CHAPTER II
BACKGROUND AND LITERATURE REVIEW

2.1 Life Cycle Analysis (LCA)

Life cycle assessment is a "cradle-to-grave" approach for assessing industrial systems. "Cradle-to-grave" begins with the gathering of raw materials from the earth to create the product, and ends at the point when all materials are returned to the earth. LCA evaluates all stages of a product's life from the perspective that they are interdependent, meaning that one operation leads to the next. LCA enables the estimation of the cumulative environmental impacts resulting from all stages in the product life cycle, often including impacts not considered in more traditional analyses (e.g., raw material extraction, material transportation, ultimate product disposal, etc.). By including the impacts throughout the product life cycle, LCA provides a comprehensive view of the environmental aspects of the product or process and a more accurate picture of the true environmental trade-offs in product selection.

LCA is a technique for assessing all the inputs and outputs of a product, process, or service (Life Cycle Inventory); assessing the associated wastes, human health and ecological burdens (Impact Assessment); and interpreting and communicating the results of the assessment (Life Cycle Interpretation) throughout the life cycle of the products or processes under review. The term "life cycle" refers to the major activities in the course of the product's life-span from its manufacture, use, maintenance, and final disposal; including the raw material acquisition required to manufacture the product. Figure 2.1 illustrates the possible life cycle stages that can be considered in an LCA and the typical inputs/outputs measured.

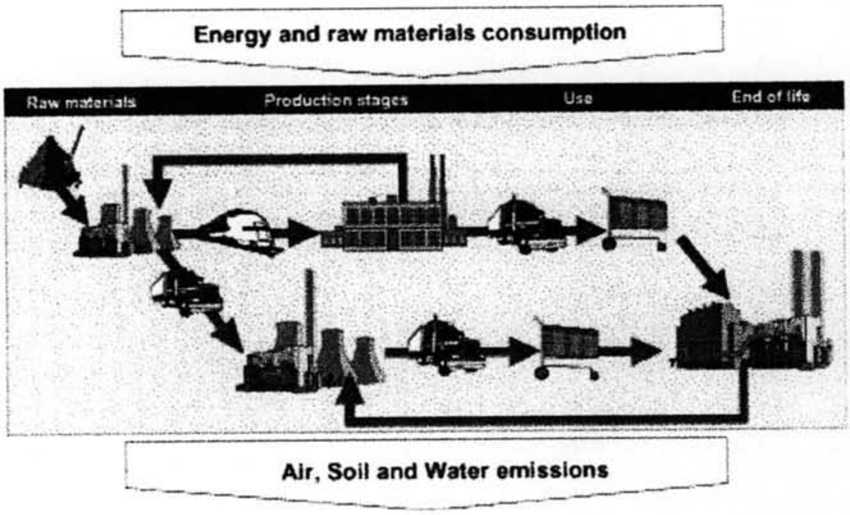

Figure 2.1 LCA frameworks.

2.1.1 A Brief History of LCA

The first LCA was carried out in the late 1960's on a Coca-Cola can. Originally these were called REPA studies. Resource and Environmental Profile Analysis looked at resource use and environmental releases of a product. In the late '80s few were carried out, mainly due to the lack of availability of basic input data.

The Society of Environmental Toxicology and Chemistry (SETAC) worked to develop a broad consensus on the conduct of LCA, which was initiated in 1990, and the Society for the Promotion of Life Cycle Development (SPOLD) was set up. It aims to promote the development of LCA as a scientific tool and to use the results for inputs into discussions concerning legislation, such as eco-labeling.

2.1.2 LCA Method

The method of LCA is now being standardized as the ISO 140040 series. The LCA framework consists of 4 elements: Goal and Scope Definition, Inventory Analysis, Impact Assessment, and Interpretation as illustrated in Figure 2.2.

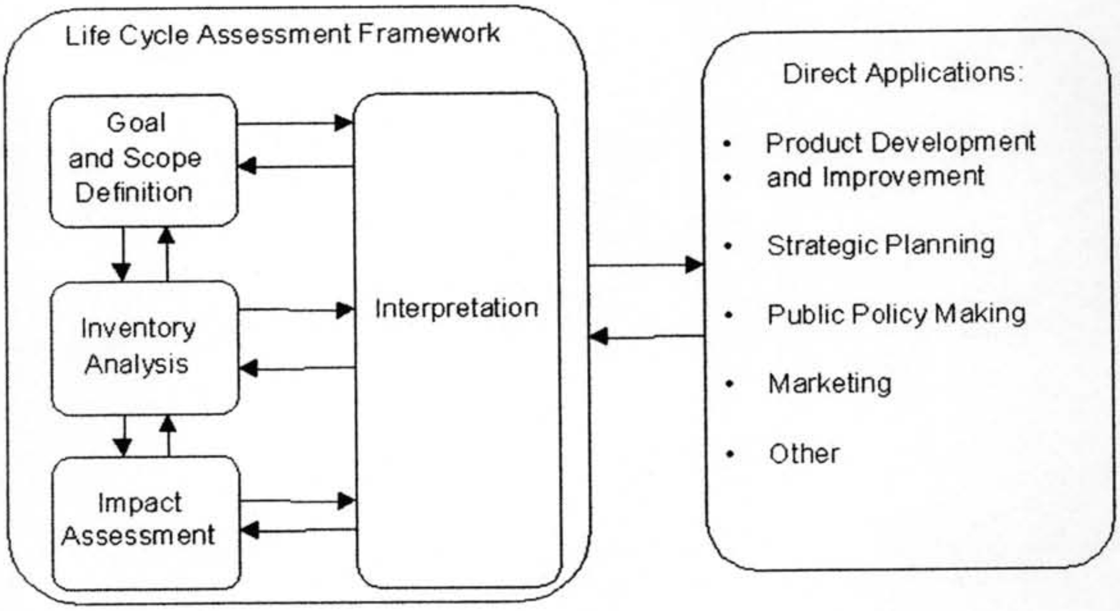

Figure 2.2 Phases and applications of an LCA (based on ISO14040).

1. Goal and Scope Definition

Define and describe the product, process or activity. Establish the context in which the assessment is to be made and identify the boundaries and environmental effects to be reviewed for the assessment.

2. Inventory Analysis

Identify and quantify energy, water and materials usage and environmental releases (e.g., air emissions, solid waste disposal, wastewater discharge).

3. Impact Assessment

Assess the human and ecological effects of energy, water, and material usage and the environmental releases identified in the inventory analysis.

4. Interpretation

Evaluate the results of the inventory analysis and impact assessment to select the preferred product, process or service with a clear understanding of the uncertainty and the assumptions used to generate the results. Examples are given in Figure 2.3.

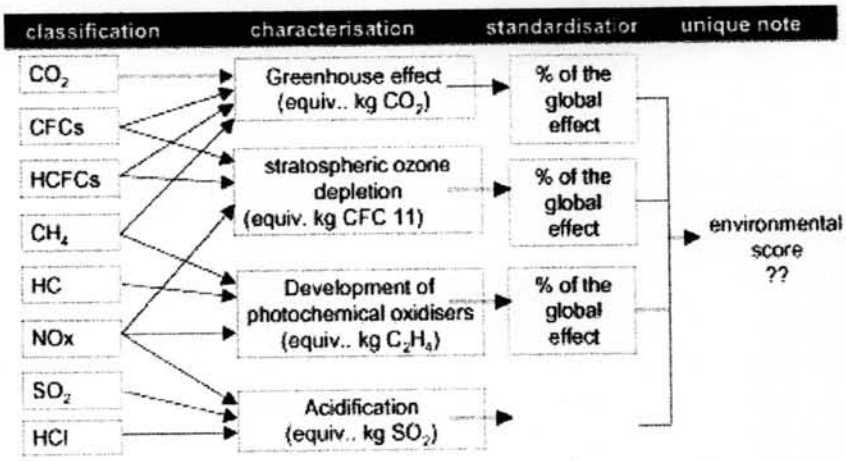

Figure 2.3 Interpretation.

2.1.3 LCA Applications

LCA is a useful tool for many applications such as product development, eco-labeling, environmental policy, and priority setting. Examples as shown below:

- Internal industrial use in product development and improvement
- Internal strategic planning and policy decision support in industry
- External industrial use for marketing purposes
- Governmental policy making in the areas of eco-labeling, green procurement and waste management opportunities.

2.2 Natural Gas

Natural gas, in itself, might be considered a very uninteresting gas - it is colorless, shapeless, and odorless in its pure form. Quite uninteresting - except that natural gas is combustible, and when burned it gives off a great deal of energy. Unlike other fossil fuels, however, natural gas is clean burning and emits lower levels of potentially harmful byproducts into the air. We require energy constantly, to heat our homes, cook our food, and generate our electricity. It is this need for energy that has elevated natural gas to such a level of importance in our society, and in our lives.

Natural gas is a combustible mixture of hydrocarbon gases. While natural gas is formed primarily of methane, it can also include ethane, propane, butane and pentane. The composition of natural gas can vary widely. Table 2.1 outlines the typical makeup of natural gas before it is refined.

Table 2.1 Typical composition of natural gas

Typical Composition of Natural Gas		
Methane	CH_4	70-90%
Ethane	C_2H_6	0-20%
Propane	C_3H_8	
Butane	C_4H_{10}	
Carbon Dioxide	CO_2	0-8%
Oxygen	O_2	0-0.2%
Nitrogen	N_2	0-5%
Hydrogen sulphide	H_2S	0-5%
Rare gases	A, He, Ne, Xe	Trace

In its pure form, such as the natural gas that is delivered to your home, it is almost pure methane that is considered 'dry'. When other hydrocarbons are present, the natural gas is 'wet'.

2.2.1 How Natural Gas is Formed?

There are many different theories as to the origins of fossil fuels. The most widely accepted theory says that fossil fuels are formed when organic matter (such as the remains of a plant or animal) is compressed under the earth, at very high pressure for a very long time. This is referred to as thermogenic methane. Similar to the formation of oil, thermogenic methane is formed from organic particles that are covered in mud and other sediment. Over time, more and more sediment and mud and other debris are piled on top of the organic matter. This sediment and debris puts a great deal of pressure on the organic matter, which compresses it. This compression, combined with high temperatures found deep underneath the earth, break down the carbon bonds in the organic matter. As one gets deeper and deeper under the earths crust, the temperature gets higher and higher. At low temperatures (shallower deposits), more oil is produced relative to natural gas. At higher temperatures, however, more natural gas is created, as opposed to oil. That is why natural gas is usually associated with oil in deposits that are 1 to 2 miles below the earth's crust. Deeper deposits, very far underground, usually contain primarily natural gas, and in many cases, pure methane.

Natural gas can also be formed through the transformation of organic matter by tiny microorganisms. This type of methane is referred to as biogenic methane. Methanogens, tiny methane producing microorganisms, chemically break down organic matter to produce methane. These microorganisms are commonly found in areas near the surface of the earth that are void of oxygen. These microorganisms also live in the intestines of most animals, including humans. Formation of methane in this manner usually takes place close to the surface of the earth, and the methane produced is usually lost into the atmosphere. In certain circumstances, however, this methane can be trapped underground, recoverable as natural gas. An example of biogenic methane is landfill gas. Waste-containing landfills produce a relatively large amount of natural gas, from the decomposition of the waste materials that they contain. New technologies are allowing this gas to be harvested and used to add to the supply of natural gas.

A third way in which methane (and natural gas) may be formed is through abiogenic processes. Extremely deep under the earth's crust, there exist hydrogen-rich gases and carbon molecules. As these gases gradually rise towards the surface of the earth, they may interact with minerals that also exist underground, in the absence of oxygen. This interaction may result in a reaction, forming elements and compounds that are found in the atmosphere (including nitrogen, oxygen, carbon dioxide, argon, and water). If these gases are under very high pressure as they move towards the surface of the earth, they are likely to form methane deposits, similar to thermogenic methane.

2.2.2 Application of Natural Gas

There are so many different applications for this fossil fuel that it is hard to provide an exhaustive list of everything it is used for. And no doubt, new uses are being discovered all the time. Their applications can be separated into 4 major sectors; Industrial, Electric Generation, Residential, and Commercial as shown in Figure 2.4.

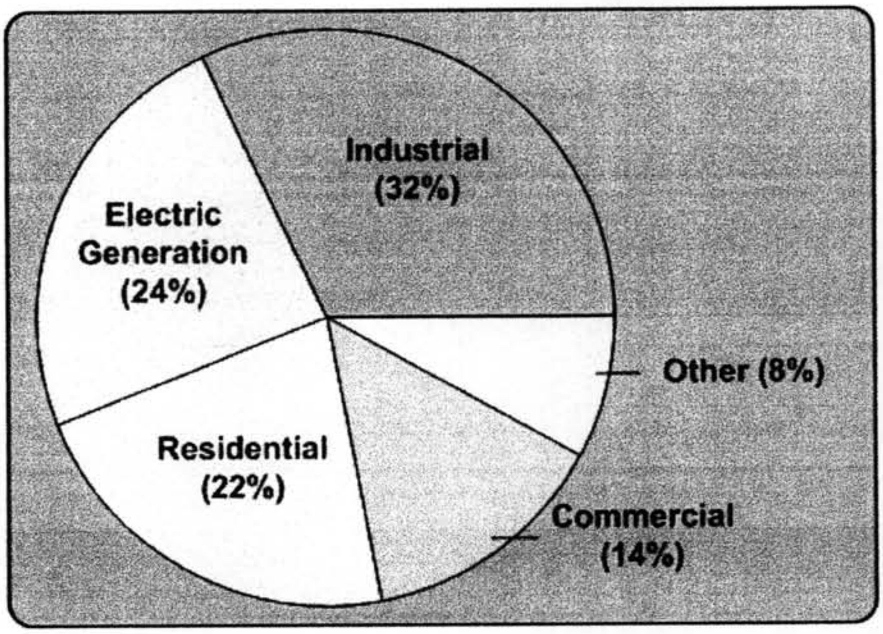

Figure 2.4 Natural Gas Use by Sector (Source: EIA - Annual Energy Outlook 2002).

1. Residential Applications

Natural gas is one of the cheapest forms of energy available to the residential consumer. In fact, natural gas has historically been much cheaper than electricity as a source of energy. Figure 2.5 shows comparison of price per Btu of various kinds of energy sources.

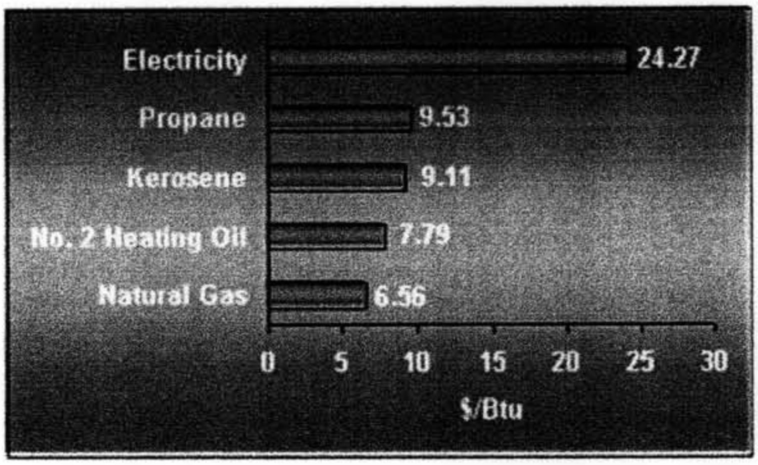

Figure 2.5 Residential Energy Costs per Btu (Source: DOE)

Not only is natural gas cheap for the residential consumer, it also has a number of varied uses. The best known uses for natural gas around the home are natural gas heating and cooking. Cooking with a natural gas range or oven can provide many benefits, including easy temperature control, self ignition and self cleaning, as well as being approximately one-half the cost of cooking with an electric range. Many of the top chefs prefer natural gas ranges for their quick heating ability and temperature control. The newer generations of natural gas ranges allow for some of the most efficient, economical, and versatile cooking appliances ever.

Natural gas appliances are also rising in popularity due to their efficiency and cost effectiveness. Although many gas powered appliances are initially more expensive than their electric counterparts, they are commonly much cheaper to operate, have a longer expected life, and require relatively low maintenance. Some examples of other natural gas appliances include space heaters, clothes dryers, pool and jacuzzi heaters, fireplaces, barbecues, garage heaters, and outdoor lights. All of these appliances offer a safe, efficient, and economical alternative to electricity or other fuel sources. Almost 70 percent of new homes use natural gas for space heating, meaning that a large portion of new homes already have the natural gas delivery infrastructure in place. The same natural gas pipes that supply gas to a furnace can be used to supply energy for all of the appliances listed above, making installation simple and easy.

Although natural gas has many uses, and can supply energy to a vast number of residential appliances, there are some energy requirements around the house which cannot be satisfied by natural gas. A television, or blender, or microwave, for instance, will likely never be powered directly by natural gas, but will instead require electricity. However, natural gas can still provide energy for these appliances at the home, by what is known as "distributed generation".

Distributed generation refers to using natural gas to generate electricity right on the doorstep. Natural gas fuel cells and microturbines both offer the residential consumer the capacity to disconnect from their local electric distributor, and generate just enough electricity to meet their needs. Although this technology is still in its infancy, it is very promising in being able to offer independent, reliable, efficient, environmentally friendly electricity for residential needs.

The very first natural gas fuel cell was installed in a house in Latham, New York, in July 1998. The system was plugged into the home's natural gas line as the fuel supply, and is now completely independent of any outside electricity. Because a significant amount of electricity is wasted when it is distributed through power lines from a central power plant to the home, on-site electric generation could lead to significantly higher energy efficiency, which translates to cost savings for the residential consumer.

2. Commercial Applications

Commercial uses of natural gas are very similar to residential uses. The commercial sector includes public and private enterprises, like office buildings, schools, churches, hotels, restaurants, and government buildings. The main uses of natural gas in this sector include space heating, water heating, and cooling. For restaurants and other establishments that require cooking facilities, natural gas is a popular choice to fulfill these needs. Figure 2.6 represents ratio of commercial use of natural gas.

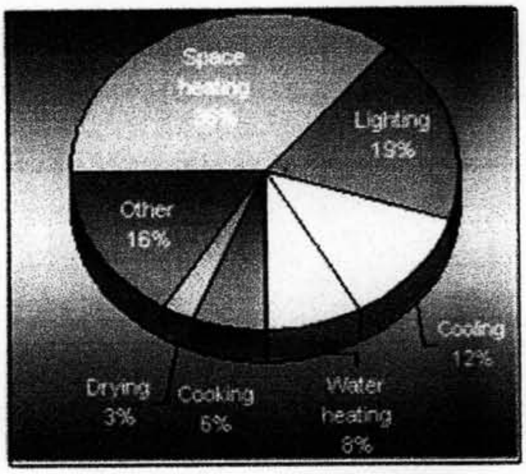

Figure 2.6 Commercial Energy Use (Source: Washington Policy and Analysis Inc, Fueling the Future 2000).

Natural gas space and water heating for commercial buildings is very similar to that found in residential houses. Natural gas is an extremely efficient, economical fuel for heating in all types of commercial buildings. Although space and water heating account for a great deal of natural gas use in commercial settings, non-space heating applications are expected to account for the majority of growth in natural gas use in those settings. Cooling and cooking represent two major growth areas for the use of natural gas in commercial settings.

Natural gas currently accounts for 13 percent of energy used in commercial cooling, but this percentage is expected to increase due to technological innovations in commercial natural gas cooling techniques. There are three types of natural gas driven cooling processes. Engine driven chillers use a natural gas engine, instead of an electric motor, to drive a compressor. With these systems, waste heat from the gas engine can be used for heating applications, increasing energy efficiency. The second category of natural gas cooling devices consist of what are called absorption chillers, which provide cool air by evaporating a refrigerant like water or ammonia. These absorption chillers are best suited to cooling large commercial buildings, like office towers and shopping malls. The third type of commercial cooling system consists of gas-based desiccant systems. These systems cool by reducing humidity in the air. Cooling this dry air requires much less energy than it would to cool humid air.

Another area of growth in commercial natural gas use is in the food service industry. Natural gas is an excellent choice for commercial cooking requirements, as it is a flexible energy source in being able to supply the food service industry with appliances that can cook food in many different ways. Natural gas is also an economical, efficient choice for large commercial food preparation establishments. New developments such as Nontraditional Restaurant Systems, which provide compact, multifunctional natural gas appliances for smaller sized food outlets such as those found in shopping malls and airports, are expanding the commercial use of natural gas. These types of systems can integrate a gas-fired fryer, griddle, oven, hot and cold storage areas, and multiple venting options in a relatively small space - providing the ease and efficiency of natural gas cooking while being compact enough to serve small kiosk type establishments.

In addition to traditional uses of natural gas for space heating, cooling, cooking and water heating, a number of technological advancements have allowed natural gas to be used to increase energy efficiency in commercial settings. Many buildings, because of their high electricity needs, have on-site generators that produce their own electricity. Natural gas powered reciprocating engines, turbines, and fuel cells are all used in commercial settings to generate electricity. These types of 'distributed generation' units offer commercial environments more independence from power disruption, high-quality consistent electricity, and control over their own energy supply.

Another technological innovation brought about is combined heating and power (CHP) and combined cooling, heating and power (CCHP) systems, which are used in commercial settings to increase energy efficiency. These are integrated systems that are able to use energy that is normally lost as heat. For example, heat that is released from natural gas powered electricity generators can be harnessed to run space or water heaters, or commercial boilers. Using this normally wasted energy can dramatically improve energy efficiency.

3. Industry Applications

Natural gas has a multitude of industrial uses, including providing the base ingredients for such varied products as plastic, fertilizer, anti-freeze, and fabrics. In fact, industry is the largest consumer of natural gas, accounting for 43 percent of natural gas use across all sectors. Natural gas is the second most used energy source in industry, trailing only electricity. Lighting is the main use of energy in the industrial sector, which accounts for the tremendous electricity requirements of this sector. Figure 2.7 shows the current as well as projected energy consumption by fuel in the industrial sector.

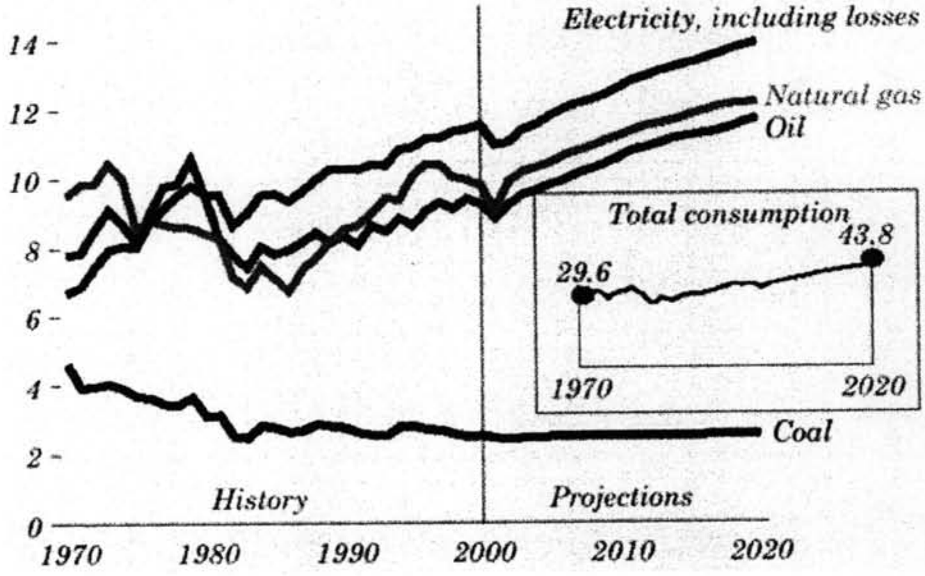

Figure 2.7 Industrial Primary Energy Consumption by Fuel 1970 – 2020 (Source: EIA Annual Energy Outlook 2002 With Projections to 2020).

Industrial applications for natural gas are many. Industrial applications include those same uses found in residential and commercial settings - heating, cooling, and cooking. Natural gas is also used for waste treatment and incineration, metals preheating (particularly for iron and steel), drying and dehumidification, glass melting, food processing, and fueling industrial boilers. Natural gas may also be used as a feedstock for the manufacturing of a number of chemicals and products. Gases such as butane, ethane, and propane may be extracted from natural gas to be used as a feedstock for such products as fertilizers and pharmaceutical products.

Natural gas as a feedstock is commonly found as a building block for methanol, which in turn has many industrial applications. Natural gas is converted to what is known as synthesis gas, which is a mixture of hydrogen and carbon oxides formed through a process known as steam reforming. In this process, natural gas is exposed to a catalyst that causes oxidization of the natural gas when brought into contact with steam. This synthesis gas, once formed, may be used to produce methanol (or Methyl Alcohol), which in turn is used to produce such substances as formaldehyde, acetic acid, and MTBE (methyl tertiary butyl ether) that is used as an additive for cleaner burning gasoline. Methanol may also be used as a fuel source in fuel cells.

In addition to these uses, there are a number of innovative and industry specific uses of natural gas. Natural gas desiccant systems, which are used for dehumidification, are increasingly popular in the plastics, pharmaceutical, candy, and even recycling industries. In each of these industries, moisture filled air can lead to damage of the end product during its manufacture. For example, in the plastics industry, moisture can cause cracks and blemishes during the manufacture of certain types of plastics. Adding a natural gas desiccant system to the manufacturing or drying environment allows industrial users to regulate more closely the amount of moisture in the air, leading to a more consistent and high-quality product.

4. Electric Generation Applications

Natural gas, because of its clean burning nature, has become a very popular fuel for the generation of electricity. In the 1970's and 80's, the choices for most electric utility generators were large coal or nuclear powered plants; but, due to economic, environmental, and technological changes, natural gas has become the fuel of choice for new power plants. In fact, in 2000, 23,453 MW (megawatts) of new electric capacity was added in the U.S. Of this, almost 95 percent, or 22,238 MW were natural gas fired additions. Figure 2.8 shows how natural gas fired electricity generation is expected to increase dramatically over the next 20 years, as all of the new capacity that is currently being constructed comes online.

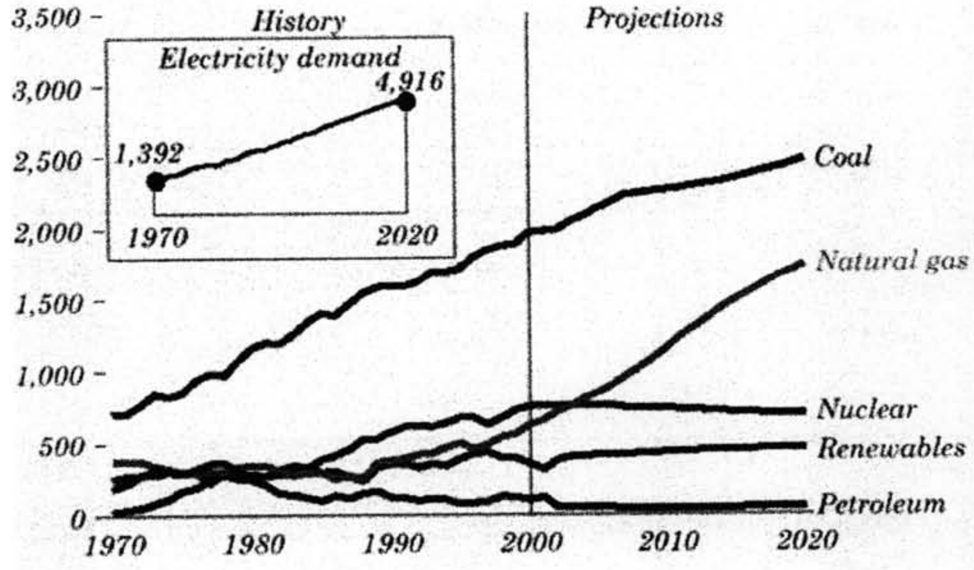

Figure 2.8 Electricity Generation by Fuel 1970-2020 (billion kilowatt hours) (Source: EIA Annual Energy Outlook 2002 with Projections to 2020).

There are many reasons for this increased reliance on natural gas to generate our electricity. While coal is the cheapest fossil fuel for generating electricity, it is also the dirtiest, releasing the highest levels of pollutants into the air. The electric generation industry, in fact, has traditionally been one of the most polluting industries in the United States. Regulations surrounding the emissions of power plants have forced these electric generators to come up with new methods of generating power, while lessening environmental damage. New technology has allowed natural gas to play an increasingly important role in the clean generation of electricity.

2.2.3 Natural Gas and the Environment

Natural gas is an extremely important source of energy for reducing pollution and maintaining a clean and healthy environment. In addition to being a domestically abundant and secure source of energy, the use of natural gas also offers a number of environmental benefits over other sources of energy, particularly other fossil fuels. This section will discuss the environmental effects of natural gas, in terms of emissions as well as the environmental impact of the natural gas industry itself

Natural gas is the cleanest of all the fossil fuels. Composed primarily of methane, the main products of the combustion of natural gas are carbon dioxide and water vapor, the same compounds we exhale when we breathe. Coal and oil are composed of much more complex molecules, with a higher carbon ratio and higher nitrogen and sulfur contents. This means that when combusted, coal and oil release higher levels of harmful emissions, including a higher ratio of carbon emissions, nitrogen oxides (NO_x), and sulfur dioxide (SO_2). Coal and fuel oil also release ash particles into the environment, substances that do not burn but instead are carried into the atmosphere and contribute to pollution. The combustion of natural gas, on the other hand, releases very small amounts of sulfur dioxide and nitrogen oxides, virtually no ash or particulate matter, and lower levels of carbon dioxide, carbon monoxide, and other reactive hydrocarbons. Table 2.2 shows fossil fuel emission levels

Table 2.2 Fossil fuel emission levels

(Source: EIA - Natural Gas Issues and Trends 1998)

Fossil Fuel Emission Levels - Pounds per Billion Btu of Energy Input			
Pollutant	**Natural Gas**	**Oil**	**Coal**
Carbon Dioxide	117,000	164,000	208,000
Carbon Monoxide	40	33	208
Nitrogen Oxides	92	448	457
Sulfur Dioxide	1	1,122	2,591
Particulates	7	84	2,744
Mercury	0.000	0.007	0.016

The use of fossil fuels for energy contributes to a number of environmental problems. Natural gas, as the cleanest of the fossil fuels, can be used in many ways to help reduce the emissions of pollutants into the atmosphere. Burning natural gas in the place of other fossil fuels emits fewer harmful pollutants into the atmosphere, and an increased reliance on natural gas can potentially reduce the emission of many of these most harmful pollutants.

2.2.4 Natural Gas Production in Thailand

Thailand found a source of natural gas in the Gulf of Thailand and since 1981 has used these reserves in electricity production and industrial factories. Since then, natural gas has been used to replace imported, high-price coal and fuel oil, which cost the country an enormous budgetary sum each year and forced the country to face oil price fluctuations in the global market – thus, risking the country's energy stability. The discovery and the use of natural gas in the Gulf of Thailand marked a new era for Thailand, allowing the country to depend on domestic energy sources.

2.2.4.1 Natural Gas in the Gulf of Thailand: From Exploration to Production

1. Seismic Exploration

The exploration for natural gas in the Gulf of Thailand started with the arrangement of a concession with the Ministry of Industry's Department of Mineral Resources. A ship was commissioned to explore areas under the granted concession in the Gulf of Thailand (exploration beyond the designated concession areas was prohibited), by sending seismic waves through layers of the earth's crust to locate underground gas formations. The resulting seismic reflection was detected with sophisticated equipment and recorded in a computer, before being taken to the head office in Bangkok for further interpretation.

2. Data Interpretation

This seismic data was transferred to a much larger computer, and then analyzed and interpreted by experienced geologists and geophysicists.

3. Exploratory Well Drilling

The best way to gain a full understanding of potential natural gas deposits is to drill an exploratory well. A team of drilling experts commissioned another ship, called the "Drill Ship," equipped with huge tools for drilling exploratory wells. (Ships were commissioned rather than purchased, as this type of ship is very costly.) The drilling method is similar to when drilling an artesian well in a rural area. However, in drilling an exploratory well, it takes many days and requires multiple relocations of the drill site to get representative samples of rocks and sand, which are then sent to the head office in Bangkok for further study and analysis.

4. Production Well Drilling

After many rounds of brainstorming and over 200 meetings, results confirmed that Thailand had discovered an abundant source of natural gas in the Gulf of Thailand. "Glowing Future Lies Ahead for Thailand" hit the newspaper headlines.

Engineers in platform design and construction teams then set up a production platform, similar in size to a football pitch and worth 600 million Baht each. One production platform can drill between 12 to 20 wells – and can drill down directly, diagonally, or with a left turn or right turn and must go through many stone layers for thousands of feet before reaching an anticipated natural gas reservoir. As it can cost 70 to 90 million Baht to drill a well, this business requires a huge investment and carries a high risk.

5. Production of Natural Gas and Liquefied Natural Gas

If the drilling is successful, gas will shoot out through the pipeline under natural pressure and sent to a production platform, designed to remove impurities – like water, pebbles, stones, and soil – from the natural gas and liquefied natural gas (LNG). Clean natural gas is then transmitted further through the underwater pipeline and delivered for sale to PTT Plc.

While natural gas is used as clean energy in electricity production, LNG and condensate are used in the oil refinery process and the aromatics industry. A portion of the natural gas and LNG are separated at the gas separation plant for use as raw materials in the petrochemical industry for the production of plastic resins and other fibers. This means clothes, shoes, cars, and many other products that make our life comfortable are all made of gas produced by UNOCAL.

Petroleum exploration and production carries a high risk and success is never guaranteed. The business operator has to invest a huge amount of money in skilled personnel recruitment, as well as the continuous development of personnel and technology. According to world statistics, the risk rate in petroleum exploration stands at 1:100, which means that from 100 exploratory wells only one offers the chance that petroleum will be discovered.

2.2.4.2 Natural gas pipeline

PTT's current natural gas pipelines are 2,652 km in length, capable of transporting 3,170 MMcfd of gas. The network comprises 2,390 km of transmission lines and 262 km of distribution lines.

1. The transmission lines

The transmission lines were laid both offshore (1,359 km) and onshore (1,031 km). The submarine transmission lines were laid from fields in the Gulf of Thailand to come ashore in Rayong and linked with PTT's natural gas separation plants there. The other offshore transmission line stretches from Bongkot and Erawan fields in the Gulf of Thailand to Khanom, Nakhon Si Thammarat.

The inland transmission lines extend, on the country's eastern side, from PTT's natural gas separation facilities to power plants in Rayong, Bang Pakong, South Bangkok, Wangnoi, and on to Ta Luang in Ayutthaya and Kaeng Khoi in Saraburi. On the western region, another onshore transmission line runs from the Thai-Burmese border in Kanchanaburi to power plants in Ratchaburi.

Both the eastern and western transmission lines were linked to form a single network by the Ratchaburi-Wangnoi connecting line, thus offering greater flexibility in sourcing natural gas from both ends.

2. The distribution lines

The distribution lines were branched out from the transmission lines to various industrial users. In order to meet the growing demand for natural gas in the next 10-15 years as well as to support the liberalization of natural gas supply market and to supplement the Asian gas grid development, PTT has prepared to embark on the Pipeline Master Plan III

The scheme would envisage a capital outlay of 93,060 million baht to be invested during 2002 and 2010.

In addition, PTT has formed joint venture companies to engage in the development of natural gas transmission businesses, namely the Trans Thai-Malaysia (Thailand) Co., Ltd. and Trans-Malaysia (Malaysia) Co., Ltd. Figure 2.9 shows the natural gas pipeline network in Thailand.

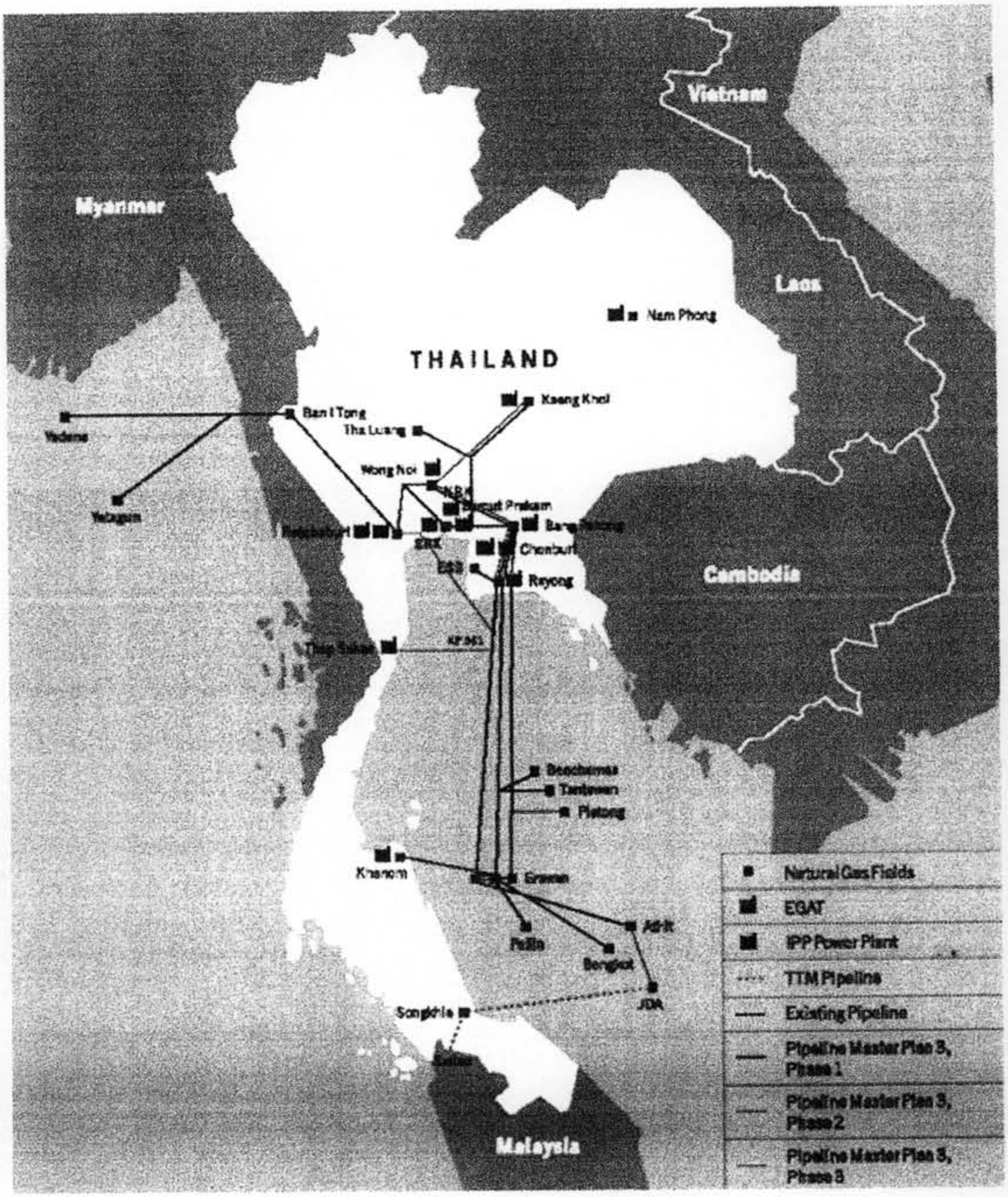

Figure 2.9 Gas Pipeline Network (Source: PTT Public Company Limited).

2.2.4.3 Gas Separation Plant in Thailand

"Gas Separation Plant" has thus emerged to add value to natural gas for Thailand's optimization of natural resources. It has also entailed the development of numerous related industries.

The Petroleum Authority of Thailand (PTT), then, constructed Gas Separation Plant Unit 1 in Mab Ta Phut sub district of Rayong Province in 1982. The inauguration ceremony of Gas Separation Plant Unit 1 was graciously presided over by His Majesty the King, Her majesty the Queen, HRH Princess Maha Chakri Sirindhorn and HRH Princess Chulabhorn on April 18, 1985

Later on, Gas Separation Plant Units 2 and 3, which came on-stream in 1991 and in 1997 respectively, were constructed in the same compound as Unit 1, in response to the increasing demand for ethane, propane, liquefied petroleum gas (LPG) or cooking gas), and natural gasoline. The products have also been supplied as feedstock of petrochemical industry. PTT's Gas Separation Plants can thus save energy imports, lower trade deficit, enhance the stability of petrochemical industry in Thailand's Eastern Seaboard, and create national energy security.

Gas Separation Plant Unit 4, of which official inauguration was held on July 12, 1996, was aimed to satisfy the demand for LPG or cooking gas and natural gasoline, especially in the south of Thailand. Natural gas used in Gas Separation Plant Unit 4 is from the Bongkot field, transmitted via a 32-inch pipeline of 170- kilometer long to the Erawan platform and sent through a 24-inch and 160-km.pipeline onshore at Thong Nian Subdistrict,Khanom District of Nakhon Si Thammarat Province. The construction of Gas Separation plant Unit 4 has facilitated and sped up product transport via tankers to PTT's LPG Terminals in Surat Thani and Songkhla, and enhanced convenience in product export.

Nevertheless, the continuously rising demand for energy resulting from economic expansion has raised the demand for natural gas. Concurrently, the demand for petrochemical feedstocks has constantly escalated. Therefore, on December 22, 1999, PTT's Board of Directors approved the construction of Gas Separation Plant Unit 5 to increase the production of ethane and LPG or cooking gas as feedstock for the expansion of Thai Olefins Public Company Limited (TOC).

Consequently, on September 27, 2001, PTT's Board of Directors approved in principle PTT's support to the 300,000-ton-per-year ethylene capacity expansion project of TOC, using ethane as feedstock. In order to reduce the production cost, the Gas Separation Plant Unit 5 Project is the first for PTT to be granted such investment promotion privileges by the Office of Board of Investment (BOI) as exemption of import duty on machinery and 8-year corporate income tax. Table 2.3 shows the production capacity and products from the 5 gas separation plants.

Table 2.3 Production Capacity and Products of Gas Separation Plant Units 1-5 (Source: PTT public company limited)

Gas In-Take Quantity	**Methane (MMSCFD)**	**Ethane (Tons/year)**	**Propane (Tons/year)**	**LPG (Tons/year)**	**Natural Gasoline (Tons/year)**
Unit 1 : 350 MMSCFD	250	330,000	191,000	243,000	76,000
Unit 2 : 250 MMSCFD	230	76,000	108,000	205,000	36,000
Unit 3 : 350 MMSCFD	315	111,000	201,000	250,000	36,000
Unit 4 : 230 MMSCFD	215	-	-	205,000	34,000
Unit 5 : 530 MMSCFD	337	520,000	151,000	495,000	177,000