Wood Mackenzie

American Petroleum Institute

Outsourcing US Refining?

The Case for a Strong Domestic Refining Industry

Final Report – June 2011

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Glossary

Bbl	barrel (defined as 42 US gallons)
Bpd	barrels per day
B10	Diesel type fuel with up to 10%vol bio-diesel
CAFE	Corporate Average Fuel Economy
CAGR	Compound Annual Growth Rate
CDU	Crude distillation capacity
EC	European Community
EIA	US Energy Information Administration
EPA	US Environmental Protection Agency
EU	European Union
EV	Electric vehicle
E85	Gasoline type fuel with up to 85%vol ethanol
FCC	Fluid Catalytic Cracking
FSU	Former Soviet Union
FQD	Fuel Quality Directive
HSFO	High Sulfur Fuel Oil
HVO	Hydrogenated Vegetable Oil
IEA	International Energy Agency
IMO	International Maritime Organisation
IOC	International Oil Company
Kbd	Thousand barrels per day
Kbcd	Thousand barrels per calendar day
LCFS	Low Carbon Fuel Standard
LPG	Liquid Petroleum Gas
LSFO	Low Sulfur Fuel Oil
LSBF	Low Sulfur Bunker Fuel
Mbd	Million barrels per day
Mbcd	Million barrels per calendar day
Med	Mediterranean
Mt	Million (metric) tonnes
NHTSA	US National Highway Traffic Safety Administration
NCM	Net Cash Margin
NGL	Natural gas liquid
NOC	National Oil Company
NWE	North West Europe is made up of Austria, Belgium, Denmark, Finland,

	Northern France, Germany, Iceland, Ireland, Luxembourg, Netherlands, Norway, Sweden, Switzerland, United Kingdom
PADD	Petroleum Administration for Defense District
pa	per annum
RED	Renewable Energy Directive
ULSD	Ultra Low Sulfur Diesel
Wt%	Weight percent
Ytd	Year to date
$/bbl	US dollar per barrel
$/te	US dollar per tonne

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Report Summary

Maintaining a viable domestic refining industry is critical

America's refiners are a strategic asset for the United States, and maintaining a viable domestic refining industry is critical to the nation's economic security.

The refining industry provides the fuels that keep America moving. The industry provides the nation's military with secure, available fuels wherever and whenever they are required. In addition, it provides affordable and clean fuel products to industries that rely on those fuels to manufacture hundreds of thousands of other consumer products that Americans depend on every single day.

Equally as important, US refineries sustain hundreds of thousands of good-paying, highly skilled American jobs across the country in addition to the raw material building blocks which support a vast number of other American production industries.

The United States will depend on refining petroleum-based products for much of its energy needs for decades to come. And, domestic refineries are competing directly with petroleum product imports. Because the refining industry operates on a global basis, America faces the choice of either manufacturing these products at home or importing them from other countries.

US refinery closures would result in domestic job losses and lower government revenue in the form of taxes. It would also result in a greater reliance on foreign refineries, such as those being developed in the Middle East and India.

Failure to maintain a viable domestic refining industry will make it difficult for the United States to secure access to crude oil reserves in Canada, at a time when there is strong competition for Canadian oil from the emerging economies such as China. Canadian oil sands hold the second-largest crude reserves in the world and Canada is the United States' No. 1 trading partner and supplier of imported oil. Failure to maintain refining capacity and secure access to this strategic resource will increase dependence on imports of refined products and further risk energy security.

The refining industry provides vital products that Americans rely on everyday

The US refining industry transforms crude oil – an otherwise largely unusable material – into fuel and other key products. Many of these products are fundamental to the way people live today: gasoline for cars; jet fuel to fly; heating oil for homes; and diesel and other fuels for trucks and railroads on which to transport goods and materials.

The industry manufactures nearly 90 percent of the gasoline consumed in the country, providing almost 246 million vehicles with billions of gallons of clean, high-quality fuel. And the United States will continue to consume oil-derived products for years to come: gasoline consumption is expected to increase by 8.4 million gallons per day by 2015 and reach a total consumption of 395 million gallons per day (source EIA, 2010 US Data Projections).

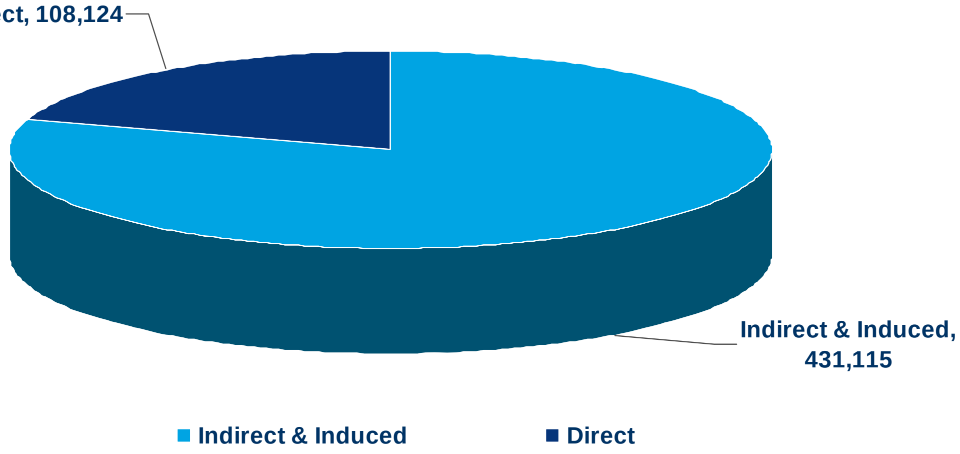
Refiners also manufacture the building blocks for millions of products most Americans would not think of as coming from oil. Take asphalt, for example. Without crude oil – and without the refineries to process it – there would not be the asphalt to build the thousands of miles of highways that crisscross the country. There would not be the raw materials used to make the paint for buildings, textiles for clothing and carpets, foams for bedding and furniture, medicines for hospitals, fertilizers for gardens, and lubricants for vehicles and machinery. And there would not be the plastics and polymers used in everything from computers to medical equipment to wind turbines and solar panels to cosmetics. The list of products is virtually endless.

Look at any item in the home, office or outside world, and the chances are that part of it is either made from a product produced by the US refining industry, or its existence depends on such a product.

The refining industry contributes to the US economy in many ways

The refining industry is one of America's largest manufacturing sectors. Refining directly employs approximately 108,000 American workers across the country, and hundreds of thousands of jobs in related industries depend on a strong, competitive refining industry.

Figure 1: US Refining Industry Supported Employment (2009)

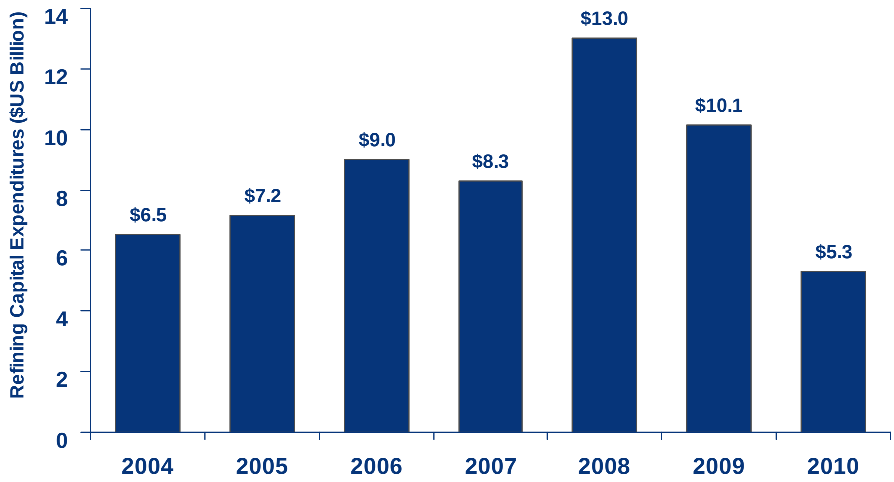


Source: API / PwC Economic Impact & Employment Report 2011; Wood Mackenzie analysis

The industry also makes a significant contribution to federal, state and local treasuries through its tax payments. Annually, refining industry activities generate billions of dollars in income taxes, sales taxes, and use and property taxes.

Refineries rely on leading-edge, world-class technologies, much of it developed in the United States, and the refining industry invests billions of dollars each year to maintain its competitiveness and environmental performance. Over the last 3 years alone, refining industry capital expenditures in the United States exceeded $28 billion.

Figure 2: Refining Capital Expenditures (2004-2010)



Source: Oil & Gas Journal, 2010; Wood Mackenzie analysis

The domestic refining industry's investments have a major economic impact across the country. For example, the recent expansion of the Motiva refinery in Port Arthur, Texas, not only provided jobs for workers in Southeast Texas, along with additional jobs at the refinery. The project also provided jobs in other locations, such as more than 600 highly skilled Maine workers who were involved in equipment manufacture and fabrication.

Figure 3: Employment Implications of Motiva Port Arthur Investment (2008-2010)

Source: Wood Mackenzie

The refining industry has a long history of investing and adapting to meet the changing fuel needs of the American people. By providing affordable fuels and products to American consumers and industries, refiners support the growth of the United States, the world's largest, most economically productive economy. The refining industry operates in a global, highly competitive market. Refined products such as gasoline and diesel are produced and traded around the world. Having a strong US refining industry is vital.

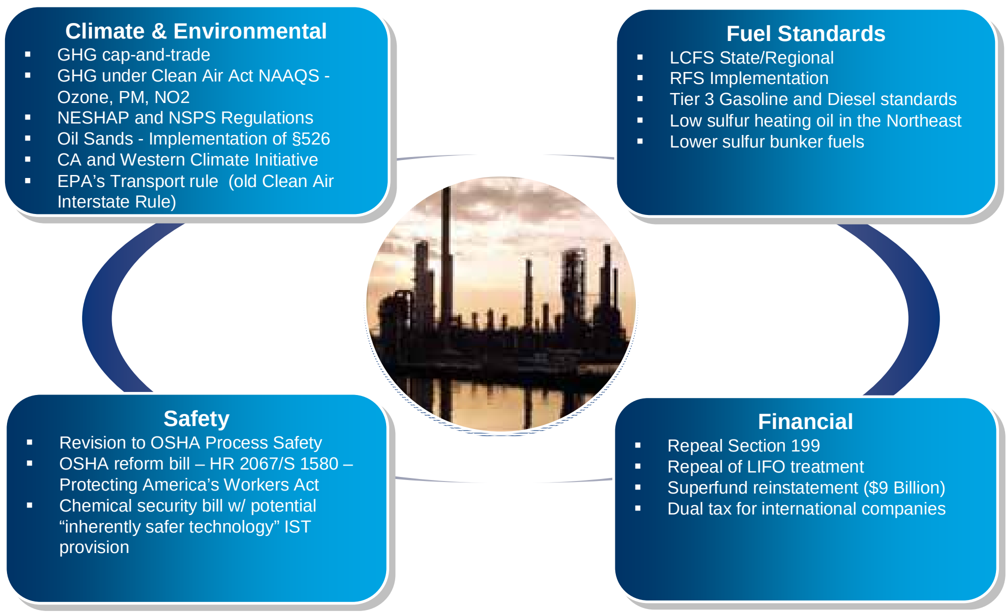
Producing quality petroleum products and raw materials in America enhances national energy and economic security.

The regulatory environment should not weaken the domestic US refining industry

If America's refining industry is to remain viable, it needs a regulatory structure that improves the environment while allowing the industry to remain competitive in the worldwide market. The domestic refining industry's outstanding history of regulatory compliance has made US refineries among the cleanest and most efficient in the world. The industry remains committed to meeting regulatory requirements.

However, government should adopt a reasonable approach to regulation. For example, it should allow time to determine if existing regulations are effective before adding new layers of additional regulations. The high and very real costs of complying with overreaching regulations that have uncertain benefits may weaken the ability of the domestic refining industry to compete with foreign refiners.

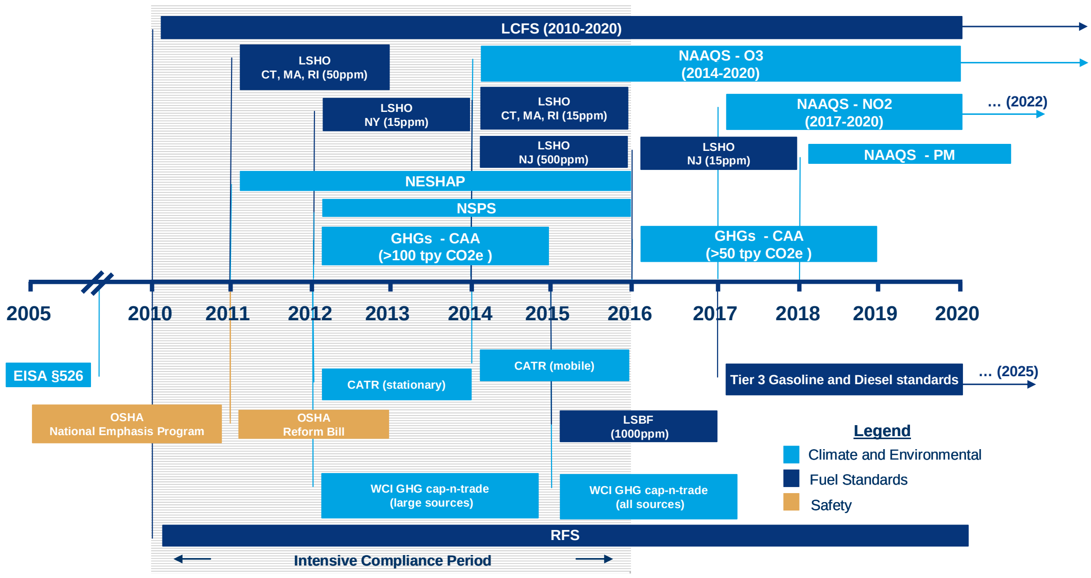
Figure 4: Major Regulations Impacting the Refining Industry



Source: Wood Mackenzie

The US refining industry already operates in an extremely complex regulatory environment. Regulations governing fuel, climate and environmental standards have an enormous financial impact on the refining industry, as do financial controls and taxation.

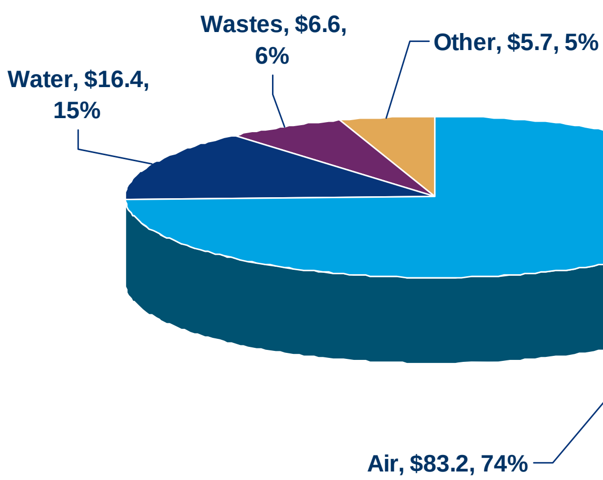
Figure 5: Regulatory Timeline Highlighting Intensive Compliance Period



Source: Wood Mackenzie

There are significant and potentially very costly additional regulations under development that may take effect over the next five years. US refiners have already invested $112 billion in environmental improvements, from 1990 to 2008.

Figure 6: Total Refining Environmental Expenditures by Medium (1990-2008)



Source: API Environmental Expenditures Report 2010; Wood Mackenzie analysis

The domestic refining industry recognizes that important decisions must be made about regulations related to America's refineries. It is essential, however, to understand the long-lasting implications of these potentially very costly regulations. The goal should be specific and targeted cost-effective policies that avoid unintended consequences. The US refining industry should not be pushed into an irreversible decline because of ineffective and overly costly regulations that undermine the industry's competitiveness in the global energy business.

A viable refining industry can continue to be a reliable provider of fuels to America's consumers

American consumers expect and deserve ready access to clean, affordable fuels and products derived from crude oil. The domestic refining industry has a long history of responsiveness to the changing fuel needs of US industry and consumers. From the development and creation of high-octane aviation fuels for the military during World War II, to super-clean high-performance low-sulfur diesel and gasoline in the last 15 years, the domestic refining industry continues to be at the leading edge of product development to meet consumers' needs.

US refineries make safety a top priority and will continue to act as responsible stewards of the environment.

Maintaining a viable domestic refining industry will allow refiners to continue to:

- Support a strong US job base
- Provide secure, reliable access to strategically important products essential to 21st century life
- Respond quickly and flexibly to the changing expectations and needs of US consumers
- Provide the basic building blocks that are the feedstocks to many American manufacturing businesses
- Help the United States maintain national and economic security
- Remain a source of considerable revenue to National, State, and Local governments.

1 Introduction

1.1 Purpose

This report has been prepared for the American Petroleum Institute by Wood Mackenzie Inc, the leading global energy consultancy.

The report examines the current status of the US refining industry and considers its critical contribution to the US economy. It draws on statistics and data from public sources, and Wood Mackenzie's proprietary information from Refinery Evaluation Model and Product Markets Service.

Wood Mackenzie's Refinery Evaluation Model (REM) is a global refinery database tool built on primary research over the past 30 years. The model contains a wide variety of publicly sourced information covering topics such as ownership, crude slate, configuration, capacities, and recent/planned investments. REM reflects Wood Mackenzie's independent analysis and estimates, and in this study REM has been used to examine potential implications for the US refining industry's competitive positioning.

Wood Mackenzie's Product Markets Service (PMS) is a tool that provides a long-term supply and demand view of oil product markets, building up a global and regional view from country-level analysis. PMS is developed from historical data gathered through the International Energy Agency (IEA), US Energy Information Administration (EIA), and local statistics across key regions - Europe, Former Soviet Union and Africa, Asia Pacific and the Middle East, North America and Latin America. Forecasts of the oil product markets are made through in-depth analysis of various proprietary Wood Mackenzie models based on assumptions developed by our macroeconomic experts: GDP, world oil demand, total liquids supply, supply/ demand balances, oil price trends. Demand is forecasted for the main products (LPG, naphtha, gasoline, kerosene, diesel/gasoil and fuel oil), as well as total demand on a country basis. In this study, PMS has been used to examine US refined product supply and demand, and refined product trade flows between the US and other global markets.

Through this analysis, the report provides a fact base that explains the US refining industry's role, the challenges the industry faces and the national case for a strong domestic refining industry in the future.

The first section demonstrates the strategic importance of the US refining industry, looking at past and present economic, technological and social contributions. The second section describes the current and future business environment in which the industry is operating, and the challenges and opportunities that this presents. The third section describes the complex regulatory environment that governs the industry, and considers potential implications on industry competitiveness in the global marketplace. In the final chapter the report considers US growth and the need for a strong domestic refining industry to support competitiveness and future growth.

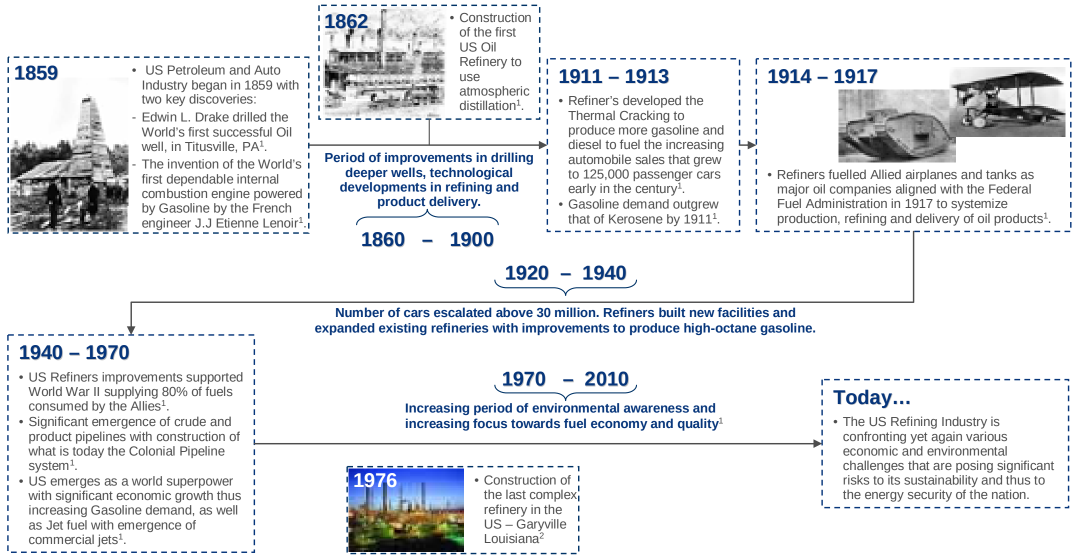
1.2 A Brief History of the US Refining Industry

Petroleum refining is the essential manufacturing process that transforms crude oil, an otherwise unusable raw material, into key products that Americans use in everyday life. Many of these products are obvious and fundamental to the way we live in the 21st century: gasoline for us to drive our automobiles, jet fuel for aircraft flights, diesel for trucks and railroads, bunker fuel oil to ship the products our industries make.

The US refining industry has provided American consumers with affordable energy reliably for nearly 150 years. Today the US refining industry manufactures nearly 90 percent of total US gasoline demand fueling almost 246 million cars with billions of gallons of clean, high-quality product.

Construction of the first US refinery using atmospheric distillation began in 1862. During the next 114 years refineries were built across the United States, located in areas of major population demand or close to regions with ready access to crude oil supplies (either domestic or imported).

Figure 7: Historic Timeline of the US Refining Industry



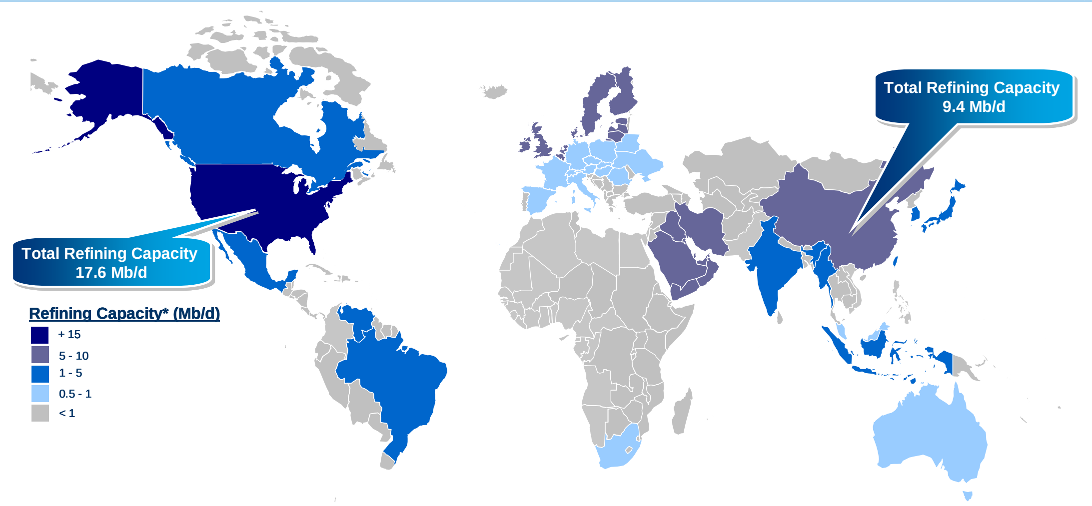
Source: Arabe, K. (2003) How Oil Refining Transformed US History & Way of Life; EIA (2010);Wood Mackenzie

The last new refinery to be built in the United States was in Garyville, Louisiana, in 1976. While no new refineries have been built in the US in the last 35 years, major investments have been made in existing refineries during this time, allowing capacity growth while at the same time increasing technological sophistication. This has resulted in the largest concentration of refining capacity in any country globally, with the highest average level of process complexity, enabling the industry to meet stringent environmental standards and fulfil growing demand for clean fuels.

1.3 US Refining Industry in a Global Context

The US has the largest refining industry of any country globally, with 17.6MB/d of refining capacity from 148 operable oil refineries (source: EIA, 2010). This is almost double China, the second largest refiner globally, which has 9.4MB/d capacity (source: Wood Mackenzie, 2010). Investments are made constantly to maintain and upgrade the size and technological complexity of refineries, in order to produce competitive products that meet consumer requirements.

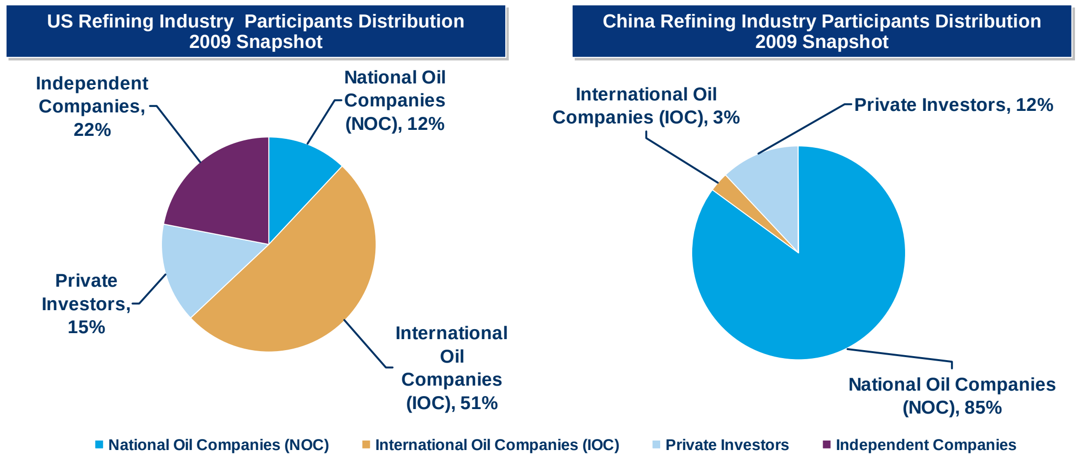
Figure 8: Refining Capacity by Country



Source: EIA Refinery Capacity Report 2010; Wood Mackenzie Refinery Evaluation Model

The US refining industry has a diverse ownership structure, with significant (>10%) participation by International Oil Companies (IOCs), National Oil Companies (NOCs), Independents and Private investors. This contrasts with other global refining centers such as China, which are dominated by National Oil Companies under direct state control.

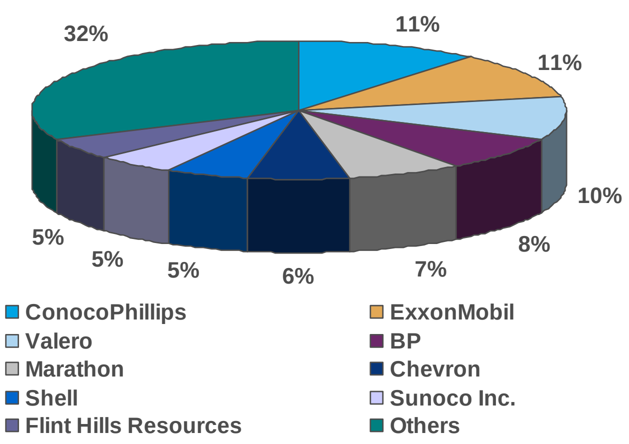
Figure 9: Comparison of Distribution of Refining Industry Participants



Source: Wood Mackenzie

More than 50 companies own and operate refineries in the United States. Of these, ExxonMobil and ConocoPhillips have the largest market shares, with Valero also strong, particularly in PADD III (Gulf Coast). On average, the top nine companies each own more than 850,000 barrels per day of refining capacity.

Figure 10: US Refining Ownership by company



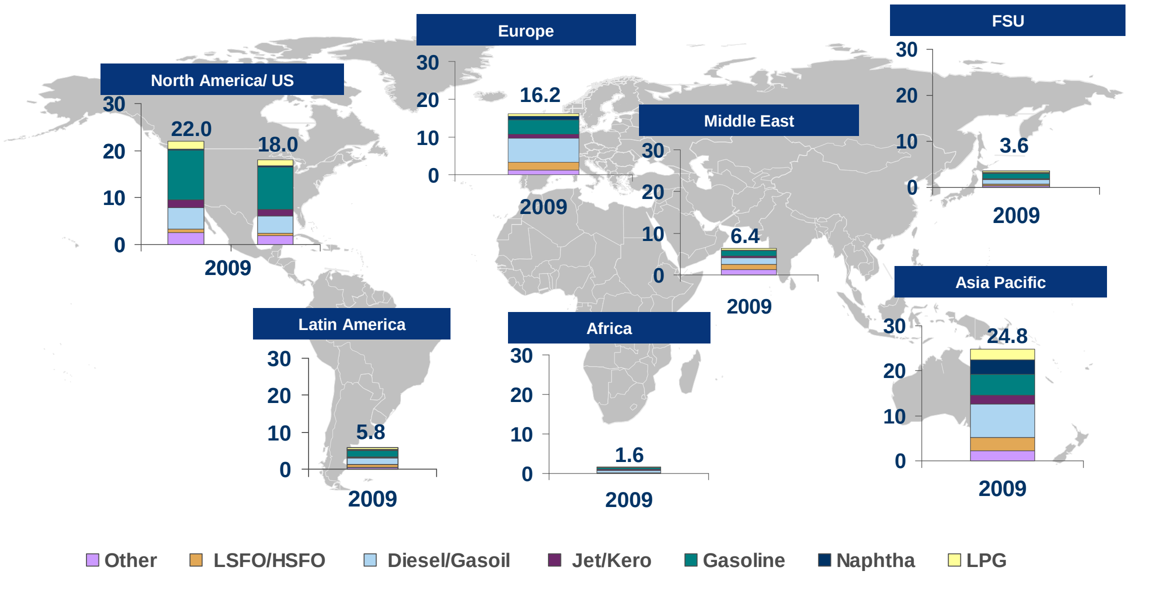
Source: Wood Mackenzie (2009)

The industry operates in a highly competitive environment, with a 5-firm concentration ratio[1] of 47 percent, which is classified as within the "low concentration" bound (<50%).

[1] *N-firm Concentration Ratio defined as sum of the market share of the largest n-firms*

In 2009 the United States demand for oil products was approximately 18 million barrels of oil equivalent per day. This represented approximately 23 percent of the global demand for oil products (approximately 83 million barrels of oil equivalent per day).[2]

Figure 11: Regional Product Profile Demand Comparison (2009)



Source: Wood Mackenzie Product Markets Service (2009)

In 2010, the United States demand for oil products grew strongly to approximately 19 million barrels of oil equivalent per day. Having a strong domestic refining industry was essential to securely and efficiently meet this surge in demand, thereby supporting the nation's economic recovery.

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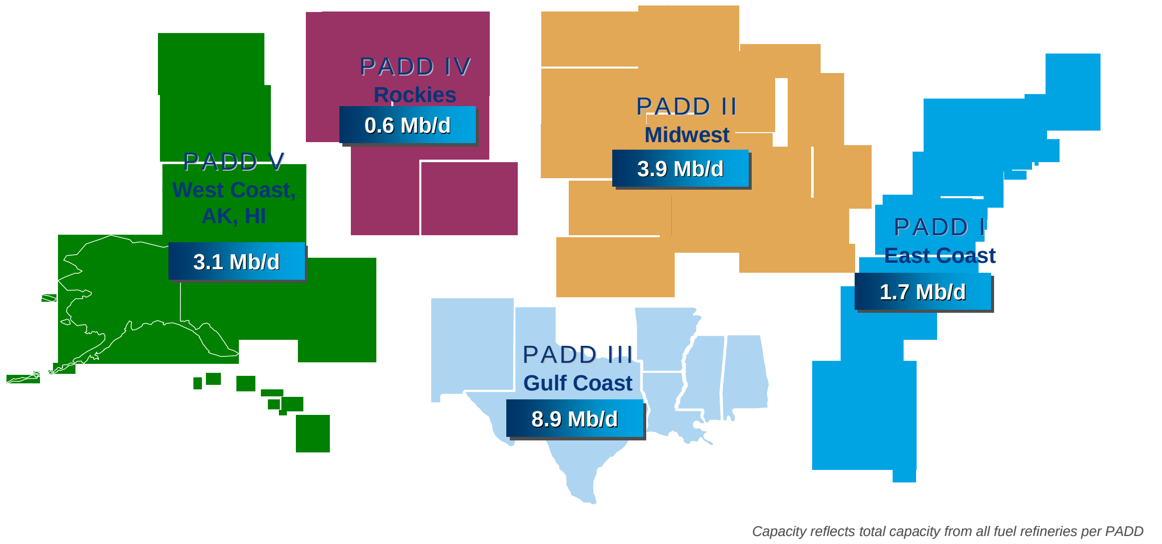
[2] *Source: Wood Mackenzie, International Energy Administration 2009*

1.4 Refining in the United States

The United States is divided into five Petroleum Administration for Defense Districts, or PADDs. These were established during World War II to help organize the allocation of fuels derived from petroleum products, including gasoline and diesel fuel. Today, these regions are still used for data collection and reporting purposes.

- PADD I (East Coast): represents all refining centers concentrated in the states of Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, Delaware, District of Columbia, Maryland, New Jersey, New York, Pennsylvania, Florida, Georgia, North Carolina, South Carolina, Virginia, and West Virginia.
- PADD II (Midwest): covers all the refineries located in Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, Ohio, Oklahoma, Tennessee, and Wisconsin.
- PADD III (Gulf Coast): allocates all refining centers in Alabama, Arkansas, Louisiana, Mississippi, New Mexico, and Texas.
- PADD IV (Rocky Mountain): extends to all refineries in Colorado, Idaho, Montana, Utah, and Wyoming.
- PADD V (West Coast): represents refineries in Alaska, Arizona, California, Hawaii, Nevada, Oregon, and Washington.

Figure 12: Refining Capacity by Petroleum Administration for Defense District (PADD)



Source: Wood Mackenzie Product Markets Service; NPRA US Refining & Storage Report (2010)

As no two refineries are the same, each PADD constitutes a unique refining center with different refining capacities, technological complexity, infrastructure and resulting product output. PADD III (US Gulf Coast) is the largest refining center, with almost 50 percent of total US refining capacity, and PADD IV (Rockies) the smallest with slightly more than 3 percent[3].

Each refinery is unique, and designed to process a specific range of crude qualities. The design is commonly described as the refinery scheme or configuration, and incorporates a wide range of processes (e.g. crude distillation, vacuum distillation, reforming, coking, naphtha and / or diesel hydro-treating, fluid catalytic cracking, hydro-cracking).

The degree of technological sophistication or *complexity* of each configuration depends on the processes it contains. A refinery with a high complexity rating indicates that it has had a continuous high level of historical capital investment made to its processes and consequently the facility is able to process heavier crudes and deliver an above average yield of lighter and higher value products.

[3] *Source: Wood Mackenzie Product Markets Service; NPRA US Refining & Storage Report (2010)*

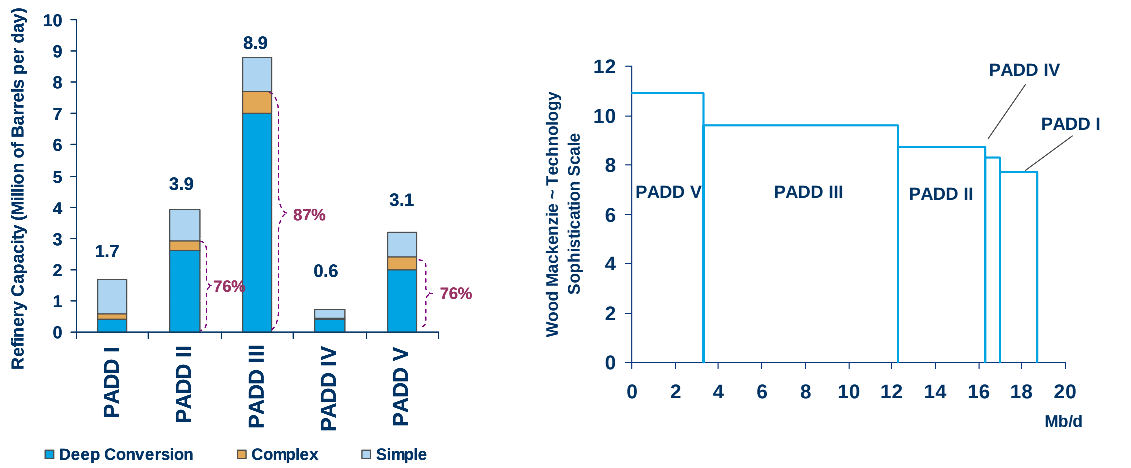
A refinery can be thus categorized as:

- Simple: composed of Crude Distillation Column, Vacuum Distillation Column and Reforming.
- Complex: the addition of conversion units such as cracking processes (i.e. Fluid Catalytic Crackers, Hydrocrackers) to a simple scheme, resulting in a complex configuration.
- Deep Conversion: the addition of conversion units such as Cokers to simple or complex configurations.

Wood Mackenzie's Refinery Evaluation Model includes an estimate of complexity rating, indicating the level of technological sophistication of a given refinery system. For the United States as a whole, Wood Mackenzie estimates the refining industry has an average complexity of 10.2, making it the most technologically advanced country in the world.

This average assessment does mask complexity variations across the different PADDs. Understanding these variations is important when considering how well different regional refining centers are placed to meet local demands, and to compete internationally with refined product imports. Refineries with the highest complexity are located in the major refining centers of the US Gulf Coast and West Coast.

Figure 13: Technological Sophistication of US Refining Infrastructure by PADD

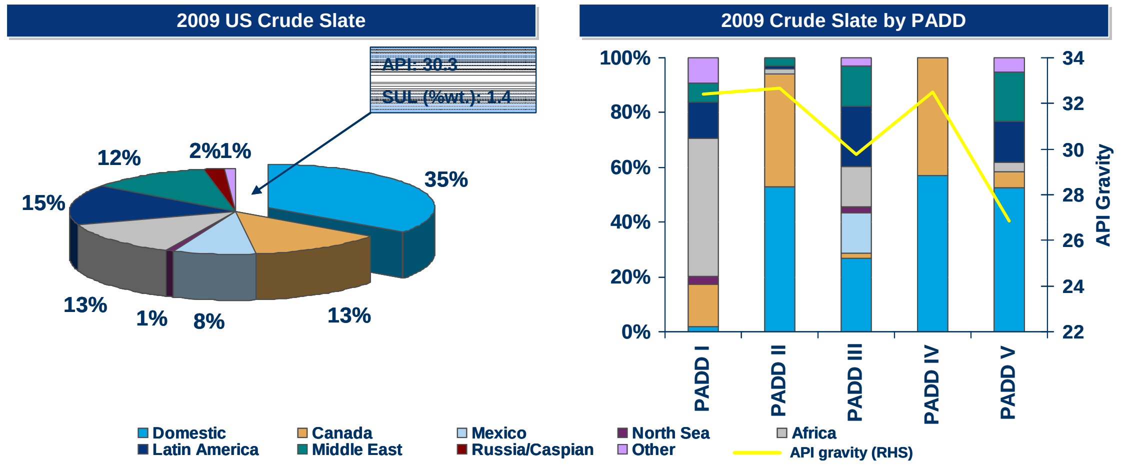


Source: Wood Mackenzie Refinery Evaluation Model

- PADD V and PADD III are among the most complex refining centers in the world. The refineries located in these centers are thus able to maximize output of higher value light products such as gasoline, aviation fuel, naphtha and diesel, and minimize production of low value residue and heavy product.
- In the case of PADD V, the world-leading levels of complexity reflect the investment necessary to produce road transport fuels that meet the particular specifications in states such as California.
- Over 87 percent of PADD III capacity is classified as highly complex. These Gulf Coast refineries are characterized by multiple upgrading units, many with additional deep conversion capacity.
- The concentration of highly complex refining capacity in PADD III enables processing of heavier, more sulfurous crudes.
- PADD II and IV are classified as moderately complex as both regions have a significant proportion of simple configuration refining capacity.
- PADD I is the only region with over 50 percent of capacity classified as "simple"; this puts PADD I at the greatest competitive risk from a technological sophistication perspective.

Each refinery's infrastructure and complexity determines the specific crude qualities it is able to process. On average the US refining industry is configured to optimally process medium-sour crude blends, supplementing domestic crude supply (35 percent of total supply) with imports. Of these imports, Canada and Mexico supply a little over 20 percent while the remaining balance, nearly 40 percent is supplied by Latin America, Middle East and Africa.

Figure 14: US Crude Slate by PADD (2009)



Source: Wood Mackenzie Product Markets Service (2009)

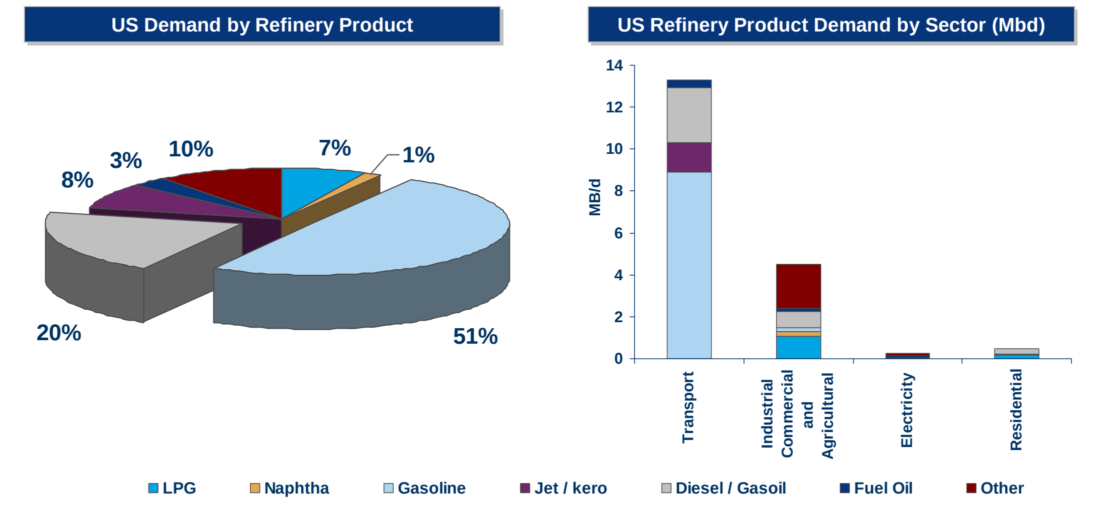
At a PADD level, location and refining complexity influence the crude slate processed in each region:

- PADD I is highly dependent on imports of foreign crude, in contrast to PADDs II, IV & V which source over 50 percent of their crude slate domestically.
- The investment to achieve higher complexity in PADD III and PADD V allows these refining centers to add value by processing heavier crudes, from areas such as Latin America, the Middle East and Alaska.
- Canadian crudes currently represent a significant portion of PADD II and PADD IV crude slates.

As historic supplies of Mexican and Venezuelan crudes decline, the highly complex refining capacity in PADD III could switch to process alternative sources of heavy, sour crude. Development of pipeline system(s) for transportation of diluted bitumen from Canadian oil sands would enable PADD III refineries to increase processing of this crude supply, potentially reducing dependence on alternative sources of heavy crude from unstable regions of the world.

US demand is primarily set by demand from the transportation sector, particularly passenger vehicles, with gasoline accounting for over 50 percent of oil product consumption.

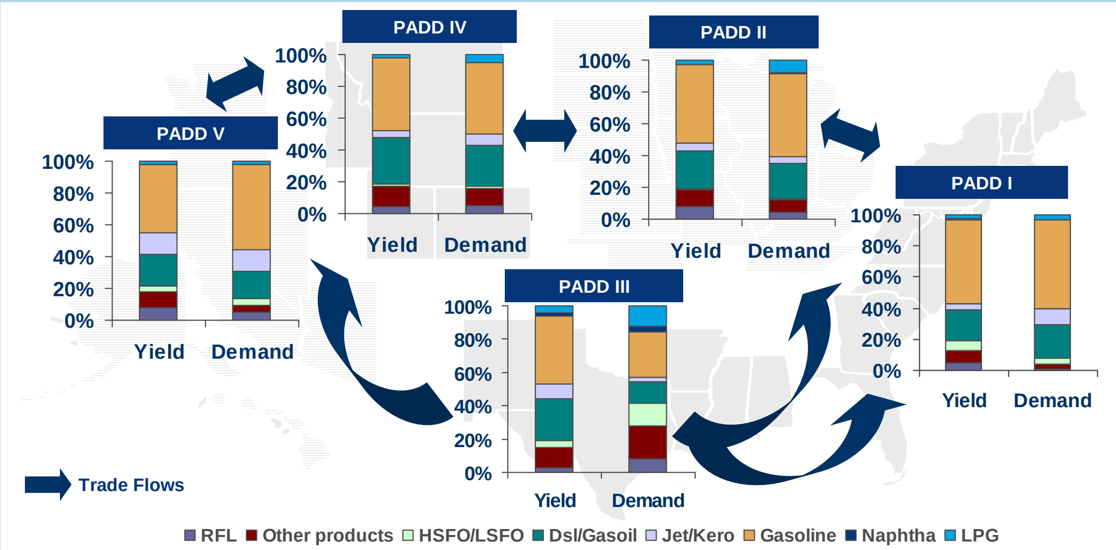
Figure 15: US Demand by Refinery Product and Sector (2009)



Source: Wood Mackenzie Product Markets Service (2009)

Refineries operate to meet the demand for products, but regional refinery yield profiles do not directly match regional demand. The major product imbalances are observed in gasoline and diesel, and inter-regional trade and product imports balance the regional supply and demand variations for each specific product.

Figure 16: Regional Yield Supply and Product Demand Comparison



Source: Wood Mackenzie Product Markets Service (2009)

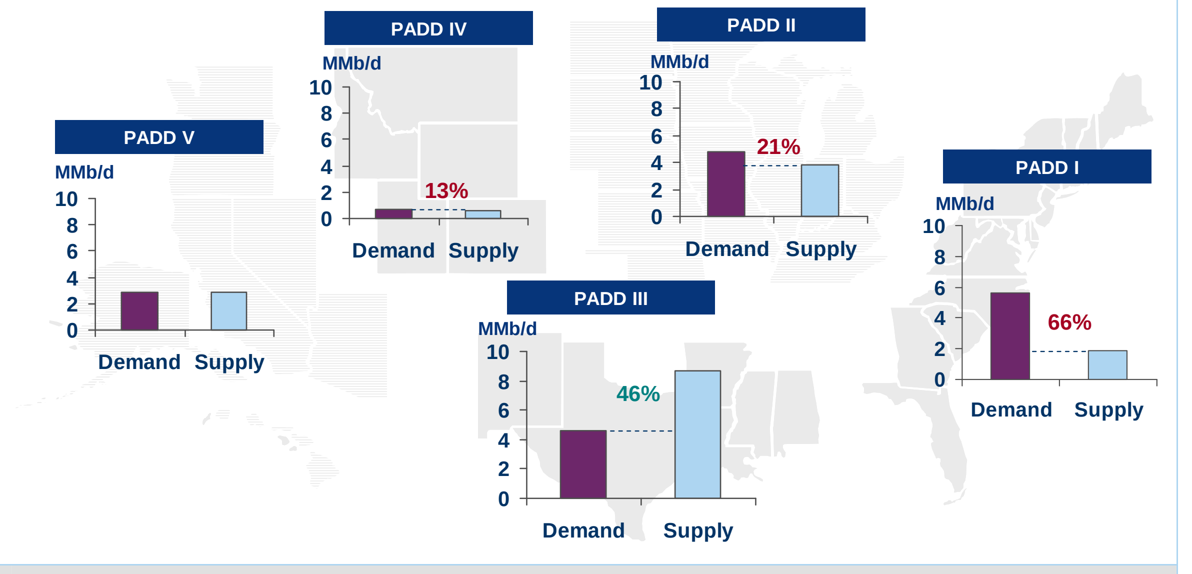
Figure 17 shows the regional variations between supply and demand in terms of total refined product. These differentials reflect the net effect of refinery capacity, utilization, inter-regional trade and product imports.

- PADD I presents the highest supply-demand differential, with nearly 66 percent of total regional demand supplied by trade flows from other US refining centers and imports. PADD I is particularly vulnerable to imports of refined products from other countries because of the extensive deep-sea port infrastructure in close proximity to high population concentration.

- PADDs II and IV also have supply-demand differentials but at lower total levels than PADD I, reflecting the fact that PADD I has much greater overall demand associated with a higher population concentration.

- PADD III has the greatest concentration of refining capacity and hence the largest total regional supply. This supply flows from PADD III into regions such as PADDs I & II.

Figure 17: Regional Supply – Demand Comparison by PADD (2009)



Source: Wood Mackenzie Product Markets Service

2 Strategic Importance of the US Refining Industry

The domestic refining industry is a strategic asset for the United States, providing secure, cost-competitive supplies of products to American consumers and the industries which depend on these products. Shipping crude oil into domestic refineries to make products such as gasoline, diesel and jet fuel is typically more environmentally and economically efficient than importing the equivalent volumes of refined products.

Maintaining a strong domestic refining industry is critical to the nation's economic security in order to:

- add significant economic value
- employ highly skilled Americans
- provide cost effective fuel, energy and feedstocks to enable productivity of other US industries
- meet US demand for refined products over the coming decades
- retain its technical advantage that enables the industry to respond readily to shifts in global energy markets
- provide secure supplies of clean, high quality refined products to individual consumers
- provide the US military with secure, available fuels where and when they are required.

2.1 Economic Contribution

As one of America's largest manufacturing sectors the US refining industry is vital to the economic security of the nation. In the US a total of 9.2 million workers are supported by US Oil and Gas operations; of this the refining industry provides more than 539,000 direct, indirect and induced jobs[4]. Refining is a major provider of skilled employment, with an average income per direct job of US$94,500[5]. Refineries can be particularly important sources of employment in their local communities' economies as they are a major provider of skilled, high paying jobs. These jobs include chartered engineers, equipment specialists, plant operators, laboratory technicians, maintenance personnel and security officers.

Figure 18: Example Employment Levels Associated with Refining

Source: Sample of study participants from the API project "Building a Case for a Strong Domestic Refining Industry", 2010

[4] *Source: PricewaterhouseCoopers study commissioned by API (2011): "The economic impacts of the oil and natural gas industry on the US economy: employment, labor income and value added"; Wood Mackenzie analysis*

[5] *Source: US Department of Commerce, Bureau of Economic Analysis, Bureau of Labor Statistics*

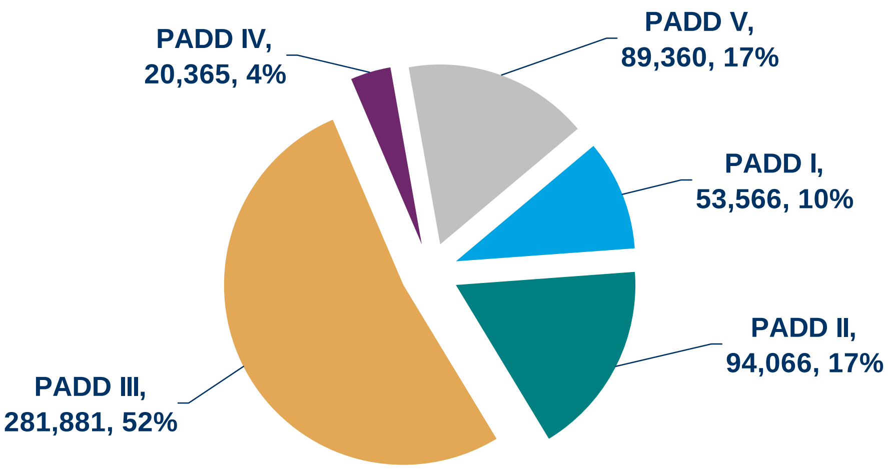
Direct employment is the term used to describe the jobs created within the refining industry. Indirect employment refers to the jobs created within other industries that provide goods and services to the refining industry. Induced employment refers to jobs created as a result of household spending of income earned either directly or indirectly from refining industry operations.

As a major provider to the nation's economy the refining industry generated nearly US$78 billion in labor income (direct, indirect and induced) and contributed over US$268 billion to US GDP in 2009[6]. This means that the refining industry supported approximately 1.9% of US GDP in that year[7].

Labor income includes wages, salaries and benefits, as well as total owners' income. Value added refers to the additional value created at a particular stage of production. It is a measure of the overall importance of an industry. Value added consists of employee compensation, proprietors' income, income to capital owners from property, and indirect business taxes (i.e., those borne by consumers rather than producers).

Wood Mackenzie used input output multipliers from the Bureau of Economics Analysis (BEA) to estimate total economic impacts (direct, indirect, induced) on a regional basis. This analysis provided an estimate of the total economic impact (employment, labor income and value added) for each PADD as shown in Figures 19 and 20 below.

Figure 19: Total Employment (direct, indirect, and induced) Supported by US Refining Operations by PADD (2009)



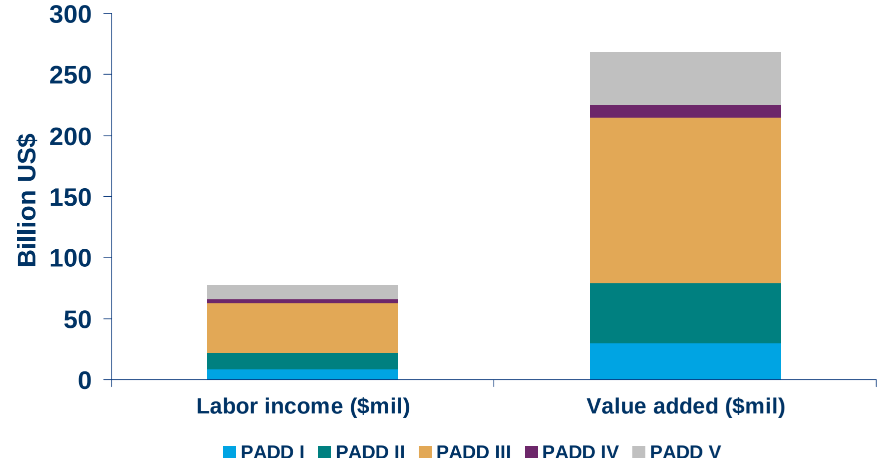
Source: API / PwC Economic Impact & Employment Report 2011; Wood Mackenzie analysis

Due to the concentration of refining infrastructure along the Gulf Coast, PADD III has the highest share of employment, labor income and economic added value (over 50 percent of the total refining industry contribution). PADD I and PADD II account for nearly 30 percent of US refining employment and GDP contribution, highlighting the strategic importance of the industry in these regions given their proximity to major concentrations of US population.

[6] *Source: PricewaterhouseCoopers study commissioned by API (2011): "The economic impacts of the oil and natural gas industry on the US economy: employment, labor income and value added"; Wood Mackenzie analysis*

[7] *Source: US Department of Commerce, Bureau of Economic Analysis*

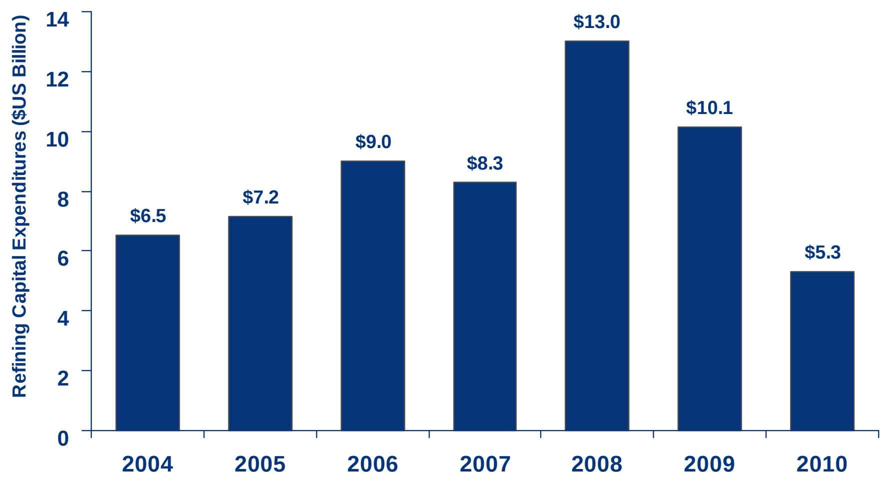
Figure 20: Refining Labor Income and Value Added by PADD (2009)



Source: API / PwC Economic Impact & Employment Report 2011; Wood Mackenzie analysis

In addition to the economic value generated from the ongoing operations, the industry makes significant capital investment to continually develop refining technical complexity and improve the production of clean, high quality fuels. In the last 3 years alone, the industry has made more than $28 billion in capital investments[8].

Figure 21: Refining Capital Investments $billion (2004-2010)



Source: Oil & Gas Journal (2010)

Investments made by the US refining industry create major positive impacts not only to the communities where the refining centers are located but also all across the country. As well as direct employment (around 108,000 jobs in 2009), indirect employment of contractors involved in fabrication, construction, testing, commissioning and maintenance stems from investment and growth of the refining industry. Induced employment benefits are also experienced in associated sectors such as financial and professional services as development of the industry supports increased levels of economic activity in other industries.

[8] *Source: Oil & Gas Journal (2010)*

For example, in addition to 6,500 local construction jobs during the development phase, Motiva's most recent investments in Port Arthur, Texas also supported employment at three domestic manufacturing/fabrication companies, such as a company in Maine which employed more than 600 highly skilled manufacturing workers to fabricate the project's refinery modules. The projects also supported many domestic suppliers of steel, engineered equipment, catalysts, IT equipment and other technical service providers. When complete, the expansion will lead to creation of more than 300 full time permanent jobs. The project is expected to continue to generate opportunities for employment with additional construction jobs in Port Arthur's adjacent communities, and upon completion in 2012 the overall economic benefits are expected to exceed US$17 billion[9].

As well as being a major employer and investor, the industry makes significant contribution to federal and state economies through its tax payments. Annually, refining industry activities generate billions of dollars in state income taxes as well as in sales, use and property taxes. Tax revenues received from the refining industry contribute to education, transport, healthcare and military public expenditures at federal and state levels. The industry is a key driver of economic activity that provides essential fuels and products; its sustainability is essential for the nation's economic livelihood.

What happens when things go wrong? - Closure of Delaware City Refinery

During the global financial crisis, economic pressures challenged the sustainability of refining operations in some locations, leading to idling of capacity and some asset closures. Refinery closures brought significant detrimental impacts to the communities and states where these assets were located. For example, in 2009 the Delaware City Refinery located in PADD I was closed with the loss of approximately 550 skilled jobs[10]. In 2010, the Eagle Point refinery in PADD I was also closed with loss of approximately 400 skilled jobs.

In the case of Delaware City, the decision by its owners in 2009 to permanently shut down the complex was due to ongoing losses and the high anticipated costs of compliance with pending state environmental regulation. After the economic and social impacts of the closure began to materialize, State of Delaware Governor Jack Markell launched initiatives to broker a sale of the refinery in an attempt to re-establish production[11]. These efforts helped to facilitate a deal for sale of the refinery and investment to return the asset to production in 2011. "We want to get people back to work in a way that is responsible, sustainable and protects public health. While there are still specifics to be resolved, today's announcement is a very significant step forward", Markell said. "Over the past several months, we have worked hard to save the many hundreds of good-paying jobs at this facility and the related economic contributions to our state's economy. We are hopeful our efforts will be successful."

The state agreed to work with the buyer after securing pledges that they would operate the refinery and make substantial investments in the refinery's infrastructure. Consistent with the buyer's plans to operate the Delaware City property as a modern refinery that is designed to remain viable for years to come, Delaware offered the following economic development incentives:

- Strategic fund loan of $20 million in FY 2011, which would convert to a grant if the buyer spends in excess of $100,000,000, which includes 600,000 man hours of labor, during the restart of the refinery and supports at least 600 full-time jobs per year in five consecutive calendar years each year after refining operations are initially restarted

- In FY 2012, a one-time appropriation of $10 million that must be used for NOx control projects at the refinery

- Offered volume cap for traditional tax-exempt facility bonds and recovery zone facility bonds in order to assist the buyer to finance the construction and installation of a gasoil hydrotreater, which will reduce NOx emissions by about 300 tons per year and enable the refinery to produce extremely low sulfur fuels, including low-sulfur heating oil used in homes and businesses.

The Delaware City case highlights the economic significance refineries can have to their communities. The State Government's response to the implications of closure was to facilitate a sale by offering a wide range of economic development incentives to secure a deal for restart of the refinery. This also emphasizes the supportive role that state and federal administrations can play when focused on economic development and effective implementation of regulation.

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[9] Source: www.portarthurrefinery.com

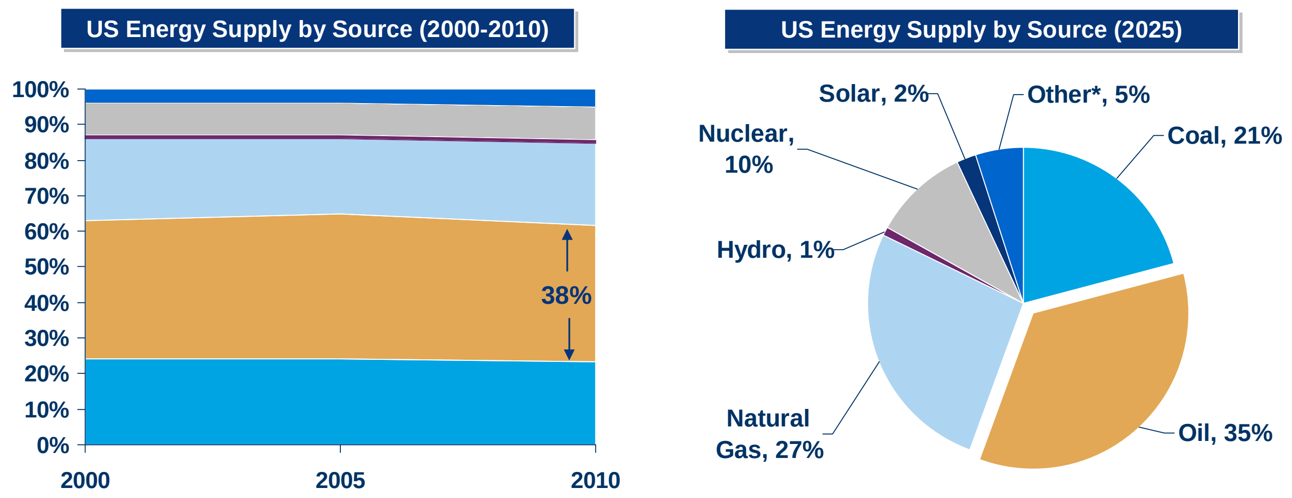
[10] Source: Andrews, A., & Pirog, R. (2010). The US Oil Refining Industry: Background in Changing Markets and Fuel Policies. Congressional Research Service

[11] Source: State of Delaware website http://governor.delaware.gov/news/2010/1004april/20100408-refining.shtml

2.2 Product Supply and Resource Security

The US domestic refining industry is an essential asset not only to the nation's economic security but also to the nation's energy security. The industry is a major provider of the nation's energy needs; today nearly 38 percent of US energy comes from oil-derived products and use of this source of energy is forecast to continue for decades to come.

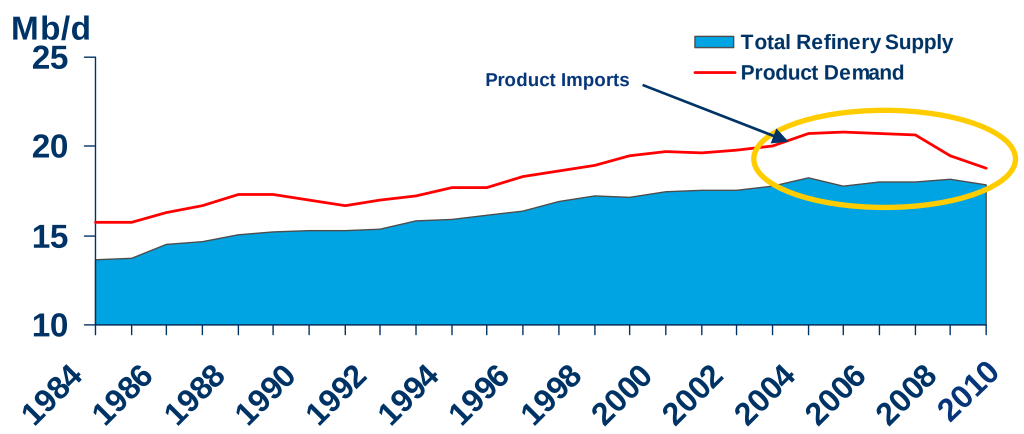
Figure 22: US Energy Supply by Source (Historic vs. 2025)



Source: Wood Mackenzie Macro Oils Service

Historically, the US refining industry has provided nearly 90 percent of total demand for oil products[12] to fuel cars, trucks, homes, and industries. Maintaining a strong domestic refining industry means that product imports occur because of economic opportunity rather than supply necessity.

Figure 23: US Total Refinery Product Supply / Demand (1984-2010)

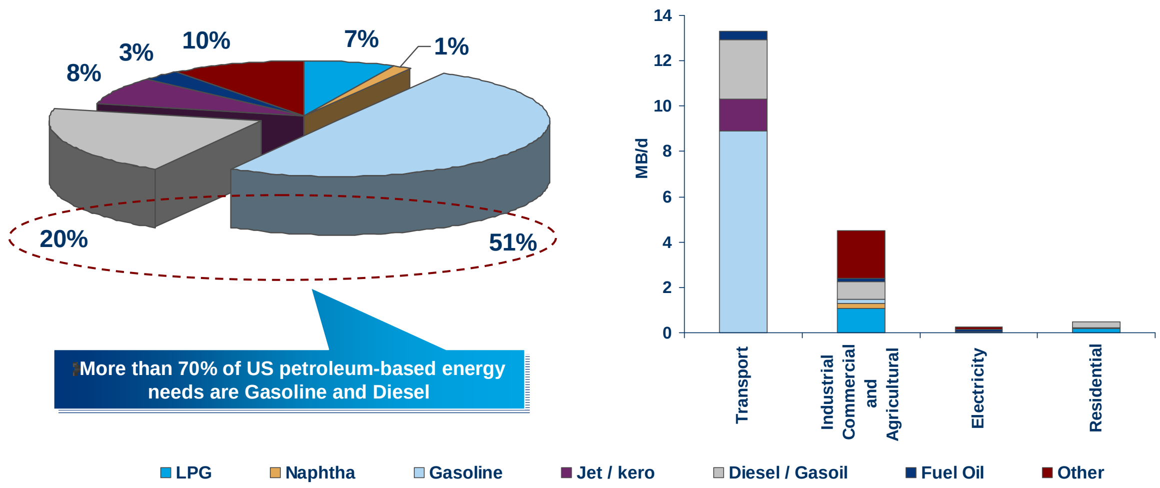


Source: EIA statistics; Wood Mackenzie analysis

[12] *Source: EIA, Wood Mackenzie*

As key transport fuels, gasoline and diesel constitute over 70 percent of total oil product demand. This reflects the importance of transportation in the everyday lives of Americans and the essential movement of goods associated with activity in the world's largest economy.

Figure 24: US Refined Product Demand Dominated by Transport Fuels (2009)

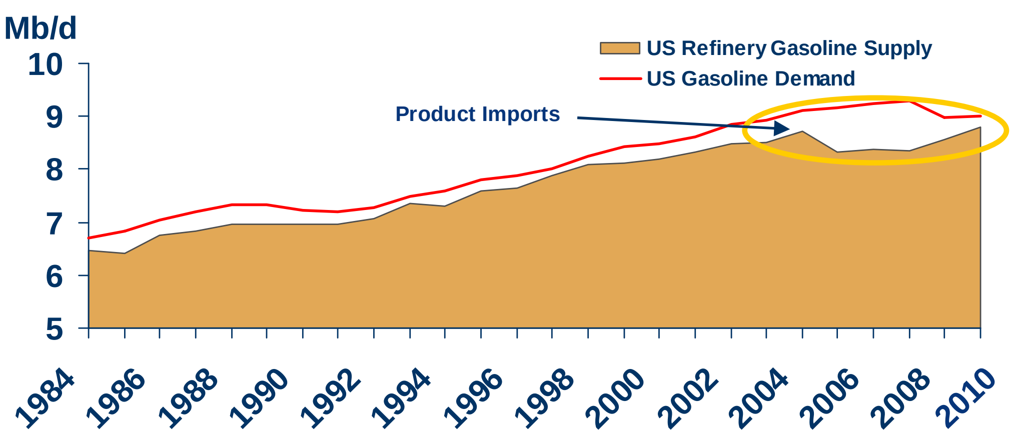


Source: Wood Mackenzie Product Markets Service

There are several contributing factors to the high demand for road transport fuels, particularly gasoline: the overall geography of the United States; the high proportion of the population that lives in widely distributed, large urban areas; low levels of public transportation provision; and relatively affordable access to private motor vehicles.

The scale of gasoline demand has led the US refining industry to configure its assets to maximize gasoline production. Even so, gasoline has been a significant source of product imports to the United States. This highlights the importance of keeping the US refining industry competitive with refineries in other regions of the world.

Figure 25: US Gasoline Supply / Demand (1984-2010)

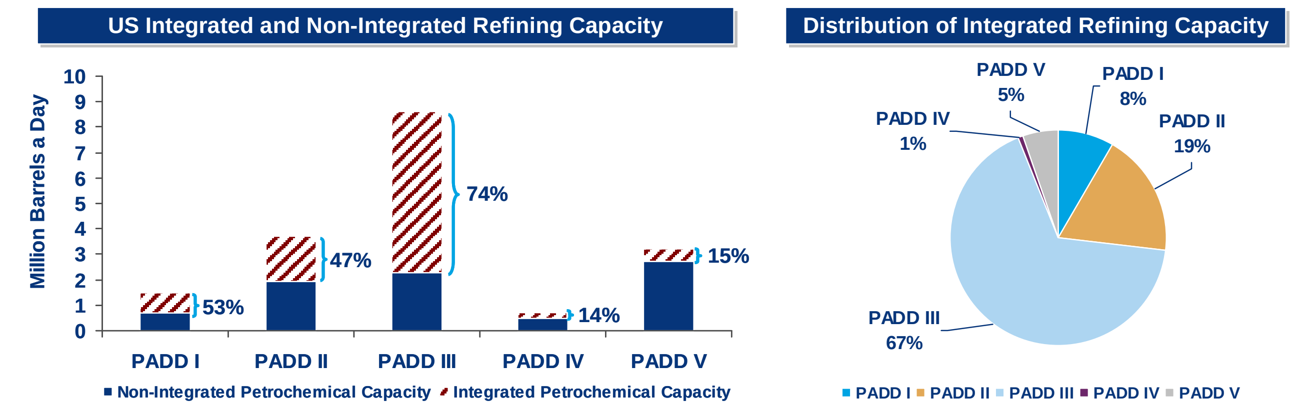


Source: EIA statistics; Wood Mackenzie analysis

As well as providing fuels for the transportation sector, the US refining industry provides essential fuels, feedstocks and energy to the industrial, commercial and agricultural sectors. These supplies directly enable production by US domestic manufacturing industries.

A specific example of the refining industry's importance as a supplier to other industries is demonstrated by reviewing the degree of integration with petrochemicals manufacturing in the US. Figure 26 shows that approximately 9.4 million barrels per day of refining capacity (out of a total 17.6 million barrels per day) is integrated with petrochemicals manufacturing across all refining regions[13]. Particularly high levels of integration are seen in PADD III (more than 6.2 million barrels per day).

Figure 26: Refinery Integration with Petrochemicals by PADD (2010)



Source: Wood Mackenzie Refinery Evaluation Model (2010)

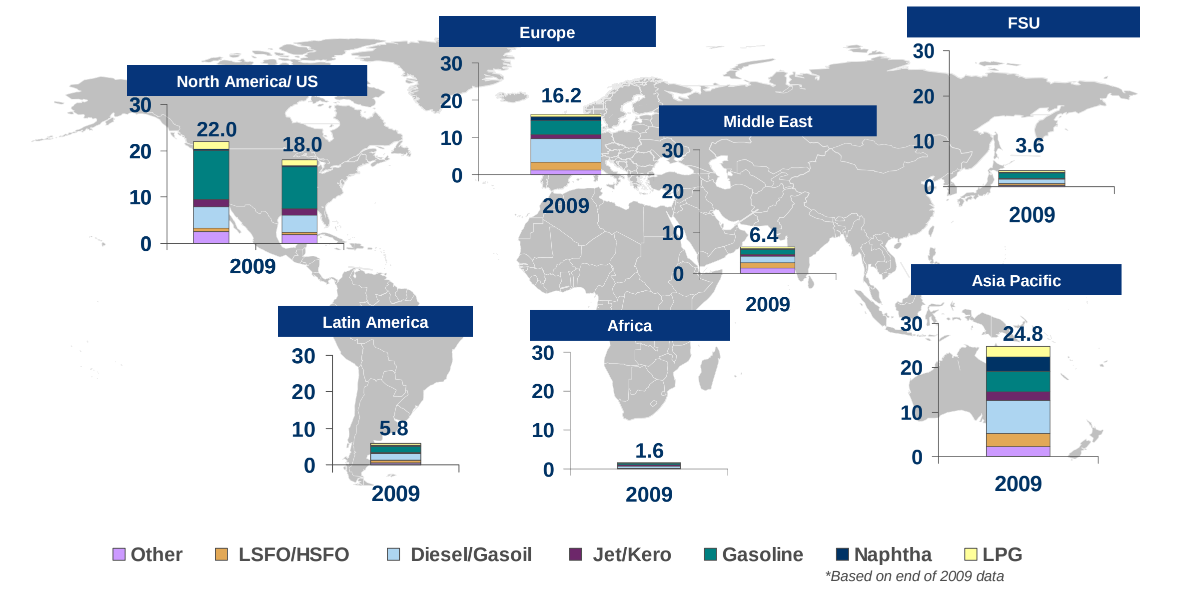
National security is also supported through the refining industry's supply of aviation kerosene, gasoline, diesel, fuel oils and lubricants to the US Air Force, Army, Navy and numerous governmental agencies. For example, the US Defense Logistics Agency sourced approx 50 million bbls of jet fuel in 2009, which is just under 20 percent of total US jet fuel demand (if sourced entirely from the US).

[13] *Source: Wood Mackenzie Refinery Evaluation Model*

2.3 Trade and the Global Market

Refined products, such as gasoline and diesel, are produced and traded around the world. As the world's largest economy, the US consumes nearly 22 percent (18 million barrels per day) of the world's 83 million barrels per day of petroleum production. By comparison, the Asia Pacific region's total oil product demand is approximately 30 percent (24.8 million barrels per day)[14].

Figure 27: Global Product Demand (Millions of Barrels per day) (2009)

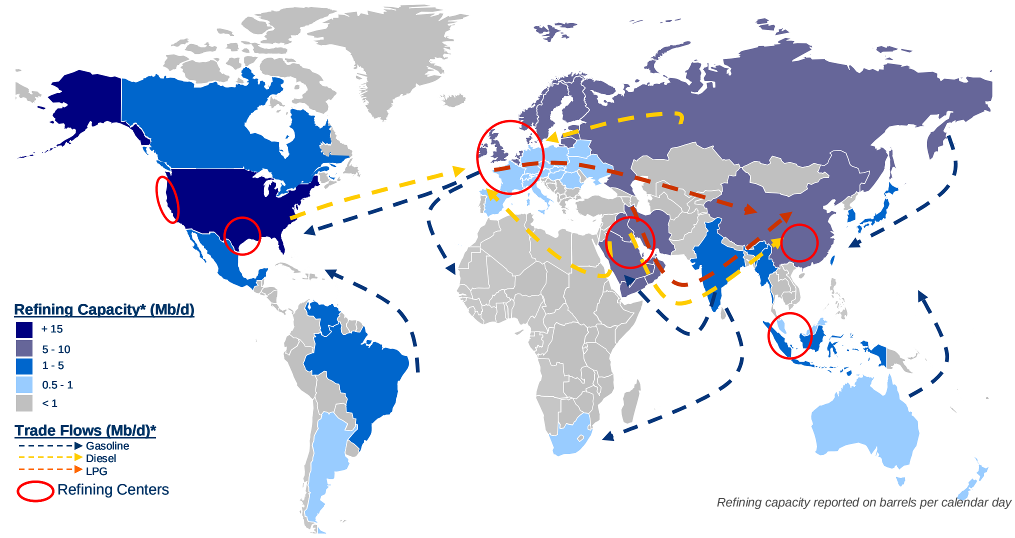


Source: Wood Mackenzie

Each region's refining centers are unique, specifically designed to the energy needs of its location. Imbalances in the supply and demand of products cause trade amongst regions as it is economic to do so. The US historically has maintained a deficit in its own supply of oil products, as demand has outpaced the growth of supply.

[14] *Source: Wood Mackenzie, International Energy Administration (end 2009 data)*

Figure 28: Principal Global Product Trade Flows (2009)



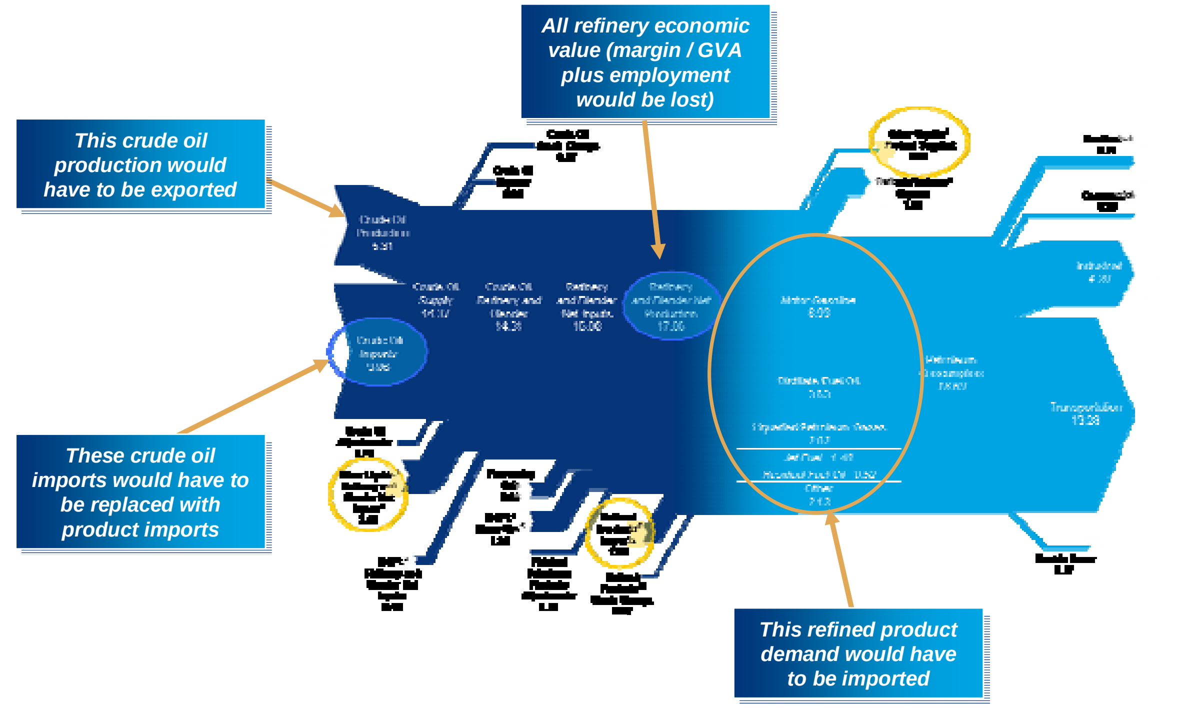
Source: Wood Mackenzie Product Markets Service (2009)

As shown in Figure 28 above, gasoline imports to the US come principally from European and South American refining centers. However, recent investments in export-oriented refining capacity in Saudi Arabia and India are increasing the potential sources of imports. Critically, Asian and European growth in demand for diesel is incentivizing refineries in these regions to increase utilization rates to maximize their diesel production. In doing so, additional excess gasoline is also being produced in Asia Pacific and Europe, with these refiners looking to export this excess gasoline to alternative markets. As a result, the US is seeing increased pressure of imports, particularly to the Atlantic seaboard and Gulf of Mexico coasts (PADDs I and III), creating a competitive threat to US refiners in these locations.

The US refining industry operates in a global market, and in addition to the imports of refined products, the US also imports crude oil. In 2009, domestic US crude supply covered approximately 35 percent of total US crude demand. In North America, Canada provided nearly 13 percent of total 2009 crude demand while Mexico provided 8 percent. Other regions such as the Middle East, Africa and Latin America together delivered almost 40 percent of 2009 US crude oil requirements.

During the continuing debate about the need for the US to reduce dependence on fossil fuels, it has been suggested that the US would be able to function appropriately without a domestic refining industry, by instead importing petroleum products as required to meet demand. However, Wood Mackenzie does not consider this to be a feasible scenario as approximately 21 percent of refinery capacity and 23 percent of refined product demand comes from the US. Conceptually, such a scenario would also require export of the US' crude production, vast increases in the amount of product shipping, with higher associated CO_2 emissions, high fuel costs to consumers as product imports would have to cover costs of freight plus supply premiums, and higher strategic stock levels. There are also broader economic consequences as it makes industries that rely on refined products for energy, transportation and feedstock less competitive.

Figure 29: Crude and Product Trade Implications without US Refining Industry



Source: US Energy Information Administration / Annual Energy Review 2009, Wood Mackenzie analysis

As US energy demand increases, so will the need for crude and refined products. The US refining industry offers secure supply of competitively priced, high quality refined products, contributes to US energy independence and supports the economy by minimizing dependence on imported foreign products. The US refining industry enables domestic energy needs to be met by imports of crude rather than finished products, which has energy security benefits as there is considerably greater global trade in crude oil than oil products and the technically advanced nature of the US refining industry means it can economically process a wide range of crude oils. Maintaining a strong US refining industry is hence essential if the growing US energy demand is to be met domestically.

3 Current and Future Business Environment

3.1 Overview

This chapter covers the current and future business environment for the US refining industry, regulatory current challenges and potential opportunities.

The US domestic refining industry faces ongoing challenges that pose significant risks to its sustainability. The challenges are common across the industry, however impacts vary by PADD as each region is influenced by its location and infrastructure. The industry's issues are summarized in three key factors:

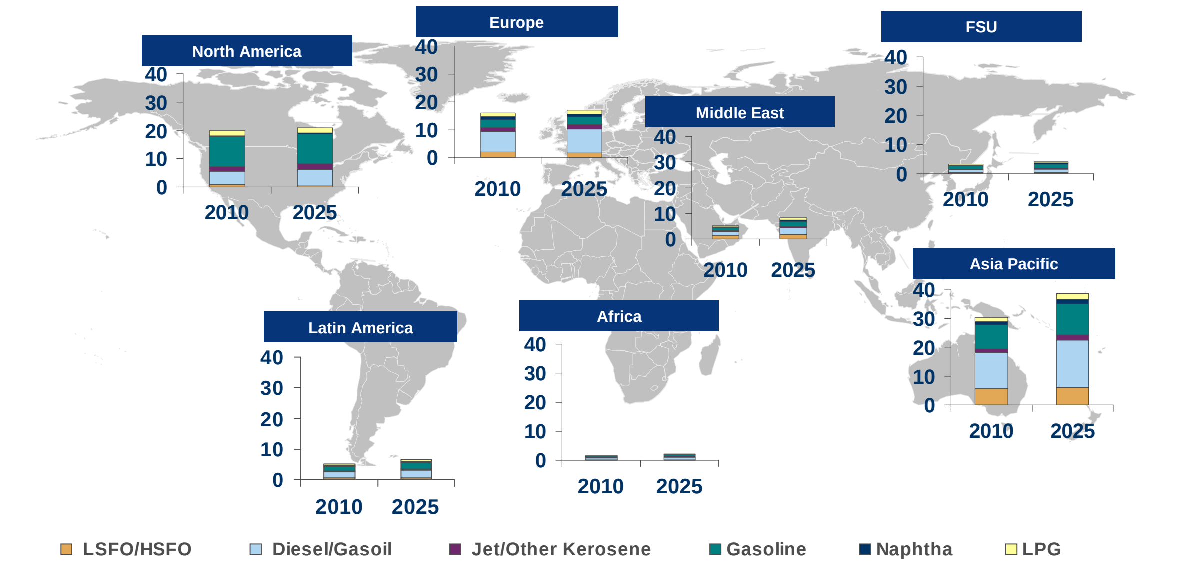
- Low levels of demand: during the 2007-2009 economic downturn US refined product demand fell significantly and demand has not yet recovered to pre-recession levels.
- Increasing threat of imports: the growing pressure from imports stems principally from excess gasoline production in Europe and Asia as refineries in those regions maximize production of middle distillates. PADD I, PADD V and to lesser extent PADD III refineries are highly exposed to these imports, with the inland refineries of PADD II and PADD IV partially insulated by location.
- Low utilizations: refinery utilizations are at historic lows and are a direct consequence of the previous factors listed, with PADD I utilizations suffering the most.

These factors may result in weak refinery margins and outlook, which in turn reduces commercial incentives for US refiners to sustain investment levels.

3.2 Supply and Demand Factors

Since the economic downturn of 2007-2009 the world demand is recovering, as is the US refinery product demand. The US refining industry demand growth profile can be best analyzed from a global perspective, where the US and Greater Europe demand is projected to grow marginally while Asia Pacific and Latin America experience significant demand increase between 2010 and 2025.

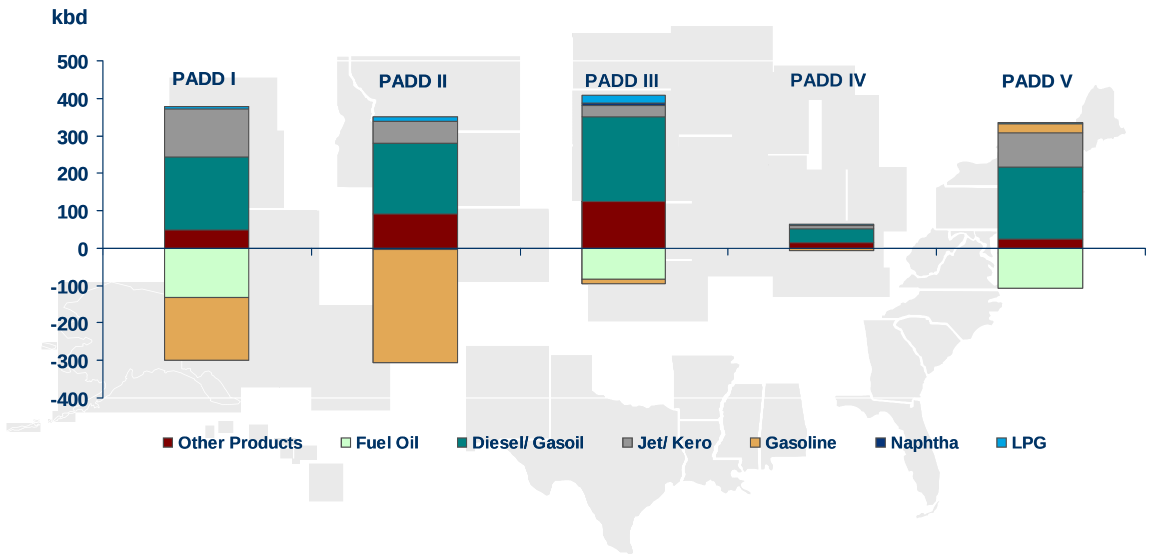
Figure 30: Global Product Demand Profile (Mb/d) (2010-2025)



Source: Wood Mackenzie – Product Markets Service

The dynamics within the US refinery product demand vary on a PADD by PADD basis. PADD III and V product demand is expected to increase significantly between 2010-2025 with total volume change of approximately 300 and 230 thousand barrels per day respectively, while the remaining PADDs present a relatively stagnant demand growth between 50 - 80 thousand barrels per day as indicated in Figure 31.

Figure 31: Regional Product Demand Growth (2010-2025)

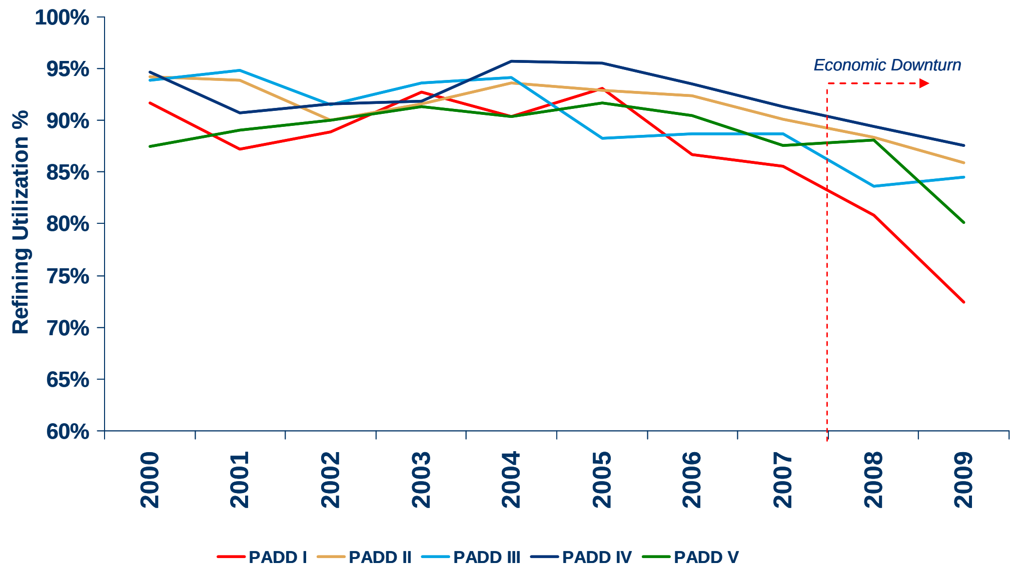


Source: Wood Mackenzie – Product Market Service

Overall, the regional demand profiles are expected to continue to be dominated by gasoline, however on a product by product basis gasoline and fuel oil demand decline over time, giving way to significant increase in distillate (jet, road diesel and heating gas oil) demand. The largest gasoline decline is expected to be within PADDs I and II while other regions' demand changes are minimal.

Historically, the US refining utilizations have been on downward trend since the beginning of the decade. US refinery utilizations have dropped nearly 6 percent during the 2007 – 2009 period. However, not all regions were affected equally with PADD I refinery utilizations falling from 85 percent to 72 percent in this period.

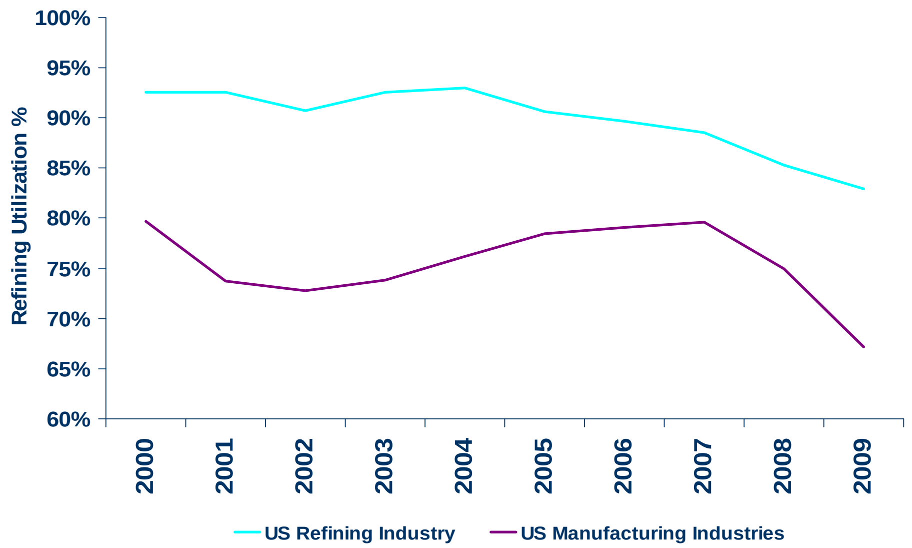
Figure 32: US Refinery Utilization % (2000-2009)



Source: EIA statistics

Comparing US refining to other manufacturing industry, US refiners have operated at consistently higher utilization levels, as demonstrated in Figure 33. While both refinery and manufacturing industry utilization rates have been declining in recent years, refiners continue to operate at higher levels than the rest of the manufacturing industry. The figure also shows that the decline in utilization rates during the 2007-2009 recession has not been as sharp.

Figure 33: Comparison of US Refining vs. Manufacturing Industry Utilizations % (2000-2009)

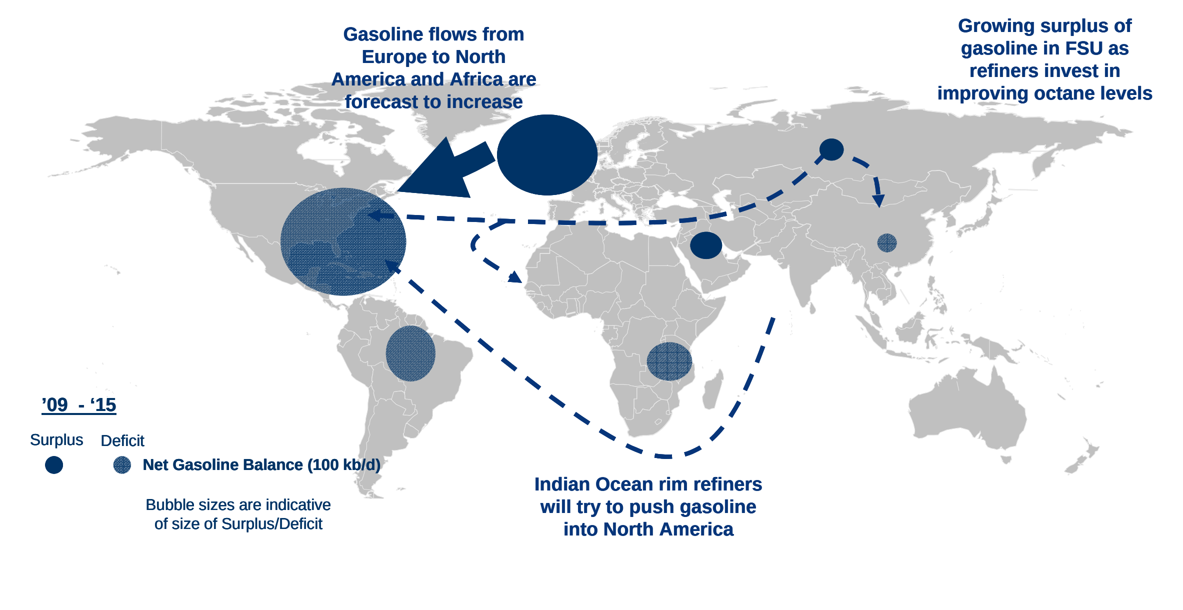


Source: Federal Reserve Statistical Release; EIA statistics

Consequently, as global market pressures continue, US refining utilization rates are expected to remain low with East and Gulf Coast utilization levels forecast to remain stagnant or decline further, with minimal prospects of recovery. Pipeline projects, such as Keystone XL, are vital to the US refining industry in order to supply crude oil that many of the USGC refineries are ideally configured to process.

On a global scale, as regional refining centers seek to optimally meet their respective demand for products there are supply / demand imbalances which drive inter-regional global trade. For example excess gasoline from European refineries will continue to supply the US, as indicated in Figure 34 below:

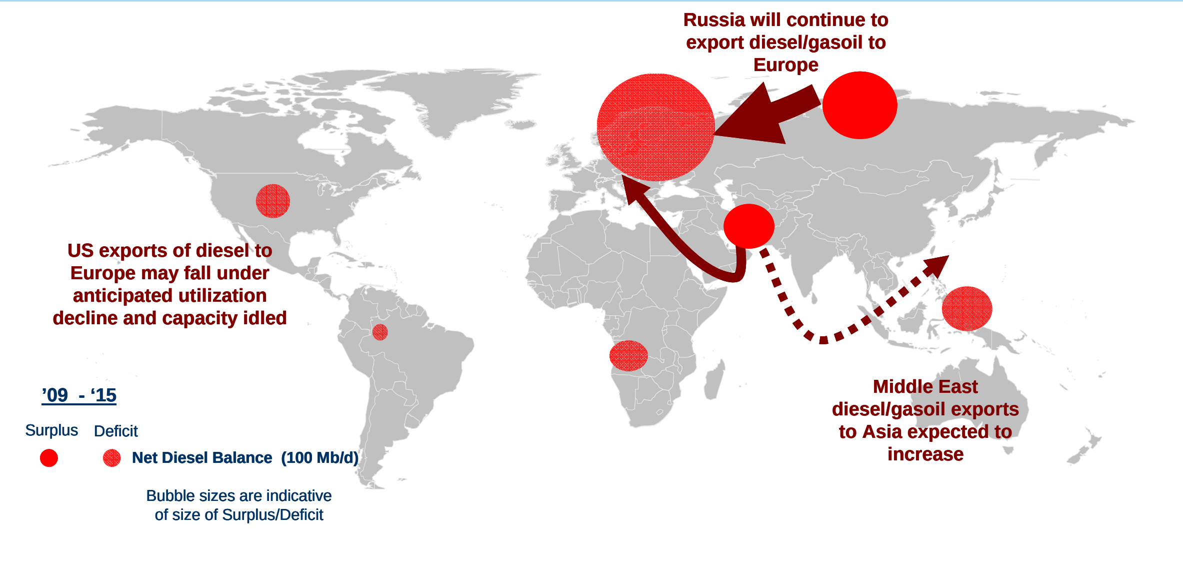
Figure 34: Gasoline Refinery Supply / Demand Balance Comparison (Mb/d) (2009-2015)



Source: Wood Mackenzie – Product Market Service

Similarly, refiners will compete to satisfy the shortfall in local European diesel supply, as indicated below:

Figure 35: Diesel Refinery Supply / Demand Balance Comparison (Mb/d) (2009-2015)

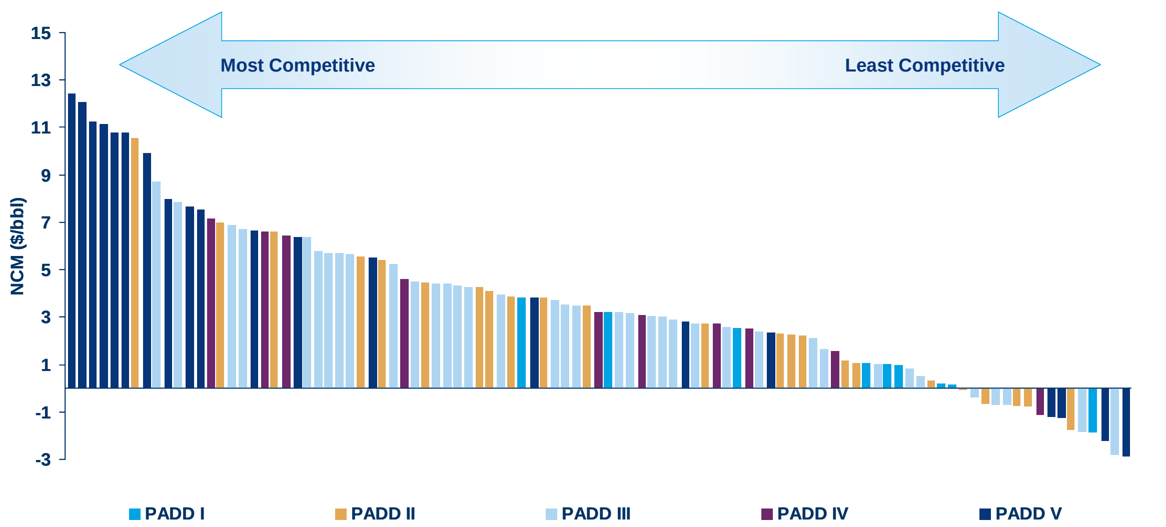


Source: Wood Mackenzie – Product Market Service

3.3 Refining Business Environment

The challenging industry environment in 2009 weakened refinery margins. Wood Mackenzie's approach to evaluating competitive position is Net Cash Margin (NCM), which is our independent assessment of the EBITDA of each refinery for a given year. Evaluating all US refineries with a capacity above 60 thousand barrels per day (60 kbd), refiners' 2009 NCM were particularly weak, with PADD I refineries severely impacted. PADD V refineries are the most competitive as they rank high with respect net cash margin (NCM) with PADD II and PADD III refineries varying across the scale.

Figure 36: US Refineries 2009 (> 60 kbd estimated) Net Cash Margins > 60 kbd, US$/bbl



Source: Wood Mackenzie – Refinery Evaluation Model

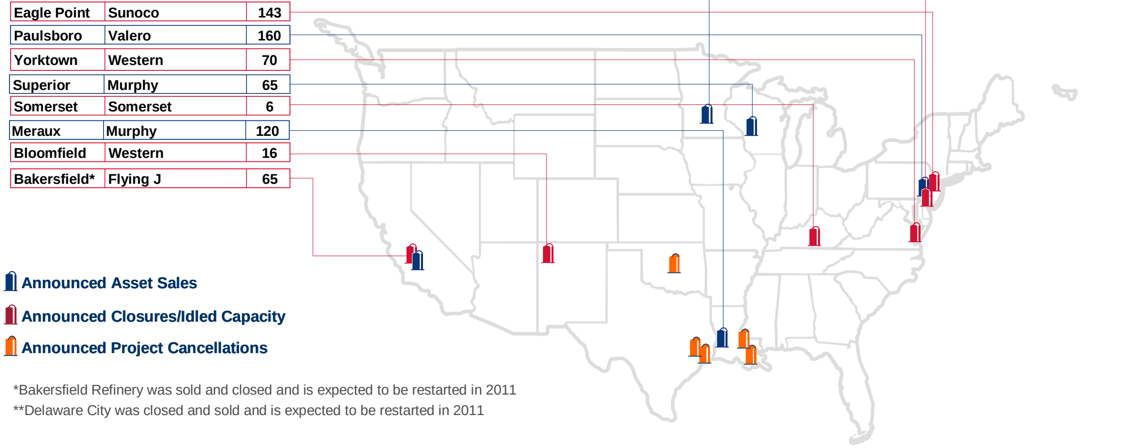
The low margin environment in 2009 resulted in significant idling of capacity, closures, and project cancellations across the US. PADD I was severely impacted, with the most of the recent refinery closures, and PADD III suffered the most in project cancellations. The majority of investment cancellations were for crude distillation and conversion expansions. Cancelled investments represented approximately 16% of total capital investment announcements during 2008-2012. The consequences of asset closures in the refining industry are significant job losses within local communities and the domestic companies that rely on the ongoing operations of these refineries. Tax revenue losses and corporate write-offs damage the nation's economy and represent the unintended consequences of lost refinery competitiveness and sustainability.

Asset closures and idled capacity have also been announced across other refining regions of the world, such as Europe with total capacity shutdown approximating the 600 thousand barrels per day of refining capacity.

Figure 37: North America Refining Activity – Closures, Asset Sales & Project Cancellations

Refinery	Company	(kb/d)
St. PaulPark	Marathon	74
Eagle Point	Sunoco	143
Paulsboro	Valero	160
Yorktown	Western	70
Superior	Murphy	65
Somerset	Somerset	6
Meraux	Murphy	120
Bloomfield	Western	16
Bakersfield*	Flying J	65

Refinery	Company	(kb/d)
Delaware City**	Valero	210



*Bakersfield Refinery was sold and closed and is expected to be restarted in 2011
**Delaware City was closed and sold and is expected to be restarted in 2011

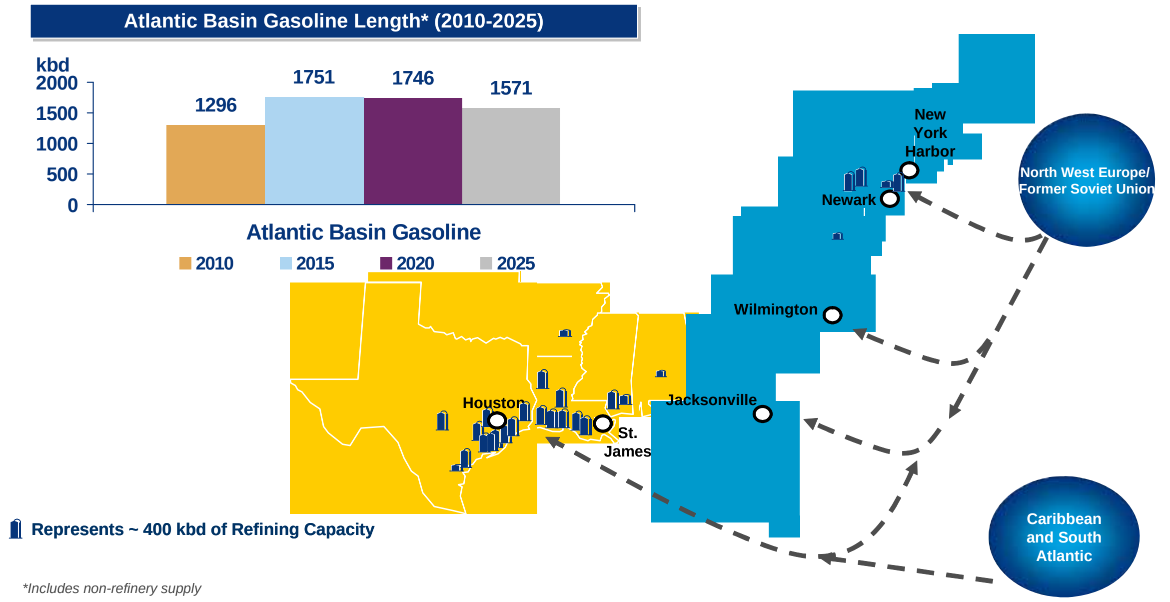
Source: EIA, press reports

3.4 Challenges and Opportunities for the Industry

Currently the US refining industry faces various challenges and opportunities, which differ by feedstock, product and regional geography. A key challenge for the US refining industry is the projected lack of sustained future demand growth for transportation fuels along with the shift from gasoline to diesel, as previously detailed in Section 3.2. The challenge is for the US refining industry to continue to economically supply this evolving demand profile, while also accommodating a growing penetration of bio-fuels, such as ethanol and biomass based diesel. This is particularly challenging in the US West Coast, due to California's Low Carbon Fuels Standard (LCFS) which legislates a reduction in the content of refinery-sourced materials in transportation fuels, while still requiring other product quality specifications to be met.

Coastal refiners are expected to face significant business environment challenges due to increasing global competition. The shift in demand growth from gasoline to diesel requires the refining industry to increase diesel supply. This is projected to result in a greater supply of gasoline within the Atlantic basin. PADD I and USGC refiners, are thus expected to be pressured by this increasing gasoline supply as shown in Figure 38 below.

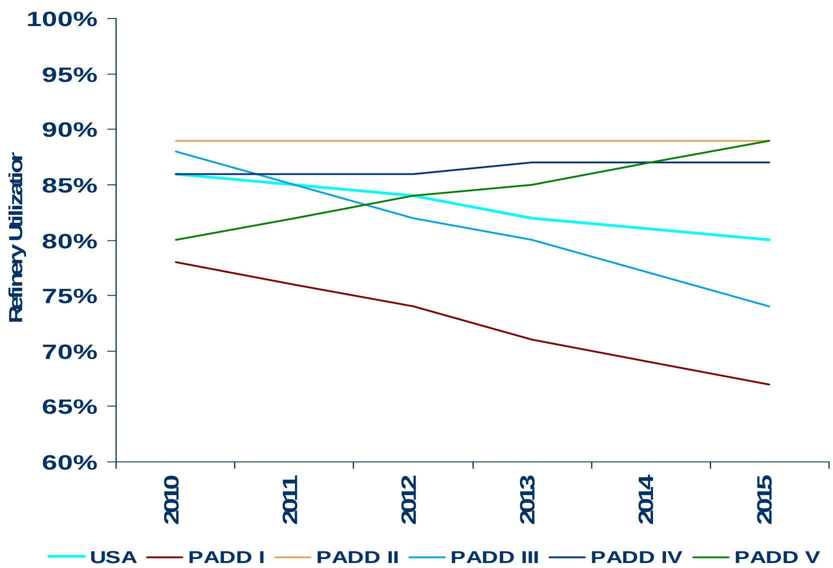
Figure 38: Atlantic Basin Gasoline Length* Forecast (2011-2025)



Source: Wood Mackenzie Analysis – Product Market Service

The net effect is expected to reduce the economic incentive for US refiners to operate at high utilization (which is typically needed for capital intensive assets in commodity markets to be profitable), as there is a growing threat of competition from imports. The impact is also felt by the USGC refiners, as higher levels of international imports reduce the opportunity for exports to the US coastal regions. The situation for the US West Coast is similar to that of the US East Coast in that there is a growing threat of imports from long haul destinations from countries such as South Korea.

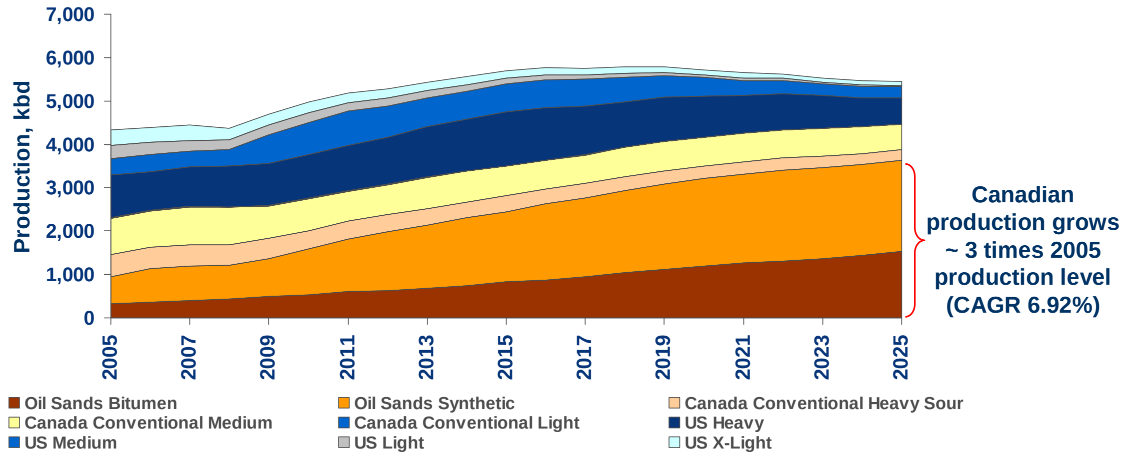
Figure 39: Projected Refinery Utilization (%) (2010-2015)



Source: Wood Mackenzie Analysis – Product Market Service

Inland refiners such as those in PADD II and IV have a more favorable outlook. These mid-continent refiners face feedstock opportunities that would support improved utilizations, specifically due to the growing availability of Canadian crudes. Figure 40 shows that the supply of Canadian crude is projected to increase substantially by 2025, reaching a combined total of 3.6 million bpd for oil sands bitumen and oil sands synthetic crude. This represents a year on year compound annual growth rate (CAGR) of 6.9% from 2005 production levels.

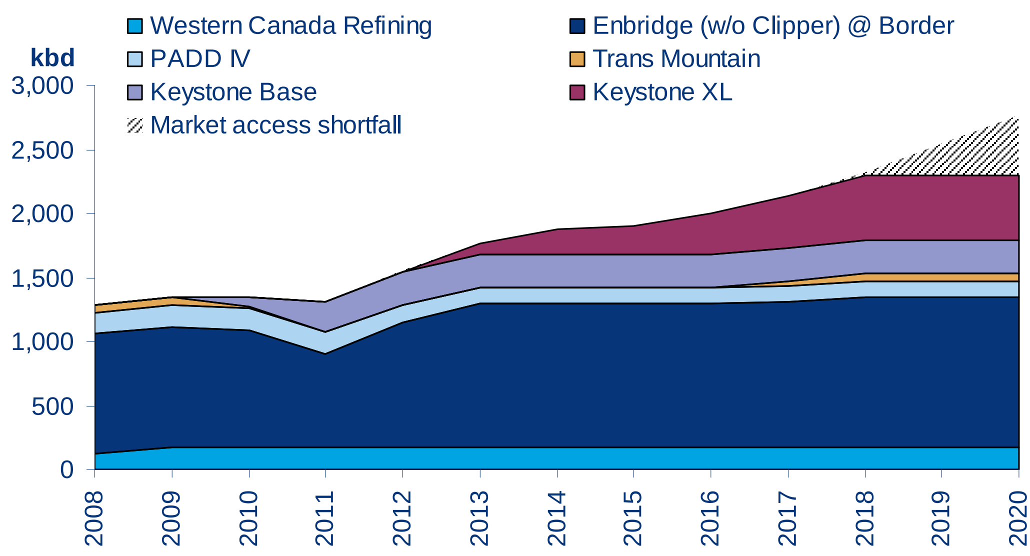
Figure 40: US-Canada Crude Production Profile (2005-2025)



Source: Wood Mackenzie – Global Oil Supply Tool

There is a limited domestic refining industry in Canada and so this increasing supply of crude provides an opportunity for mid west refiners to process a (relatively) lower cost crude supply (and in doing so replacing crudes that need to be imported via the USGC). Increasing Canadian production also provides an alternative source of crude for USGC refiners to importing from countries such as Mexico and Venezuela that are experiencing declining crude oil production. The pace of Canadian production development supports these regions' upgrades to process more Canadian oil sands material. However, Wood Mackenzie's analysis suggests that supplies will be market access limited beyond 2018, as pipeline capacity limits are reached (Figure 41), even if the Keystone XL pipeline is developed. The "market access shortfall" as shown in Figure 41, could result in further Canadian crude oil supplies not being developed, as without effective export logistics, it is unlikely to be economically attractive.

Figure 41: US Refinery Demand Forecast for Canadian Oil Sands



Source: Wood Mackenzie Analysis

In summary, the key opportunities and challenges for the various regions are:

- Atlantic Basin – growing threat of imports from long haul international destinations;
- Mid-west – capturing the opportunity of processing/monetizing Canadian oil sands while adapting to the shift in demand from gasoline to diesel/gas oil;
- West Coast – growing threat of imports from long haul international destinations in conjunction with the additional complexity of strongly growing biofuels penetration.

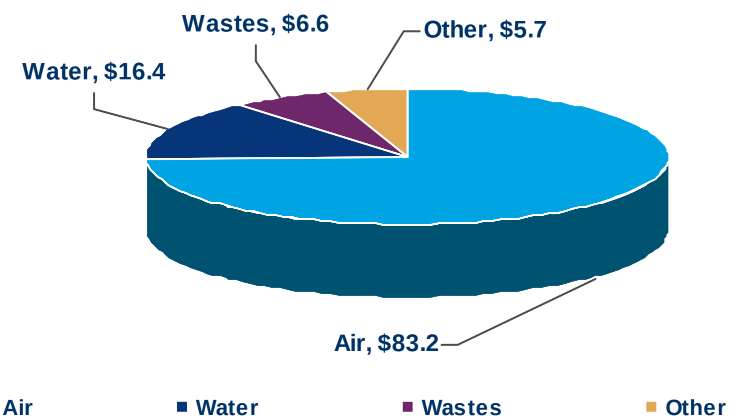
4 Regulation and Global Competitiveness

This chapter describes the complex regulatory environment in which the industry operates, and its potential implications on the industry's competitiveness in the global marketplace.

4.1 Regulatory Environment

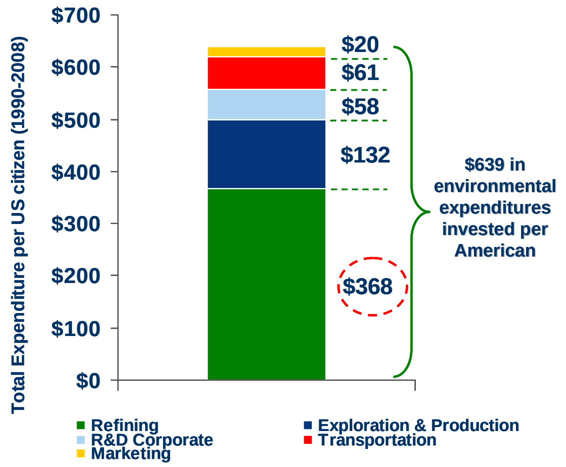
The US domestic refining industry recognizes the importance of operating efficient processes in alignment with the regulations that care for improving the environment. The industry has historically invested in its commitment to the environment as shown in Figure 42, with nearly US$112 billion since 1990. US refining has an outstanding history of regulatory compliance, which has resulted in domestic refineries that are among the cleanest and most efficient in the world.

Figure 42: Total 1990-2008 Refining Environmental Expenditures by Medium* (US$ Billion)



Source: American Petroleum Institute, (2010). Environmental Expenditures by the U.S Oil and Natural Gas Industry

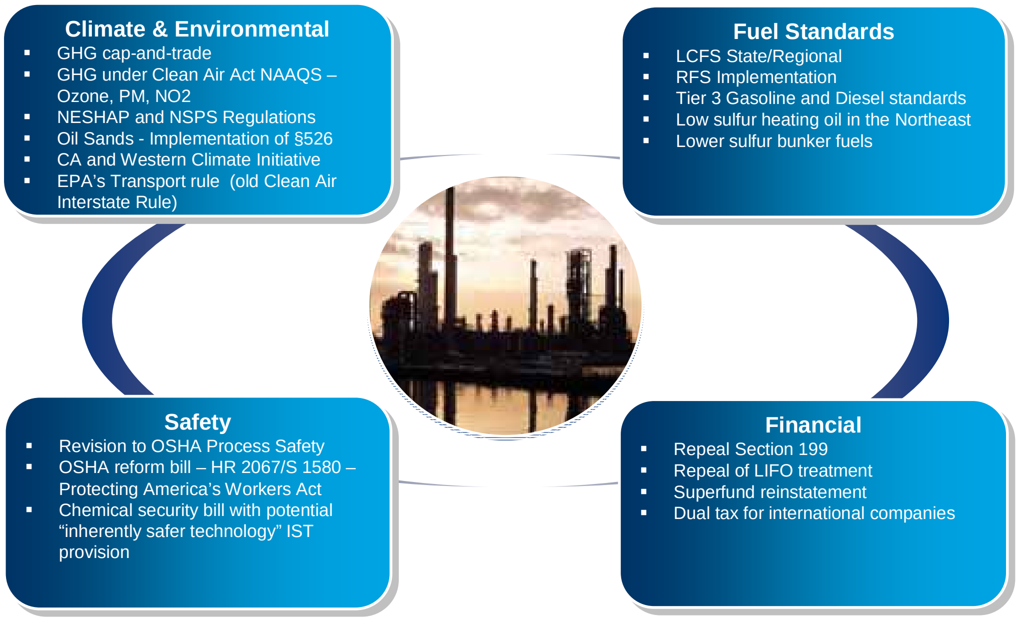
Figure 43: Environmental Expenditures per US Citizen by Business Sector 1990-2008 (US$)*



Source: American Petroleum Institute, (2010). Environmental Expenditures by the U.S Oil and Natural Gas Industry

The industry is subject to highly complex regulations and has, through technology, improved the quality of its products and processes with significant investments in advanced technology. Figure 44 depicts the key regulations currently surrounding the refining industry within the categories of safety, product fuel standards, financial controls and taxation, and climate and environmental standards, all of which heavily impact the industry.

Figure 44: Major regulations impacting the Refining Industry

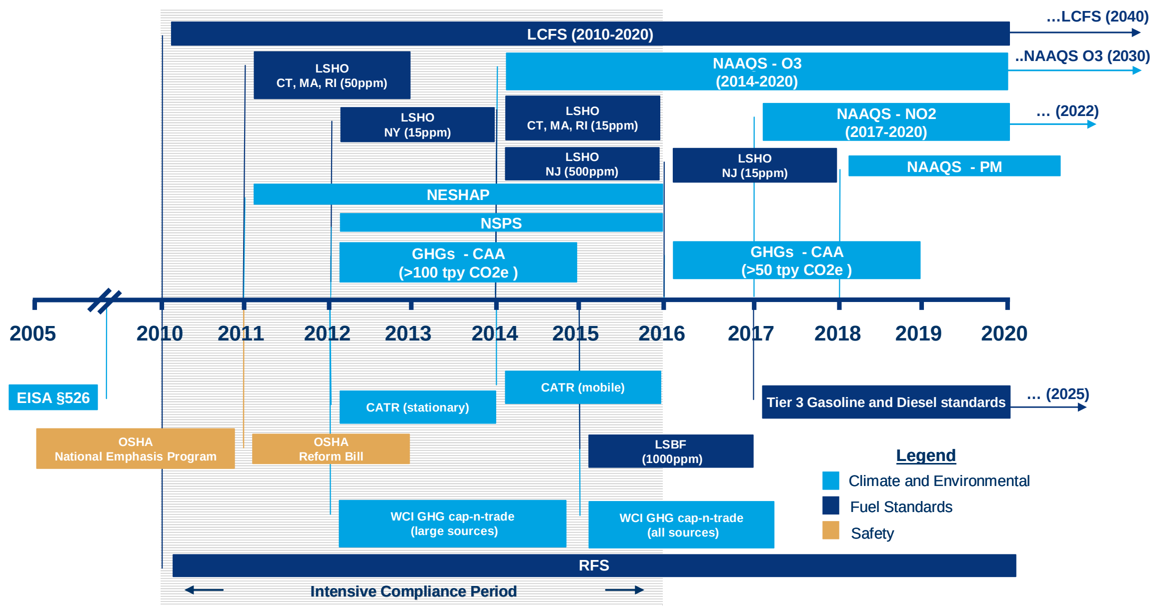


Source: Wood Mackenzie

4.2 Intense Compliance Period

US oil refineries are some of the most heavily regulated facilities in the world. Even so, many of the regulations shown in Figure 44 now propose new control standards and compliance targets for the next 5-10 years without remote consideration of regulation of the industry in other parts of the world. The risk is that new regulation in the US is more stringent with higher costs of compliance than for refining in other regions, thereby damaging US refining industry competitiveness and weakening the domestic industry.

Figure 45: Regulatory Timeline Highlighting Intensive Compliance Period



LCFS = Low Carbon Fuel Standard
LSHO = Low Sulfur Heating Oil
LSBF = Low Sulfur Bunker Fuel
GHGs – CAA tpy CO2e = Greenhouse Gas Emissions Standards within the Clean Air Act tonnes per year CO2 equivalent
NAAQS = National Ambient Air Quality Standards
NESHAP = National Emissions Standards for Hazardous Air Pollutants
EISA = Energy Independence and Security Act – Implementation of §526
WCI GHG = West Climate Initiative state GHG cap-and-trade

Source: Wood Mackenzie

Many of these regulations may create significant detrimental impacts that could potentially weaken the domestic refining industry's ability to compete globally. For example, regulations contained within the fuels standard category promote substitution of oil products by other materials, reducing demand for refined products and leading to lower refinery utilization levels. This adversely impacts the US refining industry and its ability to remain globally competitive.

The majority of policies and regulatory proposals require technological developments and involve highly complex permitting procedures that create uncertainty whether the attainment targets can be achieved. These uncertainties and complexities may therefore delay refinery investments until the proper control technology has been defined. The delay of refinery investments negatively impacts the industry's ability to remain competitive. US EPA plans to issue a tighter ozone standard in mid 2011 for implementation by 2014. If the new standard is adopted as proposed, the likely result would be more stringent regulations on refineries, with the complication that compliance requires the development of new technologies and yet-to-be-developed control measures. Refiners may hence delay investments on other aspects, such as fuels product quality compliance, as the approved technologies required to meet the control target of these components has not yet been defined.

The future of greenhouse gas emission controls within the Clean Air Act is another example of compliance. The regulation establishes thresholds for GHGs from new or modified sources defining a three step compliance target from 2011 through 2016 for air emissions and associated air permits. The regulation defines when permits are required to be obtained and includes the need to establish the best available control technology (BACT) which defines emission controls applicable to the facility considering cost, energy, environmental and economic impacts. The EPA has issued guidance on determining BACT for GHG permits, however, the BACT guidance does not specify the control technology. BACT emphasizes the state's rights to use a broader approach when reviewing possible options for reducing GHG emissions by the sources (in this case the refineries). Therefore, refiners are subject to the state's further guidance and definition of the technology authorized to apply, adding a further uncertainty to the regulation compliance requirements.

As these regulations increase capital expenditures, and subsequently raise costs of operations they continue to pressure the economic sustainability of refinery operations, which under the current low margin environment can increase the risk of refinery closures and consequential job and economic loss. Overall, the regulations tend to create unintended consequences that duly disadvantage the US domestic refining industry relative to other refining centers of the world. The risks of this imply that companies could thus move operations to other countries with less stringent controls, increasing domestic manufacturing shutdowns, with implicit employment and tax revenue loss as opportunities are created overseas.

The continuance of an overly excessive and complex US regulatory environment may, when compared to competing refining sectors:

- reduce demand for refined products through substitution with biofuels
- increase costs of operations
- require extensive capital outlay for non-discretionary investments which may have limited commercial benefit and may be implemented before environmental benefits from existing regulations have been realized
- delay capital investments to be used for discretionary spending for facility upgrading, thus decreasing competitiveness of domestic refining industry
- increase potential risk of refinery closures and job loss, thus decreasing the nation's energy and economic security.

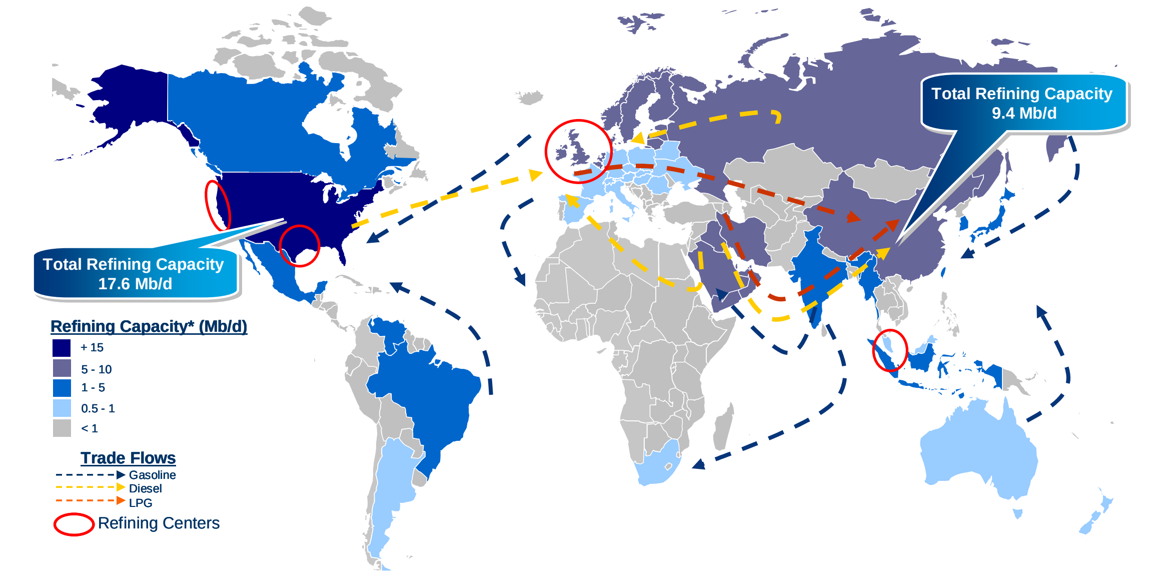
The complexity of the ongoing US regulatory environment and intense compliance period of the next 5 years present significant challenges for the competitiveness of the US refining industry. There are examples, such as Delaware (see section 2.1), where refineries have closed due to weak margins and unsustainably high investment costs to achieve regulatory compliance. Following closure, in some cases, local and state governments have subsequently provided economic and regulatory support to incentivize re-opening of these refineries.

This situation clearly demonstrates the importance for regulators and policymakers to fully understand the US refining industry in a global context. The competitive implications of new regulation should be fully investigated, understood and appropriate consultation and revision undertaken, before any detrimental implementation is enacted.

4.3 Potential Implications on Refining Industry Competitiveness

The US refining industry operates in a global market place, in which oil products can be readily transported between countries and regions. For example, European refineries are key suppliers of gasoline to the US East Coast, as shown in Figure 46 below.

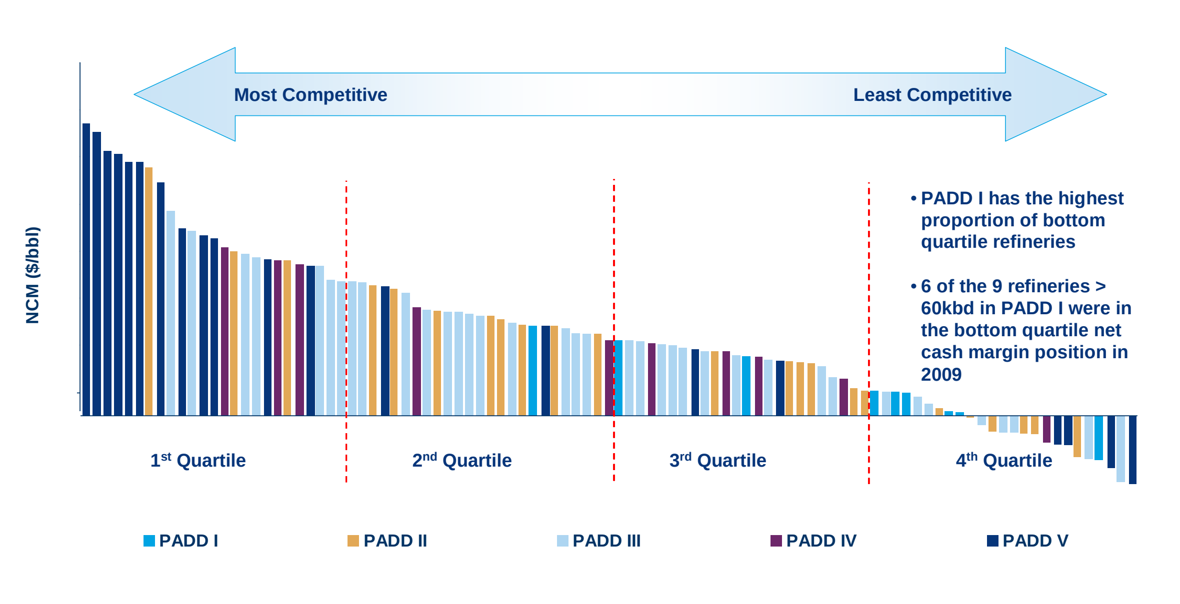
Figure 46: Global Refining Capacity Scale and Key Trade Flows (2009)



Source: Wood Mackenzie – Product Markets Service

Each refinery is unique, due to differences in size, crude slate, product yield and location. As such, the earnings generated by each refinery differ. Figure 47 shows Wood Mackenzie's independent assessment of the net cash margin (NCM) of all US refineries greater than 60 kbd capacity. It is evident that there is a wide variation in earnings across the US refining network for 2009.

Figure 47: US Refineries (> 60 kbd estimated) Net Cash Margins, US$/bbl (2009)



Source: Wood Mackenzie – Refinery Evaluation Model

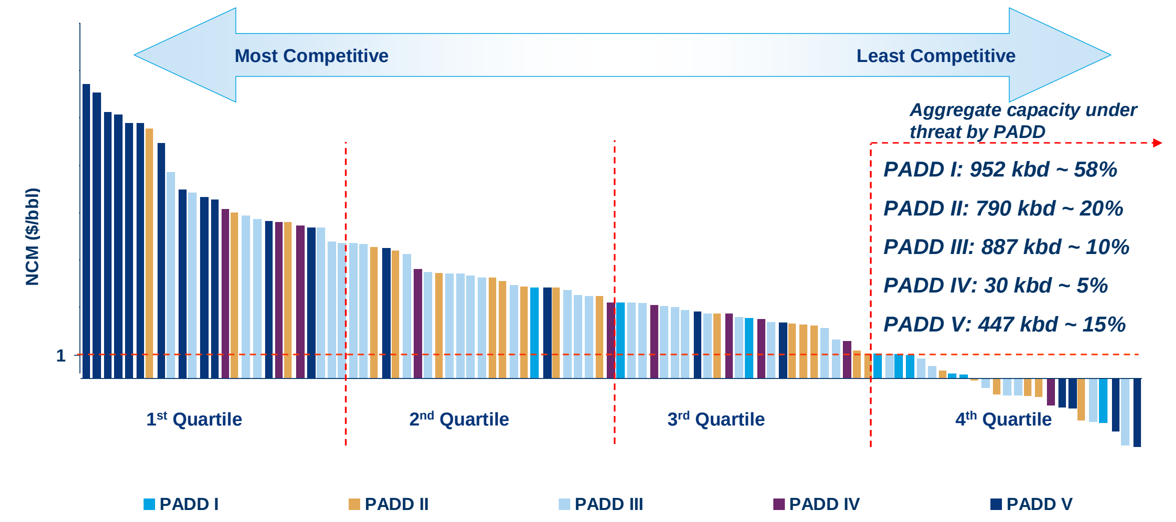
To estimate the potential economic impacts that could arise from the low margin refining environment, Wood Mackenzie analyzed US refinery closures in 2009 to estimate a threshold margin level below which refineries were deemed to be 'at risk'. To do this, Wood Mackenzie reviewed the weighted average net cash margin US refineries with capacity larger than 60kbd that closed in 2009 following the global financial crisis and recession. This net cash margin level was 98 cents per barrel.

Wood Mackenzie then reviewed the 2009 NCM for all US refineries with capacity larger than 60kbd and found that this level also coincides with the margin ceiling for the bottom quartile refineries. The approximate $1/bbl level is also observed by Wood Mackenzie to be a minimum sustainable NCM level for long term operation of refineries globally, sufficient to support typical ongoing 'stay in business' capital expenditure requirements.

The $1/bbl NCM threshold was therefore applied to the 2009 NCM curve for US refineries larger than 60kbd, identifying refineries below this threshold as being 'capacity under threat' (Figure 48).

The location of these refineries under threat by PADD was reviewed and the capacity under threat expressed as a proportion of the total capacity in each PADD.

Figure 48: Potential Aggregate Capacity Under Threat by PADD (2009)



Source: Wood Mackenzie – Refinery Evaluation Model

The potential impact of the capacity under threat in each PADD was employed to express these threats in terms of jobs at risk as follows: proportion of capacity under threat in PADD multiplied by total estimated refining employment by PADD. An equivalent calculation was carried out to estimate economic value at risk by PADD (Figures 49 and 50).

Figure 49: Estimated Employment, Labor Income & Added Value at Risk by PADD

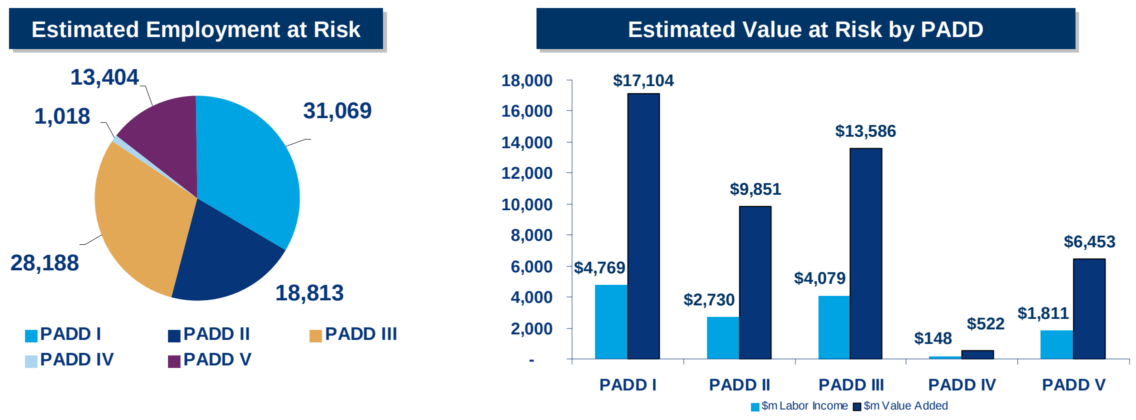
	Employment (FTE jobs)	Labor Income ($m)	Value Added ($m)	Capacity under Threat (%)	Employment (FTE jobs)	Labor Income ($m)	Value Added ($m)
PADD I	53,566	8,222	29,490	58%	31,069	4,769	17,104
PADD II	94,065	13,649	49,256	20%	18,813	2,730	9,851
PADD III	281,881	40,795	135,861	10%	28,188	4,079	13,586
PADD IV	20,365	2,962	10,439	5%	1,018	148	522
PADD V	89,360	12,076	43,018	15%	13,404	1,811	6,453

Source: API / PwC Economic Impact & Employment Report 2011[15]; Wood Mackenzie analysis

Direct employment is the term used to describe the jobs created within the refining industry. Indirect employment refers to the jobs created within other industries that provide goods and services to the refining industry. Induced employment refers to jobs created as a result of household spending of income earned either directly or indirectly from refining industry operations. Labor income includes wages, salaries and benefits, as well as total owners' income. Value added refers to the additional value created at a particular stage of production. It is a measure of the overall importance of an industry. Value added consists of employee compensation, proprietors' income, income to capital owners from property, and indirect business taxes (i.e., those borne by consumers rather than producers).

[15] *Source: PricewaterhouseCoopers study commissioned by API (2011): "The economic impacts of the oil and natural gas industry on the US economy: employment, labor income and value added"; Wood Mackenzie analysis*

Figure 50: Estimated Employment, Labor Income & Added Value at Risk by PADD



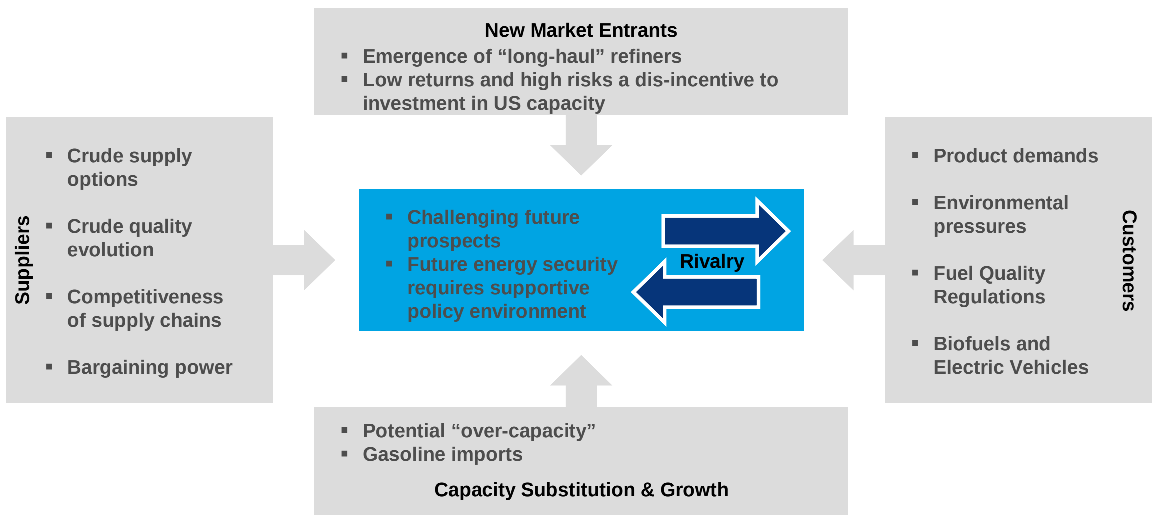
Source: API / PwC Economic Impact & Employment Report 2011[15]; Wood Mackenzie analysis

When refining margins are weak as they were in 2009, this analysis estimates approximately 17 percent of total US refining capacity, representing more than 20 percent of US refinery sites, would be under threat of closure. In direct, indirect and induced employment this represents nearly 92,500 jobs, US$14 billion per year of labor income, and US$48 billion per year of value added.

The US refining environment is becoming increasingly competitive, as shown in Figure 51 due to factors such as:

- impact of the financial crisis on demand and new projects resulting in a significant surplus of refining capacity
- new entrants (from countries such as India and Middle East)
- impact of alternative fuel components such as biofuels, and other substitute forms of alternative energy from renewable sources.

Figure 51: US Refining Competitive Environment



Source: Wood Mackenzie

The US refining industry is currently challenged by:

- the increasing complexity of the regulatory environment, much of which is to be implemented within the next five year period
- the need to make sustained investments to meet the tightening controls on climate and environmental aspects, fuel quality standards and safety/financial regulations
- this increasingly competitive global market environment, much of which is not subject to the same regulatory requirements.

As such, it is critical that the US regulatory environment does not unduly penalize the US refining industry against its international competitors, as this loss of competitiveness could result in the closure of a number of refining sites, with the associated loss in jobs, income and security of supply.

5 Supporting US Competitiveness and Future Growth

This chapter considers the need for a strong domestic refining industry to support US competitiveness, so securing the country's future growth prospects.

5.1 Potential Role for the Industry

The US refining industry currently performs a number of vital roles in the broader US economy, the following of which are relevant to the competitiveness and future growth prospects of the United States:

- It is a reliable and safe provider of clean transportation fuels to the consumer and energy/feedstocks to the wider manufacturing industry that are compliant with product specifications appropriate for US environmental needs

- It is a source of value addition, through the manufacturing of higher value products from the raw crude oil feedstock. It also provides a domestic outlet for US crude oil production, so supporting the development of domestic crude oil production in the US Gulf of Mexico and also inland production in the Lower 48. The industry's added value includes its provision of employment for highly skilled Americans

- It is a manufacturing base that facilitates ongoing transport fuel quality developments

- It is a key employer for an extensive engineering service sector, with the needs of US refiners providing significant indirect employment throughout the US and enabling the US service sector with the skills, knowledge and experience to compete to provide such services on a global basis

- It provides a secure source of transportation fuels and energy, as refineries can be flexible as to the type and quality of crude oil processed during periods of shortage, which is an advantage compared to relying on the global market to supply long haul imports of oil products under such circumstances.

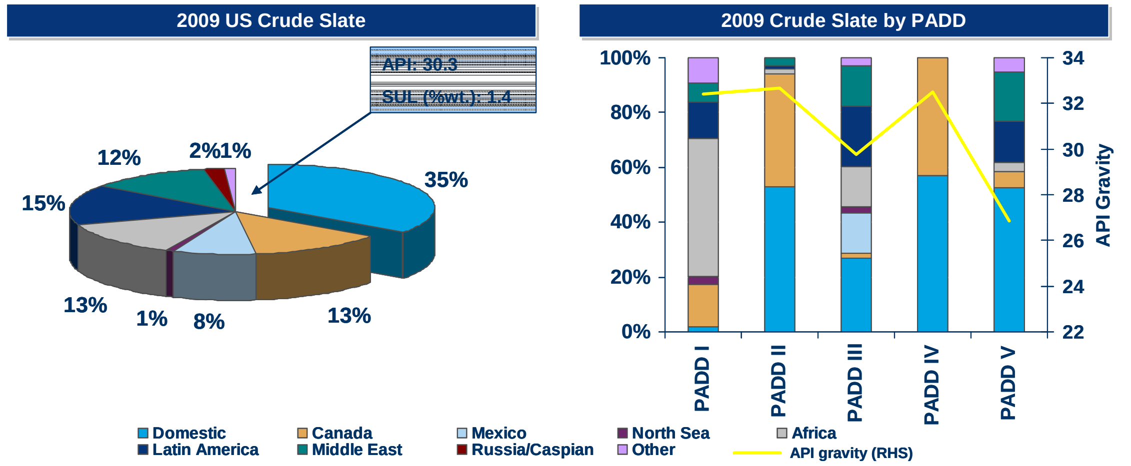
The refining industry can have a critical role in improving energy security through the ability to refine heavy oils from Canada, a strategic ally and key trading partner. The following case study provides an example of the US refining industry's pivotal role in supporting the future competitiveness and energy security of the wider US industry economy and the importance of legislative support to facilitate the refining industry's development.

Canadian oil sands case study

US demand for oil products depends significantly on imported crudes and Canada's vast oil sands resources provide a close, viable alternative to long-haul imports from overseas. Canadian oil sands are the second largest crude reserves in the world, and are strategically vital as they are a secure crude oil reserve from the US's number one trading partner. Without Canadian oil sands, equivalent volumes and qualities of crude oil would likely continue to be sourced from the Middle East and Latin America. In addition to the geographic and timing challenges of shipping crude oil from these far-away countries, and the potential political instability of the regions, there is also strong competition for Latin American and Middle East oil exports from emerging economic powers such as China.

As of 2009 Canada's crude oil supply represented nearly 13 percent of total crude demand by the US refining industry, primarily supplying PADDs II and IV. PADDs I and V also consume Canada's crude supply but in less proportion than PADDs II and IV, where it supplies approximately 40 percent of regional crude demand. Canadian crudes only supply around two percent of the total regional demand of PADD III, which has a highly complex refining region, with a concentration of deep conversion capacity ideally configured to process oil sands crude grades.

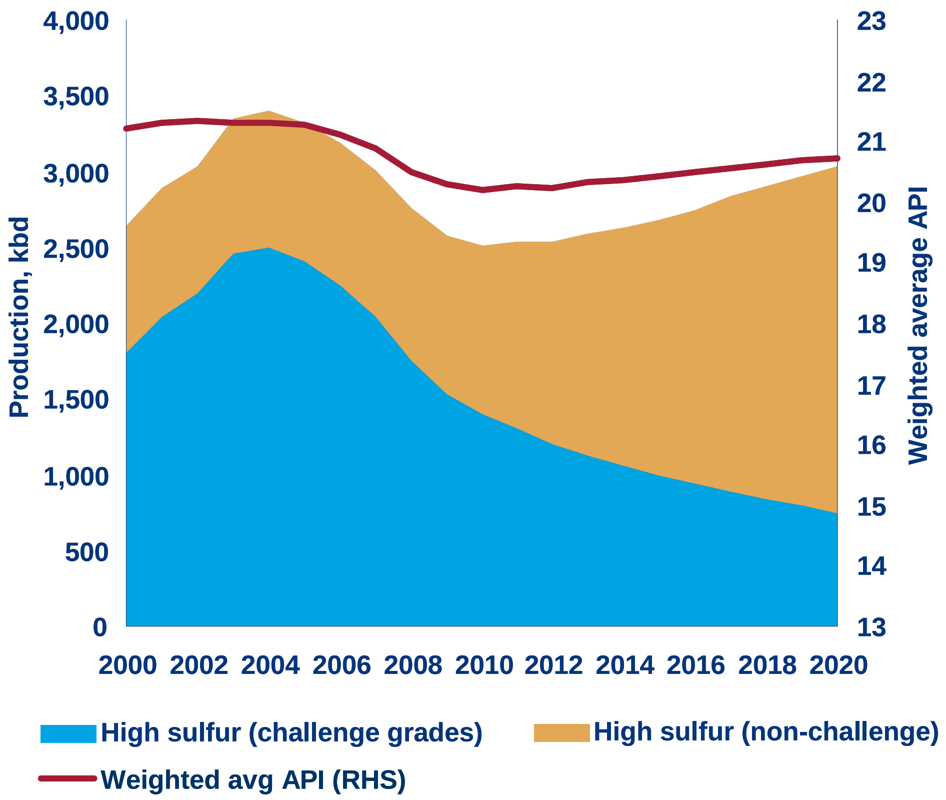
Figure 52: US 2009 Crude Slate (LHS) and US 2009 Crude Slate by PADD (RHS)



Source: Wood Mackenzie

The North American heavy crude supply outlook is dominated by the decline of Mexican grades such as Maya, and the emergence of Canadian production growth as shown in Figure 53.

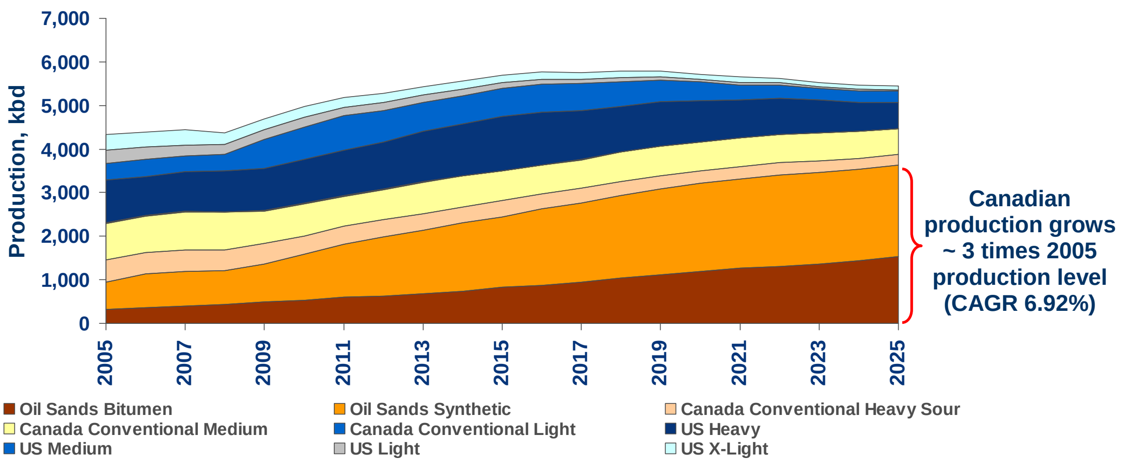
Figure 53: North American Heavy Oil Evolution (2000-2020)



Source: Wood Mackenzie

US refineries are some of the most sophisticated in the world and have the necessary complexity to process heavy grades of crude oil. In particular, refineries in PADD III have largely been configured to process Mexican heavy crude grades. However, given the declining trend of imports from Mexico as well as Venezuela, more and more recent investments across the US, particularly those in PADD II, have now been geared to match the increasing supply opportunities from Canada.

Figure 54: US-Canada Crude Production Profile (2005-2025)

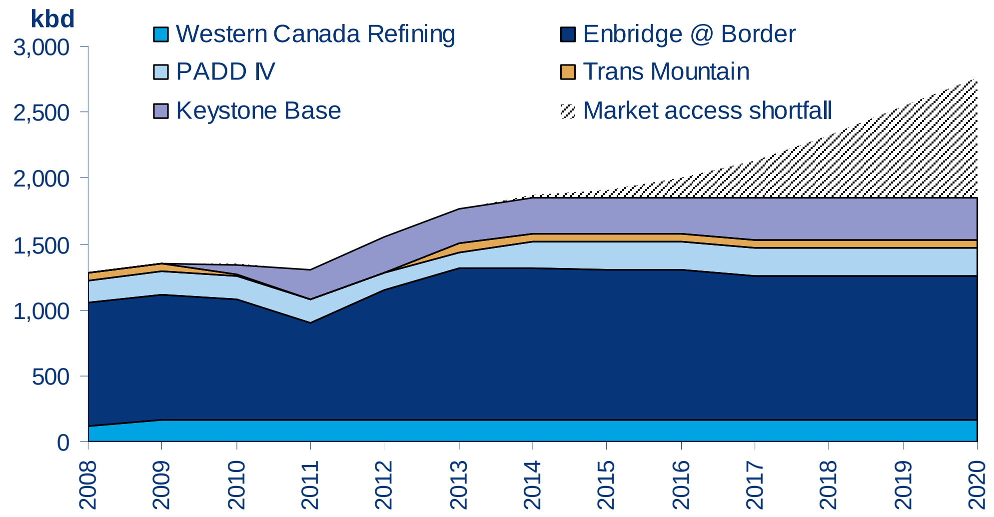


Source: Wood Mackenzie

Access to Canada's heavy oil production growth depends on the pipeline connectivity from Canada to the appropriate US refining markets and a supportive regulatory environment that permits its processing. Access to the key US markets capable of processing this crude supply is limited by pipeline capacity, particularly to reach PADD III refineries. As shown in Figure 55, Canadian production starts to be constrained by market limitation by 2014 (as there is not the pipeline infrastructure to move the crude to PADD III refiners that are capable to process it). Currently Canadian producers are seeking pipeline opportunities to export the growing production. PADD III refineries are capable of processing this crude which (is already) and has the ability to displace even more of the declining Mexican and Venezuelan imports, and also the potentially unstable and long haul imports from the Middle East and Latin America. However, the incremental volumes for PADD III are constrained due to the pending approval's for the Keystone XL pipeline project[16]. The growing production of Canadian oil sands and the existing limitations on connectivity to the US have supported other pipeline project proposals to send Canadian oil sands volumes west for export to the Asia Pacific region. If a west coast pipeline option opens to Canadian producers, Asian refiners will likely seek contractual commitments thus increasing competition for this feedstock while the US refining industry continues its dependence on supplies from overseas in potentially unstable regions.

[16] *Source: http://www.transcanada.com/keystone.html*

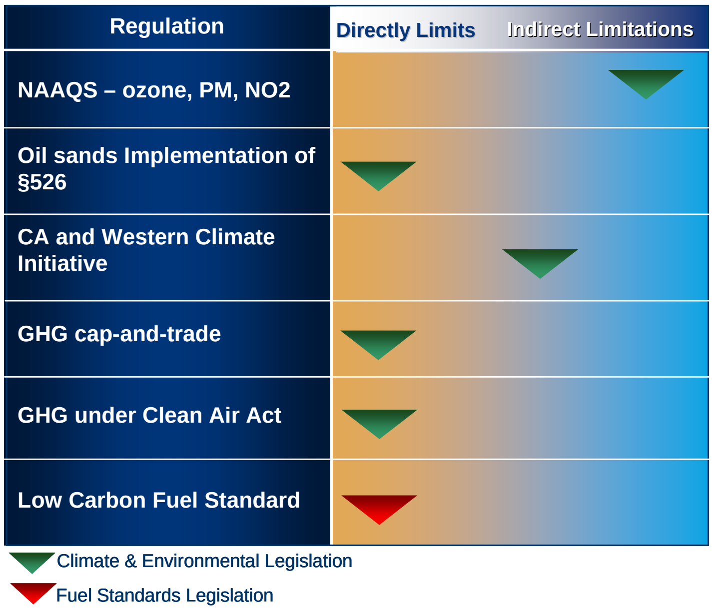
Figure 55: Western Canada Heavy Crude Oil Disposition (2008-2020)



Source: Wood Mackenzie

A supportive regulatory and policy environment is therefore required to reduce the US refining industry's dependence on unstable and unfriendly crude suppliers. The current legislative environment surrounding the US refining industry poses direct and indirect limitations on Canadian oil sands processing in the US, as shown in Figure 56:

Figure 56: Legislations posing direct and indirect limitations on Canadian Oil Sands processing



Source: Wood Mackenzie

Certain regulatory and legislative pressures against processing Canadian oil sands within the US can generate a range of detrimental potential impacts.

- Decreases US refiners' competitive position, as it limits access to this low cost source of crude oil supply
- Increases threat of product imports, as US refiners are less competitive

- Increases dependency of long haul crude imports from less friendly and unstable nations
- May lead to rationalization of capacity due to the limited availability of crude of equal quality
- Limits potential creation of US jobs supported by Canadian oil sands development which could grow from 21,000 jobs today to 465,000 jobs by 2035[17]
- Increase in greenhouse gas emissions, as it induces two-way long haul crude trade, due to Canadian oil sands crude being exported to Asia, whilst the US imports similar quantities of crude oil from regions such as the Middle East

A viable domestic refining industry requires the legislative support to access this key potential future supply of crude, as otherwise the opportunities to process this feedstock will migrate to other refining centers in emerging economies, so reducing the competitive position of the US refining industry and increasing our reliance on these long–haul imports.

5.2 Challenges, Opportunities and Next Steps

The US refining industry faces significant future challenges in supplying the evolving demand requirements of the US economy in an increasingly competitive global refining industry whilst accommodating a growing penetration of renewables.

The US industry is, however, dynamic and able to continue to deliver improved energy efficient refining operations and cleaner fuels for consumers, provided it is not unduly disadvantaged relative to its global competitors.

A key next step is for the impact of any future legislation to be closely examined to avoid unintended consequences that could unduly penalise the US refining industry, as this could result in the closure of US facilities which has wider negative effects (job losses, reduced energy security and so undermine the wider US economic development).

[17] *Source: Canadian Research Institute (2009). The impacts of Canadian Oil Sands Development on the United States' Economy*

6 Conclusions

6.1 Findings and Considerations

This study has found that refining in the United States is an industry that is strategically important, but one which faces a wide range of challenges which could have serious implications for both the sector and the country.

Wood Mackenzie's market analysis demonstrates that the US will be dependent on refined products for decades to come. The level of US refined product demand and the distribution of global refining capacity means it is impractical for the world's largest economy to meet its refined product demand without a significant domestic refining industry.

The US refining industry has the highest average level of technical sophistication and complexity globally, and is configured to optimally process medium-heavy, medium-sour crude oils to produce high quality specification transport fuels, petrochemical feedstocks and other refined products. The US refining industry is well placed to take advantage of emerging sources of crude oil supply from nearby, stable countries such as Canada. In doing so, the US refining industry can continue to support the nation's security of supply and minimize product imports.

The US refining industry adds significant economic value (approximately 1.9% of US GDP, more than 539,000 skilled jobs, average $94,000 income per employee) and enables productivity in many other US industries. The industry provides energy, fuel and feedstocks supporting many other industries, with approximately 54% of refining capacity integrated with petrochemicals. The industry makes major capital investments (more than $28billion over last 3 years) with impacts felt far beyond the immediate refining industry. The industry is also a key supplier to the US military for critical fuels, such as jet fuel for aircraft, so it is an important contributor to national security.

However, Wood Mackenzie considers the industry is facing the following significant challenges:

- Intensive compliance period in next 5 years, with the associated costs and administrative burden on achieving and demonstrating compliance against a complex set of requirements
- Risk that regulation damages US refining industry competitiveness
- Weak refining margin outlook
- Intense global competition
- Competitive threats particularly for PADD I & PADD III from gasoline imports / surplus global gasoline supplies due to maximization of diesel production in Europe and Asia Pacific
- Weak demand in PADD II, IV, and threats of imports from Asia into PADD V.

However, real opportunities exist for the industry. Regulators and policymakers should fully understand the US refining industry operates in a global context, such that competitive implications and unintended consequences of new regulation are better understood. Canadian oil sands offer a secure and cost competitive source of crude oil to replace existing declining heavy oil supplies. A more supportive policy environment would help the US refining industry to continue its mission to securely supply US consumers with the essential products they need in their everyday lives.

Appendix: What is Refining?

In its purest form refining is a link of physical and chemical processes that convert crude oil into clean finished products. Crude is made up primarily of hydrocarbons, which are chains of carbons atoms and hydrogen atoms linked together through bonds which vary in length. The chemical bonds that link these chains can be separated or combined through various processes. Essentially refining composes a series of sequential processes that take crude and separate, convert and purify it into usable clean products such as propane, gasoline, kerosene, and diesel. Each process contributes significantly to achieving the quality standards required in the final blended product. Refining is thus a vital link between crude oil producers and end users as it adds significant value to the petroleum industry by making crude oil usable to end users.

What do refineries process?

Feedstocks

A refinery's input is it's "feedstock"; this consists primarily of crude oil, as well as any additional components which are used in the refinery's processing units.

Crude Oil is a mixture of hydrocarbon molecules, with carbon chains of varying lengths. However, no two crudes are the same, with significant variation between crudes in terms of both density and sulfur content.

Density

The density of a crude determines whether it is classified as "light" or "heavy" . Density defines how heavy or light petroleum liquid is relative to water; it is measured in degrees of API gravity derived from a standard-gravity-based formula[18].

A low-density crude is often described as "light" crude. Higher density crude (with more heavy product) is often described as "heavy" crude. Heavy crude needs more sophisticated processes to transform it into useful finished products for consumers.

Crude oil classifications vary between parties, with not everyone using a standard gradation; however, a "light" crude typically has an API of >38^{o}; a "heavy" crude <28^{o}; and "extra heavy" crude (such as Canadian oil sands) will have an API of <15^{o}. The proportion of heavy product, such as residue, contained in a crude determines its density. How dense, or "heavy" a crude is depends on the relative long-carbon-chain content of the crude, compared to the shorter carbon chain molecules.

Sulfur Content

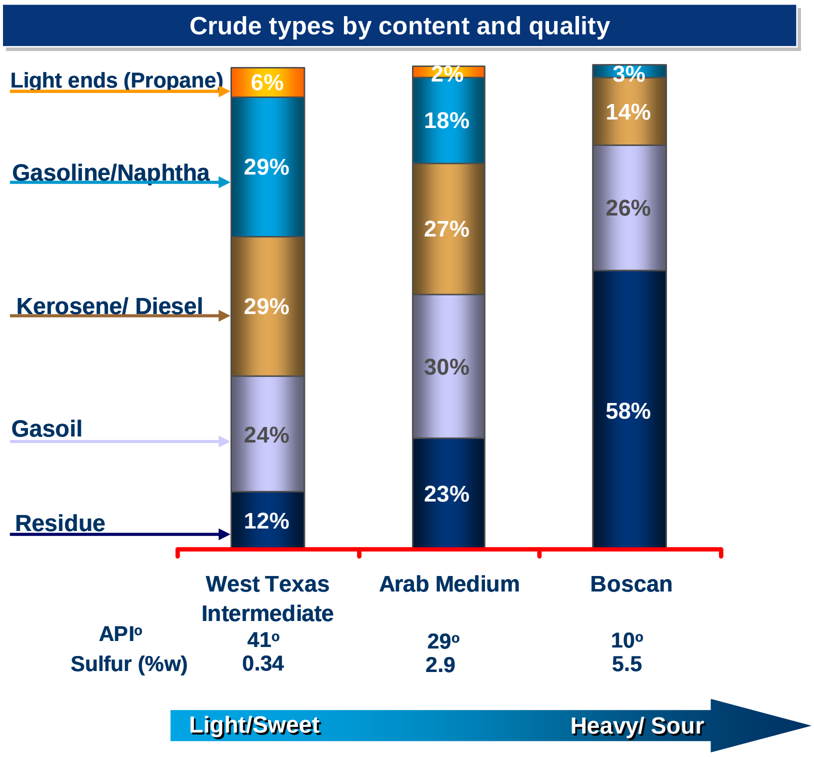
Every crude oil has naturally occurring sulfur as this is a common element contained within many crude oil types. This quality characteristic is important as special refining processes are required to remove the sulfur and generate clean finished products.

The sulfur content contained in each crude determines its classification into sweet, medium or sour. "Sweet" crudes contain low levels of sulfur, while "Sour" crudes contain a high level of sulfur. Sulfur needs to be removed during the refining and treatment processes to produce clean finished products. Sulfur content is therefore an important quality dimension of crude and is highly regulated in the product specifications.

Crude density and sulfur content qualities thus vary, with each crude resulting in different product content, as highlighted in the figure below:

[18] *API = 141.5/S.G. – 131.5*

Figure 57: Products from Different Crude Types



Source: Wood Mackenzie

What do refineries make?

Refining Outputs

The output of a refinery is referred to as it's "product slate", which is the proportion of each refined product obtained from a barrel of crude. This is usually calculated on a mass (tonnage) basis, such that it is clear that no mass is gained or lost through the refining process.

This product slate varies between refineries based on the crude input and refinery configuration. However, a typical refinery will produce some proportion of the following products:

- **Petroleum gas** is the lightest hydrocarbon chain, and includes methane, ethane, propane and butane; it is used for heating, cooking and making plastics. It is often liquefied under pressure to create liquefied petroleum gas (LPG) supplied by pipeline
- **Naphtha** is a light, easily vaporized, clear liquid used for further processing into petrochemicals; it is also an intermediate product that can be further processed to make gasoline.
- **Gasoline** is a motor fuel; it is rated by octane number, an index of quality that reflects the ability of the fuel to resist detonation and burn evenly i.e. resist "knocking"; the higher the octane number, the higher the quality.
- **Kerosene** is a liquid fuel used for jet engines or as an intermediary product.
- **Gasoil or diesel distillate** is a liquid used for automotive diesel fuel and home heating oil.
- **Heavy Fuel Oil** is a generic term for fuel which boils at higher temperature compared with diesel and gasoil, and specific grades of this type are primarily used to fuel ships (called 'bunker fuels'), or to provide industrial power – electric or otherwise.

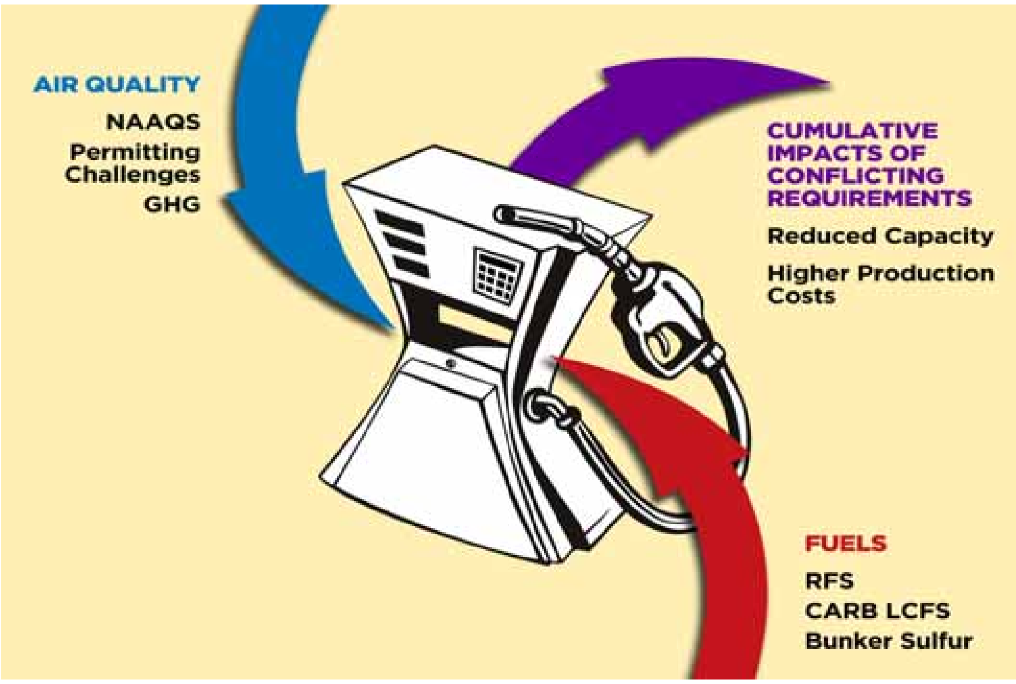
Product Quality

The finished products from the refinery as sold to the end-user have to meet specific qualities which are highly regulated and monitored. Product quality specifications vary dependent on the end-use and the country of their application. Within the US gasoline and diesel specifications vary across states and counties with some regions having more stringent specifications. Overall the most significant properties monitored per product are as follows:

- **Naphtha** is an important feedstock for industries further downstream of refining, such as petrochemical production. Sulfur content is an important limitation for most of these downstream processes.
- **Jet fuel** (kerosene type) is the most common fuel for turbine-engine aircraft. A maximum freezing-point and smoke point are specified, to allow cold-temperature use and reduce particulate emissions respectively.
- **Motor gasoline** is a blend of naphtha-boiling range material used in spark-ignition engines. Its key parameters include a minimum octane rating for adequate engine performance, a minimum sulfur specification for emission control purposes and a maximum vapor-pressure to minimize evaporation losses during fuelling, and to avoid problems with an engine's liquid fuel delivery system.
- **Diesel** must typically meet tighter maximum sulfur content and includes additional specifications, including a minimum 'cetane' rating. Cetane number is a measure of the fuel's ignition performance for use in compression-ignition engines, and is comparable to the better-known 'octane number' rating of gasoline road fuel.
- **Gasoil** has to meet a maximum sulfur content for environmental reasons.
- **Heavy fuel oil** specifications include a viscosity limit to prevent problems in pumping the fuel into the combustion chamber, and a maximum sulfur level for pollution control.

Refinery output must meet stringent quality and environmental specifications in order to bring product to market. Refining is a global industry, with global trade of both refinery feedstocks and products, and several key markets with differing product quality requirements for products dependent on regional legislation. Legislation continues to develop worldwide, with European and US laws leading the way towards increasing environmental controls and quality limits.

Figure 58: Conflicting Product Specification Requirements

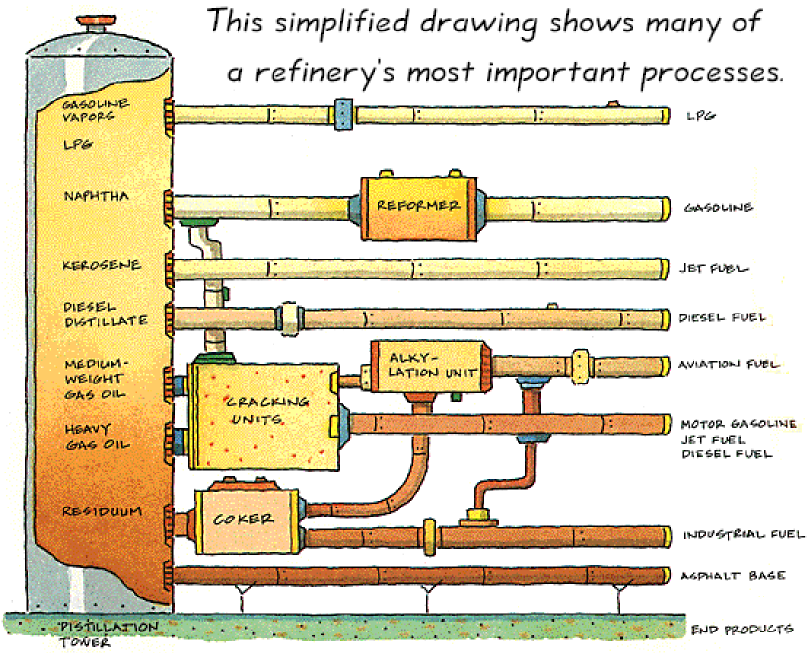


Source: API

How does a refinery make clean products?

A refinery converts crude oil into products suitable for consumption through the following four processes:

Figure 59: Key Refinery Processes



Source: API

Physical Separation

Separation is the process of dividing the long and short chained molecules contained within the crude oil mixture from each other, without any rearrangement of the molecules themselves or any altering the chemical composition of the chain.

Physical separation is conducted through distillation and composes the first process in any refinery as it is essential to separate crude oil into a range of streams that are then further fed into other processes.

Distillation focuses on separating components at atmospheric pressure ("atmospheric distillation"), or in a vacuum ("vacuum distillation") pressure through their respective boiling points. Different sized carbon chains have different boiling points – the longer the chain, the higher the boiling point. The output is a range of "fractions", or "cuts", with each fraction containing compounds which boil within a similar range; typical ranges for the major products are detailed in the figure below. Cut points are essentially the defined temperature at which each product is separated from the distillation process. The cut points or boiling points range define the product's quality and quantity. Refiners use cut points to control the yield per product and its quality.

Figure 60: Refined Product Cut Points

	Lowest boiling temperature	Highest boiling temperature
Gas	-	Room temperature
Naphtha	30ºC	200ºC
Kerosene	150ºC	250ºC
Gasoil	200ºC	360ºC
Residual oil	360ºC	-

Source: Wood Mackenzie

Conversion or Upgrading

Conversion or upgrading refers to the processes capable of altering the size and / or structure of the hydrocarbon compounds. Through these processes refineries have the capability to alter the natural "straight run" productions to achieve a greater volume of high value products; thus a refinery's conversion processes allow it to capture greater value in its production.

Upgrading is achieved through a variety of thermal and chemical processes, that include:

- Cracking – the process that breaks down longer carbon chains into shorter ones, either under the presence of heat ("thermal cracking") or a catalyst ("catalytic cracking").

  - *Thermal Cracking:* in thermal cracking, the hydrocarbons are heated, often under high pressure, in order to cause the decomposition of the heavier hydrocarbon molecules; this can be either steam cracking, vis-breaking, or coking.

  - *Catalytic Cracking* - can be either Hydrocracking of Fluidised Catalytic Cracking:

    - *Hydrocracking*: These units use hydrogen as the catalyst to break down the larger molecules. During the process, sulfur is also removed from the feedstock. Hydrocrackers are normally configured to maximize the yield of gasoil-range material. The process also produces significant quantities of low-sulfur naphtha and kerosene. Some hydrocrackers produce a low-sulfur residue material which can be upgraded, sold for further processing, or blended into fuel oil.

    - *Fluidized Catalytic Crackers (FCC*). These units are similar to hydrocrackers, except that no hydrogen is added. The absence of additional hydrogen results in a product slate of high-octane naphtha for gasoline blending, along with a highly-unsaturated gasoil range material which is low in cetane number and is only really suitable for blending into gasoil or fuel oil – it is not suitable for making diesel alone. FCC's do not perform any significant desulfurization, so either the feedstock or the products have to be hydrotreated to meet sulfur specifications. Some FCC units have been configured to maximise and separate high-value light olefin products such as ethylene, propylene and butylene.

- Unification or Combination – is effectively the reverse of cracking, as it involves the combination of shorter chain molecules into longer chained compounds to produce high octane gasoline - "alkylation" is a typical example.

- Reordering – is a process that alters the structure of the hydrocarbon molecule through the rearrangement of the hydrogen and carbon atoms; "isomerization" and "reformer" units are typical examples.

Treatment

Treatment is the process of removing the contaminants contained within crude oil fractions, such as sulfur. The removal of impurities is critical in preserving the functionality of a refinery's processing units, as some compounds will corrode the units and/or damage catalysts. The removal of impurities is also focused on ensuring that the products yielded by the refinery conform to environmental specifications.

Treatment processes vary depending on the impurities contained in the products. The types of impurities define the nature of the treatment processes used to remove them.

- *Hydrotreating* - is the process of removing sulfur by effectively substituting hydrogen for sulfur within the molecules of the feedstock; hydrotreating can be applied to the full range of products from the primary distillation process, and is able to extract significant quantities of so-called 'difficult' sulfur, which is chemically 'locked-in' to the feedstock molecular structure.

- *Desalting* - Otherwise known as "dehydration", this removes inorganic salts.

The output is a range of products which conform to the required specifications, such that the product can now be marketable. However, since these treatment processes are effectively mandatory for refineries, they add little scope for increasing the overall margin.

Blending

Blending refers to the mixing of hydrocarbon fractions to produce finished products with specific (higher value) performance properties in order to enhance the value of the refinery's overall product slate. Additives are sometimes used and include octane enhancers, metal deactivators, anti-oxidants and anti-knock agents.

What is refinery complexity?

Refinery Configuration

Each refinery is made up of a number of discreet units, each carrying out one of the processes outlined above. How many units there are, and how they are assembled together, is known as the refinery's structure, or "configuration".

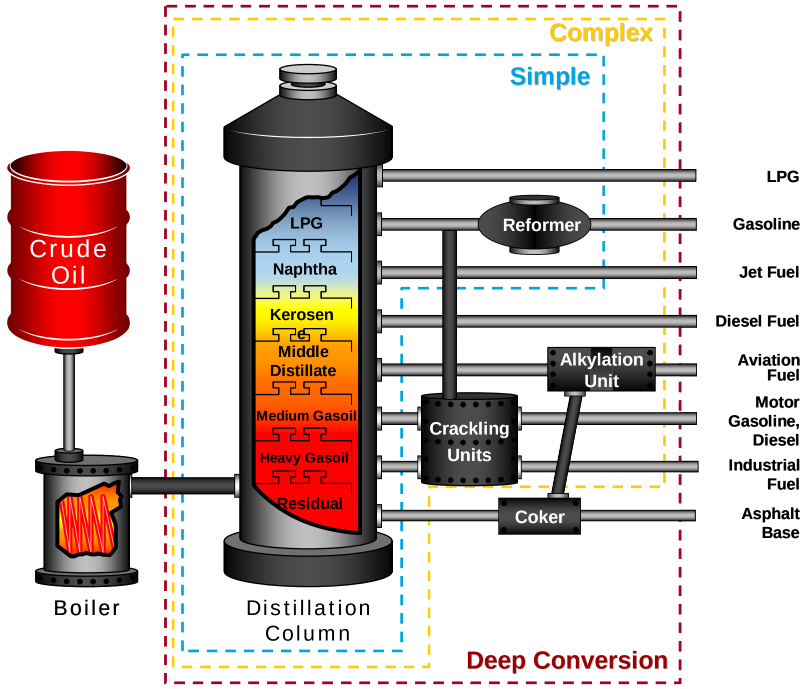
The way a refinery is configured varies significantly, as each refinery is designed with a different crude slate and product market in mind. For example, the most basic refineries may consist solely of a distillation unit; in contrast, a very complex refinery will consist of units conducting all the processes above, often with multiple variations (for example, a hydrocracking and a catalytic cracker).

Refining Complexity

Refineries are designed to process a specific range of crude qualities. The refining processes contained within a refineries' configuration or scheme determines its complexity. Refineries are categorized based on their configurations or level of technological sophistication through simple qualitative or quantitative assessments. Qualitatively refineries can be categorized as:

- **Simple:** composed of Crude Distillation Column, Vacuum Distillation Column and Reforming.
- **Complex**: is the combined configuration of a *Simple* scheme in addition to conversion units such as cracking processes (i.e. Fluid Catalytic Crackers, Hydrocrackers)
- **Deep Conversion:** considers the addition of conversion units such as Coking to a simple or complex configurations.

Figure 61: Refinery Complexity



Source: Wood Mackenzie

The quantitative assessment of refineries are conducted by a numeric calculation of the each of the processes contained within the refinery scheme through an applied weight to each of the secondary (i.e. non-distillation) units. There are various methods through which complexity can be determined, each varying in the weight assigned to each process unit. The most common is the Nelson Complexity index, which assigns a weighting based on each unit's relative cost in comparison to the distillation unit. The higher the number, the greater the refinery's complexity, and value addition potential.

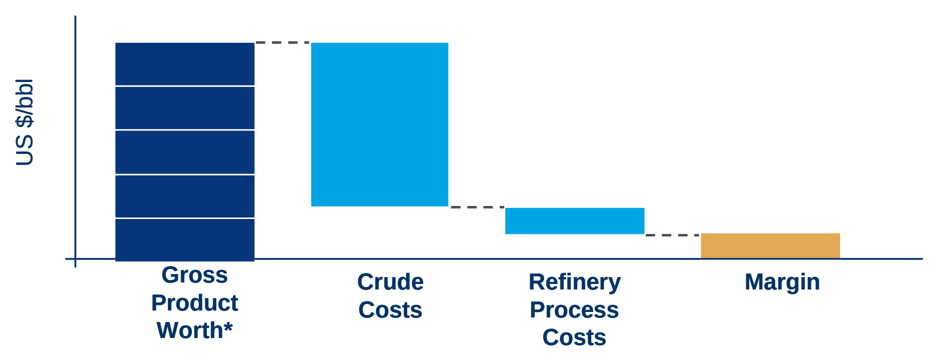
Understanding refining margins – the economic value of refining

Each refinery is customized to supply a given market. Refiners seek to do so in the most economically efficient manner through optimization of operations. The profitability of a refinery requires strategic economic decisions focused on maximizing stakeholder's best interest – those of the customers it serves, the environment, its employees and its shareholders.

Refinery economics begin with the crude selected to process and involves a detailed plan of the production it is set to supply. Availability and price of crudes are highly important, as crudes are purchases or inputs to refiners. Demand and prices of products are equally important; both the purchases and production impact revenue. Refiner's measure earnings from operations on the basis of the dollars per barrel a refinery generates after all purchases (costs and expenses) have been subtracted from product sales (revenue or gross product worth). Refiners determine the revenue or gross margin by taking the sum of each product yield, that the crude generates within a specific configuration, and multiplying it by the market value of each product. This definition describes what is called the Margin, that measures a refinery's profitability.

Wood Mackenzie's assessment of a refiner's margin is the net cash margin (NCM) which, beyond the profitability, captures a refinery's competitiveness. In financial terms this is equivalent to the earnings before interest, tax depreciation and amortization considering sophistication of infrastructure and access to feedstock's. Figure 62 below describes the simple terms of refining margins:

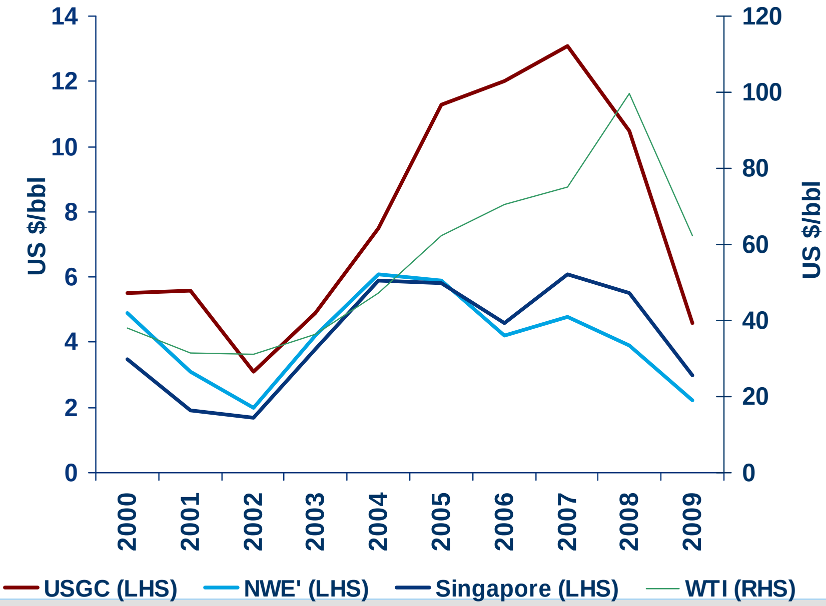
Figure 62: Refinery Margins



Source: Wood Mackenzie

Refining margins differ across regions as product market prices, crude costs and refinery operational expenses, (i.e cost of utilities) vary depending on location and complexity of a given refinery. The US Refining Industry is structurally more complex than North West Europe and Singapore refining centers. This has created a historic competitive advantage for the US refining industry allowing it to achieve superior margin performance.

Figure 63: Regional Refinery Margins Comparison



Source: Wood Mackenzie

Overall, a refinery's competitiveness is also impacted by other decisions such as its annual maintenance and or investment plan. These plans are key to a refiner's ability to maximize stakeholder's benefit as refiner's make capital investments to meet with the required environmental controls that keeps its process and products clean and to increase the refinery's infrastructure technology. These capital investment decisions enhance a refinery's technological sophistication and make its operations more competitive.

The elements of the business mentioned previously impact a refiner's decision on the optimal utilization at which to run the refinery. Refiner's continuously make adjustments to the crude throughput of the refinery as it maximizes the refinery's economic efficiency.

Wood Mackenzie's Proprietary Models

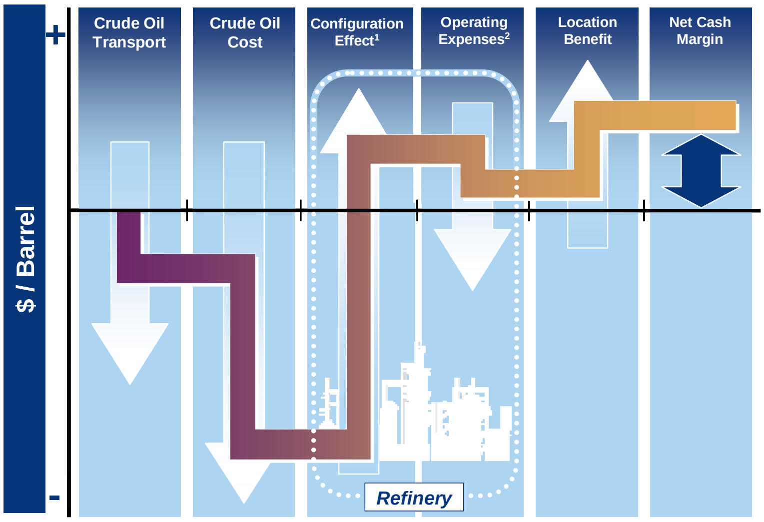
Refinery Evaluation Model

Wood Mackenzie's Refinery Evaluation Model (REM) is a global refinery database tool built on primary research over the past 30 years. The model contains a wide variety of publicly sourced information covering topics such as ownership, crude slate, configuration, capacities, and recent/planned investments. Where possible, this analysis of publicly available information is supplemented by data provided by refiners to validate the model. No information regarding actual crude acquisition costs, operating expenses, energy costs or actual product prices is included in the model, and all margin analysis reflects Wood Mackenzie's independent analysis and estimates.

The model provides an independent appraisal of refinery competitive position based on Wood Mackenzie's Net Cash Margin (NCM) methodology. This methodology comprises a detailed asset-by-asset analysis of the NCM performance and the key drivers of competitive advantage of all main fuels refineries with a crude distillation capacity in excess of 50-60kbd in the key refining regions of the world (Europe, Former Soviet Union and Africa, Asia Pacific and the Middle East, North America and Latin America)

By combining detailed capacity, infrastructure information and Wood Mackenzie's assumptions on oil product demand, prices, crude delivery costs, and operational expenses, as shown in the figure below, the model is able to provide an independent estimate of each refinery's NCM on a dollar per barrel basis. The NCM is calculated on an 'equivalent crude price' basis – e.g. assuming the same crude price at load-port for each refiner.

Figure 64: Refinery Evaluation Model Methodology Diagram



Net Cash Margin (EBITDA) = Gross Margin, *$/bbl* – Cash Operating Expenses, *$/bbl*

Source: Wood Mackenzie

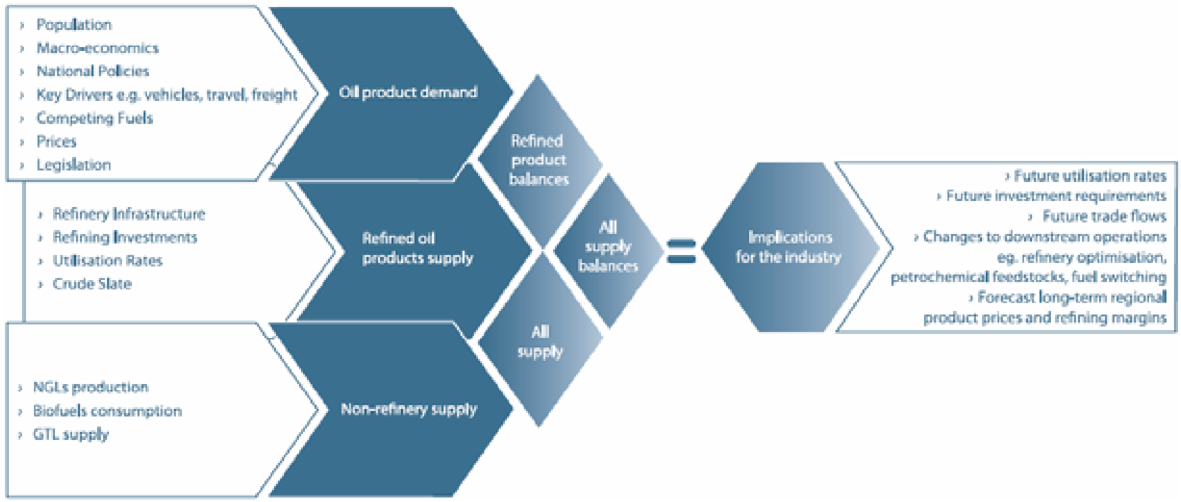
Product Market Service

Wood Mackenzie's Product Markets Service is a tool that provides a long-term supply and demand view of the oil product market by building up a global/regional picture at a country level. The analysis is developed based on historical data gathered through the IEA, EIA, and local statistics across key regions - Europe, Former Soviet Union and Africa, Asia Pacific and the Middle East, North America and Latin America

Our forecasts of the oil product market is conducted through a in-depth analysis of various proprietary models based on macroeconomic assumptions developed by our Macroeconomic experts: GDP, world oil demand, total liquids supply, supply/ demand balances, oil price trends. Demand is forecasted for the main products (LPG, naphtha, gasoline, kerosene, diesel/gasoil and fuel oil) as well as total demand - on a country basis. Aggregation of individual country forecasts represents >90% of total world oil demand.

A key input to the supply modelling is a detailed understanding of the refining infrastructure within each region for which we use our Refinery Evaluation Model. A supply picture is thus built by country / region to provide a global picture of future refined oil product supply, based on Wood Mackenzie assumptions and estimates of refinery utilization rates. All of these factors combined allow the construction of the supply / demand balances and resulting product price projections that reflect these balances and trade-flows per region.

Figure 65: Product Market Service Model Diagram



Source: Wood Mackenzie

About API

The American Petroleum Institute (API) is the only national trade association that represents all aspects of America's oil and natural gas industry. Our more than 400 corporate members, from the largest major oil company to the smallest of independents, come from all segments of the industry. They are producers, refiners, suppliers, pipeline operators and marine transporters, as well as service and supply companies that support all segments of the industry.

Although our focus is primarily domestic, in recent years our work has expanded to include a growing international dimension, and today API is recognized around the world for its broad range of programs:

- Advocacy
- Research & Statistics
- Standards
- Certification
- Education

About Wood Mackenzie

Wood Mackenzie is the most comprehensive source of knowledge about the world's energy and metals industries. We analyze and advise on every stage along the value chain - from discovery to delivery, and beyond - to provide clients with the commercial insight that makes them stronger.

With more than 600 professionals in over 20 offices worldwide, we analyze the assets, markets and companies operating upstream and downstream; in oil, gas, coal, carbon, metals and power generation. Having in-house teams dedicated to every sector of energy and metals means we are the only provider with an integrated perspective across the entire industry.

Wood Mackenzie's reputation has been built on the quality of our research. We are the only information provider that combines depth with breadth, allowing us to provide a genuinely reliable top level view of industry trends and their implications. We are consistently rated ahead of our competition for accuracy, reliability and integrity. Above all, clients value us for our authoritative industry knowledge.