# CUSTOS DE CAPITAL E OPERACIONAIS NA MINERAÇÃO

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# SUMÁRIO



- Fontes de informação
- Estimativa de capex e opex esperada para cada etapa do projeto
- Estimativa do Capex
- Estimativa do Opex

# FONTES DE INFORMAÇÃO



- Rudeno, V. The mining valuation handbook, 2012.
- Cost calculator – Infomine - http://calc2015.costs.infomine.com/welcome.aspx
- Ausimm, Cost estimation handbook, 2012.
- Mintek, Handbook on the Estimation of Metallurgical Process Costs, 1991.
- Mular, A. L.; Parkinson, E.A. Mineral Processing Equipment Costs and Preliminary Capital Cost Estimation, 1972.
- Fornecedores

# ETAPA DO PROJETO

Table 3-1. Level of Project Development and Corresponding Aspects of the Business Case (AACE International, 2011)

| Development Phase | Project Definition (%) | Capital Estimate | Capital Estimate Accuracy (%) | Scenario Options | Site Selection | Selling Prices | Input Prices | Operating Parameters |
|---|---|---|---|---|---|---|---|---|
| FEL1 Conceptual study | 0–2 | Screening, ballpark | –20 to +100 | Two or more | Country | Generic, annual mean | Historical | Benchmarked |
| FEL2 Prefeasibility study | 10–40 | Budget | –10 to +30 | One plus trade-off studies | Region | Consensus forecasts | Historical | Benchmarked vendor preliminary specifications |
| FEL3 Feasibility study | 30–70 | Definitive | –5 to +20 | One | Specific site | Market study | Historical trending to forecast | Vendor specifications |
| FEL4 Implementation | 90–100 | Control | –3 to +15 | – | – | Actual | Actual contracted input prices | Vendor specifications |
| Operations startup | 100 | – | – | – | – | Actual | Actual input prices | Vendor specifications |
| Operations | 100 | – | – | – | – | – | Actual input prices | Actual historical |

Boom et al, 2015

TABLE 1.1

Generic study classification guide.

| Terminology used in this handbook | | Scoping study – Phase 1 | Prefeasibility study – Phase 2 | Feasibility study – Phase 3 |
|---|---|---|---|---|
| Front end loading | | FEL 1 | FEL 2 | FEL 3 |
| Different titles that may be used to describe this level of study | Conceptual | Concept | Preliminary feasibility | Final feasibility |
| | Opportunity assessment | Order of magnitude (OOM) | | Basic engineering |
| | | Identification phase | Selection phase | Definition phase |
| | Screening | Scoping[a] | | 'Bankable' feasibility |
| | Scoping (see footnote) | | | Definitive feasibility |
| | | Capacity factor | Equipment factor | Forced detail |
| | | Preliminary evaluation | Intermediate economic study | |
| Estimate type (AACE) | | Class 5 | Class 4 | Class 3 |
| Expected accuracy range of capital cost | ±35% to ±100% Typically ±50% | ±30% to ±35% | ±20% to ±25% | ±10% to ±15% |
| Expected estimate contingency range | 30% to 75% | 20% to 35% | 15% to 25% | 10% to 15% |
| Level of definition (% of complete engineering (see Table 4.5) | Minimal, generally based on other operations, or in-house 'database' | 1 - 2% Basic general layouts | 10 - 15% Preliminary take-offs | 15 - 25% Detailed drawings and take-offs |
| Typical estimating methodologies (but refer Table 4.5 for detail by line item) | Capacity factored<br>Parametric models, judgement or analogy<br>Stochastic estimating methods, including cost-capacity curves, and various factors | Equipment factored or parametric models. Some 'first principles' estimating related to early scope definition | Semi-detailed unit costs, and more deterministic estimating methods<br>Preliminary MTOs<br>(Some) budget pricing | More detailed unit costs and MTOs<br>Budget prices and vendor quotes<br>Higher degree of deterministic estimating methods<br>Line items, and forced detail where definition is lacking |

Notes: a. Although the term 'scoping study' can sometimes be used synonymously with a study at a level before FEL1, throughout the rest of this handbook, it is used to indicate a study generally before that of a prefeasibility study (PFS). FEL = front end loading (Independent Project Analysis Institute (IPAI)). MTO = material take-off.

Ausimm, 2012

# ESTIMATIVA DE CUSTOS



- Custos de capital (Capex) e Operacional (Opex)
- Os custos de uma mina dependem de uma série de fatores, como (Rudeno, 2012):
  - Tipo de mineral;
  - Mina a céu aberto ou subterrânea;
  - Infraestrutura existente – energia, cidade, aeroporto, estradas, ferrovia;
  - Suprimento de água e energia;
  - Topografia;
  - Clima – chuva, neve, umidade, temperatura.

# ESTIMATIVA DO CAPEX



- Regras de dedão:
  - Materiais com pouco processamento (carvão, óleo): custo por tonelada de ROM
  - Material com processamento (metais básicos): custo por tonelada processada na usina.
  - Ouro: custo por unidade produzida (ounce).
  - Observar que os valores variam muito – apenas referência para aproximações iniciais.

# ESTIMATIVA DO CAPEX



- Regras de dedão (base 2011 US$):

Table 8.1: capital costs summary

| Commodity | Capital costs range/unit of annual production |
|---|---|
| Black coal | $10/tonne to $671/tonne |
| LNG | $194/tonne to $5 000/tonne |
| Coal seam methane | $3m/Pj to $10m/Pj |
| Copper | $1833/tonne to $14 400/tonne |
| Gold | $104/ounce to $2430/ounce |
| Iron ore | $13/tonne to $720/tonne |
| Lead–Zinc | $310/tonne to $3889/tonne |
| Mineral sands | $250tonne to $1233/tonne |
| Nickel metal | $1800/tonne to $59 204/tonne |
| Uranium | $91/t to $313/t |

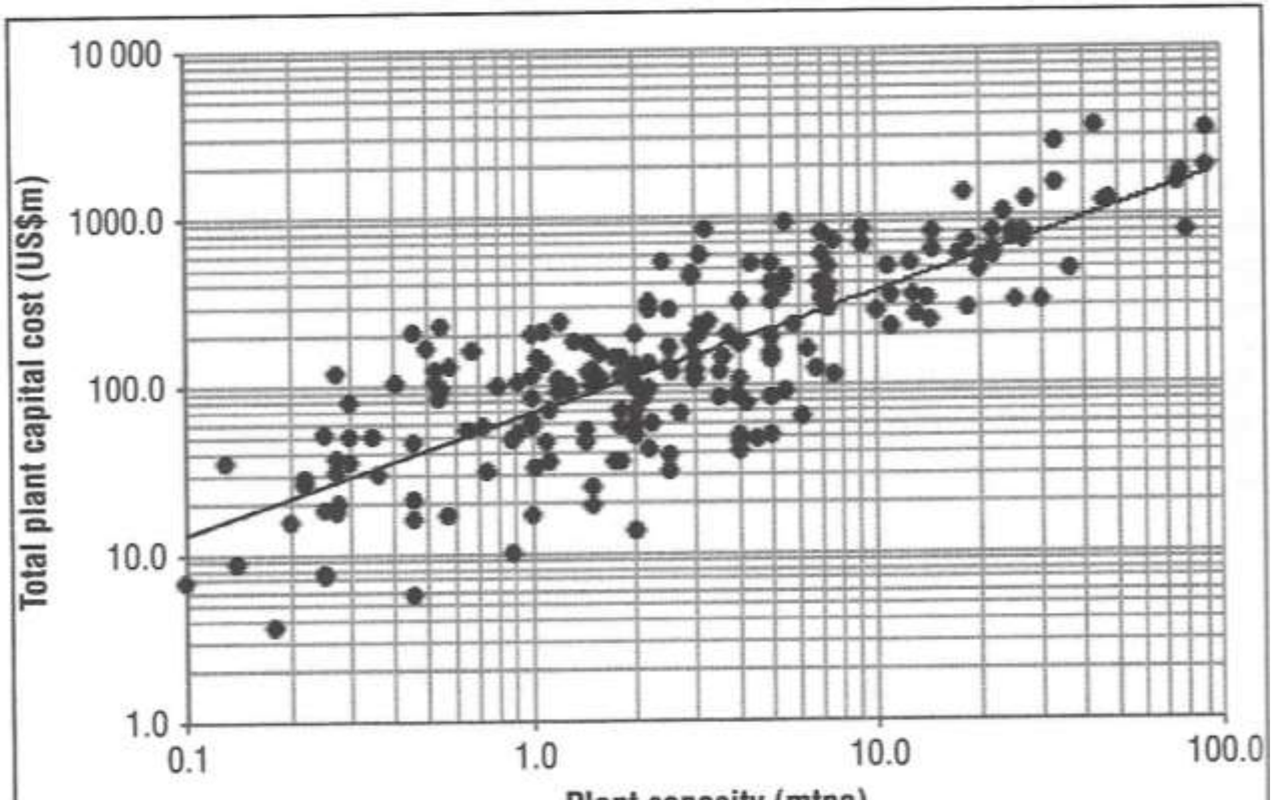
Rudenno, 2012

# ESTIMATIVA DO CAPEX



- Regras de dedão (base 2011 US$):

Figure 8.4: treatment total plant capital costs




$US\$m = 68.61 \times T^{0.720}$, $n = 204$, $r^2 = 0.66$

Rudenno, 2012

# ESTIMATIVA DO CAPEX



- Regras de dedão:
  - Regra dos seis décimos (six-tenths):

$$\frac{Custo\ da\ usina\ 1\ (desconhecido)}{Custo\ a\ usina\ 2\ (conhecido)} = \left(\frac{Capacidade\ 1}{Capacidade\ 2}\right)^{0{,}6}$$

Ausimm, 2012

# ESTIMATIV



- Conceitual: Estimativas por equipamento principais e índices para demais itens

TABLE 1.2
Plant component ratio method (after Mular, 1978).

| Notes | Capital cost estimate item | Multiplying factor (range) | | | Capital cost $ M |
|---|---|---|---|---|---|
| | | Min | Max | Factor used | |
| a. | Total direct cost of major equipment , roads, power line, major buildings, township, airstrip etc. | | | | 1000 |
| | 'Factored elements', such as: | | | | |
| b. | Piping | 7% | 25% | 15% | 150 |
| c. | Electrical | 12% | 25% | 15% | 150 |
| d. | Instrumentation and control | 3% | 10% | 5% | 50 |
| e. | Spares | 1% | 5% | 2% | 20 |
| f. | First-fill | 1% | 3% | 1% | 10 |
| | Infrastructure | | | | |
| g. | Architectural and auxiliary buildings; minor infrastructue | 7% | 15% | 9% | 90 |
| | Total direct cost for the plant | | | | 1470 |
| | Indirect costs | | | | |
| h. | Owners' costs | 5% | 15% | 7% | 103 |
| i. | Freight and taxes | 3% | 10% | 4% | 59 |
| j. | EPCM | 5% | 30% | 18% | 265 |
| k. | Construction camp, temporary facilities, catering, etc | 4% | 10% | 6% | 88 |
| | Total indirect cost for the plant | | | | 515 |
| l. | Contingency (on direct and indirect) | 15% | 40% | 30% | 595 |
| | Total installed capital cost for the plant | | | | 2580 |

a. As derived by methodologies described in this handbook.
b. Only for 'small' pipes and piperacks; larger pipes will normally be separately estimated under direct equipment costs.
c. Electrical cabling; racking; connections; small motors, large and variable voltage variable frequency (VVVF) motors generally part of equipment.
d. Instrumentation and control for minor aspects, not major capital expenditure (Capex) such as a supervisory control and data acquisition (SCADA) system.
e. Dependent on project and strategic decisions on spares holding.
f. Often calculated. Includes reagents and mill balls. Sometimes part of working capital.
g. Minor buildings only; major buildings are normally separately estimated.
h. May be very small for junior company, and significant cost for major players.
i. Country and location dependent.
j. Dependent on form of contract, complexity of project and location.
k. Appropriate to the location and size of workforce.
l. Usually derived on individual line items of direct cost depending on degree of definition. Variable depending upon study phase.

# ESTIMATIVA DO CAPEX



- Britagem primária (base 2007, só equipamentos)
  - Estrutura complementar (Tcs, prédio, lubrificação, tubulação, elétrica):
    - +2,5 a 3,5x para britadores giratórios
    - + 2 a 2,5 para mandíbulas

TABLE 11.4
Primary crusher budget prices (c 2007).

| Crusher type | Cost (A$) |
|---|---|
| Jaw crushers | |
| C100 (750 × 1000 mm) | 300 000 |
| C125 (950 × 1250 mm) | 600 000 |
| C160 (1200 × 1600 mm) | 850 000 |
| Primary gyratory crushers | |
| 54 × 74 in | 3 900 000 |
| 60 × 89 in | 5 500 000 |

Ausimm, 2012

# ESTIMATIVA DO CAPEX



- Britagem secundária e diante (base 2007, só equipamentos)
  - Estrutura complementar (Tcs, peneira, prédio, lubrificação, tubulação, elétrica):
    - +2,0 a 3,5x para prédios sem silos
    - + 4x para prédios com silos

TABLE 11.5
Cone crusher budget prices (courtesy of Metso Minerals, c 2007).

| Crusher type | Cost (A$) |
| --- | --- |
| HP300 | $450 000 |
| HP500 | $950 000 |
| HP800 | $1 700 000 |
| MP800 | $2 500.000 |
| MP1000 | $3 500 000 |

Nac vs Imp.: No Brasil: R$ 15 mi

Ausimm, 2012

# ESTIMATIVA DO CAPEX



- Britagem secundária e diante (base 2007, só equipamentos)
  - Estrutura complementar (Tcs, peneira, prédio, lubrificação, tubulação, eletétrica):
    - +2,0 a 3,5x para prédios sem silos
    - + 4x para prédios com silos

TABLE 11.7
Vertical impact crusher budget price range (courtesy Sandvik AB).

| Main application | Crusher | Weight (kg) | Capacity[a] (t/h) |
|---|---|---|---|
| Tertiary and downstream<br>Price range A$150 000 - 400 000 | CV115 | 6 000 | 10 - 50 |
| | CV116 | 9 500 | 51 - 121 |
| | CV117 | 9 500 | 122 - 192 |
| | CV118 | 11 700 | 193 - 250 |
| | CV128 | 14 826 | 251 - 444 |
| | CV129 | 14 826 | 445 - 600 |

Ausimm, 2012

# ESTIMATIVA DO CAPEX



- Britagem secundária e diante (base 2007, só equipamentos)
  - Estrutura complementar (Tcs, peneira, prédio, lubrificação, tubulação, eletétrica):
    - +2,0 a 3,5x para prédios sem silos
    - + 4x para prédios com silos

TABLE 11.6
Budget price range of cone crushers (courtesy Sandvik AB).

| Main application | Crusher | Installed power (kW) | Weight (kg) | Capacity[a] (t/h) |
|---|---|---|---|---|
| Secondary crushers<br>Price range A$300 000 - 1 000 000 | CS420 | 90 | 7 070 | 70 - 168 |
| | CS430 | 150 | 12 700 | 91 - 344 |
| | CS440 | 220 | 19 790 | 195 - 601 |
| | CS660 | 315 | 35 490 | 318 - 1050 |
| Tertiary and downstream crushers with coarse chambers may also be used in secondary applications<br>Price range A$250 000 - 2 500 000 | CH420 | 90 | 5 570 | 27 - 128 |
| | CH430 | 150 | 9 470 | 48 - 208 |
| | CH440 | 220 | 14 820 | 90 - 395 |
| | CH660 | 315 | 24 020 | 162 - 662 |
| | CH870 | 500 | 58 000 | 280 - 1512 |
| | CH880 | 600 | 70 000 | 309 - 2128 |

a. Capacity is presented as nominal values. The crusher capacity will depend on chamber selection, throw and CSS. Presented values are the extreme selection of these parameters. Values are calculated using bulk density of 1.6 t/m³. Capacity will also depend on feed material properties like moisture and particle size distribution.

Ausimm, 2012

# ESTIMATIVA DO CAPEX



- Pilha:
  - AU$ 8 a 10 milhões por 100.000 t estocadas (volume total).

- Moagem (base 2010)
  - Barras: 1,5 a 2,5 milhões US$/MW (moinhos de 1 a 1,5 MW)
  - Bolas: 2,5 milhões US$/MW (menores que 1 MW) a 0,8 milhões US$/MW (maiores que 16 MW)
    - Custo total (prédio, lubrificação, resfriamento, bombas, ciclones, tubulação, elétrica): 2,2 a 3,5 o preço do equipamento (quanto maior o equipamento, menor o fator)

Ausimm, 2012

# ESTIMATIVA DO CAPEX



- Flotação:
  - Aerador / condicionador: +10%
  - Prédio, tubulação, elétrica: +50%

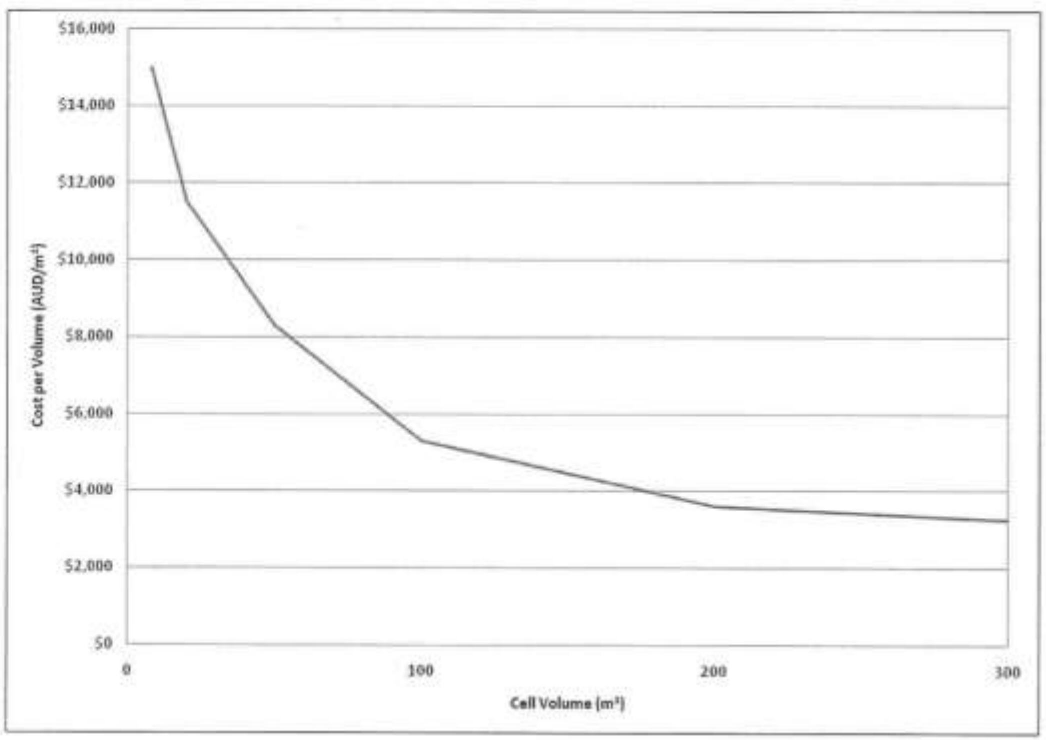



FIG 12.18 - Cost per volume for Outotec flotation cells.

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# ESTIMATIVA DO CAPEX



- Espessamento:

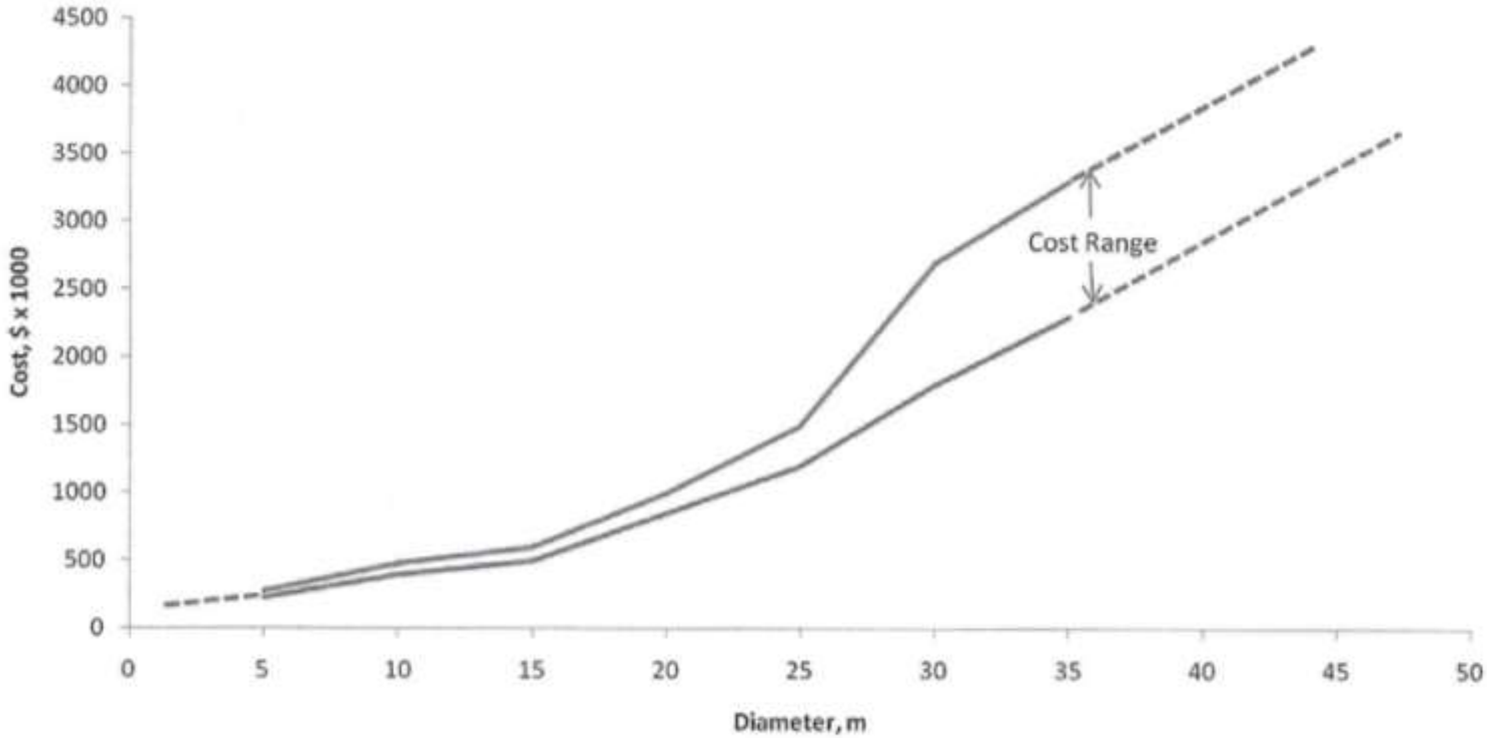



FIG 13.13 - Conventional and high-rate thickener capital cost.

Ausimm, 2012

# ESTIMATIVA DO CAPEX



- Filtro:
  - Tecidos / placas: +15%
  - Bomba / compressor: +20%

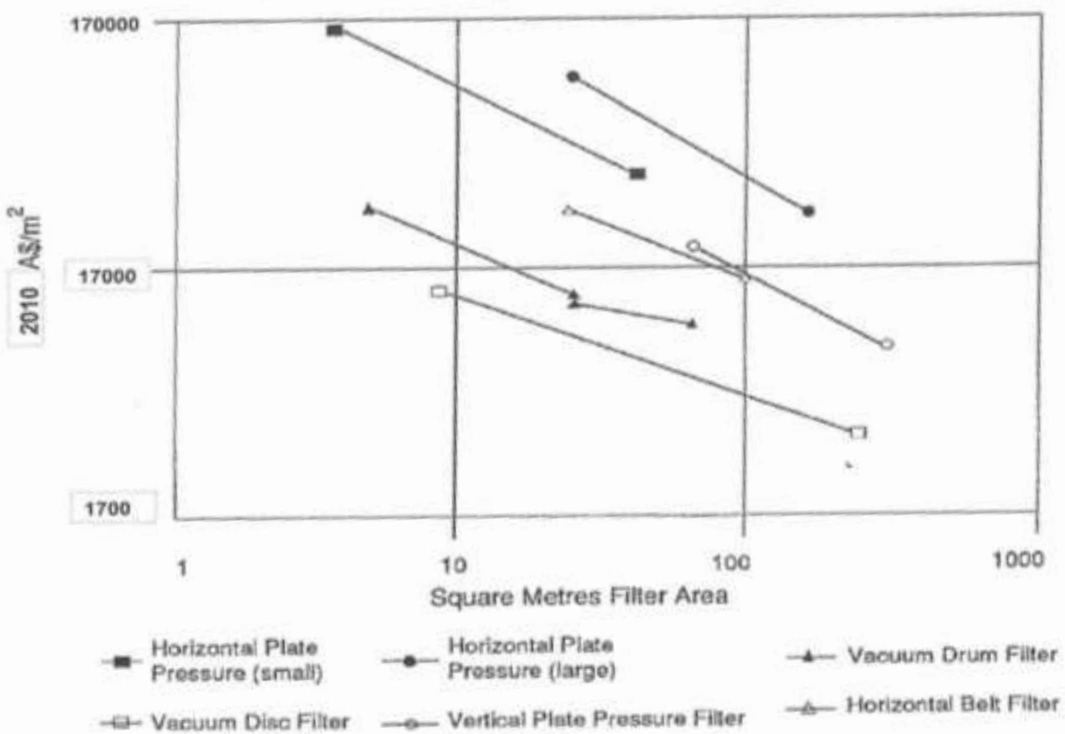



FIG 13.30 - Indicative capital costs of common filter types.

Ausimm, 2012

# ESTIMATIVA DO OPEX



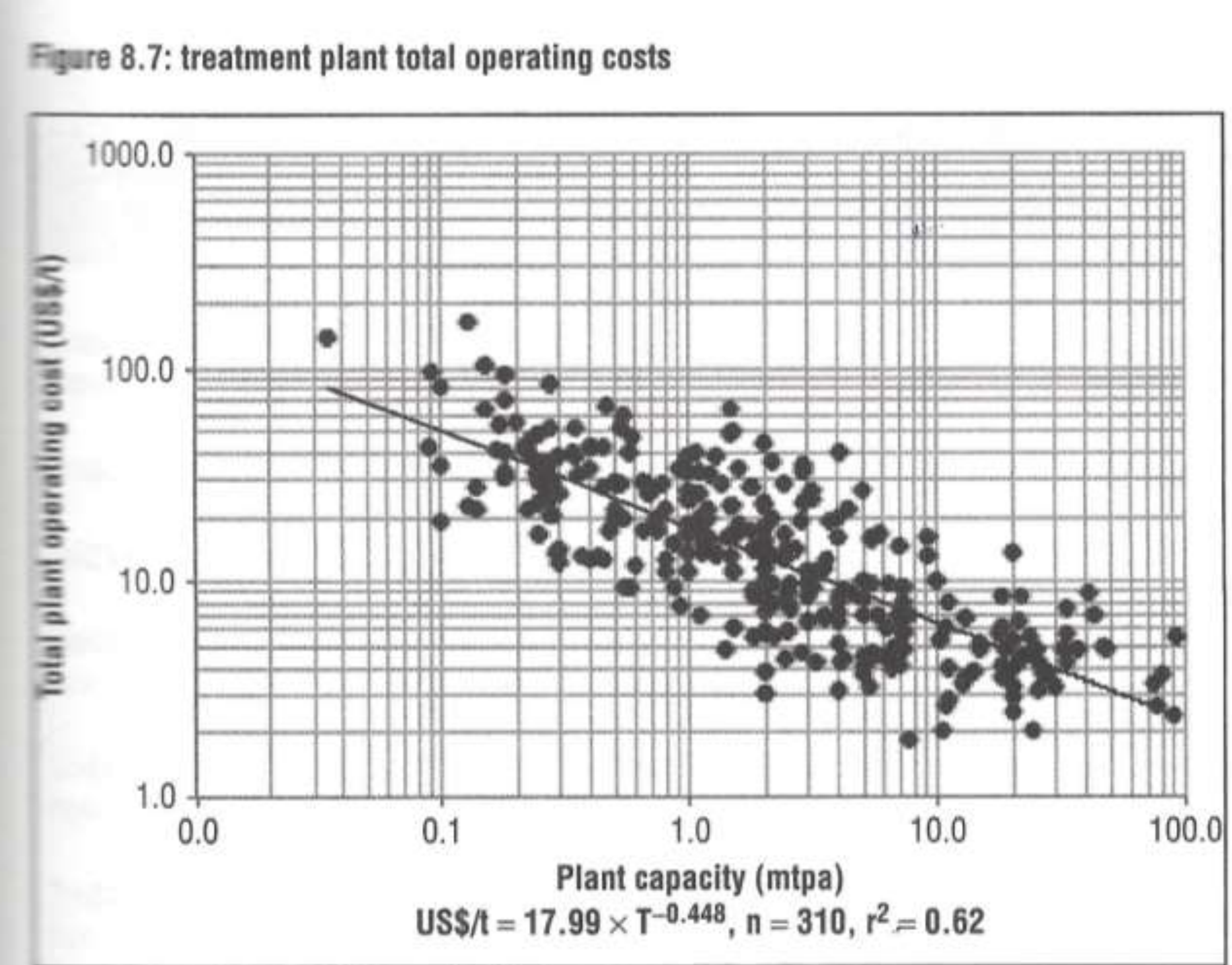
- Inclui:
  - Mão de obra
  - Consumíveis (reagentes, corpos moedores, revestimentos)
  - Manutenção
  - Itens de estoque
  - Custo de energia
  - Custo de água
  - Transporte
  - Outros: empresa/G&A, treinamento, ramp-up, seguros, financeiro

Ausimm, 2012

# ESTIMATIVA DO OPEX



- Regras de dedão (base 2011 US$):




Rudenno, 2012

# ESTIMATIVA DO OPEX



- Nosso projeto (segundo semestre):
  - Mão de obra – 15%
  - **Consumíveis (reagentes, corpos moedores) – 15%**
  - Manutenção/revestimentos – 35%
  - Itens de estoque
  - **Custo de energia – 35%**
  - **Custo de água - pesquisar**
  - Transporte
  - Outros: empresa/G&A, treinamento, ramp-up, seguros, financeiro

Ausimm, 2012

# ESTIMATIVA DO OPEX



- Nosso projeto (valores 2015 obtidos informalmente com os fornecedores):
  - Energia: R$ 300/MWh
  - Corpos moedores Maggoteaux
    - Bolas Alto Cromo: R$ 5.500,00 / ton
    - Bolas Baixo Cromo: R$ 4.700,00 / ton
  - Reagentes Flomin (CFR - no porto sem transporte e impostos)
    - amil xantato de potássio - 90% ativo com 100% de amil - Flomin C 3505 - USD 2.05 a 2.20/kg
    - ditiofosfato de sódio - Flomin C 5333 - USD 1.75/kg / Flomin C 2430 - USD 2.15/kg
    - PG - F 650 - USD 2.70 / Flomin F 742 (PG) - USD 3.50 / kg
    - MIBC - Flomin F 500 - USD 2.80/kg
    - Cal virgem – R$ 500/t
  - SNF Floculante - USD 3,00 a 4,00/kg
  - Filtro (Ausminn, 2011): AUS 2 a 3/t filtrada

  - Como adicional para os consumíveis teriam os impostos (9,25% PIS/COFINS + 4% ICMS + 5% IPI + Frete); O valor do frete vai depender muito dos volumes transportados (como média pode-se utilizar + USD 0,35/kg para quantidades acima de 5,0 tons).

# OUTROS PROJETOS DE COBRE NO BRASIL



- Dados aproximados (obtidos na internet):

| | Ano | ROM (t/ano) | Produção (Cu contido no concentrado) | Capex (milhões US$) | | Capex | | Opex (US$/t ROM) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Total | Usina | US$/t ROM | US$/t Cu | Total | Usina |
| Alemão | 2012 | 5.450.000 | 57.690 | 1.560 | | 286 | 27041 | | |
| Cristalino | 2009 | 16.000.000 | 95.200 | 1.527 | | 95 | 16040 | | |
| Salobo | 2009 | 12.000.000 | 102.600 | 1.699 | | 142 | 16559 | | |
| Avanco | 2015 | 800.000 | 12.000 | 60 | 25 | 75 | 5000 | | |
| Serrote | 2012 | 7.000.000 | 30.576 | 420 | 154 | 60 | 13736 | 13,04 | 4,87 |

# Fontes



- AUSIMM. Cost estimation handbook. Second edition. Monograph 27. The Australian Institute of Mining and Metallurgy. 2012.
- Rudeno, V. The mining valuation hadbook, 2012.