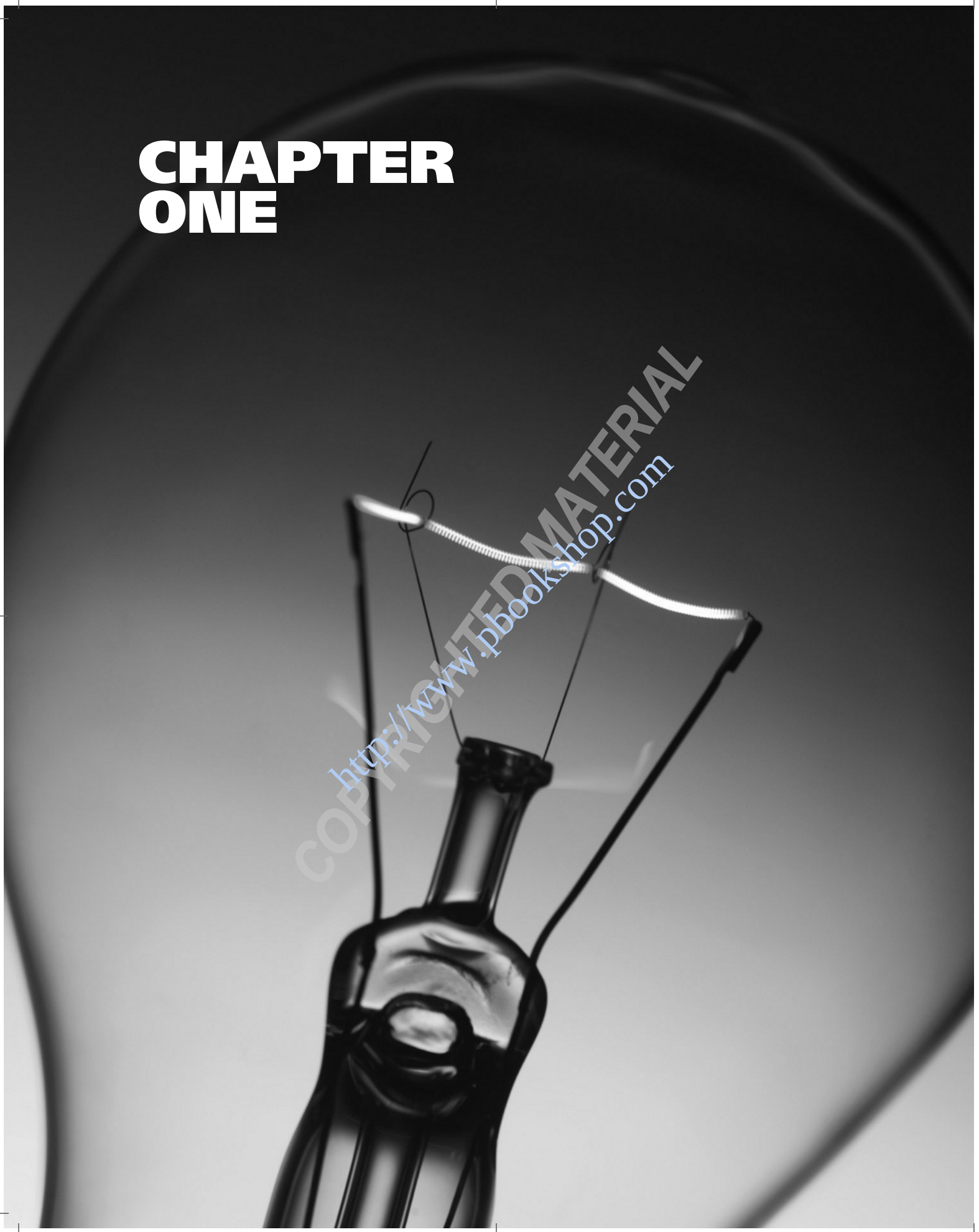
CHAPTER ONE



THE ENERGY CYCLE

The purpose of this chapter is to provide the candidate an overview of the energy cycle, or the energy value chain. Many of the concepts and issues introduced here have been intentionally simplified. In some instances, however, the complexity of the energy industry will motivate a more in-depth discussion in subsequent sections.

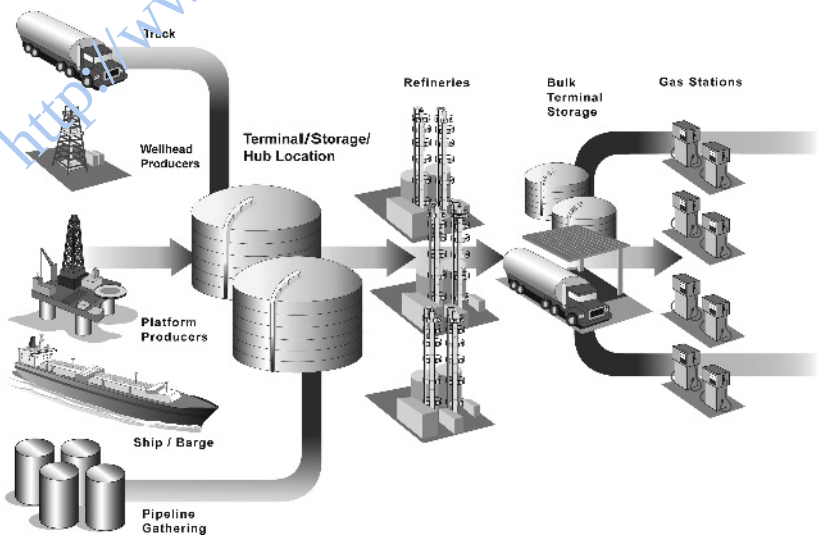
After completing this chapter, the candidate will gain a basic understanding of:

- the components of the energy cycle
- how the components of the energy cycle are connected
- the difference between integrated and specialty energy companies

1.1 Introduction

Globally, the physical energy industry generates approximately USD 1 trillion in revenue per year. In its daily activities, raw commodities are refined to generate energy. Energy is transformation; producing gasoline or heating oil from crude oil, or generating power from coal or wind. From the extraction of the raw sources of energy—crude oil, natural gas, or coal—to the use of energy by the ultimate consumer, energy sources are undergoing constant change, no matter where they are in the process. Figure 1 shows the flow of crude oil from the ground, through storage, pipelines, and refineries, to the gas stations.

Figure 1. Flow of Crude Oil



THE ENERGY CYCLE

All activities in the energy industry encompass four interrelated functions, which are described as the **energy cycle**:

- exploration and production
- transportation and storage
- refining and processing
- distribution and sales

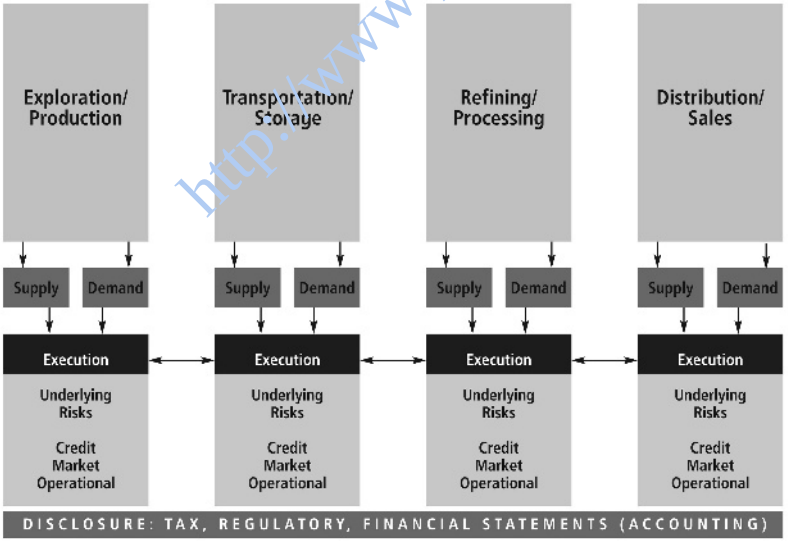
The entire energy industry revolves around these four functions. Each of these functions inherently contains complex risks that shape business strategies to mitigate these risks and their effects.

The first two steps in the energy value chain, exploration and production and transportation and storage, are generally referred to as **upstream**, and the last two steps, refining and processing and distribution and sales, as **downstream**.

The term **energy cycle** is used interchangeably with the term **commodity cycle**.

Figure 2 summarizes how these different functions interact with each other in the commodity cycle.

Figure 2. Functions in the Energy Cycle



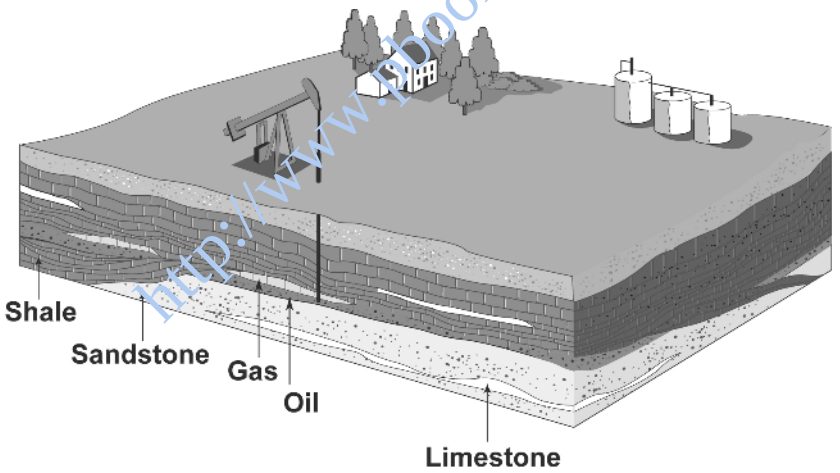
The following section explains how crude oil and natural gas move throughout the energy cycle from upstream to downstream. Since the exploration and production activities for both crude oil and natural gas are similar—as are their potential risks—they are therefore discussed together.

1.2 Exploration

Crude oil and natural gas exploration starts with a scientific analysis of the surface and subsurface structure of various areas. Using scientific information, geologists determine where in the underground layers of the earth, crude oil or natural gas deposits are likely to exist. Figure 3 shows where crude oil and natural gas can reside below the earth's surface.

In the exploration phase, extensive and costly scientific analysis is used to gain detailed information on the sub-surface structure of various geographic areas.

Figure 3. Possible Locations of Crude Oil and Natural Gas



Geophysicists use various methods of seismic exploration to gain a better understanding of the subsurface structure of the earth. Very simply, in seismic exploration, sound waves are generated and sent underground. These sound waves can be generated from an electronic source or explosion. As these waves travel through

the various layers of the earth's surface, some of the waves will bounce back to the surface. Sound waves travel through different subsurface areas at different speeds, and these differences can reveal structures where hydrocarbon deposits are likely to reside. An interpretation of the data captured from the waves reveals the composition of the subsurface structure of the earth at that location.

Apart from seismologic methods, the structure of the earth can also be analyzed using magnetometers. These instruments measure local deviations in the earth's magnetic field that could suggest the possible existence of rock formations containing crude or natural gas.

Further exploration of the structure of the subsurface may be done by drilling exploratory wells. Here, geologists drill into the earth's crust to reveal the detailed composition of the underground rock layers. As exploratory well drilling is both expensive and time consuming, wells are only drilled where scientific information derived from seismic and magnetometric studies suggest a high probability of crude oil or gas deposits. Throughout the drilling process, many tests are performed on the rock displaced by the drilling of the well. These tests are used to reveal information about the structure of the subsurface layers, the porosity and permeability of underground layers, and the potential size of a hoped-for hydrocarbon deposit.

1.3 Production or Extraction

Once the determination is made that exploring a deposit at a specific geographical location is commercially viable, several additional decisions must be made that directly impact the well's potential. With the high costs of exploration and extraction, each well must be optimally placed geographically and geologically to increase its chances of commercial success.

For example, remote areas are less likely to be explored because the cost of bringing the crude oil or natural gas to the consumer may be prohibitively expensive. This is because each well needs to be connected to a gathering and transportation system that would ultimately lead to an appropriate pipeline system for delivery to refineries, and ultimately to the final consumer. The well also needs to sit close to the optimal subsurface formation. Moreover, before a well is drilled, the exploration company needs to secure permits to drill on the land from the land owners and various interested regulatory agencies. The exploration company must also resolve often complex ownership rights to the land where the hydrocarbon deposits reside. Various economic and legal arrangements may have to be negotiated to compensate owners of the land.

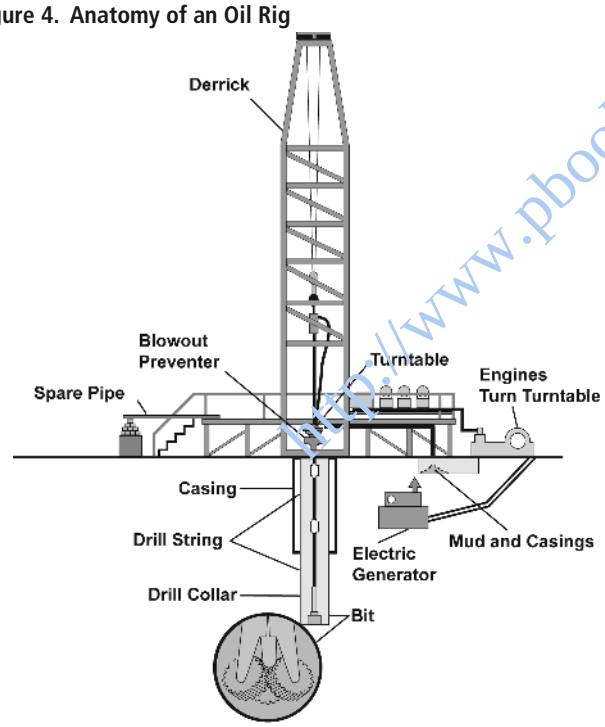
Assuming though, that a well has been drilled, it is not certain that it will lead to a crude oil or natural gas finding. If the well does not lead to a finding, it is considered to be a "dry well" and is abandoned. If the new well hits a finding, it may then be considered a "productive well." This requires further testing that, if results are positive, the well is developed for production.

Developing a well for production requires a number of preliminary steps, all of which present material operational risks that have to be addressed.

- First, the sides of the well must be strengthened with a casing, essentially a metallic tube that is lowered into the hole. The casing ensures that neither gas nor oil can escape and the hole does not collapse. Casing and cementing also prevents the contamination of subsurface water reservoirs (aquifers).
- Second, the proper equipment must be installed at the wellhead to ensure an efficient flow of the hydrocarbons out of the well. The equipment at the wellhead regulates and monitors the extraction of hydrocarbons and prevents leaking and blowouts.

Figure 4 shows a typical oil rig configuration with its surrounding structure.

Figure 4. Anatomy of an Oil Rig



Both crude oil and natural gas can be found in the same underground reservoirs. While oil wells predominantly yield just crude oil, many oil wells will yield both crude oil and natural gas. In the later instance, the natural gas pressure present in the underground rock formation is actually used to help extract the oil from the ground. When the pressure is insufficient, or the well is close to depletion, lifting (extracting) equipment is added to the wellhead to help bring the crude oil or natural gas to the surface. This equipment helps the extraction process through various methods, including the injection of steam, water, and CO_2 into the underground hydrocarbon deposits.

1.4 Processing

Crude oil and natural gas need to be cleaned and purified before they can be further processed. The production process for both crude oil and natural gas extracted from the well is complex and very technical.

The initial stage of the production process requires the separation of crude oil and natural gas from contaminants, and sometimes from each other. Just separating the crude and natural gas is insufficient to use either product for energy generation. To generate energy, both need to be further refined, converted, and processed. The production processes for crude oil and natural gas are different.

- **Crude oil**
  After extraction, the natural gas and other contaminants are removed from the crude oil. The crude oil is transported either by truck, tankers, or pipeline to storage facilities linked to a refinery for further processing and refining.

- **Natural gas**
  After extraction, natural gas needs to be cleaned of impurities and other compounds before the gas reaches the end user. Natural gas before processing is known as "wet gas"; after processing it is known as "dry gas."

  This process is complex and depends on the molecular makeup of the gas. After the gas is extracted from the ground, gas condensates, and impurities are separated. To transport the natural gas via pipelines, it needs to be conditioned by removing corrosive components such as water, sulfur, and carbon monoxides. After removing condensates, impurities, and corrosive components from the natural gas, only methane will remain. The natural gas used to generate energy is mostly—80 to 90 percent—methane.

  The crude oil removed from natural gas enters the crude oil energy chain. The various oil and gas condensates such as Liquefied Petroleum Gas (LPG) and Natural Gas Liquids (NGL) are processed and distributed separately from the natural gas.

1.5 Transportation and Storage

Both crude oil and natural gas need to be transported from the wellhead to the end-user. This requires an extensive, elaborate and highly regulated commodity specific system. Although there are some similarities between the crude oil and natural gas transportation systems, there are also considerable differences.

Pipelines, which are a major part of these transportation systems, are usually made of steel or plastic composites. Depending on the intended use of the pipeline, the diameter of the pipeline can range from 1 inch to 40 inches (2.5 cm to 120 cm). Most pipelines are buried underground at a typical depth of about 3 feet to 7 feet (about 1 to 2 meters).

Transportation and storage are closely linked. To assist in controlling seasonal variations in demand, and to offer protection from temporary disruptions in the transportation system, crude oil, natural gas, and refined products are stored in large storage facilities. Storage facilities can be above-ground tanks or underground salt caverns, aquifers, or depleted oil fields.

- **Crude oil**
  After crude oil is extracted from the ground, it is transported using a gathering system. The gathering system consists of smaller interconnected pipelines that bring crude oil from several nearby wells to a storage facility. Pipelines in the gathering system have small diameters and rarely reach more than 3,000 feet (1 km) in length. From the gathering system, crude oil is shipped to a centralized storage facility, either through larger pipelines or trucks.

  Due to economic considerations, refineries are usually located as close to the crude oil end-users as possible. From storage facilities, the crude oil is shipped to a refinery either by using tankers or pipelines. Transportation pipelines can be several thousand miles long. To move the crude oil over these long distances pumping stations apply pressure on the crude oil. The crude oil usually flows at speeds of about 1 meter to 6 meters/second (3 to 24 feet/second).

  In many cases pipeline transportation is not possible. For instance, crude oil extracted in the Persian Gulf will be refined where it is used—in Europe or Asia. To transport the crude oil over water, crude oil tankers are used. In contrast, crude oil extracted in the United States for domestic use, is usually shipped via crude oil pipelines to domestic refineries.

- **Natural gas**
  Unlike crude oil, where transportation can involve tankers, natural gas is chiefly transported using a complex network of pipelines. These pipelines quickly and efficiently transport natural gas from the wellhead to areas of high natural gas demand.

The structure of the pipeline system for natural gas is similar to that used for crude oil. At the production stage, the gathering system brings the gas extracted from several closely located wellheads to a central treatment and storage facility. At this facility the gas is treated, and in some cases further processed, before it enters a large diameter pipeline system that transports the gas over long distances. As gas will only flow when it is under pressure, constant pressure must be maintained in the pipeline. This is achieved through the use of compression stations located along the pipeline's route.

Where natural gas is produced in remote areas, or where natural gas cannot be transported using pipelines, transforming the natural gas into a liquid form offers an alternative. Several of the largest gas exporters in the world are countries around the Persian Gulf, such as Qatar and and the United Arab Emirates.. The largest gas consumers in the world are in the Far East, namely Japan and South Korea. To transport natural gas over large distances, from the Persian Gulf to the Far East, the gas is liquefied and transported using specially designed tankers. This chain is also called the Liquefied Natural Gas (LNG) chain.

1.6 Refining

At the refinery, the crude oil is refined through a heating process, **distillation**, to separate it into gasoline, heating oil and lubricants. These end products are commonly referred to as **refined products**. It is these refined products, and not the crude oil directly extracted from the ground, that are used for energy generation. The refining process and the characteristics of various refined products will be discussed in later sections.

1.7 Distribution

At each step of the energy cycle, ownership of the crude oil, natural gas, and refined products changes hands. At each ownership change, the transfer is documented by analyzing and measuring the volume and quality of the transferred product.

The refined products, such as heating oil, are transported to distributors, either using refined product pipelines or refined product tankers to storage and distribution facilities. When the refined products are transported over long distances, they can use either dedicated pipelines that only move a certain refined product or multiproduct pipelines that move a wider range of products from the refinery to distribution facilities. From these distribution facilities, the refined products, such as heating oil, can be either transported using small diameter distribution pipelines to large scale users, or by tanker trucks to smaller users. It is from these distribution facilities that gasoline is transported to retail gas stations, and heating oil to buildings.

Before the natural gas reaches its final destination, the consumer, it is distributed from the large diameter pipelines to smaller distribution pipelines. Some large volume consumers, however, are often directly connected to the larger diameter transportation pipelines. **Local distribution companies** (LDCs) deliver natural gas to consumers within a specific geographic area, such as a city. LDCs take natural gas from delivery points along major large-diameter pipelines, termed **citygates**, and in turn distribute the gas through thousands of miles of small-diameter distribution pipelines. It is estimated that in the United States alone there is more than one million miles of gas distribution pipelines. Due to the complexity of maintaining and running a gas pipeline and the major investment needed to keep it going as well as the need for energy, LDCs are generally considered natural monopolies and are closely regulated by the U.S. government.

1.8 Integrated and Specialty Companies

The energy industry is complex. Investments and activities throughout the chain are significant. When analyzing the activities of the energy industry, one has to understand most the risks or the operations at each stage of the cycle. This analysis must start with the specifics of each energy commodity.

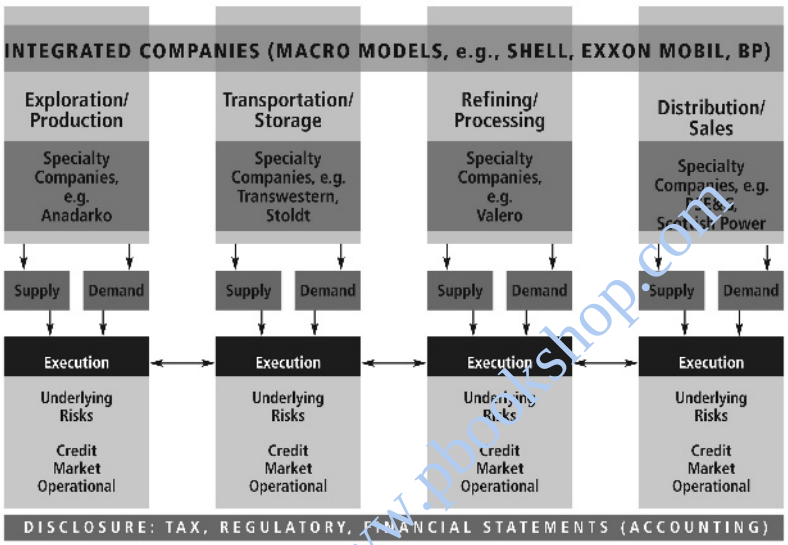
The second step is to look at the relationships between these steps in the chain. Activities in the energy value chain can be either executed under the oversight of one parent company (one corporate umbrella), or by independent companies throughout the chain. When these activities are executed under one corporate umbrella, we talk about **integrated energy companies**. Classic examples of this type of company are ExxonMobil, Chevron, Shell Oil, or BP.

For example, petroleum companies can represent a mix of large integrated companies often known as "major oil companies" or smaller "independents" or specialty companies. The independent companies, although greater in number than the majors, own a smaller share of the industry. The **independent or specialty energy companies** become specialized in one individual step in the value chain, for instance, companies that run a natural gas pipeline; a utility generating power or a company involved in the exploration and production of crude oil. Specific examples include Global Marine for the underwater exploration of crude oil and natural gas; Frontline Inc, for shipping; Valero for refinery, and MOL and ARAL for distribution.

THE ENERGY CYCLE

Figure 5 illustrates the operations of both integrated and specialty companies.

Figure 5. Operations of Integrated and Specialty Companies



Both integrated and independent companies face the same supply and demand, legal, credit, market, operational and technology problems. In the integrated companies many of the risks that would occur as an energy product moves along the value chain are generally considered to be hedged naturally and offset each other. These risks may not require specific action to mitigate a specific risk. For example, an oil and gas production company might not engage in risk mitigating hedging activities for its crude or natural gas production as it would have sufficient storage facilities to handle a disruption. An independent production company, on the other hand, might hedge against a disruption by putting into place alternative, contingent, delivery sources "just in case."

The energy industry is inherently complex. This course highlights for each commodity its typical features and widely known risks. Thus, after successfully completing this program, a candidate will have become well versed in the risks associated with particular commodities. Although the program offers numerous practical examples throughout, it is difficult to cover all operational aspects. This material does not provide a comprehensive, exhaustive, and detailed analysis of all possible features, hazard, and safety issues. Thus, we strongly encourage candidates interested in highly specific processes, risks, or problems to seek further information elsewhere.