1898 & CO. SM
PART OF BURNS McDONNELL

WHITE PAPER / **OIL REFINERY CONVERSIONS**

Is your oil refinery a candidate for renewable diesel or sustainable aviation fuel?

BY Dave Collings

Refineries have many options available for full or partial conversion to renewable diesel or sustainable aviation fuel production. With momentum continuing in the renewable fuels space, the petroleum industry is actively looking to repurpose existing refineries by converting diesel hydrotreaters, gas/oil hydrotreaters and hydrocrackers to renewable diesel units.

Full or partial conversions of existing refineries to renewable diesel or sustainable aviation fuel require techno-economic evaluations, utilizing experienced personnel from the oil refining industry. In addition, a deep understanding of this emerging renewable diesel campaign including the credit markets is also essential.

Like any decision in the refining industry, conversion decisions eventually boil down to revenue and profit margin — in other words, the return on capital employed (ROCE). Evaluating the expected ROCE from continued refinery operations versus ROCE from a full or partial conversion will be the linchpin for a final decision.

Why convert?

Renewable diesel will result in great margins per barrel of feedstock, but the conversion is likely to come with a significant derating of the processing unit or units. With derating, only a fraction of hydroprocessing capacity will be utilized, compared with much higher capacity for a conventional oil refinery. Under these circumstances, the margin per barrel needs to be much higher to cover the fixed and variable costs of the refinery. Would the economics still look attractive with such a significant reduction in capacity? In fact, there are a number of factors that will determine the outcome.

Proximity to feedstock

In crude oil refining as well as renewable diesel processing, the location of the plant is often critical to its success. Renewable diesel refineries will have feedstock advantages if they are located close to sources of soybean oil, distillers corn oil from ethanol process, canola oil, or beef tallow and white grease from beef or pork processing plants. In addition, refineries near large cities like Chicago, New York or Los Angeles will have access to large supplies of used cooking oil. See map (Figure 1) for more details on feedstock accessibility.

Existing and future product markets

California and Oregon have already enacted a low carbon fuel standard (LCFS), and most of the renewable diesel in the United States is targeting those markets (Figure 2). These LCFS programs are designed to progressively reduce the carbon intensity of transportation fuels over a defined number of years, thus creating economic advantages for renewable fuels.

A similar methodology will be in place in Canada beginning in 2022, when provisions of the Canada Clean Fuel Standard open another market. Further, there may be opportunities for oil refineries located in close proximity to states in the Northeast where new LCFS programs could be coming soon under the developing Transportation and Climate Initiative.

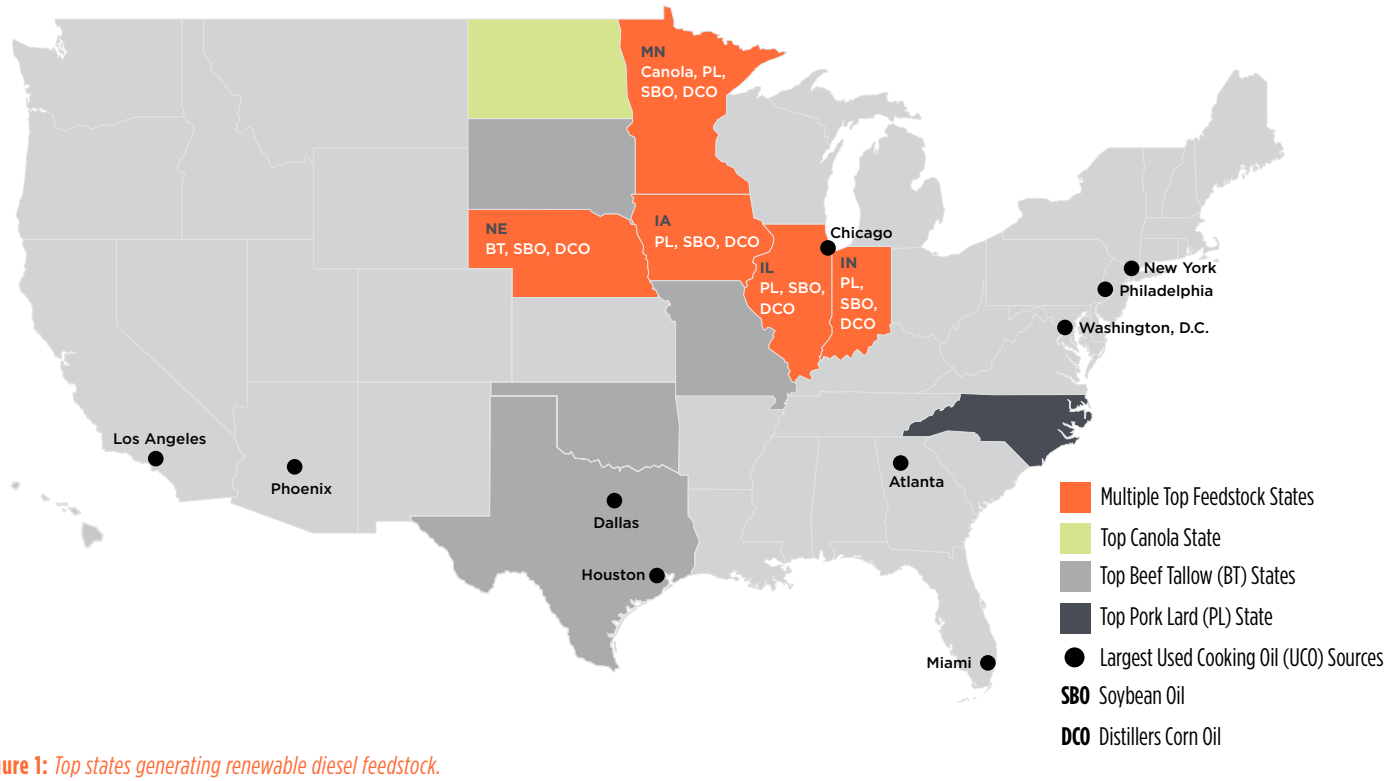

Figure 1: *Top states generating renewable diesel feedstock.*

Niche market refineries

While one may be inclined to believe that small refineries with poor conversion capability are interesting candidates for conversion to renewable diesel, this may not be the case. Many refineries, particularly in the Petroleum Administration for Defense District (PADD) 4 Rocky Mountain region, qualify as niche operators. These refineries are located in remote areas or regions with difficult terrain that limit competition and improve margins. Even refineries with unsophisticated kits can and do succeed under these conditions, outperforming larger and more complex facilities. Therefore, a more comprehensive analysis is needed to uncover all the factors that might make a refinery a compelling case for conversion.

What does your kit look like?

Refineries with the kits needed to process poorer-quality feedstock, such as heavy sour crude from Western Canada, may be in better position for conversions than those set up to process light sweet crude.

If hydroprocessing assets (i.e., gas/oil hydrotreaters, diesel hydrotreaters, hydrocrackers) are processing feedstocks with relatively low sulfur and nitrogen content and/or low aromatic content, the hydrogen uptake required would be lower. While this may be all that's needed for producing on-spec products, it may indicate that the unit would be less than ideal for renewable conversions.

For more challenging feedstocks, a diesel hydrotreater typically requires high volumes of hydrogen for producing on-spec diesel. Hydrogen volumes required for renewable diesel and sustainable aviation fuel are several times higher still. Let's say your refinery has processing capacity of 200,000 B/D, with 70,000 B/D of cumulative hydroprocessing capacity from the gas/oil hydrotreater, hydrocracker and diesel hydrotreater. Upon conversion to renewable diesel output, perhaps only 20,000 B/D renewable fuel processing capacity would be available. As a result, you would need to make approximately 10 times the margin you were seeing prior to conversion to compete with the crude oil refinery. While this may appear to be a tall order, a combination of renewable fuel incentives and poor crude oil refinery market conditions could tip the analysis in favor of renewable fuels.

Hydrogen is key to conversions

Hydrogen is a key feedstock for crude oil refineries, allowing the production of low sulfur products and providing volume swell that increases profitability. In renewable diesel

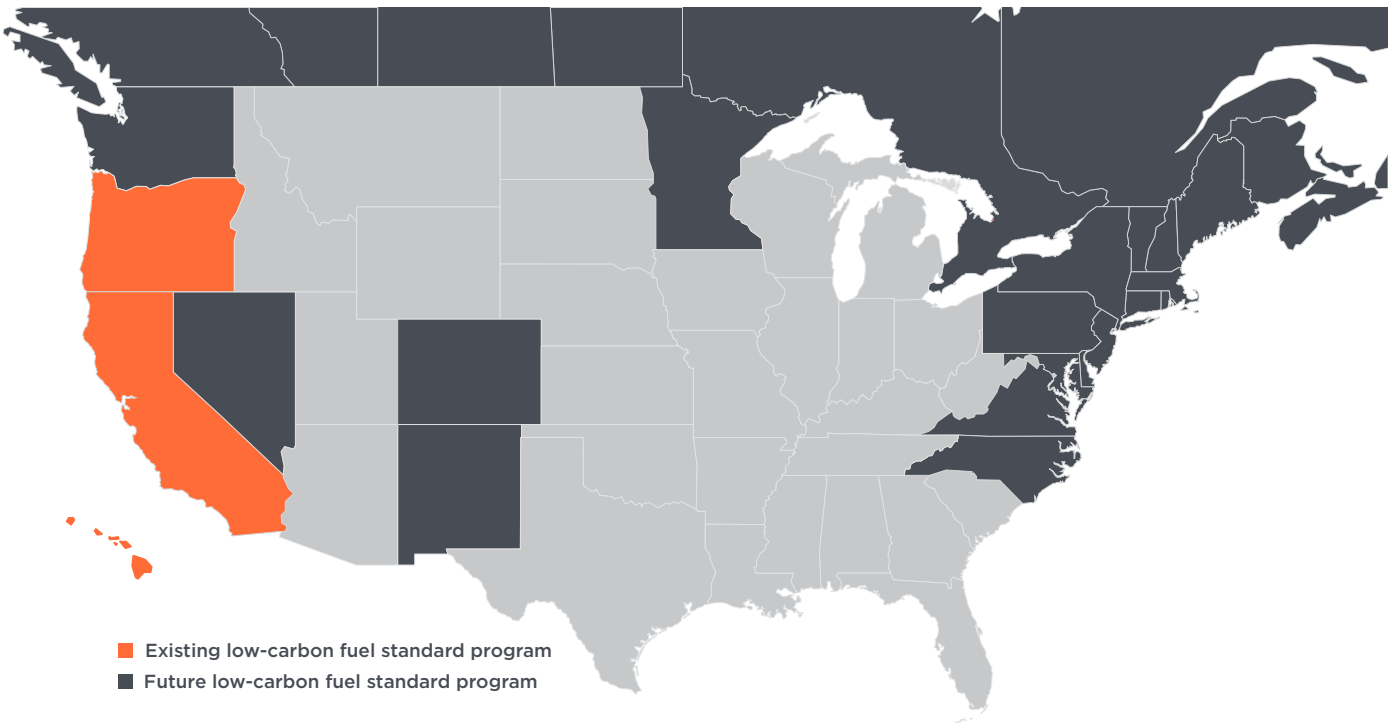

Figure 2: *Existing and emerging renewable diesel markets.*

processing, hydrogen is even more critical with the high oxygen content feedstocks, unsaturated fatty acid chains and cloud point improvement requirements.

The two main methods refineries use to produce hydrogen are naphtha reformers and steam-methane reformers (SMRs). Many refineries rely solely on naphtha reformers for a primary supply of hydrogen. Though the function of the naphtha reformer is to produce high-octane blendstock, the hydrogen produced from this process is essential for producing low-sulfur fuels at the naphtha hydrotreaters and diesel hydrotreaters as well as saturating benzene to meet specifications. When a refinery converts to renewable diesel, this hydrogen is no longer available.

Refineries that have supplemental supplies of hydrogen coming from SMRs will have an advantage in converting to renewable diesel. Many refineries along the Gulf Coast are close to pipeline SMR hydrogen and may also have important cost advantages when considering conversions. Those without this ready access will have to build an SMR or secure third-party hydrogen. These avenues will add cost that must be factored in.

Other key factors

Capacity: Knowing the capacity of your hydroprocessing unit alone is not enough to determine the corresponding renewable diesel capacity. For example, the space velocity in fossil-fuel operation may be relatively high with a short interval between catalyst change-outs. A hydroprocessing unit operating under these conditions will convert to lower renewable diesel capacity when compared to an underutilized asset.

Heat removal: The hydrodeoxygenation reaction in the renewable diesel process generates substantial heat. Consequently, the hydroprocessing unit must have heat removal capability. Hydrocrackers and high severity diesel hydrotreaters are more likely to have significant heat removal capability compared to a light sweet crude refinery diesel hydrotreater. As a result, these units tend to be better candidates for renewable diesel conversion.

Pressure: Naphtha hydrotreaters operating at relatively low pressures of between 400 and 600 pounds per square inch (psi), for example, are unlikely to be suitable for renewable diesel processing. Following the 2010 change in diesel sulfur specifications from 500 parts per million sulfur (ppm sulfur) to 15 ppm sulfur, most refinery diesel hydrotreaters now must operate at higher pressures in order to meet this specification for ultralow-sulfur diesel product. As a result, a large number of diesel hydrotreaters in the United States today are compatible with the pressure requirements for renewable diesel.

Metallurgy: Hydroprocessing units with a history of processing high sulfur and/or high total acid number (TAN) feedstocks are likely to require fewer metallurgy upgrades than low-severity hydroprocessing units. However, expect metallurgy upgrades to be a significant contributor to a revamp cost.

Pathway to success

Though a number of factors must be weighed, the ability of a refinery to economically convert and produce renewable diesel or sustainable aviation fuel ultimately depends on its performance as a crude oil refinery, the entire kit of the refinery, access to hydrogen, and proximity to renewable feedstocks and LCFS markets. While this may seem straightforward, building a business case to convert is challenging and convincing for only a handful of refineries. Only a thorough techno-economic analysis can provide guidance and understanding of the risks.

While more complex refineries with challenging crude slates will often be in the better position for conversion to renewable diesel finished product, these refineries are also often more profitable processing crude oil. Thus, choosing a candidate for conversion is a formidable task and requires a thoughtful approach.

Biography

Dave Collings is a senior technical advisory consultant at 1898 & Co., part of Burns & McDonnell. He has served in the oil and petrochemicals industries for more than 20 years, working directly for operating companies and as a consultant. In recent years, he has been advising in the renewables space, focusing primarily on the latest advancements in low-carbon liquid fuels.

About 1898 & Co.

1898 & Co. is a business, technology and cybersecurity consulting firm serving the industries that keep our world in motion. As part of Burns & McDonnell, our consultants leverage global experience in critical infrastructure assets to innovate practical solutions grounded in your operational realities. For more information, visit **1898andCo.com**.

24026-ORD-0921