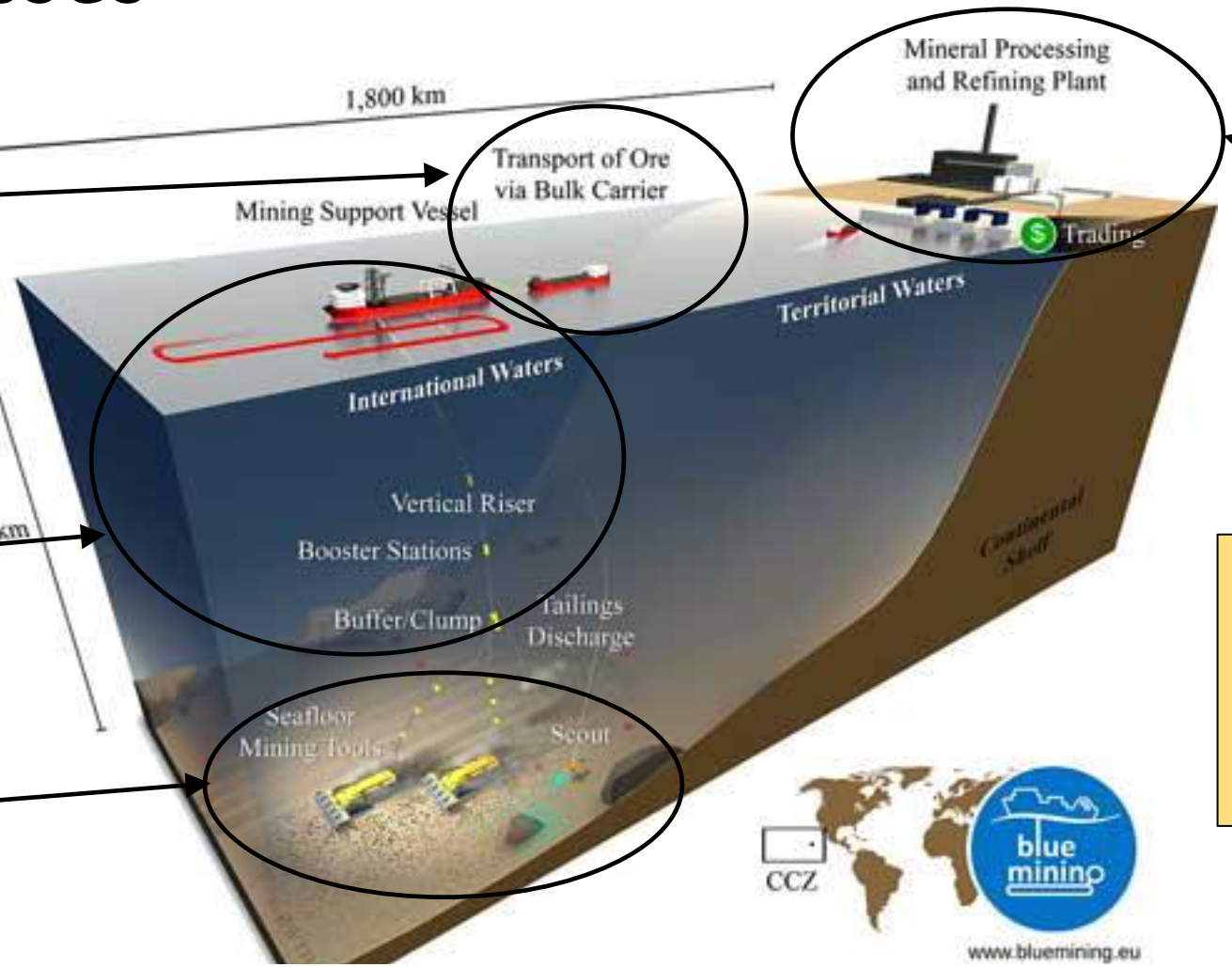
- Financial Management Decisions?
  - However, this is somewhat impacted by both regulatory & monitoring decisions
- Analysis needed to support those decisions

Assessment requires understanding the mining & refining processes

Transport

Lift/Platform/ Process Water

Nodule Collection



Metallurgical Processor
Separate the four metals

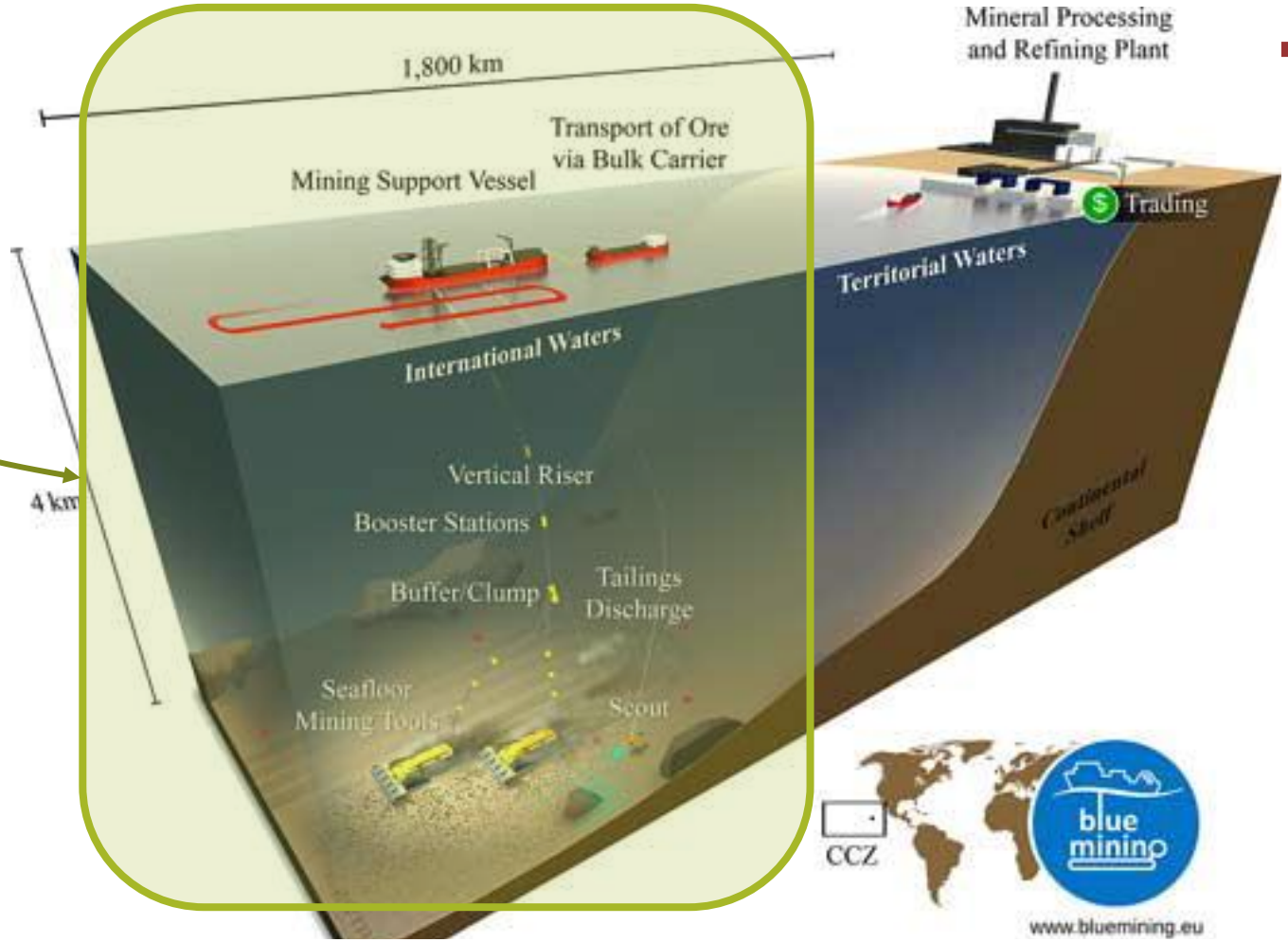
Each of these activities require:
-upfront investments
-ongoing operating …expenditures

Image from: Marvasti, A. Env. and Resource Econ (2000) 17: 395. https://doi.org/10.1023/A:1026566931709

ISA Oversight Only Related to Collector Activities

Modelled Collector

Modelling assumes that ISA royalties are only based on activities at the collector



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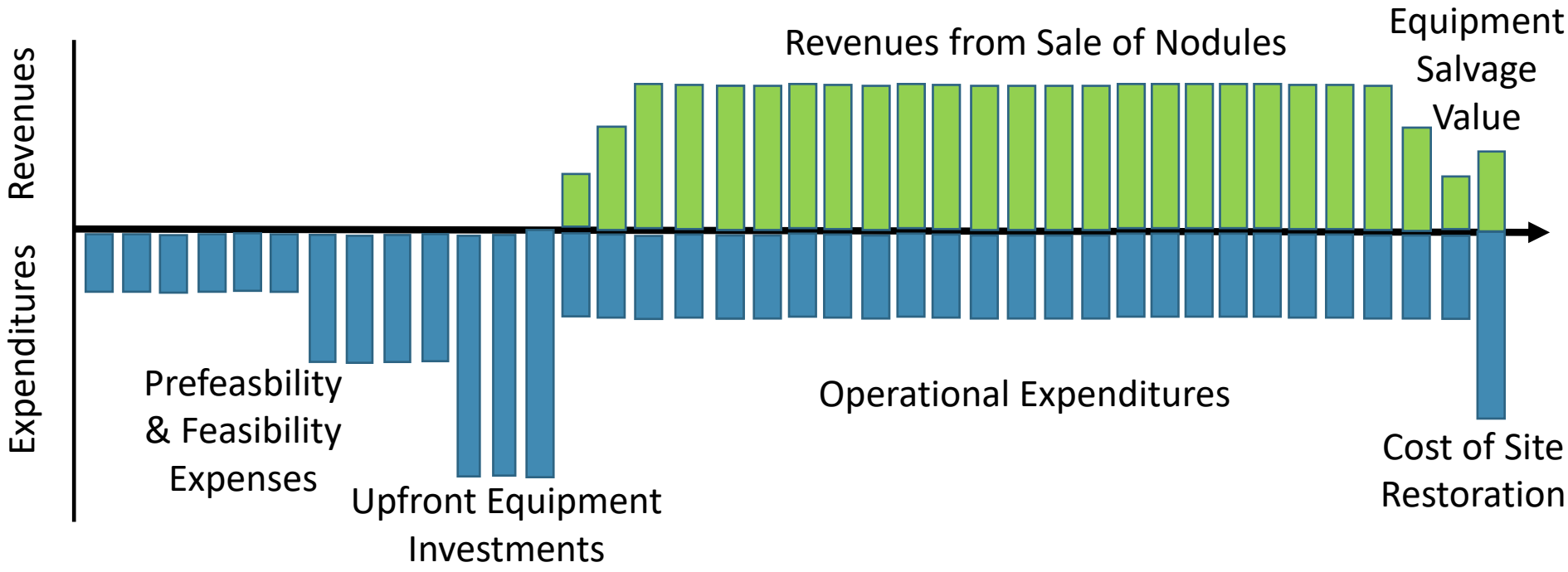
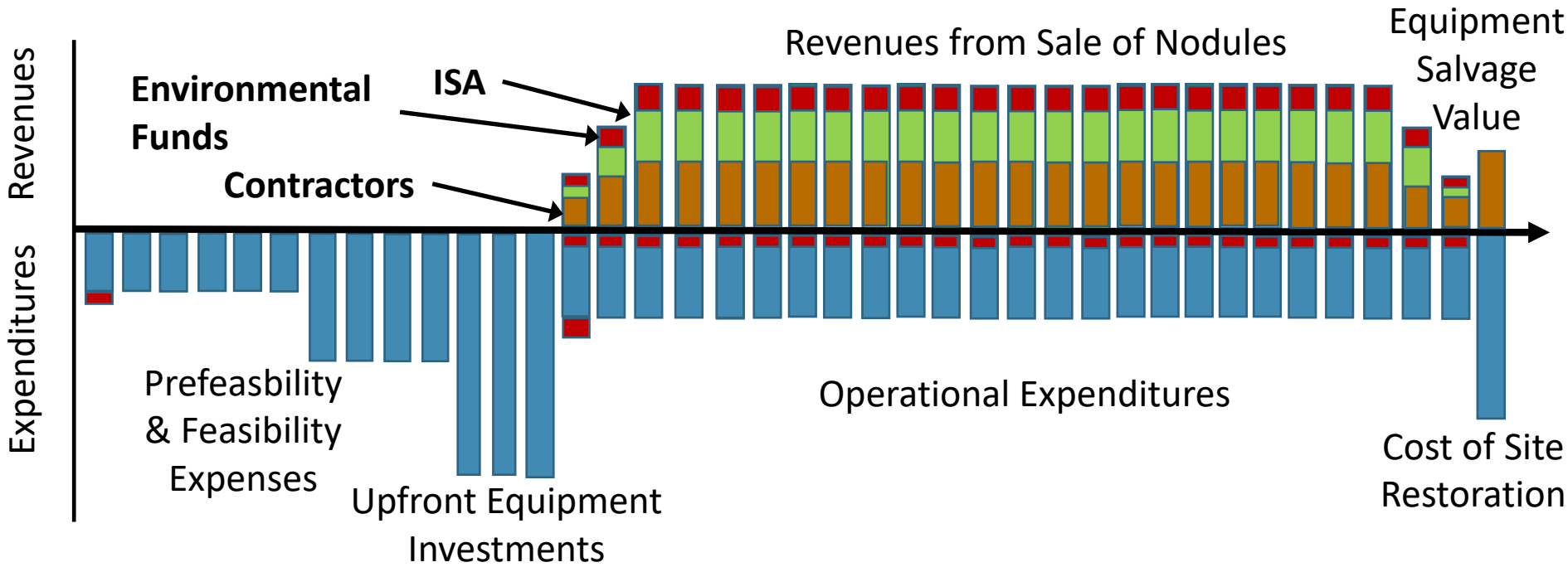
“At-Sea” Cash Flows Basis for Understanding ISA Decisions



Investors will only take on project if discounted future revenues are large enough to provide a return on their investment that is competitive with other investment opportunities

All cash flows need to be **discounted** to account for time value of money
(One dollar today is worth more to me than one dollar in the future)

How should revenues be shared?



Investors will only take on project if discounted future revenues are large enough to provide a return on their investment that is competitive with other investment opportunities

Need to offer the contractors enough revenues to make it worthwhile and to attract investors
Financial institutions/other investors require higher rates of return for projects with higher levels of risk

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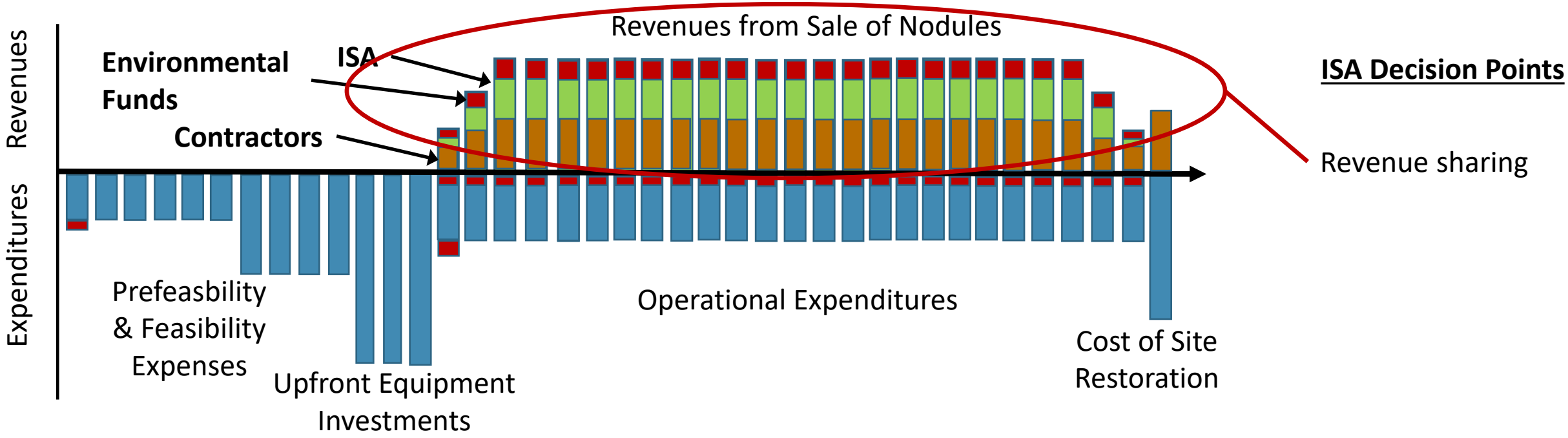

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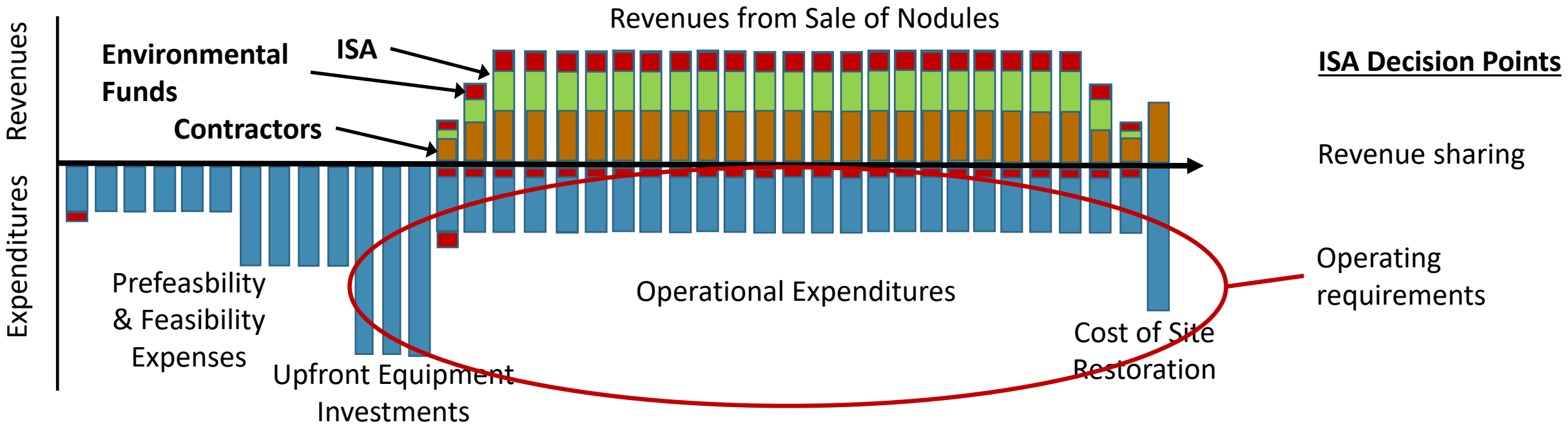

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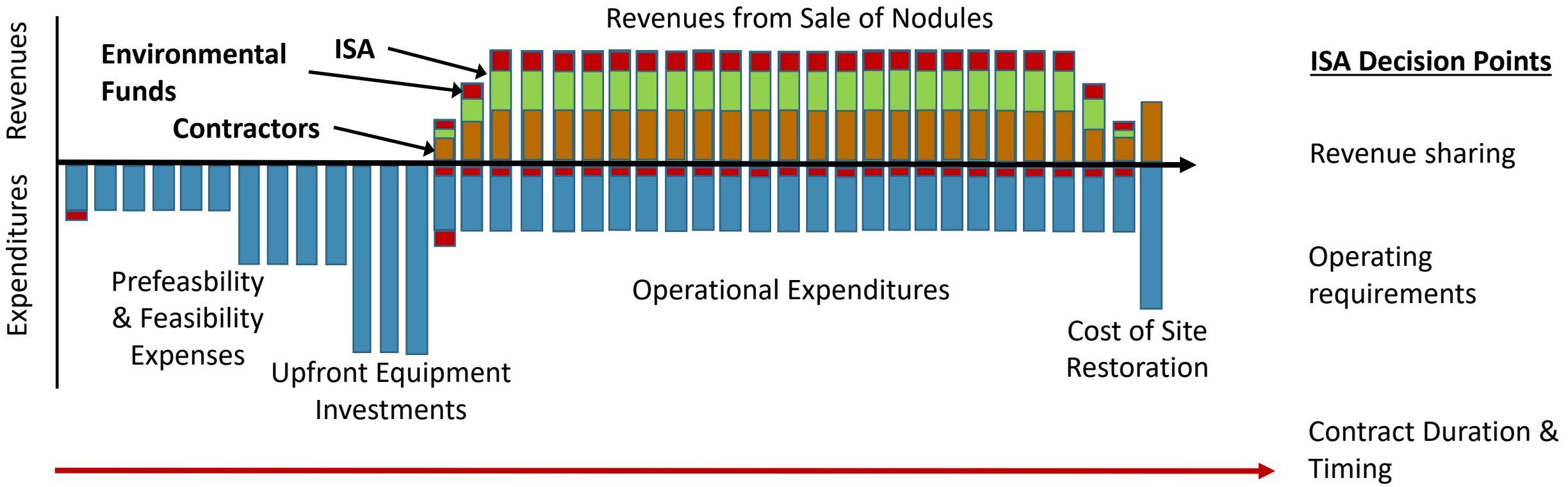


Impact of Contract Timing & Operating Conditions

- ISA Contract Timing Decisions:
  - Specifications about **contract duration** will affect years of revenue & costs and directly impact cash flows
  - Exploitation & Exploration **one-time and annual license fees** must be included in cash flows
- Operating Conditions Decisions:
  - ISA **monitoring** requirements of contractors will impact Upfront Investments & Operating Costs

Revenue Sharing

- Why is it necessary?
  - Formally collectors will receive the money from sale of nodules
  - ISA should receive some of these funds to compensate for the transfer of ownership of the nodules
  - May want some funds set aside for environmental contingencies
- How much money should go to each?
  - ISA will want to maximize its revenue
    - Cover expenses
    - Distribute to member states
  - Sufficient revenues need to go to collectors to incentivize risky investment
  - How much should be set aside for environmental contingencies?

Revenue Sharing Decisions for ISA

- Unlikely that ISA would decide an absolute level of revenues it will receive
- More likely, ISA decisions will concern:
  - Payment schemes to be used to transfer revenues from collectors to ISA & environmental contingency funds
    - Ad Valorem (royalty on the value of metals in the nodules)
    - After-tax Profits
  - Rates to be used in each scheme
  - Measurement Details
    - Ad Valorem: Gross Value at Mouth of Mine? Other?
    - After-Tax Profits: Accounting rules for measuring profit

How large should the contractors share be? What rate of return will be needed to attract investment?

Higher Risk

Greater Rate of Return Required

Nearly Guaranteed Investment
(for example: Gov't bonds)

Very low returns required
(0% - 3%)

Land based mining

Moderately high returns required
due to price & geological risk
(typically above 15%)

Seabed mining

Higher returns than land based mining
Same risks, plus technological risk
Never been done at scale before
Banks may be unwilling to provide loans

Highly Speculative Venture Capital
(Angel investments in new tech)

Very high returns required
(sometimes well in excess of 100%)

Each set of revenue sharing decisions should be evaluated on the following basis:

International Seabed Authority:

- **Average Annual Revenue**
  - Cash flow to CHM in an average or typical year
- **Net Present Value (NPV)**
  - Discounted sum of all revenues to CHM

This requires estimating all of the data in the cash flow model
- Costs
- Revenues
- Licenses, Fees, etc

Contractors:

- **Internal Rate of Return (IRR)**
  - Formally it's the discount rate for future cash flows that gives a zero NPV
  - Practically, it's used as a measure of the lifetime financial return on upfront investments

Environmental Fund:

- **Rate and Total Value of the Fund**

Techno-Economic Model Updates

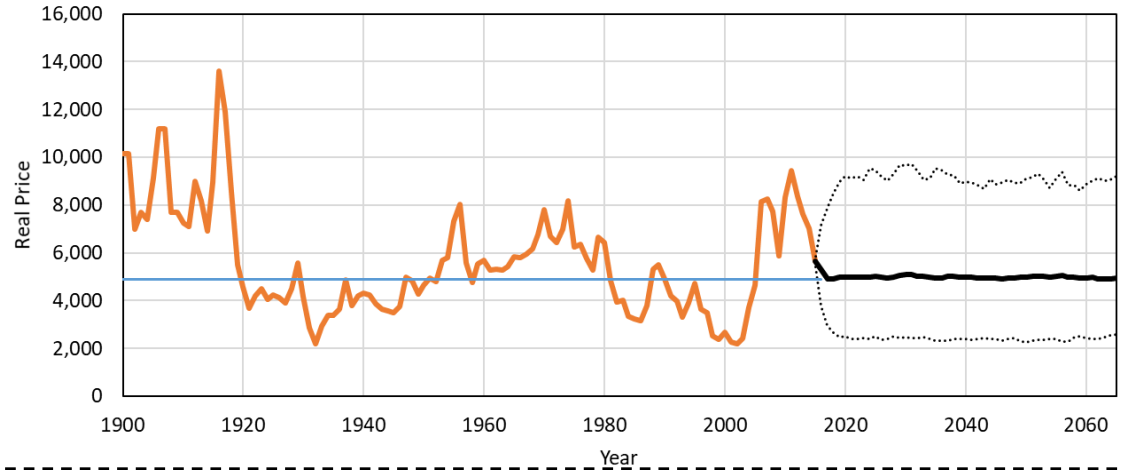
Forecasting Revenues: Market for Nodules

- Predicting future revenues would require forecast for nodule prices
- Currently no market for nodules, so difficult to directly assess
- Nodule prices should reflect prices of underlying metals
  - Price metals processors will pay for nodules depends on:
    - The prices they expect to obtain for the metals after extraction
    - The costs of metals extraction: operating expenses plus return on capital investment
- Metals processing cost models can be used to translate metals price forecasts into nodule price forecast

Approach to Price Forecasting with Uncertainty: Statistical methods vs. Expert opinions with stochasticity

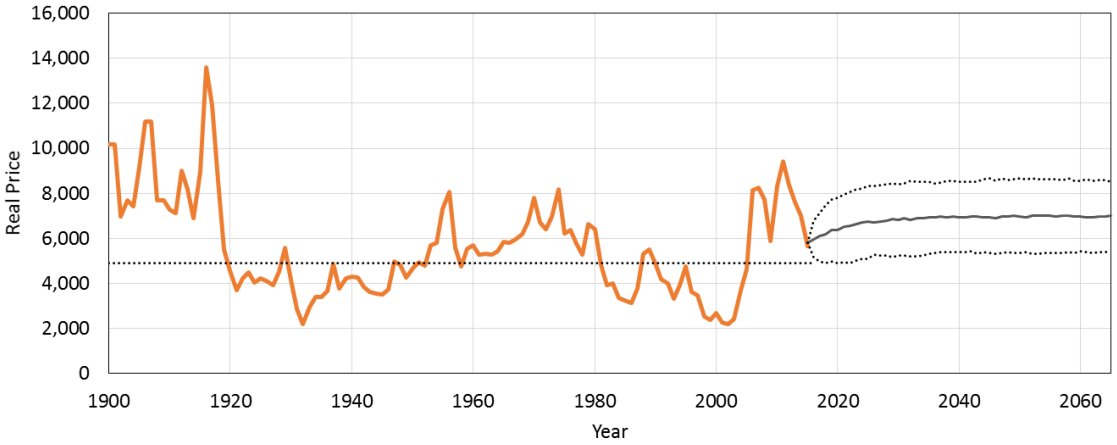
- Time series models were developed based on 100 years of historical data
  (35 years for Mn submarkets)
- These models do not consider structural changes to market
  (particularly important for Co)

Purely Statistical Copper Forecast: ~$5,000/t



- Instead, use expert long term forecasts for each metal
  - *Wood Mackenzie, CRU, SNL, Consensus*
- Add stochastic variable as determined by historical trends in price variation

Expert Copper Forecast with Stochasticity: ~$6,800/t



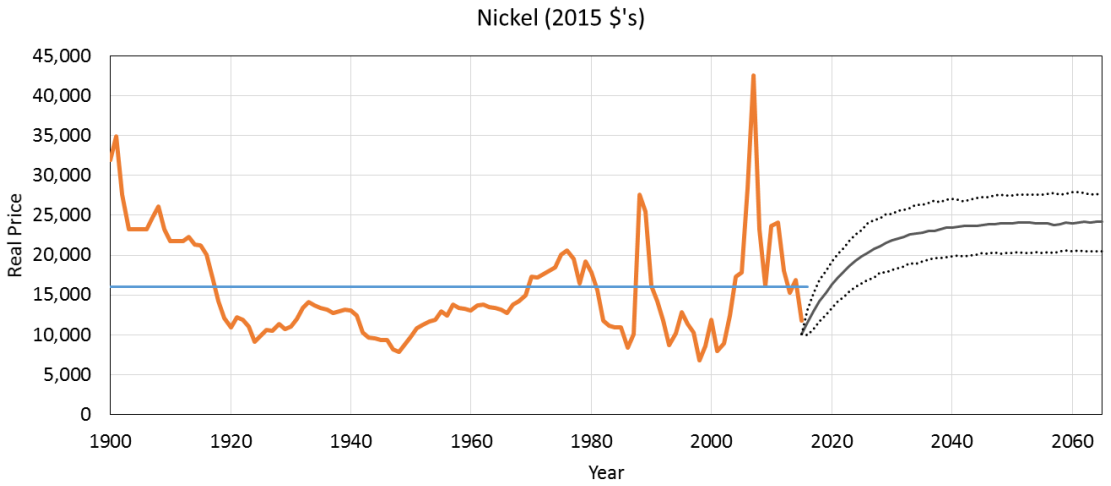
Expert Prices Forecasts with Uncertainty

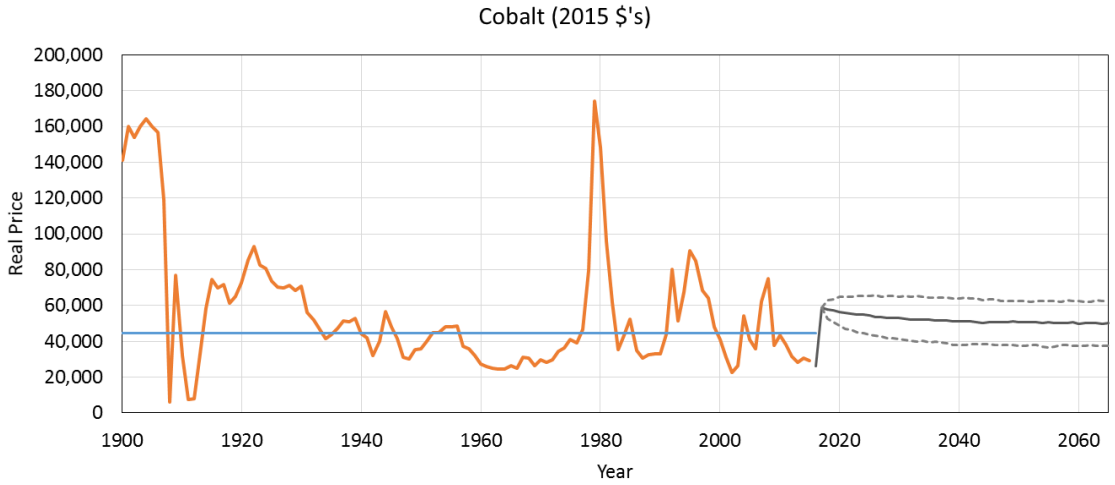
- Expert long-term forecasts from numerous mining consultancies
- Auto-regressive random walk uncertainty models

$$P_t = Int + AR_1\left(P_{t-1} - Int\right) + \varepsilon$$

Int = Long Term Price, AR1 = Reversion to mean, ε = uncertainty

	Copper	Nickel	Cobalt
Long Term Forecast	$6,980	$24,133	$50,000
Mean Reversion	0.86	0.89	0.92
E stdev	$500	$1,000	$3,000





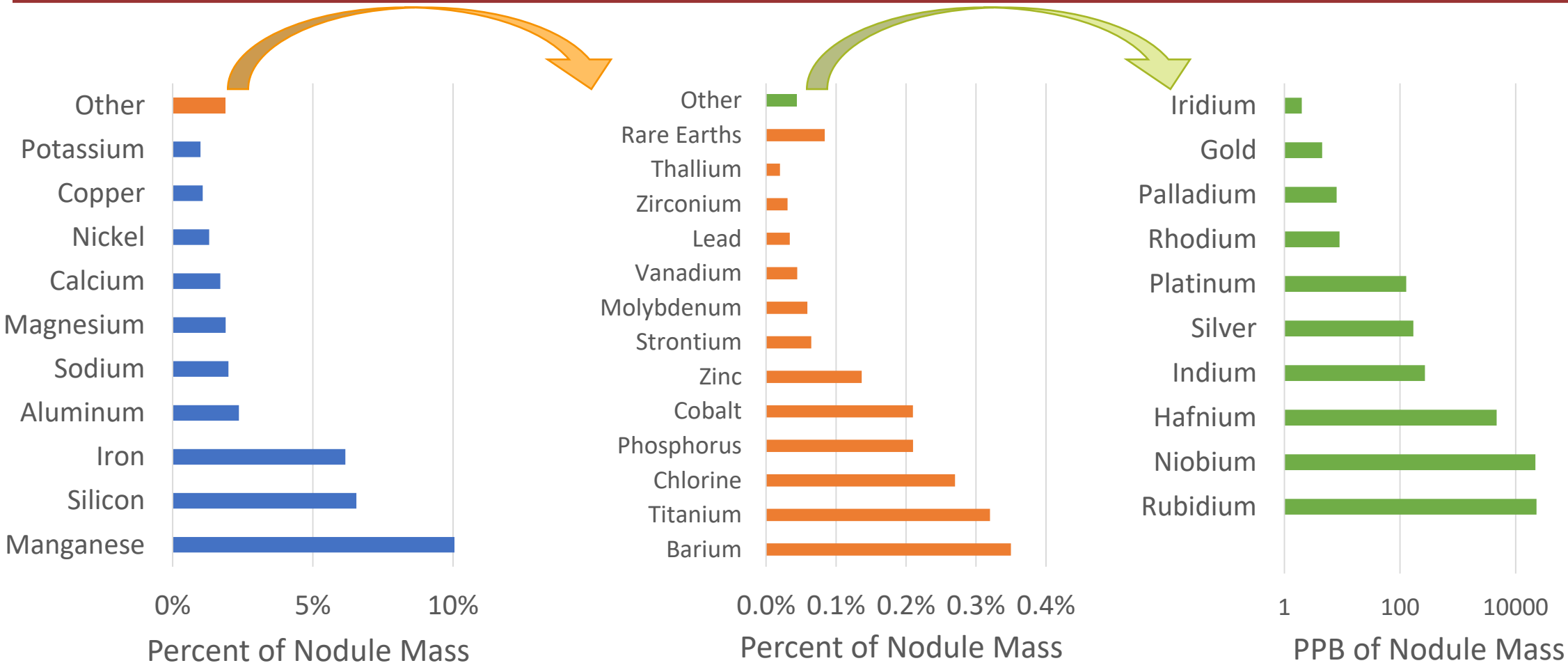
High end manganese market is limited in size
Limited forecasts by segment
Overall expect -6% price decline over model time frame

	Global Market Size *(kt)*	Max. allowable: *(per contractor)*	Quantity Sold *(kt)*
High Carbon Ferromanganese (HC FeMn)	4200	---	324
Medium Carbon Ferromanganese (MC FeMn)	1450	15%	218
Low Carbon Ferromanganese (LC FeMn)	120	15%	18
Electrolytic Manganese Metal (EMM)	1400	15%	210

Resulting Average Mn Price = $1437/t

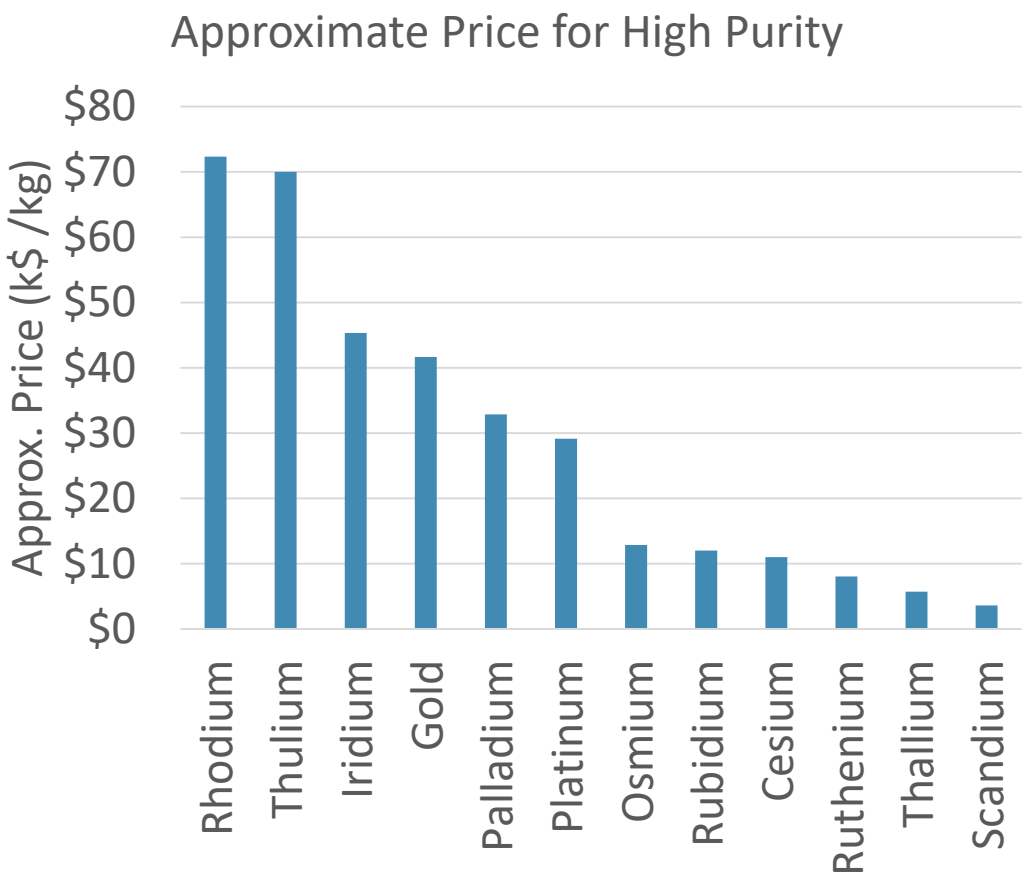
	HCFeMn	MCFeMn	LCFeMn	EMM
Intercept	$874	$1,513	$1,645	$2,218
Coeff	0.86	0.86	0.86	0.86
E stdev	$75	$130	$140	$200

Is there value that is being missed? Composition of the Nodule (Kuhn et al. 2017)



Is there value being missed? Certainly some interesting targets

- Some of the metals in the nodule have very high prices when extracted to high purity
- But concentrations are low
- Five interesting cases
  - Thallium
  - Rubidium
  - Other Rare earth elements + yttrium
  - Titanium
  - Precious



Added value for selected cases

	Unit Price ($/kg)	Amount Available*	Market Size	Add'l Revenue	Notes
Thallium	>$5,000	~600 tpy	10 tpy ☹	2%	Currently extracted from flue dust in copper smelters
Rubidium	>$10,000	~70 tpy	3 tpy ☹	1%	Extraction technology is very high cost
REEs + Y				**2-10%**	**Further examination of costs is warranted**
Ti	$4-5	9,000 tpy	large	2%	
Precious				<1%	

- Amount available refers to the mass present in 3Mt of nodules processed by one

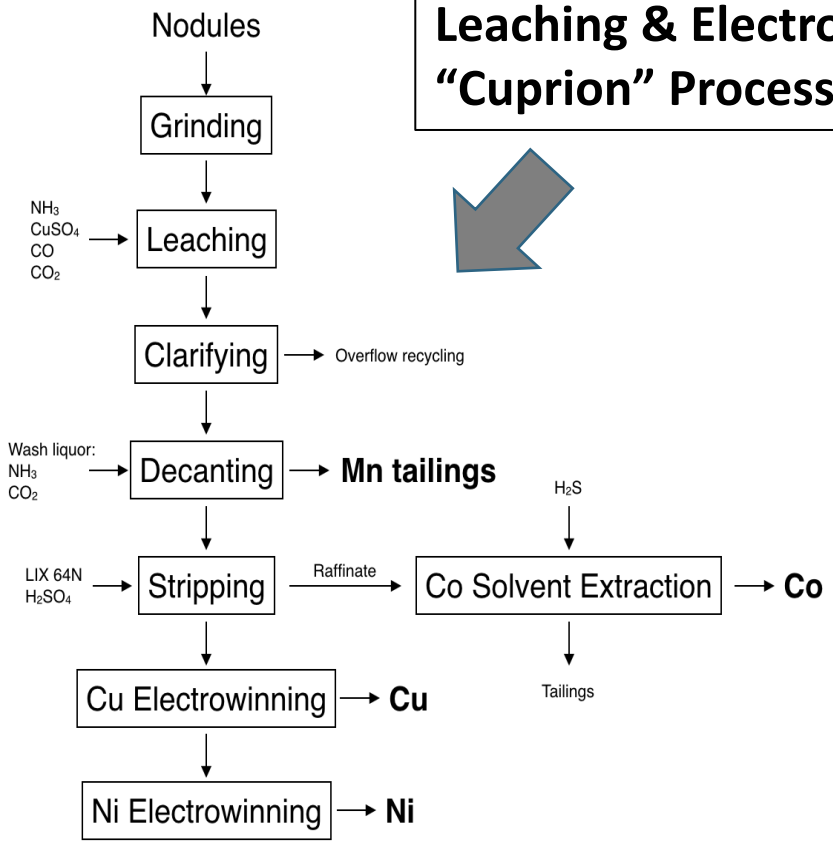
Converting Metal Prices Forecasts to Nodule Prices
No single approach to metallurgical extraction

- Three main classes of processes for main extraction of metals. These often yield three metals (Cu, Co, Ni), but in some cases could yield Mn
  - Leach & Electrowinning ("Cuprion" type processes)
  - Smelt & Leach
  - All Leach

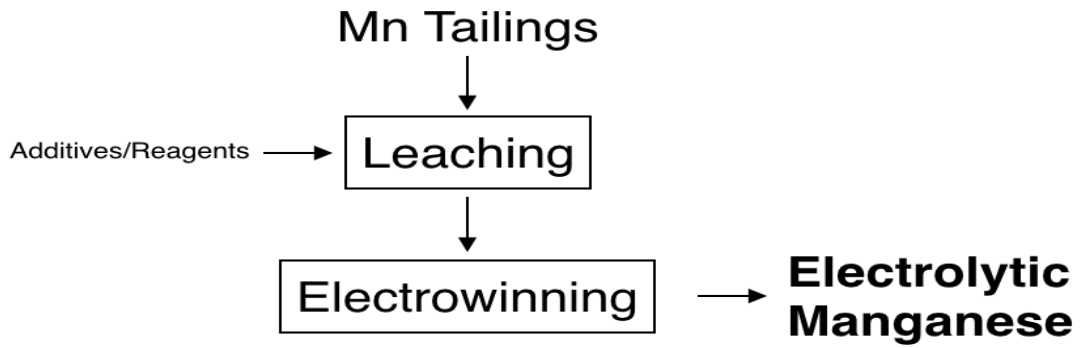
- Two main approaches to additional extraction of Manganese from tailing of three metal processes
  - Smelting: usually for Ferromanganese alloys
  - Leach & Electrowinning: for higher quality EMM

Metallurgical Process Flows: “Cuprion” & EMM Processes

Leaching & Electrowinning “Cuprion” Process



Electrolytic Manganese Processes



Initial Estimates for Cuprion & EMM CAPEX & OPEX

	Cuprion	EMM	TOTAL
CAPEX	$969M	$1,069M	$2,038M
OPEX	$295M/yr	$400M/yr	$695M/yr

OPEX Breakdown			
	Cuprion	**EMM**	**TOTAL**
Consumables	$192M/yr	$39M/yr	$231M/yr
Labor	$23M/yr	$6M/yr	$29M/yr
Energy	$53M/yr	$336M/yr	$389M/yr
Other	$27M/yr	$19M/yr	$46M/yr

Estimating nodule price:

1. For each stochastic set of metals prices
2. Determine overall metals processor cash flows using the estimated OPEX & CAPEX
3. Assume an IRR required by metals processor
4. Calculate nodule price series (over time) that results in the required IRR

Initial Cost Estimates for Collection/Transport

- Constructed detailed process based cost model for all collection & transport activities
- Obtained data from variety of sources
  - Contractor surveys & discussion
  - Literature
  - Similar industries
- Updates ongoing

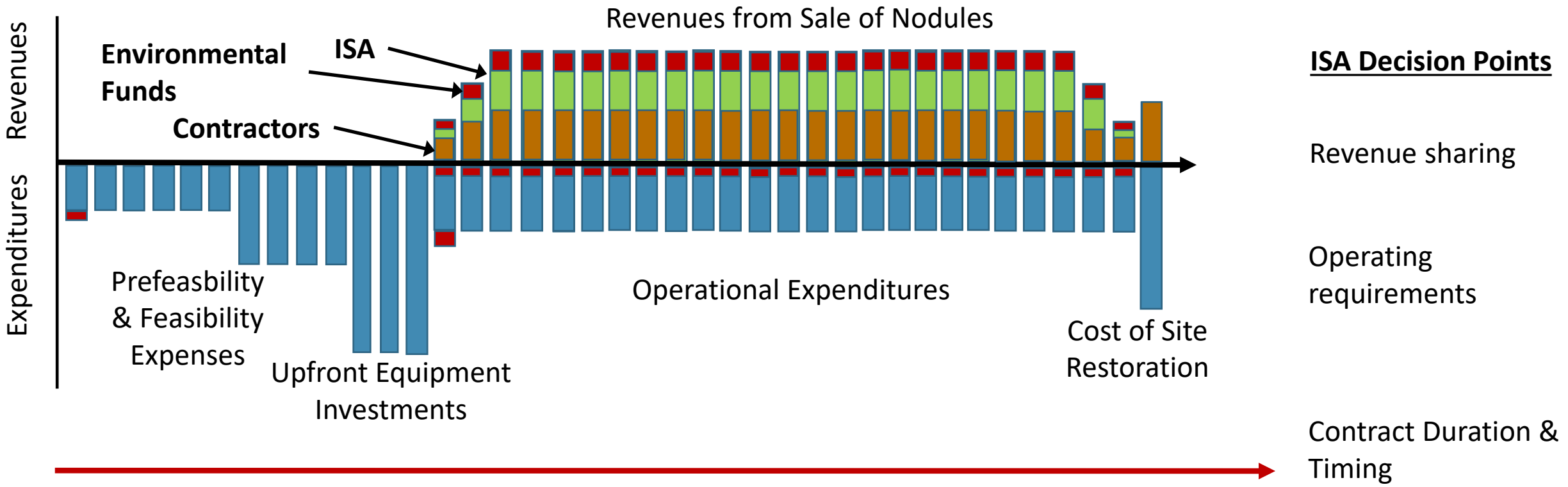
CAPEX Summary	
Collection	$80,000,000
Vertical transport	$226,500,000
Platform	$500,000,000
Process water	$77,000,000
Transport	$255,000,000
Docks	$52,500,000
Total	**$1,191,000,000**

OPEX Summary		
	Annual	Per tonne of dry nodule
Collection	$22,120,000	$7.37
Vertical transport	$58,980,000	$19.66
Platform	$171,165,250	$57.06
Process Water	$16,570,000	$5.52
Transport	$101,201,400	$33.73
Dock	$15,983,688	$5.33
TOTAL	**$386,020,338**	**$128.67**

Cash Flow Analysis Example Results

NOT FINAL

How should revenues be shared?



Key Baseline Assumptions

- Timing
  - Pre-feasibility = 6 years, Feasibility = 3 years
  - Design & Build = 3 years
  - Ramp-up = 2 years
  - Full operations = 23 years
  - Shutdown = 1 year
- Ad Valorem rates apply to Gross Value at Mouth of Mine
- After tax profits require detailed accounting rules
  - Used DB depreciation scheme for fixed costs
- Nodule transfer price estimated from value of metal and processor costs

*CAPEX and OPEX values determined from cost models. Metals prices determined from price forecasting models

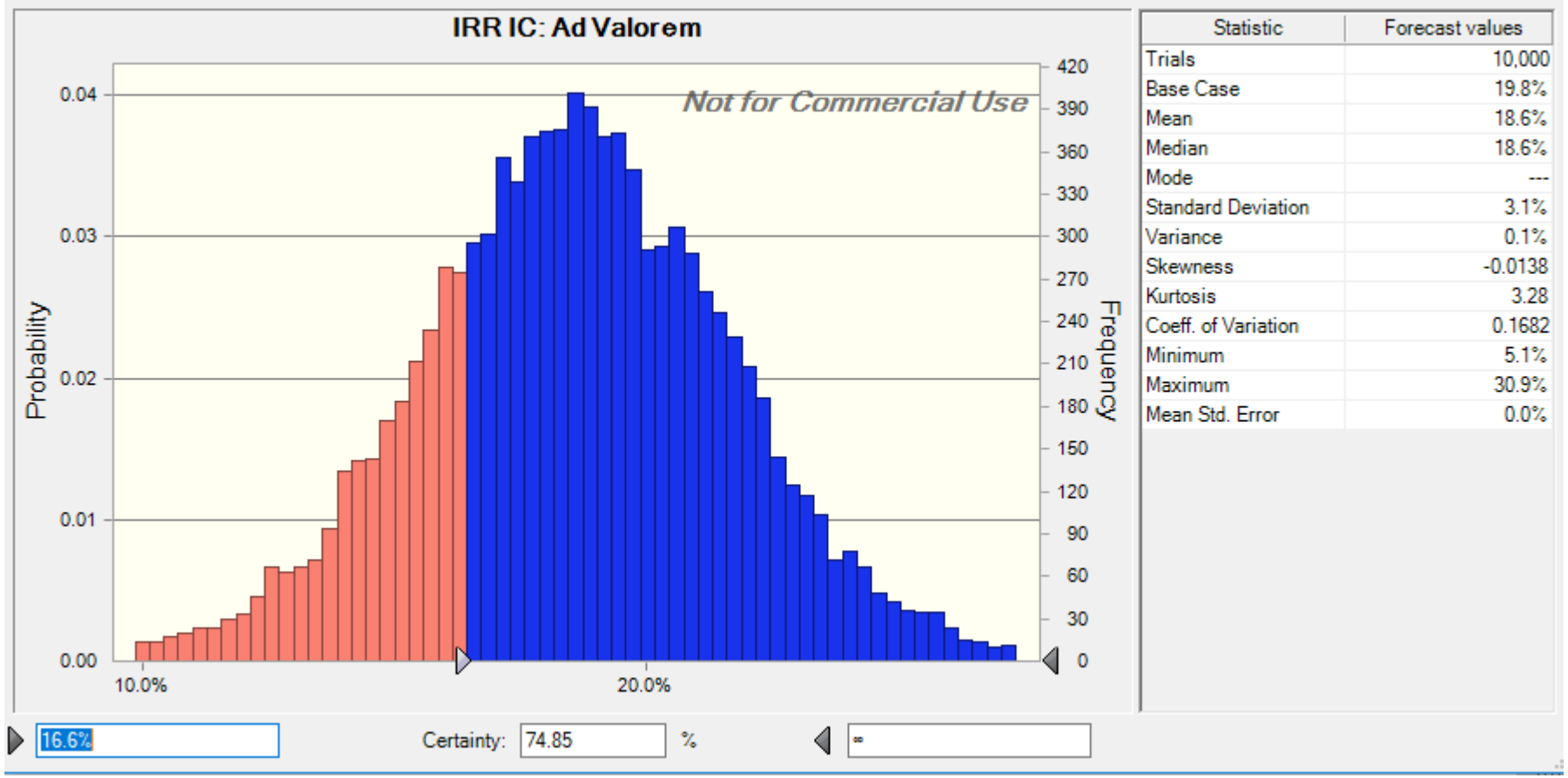
Example results without uncertainty:

NOT FINAL VERSION/DEMONSTRATION PURPOSES ONLY

		Collector IRR	Average Annual Revenue to ISA
Ad Valorem	2%	20.2%	$55.1M
	4%	18.9%	$110.2M
	2% 1st 8 yrs, 4% thereafter	19.8%	$96.6M
	4% 1st 8 yrs, 8% thereafter	17.9%	$193.2M

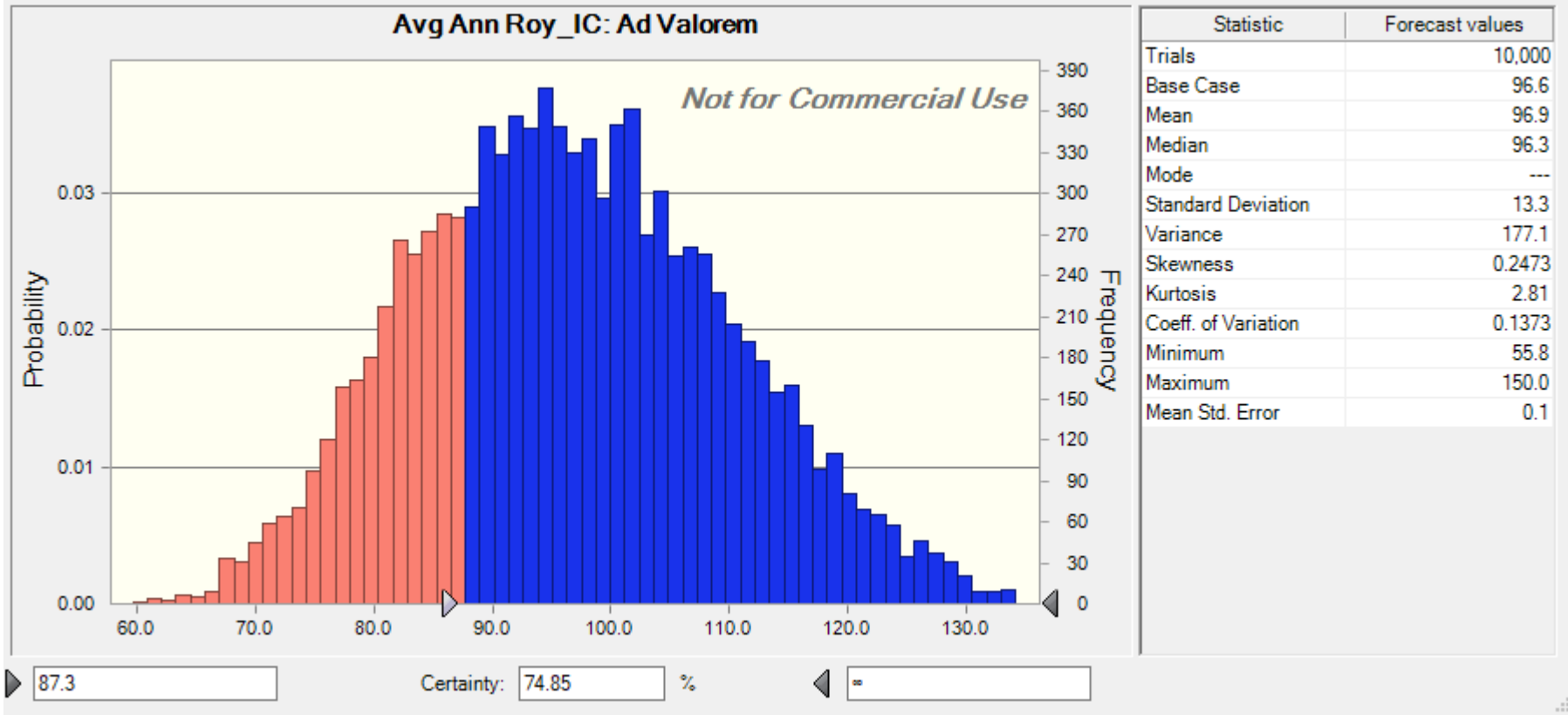
		Collector IRR	Average Annual Revenue to ISA
After Tax Profit	10%	20.5%	$50.6M
	15%	20.0%	$75.9M
	10% 1st 8 yrs, 20% thereafter	20.1%	$90.5M
	15% 1st 8 yrs, 30% thereafter	19.4%	$135.7M

Sample Results: Collector IRR
example of 2%/4% staged Ad Valorem system



Statistic	Forecast values
Trials	10,000
Base Case	19.8%
Mean	18.6%
Median	18.6%
Mode	---
Standard Deviation	3.1%
Variance	0.1%
Skewness	-0.0138
Kurtosis	3.28
Coeff. of Variation	0.1682
Minimum	5.1%
Maximum	30.9%
Mean Std. Error	0.0%

Sample Results: Average Annual Royalty to ISA example of 2%/4% staged Ad Valorem system



Statistic	Forecast values
Trials	10,000
Base Case	96.6
Mean	96.9
Median	96.3
Mode	---
Standard Deviation	13.3
Variance	177.1
Skewness	0.2473
Kurtosis	2.81
Coeff. of Variation	0.1373
Minimum	55.8
Maximum	150.0
Mean Std. Error	0.1

Potential Impact of Seabed Nodule Mining on Metals Prices

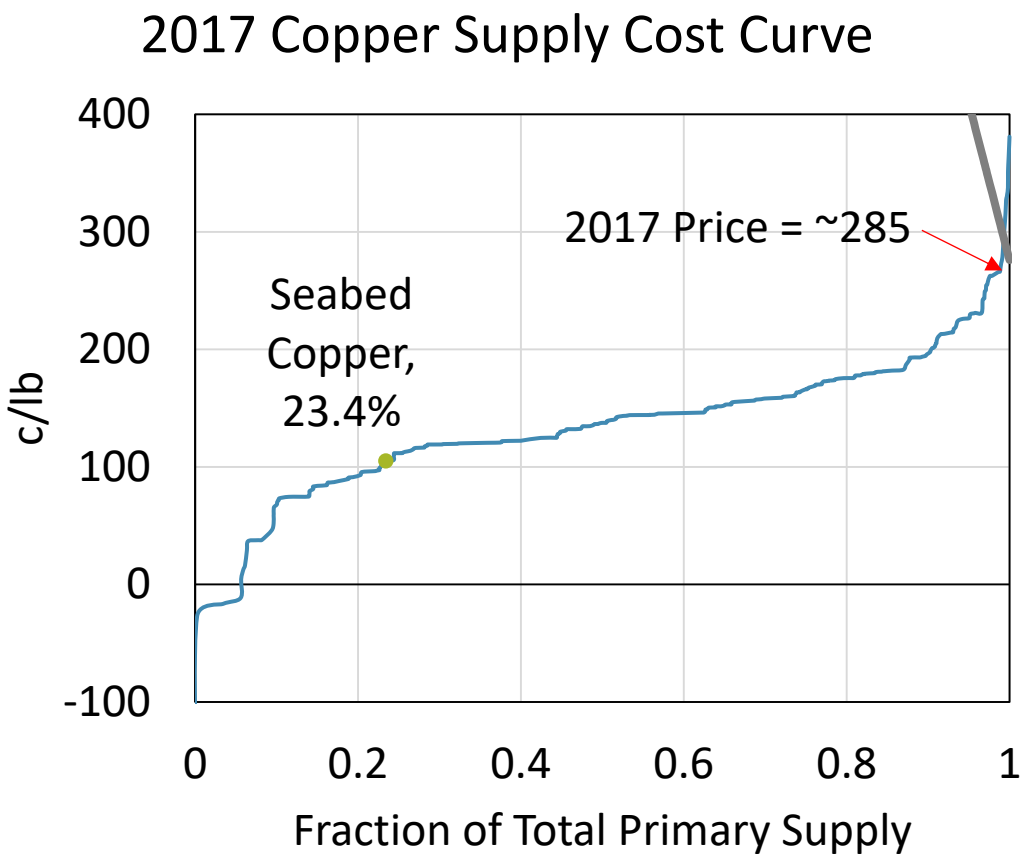
How Might Seabed Mining Alter the Metals Markets?

- For this phase of work, VERY SIMPLE analysis
  - Where does seabed mined metal fit into the supply curve today?
  - If one seabed operation was scaled up TODAY, how would it effect the price?
  - Does NOT consider changes in demand in response to that change in price or change in other suppliers behavior in response to that price

- Where does seabed mined metal fit into the current supply curve?
  - This answers the question: Is seabed produced metal competitive on the market today?
- If one seabed operation was scaled up TODAY, how would it effect the price?
  - This answers the question: How sensitive is the market to new entry
- Initial conclusions for Cu and Ni, continuing work on Co and Mn

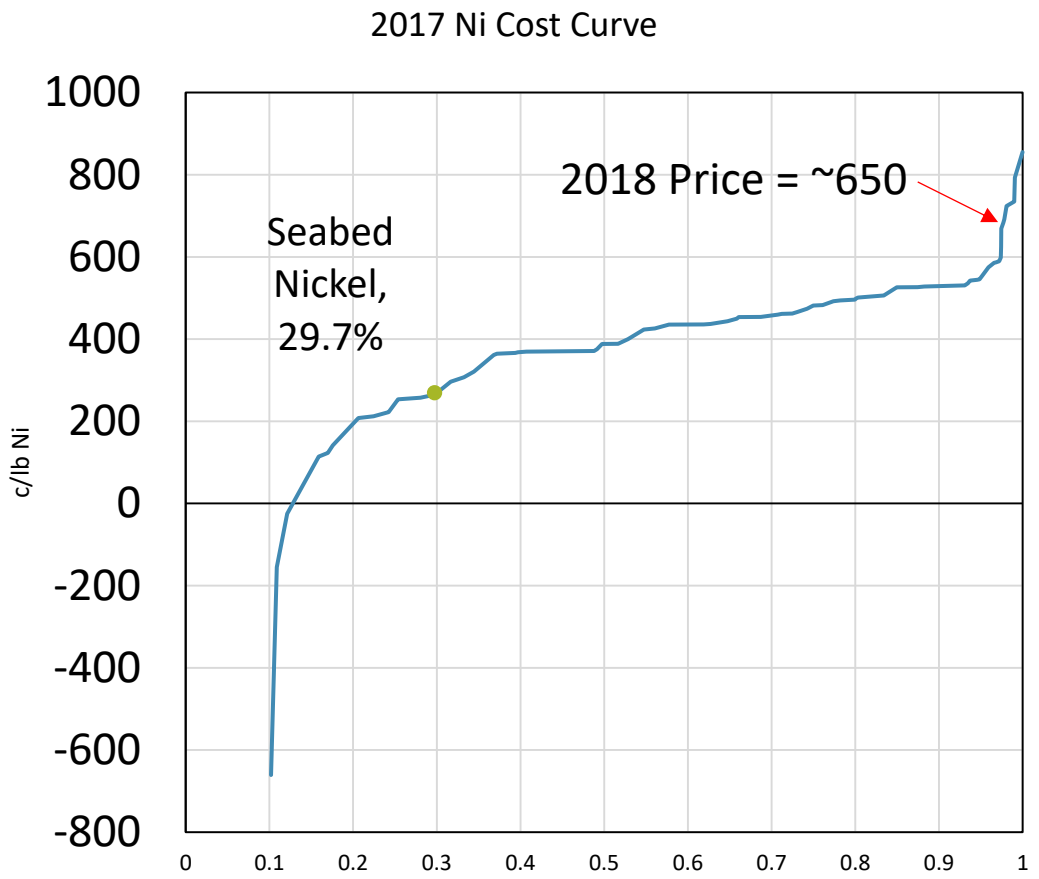
Case 1: Copper
One seabed operator would have little impact on price

- Seabed costs sit in the lower third of the current supply curve
- The copper supply curve is very steep near the prices it currently clears at
- Even though one seabed operation might only add 1% to supply, it could cause prices to drop by more than 1%
- However, demand continues to rise. So effect would be smaller.



Case 2: Nickel
One seabed operator could have small impact on price

- Seabed costs sit in the lower third of the current supply curve
- Average nickel supplier (excluding Norilsk), produces about 20kt, one seabed operation may generate 40kt/y (about 2% of primary supply)
- Supply curve is VERY steep in clearing region, so small additions can effect price, but…
- Demand is expected to rise



Responses to Issues Raised at March Council Meeting

Council Comments & Responses

Council Comment	Response
a) Revenue forecasts and metal pricing, in particular assumptions for Mn pricing	Addressed in presentation
(b) Production and downtime assumptions;	300 days per year. Assumption under review
(c) Insurance assumptions and impact on risk mitigation;	Financial insurance included in contractor OPEX. Environmental bonds separate item. Investigating a range of assumptions.
(d) Constituent metals used for revenue forecasts;	Addressed in presentation
(e) Data assumptions for pre-feasibility, feasibility and other costs;	Detailed cost model inputs sources discussed in presentation
(f) Environmental cost assumptions;	No consideration of environmental costs in financial model. Only consideration of cost of environmental model (in contractor costs) & environmental bonds (see above comment)
(g) Assumptions made for currency fluctuations;	All calculations are in US dollars. Non-dollar denominated costs could be modified for FX variations. Assumptions needed
(h) Factoring in mining efficiencies;	Collection and metals recovery efficiencies included in cost models

Council Comments & Responses

Council Comment	Response
(i) Specific considerations for other resource categories and the flexibility of the model to reflect such considerations;	See section on value of rest of nodule. Current models ONLY address nodules, not other minerals. Additional information would be needed for both cost models & revenue models. Cash flow approach would remain as is.
(j) Mechanisms to compensate the common heritage of mankind, which should include royalty and profit share and model different scenarios, and the principles and timing of review under the model;	Discussed in presentation
(k) The principles of no artificial advantage or disadvantage, namely, how to achieve neutrality;	IRR minimums for contractors need to be chosen in line with hurdles used in land-based mining industries with adjustments for higher level of risk
(l) Understanding the impact of the Authority as part of the cost structure for contractors;	Cost of meeting any Authority requirements included in the Contractor cost models
(m) Supporting the Massachusetts Institute of Technology in collating data and information for the model;	Contractor surveys, phone calls & meetings for cost info Suggest working group to advise on the many scenarios & assumptions needed for complete decision analysis
(n) Incentive mechanisms, such as the use of funds, for reducing environmental impacts.	Already represented in Cash Flow Model. Need advice on rates to be included in analysis

Next Steps

Recommended Additional Work

- Further exploration of polymetallic nodule mining
  - Further refinement of costs & metals price forecasts
  - Transparent collaboration with ISA working group
    - Establish complete set of decision variables
    - Evaluate key scenarios (to be decided in conjunction with working group)
- Understand how seabed nodule mining might affect metal prices and the economies of land based mining countries
  - Expand on initial comparisons with land-based mining cost curve
  - Suggest dynamic supply/demand models for all relevant metals
  - Evaluate impacts by country
- Assessment of environmental costs/benefits
  - Should be collaborative with marine environmental science experts
- Address other seabed minerals
  - Hydrothermal vents & cobalt rich crusts
  - Should similar revenue sharing mechanisms be considered
  - What rates are most appropriate given the economics of each mineral system