Lecture 7 : Sizing, Costing & Economic Evaluation

Chapters 4 & 5 (Textbook)

Ethanol Process: Design Problem (from Textbook)

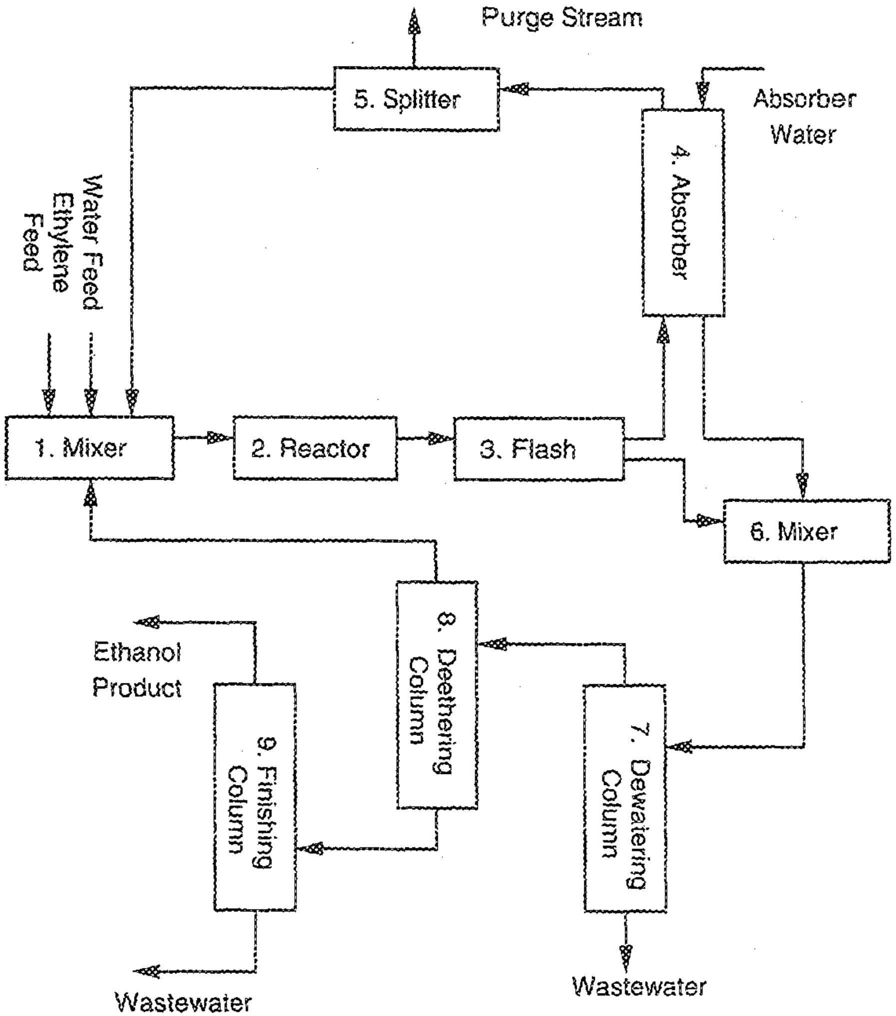


FIGURE 3.1 Ethanol flowsheet.

We have now performed mass and energy balance.

We have added pumps/compressors, heat exchangers wherever necessary.

Now we need to do the sizing calculations for all unit operations in the flowhseet.

Costing & Economic analysis

Sizing & Costing Calculations (chapter 4) plus Economic Analysis (chapter 5)

- **Data collection & design problem definition**
  - **Flowsheet (tasks 1-3)**
    - **Mass balance (task 4)**
      - **Mass & energy balance (simple) – tasks 5-6**
        - **Mass & energy balance (detailed) – task 7**
          - **Sizing calculations**
            - **Costing calculations**
              - **Fixed Capital cost**
              - **Operating (manufacturing) cost**
                - **Economic Analysis (tasks 8-9)**

Mass and Energy balances for Ethanol Process Flowsheet (task 7)

	μ_{01}	μ_{02}	μ_1	μ_2	μ_{31}	μ_{32}	μ_{41}	μ_{42}	μ_{03}
Methane (gmol/s)	1	0	200	200	199.2	0.8	199.2	0	0
Ethylene	96	0	1289	1198.77	1180.78	17.98	1155.99	24.796	0
Propylene	3	0	268.6	266.71	248.58	18.136	223.97	24.609	0
Diethyl Ether	0	0	0	2.421	1.210	1.2108	0.2906	0.9202	0
Ethanol	0	0	0.56	90.79	10.98	79.80	0.1098	10.87	0
Isopropanol	0	0	0	1.8802	0.156	1.724	0.001018	0.1550	0
Water	0	771.797	773.4	680.72	36.75	643.97	1.610	72.896	37.747
Total	100	771.797	2531.56	2441.31	1677.68	763.62	1581.177	134.25	37.747
Temperature, K	300	300	590	590	393	393	381.57	338.7	310
Pressure, bar	1	1	69	69	68.5	68.5	68	68	68
Vap. Frac	1	0	1	1	1	0	1	0	0
Enthalpy, kcal/s	1198.85	−52097.04	−21683.63	−22689.24	11515.18	−47920.28	13439.75	−5324.42	−2544.97

	μ_{51}	μ_{52}	μ_6	μ_{71}	μ_{72}	μ_{81}	μ_{82}	μ_{91}	μ_{92}
Methane (gmol/s)	198.204	0.996	0.8	0.8	0	0.8	0	0	0
Ethylene	1150.21	5.780	42.778	42.778	0	42.7781	0	0	0
Propylene	222.85	1.1198	42.746	42.746	0	42.7466	0	0	0
Diethyl Ether	0.2891	0.00145	2.131	2.131	0	2.1205	0.01065	0.01065	0
Ethanol	0.1093	0.000549	90.680	90.226	0.4534	0.451	89.775	89.3267	0.4489
Isopropanol	0.001013	5.09323E-06	1.879	1.804	0.075	0	1.804	0.1046	1.6994
Water	1.6024	0.00805	716.867	71.68	645.18	0	71.686	15.1490	56.537
Total	1573.27	7.9058	897.882	252.173	645.70	88.896	163.277	104.591	58.686
Temperature, K	381.57	381.57	372	310	480	310	418	350	383
Pressure, bar	67.5	67.5	68	17.56	18.06	10.7	11.2	1	1.5
Vap. Frac	1	1	0	0	0	1	0	0	0
Enthalpy, kcal/s	13372.55	67.197	−53244.70	−10436.14	−42629.37	590.10	−10576.78	−6787.79	−3930.30

Sizing & Costing Calculations

I. Prepare a list of unit operations found in the flowsheet

II. For each unit operation, find a design that matches the calculated input-output conditions to obtain the sizing parameters

III. Use the sizing parameters to determine the cost of each unit operation

Decisions that need to be made

Choice of equipment type

Choice of pressure (already made)

Choice of material

Other parameters specific to the unit operation

Sizing & Costing Calculations

Step I: Prepare a list of unit operations found in the flowsheet

Flow-pressure

pumps, compressors, expansion valves, ...

Heat exchange

shell & tube, condensers, reboilers, furnace

Reactors

plug-flow, CSTR, fluidized bed, ...

Separation (heat & mass transfer) - equilibrium

distillation, absorption, crystallization, ...

Separation (heat & mass transfer) - nonequilibrium

membrane-based, centrifuge, drying, ...

Other

refrigeration cycle, heat pump cycle, dryer, tank

Sizing & Costing Calculations

Step II: For each unit operation, find a design that matches the calculated input-output conditions to obtain the sizing parameters

Unit operation	Equipment	Equipment type	Sizing parameters
Distillation column	Pressure vessel	Vertical	D (diameter), L (height)
Absorption column			
Extraction column			
Tank storage			
Extraction column	Pressure vessel	Horizontal	D (diameter), L (length)
Tank (storage)			
Furnace	Processing equipment	Vessel + tubes	S (absorbed heat = energy/h)
Direct fired heater			
Heat exchanger	Processing equipment	Shell & tube	S (area)
Air cooler	Processing equipment	Vessel + tubes	S (area)
Pumps	Processing equipment	Centrifugal	S (C/H factor)
Compressor	Processing equipment	Adiabatic/isothermal; motor driven	S (brake horse power)
Compressor	Processing equipment	Adiabatic/isothermal; turbine driven	S (brake horse power)
Refrigeration	Processing equipment	Complete network	S (ton energy removed/h)

See tables 4.11 & 4.12 of textbook

Sizing & Costing Calculations

Step II: For each unit operation, find a design that matches the calculated input-output conditions to obtain the sizing parameters

Unit operation	Equipment type	Sizing parameters	Calculation procedure
Distillation column	Vertical	D (diameter), L (height)	See example 4.1 in textbook*
Absorption column			See example 4.1 in textbook*
Extraction column			See example 4.1 in textbook*
Tank storage			$V = 2\ (F_l\ \tau/\rho_l)$; see Eq. 4.1
Extraction column	Horizontal	D (diameter), L (length)	Similar to example 4.1
Tank (storage)			$V = 2\ (F_l\ \tau/\rho_l)$; see Eq. 4.1
Furnace	Vessel + tubes	S (absorbed heat = energy/h)	See Perry's Handbook
Direct fired heater			See Perry's Handbook
Heat exchanger	Shell & tube	S (area)	Eq. 4.4 plus table 4.3*
Air cooler	Vessel + tubes	S (area)	Eq. 4.4 plus table 4.3*
Pumps	Centrifugal	S (C/H factor)	See textbook*, Perry's
Compressor	Adiabatic/isothermal; motor driven	S (brake horse power)	$W_b = W/(\eta_m\ \eta_c)$; η_m=0.9; η_c=0.8 (see Eq. 4.24)*
Compressor	Adiabatic/isothermal; turbine driven	S (brake horse power)	$W_b = W/(\eta_m\ \eta_c)$; η_m=0.8; η_c=0.8 (see Eq. 4.24)*
Refrigeration	Complete network	S (ton energy removed/h)	See examples 4.3 & 4.4

* Commercial simulators also provide options for sizing parameters for most conventional unit operations

See also Perry's Handbook

Sizing & Costing Calculations: Refrigeration

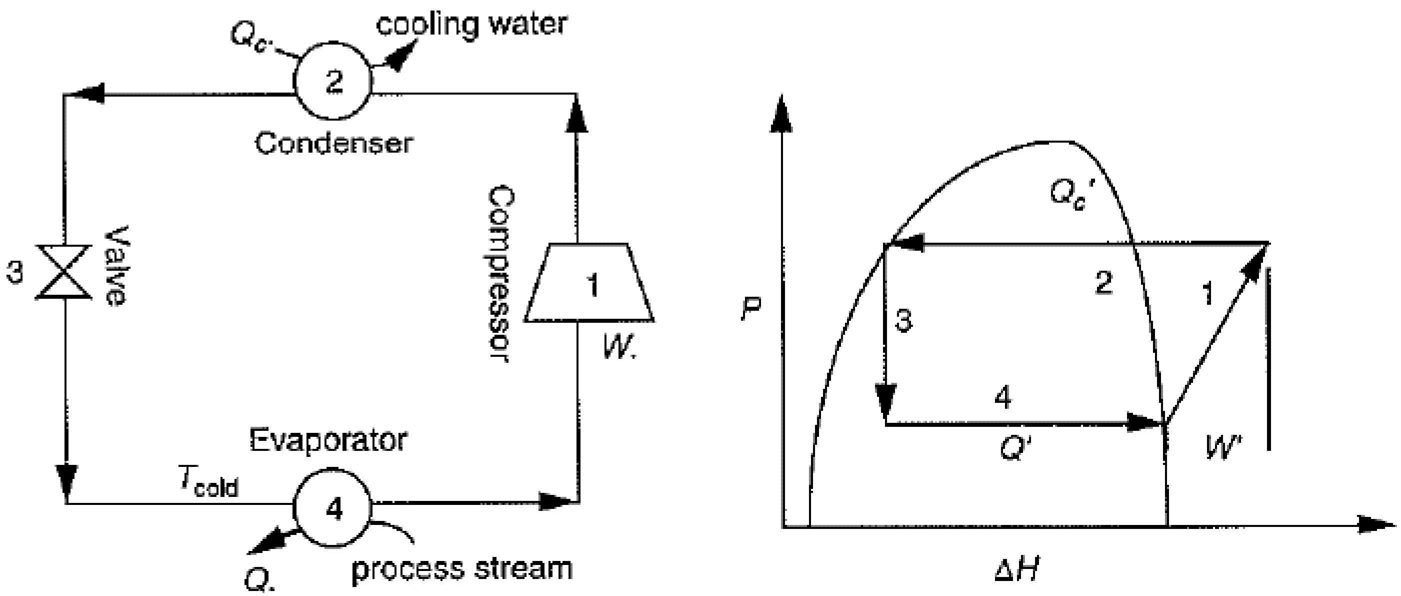


FIGURE 4.10 Refrigeration cycle and phase diagram.

EXAMPLE 4.3

Suppose we want to cool air as a process stream to 180K. Consider the refrigerants:

R	T_{boil}(K)	$0.9T_c$(K)
Ethylene	169	254
Propane	231	332

We know that ethylene will go down to 180 K but not up to 300 K. The opposite holds for propane. Therefore, we need at least two stages: one propane, one ethylene.

Distillation Column Design - Determine, Reflux ratio, Number of stages, Column diameter, Tray height, Heat duties for reboiler & condenser (*following the example 4.1 in textbook*)

- **Use the $\alpha_{lk/hk}$, ξ_{lk}, ξ_{hk} to calculate N_i & R_i**
- **Calculate $N_t = 0.8\ \max_i(N_i) + (1\text{-}0.8)\ \min_i(N_i)$; use efficiency of 80%**
- **Calculate $R = 0.8\ \max_i(N_i) + (1\text{-}0.8)\ \min_i(N_i)$**
- **Calculate L´ and V´ and from it, F_{lv}**
- **Use F_{lv} and Fig 4.4 to obtain $C_{sb,t}$ (for a selected tray spacing)**
- **Calculate flooding velocity, U_{nf}, and from it, the area A and diameter D of the column (use Eqs. 4.7 or 4.8 and 4.9)**
- **Determine Tray stack height, extra feed space, disengagement space (top & bottom), skirt height**
- **$Q_{cond} = H^V V - h^L L$**
- **Calculate Q_{reboil} from total energy balance**

Distillation Column Design - Determine, Reflux ratio, Number of stages, Column diameter, Tray height, Heat duties for reboiler & condenser (*Using PRO-II*)

- Use Short-Cut Fractionation (for column design)
- Use rigorous simulation model to obtain the final design
- Use the "sizing" calculation option for the column design
- Select the column diameter, tray spacing, etc., from the output of PRO-II
- For condenser duty = Q_{cond} (given by PRO-II), size a heat exchanger (determine area A)
- For reboiler duty = Q_{reboil} (given by PRO-II), size a heat exchanger (kettle-type) – determine area
- Determine Tray stack height, extra feed space, disengagement space (top & bottom), skirt height

Absorption Column Design - Determine, absorption factor, Number of stages, Column diameter, Tray height, Heat duties for reboiler & condenser

- **Use the $\alpha_{lk/hk}$, ξ_{lk}, ξ_{hk} to calculate N_t**
- **Calculate N_t from Kremser equation (approx = 10)**
- **Use efficiency of 20% (*not necessary if Kremser Eq used*)**
- **Calculate L´ and V´ and from it, F_{lv}**
- **Use F_{lv} and Fig 4.4 to obtain $C_{sb,t}$ (for a selected tray spacing)**
- **Calculate flooding velocity, U_{nf}, and from it, the area A and diameter D of the column (use Eqs. 4.7 or 4.8 and 4.9)**
- **Determine Tray stack height, extra feed space, disengagement space (top & bottom), skirt height**
- **Packed columns can also be calculated from the number of transfer units and height of transfer units**

Sizing & Costing Calculations

Step III: Use the sizing parameters to determine the cost of each unit operation

For each equipment, calculate the FIXED CAPITAL COST

*** total installed cost = BC (MPF + MF -1)**

*** updated bare module cost = BMC = UF (BC (MPF + MF -1))**

*** contingency cost = B**

*** building, services, land = C**

Fixed Capital cost = BMC + B + C

Sizing & Costing Calculations: BMC

For each equipment, total installed cost = BC (MPF + MF -1)

For each equipment, using the sizing parameters obtain values of C_0, S_0, S, D, D_0, L, L_0, α, β from tables 4.11 & 4.12

- **Obtain BC from**
  - **$BC = C_0(L/L_0)^{\alpha}(D/D0)^{\beta}$ for pressure vessels (table 4.11) or**
  - **$BC = C_0\ (S/S_0)^{\alpha}$ process equipment (table 4.12)**
- **Obtain MF from tables 4.11 & 4.12, based on the calculated value of BC**
- **Obtain MPF from the Guthrie material and pressure correction factors for each equipment (tables 4.1 – 4.10)**

TABLE 4.11 Base Costs for Pressure Vessels

Equipment Type	C_0($)	L_0(ft)	D_0(ft)	α	β	MF2/MF4/MF6/MF8/MF1
Vertical fabrication $1 \leq D \leq 10$ ft, $4 \leq L \leq 100$ ft	1000	4.0	3.0	0.81	1.05	4.23/4.12/4.07/4.06/4.02
Horizontal fabrication $1 \leq D \leq 10$ ft, $4 \leq L \leq 100$ ft	690	4.0	3.0	0.78	0.98	3.18/3.06/3.01/2.99/2.96
Tray stacks $2 \leq D \leq 10$ ft, $1 \leq L \leq 500$ ft	180	10.0	2.0	0.97	1.45	1.0/1.0/1.0/1.0/1.0

(Data from Guthrie, 1969)

TABLE 4.12 Base Costs for Process Equipment

Equipment Type	C_0(10^3)	S_0	Range(S)	α	MF2/MF4/MF6/MF8/MF10
Process furnaces S = Absorbed duty (10^6Btu/hr)	100	30	10–300	0.83	2.27/2.19/2.16/2.15/2.13
Direct fired heaters S = Absorbed duty (10^6Btu/hr)	20	5	1–40	0.77	2.23/2.15/2.13/2.12/2.10
Heat exchanger Shell and tube, S = Area (ft^2)	5	400	100–10^4	0.65	3.29/3.18/3.14/3.12/3.09
Heat exchanger Shell and tube, S = Area (ft^2)	0.3	5.5	2–100	0.024	1.83/1.83/1.83/1.83/1.83
Air coolers S = {Calculated area (ft^2)/15.5}	3	200	100–10^4	0.82	2.31/2.21/2.18/2.16/2.15
Centrifugal pumps	0.39	10	10–$2 \cdot 10^3$	0.17	3.38/3.28/3.24/3.23/3.20
	0.65	$2 \cdot 10^3$	$2 \cdot 10^3$–$2 \cdot 10^4$	0.36	3.38/3.28/3.24/3.23/3.20
	1.5	$2 \cdot 10^4$	$2 \cdot 10^4$–$2 \cdot 10^5$	0.64	3.38/3.28/3.24/3.23/3.20
S = C/H factor (gpm × psi)					
Compressors S = brake horsepower	23	100	30–10^4	0.77	3.11/3.01/2.97/2.96/2.93
Refrigeration S = ton refrigeration (12,000 Btu/hr removed)	60	200	50–3000	0.70	1.42

Sizing & Costing Calculations: BMC

Total installed cost = BC (MPF + MF -1) *Sum for all equipments*

Updated bare module cost = BMC = UF (BC (MPF + MF -1))

UF = (present cost index) / (base cost index) = 3.12 (approx)

Fit the following data as a function of year to obtain UF:

Year	**1957-59**	**1968**	**1970**	**1983**	**1993**	**1995**
CI	**100**	**115**	**126**	**316**	**359**	**381**

Then use the fitted function to predict the CI for *2013*

Sizing & Costing Calculations: BMC

Example: Calculate BMC for a compressor

Total work (W) is 76.56 kW (see example 4.2 of textbook)

Calculate W_b = W/0.72 = 106.3 kW = 142 hp

Use Table 4.12 to calculate BC = $BC = C_0 (S/S_0)^{\alpha}$

$S = 142$; $C_0 = 23000$; $S_0 = 100$; $\alpha = 0.77$; BC = 30000

Based on the BC value, identify the MF to use (see page 135 of textbook) from table 4.12. For BC = 30000, MF2 needs to be used from Table 4.12; MF = MF2 = 3.11

Use table 4.9 to obtain MPF = Fd = 1.0 (*for centrifugal compressor with motor – design decisions*)

BMC = UF (BC (MPF + MF -1)) = (3.12) (30000) (1 + 3.11 – 1)

Sizing & Costing Calculations: BMC

Example: Calculate BMC for a distillation column

From example 4.1, D = *0.82*m; L = *19.2* m; Tray stack height = 13.2 m (*24 inch tray spacing*)

Use Table 4.11 to calculate BC = $C_0(L/L_0)^{\alpha}(D/D0)^{\beta}$

$C_0 = 1000$; $L_0 = 4$; $D_0 = 3$; $\alpha = 0.81$; $\beta = 1.05$; BC = 8350

Based on the BC value, identify the MF to use (see page 135 of textbook) from table 4.11. For BC = 8350, MF2 needs to be used from Table 4.11; MF = MF2 = 4.23

Use table 4.7 to obtain MPF = $F_m + F_s + F_l = 1.0$ (*for sieve tray and carbon steel – design decisions*)

BMC = UF (BC (MPF + MF -1)) = (3.12) (8350) (1 + 4.23 – 1)

Example: Fixed Capital Cost Calculation

Fixed Capital Cost = A + B + C

A = Bare Module Cost (BMC)

B = Contingency = 25% of BMC (cost model)

C = Buildings, service, land = 40% of BMC cost model)

Ethanol production Case Study

A = 19380 K$ (***sum of all the unit operations***)

B = 0.25x19380 = 4845 K$

C = 0.40x19380 = 9752 K$

Fixed Capital Cost = 33977 K$

Cost Estimation: Total (Operating) Manufacturing Cost

Total manufacturing cost is the sum of the following items

Assume running time (hours/year) t_r = 7000 - 8000

1. **Raw material (F_{rm} * C_{rm} * t_r)**
2. **Maintenance (assume 5% of fixed capital costs)**
3. **Labor (assume 20 workers needed to run the plant)**
4. **Managers (assume 2 managers needed)**
5. **Insurance (assume 2% of fixed capital costs)**
6. **Lab analysis (2 lab technicians)**
7. **Utilities (F_U * C_U * t_r)**
   a. **Steam**
   b. **Electricity**
   c. **Cooling water**

Total Operating (manufacturing) cost = 1 + 2+ 3 + 4 + 5 + 6 + 7

Cost Estimation: Total Revenue

Total revenue is calculated from the following (yearly basis):

1. **Sale of the product**
2. **Sale of the by-products**
3. **Utilities credits**
   a. **Available sources of energy that can be sold**
   b. **Available water (cold or hot) that can be re-used**

For ethanol case study,

5400 K$/y < Revenue < 110000 K$/y

Economic Evaluation (Parts of Chapter 5)

- **Total Capital Investment**
- **Operating Profit**
- **Net Present Value (NPV), Payback time, Rate of return**
- **Sensitivity Analysis**

Economic Evaluation

Total Capital Investment = A + B + C + D

A = Bare Module Cost (BMC)

B = Contengency = 25% of BMC

C = Buildings, service, land = 40% of BMC

D = 1 month production costs (total manufacturing costs)

Ethanol production case study

A = 19380 K$

B = 4845 K$

C = 7752 K$

D =34317/12 = 2860 K$

Total Capital Investment = 36837 K$

Economic Evaluation

Operating Profit = P = R – M

M = Total manufacturing costs

R = Revenue from sale of products

Ethanol Production case study

M = Sum of all the operating costs of all equipments plus cost of raw materials = 34318 K$/y

R = Sale of products = 54000 K$/y (110000K$/y)

Operating profit = P = 19682 K$/y (74682 K$/y)

Economic Evaluation – Template for presentation

ECONOMIC ANALYSIS

Capital investment (fixed capital costs), €	
Working Capital, €	
Total investment, C_I, €	
Running time, h/yr	

	Item	Amount	Unit	Price**	€/yr	Delta %	€/yr
1. Raw material	Water			1.9e-4 €/mol			
2. Other material	Catalyst						
3. Maintenance			5%#				
4. Labor				34,000*			
5. Managers				40,000*			
6. Insurance			2%#				
7. Lab analysis				38,000*			
8. Utilities	Steam			8.5e-5 €/mol			
	Electricity			9.2e-3 €/kWh			
	CW			1.3e-2 €/m^3			
Total manufacturing cost							
Revenue							
Total							
Profit (P)							

* €/(man).yr ; # % of the plant cost; ** prices in Denmark (Europe)

Economic Evaluation – Template for presentation

NVP calculations

$$NPV = -C_I + P \cdot \left(1 - (1+i)^{-n}\right) / i$$

C_I, € =

P, € =

Method	Specify		Specify		Calculate	
	Item	Value	Item	Value	Item	Value
Present value						
Rate of return						
Pay back time						

Economic Evaluation (NPV, Payback Time & Rate of Return)

Net Present Value (NPV)

NPV $= - C_I + P\,[1 - (1 + i)^{-n}]/i$

C_I = Capital Investment

P = Operating Profit

i = interest rate (fraction)

n = process life time (years)

- **Calculate NPV with known values of C_I, P, i=0.1 & n=10**
- **Calculate Payback Time for NPV = 0, known values of C_I, P, i=0.1**
- **Calculate Rate of Return for NPV = 0, known values of C_I, P, n=10**

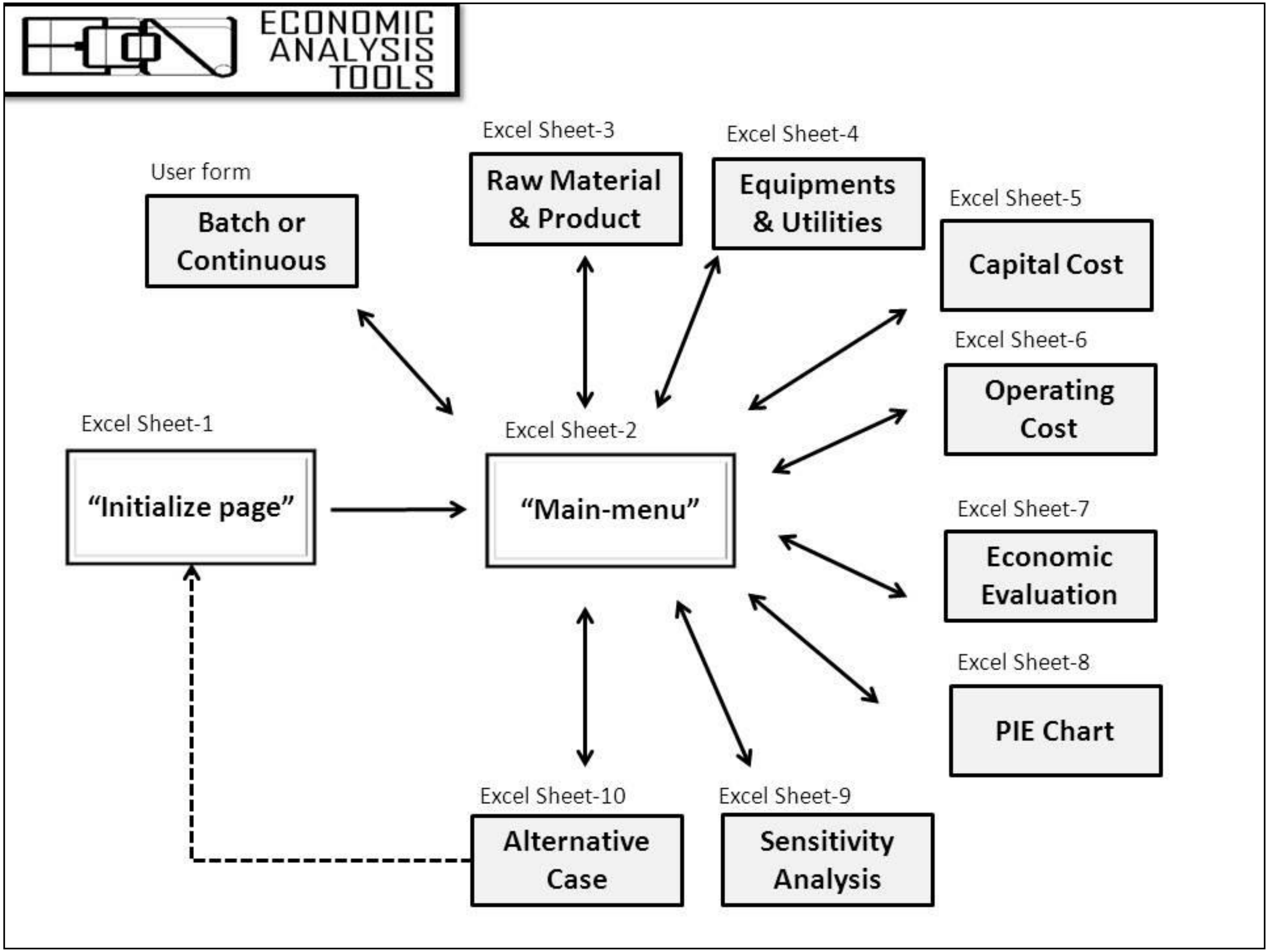
Economic Evaluation

- **Capital (Cost) Investment**
- **Operating Profit**
- **Net Present Value (NPV), Payback time, Rate of return**
- **Sensitivity Analysis**
- **What if analysis – How will NPV, Payback timeand Rate of return be affected if,**
  - **the prices of the raw material increases and the product decreases (for example by 10%)?**
  - **the cost of energy (steam) increases or decreases (for example, by 5% or 10%)?**

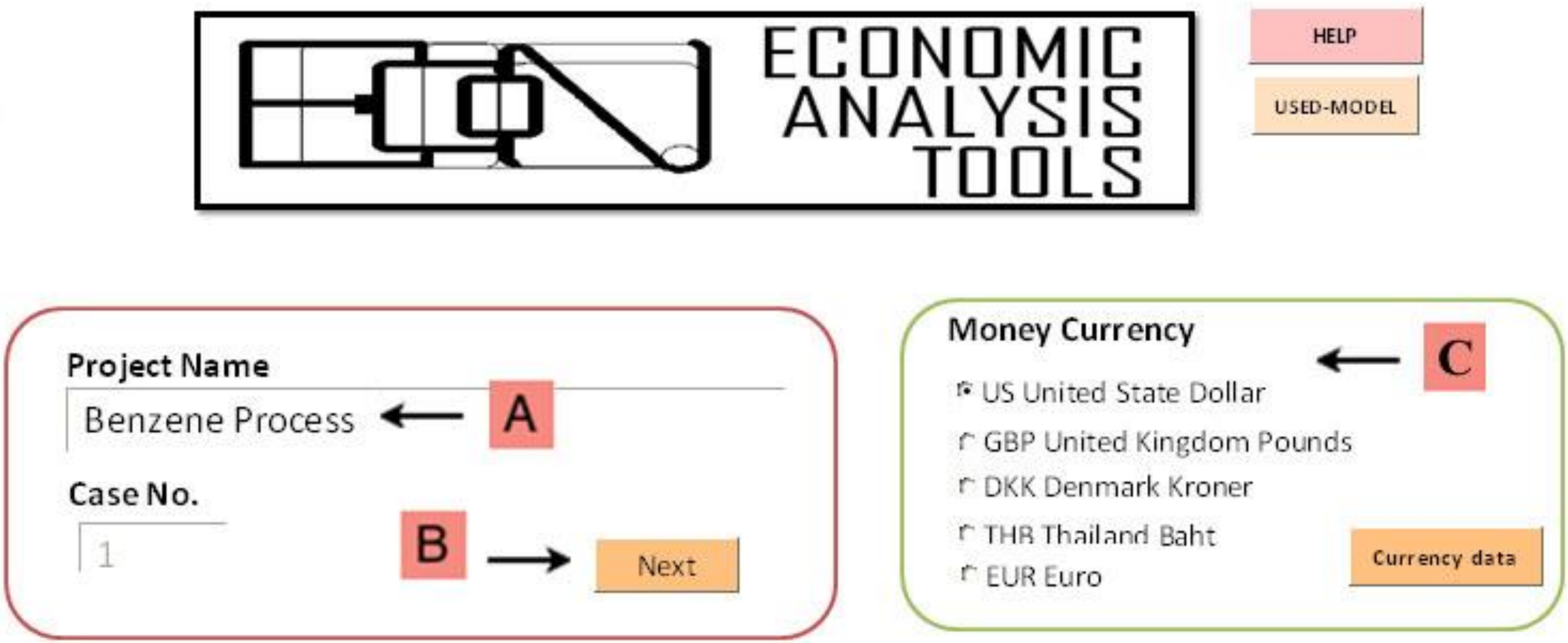
Economic Evaluation - Exercise

- **Calculate NPV, Payback time, Rate of return for the following data:**
- **Fixed capital costs = 211 (mDKr)**
- **Running time = 7000 h/y**
- **Total manufacturing cost, M = 327 mDKr**
- **Total Profit, P = 400 mDkr**
- **For i = 0.1, n = 1, NPV = ?**
- **For NPV = 0, i = 0.1, Payback time = ?**
- **For NPV = 0, n = 10, Rate of return = ?**
- **What is the value of NPV if M increases by 10% and R decreases by 9%**

ECON Software Economic Analysis

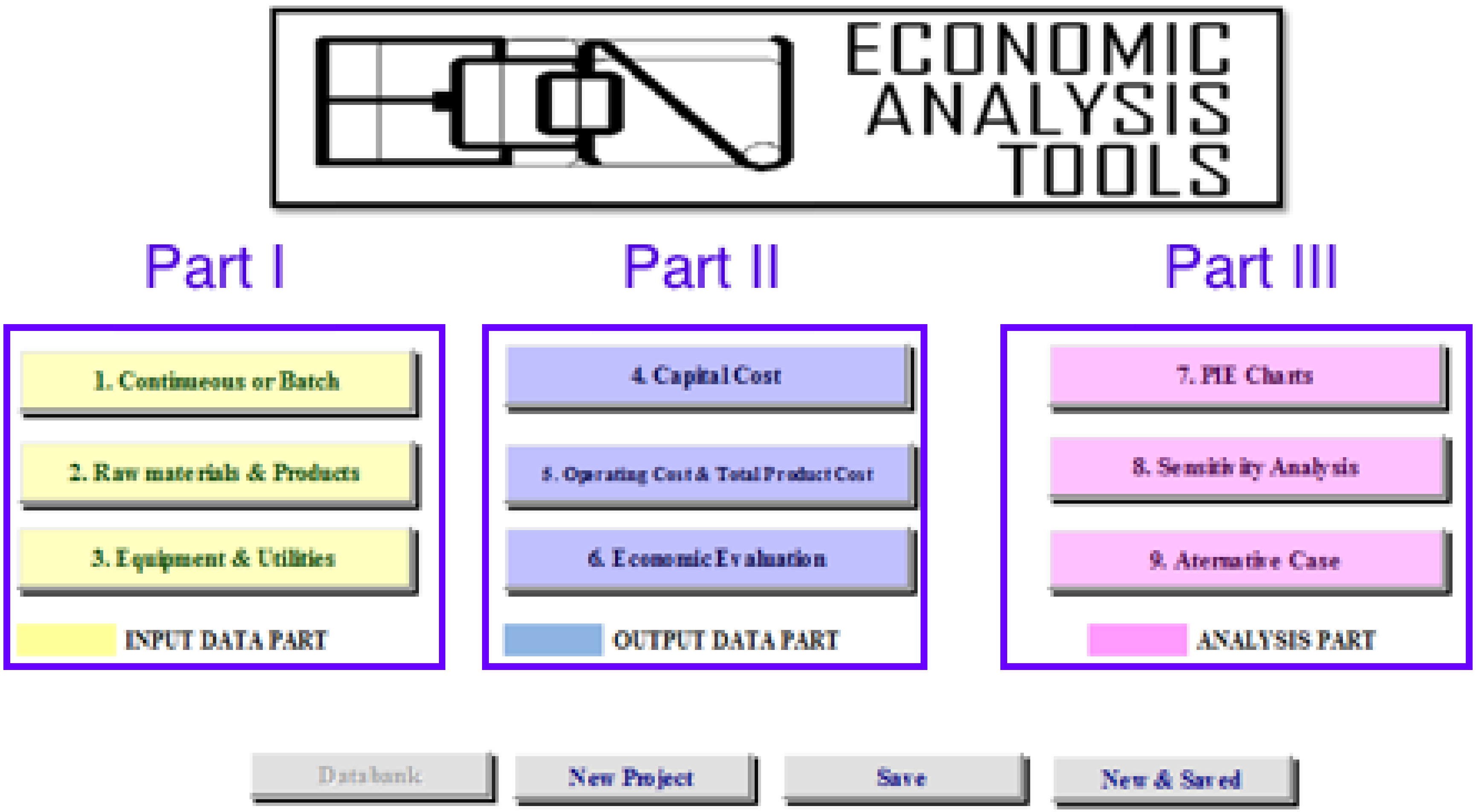


ECON Software Economic Analysis



Slides 30-38 show screen-shots from the ECON-software. Check the corresponding sheets from EXCEL to get a better picture.

ECON Software Economic Analysis



ECON Software Economic Analysis: Equipment List

EQUIPMENT

No.	EQUIPMENT	SIZE	UNIT	MATERIAL	PURCHASE COST	
M-101	Mixer	0.600000024	cubic meters	Carbon Steel	$	4,626.00
E-101	Heat Exchanger	34.151	sq.meter	304 Stainless Steel	$	6,983.00
H-101	Heater	16.02	kW	Chrome/Moly	$	28,245.00
E-102	Heat Exchanger	270.816	sq.meter	Carbon Steel	$	19,884.00
C-101	Compressor	723.28	kW	CarbonSteel	$	402,019.00
[illegible]	Heat Exchanger	[illegible]	sq.meter	Carbon Steel	$	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	$	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	$	[illegible]
[illegible]	Heat Exchanger	[illegible]	sq.meter	Carbon Steel	$	[illegible]
Tc-101	Heat Exchanger	12.39	sq.meter	Carbon Steel	$	4,730.00
T-102	Tower Unit	16.74	meters	Carbon Steel	$	137,149.00
Tt-102	Valve tray	35	trays	Carbon Steel	$	27,981.00
Tr-102	Heat Exchanger	312.87	sq.meter	Carbon Steel	$	20,887.00
Tc-102	Heat Exchanger	273.54	sq.meter	Carbon Steel	$	18,732.00
T-103	Tower Unit	12.71	meters	Carbon Steel	$	69,929.00
Tt-103	Valve tray	12	trays	Carbon Steel	$	15,288.00
Tr-103	Heat Exchanger	261.71	sq.meter	Carbon Steel	$	18,084.00
Tc-103	Heat Exchanger	207.23	sq.meter	Carbon Steel	$	15,098.00
T-F101	Tower Unit	4.728	meters	Carbon Steel	$	170,656.00
				Total	$	1,333,901.00

D1 D2 D3 D4 D5 D6 D7

D1: Equipment ID number; D2: Equipment type; D3: Sizing parameter; D4: Unit; D5: Material; D6: Equipment purchase cost; D7: Total purchase cost

ECON Software Economic Analysis: Utility List

UTILITY

No.	EQUIPMENT	Utility	SIZE	UNIT	PRICE $/GJ		UTILITY COST
M-101	Mixer	Electricity	0	kW	16.79999924	$	-
E-101	Heat Exchanger	HP utility	2452.2	kW	9.829999924	$	687,285.31
H-101	Heater	Natural Gas	16.02	kW	6	$	17,107.20
E-103	Heat Exchanger	Cooling water	0.018959	kW	0.349999994	$	0.19
C-101	Compressor	Electricity	723.28	kW	16.79999924	$	346,452.28
E-R101	Heat Exchanger	n/a		n/a	0	$	-
T-101	Tower Unit	n/a	n/a	n/a	n/a	$	-
Tt-101	Valve tray	n/a	n/a	n/a	n/a	$	-
[illegible]	Heat Exchanger	[illegible]	[illegible]	[illegible]	[illegible]	$	[illegible]
[illegible]	Heat Exchanger	[illegible]	[illegible]	[illegible]	[illegible]	$	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	$	[illegible]
Tt-102	Valve tray	n/a	n/a	n/a	n/a	$	-
Tr-102	Heat Exchanger	MP steam	2.598	kW	8.220000267	$	608.89
Tc-102	Heat Exchanger	Cooling water	4.354	kW	0.349999994	$	43.95
T-103	Tower Unit	n/a	n/a	n/a	n/a	$	-
Tt-103	Valve tray	n/a	n/a	n/a	n/a	$	-
Tr-103	Heat Exchanger	MP steam	4.768	kW	8.220000267	$	1,117.47
Tc-103	Heat Exchanger	Cooling water	4.758	kW	0.349999994	$	48.02
T-F101	Tower Unit	n/a	n/a	n/a	n/a	$	-
					Total	$	1,053,067.00

D8: Equipment ID number; D9: Equipment type; D10: Utility type; D11: Sizing parameter; D12: Unit; D13: Price per unit ($/GJ); D14: Utility cost; D15: Total utility cost

ECON Software Economic Analysis

Manufacturing Fixed-capital Investment (Direct Cost)	Percent of Delivered-equipment for Fluid Processing Plant	Result
Purchased Equipment Delivered	1.1	$1,467,291.10
Purchased Equipment Installation	0.47	$689,626.82
Instrumentation and Controls (installed)	0.36	$528,224.80
Piping (Installed)	0.68	$997,757.85
Electrical Systems (Installed)	0.11	$161,402.02
Buildings (including Services)	0.18	$264,112.40
Yard Improvement	0.1	$146,729.11
Service Facilities (installed)	0.7	$1,027,103.77
	2.6	
	Total Direct Cost	$5,282,247.96

B1

Nonmanufacturing Fixed-capital Investment (Indirect Cost)	Percent of Delivered-equipment for Fluid Processing Plant	Result
Engineering and Supervision	0.33	$484,206.06
Construction Expenses	0.41	$601,589.35
Legal Expenses	0.04	$58,691.64
Contractor's Fees	0.22	$322,804.04
Contingency	0.44	$645,608.08
	1.44	
	Total indirect cost	$2,112,899.18

B2

Fixed-capital Investment	Percent of Delivered-equipment for Fluid Processing Plant	Result
Fixed-capital Investment (FCI)		$7,395,147.14

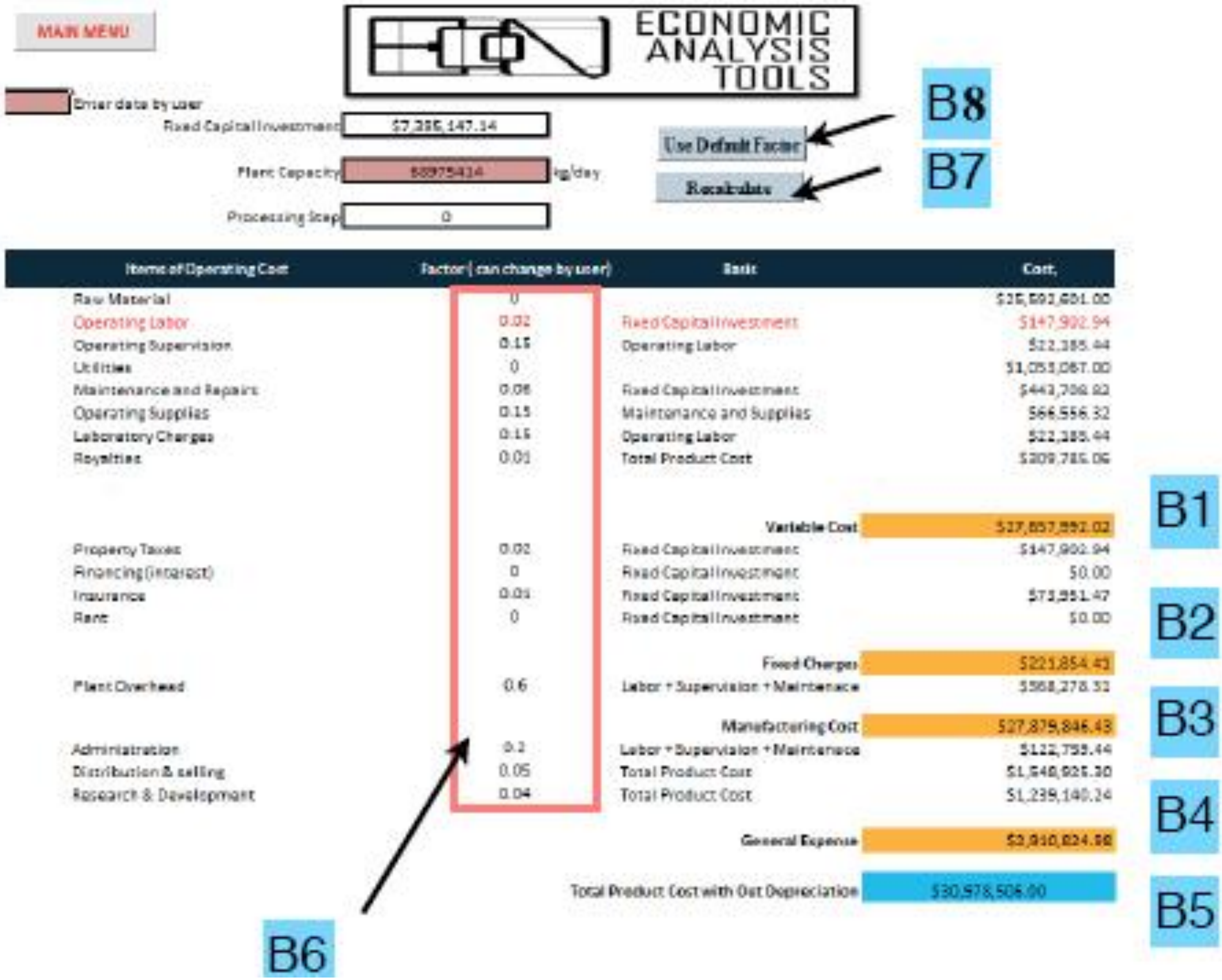
B3

Working Capital Investment	Percent of Delivered-equipment for Fluid Processing Plant	Result
Working Capital Investment (WC)	0.89	$1,305,889.08
	Total Capital Investment (TCI)	$8,701,036.22

B4

Direct cost (B1); indirect cost (B2); working cost (B3); and total capital cost (B4).

ECON Software Economic Analysis



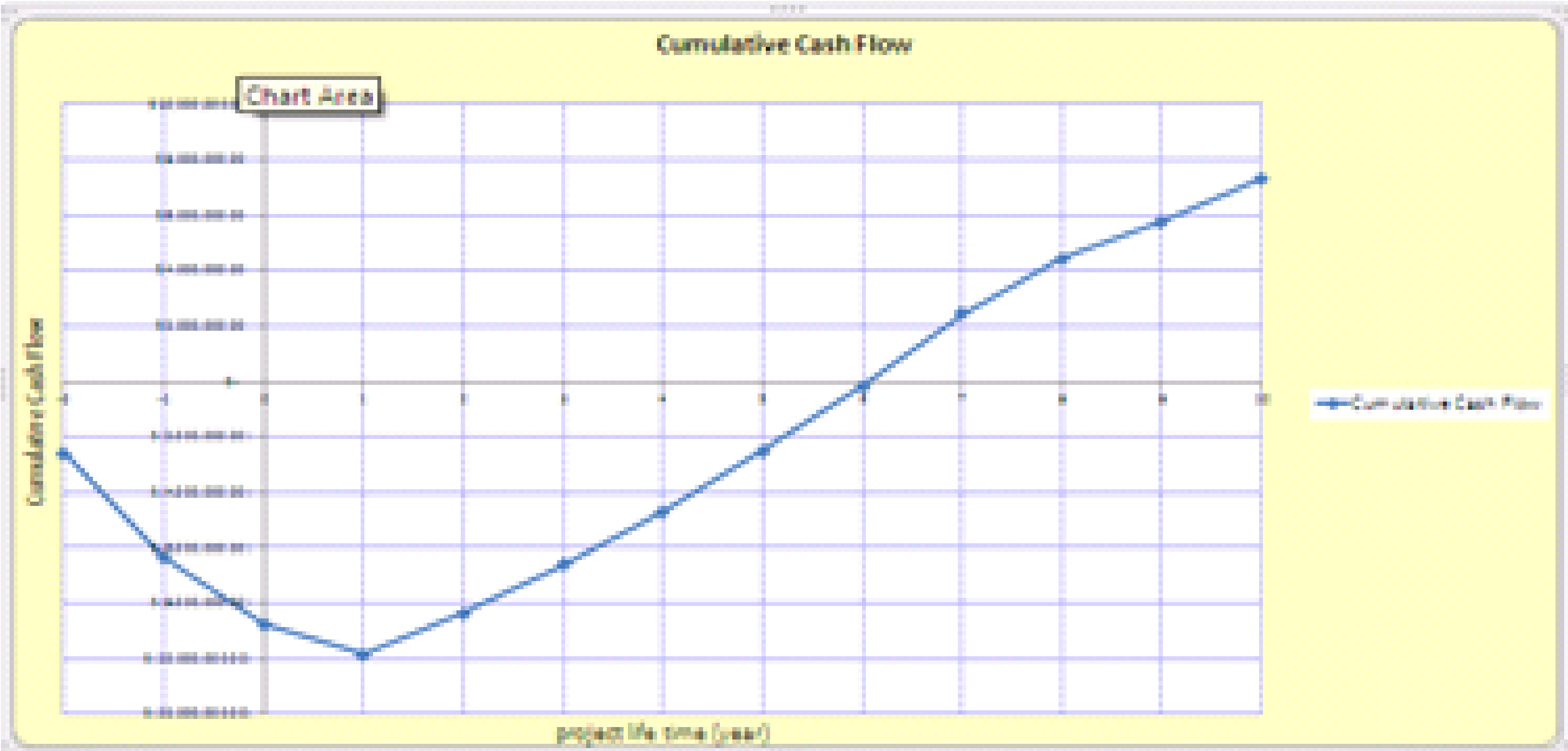
B1: variable costs; B2: fixed charges; B3: manufacturing costs; B4: general expenses; and B5: total product costs ; B6 values can be changed to recalculate the costs.

ECON Software Economic Analysis

ECONOMIC ANALYSIS TOOLS

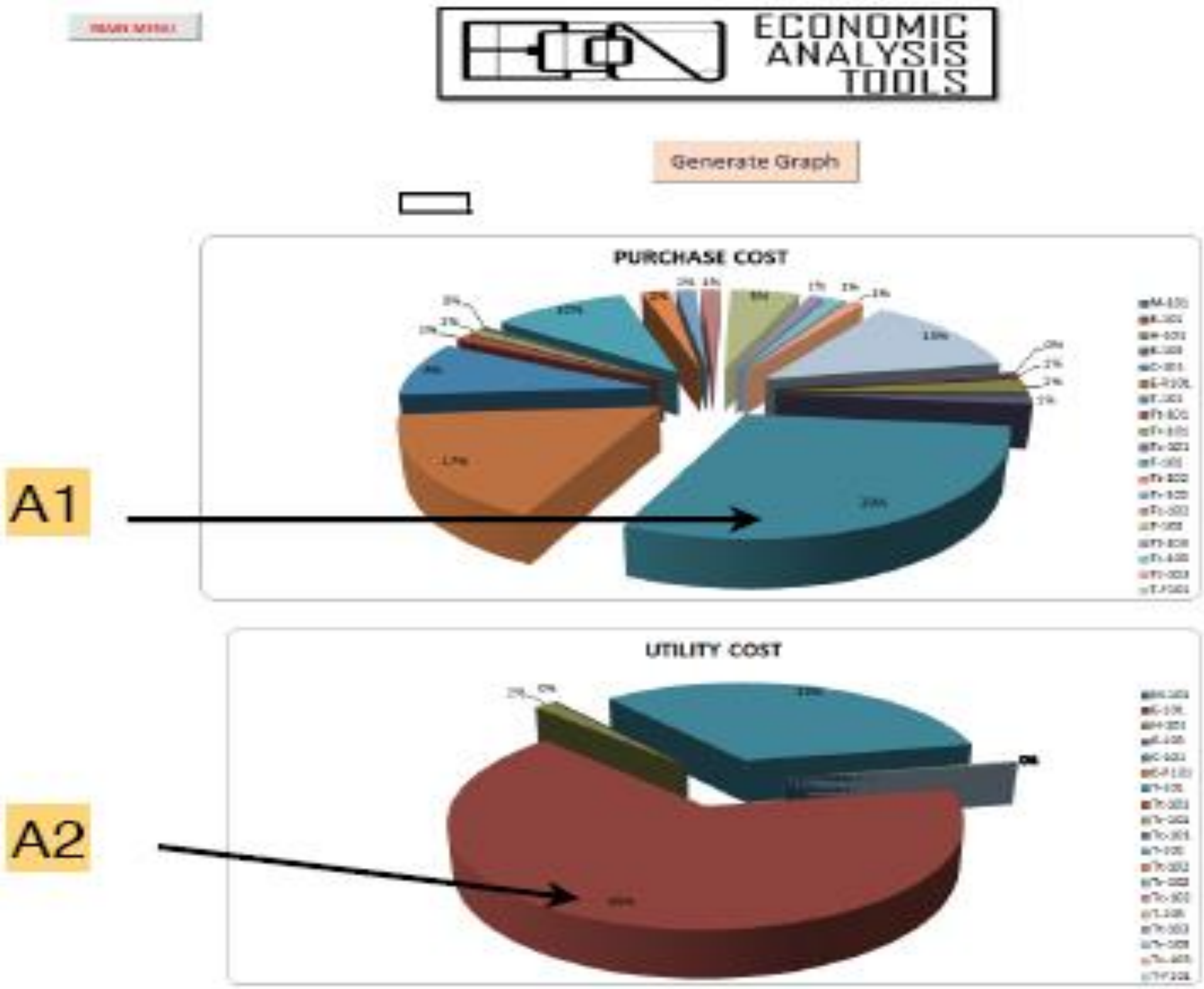
Economic Evaluation				
Year	-2	-1	0	1
Production Capacity				100%
All Money				
Land	$ -			
Fixed Capital Investment	$ (2,588,301.50)	$ (3,734,549.31)	$ (1,131,568.44)	
Working Capital Investment			$ (1,316,355.78)	
Total Capital Investment	$ (2,588,301.50)	$ (3,734,549.31)	$ (2,447,924.22)	
Start-up Expense				$ (745,441.92)
Annual Sales				$ 31,246,227.45
Total Product Cost				$ (31,917,185.71)
Depreciation Factor				7%
Depreciation				$ 532,245.53
Gross Profit				$ (884,154.65)
Net Profit				$ (884,154.65)
Total Annual Cash Flow	($2,588,301.50)	($3,734,549.31)	($2,447,924.22)	($1,097,351.04)
Cumulative Cash Flow	$ (2,588,301.50)	$ (6,322,851.00)	$ (8,770,775.00)	$ (9,868,126.00)
Annual End of Year Cash Flows and Discounting				
NPV				
Present Worth Factor	1.3225	1.15	1	0.869565217

ECON Software Economic Analysis



Sensitivity analysis

ECON Software Economic Analysis



Economic Analysis