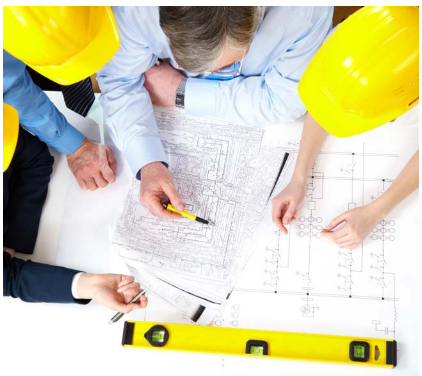
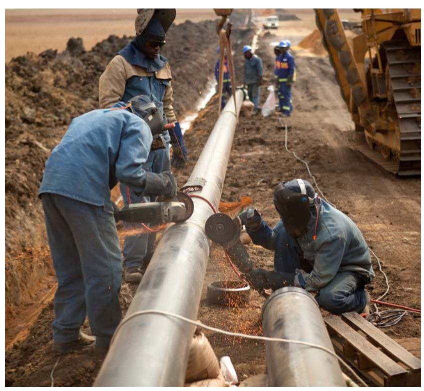
An IHS Energy / IHS Economics report

Unleashing the Supply Chain

Assessing the economic impact of a US crude oil free trade policy

March 2015





Appendix A: Summary of the *US Crude Oil Export Decision* report findings

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Additional resources

Appendices are available at www.ihs.com/crudeoilsupplychain. Additionally, the results included in this study are available on an interactive website that provides access to detailed data for the supply chain and congressional districts which can also be accessed through this website.

Study purpose

Building on prior work assessing the industry and macroeconomic impact of changing US policy to allow exports of US crude oil, this study examines the impact on an intricate and interdependent supply chain that supports the oil industry and has made the scale-up of tight oil production possible. The analysis considers 60 separate supply chain industries and provides granular impact analysis at the congressional district level to fully understand the economic and job growth impact across the nation.

This report draws on the multidisciplinary expertise of IHS, including upstream, downstream and macroeconomic teams across IHS Energy and IHS Economics. The study has been supported by a group of sponsors in numerous industries. The analysis and conclusions contained in this report are entirely those of IHS Inc., which is solely responsible for the contents herein.

Related reports

The "Great Revival" in US natural gas and crude oil production has caused significant market and economic shifts. IHS has provided continuing analysis of these developments, their impact on global oil markets, and their influence on the US economy and US competitiveness. Some of the current studies include:

$30 or $130? Scenarios for the Global Oil Market to 2020

These are momentous times for the oil market. We are in a world without OPEC—at least as we knew it. Companies and investors face a heightened degree of uncertainty about the future of oil supply, price, and demand. IHS addresses the uncertainty through a new study, *$30 or $130? Scenarios for the Global Oil Market to 2020*. IHS Scenarios provide a coherent, dynamic framework to discuss several potential futures for the oil market and to test decisions. Through interactive workshops, study participants participate in the scenario development and helping identify key supply, demand, and geopolitical drivers that will shape the oil market to 2020. Decision making is more robust when analysis takes into account more than one view of the future.

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America's New Energy Future

America's New Energy Future: The Unconventional Oil and Gas Revolution and the US Economy is a three-volume series based on IHS analyses of each shale gas and tight oil play. It calculates the investment of capital, labor and other inputs required to produce these hydrocarbons. The economic contributions of these investments are then calculated using the proprietary IHS economic contribution assessment and macroeconomic models to generate the contributions to employment, GDP growth, labor income and tax revenues that will result from the higher level of unconventional oil and natural gas development. Volume 3 in the study includes state-by-state analysis of the economic impacts and projections of additional investment in manufacturing as a result of these supplies.

See more at http://press.ihs.com/press-release/economics/us-unconventional-oil-and-gasrevolution-increase-disposable-income-more-270#.

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The following organizations provided support for this study. The analysis and conclusions in this study are those of IHS, and IHS is solely responsible for the report and its content.

Baker Hughes, Chaparral Energy, Chesapeake Energy, Chevron, Concho Resources, ConcocoPhillips, Continental Resources , Devon Energy, Energy Equipment and Infrastructure Alliance, EOG Resources, Exxon Mobil, General Electric, Halliburton, Helmerich & Payne , Hess, Marathon Oil, Newfield Exploration, Oasis Petroleum, Occidental Petroleum, Pioneer Natural Resources, QEP Resources, Rosetta Resources, and WPX Energy

Appendix A: Summary of the *US Crude Oil Export Decision* report findings

Origins of existing US crude oil policy

The ban on crude exports was adopted as part of a series of laws passed after the 1973 oil embargo and the four-fold increase in oil prices that followed. The embargo, followed by the Iranian Revolution in 1978–79, created great concern about the availability of oil supplies in a period of declining domestic production, political unrest, growing gasoline lines and consumer panic.

Price controls on crude oil and petroleum products had already been established prior to the oil embargo in an effort to fight inflation. The imposition of price controls and an effective price ceiling on crude oil and petroleum products were further legislated with the Emergency Petroleum Allocation Act (EPAA), passed a few weeks after the oil embargo. In many ways the EPAA was the key initiating legislation that placed the first official restrictions on total crude oil exports. In late 1973, crude oil and refined petroleum products were added to the commodity control list under the Export Administration Act of 1969, which placed significant restrictions on the export of crude oil.[1]

The Energy Policy and Conservation Act of 1975 was the next legislation to ban crude oil exports in response to the embargo and OPEC's price increases. The 1975 legislation was an omnibus bill that included everything from the establishment of automobile fuel efficiency standards, energy efficiency standards for appliances, and the strategic petroleum reserve to low-income weatherization assistance and policies encouraging utilities to burn coal instead of natural gas. The most contentious part, however, was the political battle over the extension of price controls on oil.

As for the ban on crude oil exports, the legislative record indicates that it was little discussed. But it was essential to keep the jerry-built system of price controls—on "old oil" and "new oil", "lower tier oil" and "upper tier oil", stripper oil, "released oil"—from collapsing under its own complexity. The ban prevented price-controlled domestic oil from being exported into the higher-priced world market "to escape domestic price regulation."[2] The crude oil export policies were added to and modified, particularly through amendments to the Mineral Leasing Act of 1920.

By the time the export ban was further codified in the 1979 Export Administration Act, the focus was on prohibiting exports to Japan of North Slope crude oil, which had begun to flow through the Trans-Alaska Pipeline in 1977. As one scholar wrote, "The legislative history makes clear" that the ban on oil exports "was directed against the export of oil produced from the Alaskan North Slope."[3] The prohibition on exporting Alaskan crude was eliminated by President Bill Clinton in 1996. President Clinton concluded that lifting the ban would improve economic growth, reduce dependence on foreign oil and increase jobs without an adverse impact on gasoline prices. But the volumes of North Slope production have fallen so low as to mean that exports have been only marginally economic in recent times. Nevertheless, the broader restriction persists even after its specific rationales—price controls and Alaskan oil—have disappeared.

The original controls on the unrestricted export of US crude oil also extended to refined petroleum products, as both were subject to the couple price control systems established in the early 1970s. Late in the 1970s, after a decade of experience with the cause, effect, and distortions caused by government market and price management, the political and academic sentiment shifted and the policies of the

1 Robert Bradley, *Oil, Gas, & Government: The US Experience Volume II* (Rowman & Littlefield Publishers, Inc., 1996), p. 770.

2 Oil and Gas Journal, October 6, 1975.

3 John. T. Evrard, "The Export Administration Act of 1979: Analysis of its Major Provisions and Impact on United States Exporters," *California Western International Law Journal, 1:1982, pp. 37-39*. The article concludes: "The prohibition on the export of domestically-produced crude oil is, therefore, an exception to the general policy of encouraging free trade. This prohibition, however, seems to lack any persuasive rationale."

previous decade were slowly dismantled. The culmination of this occurred during the first week of President Ronald Regan's administration with the issuance of Executive Order 12287, which formally and expeditiously stated that "all crude oil and refined petroleum products are exempted from the price and allocation controls adopted pursuant to the Emergency Petroleum Allocation Act of 1973."[4]

Following the removal of the 1970s-era price control system in 1981, the Department of Commerce coordinated an interagency study group called the "Task Force on Export Control of Refined Products" to evaluate the issue of quantitative restrictions on the export of all refined petroleum products. In October 1981, this interagency panel concluded the following regarding the free trade of all refined petroleum products:

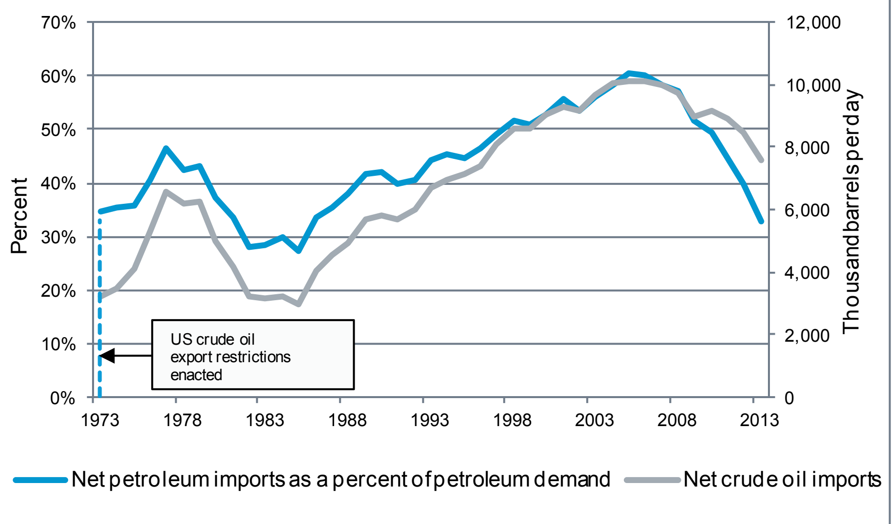
> "US consumers will benefit directly from the export of petroleum products because exports will permit US refineries greater flexibility in product output. The task force also advised that it anticipates the potential export market generally would be limited to spot situations resulting in increased US refinery efficiency.
>
> Free trade will benefit the balance of payment, take advantage of transportation efficiencies and allow the US to respond quickly to its potential international responsibilities."[5]

Following that, the ban on product exports was eliminated.

As for the crude oil export ban, it remains an artifact of an era when the federal government set oil prices, handed out import entitlements and allocated supplies. It was an era, as another scholar put it, when "the Federal Register became more important than the geologist's report." Direct government market management increased markedly. For example, the standard reporting requirements to what had become the Federal Energy Administration involved some 200,000 respondents from the private sector.[6] It was in that era that the federal government took on the responsibility of banning oil exports. But that time is long gone, along with the panic about shortages that defined it. All this provides the imperative to review the current crude oil export policy.

No matter the rationale of the 1970s policy prohibiting exports, there is scant evidence that crude export policy had much impact on US oil import reliance, although price controls, access to resources and demand trends probably did. In the years following the 1975 legislation, US oil imports have remained above 5 million B/D, fluctuating in response to domestic production, economic activity, and energy efficiency. Falling demand and imports during the early 1980s was related to a major recession, a shifting from residual fuel oil (RFO) to gas in the power sector, the impact of automobile fuel efficiency standards and (in the case of

US petroleum (crude oil and refined product) import dependence



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4 Federal Register, Volume 46, Number 26, Friday January 20, 1981, Executive Order 12287

5 Federal Register, Volume 46 Number 193, Tuesday October 8, 1981, Rules and Regulations 49109

6 Daniel Yergin, *The Prize: the Epic Quest for Oil, Money, and Power* (New York: The Free Press, 2009), p. 642.

imports) the build-up of new supply from Alaska. But that was a temporary downturn. Between 1975 and 2005, net imports rose from 36% to 60% of total US demand.

Since 2005, a steep fall has been registered in US import dependence – from 60% down to 27% for the first ten months of 2014. The multiple reasons for this include the drop in product demand from the Great Recession, the increase in domestic crude production from LTO and the increase in vehicle fuel efficiency. This dependence can be expected to fall further over the coming years as oil production increases and consumption remains relatively stable or declines.

Study case descriptions

IHS created two scenarios for the outlook for US oil production. The cases were developed based on the following: analyzing proprietary IHS databases and public data; utilizing proprietary forecast models and methodologies; and incorporating the perspectives and analyses of internal and external oil industry experts. The basis for the forecasts can be summarized as the following:

- The Base Production Case is predicated on the IHS central business planning forecast that provides a conservative view based on known defined oil and natural gas plays and assumes limited technical improvements from current performance.

- The Potential Production Case includes additional known but less well-defined areas of existing plays and moderate drilling performance and technology improvements in the future.

The US trade policy decision was then evaluated for each production case.

Basis for production cases and trade policies

Production cases

Trade policies	**Base** IHS central planning forecast. Conservative view based on defined plays and assumes limited industry improvements.	**Potential** Includes additional potential but less well defined areas of existing plays, moderate industry drilling and technology improvements.
Restricted Current policies (including condensate treatment as crude).	Base Production / Restricted Trade	Potential Production / Restricted Trade
Free Trade to broad group of trading partners including Europe and Asia (India, China).	Base Production / Free Trade	Potential Production / Free Trade

Trade policy decision

Difference in underlying US production forecast view

Note: Each case starts with the same IHS macroeconomic and international crude oil price forecast

After analyzing these cases, the Export Decision Report concluded the following:

- The growth in US crude oil production will come mainly from higher-cost unconventional resources, the development of which is predicated on the price levels of the last few years and the continued application of technology and innovation.
- Oil production growth will come primarily from the Bakken, Eagle Ford and Permian Basin areas, which produce a LTO or light sweet crude grade. This will result in increases in the volume of light oil in excess of the ability of US refineries to process it.
- Oil prices will be a primary driver of investment to increase production. Any actual or anticipated reduction in US crude prices because of export restrictions and other market supply-demand forces will prompt producers to reduce drilling in higher cost unconventional plays, resulting in lower production rates for LTO.

Forecasts have typically underestimated the growth of unconventional oil production. A main reason is the challenge of anticipating the speed of the industry's ability to apply new technology and innovation to continuously improve performance and lower costs.

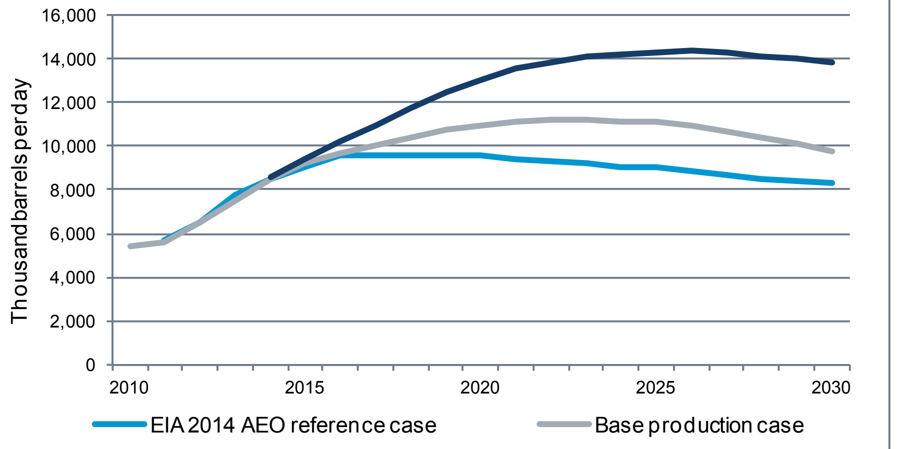
US crude oil production analysis

The upstream oil and gas producers in the United States have been revitalized by the emergence of unconventional "tight" oil resources. This has resulted in a substantial increase in US crude oil and total liquids production in the past half dozen years.[7] Total US daily production of crude oil increased from 5 million B/D in 2008 to 7.4 million B/D in calendar year 2013 and 9.0 million B/D by October 2014. This remarkable growth trend in crude output has profound implications for US and global oil markets. One critical issue concerns the capacity of the US downstream oil refining industry to efficiently handle increasing domestic output of light crude oil. Crude oil exports are for the most part banned.

The surge in US light oil supplies has already displaced similar quality imported light crude oil and is now testing refining capacity limits. Exports of crude oil under a free trade policy could resolve this issue, allowing oil producers to continue increasing their output without the wellhead discounts that are a disincentive to invest in increasing production Of key importance, it should be noted, is that wellhead price discounts do not translate into gasoline price discounts.

The US government's Energy Information Administration (US EIA) currently estimates crude oil output will peak at 9.6 million B/D in 2019 (compared to an April 2011 forecast of 5.9 million B/D) before production begins to decline.[8] [9] Although IHS anticipates that

IHS oil production forecasts compared to EIA Annual Energy Outlook (AEO) forecast



Note: EIA 2014 AEO released April 7, 2014
Source: IHS Energy, EIA
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7 Liquids include NGLs, condensate and crude oil.

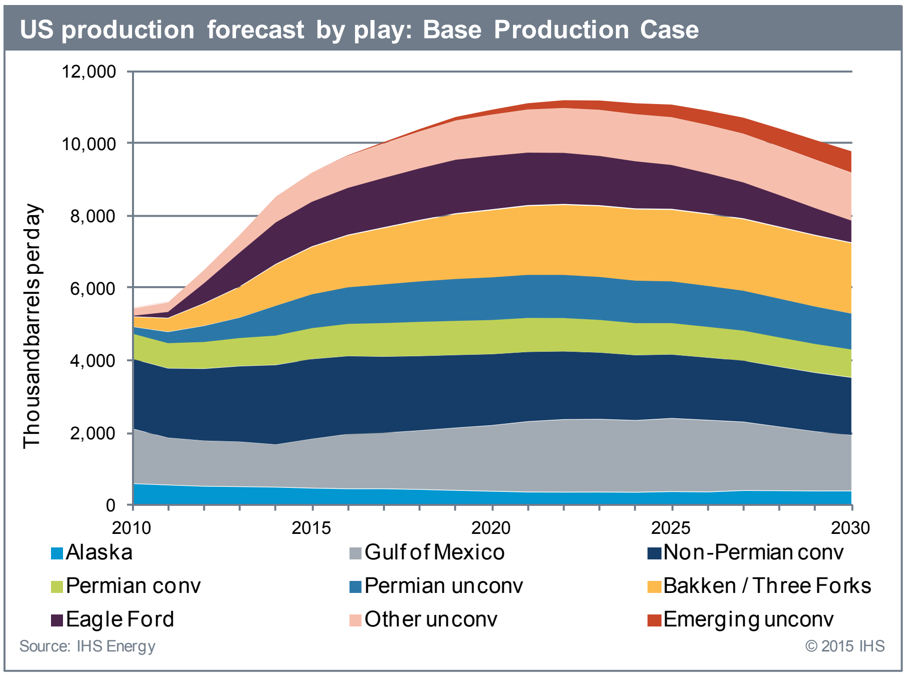
8 EIA Annual Energy Outlook, April 2011, Reference Case.

9 EIA Annual Energy Outlook, April 2014, Reference Case.

the next EIA Annual Energy Outlook will be closer to the current Short Term Energy Outlook, released in February 2015 projects US crude oil production to reach 9.5 million B/D by 2016.

However, our analysis, based on geology and production technologies, evolving oil plays and our database of producing wells in the United States suggest a different profile with a significantly higher peak output. The reasons are 1) improved performance at the well level; 2) an extensive inventory of drilling locations available from known defined and delineated reserves and contingent and perspective resources, particularly in tight oil or other unconventional oil plays; and 3) enhancements in producing technologies and the application of innovative operating practices.

The IHS Base Production Case projects increases in production through 2022, peaking at 11.2 million B/D.[10] The IHS Potential Production Case indicates a much higher output peak of 14.3 million B/D in 2026, with production declining only slightly by 2030.



IHS outlooks are the result of a fundamental bottom-up analysis that begins with each contributing geologic play. These play-level forecasts were aggregated to develop the total US crude production forecasts. Nine major contributing plays, shown below, represent conventional onshore and offshore plays, as well as unconventional plays. Numerous sub-plays exist within each of these nine plays, all of which were aggregated to this level for ease of presentation.

For the unconventional crude oil production forecast, IHS used proprietary models that incorporate a fundamental bottom-up approach.[11] The methodology includes the following parameters for each play:

- Number of drilling locations: The geographic size of the play, with risking for different production boundaries within each play, down-spacing and the number of production zones.

- Type curve: An expected or average production profile over time that will be replicated for the forecasted wells. Type curves are developed based on recent well performance data and known trends within the play, such as down-spacing.

- Drill rig count and drilling cycle times: Historic rig counts and well completions are tracked by play and forecasted based on the maturity of the play, known drill plans and total industry drilling activity. Rig cycle times reflect the average number of drill days and are forecasted based on actual performance with conservative improvements in drilling efficiency.

10 The forecast for US crude production provided to IHS clients has been revised to a peak production of 11.9 million B/D in 2027, since the Phase I report was published.

11 Play level capital cost, operating cost and production forecasting models similar to those used to generate content for the Vantage database. Type curve generation using PowerTools and Harmony proprietary software and IHS well and production databases.

Within several of these tight oil plays, producers have identified very large quantities of oil-in-place.[12] However, at this time, recovery rates are very low. Even the Potential Production Case projects that a relatively small percentage of oil-in-place will be recovered before 2030 with known technology. This reflects a further degree of forecasting conservatism for both production forecasts.

The methodology used here to assess the impact of the current, restricted trade impact included drilling activity reduction (less wells drilled) due to lower wellhead price levels and larger differentials between U.S. wellhead crude and international prices. As prices decline, some areas of tight oil plays become uneconomic. IHS maintains a detailed play-level cost and economic model, which provides breakeven costs that form the basis for determining the level of drilling reduction in each tight oil play. This reduced drilling leads to lower production through the production model above.

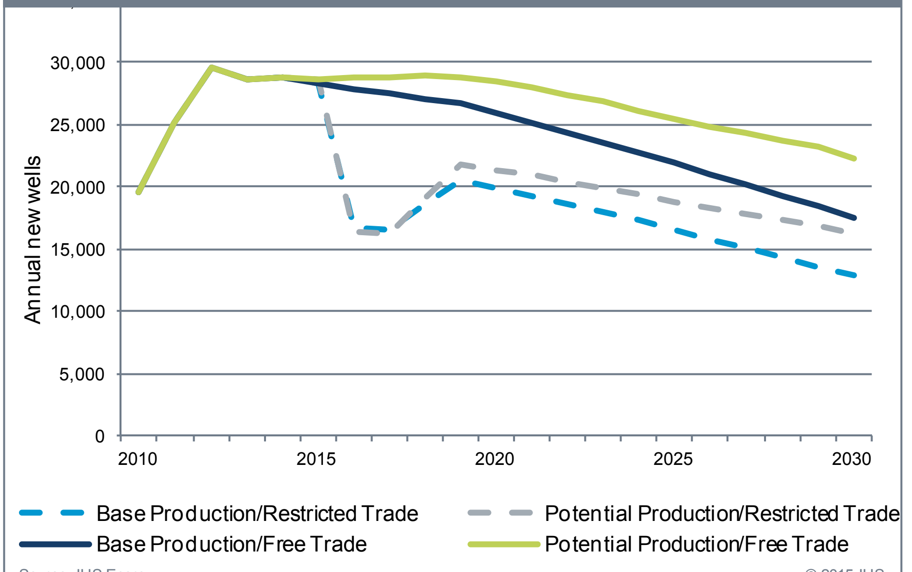
The price of oil and the expected trajectory of future oil prices are key determinants of investment in oil production. Because unconventional oil is typically at the high end of the industry's cost curve, unconventional plays are particularly sensitive to price expectations. For the past three years, the benchmark Brent oil price has stayed above $100 per barrel, providing the market incentive to explore and develop US tight oil plays.

The assessments of the Base Production Case and Potential Production Case have been predicated on long-term average prices in a $90-100 per barrel environment, and assuming the industry will be able to export oil that is in excess of domestic light crude refining capacity. At various points, market rebalancing will periodically drive prices lower. Near-term market prices have fallen below this price level due to an oversupplied market.

The US refining industry is reaching the limits of its ability to process the volumes of light tight oil (LTO) being produced. Thus, the general ban on exports of crude oil is discounting LTO prices from where they would otherwise be, negatively impacting producers' revenues, cash flows and profits. The LTO price discount is anticipated to range from $5-15 per barrel depending on which tier of the US refining system is required to process the surplus LTO. The level of price discounting experienced by producers at the well head is impacted by both the LTO refining discount and also the location of that production. Due to the inland location of many unconventional plays and the concentration of refineries in coastal regions, logistics costs to transport production to the end refining market often exceeds $10 per barrel. This combination of domestic refinery demand saturation and elevated logistics costs places a large portion of expected tight oil production at a particular sensitivity to price distortions and associated volatility.

Drilling activity reached a plateau of nearly 30,000 new oil wells per year in 2013. In the unconstrained free trade policy environment, the number of new wells is expected to remain between 25,000 and 30,000

Impact of trade policies on drilling activity in Base and Potential Production cases



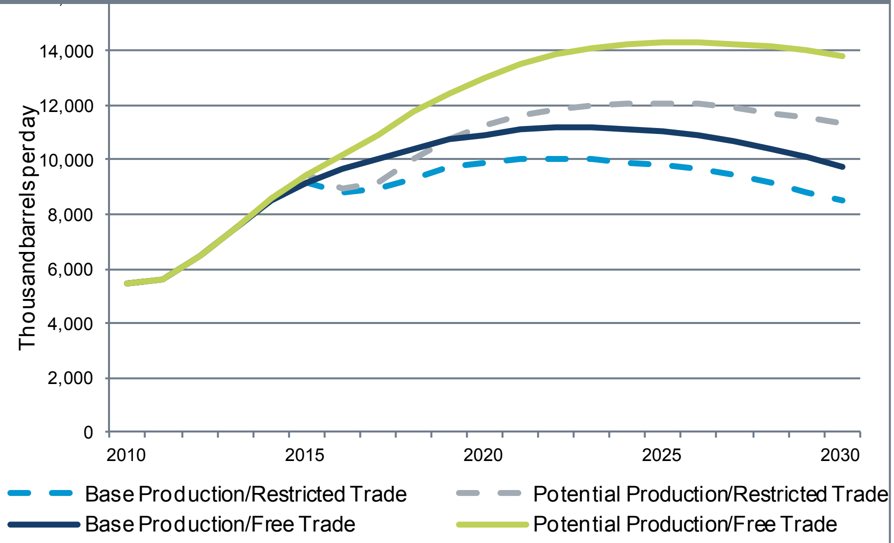
Source: IHS Energy © 2015 IHS

12 Oil-in-place refers to the total hydrocarbon content of an oil reservoir and is not to be confused with an oil reserve, which is an estimate of the economically recoverable portion of a reservoir.

through 2020 before tapering down to between 17,000 and 23,000 new wells by 2030 in the Base and Potential Production Cases, respectively. In contrast, we expect the number of wells to decrease more significantly with restricted trade policies in place because of lower wellhead crude prices and reduced investment.

These reductions in drilling will limit further production increases. A decline in forecasted production is expected as early as 2016. The cumulative impact will be a projected loss of over 1 million B/D in the Base Production Case if trade continues to be restricted and a loss of over 2 million B/D in the Potential Production Case through most of the forecast period.

Impact of trade policies on production in Base and Potential Production cases



Source: IHS Energy © 2015 IHS

US refining system and LTO processing limitations

A primary focus for the Export Decision Report was to provide an in-depth assessment of the US and North America refining systems. Specifically it looks at the natural ability of the existing system to process specific grades of crude oil (namely light tight oil), what types and the pace of investments that are likely to be made to process additional LTO, where and when the limits of the US refining system to naturally absorb LTO will be reached, and what type of crude oil price discounting can be expected when surplus tight oil is processed in refineries designed for medium and heavy grades of crude oil.

The United States has the largest refining capacity of any country, with 133 operating refineries and a combined crude oil distillation capacity of 17.9 million B/D.[13] When the NAFTA partners—Mexico and Canada—are included, total refining capacity for North America increases to 21.8 million B/D. The US refining system is characterized not only by the number and size of refineries but also by a high number of world-class, high-complexity, full-conversion refineries with a substantial degree of petrochemical and specialty products integration.

US demand for the heavy portion of the barrel is minimal. Current US demand for the heavy portion of the barrel directly usable as finished products—lubricating oils, waxes, asphalt, residual fuel oil (RFO), and petroleum coke—is less than 5% of total US crude oil demand. The complexity and sophistication of the US refining system is driven by market forces that require conversion of anywhere from 30%60% of the crude oil barrel (the heavy portion) from products with almost no demand into high-demand, finished transportation fuels, including gasoline and diesel.

13 Stream Day Capacity or Maximum Capacity Averaged over 30 Days, Annual Average Capacity is typically about 95% of Stream Day Capacity.

Key region refining configurations (million barrels per day)

	Total refinery capacity	Cracking configuration	Coking configuration	Percent cracking	Percent coking
United States	17.9	4.6	12.5	26%	70%
Europe	15.7	11.0	2.9	70%	18%
China	11.0	2.1	8.5	19%	78%
India	4.4	1.7	2.7	37%	62%
Russia	6.0	2.5	1.7	42%	29%
North America (inc. Mexico)	17.9	4.6	12.5	26%	70%

Source: IHS Energy

A point of comparison in table is the refining systems of Europe and the United States. Even though both markets have a high demand for light clean products (LCP) the European refining system was largely designed around light sweet North Sea and North African crude oils[14]. Due to this, Europe's refineries never made large-scale investments to upgrade their cracking refineries into coking refineries. The United States, by contrast, invested heavily in its refining system to process heavy Canadian, Mexican and Venezuelan crude oils and needs a much higher percentage of coking configuration refineries to produce the same LCP output. Another market factor over the past two decades was that RFO demand remained higher in Europe due to less RFO inter-fuel competition from low-cost natural gas and coal compared to the US market.

North America PADDs and Regions

Source: IHS Energy

For practical and logistical purposes, US petroleum supply and distribution data is subdivided into five Petroleum Administration Defense Districts (PADDs). Canada is subdivided into three refining regions, while Mexico is defined by one large refining region. Mexico is more isolated than the United States and Canada, as Mexico contains no cross-border crude oil pipelines with the United States and only small refined-product interconnections. In contrast, the United States and Canada represent a truly integrated crude oil and refined product distribution system, with numerous cross-border pipelines connecting the two countries, as well as growing rail (and road) connections.

14 Light Clean Products, used to describe the combination of gasoline, jet fuel, and diesel.

Due to a variety of factors such as refined product demand, local and regional availability of grades of crude oil, marine access and pipeline infrastructure, the refining system of each region has evolved differently over decades and often contains markedly divergent competitive positioning and footprints in terms of capacity, prevalent configuration type, and historic grade or crude slate.

Each region of the North American refining system plays a role in balancing the total inflows and outflows of crude oil into the US refining system. However, given the impending LTO oversupply, the importance of each refining region in North America is not proportional. PADD III in the Gulf Coast—with just over half of total US refining capacity—is expected to take center stage in coming years.

North American refining configuration
(million barrels per day)

Region	Number of refineries	Total distillation capacity (DC)	Total DC @ 90%	Topping / HDS	LSW cracking	LSR/MSR cracking	LSW coking	LSR/MSR coking	HSR coking
United States									
PADD I	9	1.3	1.1	0.1	0.8	0.1	-	0.3	-
PADD II	26	3.8	3.5	-	0.7	0.4	0.3	0.7	1.8
PADD III	52	9.2	8.2	0.3	1.1	0.7	0.6	3.8	2.7
PADD IV	16	0.6	0.6	-	0.2	0.1	-	-	0.3
PADD V	30	3.0	2.7	0.3	0.4	0.3	-	1.2	0.8
Total United States	133	17.9	16.1	0.8	3.1	1.5	0.9	6.1	5.6
Canada									
Eastern Canada	4	0.8	0.7	-	0.7	0.1	-	-	-
Ontario	5	0.5	0.4	0.1	0.1	0.2	-	-	0.1
Western Canada	8	0.7	0.6	-	0.3	-	-	-	0.3
Total Canada	17	1.9	1.7	0.1	1.1	0.3	-	-	0.4
Total North America	**150**	**19.8**	**17.8**	**0.9**	**4.1**	**1.8**	**0.9**	**6.1**	**5.9**

Source: IHS Energy

Particularly as they relate to substituting light domestically produced crude oil for heavier imports, decisions made by Gulf Coast refiners and the balancing steps taken by 1520 key refineries in the Gulf Coast region will drive the price signals and production impacts as the oversupply develops and persists. The role of refining centers outside of PADD III in affecting the North America crude balances and oil price is largely diminished after demand is initially saturated with domestic production.

PADD III is the largest, most diverse and sophisticated refining region in North America and represents the premier refining hub in the world. The Gulf Coast stands out in terms of the number of refineries (52), total distillation capacity (9.2 million B/D), significant petrochemicals integration and the presence of several truly world class facilities. To put this in perspective, PADD III alone is equivalent to 85% of the refining capacity in of all of China, which has the second-largest refining system in the world. Both with and without revisions to US trade policies, PADD III is expected to become the epicenter of LTO crude substitution, replacing sour imports with LTO and driving the crude oil price signals that IHS anticipates will emerge over the next 1224 months.

PADD III refined product demand stands at 3.3 million B/D, equivalent to only about one-third of the region's refining capacity. This large difference between refining capacity and demand enables PADD III to 1) cover most refined product deficits for the remainder of the United States, and 2) serve as the largest exporter of refined products globally. Most of the major refined product systems that supply the Midwest and East Coast originate in PADD III, coming from Houston, Beaumont or Baton Rouge. As a standalone nation, PADD III would be number one in terms of refined product exports.

A key point is that market and pricing dynamics are largely a function of crude processed and of decisions made by refineries to balance the availability of crude oils, versus the ability of the refining system to efficiently process those available crude oils. The 52 Gulf Coast refineries will be the main drivers of this dynamic. The market and pricing dynamics are complex, as all grades—domestic and imported—are in play. IHS expects these decisions to be driven by the economics of substituting one crude for another and by the size of the processing penalties incurred, as increasing volumes of lighter oil are processed in refineries that have been reconfigured for heavier and more sour grades of crude oil.

As LTO volumes have increased, the downstream industry has shifted quickly to optimize its refineries to capture the available margin from crude oil grades that are in oversupply or logistically disadvantaged and depressed in price. The increasing consumption of domestic LTO in the refining system is referred to as a crude substitution in which LTO replaces traditional crude oils. Crude substitution refers to the simple replacement of one crude grade with another.[15] The quality difference between the two crude oil grades, in conjunction with the refinery internal capacities and constraints, dictates the products that can be produced. Based on the product price and the crude price, the profit from each crude oil can be estimated. A refinery will make a crude substitution only if the profit improvement warrants it.

The increasing substitution of LTO is swiftly moving through a series of tiers, with each tier imparting a potentially more significant economic loss for the refiner. To overcome the loss and incentivize processing requires a more significant LTO price discount. While actual crude substitution varies by refinery, depending on configuration, scale, location and other factors, a generalization is useful in considering the overall refining system but particularly the PADD III supply and demand balance and pricing response. The LTO substitution tiers (or ways to process more LTO) include:

- **Tier 1 – Displacement of Light Crude Imports:** Replacement of light crude imports with similar quality light crude domestic production. On a quality basis this represents a like-for-like substitution and requires only a small amount of price discounting to incentivize, on the order of $0.50-$1.00 per barrel.

- **Tier 2 – Optimum Processing in Light / Medium Sour Capacity:** The substitution of light and medium sour quality imports for light sweet domestic production, where the refinery in question has the ability to process the entire light domestic barrel into finished products at full utilization. A crude discounting level of $1-$2 per barrel, or just the quality difference between the two crudes being considered, is necessary to incentivize this type of substitution.

- **Tier 3 – Suboptimum Processing in Light / Medium Sour Capacity:** A similar quality substitution as Tier 2 where the refinery in question does not have the ability to process the entire barrel into finished products at full utilization. The processing of light domestic surplus production results in the refinery producing increased volumes of lower value light and heavy naphtha that is sold at a discount to finished gasoline. A crude feedstock discount of $2-$4 per barrel is required to incentivize this tier of substitution.

- **Tier 4 – Suboptimum Capacity Reduction in Medium Sour Capacity:** As a final step, refiners have the option of processing additional LTO to the point that the higher naphtha distillation yield results in a lower utilization (known as a reduced crude charge rate). At this point, the refinery incurs the lost opportunity cost of forgoing the medium sour crude margin, as the total crude rate is reduced. An example of this is provided in the table below, which shows that adding 25% LTO to the refinery crude charge results in a total crude charge reduction of 15%. The lost margin associated with the lower utilization must be recovered by lower LTO pricing. When the US refining system enters this domestic crude substitution tier the price discount to incentivize this market behavior can exceed $15 per barrel.

It is important to note the increases in LTO runs over the coming years. A portion of this additional LTO will be processed in new topping capacity, but our analysis indicates that supply will outpace demand for

15 Refineries use sophisticated models to simultaneous optimize multiple crude purchase, product production and refinery operations to maximize profits.

the next several years, moving the Gulf Coast and the entire North American refining system into a structural Tier 4 operating mode. Our analysis of new refinery investments covers only what we think is economically competitive and has good probability of occurring.

Suboptimum capacity reduction in medium sour capacity (Tier 4)

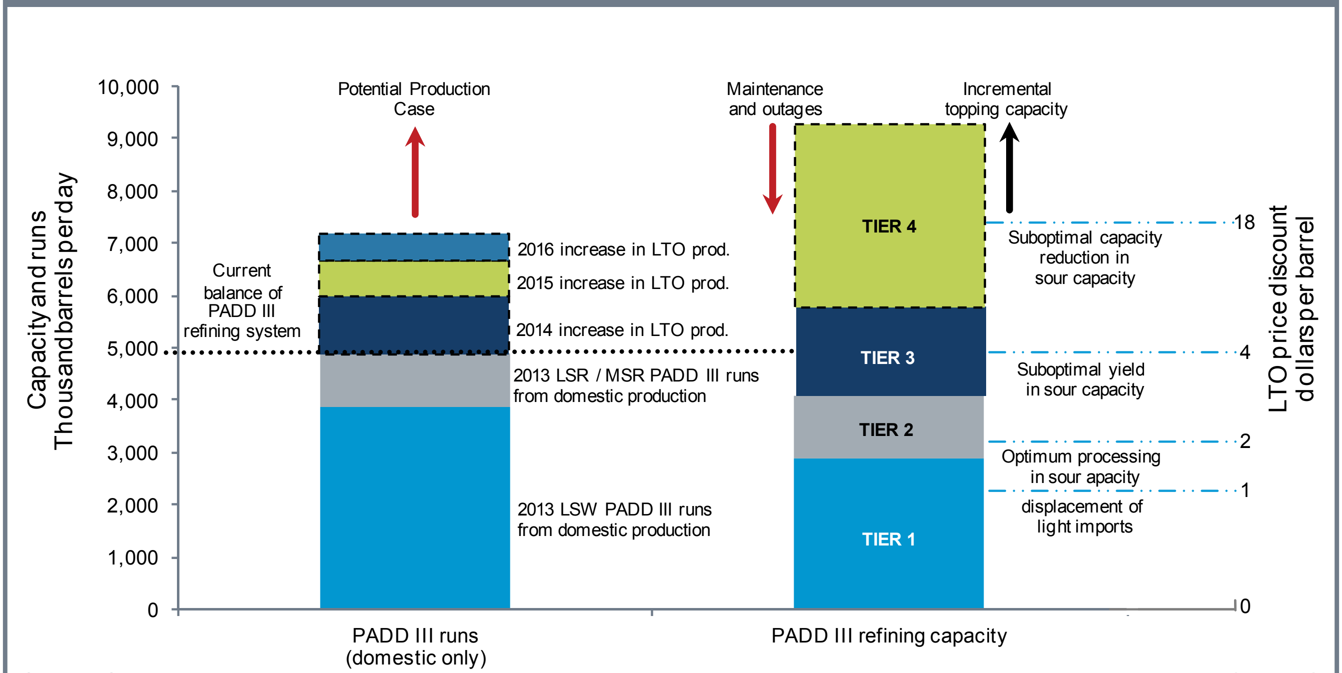
	Crude charge (barrels per day)	Naphtha yield (percent)	Naphtha yield (barrels per day)
Full medium sour processing			
Medium sour crude	200,000	25%	50,000
Light tight oil	0		
Total	**200,000**		**50,000**
			(Limiting capacity)
Light tight oil substitution for medium sour			
Medium sour crude	120,000	25%	30,000
Light tight oil	50,000	40%	20,000
Total	**170,000**		**50,000**
			(Limiting capacity)
Light tight oil percent of capacity	**25%**		
Crude charge reduction	**15%**		

Notes: Illustrative only; values rounded for presentation.

Source: IHS Energy

The following figure shows the US Gulf Coast processing tiers on the right side, with an estimated capacity to process LTO for each tier on the left side. The approximate LTO price discount associated with each tier is provided on the right axis. The price discounts for Tier 1 through Tier 3 are modest, rising from $14 per barrel, but increase sharply for Tier 4, to $15 per barrel. Current domestic crude runs for these refineries and the expected total LTO growth over the next few years are depicted on the left side of the figure. The remaining area—the arrow on top of the PADD III Runs column—includes imported crude oils (not shown). This figure supports IHS' conclusion that the Gulf Coast refining system is already operating in Tier 3, which is consistent with the level of LTO price discount observed in the market (maintenance periods aside) today.

US gulf coast refinery processing tiers and corresponding LTO discount



Source: IHS Energy

Continued growth in US production will drive deeper crude oil discounts (though not gasoline discounts), as less and less efficient refinery processing tiers are breached in an effort to process more and more LTO. The inability to export light crude oil creates an LTO price discount that provides a clear price signal for investments that is negative for producers and positive for refiners. The result is that refiners see significant risk in the form of potentially stranded investments if the export policy were to change, while producers see a risk that refiners will not invest and that prices will decline further. This market dynamic, which IHS terms Gridlock, effectively acts like a traffic jam.

Gridlock is driven not only by price signals between the US upstream (production) and downstream (processing and marketing) industries, but also by a heightened degree of uncertainty about future crude oil trade policy. This means investment to relieve system congestions will be slower in coming years, compared with a business environment of greater confidence about present and future policies.

Uncertainty about future US crude export policy exacerbates this Gridlock. Deeply discounted crude (well below the level of LTO price advantage from free trade) will significantly reduce the amount of capital that upstream participants will invest in additional drilling and production, eventually negatively affecting both US economic growth and production. Initially, some downstream participants have responded to the domestic crude discount and available export markets by adding select simple topping capacity. But they also have to recognize that a change in export policy could strand investments of this type. The United States will continue to import large quantities of heavy crude oil, but a liberalization of oil exports would allow crude to efficiently move to the highest-value markets, unlocking the Gridlock while providing greater benefits to the US economy and consumers.

Trade policy impact on crude oil and gasoline prices

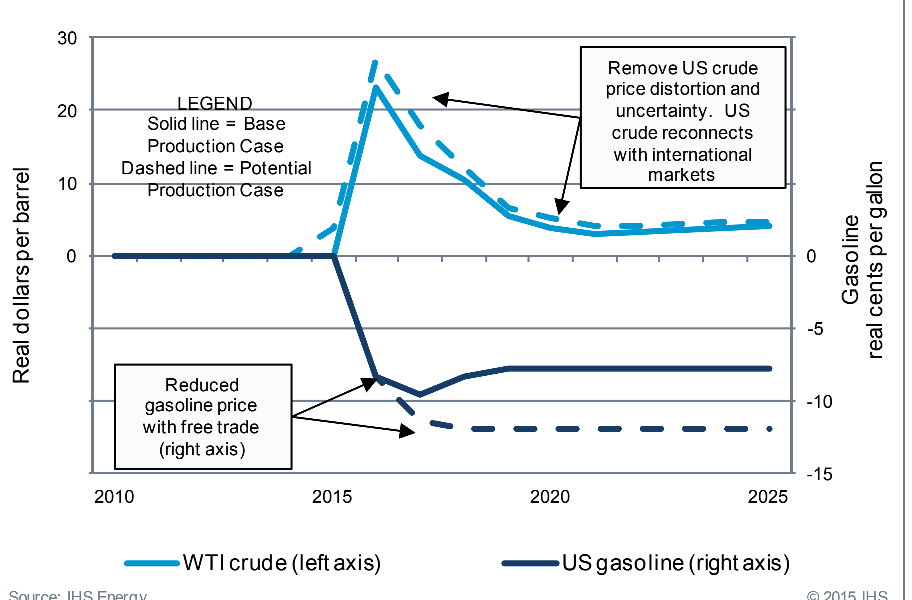
The price relationship between US crude oil and US gasoline cannot be considered in isolation from world markets.

Gasoline's tie to international crude through the free trade of refined products is based on changes in the global Brent price. But under the restrictive trade policy for domestically produced crude oil, the distorted pricing of US crude, evident in the LTO discount, has a fundamentally different pricing dynamic.

The shift of the US crude market to free trade will have the effect of lowering US gasoline prices. That is because as new crude supply is added to the global market; the international price of crude will fall, putting downward pressure on US gasoline prices. At the same time, free export of US crude oil would actually increase domestic crude prices, which will rise to meet higher international price levels, generating additional US output and adding to international crude supply.

The net gasoline and crude price changes for both Free Trade Cases is provided in the figure. This shows the dual

Free trade impact on US crude and gasoline



Source: IHS Energy

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benefit of free trade: producers receive greater price certainty and somewhat higher crude prices and consumers receive lower gasoline prices as a result of the direct effects of greater global crude supply. Specifically, free trade would:

- Reduce gasoline prices paid by US consumers by an estimated 8 cents per gallon (Base Production) and 12 cents per gallon (Potential Production) over the entire forecast period. As US crude production increases by another 12 million B/D under free trade, lower prices in the global market result in lower US gasoline prices.
- Remove the price uncertainty associated with the discount on US light crude oil, generating the economic benefits of higher crude production, increased investment, higher employment, higher household income, an improved US petroleum trade balance and increased tax revenues.