Commentary

Refining Value Chain Optimization Trends in the United States: The Shale Factor

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Shale oil or light tight oil (LTO) is a sweet, less viscous crude oil, with an average API gravity range of 35º API to 55º API, and a sulfur content as low as <0.2%. After the Global Financial Crisis in 2008, the vast reserves of LTO (Figure 2) in the geological formations such as the Permian, Eagle Ford and Bakken became more economical to produce, mainly due to technological innovation and easy access to low-cost financing. Independent producers took the lead and excelled in developing efficient, repeatable upstream development workflows, and quickly brought wells to production without going through long and exhaustive bureaucratic processes. Technology, access to low-cost debt and high crude oil price environments led LTO production to peak at more than 8 million barrels per day (MMb/d) in early 2020 (Petroleum & other liquids n.d.). As the United States’ (U.S.) domestic production of crude oil and petroleum products began to rise, net imports of petroleum into the U.S. dropped to negative territory (Figure 1). This transformed the U.S. from a net importer to a net exporter of petroleum.

**Figure 1.** The impact of tight oil production on U.S. petroleum trade flows.

![Graph showing the impact of tight oil production on U.S. petroleum trade flows.](image)

Source: KAPSARC analysis of EIA (2020) data.

**Figure 2.** Proven U.S. tight oil reserves.

![Graph showing proven U.S. tight oil reserves.](image)

Sources: EIA (2017, 2018).
LTO has a higher naphtha content and very low heavy residue yields compared to some imported light oils, such as Arab Light and West Africa Bonny Light. Our analysis of data published by the U.S. Energy Information Administration (EIA) shows that refineries have gradually increased processing LTO crudes ever since the advent of LTO. Based on the EIA’s July 2020 data, about 37% of the U.S. refinery crude diet was composed of LTO, while 23% was conventional. About 40% of refinery crude intake is imported heavy oil. After the U.S. lifted the export ban on oil in 2015, it exported some 2.7 MMb/d of surplus LTO production.

Figure 3. Share of domestic crude production in the refining sector.

![Graph showing share of domestic crude production in the refining sector.]

Source: KAPSARC analysis of EIA data.

Over the last two decades, many U.S. refiners, mainly in the U.S. Gulf Coast (PADDIII), invested heavily in crude oil flexibility projects to process broader slates of crude oil, such as heavy sour and Canadian heavy oils. Western Canadian Select (WCS), a benchmark for Canadian heavy sour crude oils, has been traded historically at an average discount to West Texas Intermediate (WTI) at the Cushing terminal in Oklahoma of more than $15 per barrel (Figure 4). Aside from quality, one of the main factors behind this wide differential is the lack of pipeline takeaway capacity to the refining hubs such as those in the U.S. Gulf Coast (USGC).
Refiners, mainly in the USGC, buy their crude feedstock based on the WTI benchmark, which is normally traded at a discount to Brent, whereas refined products are traded based on New York harbor pricing, which is based on Brent. Thus, the greater price differential between Brent and WTI results in higher refining margins. As shown in Figure 5, the crack spread margin (the overall pricing difference between a barrel of crude oil and the petroleum products refined from it) of Canadian heavy oil (WCS) is higher than the WTI grade oils. As a result, USGC refiners have benefited from the price of Canadian crude oil, which is discounted even more against Brent. As of July 2020, more than 40% of the U.S. refinery crude intakes comprised imported heavy crude oils, of which more than 50% consisted of Canadian heavy oil. The percentage of heavy crude oil (with a lower API as shown in Figure 7) exports from Canada increased, while the U.S. imports of light crude oils decreased as more domestic light crude oil entered the U.S. market. Refining margins are directly impacted by the quality and cost of crude oil. **Crude blending optimization** is one way to improve refining margins through the optimal mixing of several crude grades based on quality, yield, and cost differentials. The processing challenges of LTO, such as equipment fouling, high system pressure issues and underutilized units, can be mitigated by blending LTO with heavier crude oils such as Canadian heavy oil. This not only mitigates the processing challenges, it also greatly improves margins. As can be seen in Figure 7, Saudi light crude imports decreased by 28% since the year 2000, while Canadian crude oil imports increased by 36%. The acquisition cost of Canadian crude is lower than other imported crudes.

**Crude blending optimization is one way to improve refining margins**

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**Figure 4.** Price disparity between WCS and WTI.

![Price disparity between WCS and WTI.](image)

Source: Bloomberg.
Figure 5. Refining margins of WCS vs. WTI at U.S. Gulf Coast refineries.

Source: Bloomberg data analysis.

Figure 6. U.S. refining crude import trend by density.

Source: KAPSARC analysis of EIA data.
Most USGC refineries are gradually increasing LTO in the refinery crude diet as more pipeline takeaway capacity becomes available, mainly in the Permian and Eagle Ford plays, which is narrowing the differentials with WTI at Cushing. However, not all refineries can increase their LTO processing, mainly because of refinery configuration due to crude quality constraints. Heavy investments would be required to enable refineries to process more LTO. On the other hand, eastern refineries have been revived, due to the availability of Bakken LTO, which is compatible with the region’s refineries that take light crude oils, and the availability of direct pipeline capacity of more than half a million barrels a day to states such as Wisconsin and Illinois.

The lack of a pipeline system connecting producing and prospective tight oil plays with mainline systems, terminals, and processing areas such as the USGC, still poses constraints and wider crude price differentials. For example, the total interstate pipeline capacity between Bakken in North Dakota and Montana states is less than 1 MMb/d, while the production capacity at Bakken can easily exceed more than 1.5 MMb/d. To compensate for the lack of pipeline capacity, rail and trucking are being used to transport oil. This has an impact on its price and demand, and hence produces wider price differentials to WTI from Cushing, Oklahoma.

Figure 7. U.S. refinery domestic crude intake trends by API gravity.

Source: KAPSARC analysis of EIA data.
Figure 8. Imports of light crude oil fell with increased LTO production.

Source: KAPSARC analysis of EIA data.
Note: Import and production monthly data are yearly averages.

Figure 9. Landed cost of various imported crude grades compared to domestic light tight oil and imported light crude oil from Saudi Arabia.

Source: KAPSARC analysis of EIA data.
Note: The figure shows yearly averages of quarterly published data.
The U.S. will have the highest petrochemical growth globally

Future projects that integrate refinery and petrochemical complexes in the U.S. can overcome the challenges of LTO, using compatible process unit designs such as metallurgy and capacity. As shown in the chart below, the U.S. will have the highest petrochemical growth globally, mainly due to the rise in its production of tight oil and shale gas, such as ethane. Integrated refining and petrochemical complexes offer not only considerable opportunities for enhancing operational efficiencies and lowering operational costs, but also for increasing stream integration, processing synergies and operational flexibility.

The expected growth of U.S. integrated refining and petrochemical complexes, focused on upgrading to higher-growth and better optimized petrochemicals production, offers a value chain optimization benefit for the sector. New initiatives, such as crude-to-chemicals facilities, provide greater yields from final products by using optimized conversion processes.

Figure 10. Capacity addition investments in refining and petrochemical sectors globally.
Conclusion

The LTO crude production boom transformed the landscape of the U.S. oil and gas sector across the entire oil value chain. The quality of LTO and its production volume pose opportunities and challenges across the entire value chain. This includes areas such as refinery reconfiguration, optimization, midstream investments, and shifting trade flows due to the lifting of the export ban on petroleum oils. U.S. refiners will face margin challenges as the benefits of some of the artificial constraints enjoyed by the U.S. refiners, such as Canadian heavy oil discounts and midstream bottlenecks gradually ease or disappear. A sustained low oil price environment caused by the COVID-19 pandemic has impacted the entire oil value chain and limited future investment. Businesses across all sectors of the economy are gradually adopting net-zero emission strategies as part of their environmental, social and corporate governance (ESG) policy framework. Saudi Arabia, which has one of the lowest greenhouse gas emission intensities in its oil production (Masnadi et al. 2018), has the advantage of being able to focus on optimizing its hydrocarbon value chain in line with the circular carbon economy framework it recently endorsed. Demand for refined oil products will not disappear overnight or anytime soon because the world still needs hydrocarbon energy and petrochemicals to enable the transition to renewable generation and a net-zero future. It would be impossible to safely and efficiently mitigate the growing threat of deadly and disruptive diseases now and in the future without the petrochemical sector. This is because present day healthcare depends on petrochemical products in the production of protective equipment, pharmaceuticals and disinfectant chemicals. Thus, on the global scale, we need agile processes in all sectors of the hydrocarbon industry to overcome fiscal and ESG challenges and to enable a smooth transition to a net-zero future.
References


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