CHAPTER II
LITERATURE REVIEW

2.1 Biodiesel

Biofuels are drawing increasing attention worldwide as substitutes for petroleum-derived transportation fuels to help address energy cost, energy security and global warming concerns associated with liquid fossil fuels. The term biofuel is used here to mean any liquid fuel made from plant material that can be used as a substitute for petroleum-derived fuel. Biofuels can include relatively familiar ones, such as ethanol made from sugar cane or diesel-like fuel made from soybean oil, to less familiar fuels such as dimethyl ether or Fischer-Tropsch liquids (FTL) made from lignocellulosic biomass.

Biodiesel is a diesel replacement fuel for use in diesel engines. It is manufactured from plant oils such as soybean, tonseed or canola, recycled cooking greases or oils or animal fats. Because plants produce oils from sunlight and air, and can do so year after year on cropland, these oils are renewable. Animal fats are produced when the animal consumes plants or animals, and these too are renewable. Used cooking oils are mostly plant based, but may also contain animal fats. Used cooking oils are both recycled and renewable. The biodiesel manufacturing process converts oils and fats into chemicals called long-chain mono-alkylesters, or biodiesel. These chemicals are also referred to as fatty acid methyl esters (FAME).

For example, 100 pounds of oil or fat are reacted with 10 pounds of a short-chain alcohol which usually is methanol in the presence of a catalyst which usually is sodium hydroxide (NaOH), potassium hydroxide (KOH) and sodium chloride (NaCl) to form 100 pounds of biodiesel and 10 pounds of glycerol. Glycerol is a sugar, and is a co-product of the biodiesel process.

The regulations enable animal fats, animal oils or vegetable oils that have been in contact with animal proteins or have been extracted from foods containing ABPs and are no longer intended for human consumption to be processed into biodiesel in an approved plant.

2.2 Production of Biodiesel

Biodiesel is produced from vegetable oils or animal fats and an alcohol, through a transesterification reaction. This chemical reaction converts an ester (vegetable oil or animal fat) into a mixture of esters of the fatty acids that makes up the oil. Biodiesel is obtained from the purification of the mixture of fatty acid methyl esters (FAME). A catalyst is used to accelerate the reaction which most is NaOH, KOH and $NaOCH_3$. According to the catalyst used, transesterification can be basic, acidic or enzymatic, which is the method mostly used in industrial. A generic transesterification reaction is presented below.

$$RCOOR' + R''OH \leftrightarrow R'OH + RCOOR''$$

RCOOR' indicates an ester, R''OH is an alcohol, R'OH is another alcohol (in this case it is glycerol), RCOOR'' an ester mixture and a catalyst:

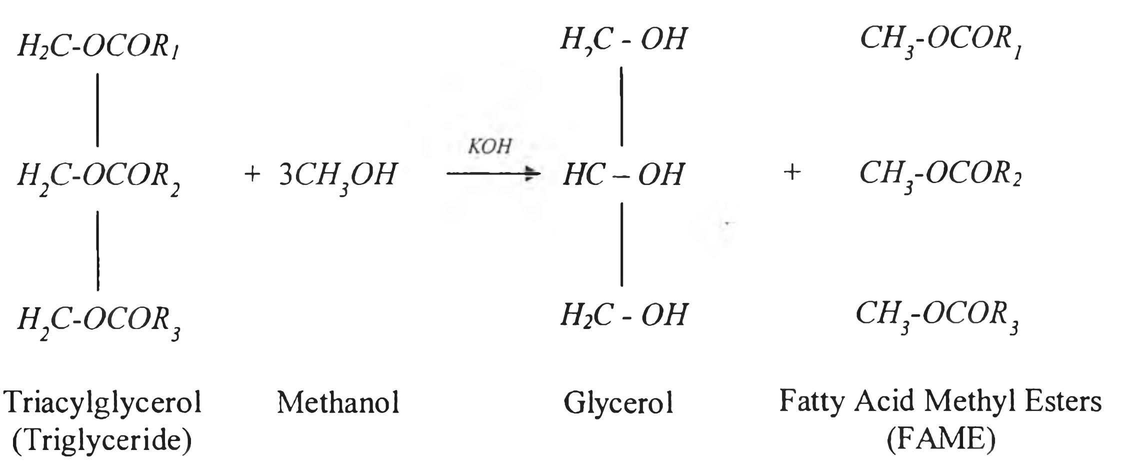

Figure 2.1 Basic transesterification reaction with methanol.

When methanol is the alcohol used in the transesterification process, the product of the reaction is a mixture of methyl esters as shown in Figure 2.1; similarly, if ethanol were used, the reaction product would be a mixture of ethyl esters ash shown in Figure 2.2. In both cases, glycerol will be the co-product of the reaction.

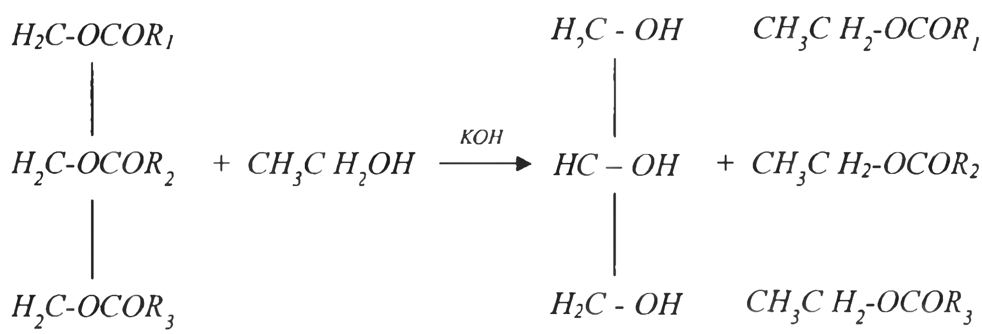

Figure 2.2 Basic transesterification reaction with ethanol.

Although transesterification is the most important step in biodiesel production since it originates the mixture of esters, additional steps are necessary to obtain a product that complies with international standards. Once the chemical reaction is completed and the two phases (mix of esters and glycerol) are separated, the mix of methyl esters have to be purified to reduce the concentration of contaminants to acceptable levels. These include remnants of catalyst, water and methanol.

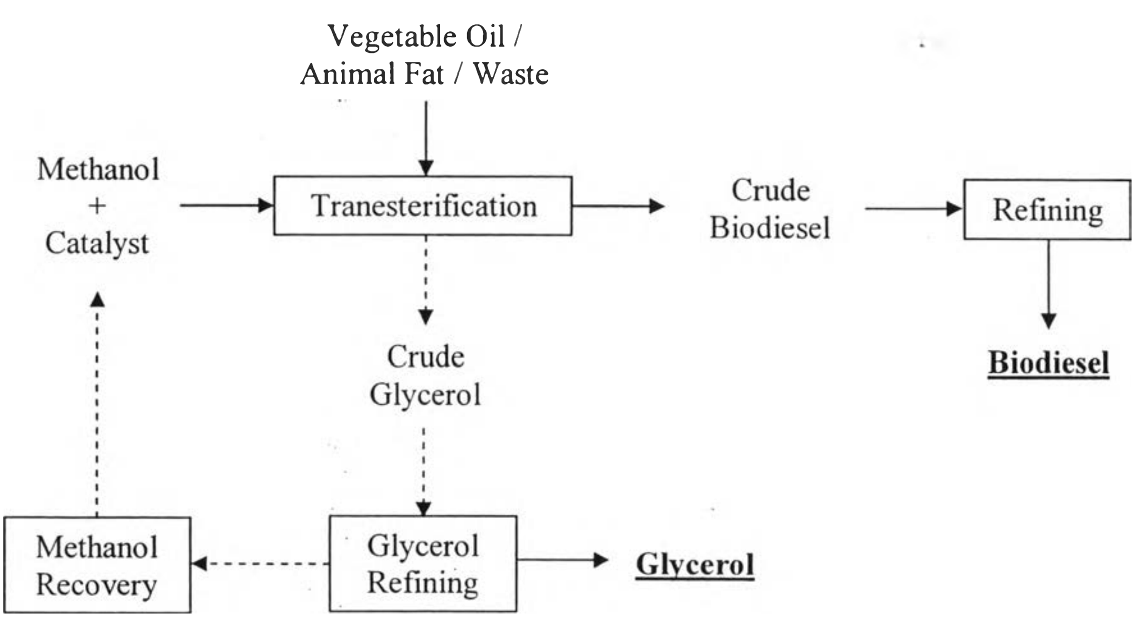

Figure 2.3 Basic biodiesel production process.

Biodiesel production process is shown in Figure 2.3, it evolves from a cottage industry to become a viable alternative transportation fuel, there will be a growing need to find new value-added uses fir the glycerol waste. This presents opportunities for industry to optimize or transform the process to increase efficiencies and reduce or reuse wastes. Numerous alternative uses of glycerol are currently being investigated and converted to commodity chemicals such as propylene glycerol, propionic acid, and isopropanol. Also waste glycerol can also convert into fertilizers and as extenders in animal feeds (Johnson and Taconi, 2007).

Tranesterification reaction can be alkali-catalyzed, acid-catalyzed or enzyme-catalyzed. The first two types have received the greatest attention. For enzyme-catalyzed, it requires much longer reaction time than alkali-catalyzed and acid-catalyzed (Nelson *et al.* 1996; Watanabe *et al.*, 2001)

2.2.1 Alkali-catalyzed System

Freedman *et al.* (1984) studied about alkali-catalyzed tranesterification on laboratory scale and 6:1 molar ratio of alcohol to soybean oil were recommended for this reaction. After the reaction, Karaosmanoglu *et al.* (1996) reseached for separation techniques to purify biodiesel product from other products. Washing with 50°C water was the best way to get 99% purity and 86% yeild of biodiesel product.

For commercial scale, alkali-catalyzed tranesterification process to produce methyl esters processed under high pressure for 90 bar and high temperature (240 °C) (Kreutzer, 1984). The process mainly consisted of a reactor for tranesterification process, methanol and glycerol column. One limitation to the alkali-caltalyzed process is its sentitivity to purity of reactants, water and free fatty acids. Liu (1994) and Basu and Norris (1996) found that water could cause ester saponification under alkaline conditions. Also free fatty acids can react with alkali catalyst to produce water and soaps. This soap is the cause for formation of emulsion which it is hard to recovery downstream and purify biodiesel.

2.2.2 Acid-catalyzed System

Acid-catalyzed tranesterification has been largely ignored due to experiment from Freedman *et al.* (1984). It showed that using 1 %wt conc. sulfuric acid at 65 °C and molar ratio of 30:1 methanol to oil took 69 hrs to obtain more than 90 % oil conversion to methyl esters. Also Canakci and Gerpen (1999) investigated the effects of the molar ratio of alcohol to soybean oil. It was found that increased ester conversion could be obtained at increased molar ratios of alcohol to oil, increaed reaction temperatures, concentrations of sulfuric acid and reaction times.

Despite its slow reaction rate, the acid-catalyzed process have benefits with respect to its independence from free fatty acid content and the consequent absence of a pretreatment step. These advantages favour the use of the acid-catalyzed process when using waste cooking oil as the raw material. Acid catalyst ususally are sulphuric acid, phosphoric acid, and hydrochloric acid.

2.3 Biodiesel Waste

In biodiesel production, it does not result in a lot of waste. It depends on process and feedstock used. Typical wastes that produced from biodiesel process are glycerol, unused catalyst, and wastewater.

2.3.1 Glycerol

Glycerol that comes out of the biodiesel process is laden with methanol and caustic chemicals. Glycerol normally is not a hazardous waste but it is probably the worst biodiesel waste product. The real problem with glycerol is that it is hard to process without investing a lot of money in expensive equipment. Glycerol has very high activation energy resulting in auto-ignition temperature of 370 °C as compared to 210 °C and 280 °C for kerosene and gasoline, respectively (DIPPR project, 2005). Pure glycerol is also contain highly viscous, 1030 cP at 22°C, making it difficult to pump and atomize. The structure of glycerol is shown in Figure 2.4.

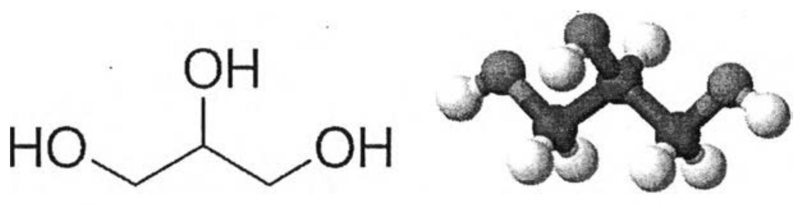

Figure 2.4 Structure of glycerol contains three carbon atoms, each of which has hydroxyl group bound to it.

Glycerol contains a lot of unrecovered MeOH to make it ignitable or enough catalyst to make it corrosive. Most of facilities have to take care if MeOH levels in glycerol are high, because it still is a hazardous material. The same principle applies to corrosiveness caused by excess catalyst. Also glycerol has a very high biochemical oxygen demand. While this does not make it a hazardous waste, it does present a threat to streams and lakes if disposed upon the land. This could also disrupt the wastewater treatment system's biological process into which the waste glycerin is disposed.

Waste glycerol is produced in large amount during transesterification process to produce biofuels and new value-added uses for this waste are needed to optimize process efficiencies and reduce the impact of waste disposal. Waste glycerol also can be used in boilers to produce process steam and co-generate electricity with the added advantages of optimizing energy integration, eliminating transportation costs and displacing the need for fossil fuels.

Gómez-Siurana *et al.* (2013) studied about glycerol combustion. The result showed that crude glycerol had a single fast weight loss at temperature from 200 °C to 220 °C. This result concluded that glycerol could completely removed at this temperature.

2.3.2 Unused Catalyst

Any catalyst which used in tranesterification process has a pH greater than or equal to 12.5 for caustic or less than or equal to 2 for acidic, it is considered to be hazardous waste. When tranesterificaiton process is finished, the remaining catalyst has to be eliminated by using neutralization to change the catalyst into form of salt and come out with other wastes.

2.3.3 Wastewater

After biodiesel is made, it is often washed with waster to remove contaminants and wastes from process. The amount of wastewater can be reduced by adding an acid to the biodiesel to split soap. In large scale of production, soap and remaining catalyst which removed from the water are added to glycerol and sold to a glycerol refiner. The wastewater can also be used for farm irrigation if it does not contain methanol.

2.4 Separation of Organic and Inorganic Compounds

2.4.1 Combustion

Combustion is the process which heat up the source. It requires three factors to complete this process, heat source, oxygen and fuel. For example, wood is the fuel and the surrounding air provides the oxygen, and a match or lighter can ignite the fire. Increasing any of these elements will increase the fire's intensity, while eliminating any one of them will cause the process to stop, for example, the oxygen can no longer get to the heat and fuel, and it goes out.

Fuel is the substance that burns during the combustion process. All fuels contain chemical potential energy; this is the amount of energy that will be released during a chemical reaction. How much energy a substance releases as it burns is called the heat of combustion. Each fuel has a specific energy density, or how many megajoules (MJs) of energy are produced per kilogram (kg) of the substance.

A wide variety of substances can be used as fuels, but hydrocarbons are some of the most common. These include methane, propane, gasoline, and jet fuel, to name just a few; all fossil fuels, including coal and natural gas, are hydrocarbons. Other substances that are commonly used as fuels include hydrogen, alcohol, and biofuels, like wood.

During combustion, fuel is turned into heat and exhaust. When gasoline burns, for example, it produces water (steam), carbon dioxide, nitrogen, carbon monoxide, and other elements. Burning can also release particulates, which are tiny particles that float in the air; those released from burning fossil fuels and wood often contribute to air pollution. Exhaust can be used for beneficial purposes, however, such as providing the thrust that pushes a rocket into the air. Most exhaust is in the form of a gas because of the heat the combustion process produces, but it can also be in liquid or solid form.

For fuel to burn in the combustion process, it must also have oxygen. The most common source is the air, which contains about 21-22 % oxygen. Other sources often know as oxidizers or oxidizing agents, include hydrogen peroxide, potassium nitrate, and many more. When an oxidizing agent is introduced to a fuel, it releases oxygen and can increase the speed at which the fire burns.

Bohon *et al.* (2010) determined component of inorganic compound in fly ash which collected from combustion of Methylated and Demethylated by using filter. Elements were determined by XRF in oxide compounds form. The result was shown in Table 2.1.

Table 2.1 Fly Ash elemental analyses (%wt)

	Methylated	Demethylated
Na	57.98	65.50
Mg	0.05	0.10
P	6.33	8.55
S	1.37	2.12
Cl	1.33	2.07
K	2.01	2.19
Ca	0.47	0.66
Fe	0.16	0.20
Cu	0.02	0.01
Zn	1.08	0.96
Trace	2.57	2.77
Undetermined	26.63	14.87

The major elements included Na, P, Cl and K. Sodium had the most weight because it was used as NaOH catalyst during transesterification process. The other major elements such as P, Cl and K were typical of biofuels.

2.4.2 Evaporation and Crystallization

Evaporation is an operation used to remove a liquid from a solution, suspension, or emulsion by boiling off some of the liquid. It can be defined as the process where liquid water is transformed into a gaseous state. Evaporation can occur only when water is available. It also requires that the humidity of the atmosphere is less than the evaporating surface (at 100 % relative humidity there is no more evaporation). The evaporation process requires large amounts of energy.

In general that the vapor pressure of a liquid varies directly with temperatures. When liquid is heated, it begins to boil as the liquid turns to vapor which forming bubbles that separate from liquid surface. Vapor pressure of the liquid becomes equal to ambient pressure, counteracting it or pushing it away. Thus the liquid is boiling.

The normal boiling point is that temperature which the vapor pressure of the liquid equals to standard atmosphere (760 mmHg). As the pressure above a liquid at room temperature is decreased, by vacuum pump, the liquid boiling point will also decrease.

For the water the relation between vapor pressure and temperature is shown in Figure 2.5. The boiling point of water is 100°C when locates in ambient pressure (760 mmHg). If pressure is decreased, boiling point of water will be decreased also.

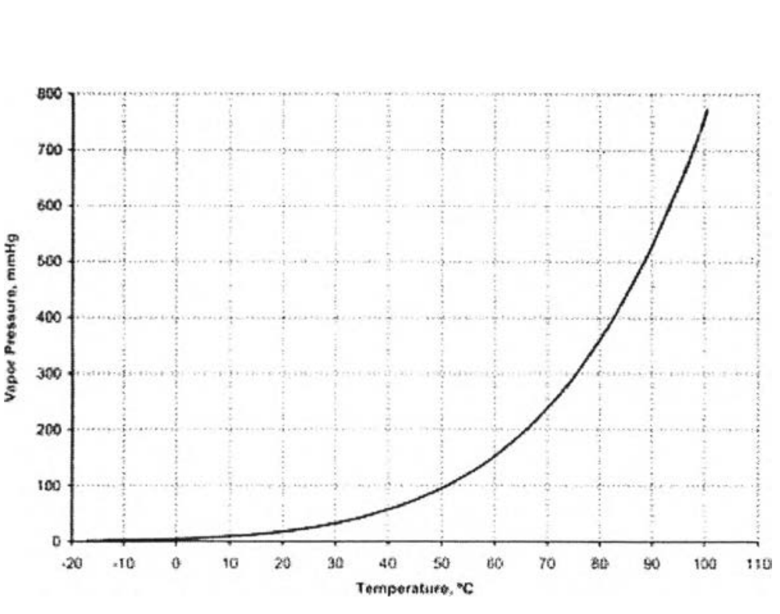

Figure 2.5 Boiling point vs vapor pressure for water as a function of vapor pressure (mmHg) and temperature (°C).

The rotary evaporator and vacuum pump take part in this process. The part of rotary evaporator is shown in Figure 2.6, it is used for removing a solvent well below its boiling point, leaving behind the less-volatile material that was dissolved in that solvent.

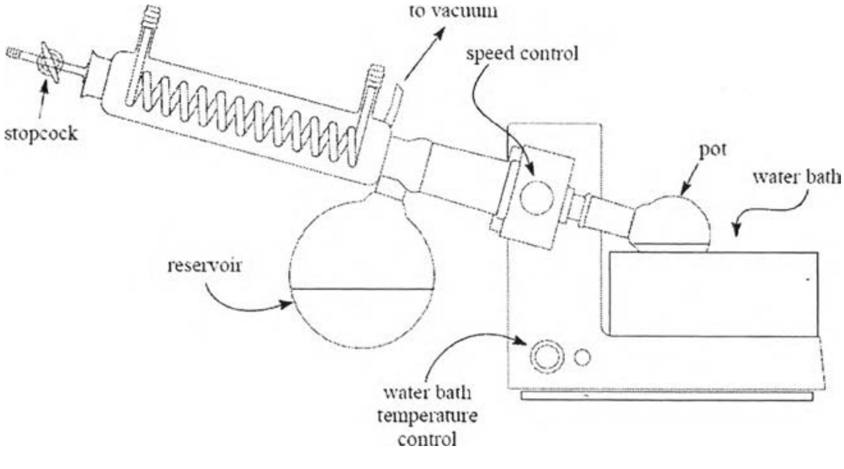

Figure 2.6 Essential parts of laboratory rotary evaporator.

The solution is poured into pot, a round bottom flask, and put in water bath. Ideally the size of the flask should be at least twice the volume of the amount of solvent. Or the round bottom flask should be filled to no more than half its maximum volume. After that the flask need to be secured with fastener to prevent falling of the sample pot. Next, cold water is circulated through rotary evaporator into condenser coils using and pump and cooling. Then aspirator is used to adjust the pressure system to target point, in this point don't let the volatile solvent get into aspirator and check the stopcock that it is already turned at 90 deg to the glass tube to instate the vacuum. Now solvent in the pot will start to evaporate.

To keeps the solvent steadily evaporation, the flask should be rotated with appropriate rate since evaporation cools down the pot which it is put in water bath. Now the warm vapors which evaporated from the sample solvent hit a condenser coil and recondense. It creates drop of liquid at condenser coil and drop into reservoir. As long as evaporation is running, the condensed solvent will be collected in the reservoir.

2.4.3 Extraction and Alcohol Precipitation

Most of molecules carry no net charge, but some possess an electric dipole or multipole. When there is unequal sharing of electric charge between atoms within a molecule. For example, Chlorine atom in HCl, because Chlorine has more electronegative than hydrogen. It pulls hydrogen's electron toward itself and creates a permanent dipole. The higher an element electronegativity number, the greater it attracts electrons toward itself. Normally solute dissolves well in a solvent that has similar chemical structure to itself (Like dissolves like). Solute and solvent are similar in chemical to each other depends on each substance polarity. Typically, polar solutes are only dissolve in the polar solvents and non-polar solutes are only dissolved in non-polar solvents. O'Neil (2006) found that a very polar solute such as urea is very soluble in highly polar water, less soluble in polar MeOH and almost insouble in non-polar solvents such as chloroform and ether.

This method is commonly used in DNA and RNA precipitation by using ethanol. Because ethanol dielectric constant ($\varepsilon = 24$) is lower than water ($\varepsilon =$

80). Ethanol will decrease the dielectric constant of solution containing nucleic acid and monovalent cations. Then attraction force between the cations and the negatively charged nucleic acid is increased, due to the resistrance of the solvent electric field is decreased to create interaction.

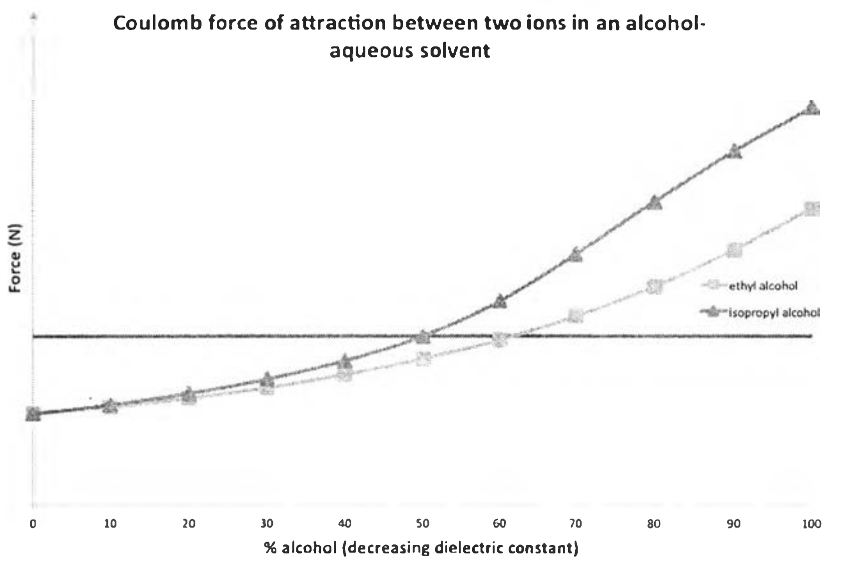

Figure 2.7 Absolute force of attraction between two opposing ions in either alcohol or isopropapnol aqueous solvent.

However isopropanol can also be used in precipitation because it has lower dielectric constant (ε = 20) and lower carbon atom than ethanol. Alcohol group (-OH) has less net effect on isopropanol than it does on ethanol and its effect decreases as the size of C-H bond increases. Figure 2.7 shows that isopropanol requires half of volume to ethanol to precipitate at the same efficiency.

2.5 Economic Evaluation

Economic evaluations involve the identification, measurement and valuation, and then compare the cost and benefit. In economic evaluations, the costs and consequences of alternative interventions or scenarios are compared to determine the best use of the remaining resources. Economic evaluations differ according to their scope and objective. Normally, economists prefer the widest possible of social perspective for example how to use scarce resource to make the most benefit. However, there are many factors that need to be concerned such as restricting the perspective to health outcomes, waste disposal after the process and waste treatment system (for industrial process).

Full economic evaluations are rarely completed. One reason is that economic evaluations are resource intensive and typically require a high level of research skills. It is important to undertaking this study. Full economic evaluation should be undertaken after an initial analysis to estimate the benefit of the study. The one factor which need to concern in economic evaluation is solid waste disposal, it differ from air and water pollutants because these wastes remain at the point of origin until a decision is made to collect and dispose of them. There are several means of disposals available including recycling, chemical conversion, incineration, pyrolysis and landfill. Federal regulations, local conditions and overall economics generally determine which method is the most acceptable.

Recycling and chemical conversion, it is a factor often overlooked in waste disposal. Specific chemicals may often be recovered by using stripping, distillation, leaching, or extraction. Valuable solids such as metals and plastics can be recovered by using magnets, electrical conductivity, floatation, or hand picking. These wastes can be converted to saleable products or innocuous materials that can be safely disposed. Hydrogenation of organics is usually used to produce fuels, acetylation of waste cellulose to form cellulose acetate, or nitrogen and phosphorus enrichment of biodiesel wastes can be used to produce fertilizer.

Incineration is the oxidation of solid, liquid, or gaseous combustible wastes to final products of carbon dioxide, water, and ash is knows as incineration. Since sulfur and nitrogen in wastes will produce their oxides, they should not be combusted without considering their effect on air quality. Multiple-chamber incinerator, rotary kilns, and multiple-hearth furnaces are most widely used in industrial waste disposal. Incineration has advantage if disposal sites are not available. This process can be adjusted to handle a variety and quantity of wastes. Heat recovery of the process can use in steam generation to reduce operating costs, and save on pollution-control equipment. The residue is also a small fraction of original weight and volume of the waste and may be acceptable for landfill.

Pyrolysis is the most acceptable option to recycle waste. Wastes are heated in air-free chamber at temperature at 1,650 °C. This technique provide several advantages to incineration such as fewer air pollution problems and lower capital costs than incineration.

Landfill is basically a simple technique that involves spreading and compacting solid wastes into cells that are covered each day with soil. The problems in landfill are the production of leachates which they may contaminate the surrounding ground and water area. Also the potential hazards associated with the accumulation of flammable gases produced during the degradation of the waste material.

2.5.1 Comparison of Different Processes

It is necessary to determine the most suitable process for obtaining a desired product. Several different manufacturing methods which making the same material, can be different processes. So they have to be compared in order to select the best one that suited to the existing conditions.

The comparison can be accomplished through the development of complete designs. However in many cases, one or two of the possible processes can be eliminated by weighted comparison of essential variable factors, and detailed design calculations for each process may not be required. The following factors should be considered in a comparison of this type (Peters *et al.,* 2013).

2.5.1.1 Technical Factors

Process flexibility, Continuous operation, Special controls involved, Commercial yields, Technical difficulties involved, Energy requirements, Special auxiliaries required, Possibility of future developments, and Health and safety hazards involved.

2.5.1.2 Raw Materials

Present and future availability, Process required, Technical difficulties, and Materials handling problems.

2.5.1.3 Waste Products and By-products

Amount produced, Value, Potential markets and uses, Manner of discard, and Environmental aspects.

2.5.1.4 Equipment

Availability, Materials of construction, Initial costs, Maintenance and installation costs, Replacement requirements, and Special designs.

2.5.1.5 Plant Location

Amount of land required, Transportation facilities, Proximity to markets and raw-material sources, Availability of service and power facilities, Availability of labor, Climate, and Legal restrictions and taxes.

2.5.1.6 Costs

Raw materials, Energy, Depreciation, Other fixed charges, Processing and overhead, special labor requirements, Real estate, Patent rights, and Environmental controls.

2.5.1.7 Time Factor

Project completion deadline, Process development required, Market timeliness, and Value of money.

2.5.1.8 Process Considerations

Technology availability, Raw materials common with other processes, Consistency of product within company, and General company objectives.

2.5.2 Estimation of Capital Investment

Before an industrial plant can be put into operation, a sum of capital must be supplies to purchase and install the necessary equipment and instrument. Land and service facilities must be obtained, and the plant must be completely built with all piping, controls, and services. However, it is necessary to have enough money available for the payment of expenses involved in the plant operation. The capital needed to be supply the necessary manufacturing and plant facilities which called fixed capital investment, while that necessary for the operation of the plant is termed the working capital. Total capital investment is the sum of fixed capital investment and working capital.

required for construction overhead and for all plant components that are not directly related to the process operation is mark as non-manufacturing fixed capital investment. These plant components include the land, processing buildings, administrative, and other officers, warehouses, laboratories, transportation, shipping, and receiving facilities, utility and waste disposal facilities, shops, and other permanent parts of the plant. The construction overhead cost consists of field office and supervision expenses, home office expenses, engineering expenses, miscellaneous construction costs, contractor's fees, and contingencies. In some cases, construction overhead is proportioned between manufacturing and non-manufacturing fixed capital investment.

Working capital for an industrial plant consists of the total amount of money invested in raw materials and supplies carried in stock, finished products in stock and semi-finished products in the process of being manufactured, accounts receivable, cash kept on hand for monthly payment of operating expenses, such as salaries, wages, and raw-material purchases, accounts payable, and taxes payable. The raw materials usually design for 1 month supply at delivered price. Also finished products in stock have a value for the total manufacturing cost for 1 month's production. Due to 30 days payment period, the working capital requires accounts receivable in production cost for 1 month of operation.

Table 2.2 Breakdown of fixed capital investment items for a chemical process

Fixed Capital Investment	Direct Costs	Purchased equipment	All equipment listed on a flow sheet
			Spare parts and non-installed equipment spares
			Surplus equipment, supplies, and equipment allowance
			Inflation cost allowance
			Freight charges
			Taxed, insurance, duties
			Allowance for modifications during startup
		Purchased equipment installation	Installation of all equipment listed on complete flow sheet
			Structural supports, insulation, paint
		Instrumentation and controls	Purchase, installation, calibration, computer tie-in
		Piping	Process piping-carbon steel, alloy, cast iron, lead, lined, aluminum, copper, ceramic, plastic, rubber, reinforced concrete
			Pipe hangers, fittings, valves
			Insulation-piping, equipment
		Electrical equipment and materials	Switches, motors, conduit, wire, fittings, feeders, grounding, instrument and control wiring, lighting, panels
			Electrical materials and labor
		Building (include services)	Process buildings-substructures, superstructures, platforms, supports, stairways, ladders, access ways, cranes, monorails, hoists, elevators
			Auxiliary building-administration and office, medical or dispensary, cafeteria, garage, product warehouse, parts warehouse, guard and safety, fire station, personnel building, shipping office and platform, research laboratory, control laboratory
			Maintenance shop-electric, piping, sheet metal, machine, welding, carpentry, instrument
			Building services-plumbing, heating, ventilation, dust collection, air conditioning, building lighting, elevators, escalators, telephones, intercommunication systems, painting, sprinkler systems, fire alarm

Table 2.2 Breakdown of fixed capital investment items for a chemical process (Cont.)

Fixed Capital Investment	Direct Costs	Yard improvements	Site development-site clearing, grading, roads, walkways, railroads, fences, parking areas, wharves and piers
		Service facilities	Utilities-steam, water, power, refrigeration, compressed air, fuel, waste disposal
			Facilities-boiler plant incinerator, wells, river intake, water treatment, cooling towers, water storage, electric substation, refrigeration plant, air plant, fuel storage, waste disposal plant, environmental controls, fine protection
			Non-process equipment-office furniture and equipment, cafeteria equipment, safety and medical equipment, shop equipment, automotive equipment, laboratory equipment, locker-room equipment, garage equipment, fire extinguishers, fire engines, loading stations
			Distribution and packaging-raw-material and product storage and handling equipment, product packaging equipment, blending facilities, loading stations
		Land	Survey and fees, and property cost
	Indirect Costs	Engineering and supervision	Engineering costs-administrative, process, design and general engineering, drafting, cost engineering, procuring, expediting, reproduction, communications, scale models.
			Engineering supervision and inspection
		Construction expenses	Construction, operation and maintenance of temporary facilities, offices, roads, parking lots, railroads, electrical, piping, communications, fencing
			Construction tools and equipment
			Construction supervision, accounting, timekeeping, purchasing, expediting
			Warehouse personnel and expense, guards
			Safety, medical, fringe benefits
			Permits, field tests, special licenses
			Taxes, insurance, interest
		Contractor's fee	
		Contingency	

2.5.2.1 Purchased Equipment

The cost of purchased equipment is the basis of several predesign methods for estimating capital investment. Sources of equipment prices, methods of adjusting equipment prices for capacity, and methods of estimating auxiliary process equipment are therefore essential to the estimator in making reliable cost estimates.

The various types of equipment can often be divided conveniently into processing equipment, raw materials handling and storage equipment, and finished products handling and storage equipment. The most accurate method for determining process equipment costs is to quote the price to fabricators or supplier. Another method is the prices from previous orders, which the prices from past have to be update to present by using cost index and logarithmic relationship knows as the six-tenth-factor rule (in case of the capacity of equipment is changed).

2.5.2.2 Purchased Equipment Installation

The installation of equipment involves costs for labor, foundations, supports, platforms, construction expenses, and other factors directly related to the erection of purchased equipment. The total installation can vary from 25 to 55 percent of the purchased equipment cost.

2.5.2.3 Insulation Cost

These factors put into estimation when process is designed for very high or very low temperature operation. Expenses for equipment insulation and piping insulation are composed of equipment installation costs and piping costs. The insulation costs are approximately 8 to 9 percent of purchased equipment cost or 2 percent of total capital investment.

2.5.2.4 Instrumentation and Controls

Instrument costs, installation-labor costs, and auxiliary equipment and materials are the part of instrumentation and controls. These expenses are sometime combined with general equipment and depended on the amount of control required in the designed process. For normal solid-fluid chemical plant, these costs are approximately 6 to 30 percent of the purchased equipment cost, 3 percent of total capital investment.

2.5.2.5 Piping

Piping cover labor, valves, fittings, pipe, supports, and other items that used for complete erection of all piping used directly in the process are added into piping cost. This includes raw material, intermediate product, finished product, steam, water, air, sewer, and other process piping. Estimation methods involve some degree of piping take off from detailed drawings and flow sheets or using factor technique when neither drawings nor flow sheets are available. Factoring by percent of purchased equipment cost and percent of fixed capital investment is based on information gained from piping cost for similar previously installed chemical process plant. Piping cost is about to 80 percent of purchased equipment cost or 20 percent of tied-capital investment.

2.5.2.6 Electrical Installation

The cost for electrical installation mainly comes from installation labor and material for power and lighting. In chemical plant, it amounts approximately 10 to 15 percent of purchased equipment or 3 to 10 percent of the fixed capital investment.

2.5.2.7 Buildings (Including Services)

These construction costs consist of worker, materials, and supplies that need for building construction. Cost for plumbing, heating, lighting, ventilation, and similar building services are also the part of buildings cost.

2.5.2.8 Yard Improvements

Yard improvement costs, for chemical plant, are approximately 10 to 20 percent of purchased equipment costs or 2 to 5 percent of fixed capital investment. These expenses include fencing, grading, roads, railroad sidings, and landscaping.

2.5.2.9 Service Facilities

Utilities for supplying steam, water, power, compressed air, and fuel are part of the service facilities of an industrial plant. Waste disposal, fire protection, and miscellaneous service items, for example, shop, first aid, and cafeteria equipment require capital investments which are include under the general heading of service facilities cost. In chemical plant, service facility costs range from

40 to 100 percent of the purchased equipment cost or 8 to 20 percent of fixed capital investment.

2.5.2.10 Land

These costs vary by cost factor from rural district and industrialized area. Cost for land can amount from 4 to 8 percent of purchased equipment cost or 1 to 2 percent of total capital investment. Because the value of land usually does not decrease with time, this cost should not be include in the fixed capital investment when estimating certain annual operating costs, such as depreciation.

2.5.2.11 Engineering and Supervision

These expenses compose of construction design and engineering, drafting, purchasing, accounting, construction and cost engineering, travel, reproductions, communications, and home office expense including overhead constitute the capital investment for engineering and supervision. They approximately amount 30 percent of purchased equipment cost or 8 percent of the total direct costs of the process plant.

2.5.2.12 Construction Expense

Another expense which involved in indirect cost, is for constriction of field expense and includes temporary construction and operation, construction tools and rentals, home office personnel that located at the construction site, construction payroll, travel and living, taxes and insurance, and other construction overhead.

2.5.2.13 Contractor's Fee

The contractor's fee varies for different situations, but it can be estimated to be 2 to 8 percent of the direct plant cost or 1.5 to 6 percent of the fixed capital investment.

2.5.2.14 Contingencies

This factor is included in an estimate of capital investment to compensate for unpredictable activities, such as storms, floods, price changes, small design changes, errors in estimation, and other foreseen expenses. Contingency cost ranges from 5 to 15 percent of direct and indirect plant costs.

Table 2.3 Estimation of capital investment costs

Direct Costs : 70-85 % of Fixed Capital Investment	
1	Equipment + installation + instrument + piping + electrical + insulation + painting : 50-60 % of fixed capital investment 1.1 Purchased equipment : 15-40 % of fixed capital investment 1.2 Installation (Insulation and painting included) : 25-55 % of purchased equipment cost 1.3 Instrumentation and controls (Installed) : 6-30 % of purchased equipment cost 1.4 Piping (Installed) : 10-80 % of purchased equipment cost 1.5 Electrical (Installed) : 10-40 % of purchased equipment cost
2	Building, process and auxiliary : 10-70 % of purchased equipment cost
3	Service facilities and yard improvements : 40-100 % of purchased equipment cost
4	Land : 1-2 % of fixed capital investment or 4-8 % of purchased equipment cost
Indirect Costs : 15-30 % of Fixed Capital Investment Cost	
1	Engineering and supervision : 5-30 % of fixed capital investment
2	Construction expense and contractor's fee : 6-30 % of direct costs
3	Contingency : 5-15 % of fixed capital investment
Fixed capital investment = Direct costs + Indirect costs	
Working capital : 10-20 % of total capital investment	
Total capital investment = Fixed capital investment + Working capital	

2.5.3 Estimation of Total Product Cost

Determination of the necessary capita; investment is only one part of a complete cost estimation. Another important part is the estimation of costs for operating the plant and selling the products. These costs can be grouped under the general heading of total product cost which divided into the categories of manufacturing costs and general expenses. Manufacturing costs are also known as operating of production costs and it depends on direct and indirect costs.

Table 2.4 Cost involved in total product cost for a typical chemical process plant

Total Product Cost	Manufacturing Costs	Direct production costs	Raw materials
			Operating labor
			Operating supervision
			Utilities
			Maintenance and repairs
			Operating supplies
			Laboratory charges
			Patents and royalties
		Fixed charges	Depreciation
			Taxes (property)
			Insurance
			Rent
		Plant overhead costs	Medical
			Safety and protection
			General plant overhead
			Payroll overhead
			Packaging
			Restaurant
			Recreation
			Salvage and control laboratories
			Plant superintendence
			Storage facilities
	General Expenses	Administrative expenses	Executive salaries
			Clerical wages
			Engineering and legal costs
			Office maintenance
			Communications
		Distribution and marketing expenses	Sales offices and salesman expenses
			Shipping
			Advertising
			Technical sales service
			Research and devilment
			Financing
			Gross-earnings expense

Table 2.2 shows the checklist which is typical of the cost involved in chemical processing operations. Total product costs are commonly calculated on one of three bases, namely, daily basis, unit of product basis, or annual basis. The annual cost basis is the best choice for estimation of total cost because the effect of seasonal variations is smoothed out, plant on-stream time or equipment operating factor is considered, it permits more rapid calculation of operating costs at less than full capacity, and it provides a convenient way of considering infrequently occurring but large expenses such as annual turnaround costs in a refinery.

The best source of information for use in total product cost estimates is data from similar or identical projects. However the different factors must be considered and adjusted properly.

2.5.3.1 Manufacturing Costs

All expenses which directly connected with the manufacturing operation or the physical equipment of a process plant are included in the manufacturing costs. These expenses are divided into three classifications, Direct production costs, Fixed charges, and Plant-overhead costs..

2.5.3.1.1 Direct Production

Raw Material is the one of the major costs for production. The amount of raw materials has to be supplied in term of unit of time or per unit of product, and it can be determined from process materials balance. Normally, the raw materials can be recovered to reduce the amount of new starting material. However, the cost should be based on the amount of raw materials actually consumed from overall materials balances. Transportation charges are included in the raw material costs, and these charges should be based on the form which the raw materials are to be purchased for use in the final plant. The cost of raw materials depends on different types of plants and it approximately ranges from 10 to 50 percent of total product cost for chemical plants.

The amount of direct supervisory and clerical labor is always required for a manufacturing operation. The necessary amount of this type of labor is related to total operating labor, complexity of operation, and product quality standards. It is 15 percent of operating labor.

The cost of utilities, for example steam electricity, process and cooling water, compressed air, natural gas, and fuel oil, depends on the amount of consumption, plant location, and source. The cost can be different due to different area or country. The required utilities can sometimes be estimated in preliminary cost analysis from available information about similar operations. The utilities may be purchased at predetermined rates from an outside source, or the service may be available from within the company. The utility costs for chemical process approximately are about 10 to 20 percent of total product cost.

Maintenance and repairs are necessary if plant want to be kept in efficient operation. These costs compose of labor, materials, and supervision. Annual costs for equipment maintenance and repairs can range from 2 percent to 20 percent of equipment cost. Charges of this type for buildings average 3 to 4 percent of the building cost. In the process industries, the total plant cost per year for maintenance and repairs is about to a6 percent of the fixed-capital cost investment. Operating rates less than plant capacity, the maintenance and repair cost normally is 85 percent of that at 100 percent capacity for a 75 percent operating rate, and 75 percent of that at 100 percent capacity for a 50 percent operating rate.

Operating supplies generally are needed to keep the process functioning efficiently. These expenses, for example, chars, lubricants, test chemicals, and custodial supplies, cannot be considered as raw materials. The annual cost for this type of supplies is about 15 percent of the total cost for maintenance and repairs.

These laboratory charges are for control of operations and for product-quality control which covered in this manufacturing cost. This expenses are generally calculated by estimating the employee-hours involved and multiplying this by the appropriate rate. Or they are approximately 10 to 20 percent of the operating labor.

Most of industrial processes are covered by patents, and it may be necessary to pay a set amount for patent rights or a royalty based on amount of material produced. These costs are usually amortized over the legally protected life of patent. Although a rough approximation of patent and royalty costs for patented processes is 0 to 6 percent of the total product cost.

Costs for catalysts and solvents can be significant and depend upon the specific manufacturing processes chosen.

2.5.3.1.2 Fixed Charges

Depreciation is decrease value which occur throughout the usual life of the material possessions. This cost is a important factor to determine the amount of income tax. The Internal Revenue Service has established allowable depreciation rates based on the probable useful life of various types of equipment and other fixed items which involved in manufacturing operations. The annual depreciation rate for machinery and equipment ordinarily is about 10 percent of fixed capital investment, while buildings are usually depreciated at an annual rate of about 3 percent of initial cost.

Local taxes depend on particular locality of the plant and the regional laws. For highly populated areas, local taxes are approximately 2 to 4 percent of fixed capital investment, and 1 to 2 percent of fixed capital investment for less populated area.

In annual rented land and buildings approximately are 8 to 12 percent of the values of the rented property.

2.5.3.1.3 Plant-overhead Costs

Plant overhead costs are for hospital and medical services, general plant maintenance and overhead including safety services, payroll overhead such as pensions, vacation allowances, social security, and life insurance, packaging, restaurant and recreation facilities, salvage services, control laboratories, property protection, plant superintendence, warehouse and storage facilities, and special employee benefits. These costs also have not much affect to changing of production rate. These costs are directly related with the production operation. Most of non-manufacturing machine, equipment, and buildings for general services not part of the process are the part of plant overhead costs. For example, hospital and medical services, general engineering, safety services, cafeteria and recreation facilities, general plant maintenance and overhead. payroll overhead including employee benefits, packaging, plant protection, janitor and similar services, employment offices, distribution of utilities, shops, lighting, interplant communications and transportation, warehouses, shipping and receiving facilities.

These charges depend on operating labor, supervision, and maintenance approximately for 50 to 70 percent.

2.5.3.2 General Expenses

These general expenses may be classified as administrative expenses, distribution and marketing expenses, research and development expenses, financing expenses and gross-earning expenses.

2.5.3.2.1 Administrative Expenses

These expenses include costs for executive and clerical wages, office supplies, engineering and legal expenses, upkeep on office buildings, and general communications. Administrative costs are costs of office supplies and equipment, outside communications, administrative buildings, and other overhead items which related with administrative activities. Also the salaries and wages for officer who not participate in the main process such as administrators, secretaries, accountants, stenographers, typists, and similar workers can include into administrative cost. These expenses may be about 20 to 30 percent of operating labor.

2.5.3.2.2 Distribution and Marketing Expenses

These costs are costs for selling and distribution of various products. These costs are for salaries, wages, special equipment, research facilities, and consultant fees related to developing new ideas or improved processes.

2.5.3.2.3 Financing Expenses

Financing include the extra costs which involved in procurement. These costs are necessary for capital investment. Interest is considered to be the compensation paid for borrowed capital. A fixed rate of interest is established when the capital is borrowed in case of this amount of capital is necessary for plant investment. The borrowed capital is considered as a fixed charged. However, it is preferable to separate interest from the other fixed charges and consider as general heading of management of financing cost. Annual interest rates are about 5 to 10 percent of total value of the borrowed capital.

2.5.3.2.4 Gross-earnings Expenses

Gross-earning expenses are based on income-tax laws. These expenses are a direct function of the gross earnings made by various interests in particular company. When considering net profits, the expenses due to income taxes are extremely important, and this cost must be included as a special type of general expense. Gross earning can be determined from the minus of total income and total production cost. Due to income-tax rates, final net profit normally less than gross earnings. These income-tax rates are based on the gross earning received from all the company interests.

2.5.5.3 Distribution and Marketing Costs

These expenses can widely vary on different types of plants depend on the material which used in process, other products which sold by company, plant location, and company policies. Salaries, wages, supplies, and other expenses for sales offices, commissions, and traveling expenses for sales officer, shipping expenses, cost of containers, advertising expenses, and technical sales service are considered as distribution and marketing costs. These costs are in the range of 2 to 20 percent of the total product cost. The high figure applies to a new product or to one sold in small quantities to a large number of customers. The lower figure applies to large-volume products, for example, bulk chemicals.

2.5.5.4 Research and Development Costs

These costs include salaries and wages for all personal directly connected with this type of work, fixed and operating expenses for all machinery and equipment involved, costs for materials and supplies, direct overhead expenses, and miscellaneous costs. Research and development costs are approximately 2 to 5 percent of every sales dollar.

The economic considerations are necessary for creating new process or project. Methods for obtaining predesign cost estimates are important because the latter are extremely important for determining the feasibility of proposed investment and to compare alternative designs. However, predesign estimates are often based partially on approximate percentages or factors that are applicable to particular plant or process. Table 1 and Table 2 show the summary the predesign estimates for capital investment costs and total product costs respectively. The percentage indicated in both table give the possible ranges. These ranges should be used when the accurate information is not available.

Table 2.5 Estimation of total product cost

Manufacturing Cost = Direct Production + Fixed Charges + Plant Overhead	
1	Direct production costs : 60 % of total product cost 1.1 Raw materials : 10-50 % of total product cost 1.2 Operating labor : 10-20 % of total product cost 1.3 Direct supervisory and clerical labor : 10-25 % of operating labor 1.4 Utilities : 10-20 % of total product cost 1.5 Maintenance and repairs : 2-10 % of fixed capital investment 1.6 Operating supplies : 10-20 % of cost for maintenance and repairs, or 0.5-1% of fixed capital investment 1.7 Laboratory charges : 10-20 % of operating labor 1.8 Patents and royalties : 0-6 % of total product cost
2	Fixed charges : 10-20 % of total product cost 2.1 Depreciation : This cost depends in life period, salvage value, and method of calculation about 10 % of fixed capital investment for machinery and equipment and 2-3 % pf building value for buildings 2.2 Local taxed : 1-4 % of fixed capital investment 2.3 Insurance : 0.4-1 % of fixed capital investment 2.4 Rent : 8-12 % of rented land and building
3	Plant overhead costs : 50-70 % of cost for operating labor, supervision and maintenance, or 5-15 % of total product cost
General Expenses = Administrative Costs + Distribution and Selling Costs + Research and Development costs	
1	Administrative costs : 15 % of costs for operating labor, supervision and maintenance, or 2-6 % of total product cost
2	Distribution and selling costs : 2-20 % of total product cost
3	Research and development costs : 5 % of total product cost
4	Financing : 0-10 % of total capital investment
Total Product Cost = Manufacturing Cost + General Expenses	