# Financial Regimes for Polymetallic Nodule Mining: A Comparison of Four Economic Models

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# Study Objective

- Review information about four financial payment system models that have been submitted to the ISA or presented in other public venues
- Attempt to identify the most likely cause of difference among reported results
- Example difference
  - the AG report states that a mining entity operating under an ad-valorem royalty of 2% of net metal value for the first eight years of production and 4% thereafter would be expected to earn an internal rate of return (IRR) of **27%.**
  - CSU report says that, given a constant ad-valorem rate of 2% for the life of the mining operation, a mining entity would only be expected to earn an IRR of **17%.**

# The four models being compared here are :

- the African Group Model (AG)
  - Available information: Report “Request for consideration by the Council of the African Group’s proposal on the Economic Model/Payment …” that was submitted to the ISA on September 7, 2018.
  - Questions answered by AG representatives
  - Model available: No
- the China Southern University Model (CSU)
  - Available information: presentation “Financial model and economic evaluation of polymetallic nodules development in the Area” by Prof. Shaojun Liu from CSU that was submitted to the ISA on September 7, 2018.
  - Questions answered by CSU representatives
  - Model available: No
- the German Federal Ministry for Economic Affairs and Energy Model (BMWi)
  - Available information: document “Analysis of the Economic Benefits of Developing Commercial Deep Sea Mining Operations …” a report for the Federal Ministry for Economic Affairs and Energy (BMWi) issued on September 30, 2016.
  - Questions answered by CSU representatives
  - Model available: No
- the Massachusetts Institute of Technology model (MIT)
  - Model available: YES

# Review Process

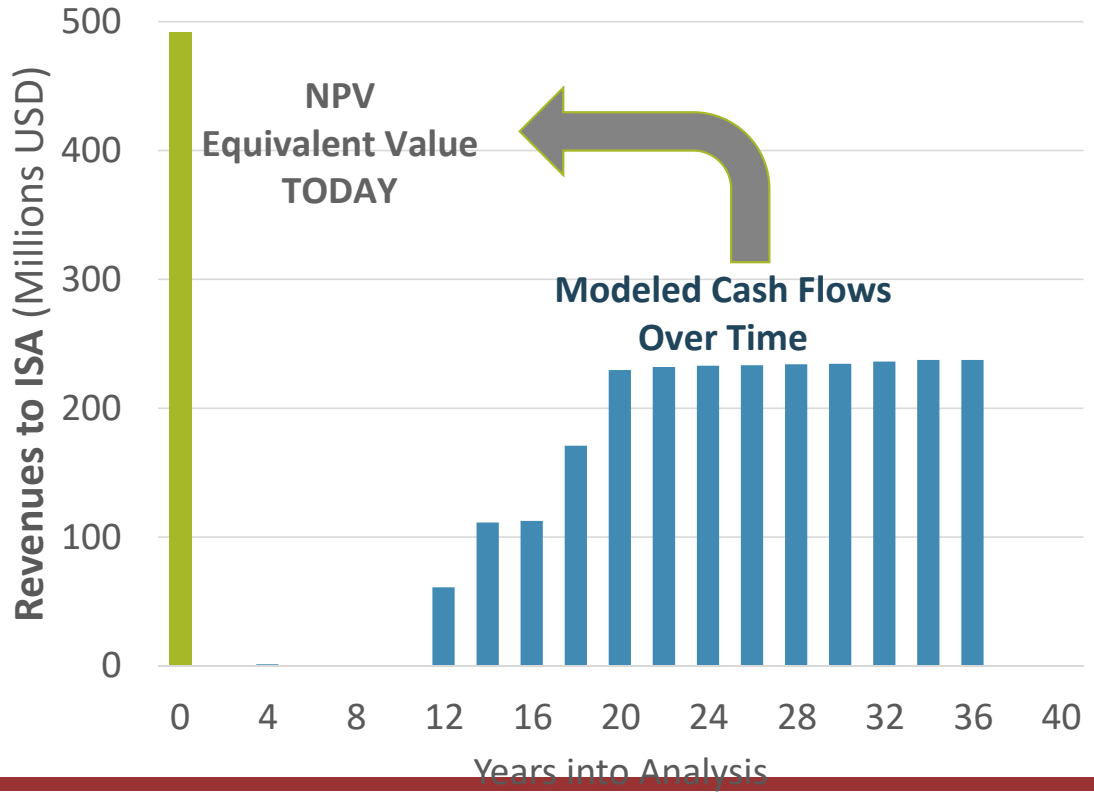
1. The authors reviewed publically available information about each of the review models and developed questions for each modeling team.
2. Each team was interviewed by phone and/or email.
3. The authors created models that used those data to replicate the results reported for each model.
   - These proxy models were then used to explore the key drivers of the differences among the results previously reported.

# Overall All Four of the Models are Analytically Similar

- ALL models are very similar
  - ALL carry out discounted cash flow analysis
- All four models explored a collection operation of 3 million dry tons of nodules per year

# Discounted Cash Flow Model is Standard Tool for Assessment Economic Viability of Any Activity

- Estimate magnitude & timing of future cash flows
  - Operating expenses
  - Investments (capital expenses)
  - Royalties, taxes, and fees
  - Revenues
- Compute various financial metrics
  - Discount all CFs to present = Net Present Value (NPV)
  - Solve for discount rate where NPV = 0 → Internal rate of return (IRR)



# Overall All Four of the Models are Analytically Similar

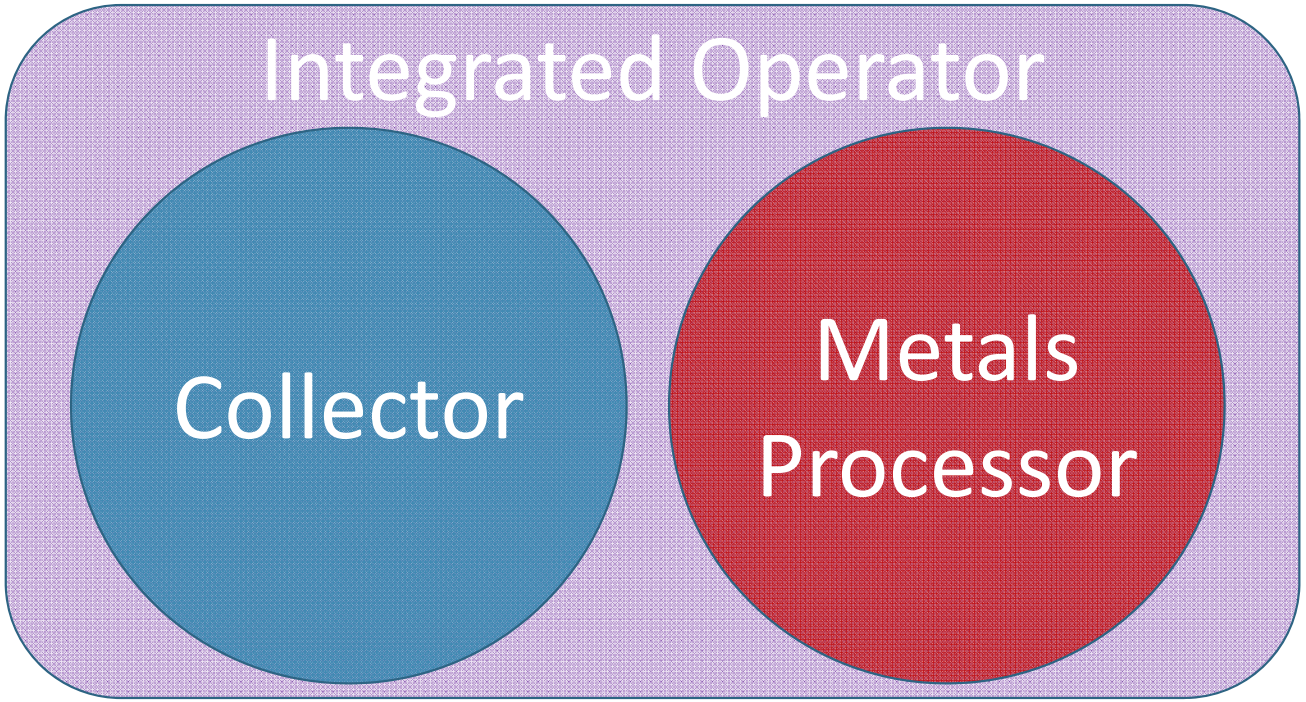
- ALL models are very similar
  - ALL carry out discounted cash flow analysis
- All four models explored a collection operation of 3 million dry tons of nodules per year
- Most commonly reported metrics were
  - IRR (3 of 4)
  - NPV (3 of 4)

| | AG | BMWi | CSU | MIT |
|---|---|---|---|---|
| **Metrics Reported** | | | | |
| **IRR** | ✓ | ✗ | ✓ | ✓ |
| **NPV** | ✗ | ✓ | ✓ | ✓ |
| **Revenues to ISA** | ✓ | ✗ | ✗ | ✓ |
| **Revenues to Sponsoring State** | ✓ | ✗ | ✗ | ✗ |
| **ISA share of profit** | ✓ | ✗ | ✗ | ✗ |
| **Sponsoring state share of profit** | ✓ | ✗ | ✗ | ✗ |
| **Other** | | | Break-even time and grade, payback period | |

# Identified 21 Significant Characteristics that Vary Across the Models

- Analytical framing
  - Reported evaluation metric
  - Operational scope
  - Analysis Period
- Production characteristics
  - Scale
  - Ramp up period
  - Metallurgical processing
  - Metals recovered
  - Metals Content of Nodules
  - Metallic yield
- Magnitude of estimated future prices
  - Cobalt
  - Copper
  - Manganese
  - Nickel
  - Gross Metal Value of Nodule (USD / tonne nodule)
  - Net Metal Value of Nodule (USD / tonne nodule)
- Magnitude of estimated operations-related cost cash flows
  - CAPEX
  - OPEX
  - Salvage value
  - Site remediation
- Magnitude of estimated financial regime-related cash flows
  - Sponsoring State Tax rate
  - Royalties
  - ISA Fees

# Operational Scope: Three models assume integrated operator; MIT model assesses separate operators



# Key Issues:
# Analysis period and timing

Analysis period comprises both Before production (feasibility activities and operation design and build (D&B)) and During production and possibly AFTER production

| | AG | BMWi | CSU | MIT |
|---|---|---|---|---|
| **Analysis Period** | 35 years | 16 | 28 | 37 |
| **Exploitation period analyzed** | 28 years incl. 3 years D&B | 16 years incl. 4 years D&B | 28 years incl. 3 years D&B | 30 years incl. 3 years D&B |

# Key Issues:
# Ramp up

- Ramp up is the period where operations are not a full capacity.
- Later analysis shows this to be very influential

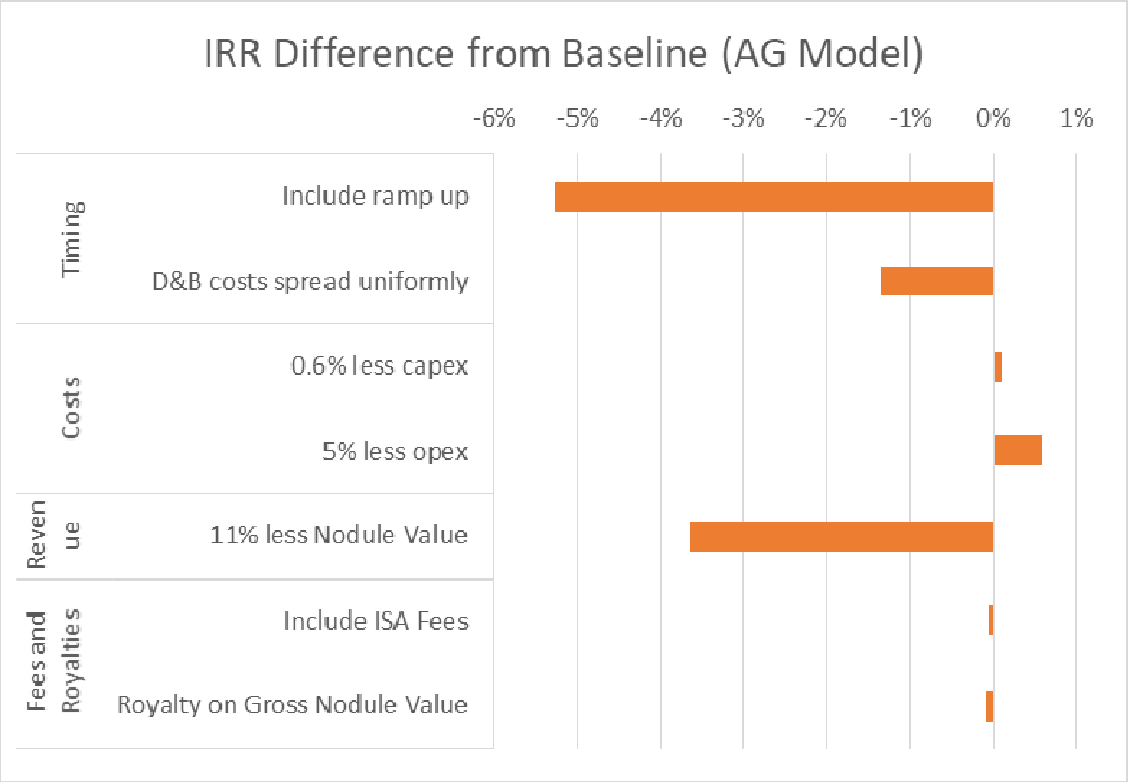
| | AG | BMWi | CSU | MIT |
|---|---|---|---|---|
| **Ramp up period (years not at full production)** | 0 years | 2 | 0 | 2 |

# Key Issues: Metallurgical process & Metals recovered

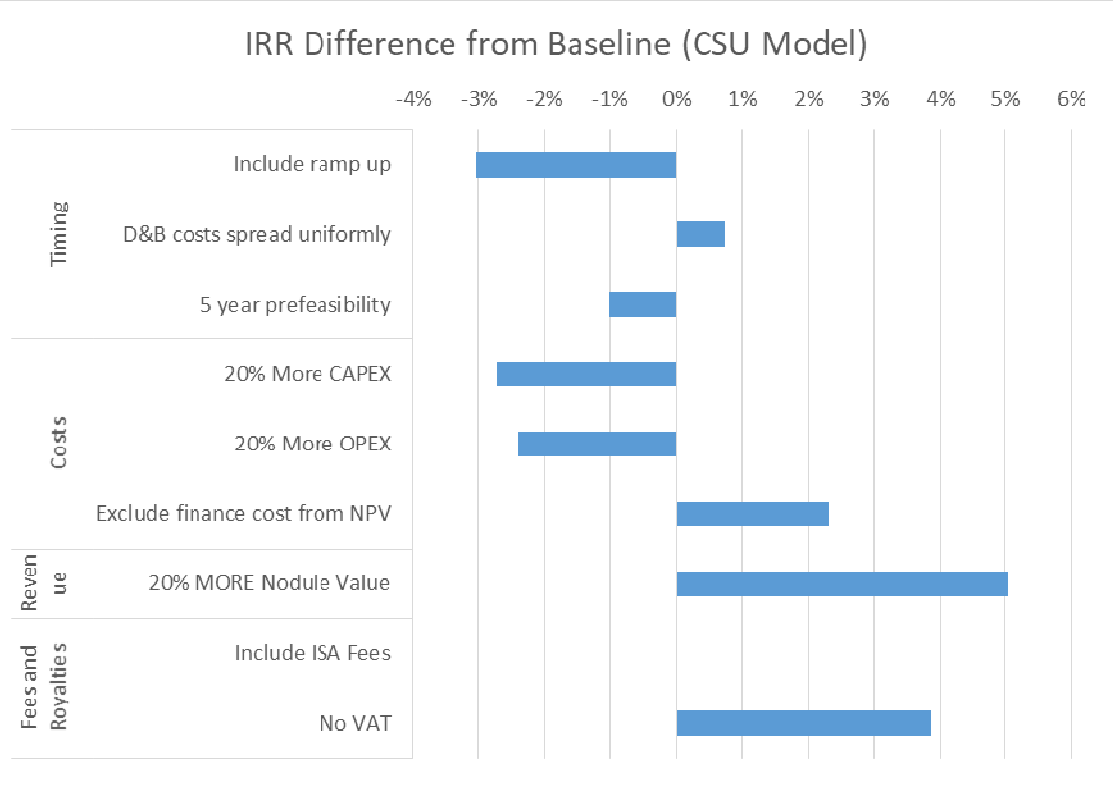
Three of the four models assumed metallurgical processing to recover Mn metal, the BMWi model assumed only three metals were recovered

| | AG | BMWi | CSU | MIT |
|---|---|---|---|---|
| **Metallurgical processing** | Mn recovered to EMM | High-pressure/high-temperature leaching using sulphuric acid | Mn recovered to EMM | Mn recovered to EMM |
| **Metals recovered** | (✓ = included) | | | |
| **Cobalt** | ✓ | ✓ | ✓ | ✓ |
| **Copper** | ✓ | ✓ | ✓ | ✓ |
| **Manganese** | ✓ | ✗ | ✓ | ✓ |
| **Nickel** | ✓ | ✓ | ✓ | ✓ |

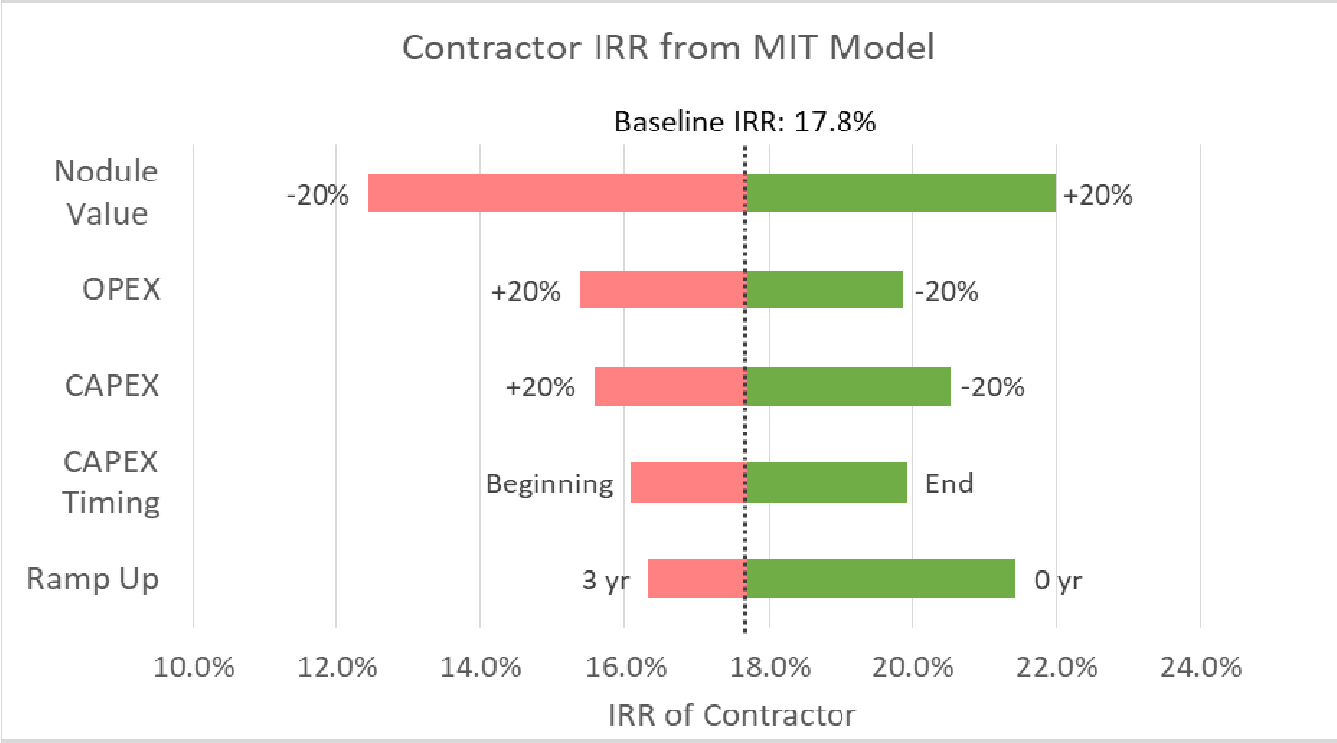
# Influential Assumptions in the AG model



# Influential Assumptions in the CSU Model



# Impact of assumptions on the MIT model



# Key Assumptions that Should be Considered by the WG based On the Model Comparison

- **Scope of analysis**
  - Integrated vs separate
  - Salable Mn ore or Mn metal
- **Value of the nodules**
  - Conservative historic prices
  - Aggressive price forecasts
- the magnitude of OPEX costs;
- the magnitude of CAPEX costs;
- **the duration of the production ramp up; and**
- **the timing of capital expenditures**