Feature Article

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# Introduction to

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Oil refinery appraisals are among the most complicated of all industrial valuations. However, oil refining is also an industry for which the U.S. Government has a huge amount of statistical information. Anyone valuing refineries should start with this information, because it provides an explanation of crude-oil-manufacturing processes, as well as a trove of data about the oil-refining business.

The figures on oil production and refineries in this article are from the U.S. Energy Information Administration (EIA), which is part of the U.S. Department of Energy and is responsible for collecting, analyzing, and disseminating energy information. EIA programs collect data on coal, petroleum, natural gas, electric, renewable, and nuclear energy; the website is www.eia.gov.

## Refinery Information from EIA

In 1942, under the Petroleum Administration for War, the United States was divided into five districts to help organize the allocation of fuels derived from petroleum products. The goal was to track the production and delivery of gasoline and diesel fuel during World War II. Today these districts are called Petroleum Administration for Defense Districts (PADDs); see figure 1. Many other charts, diagrams, and illustrations are available from EIA. Figure 2 shows some of the petroleum products that can be made from a barrel of oil. Table 1 lists top producers and the amounts they produce. Figure 3 shows U.S. energy consumption for 2015.

EIA also reports estimates for imports and exports for each PADD district, which can be important in understanding the economic aspects of a refinery for valuation. Figure 4 is a report from 2014; other import/export data are presented in figures 5 and 6.

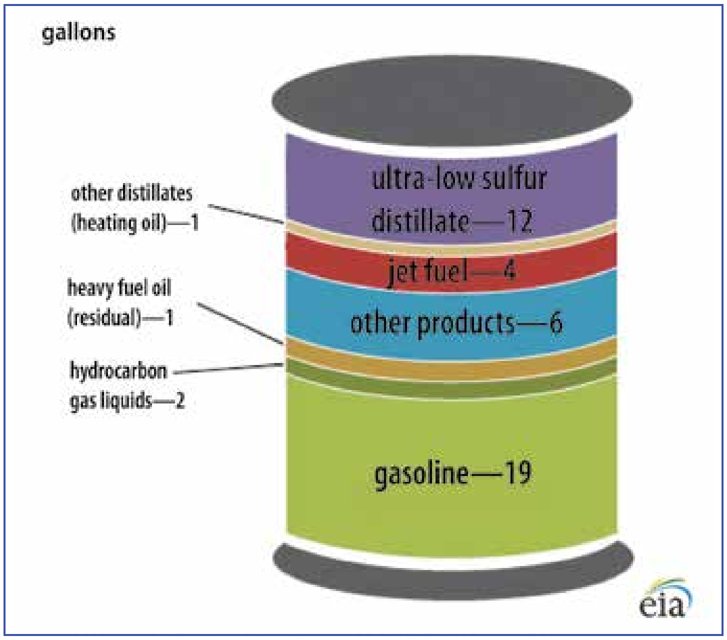
**Figure 1.** The five Petroleum Administration for Defense Districts in the United States


*Source: U.S. Energy Information Administration*

## The Basics of Crude Oil

The crude oil that refineries use varies according to the available supply and the type of crude the refinery can process. Crude oil is categorized as heavy or light according to its API

**Figure 2.** Petroleum products (gallons) made from a barrel of crude oil, 2015




*Note: A 42-gallon (U.S.) barrel of crude oil yields about 45 gallons of petroleum products because of refinery processing gain. The sum of the product amounts in the image may not equal 45 gallons because of independent rounding.*

*Source: U.S. Energy Information Administration,* Petroleum Supply Monthly, *February 2016, preliminary data for 2015*

# Valuing Oil Refineries

gravity and as sweet or sour according to its sulfur content. API stands for the American Petroleum Institute, and the API gravity is a measure of how heavy or light the petroleum liquid is compared to water. In an inverse to the number, if the API gravity is greater than 10, the crude is lighter and floats on water; if it is less than 10, it is heavier and sinks.

A rule of thumb for defining crude oil is that *heavy crude* is less than 30°API and *light crude* is greater than 30°API. Also, if crude contains a large amount of sulfur or sulfur compounds (1 to 5 percent), it is labeled *sour crude*, but if it has little or no sulfur (less than 1 percent), it is called *sweet crude.*

## The Basics of Refinery Operations

An oil refinery might also be called a distillery because that is what actually takes place. Simply put, different boiling points allow hydrocarbons to be separated by distillation to produce various petroleum products such as gasoline, kerosene, and gas oil. These products are then further refined to make a variety of products.

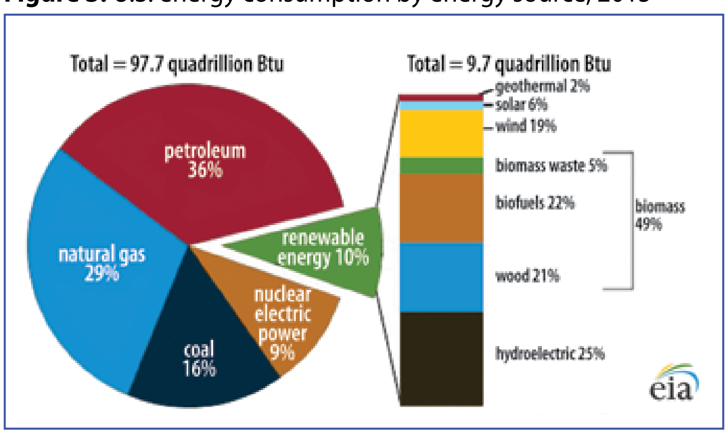
**Table 1.** Top 10 U.S. refineries* operable capacity (as of January 1, 2016)

| Rank | Corporation | Company | State | Site | Barrels per Calendar Day |
|---|---|---|---|---|---|
| 1 | Motiva Enterprises, LLC | Motiva Enterprises, LLC | Texas | Port Arthur | 603,000 |
| 2 | ExxonMobil Corp. | ExxonMobil Refining & Supply Co. | Texas | Baytown | 560,500 |
| 3 | Marathon Petroleum Corp. | Marathon Petroleum Co., LLC | Louisiana | Garyville | 539,000 |
| 4 | Marathon Petroleum Corp. | ExxonMobil Refining & Supply Co. | Louisiana | Baton Rouge | 502,500 |
| 5 | Marathon Petroleum Corp. | Marathon Petroleum Corp. | Texas | Galveston Bay | 459,000 |
| 6 | PDV America, Inc. | Citgo Petroleum Corp. | Louisiana | Lake Charles | 427,800 |
| 7 | BP PLC | BP Products North America, Inc. | Indiana | Whiting | 413,500 |
| 8 | ExxonMobil Corp. | ExxonMobil Refining & Supply Co. | Texas | Beaumont | 344,600 |
| 9 | WRB Refining LP | WRB Refining LP | Illinois | Wood River | 336, 000 |
| 10 | Carlyle Group | Philiadelphia Energy Solutions | Pennsylvania | Philadelphia | 335,000 |

** Only refineries with atmospheric cude oil distillation capacity*

*Source:* Refinery Capacity Report

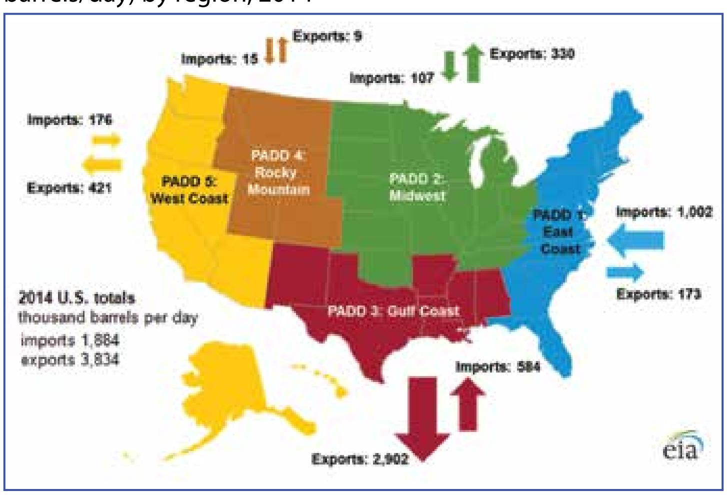
**Figure 3.** U.S. energy consumption by energy source, 2015




*Note: The sum of components may not equal 100% because of independent rounding.*

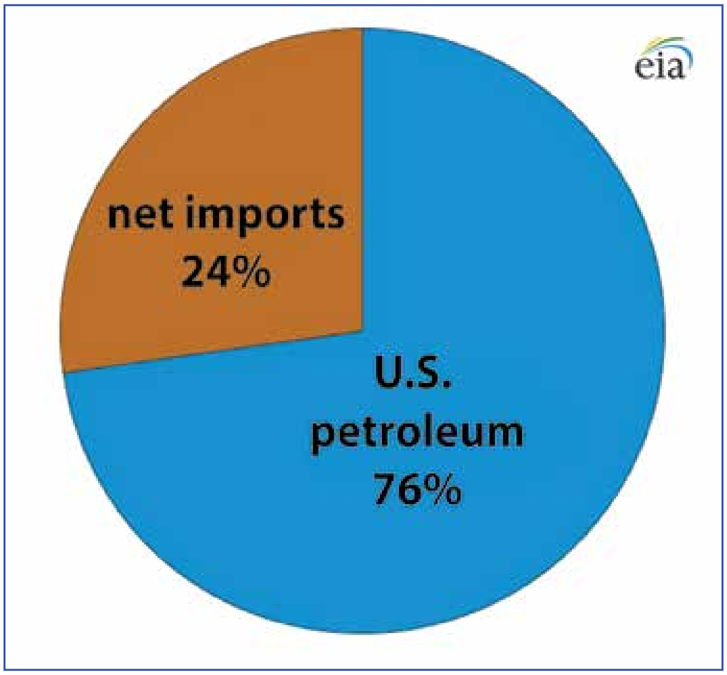
*Source: U.S. Energy Information Administration,* Monthly Energy Review, *Tables 1.3 and 10.1 (April 2016) preliminary data*

**Figure 4.** Petroleum product imports and exports (thousand barrels/day) by region, 2014




*Source: U.S. Energy Information Administration*

**Figure 5.** U.S. domestic petroleum production and net imports of petroleum as shares of petroleum consumption, 2015




*Note: Petroleum includes crude oil, petroleum products, and biofuels.*
*Source: U.S. Energy Information Administration.* Monthly Energy Review, *Table 3.3a, October 2016*

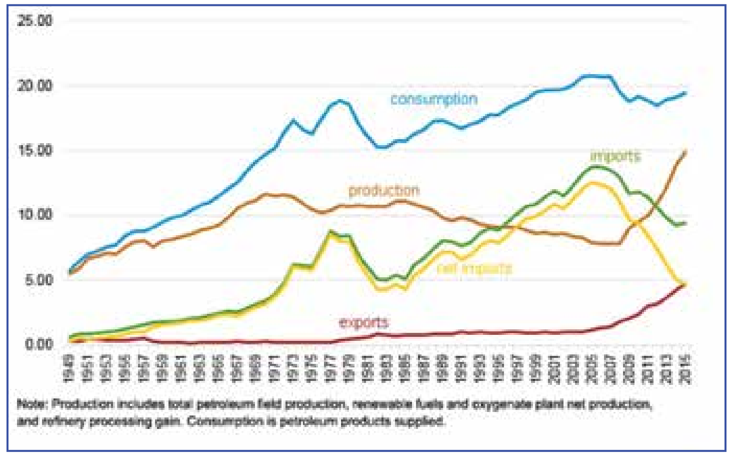
First, crude petroleum is delivered to the refinery and is heated and changed into a gas. Then the hot gases are pushed into the bottom of a distillation column, and they cool as they move up higher in the column. As they cool below their boiling point, condensation occurs and the gases become liquids. The liquids are siphoned off from the column at certain heights, leaving the heaviest at the bottom and the lightest at the top. Unprocessed gasoline goes to the top, diesel fuels are mid-range, and the heavier product goes to the bottom, which may be used for an asphalt plant or may go to a coker for more processing.

There is quite a variance in the temperatures needed in the distillation process. The crude oil comprises thousands of different chemical compounds called hydrocarbons, and the different boiling points range from about 90°F to 1,100°F, depending on the product being produced. Figure 7 shows how this first step is achieved. After this basic distillation is completed, more steps are necessary to make the final products, as shown in figure 8.

## Refineries and Complexity

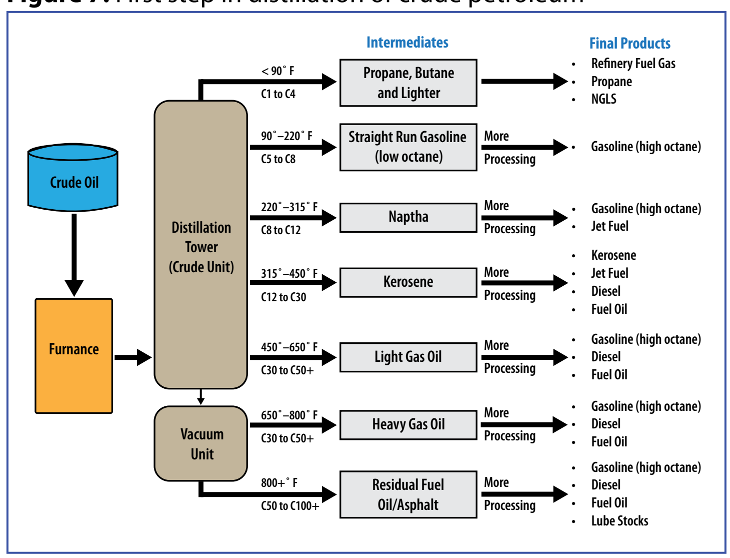
The simplest refineries are called topping refineries, and they have a distillation column and not much else. They are typically smaller refineries, account for a small percentage of the total, and require light sweet crude to operate. Most refineries are able to use heavier crude because they are more complex

**Figure 6.** U.S. petroleum consumption, production imports, exports, and net imports (million barrels/day), 1949–2015



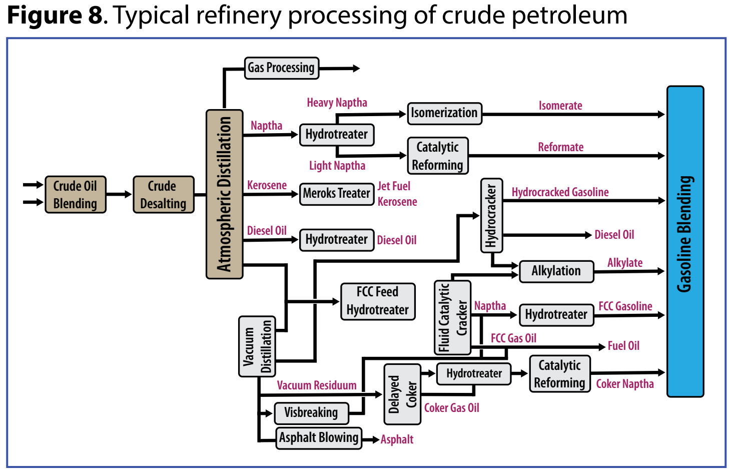

*Note: Production includes total petroleum field production, renewable fuels, and oxygenate plant net production, and refinery processing gain. Consumption is petroleum products supplied.*
*Source: U.S. Energy Information Administration.* Monthly Energy Review, *Table 3.1, October 2016*

**Figure 7.** First step in distillation of crude petroleum




*Source: Adapted from U.S. Energy Information Administration and Wikimedia Commons.*

**Figure 8.** Typical refinery processing of crude petroleum




*Source: Adapted from U.S. Energy Information Administration and Wikimedia Commons.*

and have any combination of secondary processing units to process other products. Besides gasoline and blended stocks of gasoline, other products include various grades of diesel, jet and other aviation fuel, kerosene, fuel oil, solvents, sulfur, coke, asphalt, chemical feedstocks, and so on. The following information from the EIA website explains complexity.

> *A refinery's level of complexity is often based on its secondary conversion capacity. The Nelson Complexity Index is one measure of refinery complexity. This index was developed in the 1960s by W.L. Nelson in a series of articles for the Oil & Gas Journal. The index measures the complexity and cost of each major type of refinery equipment. In forming the index, the distillation column is given a value of 1 and the other units are assigned a value based on conversion and cost relative to the distillation column. The larger the Nelson index of a refinery, the more complex it is.*
>
> *As an example, Phillips 66 reports that its U.S. refineries range in Nelson complexity from 7.0 at its Ferndale refinery in Washington because it has a fluid catalytic cracker, alkylation, and hydrotreating units, to 14.1 at its Los Angeles refinery in California because it has a fluid catalytic cracker, alkylation, hydrocracking, reforming, and coking units. In addition to those two West Coast examples, the U.S. Gulf Coast has some of the world's most sophisticated refineries.*

Equivalent Distillation Capacity (EDC) is another metric used in comparing refinery costs. Using the EDC calculation, the atmospheric distillation capacity of a refinery is multiplied by its overall complexity rating.

Based on Nelson complexity, the simplest topping refineries may have a complexity factor of 1 to 3, whereas the most complex may reach factors of about 18. These complex refineries have the capability to process the heaviest, highest sulfur content crude, which is the most difficult to separate.

The secondary processes in a refinery may include various equipment such as a *desulfurization unit* to remove sulfur, a *reformer unit* to change the molecular structure of crude to produce high-octane gasoline, or an *alkylation unit* to use an acid catalyst to make alkylate, which has a high octane for producing gasoline blend stocks. Some refineries have a *coker unit* for thermal cracking to make butane, naphtha, and other products, or a *fluid catalytic cracking unit* to use heat to *crack* molecules to make low-quality diesel fuel.

Other treatments include *hydrotreating*, which removes impurities by using hydrogen to bind with sulfur and nitrogen. A *hydrocracking process* breaks down or *cracks* diesel stock material into gasoline blending stocks. *Isomerization* rearranges the atoms in a molecule to make butane and isobutene.

## Crack Spread

An important term to understand in analyzing refineries is *crack spread*. Crack spread is a broad estimate used in the oil industry to estimate the differential between the price of crude oil and the petroleum products refineries produce. The name comes from the process that refineries use to make their final products. They *crack* a long chain of hydrocarbons of crude oil to make shorter chain products such as gasoline and diesel fuel.

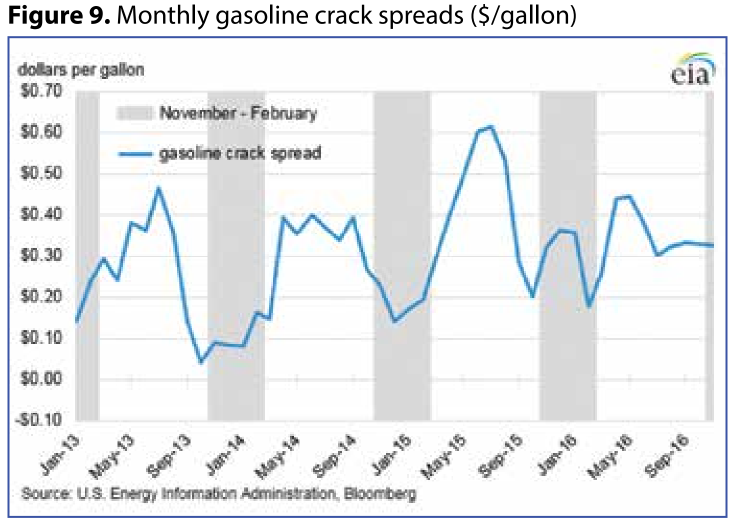
***An oil refinery might also be called a distillery because that is what actually takes place. Simply put, different boiling points allow hydrocarbons to be separated by distillation to produce various petroleum products such as gasoline, kerosene, and gas oil.***

Another way of saying this is that a crack spread measures the difference between the cost paid by the refinery for crude oil and the selling price of finished products. A 3:2:1 crack spread would be the profit margin based on the purchase cost of 3 barrels of crude oil and the production of 2 barrels of gasoline and 1 barrel of diesel fuel. Crack spreads are continually changing, so they are only an indicator of the short-term profit margins of oil refineries. Moreover, they do not include variable costs and fixed costs incurred by a specific refinery. Figure 9 shows the variation in gasoline crack spreads from January 2013 to September 2016.

## The Valuation Process

Because of the complexity of valuing a refinery, it is helpful for an appraiser to use all three approaches to value, but it is

**Figure 9.** Monthly gasoline crack spreads ($/gallon)




*Source: U.S. Energy Information Administration, Bloomberg* not essential if there is enough evidence to produce a valid conclusion of value using two approaches. In some states an income approach, and particularly a discounted cash flow analysis (DCF), is not allowed, mostly because of forecasts and projections that are made to determine the value. In such cases, the cost approach and the sales comparison approach may provide an adequate understanding of the value, but they need to be carefully applied.

**The Cost Approach**

For assessment purposes, original costs are normally trended, and the result is a depreciated reproduction cost of the refinery. Another approach would be a replacement cost for the refinery, which would be derived from the cost to build a state-of-the-art refinery, with depreciation subtracted for physical, functional, and economic obsolescence. However, both methods can be problematic.

The problem with the reproduction trending method, particularly for an older refinery, is that the replacement for it might be significantly different from its original construction and the machinery and equipment may have less value due to technological progress that is not reflected in typical trends.

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The problem with the replacement cost method is that estimating the various forms of depreciation is exceedingly subjective. This allows the appraiser to choose from a broad range of value, which can result in a questionable value conclusion.

Subjectivity is an issue because the methods and estimates used by the appraiser depend upon his or her experience and personal opinions, and those may vary drastically among appraisers. The estimates begin with a determination of how much the physical depreciation, or actual wear and tear, has diminished the value. Next, an estimate for functional obsolescence is made, which might include a calculation of the excess operating costs incurred to operate an older facility compared to a new one. This should also include a comparison of the existing layout compared to a state-of-the-art one.

The third estimate is for economic obsolescence, which may be applicable if, for instance, the refinery's location is no longer proximate to the crude oil sources for which it was constructed. An example might be a refinery built to process light sweet crude in North Dakota to take advantage of the oil wells there that use hydraulic fracturing (fracking). When oil prices decline to the point that it is no longer cost-effective to draw from those wells, the refineries may lack the product necessary for profitable operation, which may significantly reduce their value, depending on the outlook for crude prices.

**Common Cost Approach Errors**

*Reproduction to Replacement Cost Differential*

Some appraisers think that subtracting the replacement cost from the reproduction cost (a modern plant compared to a replica of the original plant) yields the economic obsolescence for the facility. However, this does not apply to refineries, nor does it apply to a myriad of other properties. There are several reasons, but the main one is that a replacement facility may cost more or less to build than a reproduction of the original facility, depending on the technologies involved. A replacement facility may cost more to construct, but the larger investment may also increase production capacity and the efficiency of the operation. Consequently, this concept is not applicable to determining obsolescence for refineries as well as for many other industrial properties.

*Entrepreneurial Profit*

*Entrepreneurial profit* is generally an element of profit included in the cost approach for commercial properties such as apartment complexes and shopping malls. It is sometimes referred to as *entrepreneurial incentive*, meaning the economic reward required to induce an entrepreneur to incur the risk associated with taking on a project. This is not the same as contractor profit—it is in addition to the expense of paying a contractor.

For complex industrial facilities, entrepreneurial profit should not be included in the cost approach, for several reasons. First, these types of properties are not built on a speculative basis. An entrepreneur may build a strip center and expect a profit when it is fully rented and sold. Entrepreneurs do not build oil refineries, paper mills, semiconductor facilities, or food-processing facilities hoping they can sell them and make a profit, because there are no potential buyers—manufacturers build them for themselves because they are specialized.

In fact, complex industrial facilities are actually specialized in two ways. First, they are specialized in the type of product being made, which requires a certain type of structure and machinery and equipment. Second, they are specialized in that manufacturers employ different layouts and methods to make their products. In other words, two manufacturers may make the same product, but use different processes and equipment to achieve production. Moreover, the designs and methods used by them are often proprietary and confidential. Consequently, it is obvious that no entrepreneur would attempt to construct such a specialized facility in the hopes of selling it and making a profit.

Nevertheless, in properties that do qualify for entrepreneurial profit, it must be quantified; a simple percentage cannot be attributed to this cost unless a survey of expected profits is conducted for similar properties. For an oil refinery, as with other specialized plants, this would be impossible to determine because, as previously stated, entrepreneurs do not build such facilities.

*The Use of Costing Services*

Costing services like Marshall & Swift may be a good starting point for an appraiser to calculate a replacement cost for a complex industrial facility, but it is up to the appraiser to determine whether the information provided is accurate. If the cost approach required only the assimilation of data from a costing service, then an appraiser would not be needed; a data entry person could determine the value. This is why it is so important for appraisers to do additional research, which may include analyzing costing data, talking to cost engineers if they are available, examining the costs to build similar refineries, and perhaps talking to other appraisers with experience in the industry.

**The Sales Comparison Approach**

There are often sales of refineries that can be used in the sales comparison approach, but the challenge is in adjusting the sales to bring them into parity with the refinery under valuation. In order to make the proper adjustments, a significant amount of research is required by the appraiser, as well as knowledge of the differences in refinery operations and equipment. The following are major considerations in choosing and adjusting comparable sales.

*What Is Included in the Sale?*

The sale of a refinery often includes a large amount of inventory (which also may be referred to as working capital in a business valuation) that is necessary to the operation but is also nontaxable in most states. This requires the appraiser to carefully examine each sale to make this deduction, which can often be worth as much or even more than the refinery is worth. In other words, the actual refinery may be worth $500 million and the inventory of crude may be worth $400 million for a combined purchase price of $900 million.

*Complexity Adjustments*

At first, it may seem that a refinery that is more complex has more value than one that is less complex, but this is a simplistic assumption that may prove to be erroneous. For instance, a refinery may be highly complex but is unable to utilize equipment that allows the refining of some products, because demand for those products has diminished. In such a situation, the cost of upkeep for the additional refining processes may be a financial drain on fixed operating costs and a detriment to the value of the refinery, causing the higher complexity to actually reduce the value of the refinery.

*Location*

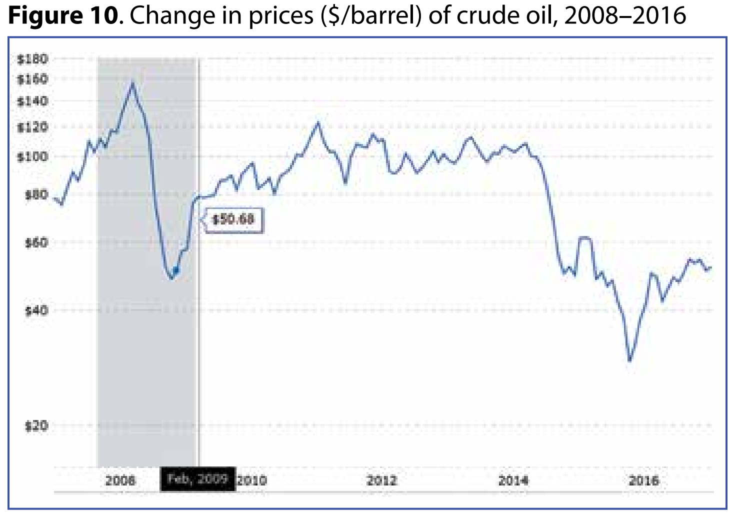
The refinery's proximity to pipelines, rails, waterways, oil fields, and the markets it serves must all be considered. In some states, such as California, the type of gasoline that can be sold requires more specialized refining, which might involve higher operating costs and/or special equipment. A refinery may lose value if the source of crude oil it was built for is no longer available. It is generally better to use sales in the same PADD as the subject property, if possible. Nevertheless, even sales within the same PADD may have geographical differences that may affect the value.

*Date of Sale*

As is the case with most industries that produce commodities, market swings occur in the refinery business. However, the price of crude oil, particularly in recent years, has been fluctuating so much that it has produced a roller coaster effect on the industry. Over a relatively short period, oil prices have increased to more than $100 a barrel and then dropped to about $40 a barrel, making the date of sale an important consideration.

Note, however, that an inverse correlation between oil production profits and refinery profits can exist. This can occur when lower oil prices diminish profits for production, but the lower price also increases demand for gasoline, causing the margins for refineries to increase and making them more profitable.

**Figure 10**. Change in prices ($/barrel) of crude oil, 2008–2016




*Source: http://www.macrotrends.net/1369/crude-oil-price-history-chart. Reproduced with permission.*

For example, if a refinery steps up production from 80 to 97 percent, profits increase because fixed costs stay the same and variable costs diminish with higher production. Increased demand also allows higher prices for refining. Consequently, it is quite possible for a company that is vertically integrated (by extracting oil and also refining it) to have profits from oil production fall, while profits in its refinery business simultaneously increase. Figure 10 shows the price changes in crude in the past 10 years.

*Age of the Refinery*

The original age of the refinery must be considered, as well as the age of the equipment. And, as with any industrial facility, the maintenance of the facility is a major issue in determining the value. However, the age can also be misleading, because one older refinery may have been upgraded with state-of-the-art equipment, whereas another of the same vintage may have made only the improvements necessary to comply with Occupational Safety and Health Administration, Environmental Protection Agency, and other governmental agency regulations.

Also, note that although statistics show that more refineries have been closing in recent years, actual production is increasing. This fact counters the argument that the refinery business is in a decline. Rather, advancements in technology allow increased production for most upgraded facilities, and the refineries that are closing are generally the ones for which modernizing is not cost-effective. Since the 1980s, total refinery production output has been increasing, inefficient plants have been closing down at a rate of about one per year, and capacity continues to increase for individual refineries.

Environmental requirements are constantly changing in the refinery business, and some refineries close rather than make the often large capital investments necessary to stay in business. When the appraiser is examining sales and closures, these transactional aspects should be carefully considered so appropriate adjustments can be made.

*Production Capacity*

Capacity is important in making comparisons. Smaller refineries are sometimes *boutique* operations and are not comparable to larger refineries. The production capacity has to be considered in light of the location and other capabilities of the refinery, because optimum capacity varies depending on these characteristics.

*International Sales*

Normally it is not advisable to use sales outside the country where the subject property is located. Refineries are much more highly regulated in some countries, such as those in Europe, but may have less regulation in less developed countries.

*Other Adjustments*

There are a myriad of other possible adjustments, depending on the characteristics of the subject property. Specific adjustments for equipment, loading and transportation logistics, and other issues may warrant consideration.

**The Income Approach**

Those familiar with how the income approach is used in the valuation of industrial properties know that a wide variance in values between two sides in a hearing is not uncommon. For instance, the value for one side may be $220 million and for the other side, $980 million. One reason values can be so divergent between two business valuation experts is that in an approach such as a DCF analysis projections are made for future earnings, which depend on the opinion of the appraiser. Many other estimates are used in income approaches, including discount rates, capitalization rates, risk factors, normalized earnings, maintenance and capital spending requirements, and so on.

## Summary

For the best refinery valuation possible, it is important for the appraiser to have a working knowledge of refinery operations and utilize all the applicable approaches to value. If the industrial appraiser lacks finance experience, it can be helpful to hire a business valuation appraiser for the income approach to value. For litigation, an expert witness review appraiser is another option for an analysis of the opposition's appraisal to give the assessor an idea of its validity and for potential court testimony.

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