

Class 18

Estimating Total Capital Investment (C_{TCI})

Estimating Total Capital Investment (TCI)

Table 16.9 Components of Total Capital Investment (TCI)

Total bare-module costs for fabricated equipment	C_{FE}			
Total bare-module costs for process machinery	C_{PM}			
Total bare-module costs for spares	C_{spare}			
Total bare-module costs for storage and surge tanks	$C_{storage}$			
Total cost for initial catalyst charges	$C_{catalyst}$			
Total bare-module investment, TBM		C_{TBM}		
Cost of site preparation		C_{site}		
Cost of service facilities		C_{serv}		
Allocated costs for utility plants and related facilities		C_{alloc}		
Total of direct permanent investment, DPI			C_{DPI}	
Cost of contingencies and contractor's fee			C_{cont}	
Total depreciable capital, TDC				C_{TDC}
Cost of land				C_{land}
Cost of royalties				C_{royal}
Cost of plant startup				$C_{startup}$
Total permanent investment, TPI (= C_{FCI})				C_{TPI}
Working capital				C_{WC}
Total capital investment, TCI				C_{TCI}

Total Capital Investment

C_{TCI} (Chemical Plant) is a one-time expense for the design, construction, and start-up of a new plant or revamp of an existing plant

Analogous to the purchase price of a new house

-land, building permit fees, excavation of land, improvements of land to provide utilities & access, preparation of architectural & construction drawings, construction of the house, landscaping, and contractor's fee

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Bare Module Costs

Bare Module Cost

Modules: pumps, heat exchangers, compressors, vessels, distillation columns, reactors, etc.

Modules include a piece of process equipment or machinery that is installed and connected to other modules

- Direct Costs**
- Indirect Costs**

Direct Bare Module Costs

C_P or C_{PE} - purchase price of equipment

- piping to and from other modules

- concrete (or other) foundation

- ladders/other steel supporting structure

C_M - instrumentation/controllers

- lighting

- electrical wiring

- insulation

- paint

C_L - direct labor to install

Indirect Bare Module Costs, C_{IE}

C_{FIT} - freight, insurance, taxes

C_O - construction overhead (fringe benefits of workers, burden – i.e. SS tax & unemployment insurance – and salaries, fringe benefits, & burden for mgmt; temporary buildings, roads, parking areas, rented machinery, job site cleanup, security costs, etc.)

C_E - contractor engineering expenses (salaries for process/project engineers, etc.)

$$C_{BM} = F_{BM} (C_{PE})$$

Bare module cost Bare module factor Purchased equipment cost

The diagram shows the equation $C_{BM} = F_{BM} (C_{PE})$. Three arrows point from labels below to the variables in the equation: 'Bare module cost' points to C_{BM} , 'Bare module factor' points to F_{BM} , and 'Purchased equipment cost' points to C_{PE} .

Table 16.10 Example of Installation Costs for a Heat Exchanger to Give the Bare-Module and Total-Module Costs

	Cost (\$)	Total Costs (\$)	Fraction of f.o.b. Purchase Cost (C_p)
Direct module expenses			
Equipment purchase price, f.o.b., C_p		10,000	1.00 C_p
Field materials used for installation			
Piping	4,560		
Concrete	510		
Steel	310		
Instruments and controllers	1,020		
Electrical	200		
Insulation	490		
Paint	50		
Total of direct field materials, C_M		7,140	$C_M = 0.714 C_p$
Direct field labor for installation			
Material erection	5,540		
Equipment setting	760		
Total of direct field labor, C_L		6,300	$C_L = 0.63 C_p$
Indirect module expenses			
Freight, insurance, taxes, C_{FIT}	800		$C_{FIT} = 0.08 C_p$
Construction overhead, C_O	5,710		$C_O = 0.571 C_p$
Contractor engineering expenses, C_E	2,960		$C_E = 0.296 C_p$
Total indirect expenses, C_{IE}		9,470	$C_{IE} = 0.947 C_p$
Bare-module cost, C_{BM}		32,910	$C_{BM} = 3.291 C_p$
			$F_{BM} = 3.291$

Note: $C_M / (C_M + C_L) = 0.53$

Table 16.11 Bare-Module Factors of Guthrie (1974) for Ordinary Materials of Construction and Low-to-Moderate Pressures

	Bare-module Factor (F_{BM})
Furnaces and direct-fired heaters, Shop-fabricated	2.19
Furnaces and direct fired heaters, Field-fabricated	1.86
Shell-and-tube heat exchangers	3.17
Double-pipe heat exchangers	1.80
Fin-tube air coolers	2.17
Vertical pressure vessels	4.16
Horizontal pressure vessels	3.05
Pumps and drivers	3.30
Gas compressors and drivers	2.15
Centrifuges	2.03
Horizontal conveyors	1.61
Bucket conveyors	1.74
Crushers	1.39
Mills	2.30
Crystallizers	2.06
Dryers	2.06
Evaporators	2.45
Filters	2.32
Flakers	2.05
Screens	1.73

**Distillation, absorption,
Stripping, flash drums**

C_{FE}, fabricated equipment

**Heat exchanger, Vessel,
Distillation column, etc.**

C_{PM}, process machinery

**Pump, Compressor
Centrifuge, etc.**

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Cost of site preparation		C_{site}	← Site Preparation
Cost of service facilities		C_{serv}	
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Cost of land			C_{land}
Cost of royalties			C_{royal}
Cost of plant startup			$C_{startup}$
Total permanent investment, TPI	$(= C_{FCI})$		C_{TPI}
Working capital			C_{WC}
Total capital investment, TCI			C_{TCI}

Site Preparation and Development

Land surveys, dewatering and drainage, surface clearing, rock blasting, excavation, grading, piling; and addition of fencing, roads, sidewalks, railroad sidings, sewer lines, fire protection facilities, and landscaping

C_{site} , grass roots plant ~ 10-20% of C_{TBM}

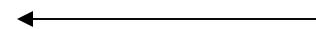
C_{site} , addition ~ 4-6% of C_{TBM}

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Other Facilities



Service Facilities (on-site), C_{serv}

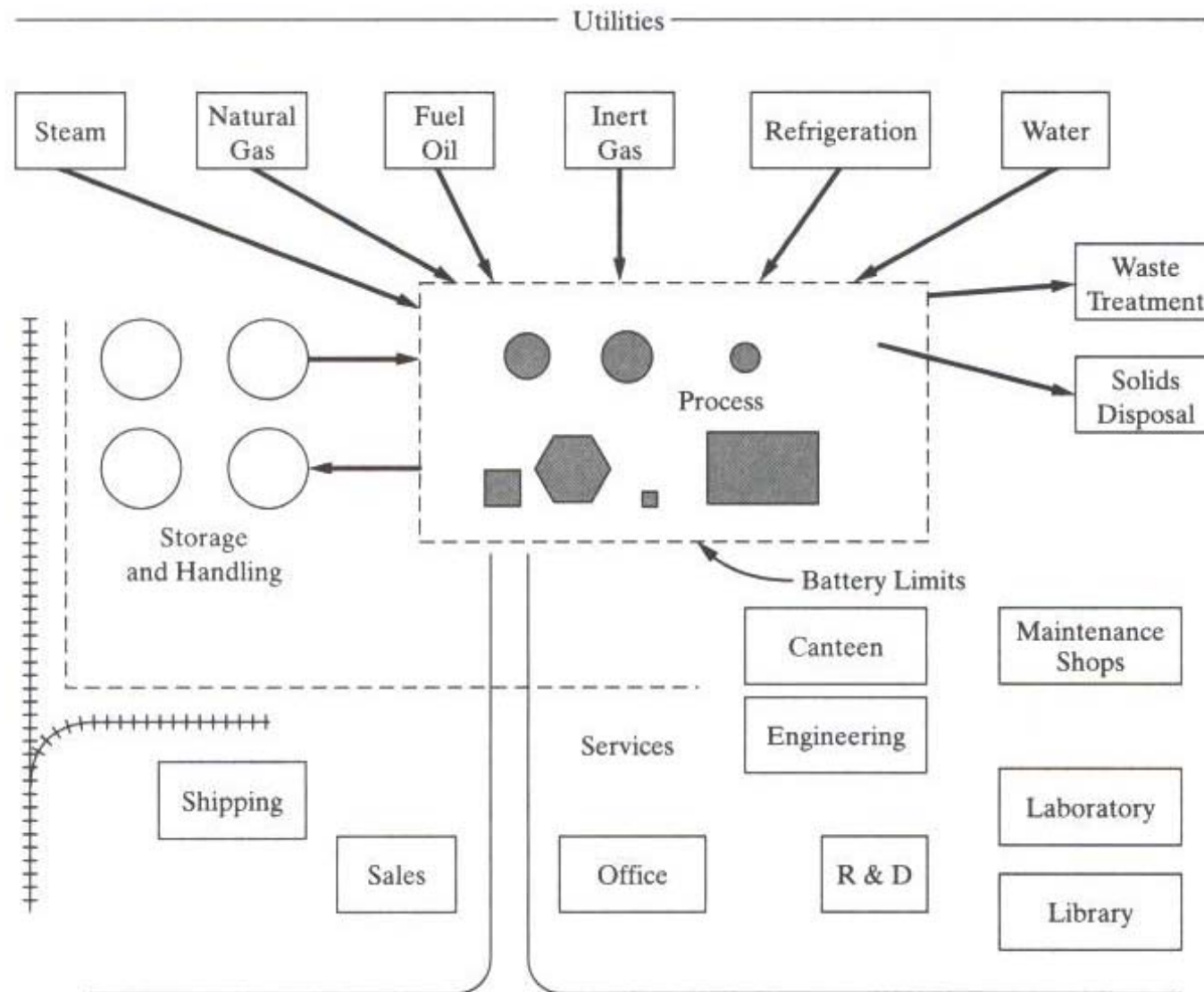


Figure 16.2 Plant services outside of process battery limits (courtesy of C.A. Miller).

Allocated Costs (off-site) Facilities, C_{alloc}

Table 16.12 Allocated Capital Investment Costs for Utility Plants and Related Facilities

	Capital Cost Rate
Steam	\$50/(lb/hr)
Electricity	\$203/kW
Cooling water	\$58/gpm
Process water	\$347/gpm
Refrigeration	\$1,330/ton
Liquid waste disposal	\$3/1,000 gpy

gpy = gallons per year

Note: 1995

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Direct Permanent Investment

C_{DPI}
 C_{cont}

C_{TDC}
 C_{land}
 C_{royal}
 $C_{startup}$

C_{TPI}
 C_{WC}

C_{TCI}

Direct Permanent Investment, C_{DPI}

$$C_{DPI} = C_{TBM} + C_{site} + C_{serv} \text{ (on-site)} + C_{alloc} \text{ (off-site)}$$

Estimating C_{DPI} via factoring C_{TBM}

$$C_{DPI} = (1 + F_1 + F_2) C_{TBM}$$

	<u>F_1</u>
Outdoor Construction:	0.15
Mixed Indoor/Outdoor Construction:	0.40
Indoor Construction:	0.80
	<u>F_2</u>
Minor Additions to Existing Facilities:	0.10
Major Additions to Existing Facilities:	0.30
Grass-roots Plant:	0.80

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Contingency & Contractor Fees

C_{DPI}
 C_{cont} ←

C_{TDC}
 C_{land}
 C_{royal}
 $C_{startup}$

C_{TPI}
 C_{WC}

C_{TCI}

Contingency and Contractor's Fee, C_{cont}

Lower contingency for Known (familiar) process

Higher contingency for new (research driven) process

Estimates

Contingency: unanticipated costs (~15% of C_{DPI} , useful estimate)

Contractor's Fee: (~ 3% of C_{DPI} , useful estimate)

Note: contingency for most designs by student teams ~ 35%

Total Depreciable Capital, C_{TDC}

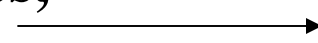
$$C_{TDC} = C_{DPI} + C_{cont}$$

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**Land, royalties,
& startup**



Land, Royalties, and Startup Costs

Land, C_{land} , is non-depreciable since it rarely decreases in value (estimate ~ 2% of Total Depreciable Capital, C_{TDC})

Royalties, C_{royal} : usually has two components – (1) an up front fee that may be included in the capital investment (estimate as 2% of C_{TDC}) and (2) a percentage of product sales (estimate as 3%). Note: if no patents are being licensed, there is no royalty

Startup Costs, C_{startup} : costs associated with commissioning the plant - checking equipment performance, calibration of instruments, etc.)

~ 2% of C_{TDC} for well known process

~ 10% of C_{TDC} for typical estimate

~ 30% of C_{TDC} for radically new equipment

Total Permanent Investment, C_{TPI} ,
or
Fixed Capital Investment, C_{FCI}

$$C_{TPI} = C_{FCI} = C_{TDC} + C_{land} + C_{royal} + C_{startup}$$

Investment Site Factor, F_{ISF}

Multiple of C_{TPI} to account for costs in different localities,
Based on the availability of labor, workforce efficiency, local
Rules and customs, union status, etc.

$$C_{TPI} \text{ (corrected)} = F_{ISF} C_{TPI}$$

Table 16.13 Typical
Investment Site Factors, F_{ISF}

U.S. Gulf Coast	1.00
U.S. Southwest	0.95
U.S. Northeast	1.10
U.S. Midwest	1.15
U.S. West Coast	1.25
Western Europe	1.20
Mexico	0.95
Japan	1.15
Pacific Rim	1.00
India	0.85

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Cost of plant startup				$C_{startup}$
Total permanent investment, TPI(= C_{FCI})				C_{TPI}
Working capital				C_{WC}
Total capital investment, TCI				C_{TCI}

Working Capital →

Working Capital, C_{WC}

Needed to cover operating costs required for the early operation of the plant, including the cost of inventory (product made, but not sold, raw materials, intermediate products, spare catalyst charge, spare parts, wages/benefits for employees for 1 or 2 months)

Estimate: ~ 15% of C_{TCI}

$$**C_{TCI} = C_{TPI} \text{ (or } C_{FCI}) + C_{WC}**$$

Example – Ammonia Plant

Table 16.14 Capital Cost Estimate of Bare-Module Equipment Cost for an Ammonia Plant—Costs in Millions of U.S. Dollars (Year 2000)

	C_P	F_{BM}	C_{BM}
Fabricated equipment			
Heat exchangers	5.25	3.3	17.33
Flash drum	0.01	4.3	0.04
Distillation column	0.07	4.3	0.30
Adsorbers	0.18	4.3	0.77
Absorber	0.20	4.3	0.86
Membrane separators	3.56	3.2	11.39
Reactor	0.34	4.3	1.46
Process machinery			
Gas compressors	21.84	3.5	76.44
Pumps	0.07	3.4	0.24
Total bare-module cost for on-site equipment			108.83

Table 16.15 Total Capital Investment for an Ammonia Plant—Costs in Millions of U.S. Dollars (Year 2000)

Total bare-module cost for on-site equipment	108.83			
Cost for spares	0.52			
Cost for storage and surge tanks	0.45			
Cost for initial catalyst charge	0.50			
Total bare-module investment		110.30		
Cost of site preparation		3.31		
Cost of service facilities		1.65		
Allocated costs for utility plants and related facilities		15.45		
Direct permanent investment			130.71	
Cost of contingencies and contractor's fee			23.53	
Total depreciable capital			154.24	
Cost of land			3.08	
Cost of plant startup			12.32	
Total permanent investment				169.64
Working capital				10.09
Total capital investment				179.73

**Need to Relate
Bare Module
Cost
Method to
Lang Ratio
Factoring
Method**

Table 16.17 Breakdown of Lang Factors by Peters and Timmerhaus (1968)

	Percent of Delivered-Equipment Cost for		
	Solids Processing Plant	Solids–fluids Processing Plant	Fluids Processing Plant
Delivered cost of process equipment	100	100	100
Installation	45	39	47
Instrumentation and controls	9	13	18
Piping	16	31	66
Electrical	10	10	11
Buildings (including services)	25	29	18
Yard improvements	13	10	10
Service facilities	40	55	70
Land	6	6	6
Total direct plant cost	264	293	346
Engineering and supervision	33	32	33
Construction expenses	39	34	41
Total and indirect plant costs	336	359	420
Contractor's fee	17	18	21
Contingency	34	36	42
Fixed capital investment	387	413	483
Lang factor, $f_{L_{TM}}$, for use in Eq. (16.9)	3.9	4.1	4.8
Working capital	68	74	86
Total capital investment	455	487	569
Lang factor, $f_{L_{TCI}}$, for use in Eq. (16.10)	4.6	4.9	5.7

Relating Ratio Factoring Method to Bare Module Cost Method

	<u>Solids</u>	<u>Solids-Fluid</u>	<u>Fluid</u>
PE Delivered	100	100	100
PE Installed	45	39	47
Instruments & Controls Installed	9	13	18
Piping Installed	16	31	66
Electrical Installed	10	10	11
Contractor Fee	17	18	21
Engineering & Supervision	33	32	33
Construction Expenses	39	34	41

C_{TBM}	269	277	337

C_{TBM} includes Purchased Equipment (PE) delivered and installed (equipment and associated piping, electrical, instruments & controls)

Relating Ratio Factoring Method to Bare Module Cost Method

<u>$C_{\text{site}} + C_{\text{serv}}$</u>	<u>Solids</u>	<u>Solids-Fluid</u>	<u>Fluid</u>
Buildings (including services)	25	29	18
Yard Improvement	13	10	10
<u>C_{alloc}</u>			
Service Facilities Installed	40	55	70
<u>C_{DPI}</u>			
	347	371	435

C_{alloc} is only included when it is desired to provide or upgrade utility plants and related facilities for liquid waste disposal and waste treatment; if utilities & waste treatment are purchased ,
 $C_{\text{alloc}} = 0$

Relating Ratio Factoring Method to Bare Module Cost Method

	<u>Solids</u>	<u>Solids-Fluid</u>	<u>Fluid</u>
C_{cont} (Contingency)	34	36	42

C_{TDC}	381	407	477
C_{land} (Cost of Land)	6	6	6
C_{royal} (Cost of Royalties)	---	---	---
$C_{\text{start-up}}$ (Start-up cost)	---	---	---

C_{TPI} or C_{FCI}	387	413	483
C_{WC}	68	74	86

C_{TCI} (Total Capital Investment)	455	487	569

Total Capital Investment Estimation (Factors)

	<u>Solids</u>	<u>Solids-Fluid</u>	<u>Fluid</u>
C_{TBM}	C_{TBM}^S	C_{TBM}^{SF}	C_{TBM}^F
$C_{site} + C_{serv}$	$0.14(C_{TBM}^S)$	$0.14(C_{TBM}^{SF})$	$0.08(C_{TBM}^F)$
C_{alloc} Table 16.12 or \Rightarrow	$0.15(C_{TBM}^S)$	$0.20(C_{TBM}^{SF})$	$0.21(C_{TBM}^F)$

C_{DPI}	$1.29(C_{TBM}^S)$	$1.34(C_{TBM}^{SF})$	$1.29(C_{TBM}^F)$
C_{cont} (0.1 to 0.2) C_{DPI}	$0.15(C_{DPI}^S)$	$0.15(C_{DPI}^{SF})$	$0.15(C_{DPI}^F)$

C_{TDC}	$1.15(C_{DPI}^S)$	$1.15(C_{DPI}^{SF})$	$1.15(C_{DPI}^F)$
C_{land}	$0.02(C_{TDC}^S)$	$0.02(C_{TDC}^{SF})$	$0.02(C_{TDC}^F)$
C_{royal}	---	---	---
$C_{startup}$	$0.1(C_{TDC}^S)$	$0.1(C_{TDC}^{SF})$	$0.1(C_{TDC}^F)$

C_{TPI}	$1.12(C_{TDC}^S)$ + C_{royal}	$1.12(C_{TDC}^{SF})$ + C_{royal}	$1.12(C_{TDC}^F)$ + C_{royal}

Total Capital Investment Estimation (Factors) continued

	<u>Solids</u>	<u>Solids-Fluid</u>	<u>Fluid</u>
C_{TPI}	C_{TPI}^S	C_{TPI}^{SF}	C_{TPI}^F

$$C_{TPI} \text{ (corrected)} = F_{ISF} C_{TPI}; \text{ (} F_{ISF} \text{ from Table 16.13)}$$

C_{WC} (estimated from operating costs, chapter 17, or 15% of C_{TCI})	$0.15(C_{TCI}^S)$	$0.15(C_{TCI}^{SF})$	$0.15(C_{TCI}^F)$
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C_{TCI}	$C_{TPI}^S \text{ (corrected)}$ $+ 0.15(C_{TCI}^S)$	$C_{TPI}^{SF} \text{ (corrected)}$ $+ 0.15(C_{TCI}^{SF})$	$C_{TPI}^F \text{ (corrected)}$ $+ 0.15(C_{TCI}^F)$
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Example: Bare Module Cost, C_{BM} , Calculation

Find the present bare module cost of a carbon steel bag filter used to collect dust from a house vacuum system in a process plant (actual flow rate of gas is 1,000,000 ft³/min).

From Table 16.32, purchased cost is

$$C_p = \exp\{10.020 - 0.4381[\ln(10^6)] + 0.05563[\ln(10^6)]^2\}$$

= \$2.16 million (carbon steel) (CE Index = 394)

$$C_p \text{ (today)} = \$2.16 \text{ million} (550/394) = \$3.02 \text{ million}$$

$$F_{BM} \text{ (filter)} = 2.32$$

$$C_{BM} = 2.32 (\$3.02 \text{ million}) = \$7 \text{ million}$$

Example: Bare Module Cost Calculation

Alternative Method: Determine Purchased Equipment Cost and then apply factors

C_{PE} (from Table 16.32 and corrected): \$3.02 million

C_{PE} (Delivered) = 1.05 (\$3.02 million) = \$3.17 million

Factors: Fluid Processing Equipment (3.37)

Solids-Fluid Processing Equipment (2.77)

Solids Processing Equipment (2.69)

Use solids processing plant: $C_{BM} = 2.69$ (\$3.17 million)

$C_{BM} \sim \$8.5$ million

Example: Plant C_{TCI} Estimate

The Purchased Equipment Cost (C_{PE}) for a Fluid Processing Plant has been determined to be \$3MM. The land is available at no cost and all patents are assigned (no royalties). The plant is to be constructed in Arizona. Estimate the C_{TCI} for this plant?

Method 1: Lang's Method

$$C_{TCI} = (1.05)(\$3MM)(5.7) \sim \$18 \text{ MM}$$

Method 2: Factoring Method

$$C_{TBM} = (3.37)(\$3 \text{ MM}) = \$10.11 \text{ MM}$$

$$C_{DPI} = (1.29)(C_{TBM}) = 1.29(10.11\text{MM}) = \$13.04 \text{ MM}$$

$$C_{TDC} = 1.15 C_{DPI} = (1.15)(13.04) = \$15\text{MM}$$

$$C_{TPI} = 1.10 (C_{TDC}) = \$16.5 \text{ MM}$$

$$C_{TPI} \text{ corrected} = (0.95)(\$16.5 \text{ MM}) = \$15.68 \text{ MM}$$

$$C_{TCI} = C_{TPI} \text{ corrected} + 0.15 (C_{TCI})$$

$$C_{TCI} = \$15.68 \text{ MM} + 0.15 (C_{TCI})$$

$$0.85 C_{TCI} = \$15.68 \text{ MM}$$

$$\text{Then, } C_{TCI} = \$15.68 \text{ MM}/0.85 = \$18.5 \text{ MM}$$

Clicker Question # 5

The following costs cannot be depreciated

- a) Process Equipment**
- b) Working Capital**
- c) Preparation of the Site**
- d) Contingency and Contractor's Fees**
- e) Initial Catalyst Charge**