



V ACKNOWLEDGEMENTS

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SECTION 1: GENERAL INFORMATION

Introduction to Front End / Conceptual Estimating:
The General Forecast for 2020 and beyond
The Project Control Cycle / Issues and Factors
Cost breakdown of a Typical Chemical Process Facility
The CAPEX Estimating Process
Capital Cost Estimating the Four Basic Steps
Presenting the Estimate to Senior Management
Optimizing the Estimating effort
Cost Estimating / Engineering terms
Developing An Estimate Plan
Estimating Methods

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SECTION 2: COST-ESTIMATING CONCEPTUAL FRONT-END DATA

Blue Sky / O.O.M. Order of Magnitude Estimate / Factored / Ratio Estimates
/ Exponent Estimates / Square Foot.
Capacity / Exponent Estimates (6/10th rule) Method
(+/- 25% - 30% Accuracy)
Lang, Wroth, Guthrie, Chilton and Hand factors
50+ Typical Ratio Factored / Percentage Values / Historical Facility Cost Close
Out Reports
Cost-Capacity equations / exponents (180 +)

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|-----|---|
| 163 | <p>3</p> <p>SECTION 3: SQUARE FOOT / SQUARE METER COST DATA</p> <p>New Industrial / Commercial Sq. Ft. – M2 Building Costs (100 + facility examples)</p> <p>Major Revamp / Rehabilitation Issues</p> <p>Moderate Revamp / Rehabilitation Issues</p> <p>Minor Revamp / Superficial Facelift Issues</p> <p>25 floors - 200 apartments Major N.E. USA City</p> |
| 173 | <p>4</p> <p>SECTION 4: SEMI-DETAILED COST-ESTIMATING DATA</p> <p>General Conditions / Demolition work</p> <p>Site Construction work</p> <p>Civil, Foundations / U.G. Utility work</p> <p>Structural Steel Framing / Platforms</p> <p>External Wall Systems</p> <p>Roofing, Siding & Miscellaneous items</p> <p>Internal walls / Doors / Ceilings / Flooring / Glass</p> <p>Material Handling Equipment and Specialized Equipment</p> <p>Mechanical Equipment / Plumbing / HVAC & Fire protection</p> <p>Electrical / Instrumentation systems</p> <p>Clean room construction items</p> <p>Home Office Engineering, Procurement and Construction (EPC) Staff Rates</p> <p>Typical Engineering Production Hours</p> <p>Process Piping Systems</p> <p>Piping Material adjustments</p> <p>Major Equipment Insulation</p> <p>“All In” Unit Material Price Checklist</p> <p>Budget Pricing Stainless Steel Tubing / Piping</p> <p>Average Number of Fittings / Valves</p> <p>Major Equipment and Piping Insulation</p> <p>Instrumentation Costs</p> <p>Welding metrics</p> <p>Pipeline(s) Metrics</p> <p>Rail Road Cost Benchmarks</p> <p>Robotic systems</p> <p>In-direct Labor Open Shop Benchmarks and Assumptions</p> <p>Warehouse Miscellaneous Equipment</p> |

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|------------|---|
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| 437 | 6 SECTION 6: EPC HISTORICAL COST MODELS & BENCHMARKS General Production Benchmarks (80 +) Estimate Assessment Sheet / Ratio Analysis Major Equipment delivery times / USA Construction Productivity |
| 457 | ABOUT THE FIRM |

vendor assistance and off-sites, percentages / multipliers include contingency funds because the above stated values are based on numerous "historical" return cost data, where the contingency was expended / incorporated into the capital cost of the completed facility. Engineering, Procurement Activities and Construction Management costs are included in the indirect costs. EPC Office includes engineering and design, procurement, project management / control and required administration. Owner C.M. is not

included in the EPC office percentage.

Note: the factors for piping, electrical and instrumentation work indicated in (2) and (3) above could be reduced by 20 – 40% (use 30%) if work is fabricated as modules / pre-assemblies / skid, structural steel values should be increased by 10 – 20 % if work is completed as modules / pre-assemblies / skid (use 15%).

Table 3
AVERAGE HISTORICAL (MULTIPLIER) FACTORS – SOLIDS PLANTS

| REF | DIRECT CONSTRUCTION COSTS | TYPICAL % OF M.E. | % BULK MATERIALS | % LABOR - S/C | TOTAL | REMARKS |
|-------------------------------|--|-------------------|------------------|---------------|-------------|-----------------------------------|
| 1 | Major Equipment (M.E.) | 0 | 1.00* | 0.00 | 1.00 | Assume \$1.00 million |
| 2 | Freight (used 4%) | 2.5 - 5 | 0.02 | 0.02 | 0.04 | 50/50 split |
| 3 | Overseas Freight | 5 - 8 | N/A | N/A | | N/A for this example |
| 4 | M.E. Setting (Millwright work) | 1 - 7 | 0.01 | 0.05 | 0.06 | Heavy lift cranes in line 15 |
| 5 | Site work / civil (excavation / roads) | 3 - 10 | 0.03 | 0.04 | 0.07 | Site clearance / minor demolition |
| 6 | Concrete work | 10 - 50 | 0.04 | 0.12 | 0.16 | SOG & elevated |
| 7 | Structural steel | 20 - 50 | 0.13 | 0.15 | 0.28 | Including platforms |
| 8 | Facilities / Buildings (including services) | 3 - 20 | 0.03 | 0.02 | 0.05 | |
| 9 | Piping** (includes hangars & testing) | 25 - 100 | 0.25 | 0.40 | 0.65 | ISBL only |
| 10 | Electrical | 15 - 45 | 0.09 | 0.13 | 0.22 | Including tracing |
| 11 | Instrumentation / Controls | 15 - 60 | 0.13 | 0.12 | 0.25 | |
| 12 | Insulation | 3 - 25 | 0.02 | 0.03 | 0.05 | |
| 13 | Painting | 2 - 10 | 0.01 | 0.01 | 0.02 | |
| 14 | Safety / F P / Misc. (A) | 4 - 12 | 0.02 | 0.03 | 0.05 | |
| | TOTAL DIRECT COST | | 1.78 | 1.12 | 2.90 | |
| INDIRECT PROJECT COSTS | | | | | | |
| 15 | Field Establishment Costs *** | | | | 0.25 | 22% of labor / S.C. costs |
| 16 | EPC Office H.O. range 20% - 30% | | | | 0.67 | 23% of total direct costs |
| 17 | Construction Management range 20% -.45% of line 16 | | | | 0.17 | 25% of EPC H.O |
| 18 | Owner Engineering & CM 5% – 15% of line 16 & 17 | | | | 0.08 | 10% of line 16 & 17 |
| 19 | TOTAL INDIRECT COSTS | | | | 1.17 | |
| 20 | TOTAL COST MULTIPLIER | | | | 4.07 | |

(A) = Start up costs, initial chemicals, expense items and other minor items.

* 1.00 = Total value of Major Equipment / Assume 25 items (M.E.)

** 25% - 100% is based on using a 60 - 40 split of Carbon Steel and 304-316 SS. This value could in some situations exceed 100% in circumstances where exotic / expensive piping materials are utilized, i.e. Glass / Kynar / Teflon lined / Alloy 20 / Nickel, etc., or high percentage of 304 - 316 SS etc. is used due to hazardous / highly corrosive chemical applications.

*** Field establishment includes, construction equipment, field offices, field in directs, G.C.'s & S/C trailers, temporary warehouses, Division 1 (Preliminaries) etc. If the proposed project is a hybrid of a liquids and solids plant, use an average of both plants / facilities.

Table 30
CEMENT MANUFACTURING FACILITY
BASIS OF COST - 2015 COST DATA FROM 7 # COMPLETED &
OPERATING FACILITIES IN USA AND MEXICO

| CAPEX / OPEX CATEGORY | 250,000 TON OF PRODUCTION PER YEAR CAPEX COST | 500,000 TON OF PRODUCTION PER YEAR CAPEX COST | 750,000 TON OF PRODUCTION PER YEAR CAPEX COST |
|--|---|---|---|
| Cement Production Equipment | 40% to 50% | 40% to 50% | 40% to 50% |
| Construction Bulk Materials | 15% to 25% | 15% to 25% | 15% to 25% |
| Construction Labor & Indirects | 15%-20% | 15% to 20% | 15% to 20% |
| Detailed Design & Procurement of Capial Equipment & Bulks | 7% to 11% | 7% to 11% | 7% to 11% |
| Construction Management | 3.5% to 5% | 3.5% to 5% | 3.5% to 5% |
| Total CAPEX Value Average | \$83,776,000 | \$161,660,000 | \$233,550,000 |
| Total CAPEX Value Range Low | \$67,020,800 | \$129,328,000 | \$186,840,000 |
| Total CAPEX Value Range High | \$100,531,200 | \$193,992,000 | \$280,260,000 |
| Cost per Ton (Average) | \$335,104 | \$323,320 | \$311,400 |
| OPEX costs per year, facility operating personel, fuel, property taxes, electricity, water, maintenance and spares | \$10 Million - \$25 million (average \$15 million per year) | \$15 Million - \$30 million (average \$20 million per year) | \$20 Million - \$35 million (average \$25 million per year) |
| For facilities with extensive pollution / air quality requirements such as ESP, Baghouses, SDA & NOX systems | Increase Total CAPEX values by 20% to 45% | Increase Total CAPEX values by 20% to 45% | Increase Total CAPEX values by 20% to 45% |

Table 49

USA ETHYLENE PRODUCTION FACILITY: AVERAGE OF UNION / NON-UNION CONSTRUCTION: COST BASIS 2019

| PRODUCTION CAPACITY (TONS PER ANNUM TPA) | NUMBER OF MAJOR EQUIPMENT ITEMS (M.E.) | NUMBER OF TAGGED INSTRUMENTATION EQUIPMENT ITEMS (M.E.) | TOTAL EPC AVERAGE COST PER TON ISBL | TOTAL EPC AVERAGE COST PER TON OSBL | TOTAL EPC AVERAGE COST PER TON ISBL & OSBL | ACCURACY OF DATA |
|--|--|---|-------------------------------------|-------------------------------------|--|------------------|
| 500,000 | 145 | 1,760 | \$3,425 | \$381 | \$3,806 | +/- 15% |
| 750,000 | 215 | 2,645 | \$3,360 | \$415 | \$3,775 | +/- 15% |
| 1,000,000 | 323 | 3,510 | \$3,297 | \$450 | \$3,747 | +/- 15% |
| 1,250,000 | 345 | 4,388 | \$3,172 | \$516 | \$3,688 | +/- 15% |
| 1,500,000 | 427 | 5,260 | \$3,090 | \$545 | \$3,635 | +/- 15% |

NOTES:

- Typical Cost of Major Equipment Item = \$1,575,000 to \$1,675,000
- Typical Cost of Tagged Instrument Item = \$8,700 to \$9,250
- Costs exclude Feed Studies, Land Purchase, Owner Engineering & Construction Management.
- Furnaces Represent 53% of M.E. Engineering & Fees = 14.2% of EPC cost
- Typical Owner Costs (10 to 20 professionals) Project Manager, Deputy Project Manager, Mechanical, Chemical, Electrical and Civil Engineers, Purchasing, QA QC, Estimators, Planners, Construction Manager, Inspectors, Document Control, Secretary- 10 to 20 people x 24 months:

Typical Open Shop (Non Union) Skilled Worker (PIPEFITTER, ELECTRICIAN ETC. ALL-IN HOURLY RATE BILL OUT RATE):

| DESCRIPTION | % OF BASE RATE | \$ COST |
|--|----------------|---------|
| BASE SKILLED JOURNEYMAN RATE (2Q – 2019) | | \$29.25 |
| PAYROLL TAXES & INSURANCES | | |
| WORKERS COMPENSATION INSURANCE | 17.3 | \$5.06 |
| GENERAL LIABILITY INSURANCE | 4.2 | \$1.23 |
| FICA | 14.3 | \$4.18 |
| FUI / SUI | 4.3 | \$1.26 |
| BUILDERS ALL RISK INSURANCE | 7.6 | \$2.22 |
| FRINGE BENEFITS | 21.2 | \$6.20 |
| PREMIUM TIME | 7.7 | \$2.25 |
| FIELD OFFICE / TEMP FACILITIES | 8.3 | \$2.43 |
| FIELD OFFICE SUPPLIES / COMPUTERS / COPY MACHINES / COMMUNICATIONS | 4.3 | \$1.26 |
| SAFETY ITEMS / FIREWATCH | 8.6 | \$2.52 |
| SMALL TOOLS / CONSUMABLES | 10.9 | \$3.19 |
| FIELD STAFF / PROCUREMENT / MATERIAL LOGISTICS | 22.8 | \$6.67 |
| SCAFFOLDING | 6.7 | \$1.96 |
| EQUIPMENT RENTAL (excludes Heavy Lift Cranes) | 18.5 | \$5.41 |
| HOME OFFICE SUPPORT / COORDINATION | 8.6 | \$2.52 |
| PER DIEM | 5.3 | \$1.55 |
| PROFIT / CONTRACTOR FEE | 15.5 | \$4.53 |
| OTHER / MISCL ITEMS | 9.5 | \$2.78 |
| TOTAL ALL-IN FIELD WAGE RATE | 195.6 | \$86.46 |

Table 53
500 MW HYDRO POWER PLANT USA N.E. USA (2020 COST BASIS)

| | DESCRIPTION | \$ MILLIONS | % OF TOTAL COST |
|----|---|----------------------|-----------------|
| 1 | General Conditions / Preliminaries / Site Establishment | 91,814,580 | 3.76% |
| 2 | Site Work | 307,966,230 | 12.63% |
| 3 | Civil workk | 364,343,760 | 14.94% |
| 4 | Rip Wrap | 55,845,900 | 2.29% |
| 5 | Concrete Walls / Dam | 373,162,680 | 15.30% |
| 6 | O & M Building & Controls - Monitoring | 24,750,535 | 1.01% |
| 7 | Intake Structure | 23,760,535 | 0.97% |
| 8 | Shafts / Tunnels / Penstock | 110,887,603 | 4.55% |
| 9 | Mechanical Equipment / Turbines / Generators | 416,790,000 | 17.09% |
| 10 | Electrical Systems / Switch Yard / Sub Stations | 76,230,000 | 3.13% |
| 11 | Site In-Directs (Supervision, Construction Equipment, Scaffolding, Testing) | 199,980,000 | 8.20% |
| 12 | S/T CONSTRUCTION COST | 2,045,531,822 | |
| 13 | Engineering / Detailed Design / Procurement | 193,965,000 | 7.95% |
| 14 | Project & Construction Management | 11,055,000 | 0.45% |
| 15 | Fees / O-H & P | 181,905,000 | 7.46% |
| 16 | Owner Engineering & Construction Oversight | 6,633,000 | 0.27% |
| 17 | S/T ENGINEERING / PM & CM + FEES + OWNER COSTS | 393,558,000 | |
| 18 | TOTAL COST | 2,439,089,822 | 100.00% |
| 19 | COST PER MW | 4,878,180 | |
| 20 | LOWER COST RANGE PER MW -15% | 4,146,453 | |
| 21 | HIGH COST RANGE PER MW +15% | 5,609,907 | |
| | Exclude land purchase | | |

Table 54
POWER PLANT COST METRICS USA (2020 COST BASIS)

| # | POWER PLANT TYPE | TYPICAL SIZE IN MW | \$ COST PER MW MINIMUM | \$ COST PER MW MAXIMUM | \$ OPEX PER MW ANNUAL FIXED & VARIABLE COSTS MINIMUM | \$ OPEX PER MW ANNUAL FIXED & VARIABLE COSTS MAXIMUM |
|----|----------------------|--------------------|------------------------|------------------------|--|--|
| 1 | Coal | 150 - 250 | 2,330,000 | 2,950,000 | 25,000 | 50,000 |
| 2 | Coal | 250 - 500 | 2,230,000 | 2,770,000 | 25,000 | 50,000 |
| 3 | Gas - Combined Cycle | 150 - 250 | 970,000 | 1,385,000 | 10,000 | 15,000 |
| 4 | Gas - Combined Cycle | 250 - 500 | 900,000 | 1,245,000 | 10,000 | 15,000 |
| 5 | Gas - Simple Cycle | 150 - 250 | 885,000 | 1,175,000 | 10,000 | 15,000 |
| 6 | Gas - Simple Cycle | 250 - 500 | 850,000 | 1,130,000 | 10,000 | 15,000 |
| 7 | Fuel Cell | 150 - 250 | 2,570,000 | 6,220,000 | 20,000 | 40,000 |
| 8 | Fuel Cell | 250 - 500 | 2,530,000 | 6,140,000 | 20,000 | 40,000 |
| 9 | Wind Power Onshore | 50 - 75 | 2,600,000 | 2,850,000 | 1,000 | 2,500 |
| 10 | Wind Power Onshore | 75 - 150 | 2,450,000 | 3,330,000 | 1,000 | 2,500 |
| 11 | Wind Power Offshore | 50 - 75 | 3,150,000 | 3,450,000 | 2,500 | 5,000 |
| 12 | Wind Power Offshore | 75 - 150 | 3,000,000 | 3,250,000 | 2,500 | 5,000 |
| 13 | Solar PV | 25 - 50 | 2,750,000 | 4,800,000 | 1,000 | 2,500 |
| 14 | Solar PV | 50 - 100 | 2,,600,000 | 4,550,000 | 1,000 | 2,500 |

| DIAMETER | \$ MATERIAL COST PER LF | \$ M-H COST PER LF | \$ COST PER LF | \$ MATERIAL COST PER M | \$ M-H COST PER M | \$ COST PER M |
|---|-------------------------|--------------------|----------------|------------------------|-------------------|---------------|
| FRP - Furan Complicated / Intricate (ISBL - Inside Facility) Piping - Numerous changes in direction (CONTINUED) | | | | | | |
| 4" / 100 mm | 169.32 | 95.04 | 264.37 | 555.38 | 311.74 | 867.12 |
| 6" / 150 mm | 173.89 | 172.81 | 346.70 | 570.36 | 566.81 | 1,137.17 |
| 8" / 200 mm | 205.93 | 214.45 | 420.38 | 675.46 | 703.39 | 1,378.85 |
| 10" / 250 mm | 276.10 | 253.72 | 529.82 | 905.61 | 832.20 | 1,737.81 |
| 12" / 300 mm | 341.69 | 301.63 | 643.32 | 1,120.74 | 989.34 | 2,110.08 |
| Add 4.5% - 7.5% to labor & material costs for hangars, bolts, gaskets & testing | | | | | | |
| FRP - Furan Straight run / OSBL Piping | | | | | | |
| 2" / 50 mm | 53.40 | 19.64 | 73.03 | 175.14 | 64.40 | 239.54 |
| 3" / 75 mm | 67.20 | 27.27 | 94.47 | 220.40 | 89.45 | 309.85 |
| 4" / 100 mm | 80.62 | 35.06 | 115.68 | 264.44 | 114.98 | 379.42 |
| 6" / 150 mm | 103.02 | 58.42 | 161.44 | 337.90 | 191.62 | 529.52 |
| 8" / 200 mm | 155.27 | 85.69 | 240.96 | 509.28 | 281.07 | 790.34 |
| 10" / 250 mm | 200.06 | 105.17 | 305.22 | 656.18 | 344.94 | 1,001.13 |
| 12" / 300 mm | 250.82 | 128.54 | 379.37 | 822.70 | 421.62 | 1,244.32 |
| Add 4.5% - 7.5% to labor & material costs for hangars, bolts, gaskets & testing | | | | | | |
| FRP - Epoxy - Double Walled Pipe Complicated / Intricate (ISBL - Inside Facility) Piping - Numerous changes in direction | | | | | | |
| 1" dia. inside a 3" dia. | 175.77 | 101.68 | 277.46 | 576.54 | 333.52 | 910.06 |
| 2" dia. inside a 4" dia. | 254.42 | 175.98 | 430.40 | 834.49 | 577.22 | 1,411.72 |
| 3" dia. inside a 6" dia. | 279.09 | 293.31 | 572.40 | 915.41 | 962.05 | 1,877.46 |
| 4" dia. inside a 8" dia. | 337.68 | 379.36 | 717.04 | 1,107.59 | 1,244.29 | 2,351.89 |
| 6" dia. inside a 10" dia. | 420.94 | 524.05 | 945.00 | 1,380.69 | 1,718.89 | 3,099.59 |
| Add 4.5% - 7.5% to labor & material costs for hangars, bolts, gaskets & testing | | | | | | |
| FRP - Epoxy - Double Walled Pipe Straight run / OSBL Piping | | | | | | |
| 1" dia. inside a 3" dia. | 66.29 | 43.02 | 109.31 | 217.42 | 141.12 | 358.54 |
| 2" dia. inside a 4" dia. | 90.95 | 50.84 | 141.79 | 298.30 | 166.76 | 465.06 |
| 3" dia. inside a 6" dia. | 115.61 | 89.95 | 205.55 | 379.19 | 295.02 | 674.21 |
| 4" dia. inside a 8" dia. | 143.35 | 129.53 | 272.87 | 470.17 | 424.86 | 895.03 |
| 6" dia. inside a 10" dia. | 234.27 | 183.81 | 418.08 | 768.40 | 602.90 | 1,371.30 |
| Add 4.5% - 7.5% to labor & material costs for hangars, bolts, gaskets & testing | | | | | | |

CONCRETE GENERAL ESTIMATING DATA

| TYPE | PER SF | PER M2 |
|----------------------------|-----------------|------------------|
| Bush hammer concrete | \$0.65 - \$1.30 | \$7.00 - \$14.00 |
| Acid wash concrete | \$0.23 - \$0.40 | \$2.47 - \$4.30 |
| Pattern concrete slabs | \$0.50 - \$0.84 | \$5.38 - \$9.04 |
| Colorize concrete slab | \$0.63 - \$1.05 | \$6.80 - \$11.30 |
| Bag / Dress concrete walls | \$0.30 - \$0.75 | \$3.23 - \$8.07 |

Estimating Thoughts for Structural Steel and Miscellaneous Steel

Obtain and review any available engineering deliverables / drawings or sketches. Take off lengths of steel section and multiply by appropriate weight in pounds per LF, determine pounds / tons of steel that is depicted on the drawings. Structural steel is usually fabricated in a vendors shop, and delivered to the site for eventual erection. Structural steel has a number of differing specifications / materials of construction, that have differing cost consequences the most widely used is A36.

Issues that may perhaps impact the erection activity of new structural steel are:

- Lifting equipment / cranes / hoists
- Mobilization / de-mobilization of crane (crane are typically rented by the day or week)
- Crane reach
- Lifting capacity

- Number of floors
- Bolted connections
- Welded connections
- Painting / touch up painting

Platforms, ladders, handrails, stair risers and other miscellaneous: perform take off and establish pounds / tons of material and assign appropriate installation man-hours. Checker plate, grating and floor plate and metal decking: perform take off and establish square feet of material and assign appropriate installation man-hours, allow at least 5% for waste in the cutting / fit up activity.

Order of Magnitude Structural Steel Estimating Data

Structural Steel weights per SF:

- Manufacturing Building = 10 - 15 lb / S.F.
- 5 Floor Office Building = 15 - 25 lb / S.F.
- Heavy industrial Facility = 25 - 75 lb / S.F.
- Process Structures: Preliminary weights of structures can vary from 1.5 lb to 3.5 lb (Cubic Foot of enclosed area).

Structural Steel as percentage of major equipment cost: usually falls in the 5% to 8% of major equipment cost. The following pie chart delineates the various cost / fabrication and installation activities associated with structural steel.

PERCENTAGE BREAKDOWN OF STRUCTURAL STEEL BASED ON 500-TON, 3-STORY BUILDING:

