# CHAPTER II
# BACKGROUND AND LITERATURE REVIEW

## 2.1 Historic of Oil Crisis

1973 oil crisis – Cause: Arab members of the Organization of Petroleum Exporting Countries (OPEC) interrupted the oil export to nations that had supported Israel in its conflict with Syria and Egypt. This action compressed Israel leaded to the first oil crisis of the world.

1979 energy crisis – Cause: Saddam Hussein invasion and act in response to Iran that support revolution in Iraqi, then oil production in Iran stopped and reduced in the oil market that was the second oil crisis of the world.

1990 – 1991 extreamely high in the price of oil – Cause: the Gulf War. The war began with the Iraqi invasion of Kuwait on August 2, 1990. Because of Iraqi mentioned that Kuwait produced oil over quata cause loss of Iraqi's benefit (decline of oil price). The oil fields of Kuwait were damaged and reduced the oil output.

Oil price increases of 2004 and 2005 – Cause: Recovery of the world's economy increases percentage of the world's demand for petroleum

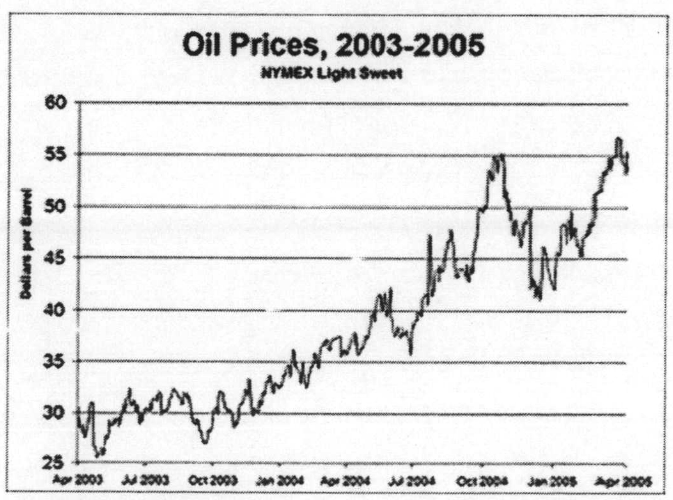



**Figure 2.1** Oil price from 2003-2005. (source : http://www.eia.doe.gov)

The need for the development of alternative fuel sources to replace over-dependent on petroleum, has been growing because of concerns about these oil crisises and the reserves of oil are finite and will one day run out completely.

## 2.2 Basic Knowledge of Fuels

There are two types of oils. The first is fossil fuels or petroleum obtained from beneath the earth's surface, which undergo a transformation process involving high pressures and temperatures to yield a range of products, such as liquefied petroleum gas (LPG), gasoline, kerosene, aviation fuel, diesel oil, fuel oil and asphalt. These products are used as fuel for engines and raw material in industrial plants. They are inedible and their reserves are depletable. According to estimates by geologists, without new discoveries the earth's limited reserves of fossil fuels will be depleted within the next few decades. Despite the decreasing supply of fossil fuels, the demand for energy is continuously rising. Researchers around the globe have been looking for alternative sources of energy to replace fossil fuels, and one of the solutions was biofuels. The second type of oil refers to those derived from plants or animals, which are edible. A variety of oil can be extracted from several types of plants. Biofuels can be directly extracted from oil-yielding plants, such as soybean, peanut, coconut, oil palm, sesame, castor, and sunflower seed (Ministry of Energy, Thailand).

## 2.3 Fossil Fuel

Fossil fuels, also known as mineral fuels which are also liquid fuels come from dead animals and plants which died many millions of years ago, are hydrocarbon-containing natural resources such as coal, petroleum and natural gas. The most notable of these is gasoline. The burning of fossil fuels by humans is the major source of emissions of carbon dioxide which is one of the greenhouse gases that is belived to contribute to global warming. A grobal movement toward the generation of renewable energy is therefore underway to help meet the increased global energy needs (http://en.wikipedia.org ).

2.3.1 Gasoline

Gasoline is the most widely used liquid fuel. Gasoline, as its known in United States and Canada, (Known as petrol in Britain, Australia, New Zealand, and many countries) is made of hydrocarbon molecules forming aliphatic compounds, or chains of carbon with hydrocarbon atoms attached. However, many aromatic compounds (carbon chains forming rings) such as benzene are found naturally in gasoline and cause the health risks associated with expanded exposure to the fuel. Production of gasoline is achieved by distillation of crude oil. The desirable liquid is separated from the crude oil in refineries (http://en.wikipedia.org ).

2.3.2 Diesel

Diesel is used as fuel in a diesel engine invented by German engineer Rudolf Diesel. Conventional diesel is similar to gasoline in that it is a mixture of aliphatic hydrocarbons extracted from petroleum. After distillation, the diesel fraction is normally processed to reduce the amount of surfur in the fuel. Sulfhur causes corrosion in vehicles, acid rain and higher emissions of soot from the tail pipe (exhaust pipe). In Europe, emission standards and preferential taxation have both forced oil refineries to dramatically reduce the level of surfur in diesel fuels. However, lowering surfur also reduces the lubricity of the fuel, meaning that additives must be put into the fuel to help lubricate engines. Biodiesel is an effective lubricity additive.

## 2.4 Liquid Biofuel

Simply stated a biofuel is any renewable source of combustible material whose energy content can be beneficially utilised. The emphasis is on renewable. This means all biofuels stem from agricultural source and the carbon dioxide produced during their combustion can be recycled as renewed biofuel (http://www.aie.org.au ). Liquid biofuel is usually bioalcohol such as ethanol, methanol, biodiesel, gasohol and diesohol. Fossil fuels, such as coal, oil and natural gas are not renewable. They are a finite resource and once consumed they are lost for ever. The increasing development and use of biofuels will not only conserve these non-renewable resources for future generations but will also counter their impact on the ever-increasing levels of carbon dioxide in the atmosphere. Severe pollution in large urban areas of the USA and Europe has prompted governments to seek alternatives.

2.4.1 Biodiesel

Biodiesel is the name of a clean burning alternative fuel, produced from domestic, renewable resources such as vegetable oils or animal fats. Biodiesel is simple to use, biodegradable, nontoxic, and essentially free of sulfur and aromatics (http://www.biodiesel.org). Biodiesel has very similar properties to petroleum-derived diesel fuel and hence can be used either blended with diesel at any proportion that are denoted as, "BXX" with "XX" representing the percentage of biodiesel contained in the blend (ie: B20 is 20% biodiesel, 80% petroleum diesel) or as a 100% replacement. No engine modifications are required, though there may be cold weather problems from phase separation at ambient temperatures below 0°C (http:/www.biodiesel.de). However, biodiesel has combustion properties very similar to regular diesel, including combustion energy and cetane ratings (http://en.wikipedia.org) and has significantly fewer emissions than petroleum-based diesel (petro-diesel) when burned. There have been reports that a diesel-biodiesel mix results in lower emissions than either can achieve alone (http://en.wikipedia.org). Biodiesel refers to the pure fuel before blending with diesel fuel.

Biodiesel is made through a chemical process called transesterification whereby the glycerin is separated from the fat or vegetable oil. The process leaves behind two products -- methyl esters (the chemical name for biodiesel) and glycerin (a valuable byproduct usually sold to be used in soaps and other products) (http://www.biodiesel.org). A variety of biolipids can be used to produce biodiesel. These include: virgin oil feedstock (rapeseed and soybean oils are most commonly used, though other crops such as mustard, palm oil, hemp and even algae show promise); waste vegetable oil; animal fats. The first commercial production of biodiesel took place in Austria in 1988 and since then, through the Austrian Biofuels Institute, Austria has played a leading role in establishing the

European market for biodiesel. The International Energy Agency reported in 1998 that 21 countries around the world had implemented biodiesel projects. The majority of these will have been relatively small in capacity. The North American market has only now just started to grow. In all, world biodiesel production in 2003 has reached 3,200 Mlpa with the expectation of high growth rates for the future (Koerbitz, 2003). Environmental benefits of biodiesel are containing no sulfur or aromatics, and use of biodiesel in a conventional diesel engine results in substantial reduction of unburned hydrocarbons, carbon monoxide and particulate matter.

### 2.4.2 Ethanol

The use of alcohol as a fuel for internal combustion engines, either alone or in combination with other fuels, has been given much attention mostly because of its possible environmental and long-term economical advantages over fossil fuel.

Ethanol is a monohydric primary alcohol. It melts at -117.3°C and boils at 78.5°C. It is miscible (i.e., mixes without separation) with water in all proportions and is separated from water only with difficulty; ethanol that is completely free of water is called absolute ethanol. Ethanol burns in air with a blue flame, forming carbon dioxide and water. It reacts with active metals to form the metal ethoxide and hydrogen, e.g., with sodium it forms sodium ethoxide. It reacts with certain acids to form esters, e.g., with acetic acid it forms ethyl acetate. It can be oxidized to form acetic acid and acetaldehyde. It can be dehydrated to form diethyl ether or, at higher temperatures, ethylene. On the other hand, ethanol can be produced from a variety of crops, such as corn, wheat, potato wastes, cheese whey, rice straw, sawdust, hemp, kenaf, sugarcane, sugar beets, maize, barley, potatoes, cassava, sunflower, eucalyptus, urban wastes, paper mill wastes, yard clippings, molasses, seaweed, surplus food crops, and other cellulose waste. However, it may also be used as a fuel, most often in combination with gasoline. Ethanol for use in gasoline and industrial purposes may be called a fossil fuel because it is synthesized from the petroleum product ethylene, which is cheaper than production from fermentation of grains or sugarcane. Denatured, or industrial, alcohol is ethanol to which poisonous or nauseating substances have been added to prevent its use as a beverage; a beverage tax is not charged on such alcohol, so its cost is quite low. Medically, ethanol is a soporific, i.e., sleep-producing; although it is less toxic than the other alcohols, death usually occurs if the concentration of ethanol in the bloodstream exceeds about 5% (http://www.encyclopedia.com ).

Ethanol is flammable and pure ethanol burns more cleanly than many other fuels. Assuming it is derived from biomass, the combustion of ethanol produces no net carbon dioxide. When fully combusted, its combustion products are only carbon dioxide and water which are also the by-products of regular cellulose waste decomposition. For this reason, it is favoured for environmentally conscious transport schemes and has been used to fuel public buses. (http://www.encyclopedia.com ).

2.4.3 Methanol

Methanol alcohol, or wood alcohol, $CH_3OH$, a colorless, flammable liquid that is miscible with water in all proportions. Methanol is a monohydric alcohol . It melts at -97.8°C and boils at 67°C. It reacts with certain acids to form methyl esters. Methanol is a deadly poison. However, unlike ethanol, methanol is a toxic product; extensive exposure to it could lead to permanent health damage, including blindness (http://en.wikipedia.org ). As a result, commercial use of methanol has sometimes been prohibited. Small amounts are used in some gasoline extender in the production of gasohol .

2.4.4 Butanol

Butanol is an alcohol which may be used as a fuel with the normal combustion engine, typically as a product of the ferment of biomass with the bacterium clostridium acetobutylicum. The advantages of butanol are its high octane rating (over 100) and high energy content, only about 10% lower than gasoline, and subsequently about 50% more energy-dense than ethanol, 100% more so than methanol. Buthanol's only major disadvantages are its high flashpoint (95F or 35C) which is a benefit for fire safety, but a difficultly for starting engines, particularly in cold weather. (In comparison, ethanol has a flashpoint of 13C; methanol has a flashpoint of 11C; and propanol has a flashpoint of 15C.), toxicity, and the fact that the fermentation process for renewable butanol emits a foul odour. The cost of buthanol is about $8 approx. per gallon, so another drawback is its high cost in proportion to ethanol (approx. $1.50 per gallon) and methanol (http://en.wikipedia.org).

### 2.4.5 Gasohol

A renewable fuel gasohol made from a mixture of gasoline and ethanol. The most common gasohol variant is "E10", containing 10% ethanol and 90% gasoline. Other blends include E5 and E7. These concentrations are generally safe for recent, unmodified automobile engines. Gasohol has higher octane, or antiknock, properties than gasoline and burns more slowly, coolly, and completely, resulting in reduced emissions of some pollutants, but it also vaporizes more readily, potentially aggravating ozone pollution in warm weather. The blending of ethanol in gasoline to improve efficiency and reduce "knock" in motor car engines began some eighty years ago in Baltimore, USA. Sales continued in the mid-west during the 1930s but the ethanol blends could not compete with cheaper petroleum based gasoline. Low petroleum prices essentially kept ethanol out the US gasoline market until the oil crisis of 1979 when the threat of long petrol queues and no oil supply became a national security issue. Demand for ethanol as a gasoline extender increased significantly after 1990 when the US Clean Air Act was amended to mandate the blending of oxygenates in gasoline. At first, MTBE provided the answer but because of its threat to water pollution, it is now being phased out resulting in a further boost in demand for ethanol (http://www.aie.org.au). Ethanol-based gasohol is expensive and energy intensive to produce, and can damage rubber seals and diaphragms and certain finishes if the ethanol is present in higher concentrations. Since 1998, however, many American automobiles have been equipped to enable them to run on E85, a mixture of 85% ethanol and 15% gasoline. Methanol-based gasohol is also expensive to produce and is toxic and corrosive, and its emissions produce cancer-causing formaldehyde (http://www.encyclopedia.com).

2.4.6 Diesohol

Diesel engines, due to their dominant advantages of high thermal efficiency, rigid and simple structure, and fuel economy, are the major power sources for marine and inland transportation and industrial power plants. They are the most fuel combustion efficient engines known and are expected to remain widely used in the foreseeable future. At the same time, diesel engines are major contributors of various types of air pollutant emissions such as particulate matter (PM), smoke, nitrogen oxides (NOx), hydrocarbon (HC), carbon monoxide (CO), and sulfur oxides (SOx) and other harmful compounds. With the increasing concern of environmental protection and more stringent government regulation on exhaust emissions, reduction in engine emissions becomes a major research task in engine development. There are many researchers are dedicating to develop a new technology to reduce PM and NOx simultaneously (Lu *et al.*, 2004).

The introduction of oxygenated compounds such as alcohols into diesel fuel is still today the best way to have results in matter of pollution and could help the country save on diesel imports, currently state-subsidised to maintain affordability. The use of ethanol in diesel engines is, to begin with, unusual in that the ignition capacity of the diesel fuel is hindered by ethanol. The initial investigations into the use of ethanol in diesel engines were carried out in South Africa in the 1970s (Republic of South Africa, 1980) and continued in Germany and the United States during the 1980s (Weidmann K and Menrad H, 1985). Most of these works relate a reduction in the smoke and particle levels emitted in the exhaust (Pischinger FF and Havenith C, 1980). This point, of increasing importance today, alone justifies the incorporation of ethanol into fuels. Studies on the use of ethanol in Diesel engines have been continuing since the 1970s. The initial investigations were focused on reduction of the smoke and particle levels in the exhaust. Ethanol addition to Diesel fuel results in different physico - chemical changes in Diesel fuel properties, particularly reductions in cetane number, viscosity and heating value (Henham *et al.*, 1991).

Diesel and alcohol do not mix easily and formulating diesohol requires the use of additives to create stable blends. Anhydrous ethanol will readily blend with diesel. Hydrated ethanol containing more than 2% v/v water is not completely miscible with diesel but can form an emulsion using a suitable emulsifier. In recent years, with the development of technology, a number of researches, Akzo Nobel Surface Chemistry (Lofvenberg, 2002) and Lubrizol Corporation (Corkwell *et al.*, 2002) have developed and produced a low cost additive, which make it possible to blend ethanol with diesel to get a stable and clear fuel.

Letcher *et al.* (1983) found that ethanol solubility in diesel is affected mainly by two factors, temperature and water content of the blend. At warm ambient temperatures dry ethanol blends readily with diesel fuel. However, below about 10 °C the two fuels separate, a temperature limit that is easily exceeded in many parts of the world for a large portion of the year. Prevention of this separation can be accomplished in two ways: by adding an emulsifier which acts to suspend small droplets of ethanol within the diesel fuel, or by adding a co-solvent that acts as a bridging agent through molecular compatibility and bonding to produce a homogeneous blend.

For example, Gerdes and Suppes (2001) studied the miscibility of ethanol in diesel fuels. The aromatic content of diesel fuel also affects the solubility of ethanol in diesel and therefore the effectiveness of emulsifiers and co-solvents. The polar nature of ethanol induces a dipole in the aromatic molecule allowing them to interact reasonably strongly, while the aromatics remain compatible with other hydrocarbons in diesel fuel. Hence aromatics act to some degree as bridging agents and co-solvents. Reducing the aromatic content of diesel fuels will influence the miscibility of ethanol in diesel fuel and will affect the amount of additive required to achieve a stable blend.

In 2001, Satge′ de Caro *et al.* studied the combining an additive with diesel–ethanol blends for use in diesel engines. Absolute ethanol is highly soluble in diesel fuel at contents of approximately 0–30% and 70–100%. Within these zones of miscibility they observed cloudiness in the mixture followed by separation, when the water content of the ethanol exceeded 1%. The occurrence of this phenomenon has therefore to be prevented by using additives. The organic molecules, 1-octylamino-3-octyloxy-2-propanol were conbined with the dinitrated derivative N-(2-nitrato-3-octyloxy propyl), Noctyl nitramine have been selected as the additive (Satge′ de Caro et al., 1995). Tests are carried out on a bus fleet in Chicago involving an 80%

diesel, 15% ethanol and 5% additive mixture. The results have been shown that engine behaviour seemed to be improved in the presence of additives with a reduction of pollutant emissions in exhaust gas, cyclic irregularities and ignition delay.

Oxygenated diesel fuel blends have advantages over regular diesel. Oxygenate significantly reduces particulate matter (PM) and reduces toxic gases such as CO, sulfur oxides ($SO_x$) and nitrogen oxides ($NO_x$) from tailpipe emissions (Fernando, 2004). In 2003, Lin and Wang studied the effects of an oxygenated additive on the emulsification characteristics of two- and three-phase diesel emulsions. The content and quantity of the emulsifier, hydrophilic–lipophilic balance (HLB), or additives can affect the formation rate and emulsification stability (ES) of three-phase emulsions, systematic investigation on the suitable proportions of diesel oil, emulsifier and additive combination needed to improve emulsification characteristics and fuel properties is required (Crookes *et al.,* 1997). In their study, an oxygenated diglyme additive, and Span 80 and Tween 80 emulsifiers are used to prepare the emulsions. They found that the viscosity of the two-phase emulsion increased with the addition of the diglyme oxygenated additive. Moreover, the diglyme additive might further promote the emulsification capability of the hydrophilic surfactant Tween 80 to enhance the emulsification stability of the O/W emulsion. Hence, the viscosity of the O/W emulsion was significantly increased with the diglyme addition (Lin and Wang, 2003). Larger value of emulsification stability (ES) appears as more oxygenated diglyme is added to the oil phase of the O/W emulsions. The diglyme addition in O/W emulsions is particularly beneficial to the emulsifying capability ofhydrophilic surfactant Tween 80, leading to better emulsification stability (ES) and the emulsification activity (EA).

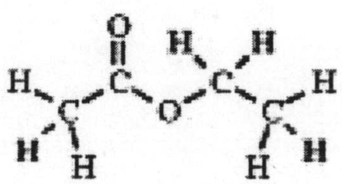
In 2005, Hansen *et al.* investigated the relative compatibilities of ethanol, biodiesel, and diesel fuel. As ethanol is immiscible in diesel over a wide range of temperature, they found that biodiesel, which is another renewable fuel, can be used successfully as an ampliphile to stabilize ethanol and diesel. Water in an EB-diesel blend proved to separate the phase, with the exception of two blends. They were ethanol : biodiesel : (low sulfur) diesel = 3.75% : 25% : 71.25 and ethanol : biodiesel : (ultralow-sulfur) diesel = 4.00%: 20% : 76.00% .

Satge′ de Caro *et al.* (2001) examined two additives (1-octylamino-3-octyloxy-2-propanol and 2- nitrato-3-octyloxy propyl), each at a level of 1%, to be able to use 10–20% ethanol in Diesel fuel. It was found that 2% additives were useful to adjust the fuel properties of the blends. In particular, the additives enhance phase stability and improve the cetane number in the ethanol–Diesel fuel blends. The presence of additives also improves cyclic irregularities and ignition delay (Can et al., 2004).

In 2002, Guru *et al.* investigated the synthesized of organic compounds, Mn, Mg, Cu and Ca metals, used as diesel fuel additives. It was observed that the organic based manganese drops the viscosity and flash point and improves the contents of the exhaust gases. Among the compounds of organic based metals, Mn is the best to improve the diesel fuel properties.

## 2.5 Basic knowledge of Ethyl Acetate

Ethyl acetate is a colourless liquid at room temperature with a fruity odour, b.p. 77°C, having a molecular weight of 88.10.



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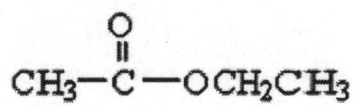

$C_4H_8O_2$ $CH_3COOC_2H_5$

**Figure 2.2** Structural Formula of Ethyl Acetate.

It is slightly soluble in water and soluble in most organic solvents, such as alcohol, acetone, ether and chloroform. It can be used as a solvent in a wide range of applications, across many industries, including:

(a) Surface coating and thinners: Ethyl acetate is one of the most popular solvents and finds wide use in the manufacture of nitrocellulose lacquers, varnishes and thinners. It exhibits high dilution ratios with both aromatic and aliphatic diluents and is the least toxic of industrial organic solvents.

(b) Pharmaceuticals: Ethyl acetate is an important component in extractants for the concentration and purification of antibiotics. It is also used as an intermediate in the manufacture of various drugs.

(c) Flavours and essences: Ethyl acetate finds extensive use in the preparation of synthetic fruit essences, flavours and perfumes.

(d) Flexible packaging: Substantial quantities of ethyl acetate are used in the manufacture of flexible packaging and in the manufacture of polyester films and BOPP films. It is also used in the treatment of aluminium foils.

(e) Miscellaneous: Ethyl acetate is used in the manufacture of adhesives, cleaning fluids, inks, nail-polish removers and silk, coated papers, explosives, artificial leather, photographic films & plates.

Otherwise, Ethyl acetate is normally produced via reversible reaction such as esterification of ethanol and acetic acid. For example, it uses only ethanol, which is non-corrosive and less toxic.

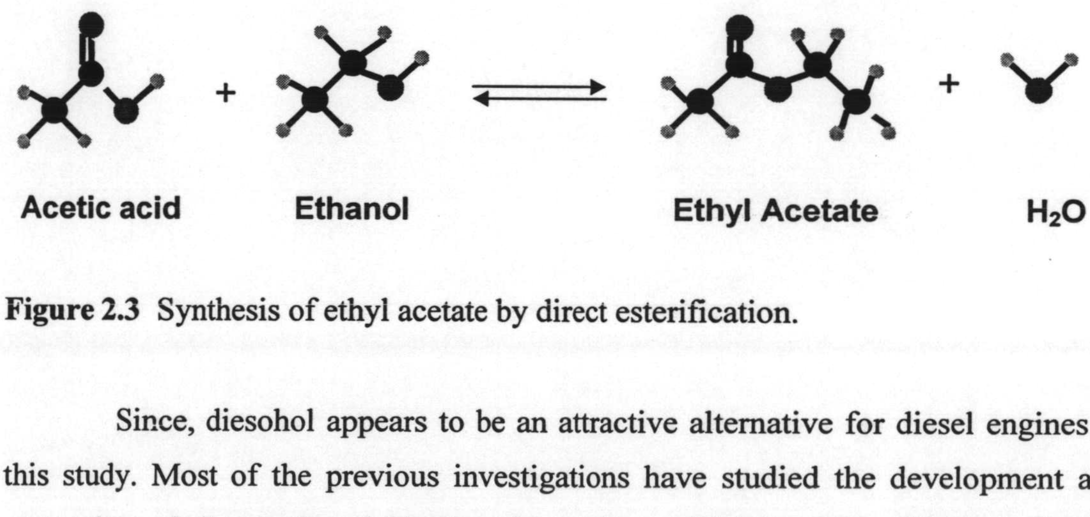


**Figure 2.3** Synthesis of ethyl acetate by direct esterification.

Since, diesohol appears to be an attractive alternative for diesel engines in this study. Most of the previous investigations have studied the development and promotion of diesel-ethanol blends with various additives. The majority of these additive must be imported from many countries that lose foreign currency. Thus, in this study most of raw material within the country will be used to mix with diesel fuel. It is instrumental for raising agricultural commodity prices and incomes of farmers, hence helping combat poverty and promoting greater development in rural communities in Thailand. The addition of an oxygenated additive into diesohol such as ethyl acetate in this study is one of the possible approaches to satisfy homogeneity and prevent phase separation. At the same time, both of ethanol and ethyl acetate derived from agricultural products within country (acetic acid can obtained from fermentation of various agricultural products in the country). In addition, the use of ethyl acetate, produced via reversible reaction such as esterification of ethanol and acetic acid, suit the purpose that makes all remain ethanol in ethanol production to be useful.

## 2.6 Emission

### 2.6.1 Gaseous Pollutant Emissions

The emissions that produced by a vehicle also known as tailpipe emissions: this is what most people think of when they think of vehicle air pollution; the products of burning fuel in the vehicle's engine, emitted from the vehicle's exhaust system. The major pollutants emitted include:

a) Carbon monoxide (CO): a product of incomplete combustion, CO from automobile and industrial emissions is a dangerous pollutant that may contribute to the greenhouse effect and global warming. CO is dangerous and life-threatening to humans and other forms of air-breathing life, it reduces the blood's ability to carry $O_2$ and is dangerous to people with heart disease, as inhaling even relatively small amounts of it can lead to hypoxic injury, neurological damage, and possibly death.

b) Carbon dioxide ($CO_2$): although this is a product of the complete combustion of hydrocarbons, is plentiful in the atmosphere, has no immediate harmful effects to humans and is essential to plant life, emissions of $CO_2$ are considered a pollutant because it is a significant greenhouse gas and increasing its levels in the atmosphere is thought by many to be a contributor to global warming.

c) Hydrocarbons (HC): it made up of unburned or partially burned fuel, and is a major contributor to urban smog, as well as being toxic. Smog is caused by a reaction between sunlight and emissions mainly from human activity. Smog is a problem in a number of cities and continues to harm human health. It is especially harmful for seniors, children, and people with heart and lung conditions such as emphysema, bronchitis, and asthma. It can inflame breathing passages, decreasing the lung's working capacity, and causing shortness of breath, pain when inhaling deeply, wheezing, and coughing. It can cause eye and nose irritation and dry out the protective membranes of the nose and throat and interfere with the body's ability to fight infection, increasing susceptibility to illness.

d) Nitrogen oxides (NOx): These are generated when nitrogen in the air reacts with oxygen under the high temperature and pressure conditions inside the engine. NOx emissions contribute to both smog and acid rain. $NO_x$ is a generic term for the various nitrogen oxides produced during combustion. They are believed to aggravate asthmatic conditions, react with the $O_2$ in the air to produce ozone, which is also an irritant and eventually form nitric acid when dissolved in water. When dissolved in atmospheric moisture the result can be acid rain which can damage both trees and entire forest ecosystems.

### 2.6.2 Emission Standard

Emission standards are requirements that set specific limits to the amount of pollutants that can be released into the environment. Many emission standards focus on regulating pollutants released by automobiles and other transport vehicles, but they can also regulate emissions from industry, power plants, small equipment such as lawn mowers and diesel generators. Standards generally regulate the emissions of $NO_x$, particulate matter (PM) or soot, carbon monoxide (CO), or volatile hydrocarbons. The main components of automobile exhaust, carbon dioxide ($CO_2$) and water vapor ($H_2O$), have so far not been regulated by emission standards, but the European Union is moving towards mandatory $CO_2$ standards.

In the United States, emissions standards are managed by the Environmental Protection Agency (EPA) as well as some state governments. However, the European Union has its own set of emission standards that all new vehicles must meet. It is popularly refered to as Euro3. EURO III(1999-2005), the emission standard for vehicles introduced in the EU in 1999. It limits diesel car emissions to 2.1 g/kWh CO, 0.66 g/kWh HC, 0.5 g/km of NOx and 0.05 g/km of Particulate Matter (PM), petrol cars to 0.15 g/km NOx and Heavy Goods Vehicles

(HGVs) to 5 g/kWh of NOx and 0.1 g/kWh of PM. It has been replaced by Euro IV in 2005 (http://en.wikipedia.org).