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Refinery Outages: Description and Potential Impact on Petroleum Product Prices

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Preface and Contacts

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Executive Summary

Chairman Jeff Bingaman of the Senate Committee on Energy and Natural Resources requested that EIA conduct a study of the impact that refinery shutdowns have had on the price of oil and gasoline.[1] Up until the mid 1990's, the U.S. had excess refinery capacity. Refinery utilization in 1985 averaged 78 percent, and refinery outages seemed to have little if any impact on product prices, since a substantial amount of extra capacity existed to compensate for outages. Between 1985 and 1995, demand grew, while refinery capacity remained relatively flat, resulting in utilization increasing to 92 percent by 1995. Since then, U.S. refineries have been running near capacity during the peak-demand summer months. With little spare refinery capacity available during peak demand times, unexpected refinery outages can result in local supply disruptions that result in temporary price surges. Still, refinery outages do not always result in price pressure. Other factors can influence the impact that outages have, such as the time of year relative to seasonal demand peaks, availability of imports, availability of inventories, and even what has transpired in the market place in the prior weeks. The remainder of this summary provides brief answers to the questions posed in Chairman Bingaman's request.

What is a refinery turnaround, and what activities take place during a turnaround? There are various types of outages, one of which is the refinery turnaround. A refinery turnaround is a planned, periodic shutdown of one or more refinery processing units (or possibly the entire refinery) to perform maintenance, inspection, and repair of equipment and to replace process materials and equipment that have worn out or broken, in order to ensure safe and efficient operations. It is analogous to the major maintenance performed on automobiles, but much more complex. Often, improvements in equipment or the processing scheme can only be implemented during these turnaround or shutdown periods.

Currently, routine turnarounds on key fuel production units are planned for every 3-to-5 years. They may involve 1-2 years of advance planning (sometimes more when major processing or equipment changes are needed) using dedicated teams from the company as well as outside contracting and engineering firms. While the objective is to minimize the time a unit is offline, the turnaround can result in a unit being offline for several weeks to several months. During a major unit turnaround, as many as 1500-2000 skilled contractor workers may be brought on site to perform a myriad of interrelated jobs that require significant coordination and safety measures. Additional personnel vary depending on the circumstances, but it is not unusual to see staff more than triple during a turnaround.

What are planned versus unplanned outages? Refinery turnarounds are planned, but they are not the only planned outages. There are less extensive planned shutdowns, which are planned, targeted shutdowns of smaller scope. These "pit stops" help to bridge the gap between planned turnaround intervals, but still require much coordination and

[1] See Appendix A for a copy of the letter requesting the study.

oversight due to the interrelationships among units in a refinery and the complexity and hazardous nature of the processes involved.

Unplanned shutdowns also occur. Some unplanned shutdowns do not require immediate emergency actions, and an affected unit can continue to operate for several weeks, providing some room for planning, including material and equipment purchases, before the shutdown. Emergency shutdowns must sometimes be made however. In this case, a unit or entire refinery must be brought down immediately without warning. For example, a fire or power outage could create such a shutdown requirement.

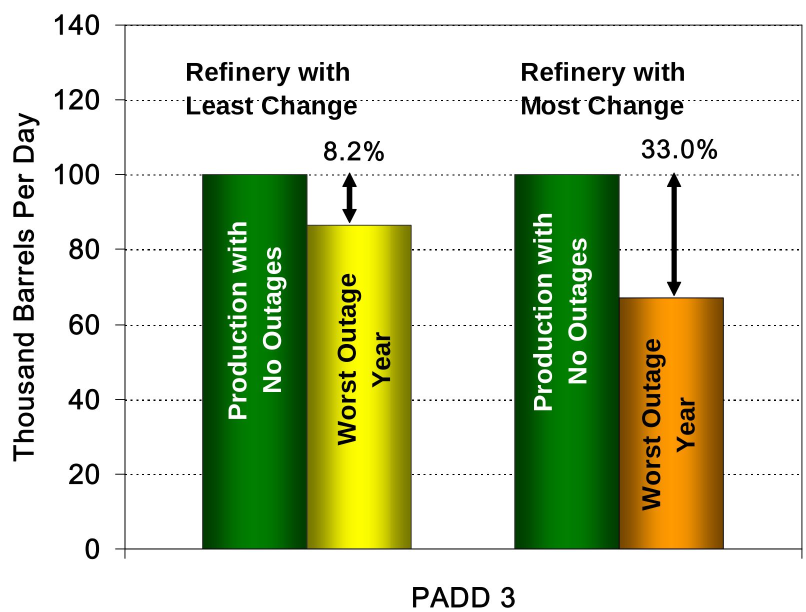
Planned turnarounds and shutdowns can also result in unplanned outage time. Sometimes when a processing unit is brought down for planned maintenance, other problems are discovered that may extend the time offline.

When do outages occur and how are they planned, including information available on such plans? Outages occur most frequently in the first quarter and in the fall. These times are when total U.S. petroleum product and crude oil demands are at their lowest points seasonally. Within those periods, other factors affect turnaround and shutdown timing, such as availability of labor, given the very large swings in skilled workers needed for turnarounds. For example, holidays and hunting season are avoided. Since adequate skilled workers are not available to handle simultaneous large turnarounds, contract and engineering firms cannot schedule such activities at the same time. Various sources of information are available to assist in avoiding clashing projects. The contractor and engineering firms themselves are important players. Large turnarounds require enough outside contracting that plans become known even when companies do not announce them. Private information sources like Industrial Information Resources publish information on such plans, and the trade press picks up public announcements as well as information on shutdowns that must be provided to organizations such as the Texas Commission on Environmental Quality, which requires filings on operational changes that may result in potential changes in emissions.

What flexibility do refiners have in changing their outage plans? The size and complexity of a refinery turnaround leaves little flexibility to change plans. The large commitments for labor, equipment, and materials needed for process improvements make changes very costly at best, and safety concerns can override all other considerations. Smaller outages may have some flexibility, but even this varies, depending on the reason for the outage and the associated safety and reliability concerns.

How much production variation might occur year to year in a given refinery? Variations in production as a result of outages can be large for individual refineries. EIA examined individual refinery production from 1999-2005, comparing the highest production year to the lowest production year for a representative subset of facilities. In the Gulf Coast region, represented by Petroleum Administration for Defense District (PADD) 3, for example, the refinery that showed the smallest difference in gasoline production between its best year with no major outages and worst outage year experienced an 8.2 percent drop, while the refinery that showed the greatest gasoline production decline fell 33.0 percent from its best year without major outages. That is, for PADD 3, assume each of the refineries produced gasoline at 100,000 barrels per day when not experiencing any outages (Figure ES1). In PADD 3, the refinery showing the least production impacts from outages only dropped 8.2 percent from its level with no outages, which, in this illustration, would have reduced its gasoline output to 91,800 barrels per day. However the refinery that experienced the worst loss of gasoline from outages dropped 33.0 percent, which would bring its production down to 67,000 barrels per day in this example. The Midwest and East Coast regions did not see quite the same percentage drops in production with major outages of lower complexity refineries. The largest drop in the Midwest was about 26 percent from maximum production, and on the East Coast the largest drop was about 20 percent.

Figure ES1. Illustration of Individual Refinery Gasoline Production Minimum and Maximum Average Annual Impacts of Outages from 1999-2005



Note: The hypothetical 100,000 barrel day production with no outages is about the average gasoline production per refinery in PADD 3. .

How have outages affected production? EIA data were used to examine the relationship between input variations that reflected outages and product production on an individual refinery basis. EIA data do not reflect outages directly, but EIA collects unit input data that will drop significantly when a unit is out of service. Because units such as the fluid catalytic crackers (FCC) and alkylation units can account for as much as 50 percent of a refinery's gasoline production, an FCC outage can have a large impact on overall production. However, the impact of shutting down such a unit may be larger than 50 percent of gasoline production. A refinery cannot usually simply shut down one unit and continue to run the other units at the normal rates. Other units contributing to gasoline production may also be pulled back. For example, refineries typically have inadequate storage to hold the material coming from the crude oil distillation tower to the FCC unit. Even if such storage existed, the FCC unit would not have adequate capacity to run the stored feedstock later.

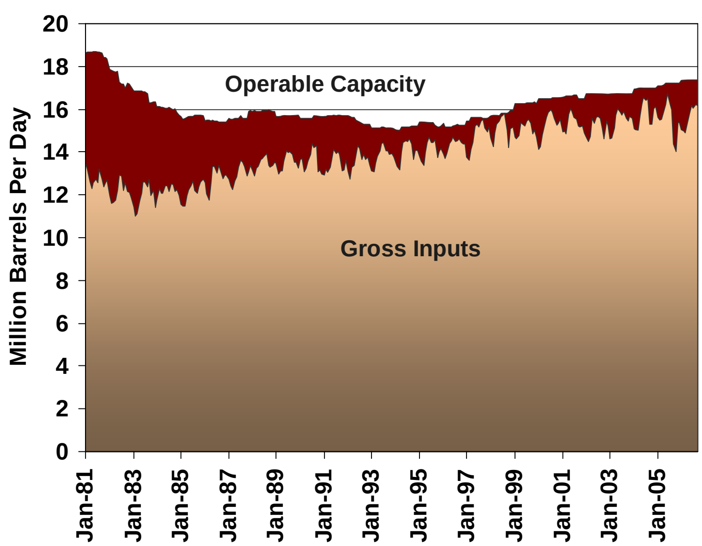
How have outages affected prices? Within the limitations of the monthly and weekly data available, EIA's statistical analysis of outages indicates that generally there is not a significant price impact. Prices are affected not by production changes alone, but mainly by the balance in supply and demand, as represented by inventory levels. If supplies are abundant relative to demand (e.g., high inventories and off peak time of year), a refinery outage, even an unplanned outage, is likely to have little impact. The lack of a statistical relationship between outages and gasoline crack spread may be surprising to some analysts. Keep in mind, the statistical analyses used are designed to capture normal market variations and responses, and while they indicate that most of the time, outages have little impact on prices on a monthly average basis, they do not imply outages never affect prices.

There are times when the marginal supply of barrels lost due to outages have added to price pressure, such as when a tight market balance already exists and alternative supply sources are not readily available. Clearly the outages that occurred during Hurricanes Rita and Katrina were large enough to impact price. Another case was highlighted in an earlier report on California gasoline where several large unexpected outages in conjunction with tight gasoline market conditions seemed to drive up prices. However, outages with measurable impacts on monthly prices are relatively rare.

1. Introduction

Chairman Jeff Bingaman of the Senate Committee on Energy and Natural Resources requested that EIA conduct a study of the impact that refinery shutdowns have had on the price of oil and gasoline.[2] Up until the mid 1990's, the U.S. had significant excess refinery capacity (Figure 1). Refinery utilization in 1985 averaged 78 percent, and refinery outages seemed to have little if any impact on product prices, since a substantial amount of extra capacity existed to compensate for outages. Between 1985 and 1995, demand grew, while refinery capacity remained relatively flat, resulting in utilization increasing to 92 percent by 1995. Since then, both demand and capacity have increased, and U.S. refineries have been running near capacity during the peak-demand summer months. With little spare refinery capacity available during peak demand times, unexpected refinery outages can result in local supply disruptions that result in temporary price surges. One of the most extreme examples of refinery outages and price impacts was the refinery damage resulting from hurricanes Rita and Katrina in 2005. Still, refinery outages do not always result in price pressure. Other factors can influence the impact that outages have, such as the time of year relative to seasonal demand peaks, availability of imports, availability of inventories, and even what has transpired in the market place in the prior weeks.

Figure 1. U.S. Refining Capacity and Inputs



Source: EIA Petroleum Supply Annual and Monthly

Hurricanes Katrina and Rita brought attention to the small amount of surplus refining capacity in the United States, and heightened concerns over the potential impact on prices

[2] See Appendix A for a copy of the letter requesting the study.

refinery outages might have in the future. However, increasing refining profitability and expectations of continued demand growth worldwide for petroleum have resulted in plans for refining expansion in the United States and abroad. With increased interest in renewable fuels and enhanced vehicle efficiency potentially cutting projected growth in petroleum demand, some analysts have even been raising concerns over a potential future glut in world refining capacity.

Chapter 2 provides background information that describes refinery operations and various types of outages, focusing on one of the largest types of outages, refinery turnarounds. Chapter 3 looks at historical outages to examine when they occur seasonally, how they vary year to year and regionally, and how much of the variation in refinery utilization can be explained by outages versus changes in refinery operations due to changing market conditions. Chapter 4 focuses on price implications of these outages, and Chapter 5 summarizes the findings.

2. Background on Refinery Operations

Because refineries operate around the clock during normal operations, periodic maintenance is required, along with occasional major overhauls. As any car owner knows, maintenance and repairs vary significantly, as is the case with refineries. For the car owner, major overhauls are highlighted in the new car owner's manual under the preventive maintenance schedule, along with suggested times for more frequent, minor maintenance, including fluid changes, belt tightening, mechanical adjustments and parts or tire replacement. Such maintenance is required to ensure reliable transportation. When refiners perform maintenance, they usually need to stop processing hydrocarbons and slow or stop producing finished products. As described in more detail below, the complexity and magnitude of the refinery work far exceeds the car maintenance example.

Refinery outages, which derive from a number of situations, may be planned or unplanned. In all cases, part or all of a refinery is taken out of service. For the purposes of this report, four types of outages will be defined: planned turnaround, planned shutdown, unplanned shutdown, and emergency shutdown.

Planned refinery turnarounds are major maintenance or overhaul activities. The frequency of major turnarounds varies by type of unit, but may only need to be done every 3 to 5 years, for example. Planned turnarounds frequently require 1 to 2 years of planning and preparation, and sometimes longer when major capital equipment changes are required. The actual turnaround may then last about 20 to 60 days.

Planned shutdowns are planned, targeted shutdowns of smaller scope than a full turnaround. These mini-turnarounds (or "pit-stops"), which help to bridge the gap between planned turnaround intervals, may be 2 to 6 months in planning and preparation, and the outage may last 5 to 15 days before returning the processing unit to normal operation.

Unplanned shutdowns are unexpected, but do not require immediate emergency actions. Even well maintained refinery systems develop unexpected problems. Unplanned shutdowns might result from signs of abnormal or deteriorating process operation. In this situation, the refinery symptom indicates the affected unit can continue operating for a time, perhaps 3-4 weeks, providing some room for planning, including material and equipment purchases, before the shutdown. Still, this is short notice, and repair plans must be developed on the fly or from previous turnaround procedures or plans. Because of the unexpected nature of such outages, unknown problems can be discovered and cause the unplanned outage to be extended. Unplanned shutdowns are often prolonged due to manufacturing and shipment delays of parts and equipment.

Planned turnarounds and shutdowns can also result in unplanned outage time. Sometimes when a processing unit is brought down for planned maintenance, other problems are discovered that may extend the time offline. When planned turnaround or shutdown activities are complete, restarting a unit that has been offline can be more difficult than anticipated, resulting in unplanned outage time. Sometimes the unit may have to be brought down several times before it is able to run steadily at full operation. Such problems can sometimes extend over several months.

Emergency shutdowns occur when a unit or entire refinery must be brought down immediately without warning. For example, a fire or power outage could create such a shutdown requirement. A recent survey of FCC units[3] indicated the biggest reason for unplanned and emergency shutdowns of these units was unexpected loss of utilities (e.g., electricity) to the unit. Unsafe conditions, such as potential severe weather, can also require emergency shutdowns until the weather danger is past, although some weather conditions such as evolving hurricanes allow for more planning. Emergency shutdowns can present some of the largest safety issues, and increase the potential for mechanical damage as a result of the fast shutdown.

In all shutdown cases, when major fuel-producing units are offline, production of gasoline or distillate fuels may be reduced. The next section provides a brief overview of refining fundamentals needed to understand this relationship.

2.1. Refining Basics: Key Refinery Units Affecting Fuel Production

A refinery turnaround does not usually require a complete shutdown of the refinery. However when significant fuel-producing units are taken offline, gasoline, kerosene, jet fuel, diesel fuel, or heating oil production may be affected. Figure 2 shows a basic schematic of a refinery and lists the basic gasoline and distillate outputs of the major processing units.

Figure 2 illustrates that one product, such as gasoline, may actually be made of different streams from the refinery. The diagram shows gasoline is a mixture of reformate, alkylate, hydrocrackate gasoline, FCC gasoline and even potentially some straight-run gasoline directly from the distillation tower. Each of these gasoline streams has different emission and driving-performance characteristics. Gasoline for retail is a blend of these streams designed to meet emission requirements and provide good driving performance. When one significant gasoline production unit such as the FCC unit is out of service, the refinery is hampered in its ability to produce gasoline with adequate driving and environmental characteristics, even though the reformer and other gasoline-producing units are still operable. Still, with planned turnarounds, this loss can be addressed to some degree with advance planning, which will be discussed later. The remaining discussion in this section describes the roles of different refinery units to production in more detail.

Beginning from the left side of the figure, crude oil feeds into the distillation tower. When crude oil is distilled, before it ever goes to the various units downstream of the crude oil tower, it is separated into various boiling-range streams. The lighter streams

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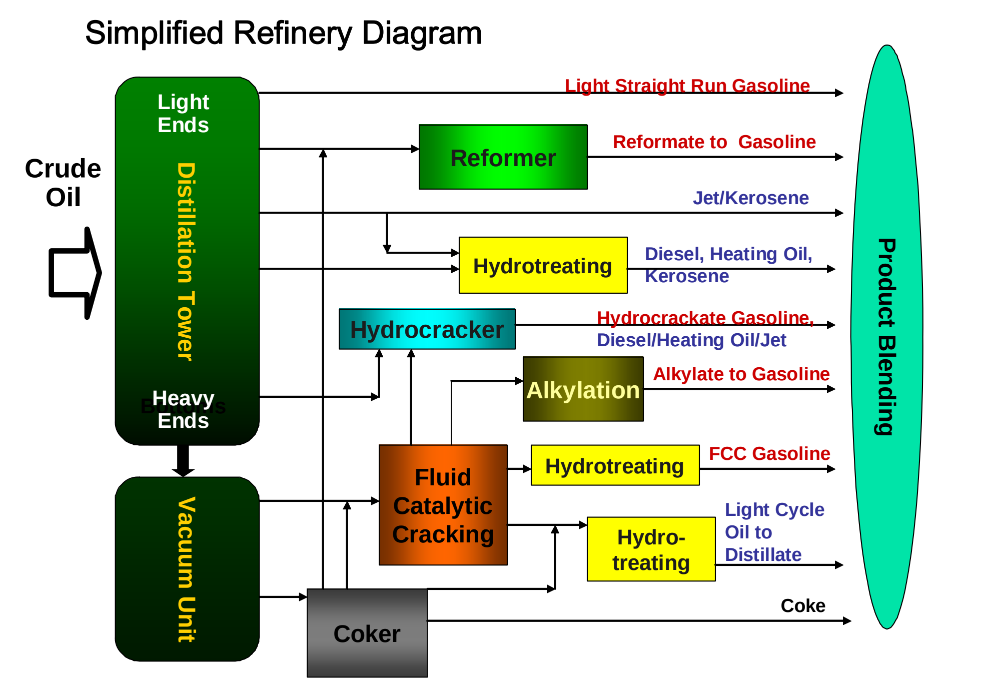
[3] "Industry Self-Survey Reveals FCC Reliability Trends", *Octane Week*, Hart Energy Publishing, LP (November 20, 2006) p. 1.

eventually go to gasoline, the middle streams to distillates (with sulfur removal) and the heavier, high-boiling-point streams go to residual fuel or are sent to other units like the hydrocracker, FCC or coking unit to be broken down to make more lighter, high-valued products.

Figure 2.



The units downstream of the distillation tower (also called the distillation unit) are where most of the crude oil molecules are transformed (i.e., refined) into higher quality, higher valued transportation fuels. For example, the light straight-run gasoline stream that goes directly into the gasoline pool only constitutes about 5 percent of the total gasoline produced. The remaining gasoline volumes come from the downstream units. The downstream units basically do 3 things: break apart heavy, low-valued molecules into lighter, more valuable materials; re-arrange molecules to improve performance or meet emission goals; and remove undesirable materials such as sulfur or toxic compounds.

A hydrocracking unit, or hydrocracker, takes light gasoil, which is heavier and has a higher boiling range than distillate fuel oil, and cracks the heavy molecules into distillate and some gasoline. Many refiners do not have hydrocrackers. In the Gulf Coast region defined by Petroleum Administration for Defense District (PADD) 3, total hydrocracking inputs represent about 8 percent of total gross inputs to refineries in the region. (See Appendix D for PADD geographic definitions.) However, in refineries that have hydrocrackers, the hydrocracking inputs represent 13 percent of total gross inputs. As the name implies, the hydrocracker is a hydrogen-adding process to break apart large, heavy, low-valued molecules into the higher-valued lighter materials. The hydrocracker upgrades leftover, low quality heavy distillates from the distillation tower, the FCC and the coking unit into high-quality, clean-burning jet fuel, distillates, and gasoline. In the emerging low-sulfur world, the hydrocracker often converts high-sulfur materials, which would end up in marine or boiler fuel, into low-sulfur fuels for vehicles and airplanes. The hydrocracker streams eventually contribute about 5 percent of the gasoline volume in a refinery.

The reformer is a major gasoline-producing unit, providing about one third of the gasoline volume a refinery produces. A reformer takes low octane gasoline material and "reforms" molecules to produce molecules with more complex structures and higher octane than the simpler naphtha feedstocks. The high-octane reformate that is produced contains aromatics that have some undesirable environmental properties. Thus, while the output of the reformer produces a gasoline stream with desirable driving properties, the stream must be balanced with other cleaner-burning components to reduce its undesirable environmental aspects.

The fluid catalytic cracking unit (FCC) is another major gasoline-producing unit. It takes heavy gasoil and cracks these heavy molecules into smaller molecules that are used to make additional gasoline and some distillate fuel as well. A continuously operating FCC unit will have a primary reactor, where a hot catalyst reacts with the heavy gasoil molecules to break them apart, a dedicated distillation tower to separate the cracked molecules by boiling range, and a regenerator to burn off the carbon on the catalyst, allowing it to be reused in the reactor. The FCC is one of the largest downstream units and one of the few units whose size is relatively consistent with the size of the distillation tower across refineries. FCC units tend to be from 35 to 40 percent of the size of the distillation tower. Consistent with that, in PADD 3, feed to FCC units represents almost 40 percent of the gross inputs to crude oil distillation towers in that region. The FCC unit is mainly a gasoline-producing unit and provides more than 1/3 of the gasoline volume a refinery produces. However, the FCC unit also provides the inputs (olefins) to the alkylation unit, where the alkylate gasoline component is produced. Alkylate has desirable clean-burning properties as well as good drivability characteristics, making it one of the more valuable gasoline components. The FCC and alkylation units, combined, supply close to one half of the gasoline volumes a refinery produces.

The coking unit takes residual fuel oil, sometimes referred to as "bottoms" material, and cracks it into gasoline and distillate fuels, leaving petroleum coke behind. Many refiners do not have coking units. The size of the coking unit in a refinery is mainly a function of the volume of heavier crude oils being used. (The heavy crude oils produce larger percentages of heavy, residual fuel oil than light crude oils.) Most refiners on the East Coast tend to use lighter crude oils, and as a result, most refineries in this region do not have coking units. Many Gulf Coast refineries use heavy crude oils from Mexico, Venezuela, and the Middle East, and have installed coking units. Refineries using the heavier syncrudes from Canada also have or are installing coking units, and most PADD 5 refineries have installed coking units for use with heavy California and other heavy crude oils. In PADD 3, inputs to coking units in total are about 15 percent of the gross input to distillation towers, but unlike the FCC units, the size relative to distillation can vary significantly among refineries. Streams from the coking unit are further processed in the refinery and eventually constitute 5 to 10 percent of gasoline volume a refinery produces.

In summary, an outage in any major refinery unit can affect production of finished products, such as gasoline or distillate. Furthermore, the integration of these units means that shutdown of one unit for repairs or maintenance can result in shutdown or reduced operations at other units.

The remainder of this chapter will focus on refinery turnarounds. Turnarounds, which are the major maintenance or overhaul refinery shutdowns, usually present the largest loss of product from a refinery because of the length of time a unit is taken out of commission. An examination of the activities involved in a turnaround provides some appreciation for the complexity of all shutdowns, including the shorter, less comprehensive outages. The other types of refinery outages (unplanned shutdowns, planned shutdowns, emergency shutdowns) will not be covered in as much detail, since they are essentially smaller, condensed versions of the refinery turnaround.

2.2. Refinery Turnarounds

Recall that a turnaround is a planned, periodic shutdown of a refinery processing unit (or possibly entire refinery) to perform maintenance, inspection, and repair of equipment and to replace process materials and equipment that have worn out or broken in order to ensure safe and efficient operations. Often, improvements in equipment or the processing scheme can only be implemented during these turnaround or shutdown periods. Currently, routine turnarounds on key fuel production units are planned for every 3 to 5 years.

2.3. Activities During a Turnaround

Maintenance activities during a planned turnaround might include:

- Routine inspections for corrosion, equipment integrity or wear, deposit formation, integrity of electrical and piping systems;
- Special inspections (often arising from anomalies in the prior operating period) of major vessels or rotating equipment or pumps to investigate for abnormal situations;
- Installation of replacement equipment for parts or entire pumps or instruments that wear out;
- Replacement of catalysts or process materials that have been depleted during operations.

Improvement activities could include:

- Installation of new, upgraded equipment or technology to improve the refinery processing;
- Installation of new, major capital equipment or systems that may significantly alter the refinery process and product output.

Safety is a major concern when implementing refinery turnarounds. Refineries run with materials at high temperatures and high pressures, and some of the materials themselves are caustic or toxic and must be handled appropriately. Maintenance is required to assure safe operations, and turnarounds themselves require extra safety precautions, as illustrated by the explosion and fire that killed 15 people and injured more than 100 personnel at BP's Texas City refinery in 2005 during a turnaround procedure.

2.4. Turnaround Planning & Flexibility to Change Plans

Turnarounds are large and expensive. A description of a 29-day FCC turnaround at Valero's St. Charles refinery indicated that the event would cost $39 million dollars and use 1800 outside contractors. Furthermore, it was estimated that Valero would lose between $1.2 million and $3 million dollars for each day the turnaround went beyond its planned time, highlighting the importance of good planning and implementation. [4]

For turnarounds, a refinery will have a shutdown organization that plans for the event 1-to-2 years in advance (longer if major capital equipment or process changes are involved). While these organizations vary among companies, in larger refineries, the shutdown organization may be a permanent group, which moves their efforts from one process unit's turnaround (e.g., FCC) in year 2008 to another's turnaround (say crude distillation tower) in 2010. The shutdown team would typically use sophisticated planning and scheduling software (such as Impress, Primavera, ATC Professional, and SAP). These computer programs can coordinate thousands of individual maintenance jobs (which may include 100,000+ separate steps in those jobs), including the steps performed by contractors. The precise definition of tasks and schedules permits the commitment of human resources and equipment in advance.

A recent survey of FCC operations[5] summarized FCC operating experiences for 28 FCC units. While 22 of the units targeted 4 to 5 years between turnarounds, only 16 actually achieved their targets. Turnaround times also tended to be longer than planned, with the average slippage being 5 days. Some companies indicated that in recent years, the slippages were the result of a lack of skilled labor, creating the need for longer outages.

The market has limited the ability of refineries to do major turnarounds simultaneously. A major turnaround on an FCC unit can involve tremendous swings of outside labor into and out of the plant. A 200,000-barrel-per-day refinery might normally have 500 people on staff.[6] During the turnaround, there may be 1500 - 2000 additional people on the refinery site for a month or so, increasing the personnel on site by more than a factor of 3. Industry has been reporting a shortage of skilled workers, especially those trained in the petrochemical industry. Added to that general shortage is increased labor demand in the past few years from hurricanes Katrina and Rita, tar sands work in Canada, and now the

[4] Plantservices.com, "Turnaround done down to the dime" http://www.plantservices.com/articles/2006/248.html
[5] Octane Week, p. 1.
[6] Staffing numbers count all personnel needed for 7-day, 24-hour operations.

ethanol plant boom. The need for large labor swings during turnarounds, coupled with the skilled labor shortage, prevents companies from doing much of this work simultaneously.

Because of the size of turnarounds and advance planning needed, information is available as plans evolve to help companies stagger the outages. The turnarounds use contract and engineering (C&E) firms that provide the swing labor as well as other services. These firms become an important coordinating force, in that they cannot provide the swing labor for simultaneous turnarounds. Various private publications assemble information about turnaround plans, and the trade press picks up outage plans from various sources and reports them. For example, the Texas Commission on Environmental Quality requires reporting of various emission events, which include those associated with outages. Private firms such as Industrial Information Resources (IIR) collect and assemble detailed refinery outage information across the country. A sample of the type of detail provided by this organization is shown in Appendix B.

The size and complexity of a refinery turnaround leaves little flexibility for changing plans significantly, even when market conditions favor keeping the refinery running. The American Petroleum Institute indicated that delaying a turnaround could increase its costs by 20 to 50 percent[7], and safety concerns must be taken into account. Furthermore, delaying turnarounds increases the chances for unplanned outages of the unit. Smaller outages may be postponed more easily, but even in these cases, safety concerns may dictate the timing. In the case of planned or unplanned shutdowns as described earlier, much would depend on the reason for the outage. Using the car analogy, when the engine light comes on, a car owner would likely have to take care of the problem immediately. However, the planned oil change can be postponed for some time, if necessary.

2.5. Generic FCC Turnaround Timeline

As noted above, companies typically schedule major FCC turnarounds every 4 or 5 years. While the turnaround itself may only last a month or two, planning for the event would typically begin several years ahead. The following discussion outlines the type of planning that is involved with a major turnaround. This example assumes an FCC turnaround that would take place every 5 years. The level of effort varies among FCC turnarounds. Every second or third turnaround might require more significant work to replace worn equipment.[8]

36-30 Months Prior to Turnaround

A decision is made about whether a major new technology or long-lead-time equipment will be part of the turnaround. If so, then scheduling must be determined for equipment orders and special aspects (e.g., special cranes, personnel and procedures). New vessels, compressors, or turbines can often take 2 or more years to design and fabricate. Also,

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[7] http://www.api.org/aboutoilgas/sectors/refining/refinery-turnaround.cfm

[8] A more detailed discussion that exemplifies the planning process of an FCC turnaround can be found at: http://www.impress.com/contentmgr/showdetails.php/id/321

some complicated crane construction and associated work, which must be reserved well in advance, can only be done by a few companies. If special work is not required, the turnaround is treated as normal, with main planning starting 2 years in advance.

24 Months Prior to Turnaround

The project concept is defined and approved, including equipment upgrades that may be needed and changes to equipment to improve operations and/or yields. Detailed designs for any equipment modifications must be categorized. Some vessel modifications and piping revisions may require an outside engineering firm and extensive interaction with operations. Refineries have a management process, referred to as "management of change" (MOC) process in this report, that will look at safety, environmental and operation changes that these modifications can cause. In the past decade, this management process has become a serious, lengthy examination of any changes that are proposed. Even information systems for the project become an issue. For this MOC process to work, the final engineering design and plans for how the change will be operated must be completed at least 6 months before the turnaround begins.

18 Months Prior to Turnaround

The detailed project planning process gets underway. Over a 6 month period, equipment inspections may be performed, critical equipment maintained, and systems reviewed to flesh out the specific activities that need to be performed in more detail. Work begins to organize the complex management of the project. Long lead-time materials may be purchased, and negotiations begin with the various contractors that deal with refinery turnarounds. In addition, progress is checked on any new vessels, compressors, or turbines that were ordered. The MOC schedule is also reviewed for (1) any new equipment, (2) equipment or piping modifications, and (3) new operating procedures for equipment after the turnaround.

10-12 Months Prior to Turnaround

Equipment deliveries and modification designs are being checked regularly. The basic scope of the project (maintenance and minor modifications) is finalized, and remaining contracting with outside shop facilities is negotiated. These outside shops work on compressors, turbines, control valves, relief valves, heat exchangers, critical piping systems, etc. Management assures that the MOC process begins on new equipment, equipment and piping modifications, and new operating procedures.

Last Months Prior to Turnaround

The turnaround organization takes control of schedules and management of the activities of the event. Often this organization will set up on site several months prior to the turnaround. Almost like a Special Weapons and Tactics (SWAT) organization, they begin to establish the special communication, tracking, and physical aspects necessary for a well-coordinated turnaround. Given that the crude tower and some sulfur removal units may also be affected, crude oil acquisitions are adjusted both to reduce volumes acquired and potentially to use lower sulfur crude oils. (Changes in crude oil arrangements must be made months in advance. Travel time alone for a crude oil tanker can be 45 days from the Persian Gulf to the United States.) With the lower crude unit runs, product planners would look at opportunities for storing and/or purchasing intermediate feedstocks not only for the FCC unit, but also for the other gasoline-producing units. Direct product purchases would also be arranged.

In summary, many levels of planning and decision-making are involved at specific intervals prior to the actual turnaround. As the turnaround time nears, the magnitude of the coordination effort and commitments makes changes both difficult and expensive.

3. Historical Refinery Outages

This chapter summarizes what can be gleaned about historical outages from EIA data. It explains the approaches used to estimate outage impacts and examines year-to-year as well as seasonal variations in outages.

3.1. Data

EIA does not collect data on refinery outages directly. However, large outages can be inferred from the monthly data collected on inputs to the major refinery units. Outages are likely to be the cause of any substantial drops in those inputs. For example, if a unit normally runs at 60,000 barrels per day of input, but it experiences an outage for a week, the input level for the month would only average about 77 percent of the 60,000 barrels per day, or about 46,500 barrels per day for the month. If the unit were out only for a day, it would average 58,000 barrels per day, or 97 percent of the typical operation. The input at 58,000 barrels per day may also be the result of the unit being operated all days, but at a reduced level due to reduced crude input to the refinery or to achieve a balance across the whole refinery. The data do not show the size or duration of reduced inputs within the month – only the average reduction for the month.[9]

Monthly input data are available for distillation, fluid catalytic cracking, catalytic hydrocracking, and coking units. While other units can affect production of products, such as gasoline and distillates, input information is not available. Still, the units for which data are available provide a good basis on which to understand how refinery outages can impact product output and thus potentially affect prices. As a result, all data used in this chapter for analysis is monthly, with most of it coming from the form EIA-810 survey.

3.2. Separating Outages from Other Factors Impacting Refinery Production

While outages are the focus of this report, it is the outage impact on production that potentially impacts prices. Production is affected by both crude oil and other feedstock inputs as well as by the yield of that product from the feedstocks. Inputs are reduced during outages, but they are also reduced when a refiner adjusts to changing market conditions. Refiners also adjust the yield of a given product from a barrel of crude oil. When exploring the outage issue, the separate impacts on production due to changes in inputs to meet seasonal needs, outages, and yield adjustments must be considered.

[9] While EIA collects some data weekly, this collection does not include inputs to downstream refinery units.

As mentioned above, inputs can vary not only as a result of outages but also due to decisions to increase or reduce inputs according to market conditions. Production may be shifted to meet seasonal variations in product demand. A particular company might have access to economic import supplies for a time and choose to adjust refinery runs accordingly.

Product yields vary from refinery to refinery, as a result of their crude oil slate and refinery equipment, and within a refinery over time. Within a refinery, yields are adjusted to meet the shifting seasonal product slate and to respond to environmental requirements. During the summer months, when gasoline demand is highest, some gasoline components, such as butane and pentane, must be removed to meet summer Reid vapor pressure (RVP) requirements.[10] These high-RVP components can be put back into the gasoline during the winter because of much less evaporation in cold months. The refinery yield adjustments are made to take into consideration this shift in gasoline-component use along with the seasonal demand shifts. The yield adjustments are not large, generally shifting only a few percentage points, but they do affect output. All of these factors must be taken into account when determining production variations due to outages, discussed later in this report.

3.3. Methodology

Two basic approaches were used to examine EIA data (Figure 3). The first approach was used to characterize outages, exploring how outages varied regionally (by PADD), seasonally over the year, and from year to year. The second approach was developed to explore how outages might impact gasoline and distillate production. In both cases, unit utilization is calculated as input divided by unit capability. Since reported unit capacity is not always representative of the unit's operations, unit capability was estimated in several ways, as described in the sections below, and used in place of reported capacity.

3.3.1 Outage Characterization Approach

All refineries in a given PADD were used in the first approach to characterize outages. The capability of a given unit was defined as the maximum input observed in a given year.[11] This measure of unit capability varies somewhat from year to year and reflects capacity expansions, as inputs will increase when capacity is expanded.[12]

The maximum capability for a region was the sum of the maximum capabilities for the individual refinery units, which in reality would rarely, if ever, be achieved since all units would unlikely be running at maximum capability simultaneously. (Thus, this measure of capability generally will be higher than the maximum reported aggregate inputs for a given year.)

[10] The summer RVP requirements are set to reduce evaporation of volatile organic compounds, which are ozone precursors.
[11] Maximum inputs for each year were inspected. In some cases, a maximum input for a specific year was adjusted to be consistent with adjacent years when the specific year seemed atypical.
[12] Maximum input observed compared favorably with capacity reported to EIA.

Next, the occurrence of outages had to be identified. An outage was defined as occurring any time a unit's utilization (inputs divided by capability) fell below 85 percent. Then, the volumes lost for that unit were estimated as the difference between its actual input and its maximum input for that year. Any unit that averaged more than 85-percent utilization was not considered as experiencing an outage.

Outages of short duration would not be captured with this 85-percent cutoff, but such outages would not be expected to have much impact on production. Furthermore, this cutoff would exclude most input changes made to meet changes in seasonal demand.[13] Outages using this methodology were compared to outages reported in the trade press. This methodology usually identified the reported outages. In several cases, large outages shown in the data indicated that not all outages were identified in the trade press reviewd by EIA. In summary, this methodology appears adequate to identify large outages.

Figure 3. Illustration of Two Approaches for Analyzing Outages

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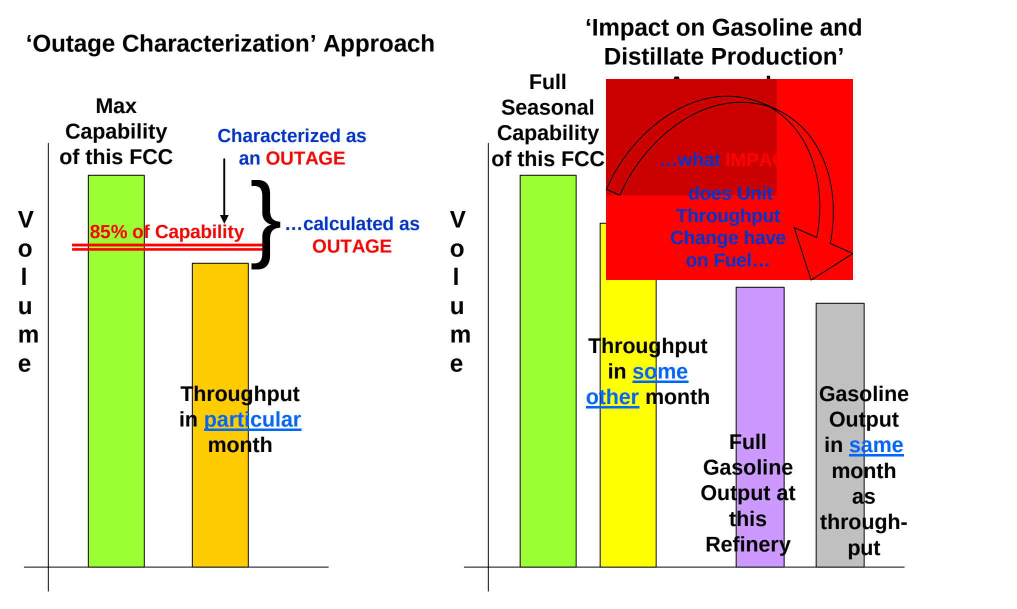


3.3.2 Impact on Gasoline and Distillate Production Approach

The second approach was used to compare unit outages with losses in gasoline or distillate production. This approach required considerable inspection of individual refinery data, and as such was limited to a subset of refineries in each PADD. Refineries were chosen mainly to be able to isolate FCC outages on gasoline production. The PADD 1 subset of 5 refineries represented 55 percent of the PADD's crude oil refining

[13] When a cutoff of 80 percent was used, the basic characterizations did not change.

capacity, the PADD 2 subset of 9 refineries represented 57 percent, and the PADD 3 subset of 11 refineries covered 35 percent. The basic year-to-year variations in FCC inputs tracked well with the entire PADD profile.

For the analysis of outage impacts on product production, variation in unit input below some full seasonal operating level was calculated. Unlike the outage characterization methodology described above, any reduction in inputs was of interest, so no cutoff point was needed. To generate unit volumes lost, an estimate of unit seasonal capability was used to compare with actual inputs. For each year, a summer and winter capability, or seasonal full-operating level, was established by using months when no outages seemed to be occurring. Actual unit inputs were then compared to the full-operation seasonal capabilities to estimate unit volumes lost. These lost volumes were then compared to lost gasoline and distillate output. Gasoline and distillate output losses were estimated similarly to the downstream unit volume losses. A seasonal full-production level was estimated and compared to actual. The product volumes lost were the difference between seasonal full production and actual production.

3.4. Outage Characterization

Using the first approach described above, this section looks at all refineries in a region and focuses on reduced inputs of at least 85 percent of the year's maximum inputs. Many of the figures used in this chapter use percentage variations of inputs from maximum input capability as a means of measuring outages. Table 1 shows the maximum inputs for 2005 across PADDs 1, 2, 3 and 5[14], illustrating the variation in refining capability regionally. Note the size of PADD 3 relative to the other PADDs. This PADD will sometimes be shown as illustrative of the other regions.

3.4.1 Year-to-Year Outage Variations

Outages vary over time, with some years having more outages than others. Figures 4-7 illustrate the annual outage variations by PADD for the major units. The data compare total capacity lost for those units running less than 85 percent to the total PADD potential peak input. For example, in 1999, the FCC units in PADD 3 that experienced one or more months of utilization at less than 85 percent resulted in a loss of 6 percent of potential total peak output for the PADD. From 1999 to 2004, the estimated input volumes lost to outages for the FCC units varied between about 5 percent and 10 percent. The PADD 3 losses in 2005 were higher due to the damage caused by hurricanes Rita and Katrina and to the problems experienced at BP's large Texas City refinery.

[14] PADD 4 is not included because the total number of refineries and their capability is small when compared to other refineries, making confidentiality an issue. The findings in the other regions, however, would generally be applicable to PADD 4.

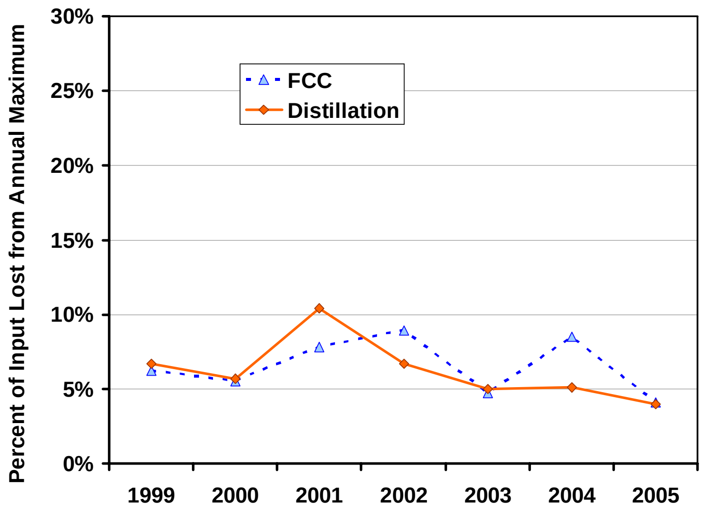
Table 1. Refinery Capability Overview in 2005

	Total Input Capability (Thousand Barrels Per Day)	Number of Refineries	Average Unit Capability (Thousand Barrels Per Day)
PADD 1			
Distillation	1704	15	114
FCC	713	10	71
Coking	91	3	30
Hydrocracking	40	2	20
PADD 2			
Distillation	3608	26	139
FCC	1236	25	49
Coking	347	12	29
Hydrocracking	166	6	28
PADD 3			
Distillation	8405	53	159
FCC	3105	39	80
Coking	1340	24	56
Hydrocracking	661	17	39
PADD 5			
Distillation	3173	35	91
FCC	862	14	62
Coking	566	14	40
Hydrocracking	585	14	42
Note: Capability is defined as aggregate maximum input for the units. These values are close to reported aggregate stream-day capacity. Average unit capability is total input capability divided by the number of units in the given PADD. Source: Form EIA-810			

In all PADDs, FCC and distillation towers show similar monthly input patterns, and thus similar outage patterns. This likely reflects the need to pull back on crude inputs when the FCC unit is out for any length of time, due mainly to the size of the FCC unit. Excess intermediate feedstock for the FCC unit would build rapidly when it is out of service, and a refinery would not have room to store the feedstock or even catch up by running it later when the unit was back on line.

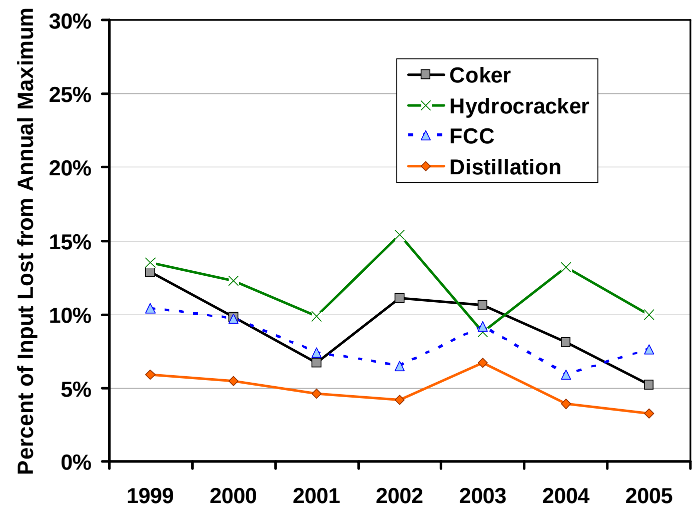
Loss of production capability from outages was estimated to be a little higher for coking units than for FCC units, and losses generally were highest for hydrocrackers. This is consistent with typical turnaround schedules. FCC units have longer time spans between major turnarounds than hydrocrackers, for example. Thus, in any one year, one would expect to see more hydrocracker outages on a percentage basis than FCC units.

Figure 4. Annual PADD 1 Unit Capability Lost to Large Outages



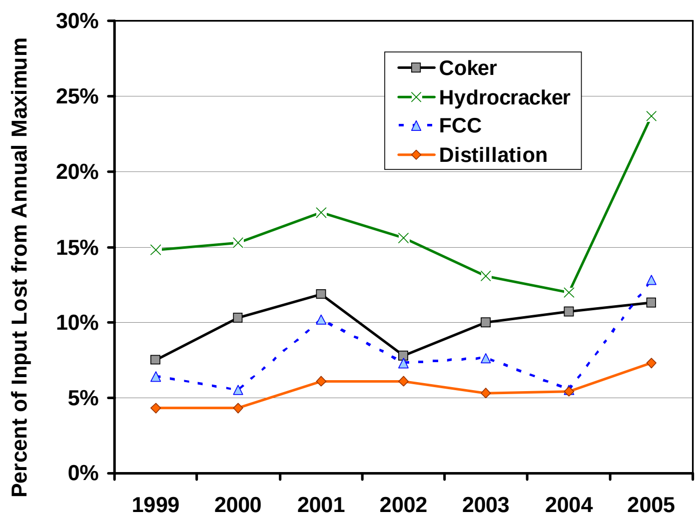
Note: Lost input from units running less than 85% utilization. Some data suppressed for confidentiality. Source: Form EIA-810

Figure 5. Annual PADD 2 Unit Capability Lost to Large Outages



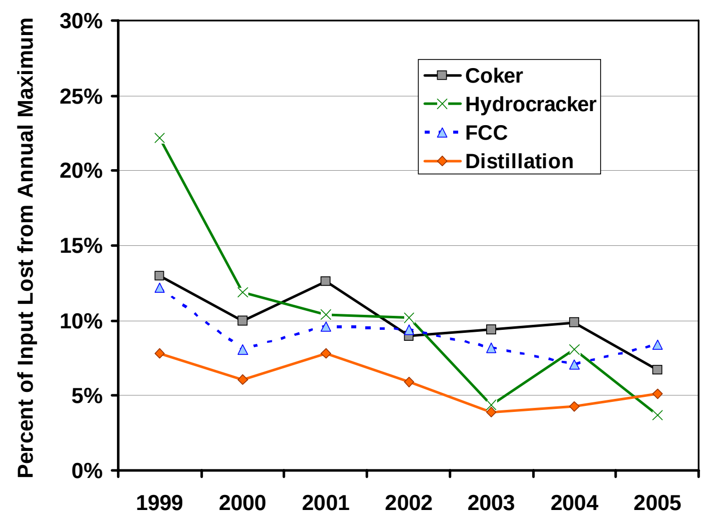
Note: Lost input from units running less than 85% utilization.
Source: Form EIA-810

Figure 6. Annual PADD 3 Unit Capability Lost to Large Outages



Note: Lost input from units running less than 85% utilization.
Source: Form EIA-810

Figure 7. Annual PADD 5 Unit Capability Lost to Large Outages

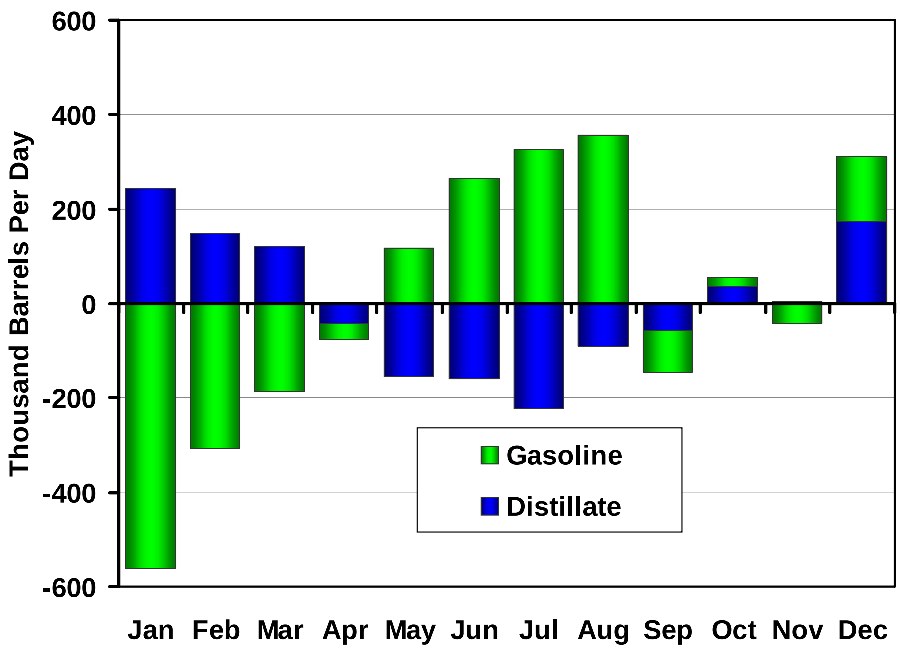


Note: Lost input from units running less than 85% utilization.
Source: Form EIA-810

3.4.2 Seasonal Outage Variations

Refiners typically take process units out of service for maintenance in the fourth or first quarter of the year, which coincides with the low seasonal product demand. The demand for total refined petroleum products, such as gasoline, jet fuel, diesel, residual fuel oil, etc., is driven by gasoline and distillate fuel (i.e., heating oil and diesel) demands, which together represent over 70 percent of the U.S. product volumes coming from crude oil. These products have counter-seasonal demand profiles, as shown in Figure 8. For example, in January, gasoline demand averaged almost 600 thousand barrels per day lower than its annual average, while distillate demand was more than 200 thousand barrels per day higher than its annual average, reflecting the winter need for heating oil.

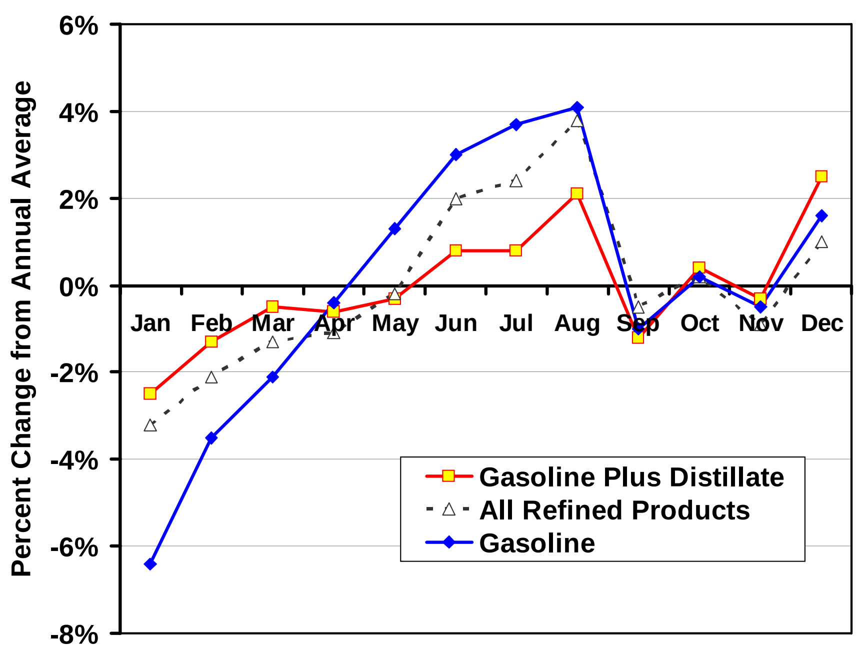
Figure 8. Seasonal Variations for Gasoline and Distillate Product Supplied (Monthly Change from Annual Average 1999-2005)



Note: Each month's data was averaged from 1999-2005. The annual average of the 12 month averages was the base for the monthly percent changes. For reference, during 1999-2005, gasoline demand was about 9 million barrels per day, and distillate was about 4 million barrels per day.
Source: EIA Petroleum Product Supplied, Petroleum Supply Annual.

Even though these two major products move counter-seasonally, the greater size of the gasoline market still drives much of the total finished product seasonal demand, as shown in Figure 9, which illustrates demand peaking in the summer and being lowest during the first quarter, following the gasoline seasonal pattern. (In December, gasoline and distillate both usually run above average, pushing the total up for that one month before the low first quarter.) The most opportune time for maintenance from a demand standpoint would appear to be in the first quarter, with September through November providing another opportunity. While the outage patterns reflect this situation, other factors influence timing of major turnarounds as well.

Figure 9. Seasonal Pattern for Finished Product Demand
(Monthly Percent Change from Annual Average Product Supplied)



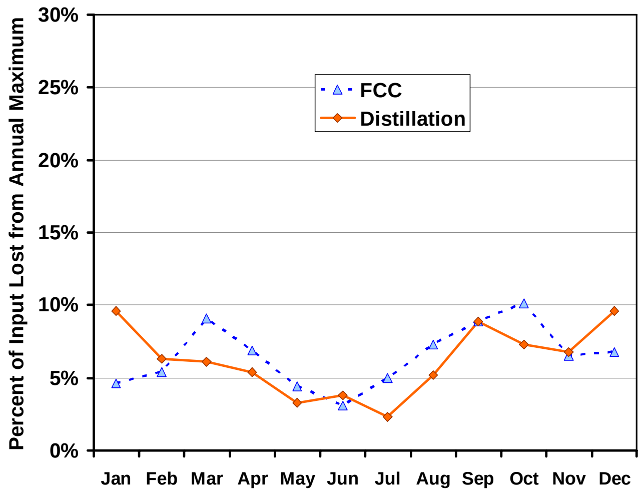
Note: Each month's data was averaged from 1999-2005. The annual average of the 12 month averages was the base for the monthly percent changes.
Source: EIA Petroleum Product Supplied, Petroleum Supply Annual.

Weather conditions affect turnarounds. Refineries in northern areas will push their turnarounds later into the spring than southern refineries, avoiding bitter winter weather, since snow and ice make turnarounds difficult. On the Gulf Coast, January frequently sees high winds, which prevent the use of large cranes needed for major turnarounds, even though the demand profile is favorable at that time.

Labor availability also enters into turnaround timing, since turnarounds involve large labor forces, and these labor forces are in short supply. Holidays are avoided, as is hunting season in many areas. Shortage of labor also forces turnarounds to be spread out.

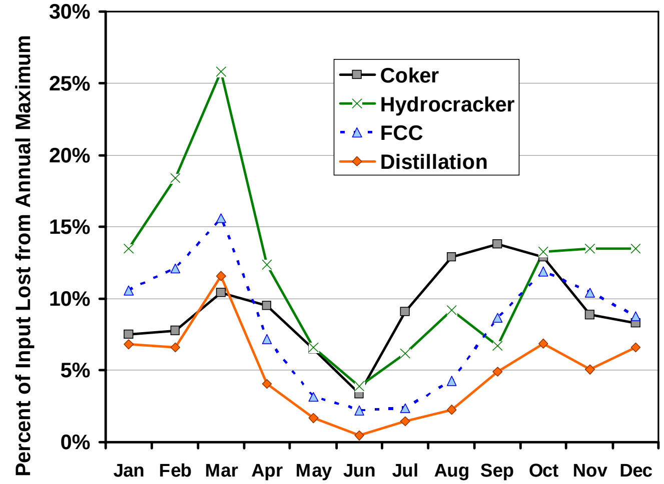
Figures 10 through 13 show the seasonal refinery outage patterns for PADDs 1, 2, 3 and 5. For example, Figure 11, which shows the average monthly outages from 1999 through 2005 for the major units in PADD 3, illustrates that inputs to FCC units were down about 15 percent in January and February, compared to 2 to 4 percent down from maximum input capability for May through August.

Figure 10. Seasonal PADD 1 Unit Capability Lost to Large Outages



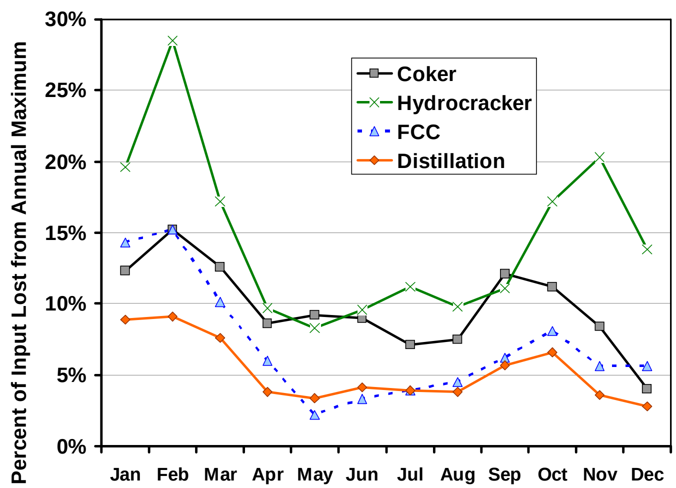
Lost input is from units running less than 85% of maximum in a month.
Source: Form EIA-810

Figure 11. Seasonal PADD 2 Unit Capability Lost to Large Outages



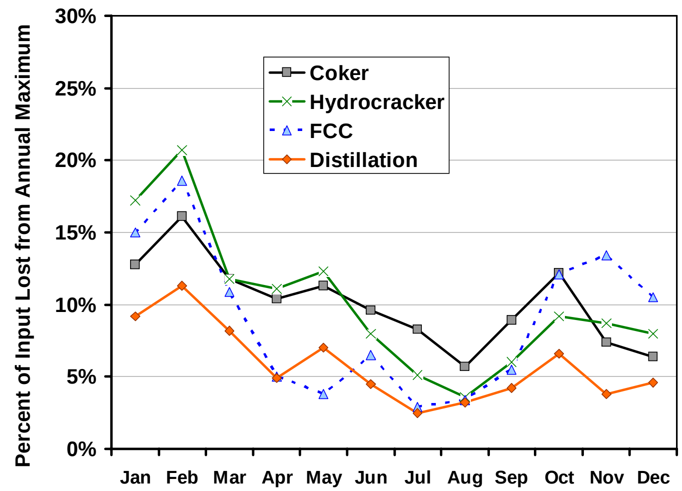
Lost input is from units running less than 85% of maximum in a month.
Source: Form EIA-810

Figure 12. Seasonal PADD 3 Unit Capability Lost to Large Outages



Lost input is from units running less than 85% of maximum in a month.
Source: Form EIA-810

Figure 13. Seasonal PADD 5 Unit Capability Lost to Large Outages



Lost input is from units running less than 85% of maximum in a month.
Source: Form EIA-810

The seasonal outage pattern for hydrocrackers is similar to FCC units. Cokers seem to show less seasonal variation compared to the cracking units, but both hydrocrackers and coking units experience fairly large outages as a percent of maximum runs, compared to the FCC units or distillation towers.

3.4.3 Outage Share of Total Input Variation and Relationship to Utilization

While unit inputs can vary as a result of responses to changing market conditions as well as outages, the data seem to indicate that most of the variation in unit input is attributable to outages. Figures 14-17 illustrate this for FCC units in PADDs 1, 2, 3 and 5. The top two lines of each graph show reported annual stream-day capacity and the capability estimated from peak inputs for a given year. These two lines are close for every PADD, indicating peak capability used in this analysis is a relatively good measure of stream-day capacity. The bottom area shows the actual FCC input volumes, and the line above actual inputs shows the actual inputs plus those volumes lost to outages, keeping in mind that an outage is defined to occur when a refinery's FCC unit runs less than 85 percent of its peak volume in a given month. For example, for PADD 1 in July 2002, actual FCC input was 586,000 barrels per day. EIA estimated that 97,000 barrels per day was off line due to outages. Had those FCC units been running at full capability,[15] inputs to FCC units in PADD 1 would have been 683,000 barrels per day, shown by the blue line. The maximum capability for PADD 1 at that point appeared to be 701,000 barrels per day (red line), and stream day capacity was 722,000 barrels per day.

The inputs-plus-outage volumes represented by the blue lines are fairly close to the stream day capacity reported to EIA and peak capability, showing that the outage volumes for the individual refineries, when aggregated (area between the yellow actual FCC inputs and the blue line), represent most of the reduction in FCC unit volumes. Furthermore, the relatively small month-to-month variation of the inputs-plus-outage volumes suggests very little FCC input change is occurring to adjust to variation in product demand and other market conditions over that which occurs from maintenance or other outages.

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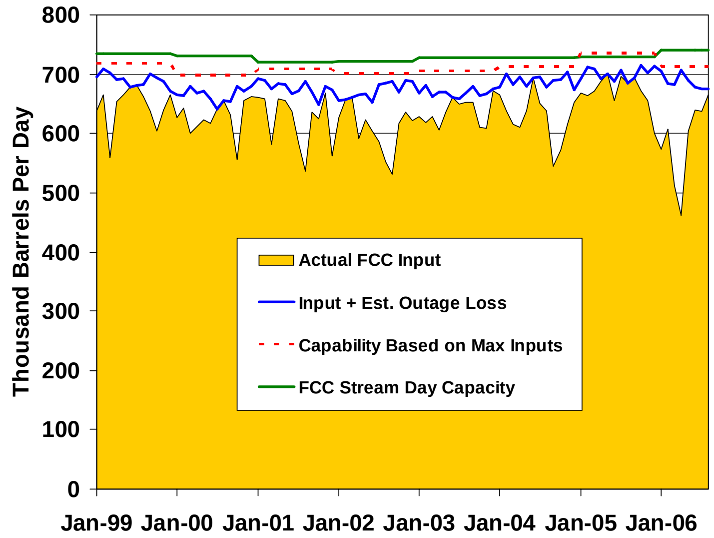
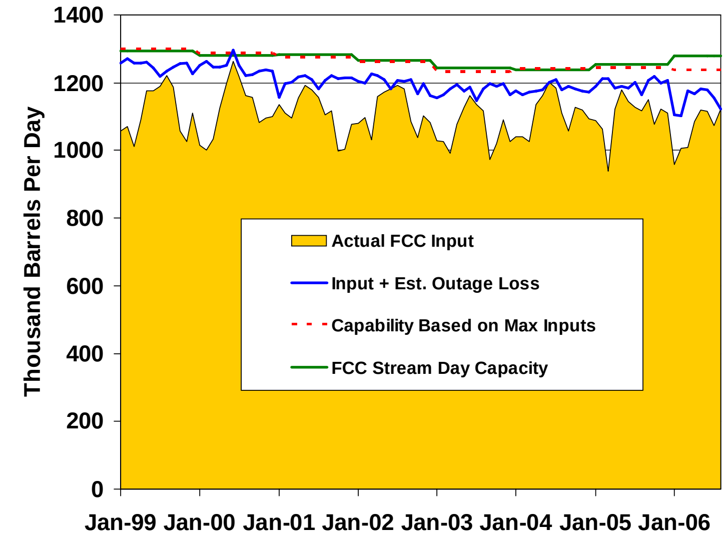
[15] While lost production from outages was estimated as the difference between maximum production capability and actual inputs, an alternative approach could have assumed outage units would have operated at small reductions from maximum. The information available would not allow a very accurate estimate of the small variation from full capability that might have occurred, and would not have changed the conclusion.

Figure14. PADD 1 FCC Inputs and Capability



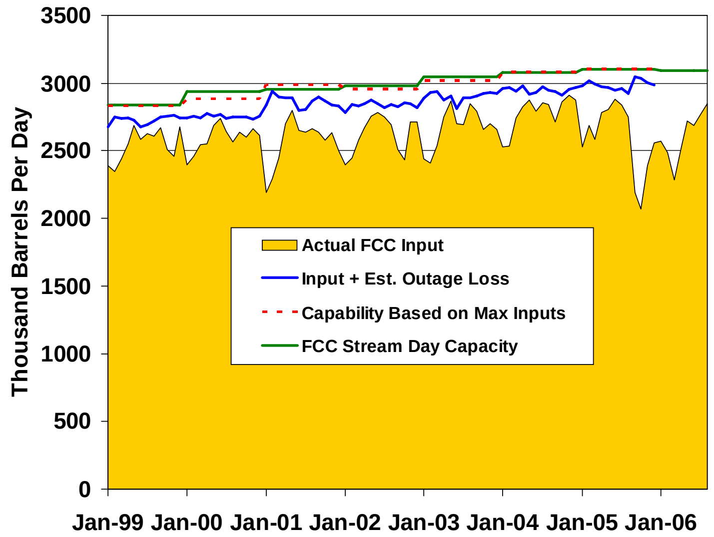
Source: Form EIA-810

Figure15. PADD 2 FCC Inputs and Capability



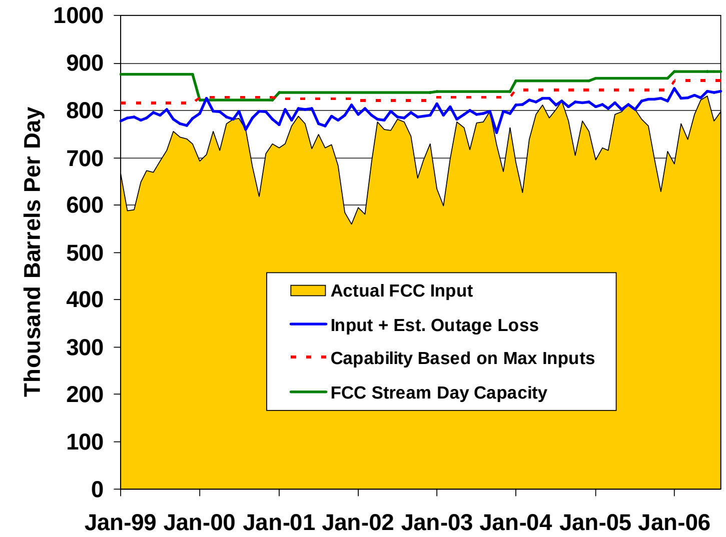
Source: Form EIA-810

Figure16. PADD 3 FCC Inputs and Capability



Source: Form EIA-810

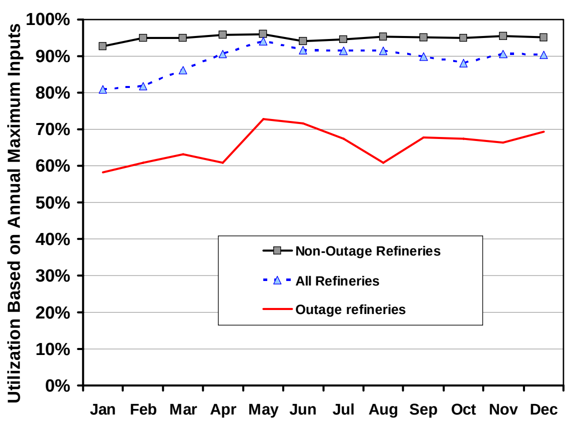
Figure17. PADD 5 FCC Inputs and Capability



Source: Form EIA-810

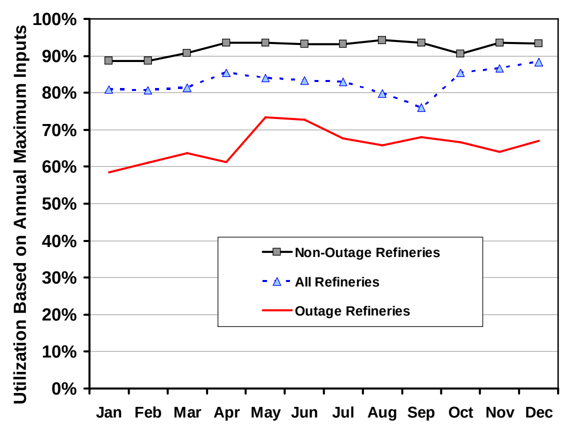
It follows that if outages explain most of the FCC input variations, they also explain much of the variation in FCC utilization, as measured by inputs as a percent of FCC capability based on maximum inputs.[16] When outages are removed from the FCC utilization calculation, the remaining refineries without outages operate at high utilizations, as shown in Figures 18 and 19 for FCC units and distillation towers in PADD 3. The refineries in PADD 3 without outages operate in the 94 to 96 percent of stream day capacity for the total FCC capacity across the PADD. In recent summers when utilization was at its peak, EIA estimates that refiners could not increase throughput to FCC by more than 1 percent. Distillation inputs are also at high levels.

Figure 18. PADD 3 Average Monthly FCC Unit Utilization (1999-2005)



Note: Utilization is FCC inputs divided by FCC maximum input capability.
Source: Form EIA-810

Figure 19. PADD 3 Average Monthly Distillation Tower Utilization (1999-2005)



Note: Utilization is FCC inputs divided by FCC maximum input capability.
Source: Form EIA-810

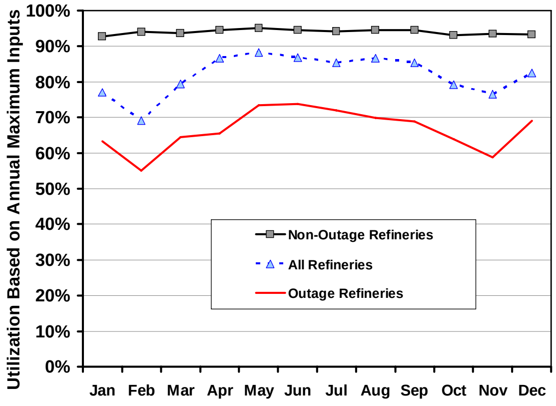
While utilizations of coking and hydrocracking units for all refineries in PADD 3 average lower than FCC units across the year (82 percent of maximum inputs for hydrocrackers, 86 percent for coking, and 89 percent for FCC), the utilizations for hydrocracking and coking units not experiencing outages is quite high and similar to that for FCC and distillation towers (Figures 20 and 21). These findings support the observations frequently made that downstream units like FCC, hydrocracking, and coking units, tend to be run at full capacity most of the time. Planned and unplanned outages are the major factors reducing their throughputs.

3.5. Impacts of Outages on Gasoline and Distillate Production

This section focuses on the impacts different unit outages have on the production of gasoline and distillate. Figures 22 and 23 illustrate, in aggregate, how gasoline production varies with inputs of distillation and FCC units.

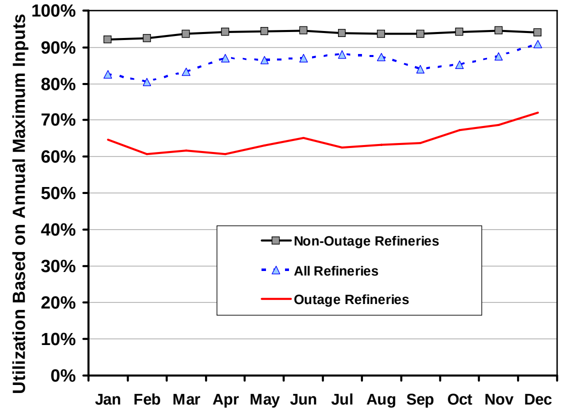
[16] Aggregate output of units not experiencing outages did not seem to rise when large outages occurred, which is partially the result of non-outage units already running at very high utilizations.

Figure 20. PADD 3 Average Monthly Hydrocracking Unit Utilization (1999-2005)



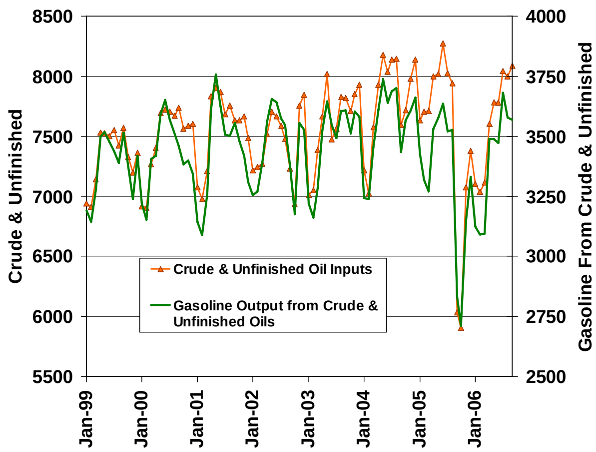
Source: Form EIA-810

Figure 21. PADD 3 Average Monthly Coking Unit Utilization (1999-2005)



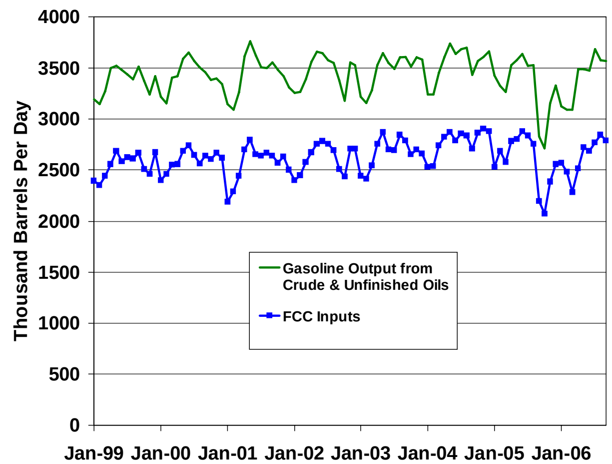
Source: Form EIA-810

Figure 22. PADD 3 Gasoline Output and Crude & Unfinished Oils Input (Thousand Barrels Per Day)



Note: Since gasoline production is about 50 percent of refinery inputs, the gasoline scale is 50 percent of crude & unfinished to compare variations. Gasoline output reflects only those volumes derived from crude and unfinished oils. It excludes oxygenates and other components from outside the refinery.
Source: Folrm EIA-810

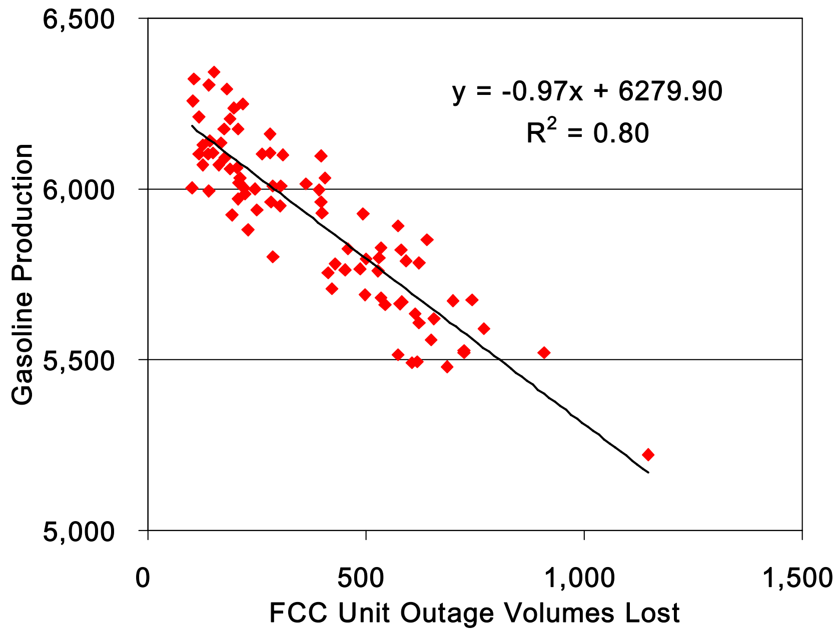
Figure 23. PADD 3 Gasoline Output and FCC Input (Thousand Barrels Per Day)



Note: Gasoline output reflects only those volumes derived from crude and unfinished oils. It excludes oxygenates and other components from outside the refinery.
Source: Form EIA-810

Figure 24 shows the aggregate gasoline production for PADDs 1 through 3 and volumes lost from FCC units experiencing an outage, as determined by the 85-percent utilization cutoff. That is, refineries showing less than 85-percent utilization were considered to be experiencing an outage. The volume lost for such a refinery would be its full capacity minus its actual inputs, as used in Section 3.4. This graph shows that there is about a one-for-one loss. A loss of one barrel of FCC input is correlated with a loss of one barrel of gasoline.

Figure 24. Gasoline Production Relationship to FCC Input in PADDs 1-3 (Thousand Barrels Per Day)



Source: Form EIA-810 data

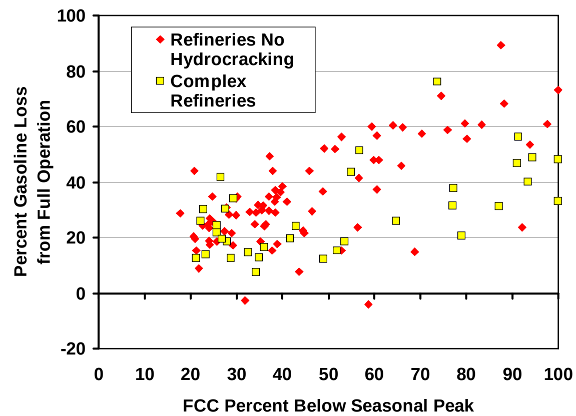
The one-for-one relationship is not surprising, even though the FCC unit and the alkylation unit that it supplies together only represent about 50 percent of the total gasoline pool in a given refinery. As described earlier, when a unit is taken out of service, particularly a large unit like the FCC unit, the refinery may have to run distillation and other units at lower rates. The physical connections between different refinery units, storage limitations, and distribution system limitations for moving intermediate feedstocks into and out of a refinery result in correlations among unit outages. Inputs to the distillation tower may be reduced when the FCC unit is down in order to reduce the amount of FCC feedstock being generated. In addition, reduction in distillation tower runs will affect coking unit inputs unless coking unit feedstock is not readily available for purchase.

Furthermore, since the data in Figure 24 are aggregate values, they may be picking up refineries that are doing maintenance on units other than FCC units. For example, in January, when FCC outages would be expected to be high, maintenance on other units would also be expected to be high. The data in Figure 24 measure the amount of FCC outage, but only measure gasoline aggregate production, and thus pick up the gasoline production losses from other maintenance unrelated to an FCC outage. In order to remove these other maintenance impacts on gasoline, individual refinery data must be examined.

Individual refineries were explored in greater detail in order to investigate the explicit link between an outage in a given refinery and its product production. With individual refinery data, single unit outages can be isolated to some extent from those outages where multiple units are off line. The remaining analysis of individual refineries in this section uses the second methodology described at the beginning of this chapter, which uses a subset of refineries, rather than all refineries.

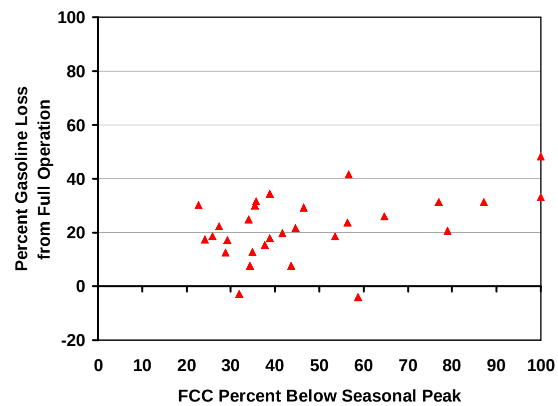
Figure 25 shows the reduction in gasoline output in months when there was an apparent FCC unit outage, but not necessarily an isolated FCC outage, at any of the 11 PADD-3 refineries that had FCC outages. Each data point represents one month at one of the 11 refineries and includes data points when other units were out along with the FCC unit. The data points illustrate higher gasoline production impacts at higher FCC outage rates. Since these data points may include situations when other units are also down, it is not surprising to see gasoline outage rates in some cases being quite high as discussed earlier in this section. Figure 25 also highlights the large, most complex refineries containing hydrocrackers in order to show that these refineries exhibited relatively less gasoline production loss than other refineries when the FCC unit was down. This may be partially due to the more complex refineries having more conversion units that contribute to gasoline production than a refinery with only an FCC unit and no hydrocracker. The hydrocracker may be able to use some of the feedstock that would have gone to the FCC unit.

Figure 25. PADD 3 Lost Gasoline Production with Large FCC Outages (Other Units May Also be Out)



Note: Data for11 refineries. Data cut off at about 20% FCC outage for display clarity only.
Source: Form EIA-810

Figure 26. PADD 3 Lost Gasoline Production when FCC was Main Outage



Note: Data for 11 refineries. Data cut off at about 20% FCC outage for display clarity only.
Source: Form EIA-810

Figure 26 isolates those times when the FCC unit was the main outage.[17] That is, data points in Figure 26 are limited to those when the FCC unit inputs were less than 85

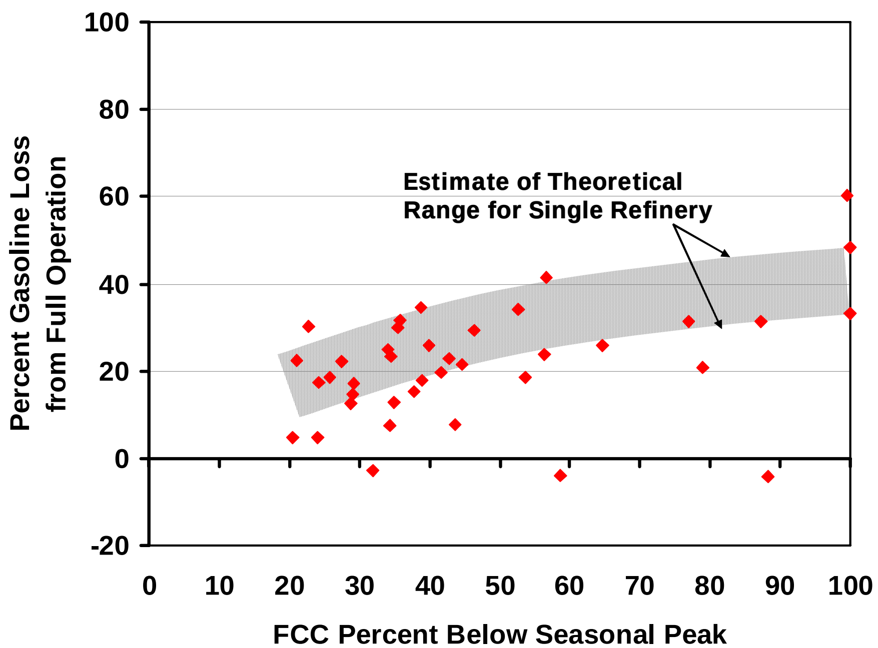
[17] In order to isolate the effect of specific unit outages on production of gasoline and distillate products, refinery data were analyzed to select those times when one unit was out, rather than when several units were out simultaneously. When an FCC unit was out, for example, the data frequently showed reduced inputs to the distillation tower, and at times, also to hydrocracking and coking units. With simultaneous

percent of maximum input capability, but all other units were running higher than 85 percent of their maximum values. Note that in these cases, the gasoline loss is lower than in Figure 25. Clearly multiple unit outages shown in Figure 25 occur frequently and have a larger effect on production than single unit outages.

Adding more data from other PADDs does not change the picture much, as shown in Figure 27, which extends Figure 26 to include PADDs 1 and 2 along with PADD 3. Figure 27 shows the reduction in gasoline output in months when the FCC unit was the main outage at any of 17 refineries in these PADDs. This figure also shows a theoretical estimate for a single refinery of gasoline production loss at various levels of FCC unit outage. Some of the EIA data points fall outside of this range.

Figures 25 through 27 show a lot of scatter. One of the reasons for the scatter is the limitation of the monthly data. For example, the FCC unit might be brought down completely towards the end of one month, showing perhaps a 30-percent outage on average for the month. But gasoline production may not be affected much in that month, as the refinery uses inventories or stored FCC gasoline to keep production up for a time. However, by the second month, the gasoline production is affected as the FCC outage continues.

Figure 27. PADDs 1, 2, & 3 Gasoline Loss When FCC Main Outage



Note: Data for 17 refineries. Data cut off at about 20% FCC outage for display clarity only.
Source: Form EIA-810

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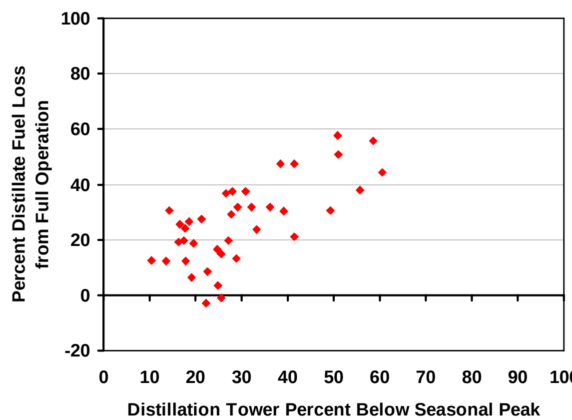
unit outages, it is difficult to attribute any loss of product production to a specific unit. However, there were enough times when the FCC unit was the main unit experiencing an outage to explore this impact.

While some gasoline production would be affected if the coking unit or hydrocracker were not functioning, the monthly data show much less impact on gasoline when examining situations in which these units are the main ones offline when compared to the impacts of an FCC outage.

Turning to distillate fuel (i.e., diesel and heating oil) production, this product derives mostly from the stream coming directly from the crude distillation tower, so it is not surprising that the largest variation in distillate product production seems to stem from distillation tower outages as shown in Figure 28.

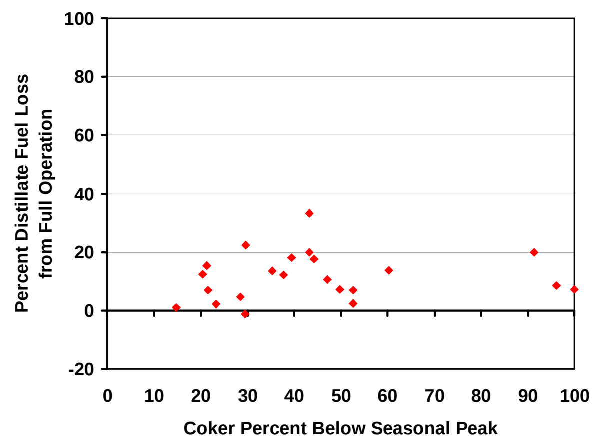
Figure 29 shows distillate outages when the coking unit was the main outage. While there is no correlation between the size of the coking unit outage and the loss of distillate production, distillate production can be affected when the coking unit is down. It would seem that distillate production is rarely affected more than 20 percent with a coking unit outage. Although the data do not provide a means of clearly quantifying unit outage impacts on gasoline or distillate production, the unit outages clearly have an impact, which varies.

Figure 28. PADDs 1, 2, & 3 Distillate Fuel Losses When Crude Distillation Tower was Main outage



Note: Data for 14 refineries.
Source: Form EIA-810

Figure 29. PADDs 1, 2, & 3 Distillate Fuel Losses When Coking Unit was Main Outage



Note: Data for 8 refineries.
Source: Form EIA-810

The last outage dimension for discussion is the year-to-year production variation in individual refineries. A single refinery's production can vary significantly among different years. EIA examined individual refinery production from 1999-2005, comparing the highest production year, when no apparent outages were occurring, to the lowest production year for a subset of facilities. Table 2 summarizes the results. Note that hurricane-affected refineries were excluded. For each refinery, gasoline and gasoline plus distillate production for the year were calculated. Then the percent change between the best no outage year and worst outage year was calculated.

On the Gulf Coast (PADD 3), for example, the refinery that showed the smallest difference in gasoline production between its best year with no outages and worst outage year experienced an 8.2 percent drop, while the refinery that showed the greatest gasoline production decline fell 33.0 percent from its best year without outages. That is, for PADD 3, assume each of the refineries produced gasoline at 100,000 barrels per day[18] when not experiencing any outages. In PADD 3, the refinery showing the least production impacts from outages only dropped 8.2 percent from its level with no outages, which, in this illustration, would have reduced its gasoline output to 91,800 barrels per day. However the refinery that experienced the worst loss of gasoline from outages dropped 33.0 percent, which would bring its production down to 67,000 barrels per day in this example. The Midwest and East Coast regions did not see quite the same percentage drops in production with major outages of lower complexity refineries. The largest drop in the Midwest was about 26 percent from maximum production, and on the East Coast the largest drop was about 20 percent.

Table 2. Variation in Individual Refinery Annual Production Maximum to Minimum from 1999 through 2005

PADD	No. Refineries	Product	Individual Refinery Percent Production Variation from Minimum Year to Maximum Production Year	
			Largest Variation	Smallest Variation
1	5	Gasoline production	19.5%	13.6%
		Gasoline + Distillate	18.1%	8.1%
2	9	Gasoline production	26.2%	9.4%
		Gasoline + Distillate	19.2%	9.0%
3	11	Gasoline production	33.0%	8.2%
		Gasoline + Distillate	35.0%	6.6%

Note: Impacts from hurricanes Katrina & Rita were excluded.
Source: Form EIA-810

[18] PADD 3 annual average gasoline production per refinery (excluding non-gasoline producing refineries) is about 100,000 barrels per day.

4. Impacts of Refinery Outages on Price

Outages are important to price because they affect production and thus supply of product. When summer gasoline demand is peaking, the U.S. has little excess refining capacity available to make up for the loss of production from an outage. Still, as discussed in Chapter 3, most outages don't occur during the peak summer demand periods. Furthermore, a drop in production alone from one or more outages may not have an impact on price. The balance between total supply and demand, in conjunction with market expectations about near-term future supply and demand, is ultimately what affects short-term price variations. Unexpected surges in demand can arise, such as when a severe cold snap occurs, tightening the market and increasing pressure on prices. On the supply side, total refinery production, inventories, net imports, and even the time of year impact the supply-demand balance and thus the price.

Inventory levels are an oft-cited measure of excess supply or demand in the market, and thus may exert pressure on prices. Product inventories, such as gasoline, frequently have a typical seasonal pattern, but if they are low relative to their typical levels and continuing to fall, it may indicate excess demand in the market. During such times, prices will generally rise, as the market perceives this imbalance and buyers bid prices up to obtain apparently scarce supply. The reverse holds as well: high and rising stocks may indicate excess supply relative to demand, and, in such a case, induce prices to fall.

Since the EIA outage data show the best relationships to loss of gasoline production, the impacts of outages on gasoline price are explored. Retail gasoline prices vary mainly as a result of changes in crude oil prices and changes in prices at the spot or wholesale level,[19] as discussed in more detail in Appendix C and shown in Figure 30. Refinery outages would be expected to have the largest impact on regional spot gasoline prices rather than international crude oil prices. As a result, the difference between gasoline spot price and crude oil price, referred to as the gasoline crack spread, is the price response that would potentially best reflect any impact from outages. This is shown as the orange area on Figure 30.

The relationship between this gasoline crack spread and inventories, which reflect the balance between supply and demand, is illustrated using weekly data in Figure 31. The figure shows movements in the gasoline crack spread and inventories over or under their typical seasonal levels. Figure 31 demonstrates that movements in the gasoline crack spread relative to its seasonal norm tend to be inversely related to the inventory level relative to its seasonal norm. EIA has shown similar relationships between crude oil prices and inventories[20] as well.

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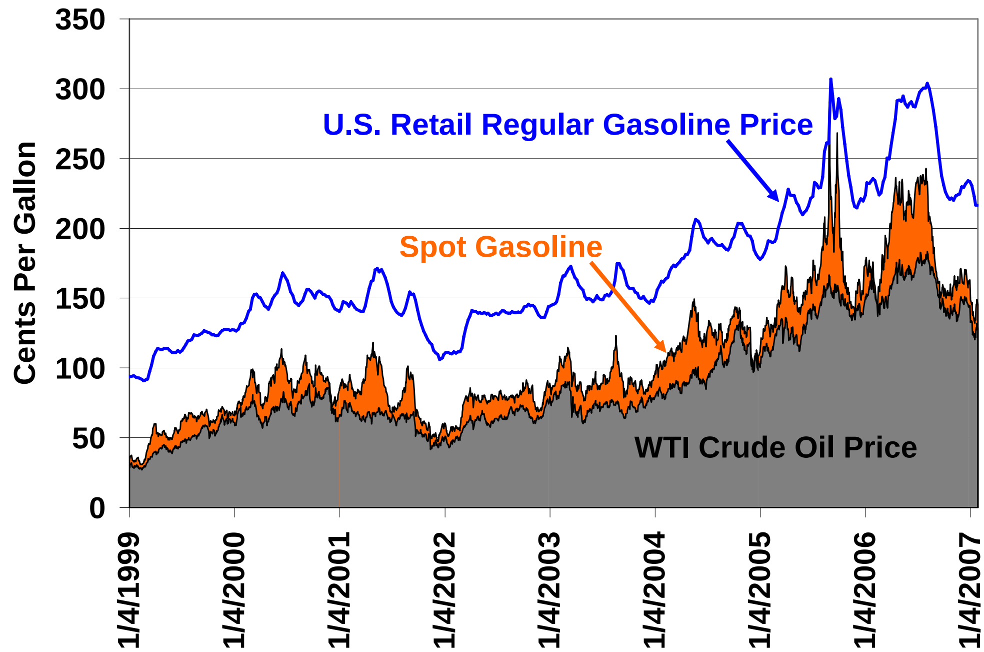
[19] EIA has shown that regionally wholesale prices are passed through to retail consumers on a lagged basis, which tends to dampen the increases and decreases seen at the spot level. http://www.eia.doe.gov/pub/oil_gas/petroleum/feature_articles/2003/gasolinepass/gasolinepass.htm

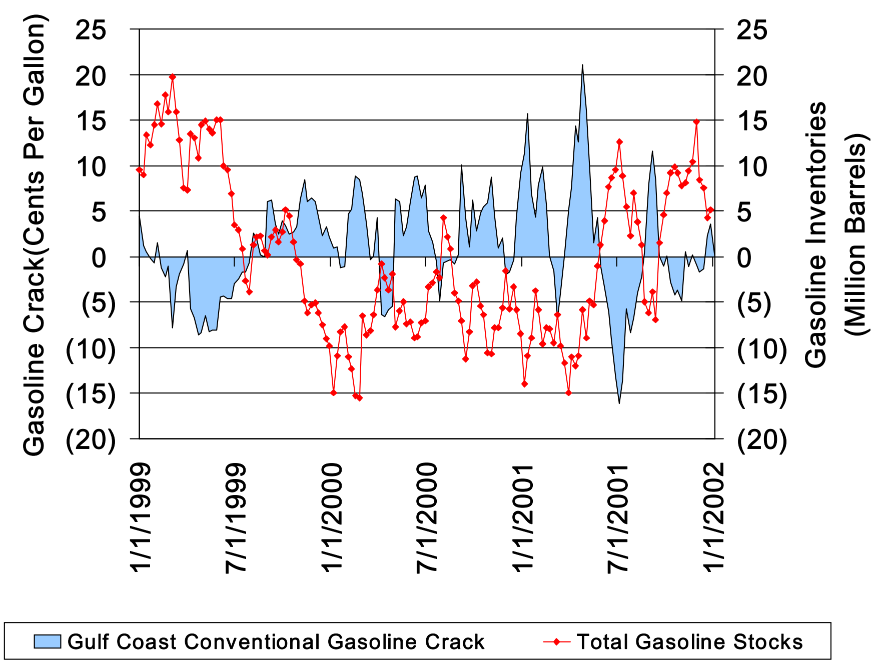
[20] "Forecasting Crude Oil Spot Price Using OECD Petroleum Inventory Levels," M. Ye, et al., *International Advances in Economic Research*, Vol 8, No. 4, November 2002, pp 324-334)

Figure 30. Crude Oil and U.S. Gasoline Prices



Source: Spot prices: Daily Reuters -- Gasoline prices are a weighted average across major U.S. regions. Retail prices are EIA weekly U.S. conventional gasoline prices.

Figure 31. Weekly Variations from Typical Seasonal Values of Inventories and Gasoline Crack Spreads



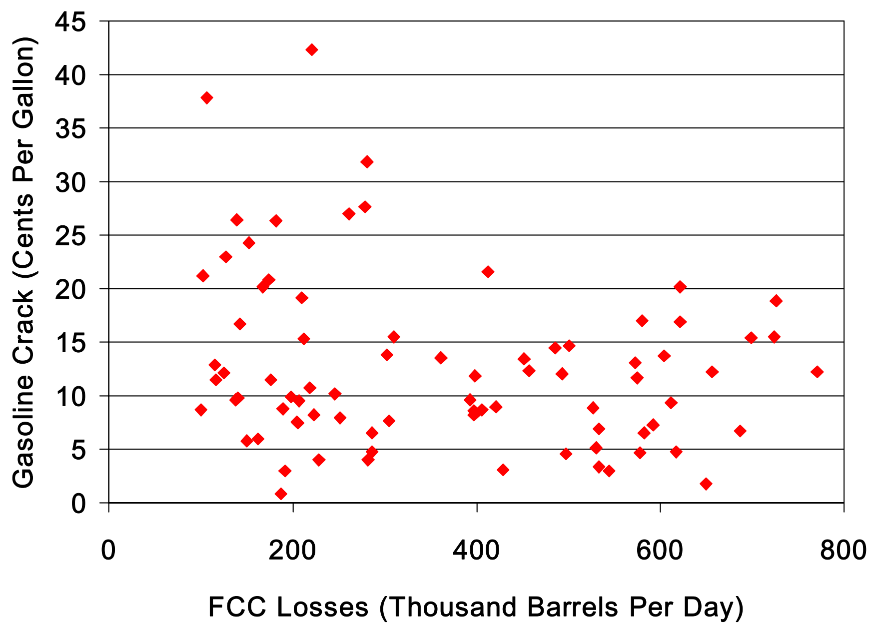
Source: Spot prices: Reuters, Inventories: EIA Weekly Petroleum Status Report.

The statistical analysis that follows would be expected to detect some relationship between the inventories and gasoline crack spread, but the issue is whether or not the outage effects can be statistically isolated as a significant variable explaining the variations in the gasoline crack spread.

4.1. Statistical Analysis

Historical outage data were only available on a monthly basis. No significant relationship between monthly gasoline crack spread variations and outages could be found in the region encompassing PADDs 1 through 3. Figure 32 shows the lack of correlation between the FCC losses discussed in the previous chapter and the gasoline crack spread. While the FCC losses shown in the graph encompass several PADDs, no reasonable relationship was found between FCC losses and gasoline crack spreads in individual PADDs either.

Figure 32. Relationship between Losses of FCC Production (PADDs 1, 2, and 3) and Gulf Coast Conventional Gasoline Crack Spread



Sources: Gasoline crack: Monthly average Bloomberg Gulf Coast spot conventional gasoline minus WTI crude oil price. FCC losses- EIA estimates using EIA Form 810.

Table 3 shows correlations between the gasoline crack spread and some gasoline market variables. Inventories and imports have the largest correlation with the gasoline crack, with the other variables showing little relationship. Inspection of Figure 31 shows gasoline inventories moving in the opposite direction of the gasoline crack spread (i.e., inventories move up as the gasoline crack spread moves down). This is indicated by the negative correlation in Table 3. Although imports seem correlated with the gasoline crack spread, further more detailed analysis of the market variables showed inventories to be the only significant market variable helping to explain the gasoline crack spread variations.

Table 3. Correlations of Market Variables with Gasoline Crack Spread

	USGC Unleaded Crack
USGC Unleaded Crack	1.0000
FCC Volume Lost	-0.0234
Input to FCC Units	0.0910
Gross Inputs to Refineries	0.1134
Gasoline Output	0.1022
Net Gasoline Imports	-0.1865
Total Gasoline Inventories	-0.4838

Note: The correlation coefficient ranges from -1 to +1. The closer to +1 or -1, the more closely the variables move together directly or inversely respectively. Volume data were aggregated for PADDs 1, 2, and 3. Gross inputs include crude oil and unfinished oil inputs to refineries. Gasoline net imports and total gasoline inventories include gasoline blending components. The variables have had trends, seasonal variations, and hurricane impacts removed.

Analysts sometimes raise concerns that unplanned outages could affect prices differently than planned outages. On one hand, unplanned outages would generally be expected to be smaller than the large planned turnarounds, which would lower any potential impact on price relative to planned outages. However, unplanned outages may not allow for adequate time to arrange for additional supplies, and would be the outages most likely to occur during the peak summer demand season, when extra supply is not readily available. Thus, they could have a larger price impact on the margin than their size alone might imply.

EIA data do not distinguish between planned and unplanned outages. However, the deviation of all outages from their normal seasonal pattern (i.e., using data in which the trends and seasonal variations have been removed)[21], should isolate the impacts of unplanned outages, since they would likely show up as larger than typical outages. However, as Table 3 shows, no large correlation was evident. Data were also analyzed for the summer months alone, assuming most outages that occur during the peak gasoline demand months are unplanned. This data also showed no large positive correlation between outages and the gasoline crack spread.

[21] The seasonal pattern for outages did not correspond to the seasonal pattern for gasoline crack spreads. The data were also analyzed leaving seasonal patterns in place. No pattern was evident between FCC outages and increasing gasoline crack spread whether the data were deseasonalized or not.

Monthly data are likely too "coarse" to pick up outage impacts directly in that outage factors affecting price may already be resolved before the month is over. As a result, weekly data were explored as well. Since EIA unit input information is not available on a weekly basis, other variables that might reflect outages were explored, such as net imports and refinery utilization. Recall that the monthly data analysis indicated that most of the variation in refinery unit utilization seemed to be the result of outages. Net imports were explored to examine the possibility that import increases might be used often to replace losses from outages, in which case net imports would correlate with outages. No significant relationship was found between gasoline crack spreads and these variables. The only solid evidence for any price relationship using weekly data was between the gasoline crack spread and inventory levels.

4.2. Limitations of Statistical Analysis

The lack of statistical relationships between outages and gasoline price spreads may be surprising to some analysts. But the lack of a statistical correlation between these variables should not be interpreted as meaning outages have no impact on prices. The statistical analyses used are designed to capture normal market variations and responses. They indicate that most of the time, outages have little impact on monthly average prices. Refining outages impact the production of petroleum products, but production is only one aspect of supply, and most outages occur during times when petroleum markets are not tight – such as after the winter distillate peak demand season, but before the summer peak gasoline season. During these low demand periods, adequate inventories, imports, and even some extra production from facilities not undergoing major turnarounds can be used to replace production lost from outages. Nonetheless, there are situations in which outages do seem to affect the market.

Consider three situations that would have different price impacts, and yet would not be detected using statistical methods on monthly averages. The first is the quick market reaction to an outage and subsequent quick correction. The trade press will frequently announce an outage and attribute a rise in spot product prices to that event. The market normally determines that the outage should not be a problem and any price response quickly reverses, sometimes within an hour or so. Such volatility would not be seen by retail customers and would not be detected in our statistical analysis.

The second situation is one where an outage may result in a supply shortage for a week or so, and initially little or no compensating supply arrives. An inventory decline would occur in this case. However, before the month is out, new supply from imports, recovery of the affected refinery, or increased production from other refineries fills the gap, and the situation is resolved well before the end of the month. While some price pressure may occur in these cases, it may not be large, and the average price for the month in most cases would not show a significant variation as a result of the outage.

The third case is the situation where there is major supply disruption due to outages. One such example was described in an earlier EIA report that focused on California.[22] The California situation EIA reviewed involved one set of circumstances conducive to an outage having a price impact: one or more outages of large magnitude relative to other supply in the region, occurring during a peak demand period in an area where alternative supply sources are not readily available. This combination of events came together in a manner that significantly affected prices. Another vulnerable time period is in the spring when supply is switching from winter gasoline to summer grade gasoline, and demand is increasing. During that time, prices can be initially depressed as suppliers draw down their winter-grade gasoline, which cannot be used during the summer months. Supplies of summer-grade gasoline are being produced and stored, but not used. Prices then increase seasonally as the summer-grade gasoline season begins and demand rises towards its summer peak. However, if refineries are having difficulty coming back on line from turnarounds, they may be slow to ramp up production of summer-grade gasoline to meet increasing seasonal demand during this transition, and extra price pressure can occur. This was the case in the spring of 2006, when a number of refineries were still trying to recover from the hurricanes in fall 2005. While gasoline imports increased to offset some of the refinery supply loss, the volumes of affected capacity were unusual. Typically, increased imports and other supplies would cushion smaller outages to minimize the price impact.

In summary, refinery outages generally occur when markets are not tight, and they therefore have little or no measurable impact on monthly average prices, which is one of the reasons the statistical analysis did show a relationship. At times, however, particularly when markets are tight, the loss of marginal production from an outage has raised prices. Although, outages with measurable impacts on monthly average prices are relatively rare.

[22] Energy Information Administration, "2003 California Gasoline Price Study: Preliminary Findings," May 2003, SR/O&G/2003-01, page 19.
http://www.eia.doe.gov/pub/oil_gas/petroleum/analysis_publications/caprice/prcaprice.pdf .

5. Conclusion

Refinery outages vary in size and timing and, while some are planned, unplanned outages occur as well. The largest planned outages are refinery turnarounds, which are major maintenance or overhaul activities. Safety is a major concern when implementing refinery turnarounds. Refineries run with materials at high temperatures and high pressures, and some of the materials themselves are caustic or toxic and must be handled appropriately. Maintenance is required to assure safe operations, and turnarounds themselves require extra safety precautions.

The frequency of major turnarounds varies by type of unit, but may only need to be done every 3 to 5 years on any given unit. Planned turnarounds often require 1 to 2 years of planning and preparation to organize, line up the skilled labor, and arrange for materials and equipment. The actual turnaround may then last about 20 to 60 days. Because a refinery has many units, it will frequently have turnarounds of different units in different years, although some unit turnarounds may be done at the same time, depending on the circumstances.

The size and complexity of a refinery turnaround leaves little flexibility for changing plans significantly, even when market conditions favor keeping the refinery running. A major FCC turnaround might require an increase of outside labor of more than 3 times the labor force usually present in the refinery, and long-lead times are needed for some materials and equipment.

The skilled laborers used in turnarounds are in short supply, which limits companies from doing major turnarounds at the same time. Still, the number of outages is highest during certain times of the year. The first and fourth quarters are preferred times, since this is when petroleum demand is seasonally low and weather conditions are favorable.

Unplanned outages can be very disruptive since they allow for little, if any, lead time to plan for the shutdown. Some unplanned outages can be postponed for several weeks while materials, equipment, and labor are ordered. Others may require immediate, emergency shutdowns. The volume lost from unplanned outages would generally be smaller over the course of a month than for planned turnarounds, but unplanned outages can occur during high demand periods, when the market is more sensitive to marginal barrels lost.

An outage in any major refinery unit can affect production of finished products, such as gasoline or distillate. Furthermore, the integration of refinery units means that the shutdown of one unit for repairs or maintenance can result in the shutdown or reduced operations of other units.

Within the limitations of the monthly and weekly data available, EIA's statistical analysis of outages indicates that generally there is not a significant price impact. Prices are affected not by production changes alone, but mainly by the balance in supply and demand, as represented by inventory levels. If supplies are abundant relative to demand (e.g., high inventories and off peak time of year), a refinery outage, even an unplanned outage, is likely to have little impact. The lack of a statistical relationship between outages and gasoline crack spread may be surprising to some analysts. Keep in mind, the statistical analyses used are designed to capture normal market variations and responses, and while they indicate that most of the time, outages have little impact on prices on a monthly average basis, they do not imply outages never affect prices.

There are times when the marginal supply of barrels lost due to outages have added to price pressure, such as when a tight market balance already exists and alternative supply sources are not readily available. Clearly the outages that occurred during Hurricanes Rita and Katrina were large enough to impact price. Another case was highlighted in an earlier report on California gasoline where several large unexpected outages in conjunction with tight gasoline market conditions seemed to drive up prices. However, outages with measurable impacts on monthly prices are relatively rare.

Appendix A. Study Request

Chron

United States Senate

COMMITTEE ON
ENERGY AND NATURAL RESOURCES
WASHINGTON, DC 20510–6150

ENERGY.SENATE.GOV

July 13, 2006

Secretary Samuel Bodman
United States Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Secretary Bodman:

As you well know, gasoline and oil prices are hovering near record highs. Families preparing for summer vacations are facing higher costs to travel by car, rail and plane as a result. We have heard from many industry experts as to the reasons for the increase in prices this year. Global incidents in a number of producing countries in addition to increased demand have clearly contributed.

Today we will hold a hearing in our Committee on a bill (HR.5254) that seeks to increase refinery construction. Proponents of this bill claim that it will increase our supply of refined products.

We have heard from several experts that the reason we are facing high prices at the pump stems from underlying supply issues. The amount of global excess capacity to produce oil and refine gasoline has been declining. Experts claim that it has entered 'the red zone' and coupled with other threats to energy output (Nigeria, Venezuela, Iraq and Iran), some perfect storm has been created.

Certainly we saw what kind of an effect storms can have on our own ability to refine oil last year with the damage sustained from Hurricanes Katrina and Rita. Refineries were shutdown last year in July as you may recall, adding pressure to supply and prices just before the hurricanes hit. Experts tell us that it is possible we will experience similar damage during the hurricane season this year also.

In light of the effect that our already constrained domestic refining system was under, and given the shutdowns with the hurricanes (and potentially more such incidents this year), I would request that you work with the EIA Administrator to conduct a study of the impact refinery shutdowns have had on the price of oil and gasoline. I have attached a proposed outline for the study in Attachment 1 and look forward to working with you on this.

Sincere regards,

Jeff Bingaman

Jeff Bingaman
Ranking Member

Attachment 1

Refinery Turnaround Study Outline

Refinery utilization is over 90% on an annual basis and refineries run 24/7 normally for most of the year. However at certain times, refineries reduce production as various units are maintained (e.g., replace parts and catalysts, clean and repair) and equipment changes are made to meet environmental requirements, expand capacity, or improve operations. Refiners maintain that they plan turnarounds during lower demand periods. For competitive reasons, companies are not permitted to coordinate their maintenance plans. However, some knowledge is available regarding these plans because such maintenance involves lining up product purchases from other companies and communicating with various outside parties, such as environmental government agencies and contractors.

Since turnarounds reduce the volume of products made, the possibility arises for periods of unusually high maintenance across several companies creating larger than usual losses of supply and higher prices. The question is whether industry could better plan its maintenance to reduce the potential for simultaneous large outages, and is there a role for government in making this happen. In order to better debate this question, EIA can provide some historical perspective that addresses the following issues:

Background:

- What is a refinery turnaround?
  - What activities go on
  - How much production variation can occur year to year in a given refinery – E.g., how does the production impact vary with the types of units undergoing maintenance?
  - What are planned versus unplanned outages?
- When do such activities usually take place?
- How do refiners plan for turnarounds, including coordination of outside contractors, and is their scheduling affected by known plans of other refineries?
- What information is available on planned outages?
- What flexibility do refiners have in changing their planned activities – e.g., to what extent do reliability and safety prohibit deferring maintenance?

Historical Maintenance Review

- How have outages affected production historically?
  - Seasonal variation
  - Year-to-year variation
- What has been the cause of the year-to-year variation?
  - Impacts on production of different major unit outages
  - Maintenance problems extending beyond planned periods
  - Number of refineries undergoing larger than usual maintenance

- What relationship have we seen between levels of maintenance activities and prices

Appendix B. Illustrating IIR Outage Detail PADD 1

IIR PetroCast Live
INDUSTRIAL INFO RESOURCES
1-800-762-3361

Refinery 180 Off-line Report

1/15/2007 5:36:22PM

PAD District 1

Crude | FCCU | Thermal Cracking | Reformer | Hydro Cracking

Barrels Off-line by Day

Crude Distillation: Daily Off-Line Capacity: 182,053 bbl/d | Total Off-line: 17,295,000 | Date Range: 1/15/2007 - 4/19/2007

01/12/07	Sunoco Incorporated - Girard Point Refinery	02/02/07	03/10/07	197,000 bbl/d	PA Atmospheric Distillation
01/11/07	CITGO Asphalt Refining Company - Savannah Refinery	12/15/06	01/17/07	17,000 bbl/d	GA Atmospheric Distillation
12/22/06	Valero Refining Company - Paulsboro Refinery	04/06/07	04/20/07	55,000 bbl/d	NJ Atmospheric Distillation
12/08/06	CITGO Asphalt Refining Company - Paulsboro Refinery	12/01/06	02/15/07	50,000 bbl/d	NJ Atmospheric Distillation
12/08/06	CITGO Asphalt Refining Company - Paulsboro Refinery	12/15/06	02/15/07	45,000 bbl/d	NJ Atmospheric Distillation
11/23/06	Chevron Corporation - Perth Amboy Asphalt Refinery	10/28/06	03/01/07	80,000 bbl/d	NJ Atmospheric Distillation
11/23/06	Ergon West Virginia Incorporated - Congo Refinery	03/09/07	04/07/07	20,000 bbl/d	WV Atmospheric Distillation
11/23/06	United Refining Company - Warren Refinery	03/16/07	04/14/07	65,000 bbl/d	PA Atmospheric Distillation

Reformers: Daily Off-Line Capacity: 29,746 bbl/d | Total Off-line: 2,112,000 | Date Range: 2/2/2007 - 4/13/2007

01/12/07	Sunoco Incorporated - Girard Point Refinery	02/02/07	03/10/07	35,500 bbl/d	PA Semiregen/Cyclic Reformer
01/11/07	Giant Industries Incorporated - Yorktown Refinery	03/09/07	03/31/07	9,500 bbl/d	VA Semiregen/Cyclic Reformer
11/23/06	United Refining Company - Warren Refinery	03/16/07	04/14/07	20,000 bbl/d	PA Semiregen/Cyclic Reformer

FCCU: Daily Off-Line Capacity: 56,571 bbl/d | Total Off-line: 3,960,000 | Date Range: 1/15/2007 - 3/25/2007

01/15/07	Hess Corporation - Port Reading Refinery	01/09/07	01/15/07	60,000 bbl/d	NJ FCCU (Fluid Catalytic	U
CHANGE: Comments: Minor fire--PREVSTART: 1/9/2007--PREVEND: 1/13/2007						
12/08/06	Sunoco Incorporated - Girard Point Refinery	02/02/07	03/25/07	75,000 bbl/d	PA FCCU (Fluid Catalytic Cracker)	

Barrels Off-line from 1/15/2007 to 7/13/2007

Appendix C. Price Components[23]

Retail price variations can be better understood by looking at the major components that comprise this price. This background section was taken from an earlier EIA report focusing on California, but the basics are the same in any market. Retail gasoline prices can be broken down into the following four major elements:

- Crude oil costs – the average cost of crude oil or other inputs to refinery distillation towers, such as residual fuel oil, including transportation to the refinery.
- Refining costs and profits – as represented by the spread between crude oil costs and refinery gate (as approximated by spot market) product prices; any excess after covering refinery operating costs represents profit to refiners and/or importers.
- Distribution and marketing costs and profits – as represented by the spread between spot and retail product prices (less taxes); any excess after covering transportation, storage, and marketing costs represents profit to companies within the distribution/marketing chain.
- Taxes – including Federal, State and local excise, sales, gross receipts or other taxes applied to petroleum products (taxes on crude oil are included under crude oil costs).

Table C1 shows U.S. average breakdown of retail regular gasoline prices into these four elements.

Table C1. Illustrative Gasoline Price Components

Average Gasoline Price Components	***U.S. 2006***
Retail Price (including taxes)	256.8
Taxes	46.0
Retail Price (excluding taxes)	210.8
Distribution/ Marketing Costs and Profits	23.2
Spot Price	173.2
Refining Costs and Profits	44.2
Crude Oil Price*	143.4

*Crude oil price is represented by West Texas Intermediate (WTI) for U.S.
Sources: retail prices and taxes, EIA; spot prices, Reuters

Spot gasoline prices and crude oil price together account for most of the variation in retail prices, as shown in Figure 29. Spot prices are influenced by crude oil prices and by local market conditions. Crude oil prices are in turn driven mostly by global market conditions and directly affect product prices because they are the primary feedstock. However, crude oil prices also impact the tendency to build or draw down product inventories, which can add to or reduce product prices.

[23] This background section was taken directly from an earlier EIA report focusing on California, but the basics are the same in any market: Energy Information Administration, 2003 California Gasoline Price Study: Preliminary Findings, Appendix C, SR/O&G/2003-01, May 2003.

Note that an increase or decrease in either the refining or distribution/marketing component does not necessarily indicate a change in the underlying costs. For instance, if a major refinery goes out of operation temporarily, supply falls short of demand, and prices go up. Other refiners not experiencing production difficulties may see no change in cost, but a significant increase in profit due to the higher prices. This also does not necessarily mean that the refiners have intentionally raised their prices to take advantage of the situation. Because spot market prices reflect a constant exchange of offers to buy and sell product, it is often as much a matter of buyers increasing the price they will offer, due to the tightness of the market (less supply in relation to demand), as it is the refiners increasing their asking price. In practice, of course, both buyers and sellers have sufficient awareness of the existing situation, and experience with different market conditions, that both "bid" and "asked" prices continually adjust to reflect changing market conditions.

Although the refinery costs and profit component, estimated as the spread between spot gasoline price and crude oil price, has historically been the price component showing the most variation apart from crude oil prices, some discussion of the distribution and marketing element (retail-to-spot price differential) is appropriate. In a number of previous studies of gasoline price pass-through from wholesale to retail,[24] EIA has found that retail gasoline price changes are almost entirely a function of wholesale price changes over the previous weeks. This relationship takes the form of a "distributed lag," where a given movement in spot gasoline prices is passed through over a period of several weeks. While the speed and duration of pass-through varies regionally, it tends to be so consistent over time in a given region that retail price changes can be predicted, with a fair degree of accuracy, from prior spot price changes. Thus, the differential between retail and spot prices generally varies only according to the amount of wholesale price changes yet to be passed through to retail at any given time. When wholesale prices are rising, and retail has not caught up, the differential narrows; conversely, as prices fall, the differential widens until prices stabilize and retail prices fully reflect the declines at the wholesale level.

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[24] Energy Information Administration, Gasoline Price Passthrough, January 2003, http://www.eia.doe.gov/pub/oil_gas/petroleum/feature_articles/2003/gasolinepass/gasolinepass.htm

Appendix D. Glossary

Alkylate: The product of an alkylation reaction. It usually refers to the high-octane product from alkylation units. Alkylate is used in blending high-octane gasoline.

Alkylation: A refining process for chemically combining isobutane with olefin hydrocarbons (for example, propylene, butylenes) through the control of temperature and pressure in the presence of an acid catalyst, usually sulfuric acid or hydrofluoric acid. The end product is alkylate, an isoparaffin, which has high octane value and is blended with motor and aviation gasoline to improve the anti-knock value of the fuel.

Aromatics: Hydrocarbons characterized by unsaturated ring structures of carbon atoms. The basic ring has six carbon atoms and is shaped like a hexagon. Heavier aromatics with two or more hexagonal rings with common sides (polycyclic aromatics) are also present in gasoline; some are formed during combustion. Some aromatics are ozone-forming; some are toxic. Benzene and polycyclics are toxic; xylenes and some of the more complex aromatics are active ozone-formers. Petroleum aromatics include benzene, toluene, and xylene.

Benzene: A hydrocarbon of the composition C_6H_6 and the initial member of the aromatic or benzene series. Its molecular structure is conceived as a ring of six carbon atoms with double linkage between each alternating pair and with hydrogen attached to each carbon atom. Benzene is a minor constituent of most crude oils and is produced mainly by the catalytic reforming of petroleum naphthas and from the various cracking processes. Benzene is a toxic compound.

Calendar Day Capacity: The amount of input that a unit can process under usual operating conditions. The amount is expressed in terms of capacity during a 24-hour period and reduces the maximum processing capability of all units at the facility under continuous operation (see Barrels per Stream Day) to account for the following limitations that may delay, interrupt, or slow down production:

- The capability of downstream facilities to absorb the output of crude oil processing facilities of a given refinery. No reduction is made when a planned distribution of intermediate streams through other than downstream facilities is part of a refinery's normal operation;
- The types and grades of inputs to be processed;
- The environmental constraints associated with refinery operations;
- The reduction of capacity for scheduled downtime due to such conditions as routine inspection, maintenance, repairs, and turnaround; and
- The reduction of capacity for unscheduled downtime due to such conditions as mechanical problems, repairs, and slowdowns.

Naphtha: Generic term applied to a petroleum fraction with an approximate boiling range between 122º and 400º F.

Octane Number: A number used to indicate gasoline's antiknock performance in motor vehicle engines. The two recognized laboratory engine test methods for determining the antiknock rating, i.e., octane rating of gasoline, are the Research method and the Motor method. To provide a single number as guidance to the consumer, the antiknock index (R+M)/2, which is the average of the Research and Motor octane numbers, was developed.

Olefins: Olefins are highly reactive unsaturated organic compounds (that is, the carbon atoms in the molecule are able to accept additional atoms such as hydrogen or chlorine). Some are present in gasoline as a result of refinery manufacturing processes such as cracking. Some are created in the engine during combustion; most of these can be removed in the catalytic converter. They tend to be ozone-formers and toxic.

Petroleum Administration for Defense District (PADD): A geographic aggregation of the 50 States and the District of Columbia into five Districts, with PADD I further split into three subdistricts. The PADDs include the States listed below:

PADD 1 (East Coast) Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont, Delaware, District of Columbia, Maryland, New Jersey, New York, and Pennsylvania, Florida, Georgia, North Carolina, South Carolina, Virginia, and West Virginia.

PADD 2 (Midwest): Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, Oklahoma, South Dakota, Tennessee, and Wisconsin.

PADD 3 (Gulf Coast): Alabama, Arkansas, Louisiana, Mississippi, New Mexico, and Texas.

PADD 4 (Rocky Mountain): Colorado, Idaho, Montana, Utah, and Wyoming.

PADD 5 (West Coast): Alaska, Arizona, California, Hawaii, Nevada, Oregon, and Washington.

Reformate: The product of the reforming process, which runs at high temperature with a catalyst to convert paraffinic and naphthenic hydrocarbons into high-octane stocks, primarily aromatics suitable for blending into finished gasoline.

Reid Vapor Pressure (RVP): A measure of product volatility, measured in pounds per square inch (psi). The higher the RVP, the more volatile a gasoline is and the more readily it evaporates.

Stream-Day Capacity: The maximum number of barrels of input that a unit can process within a 24-hour period when running at full capacity under optimal crude and product slate conditions with no allowance for downtime.