COME CLEAN, PART 5 - WHY EVERYONE'S TALKING ABOUT RENEWABLE DIESEL

June 27, 2021

Renewable diesel is a popular topic in the transportation fuel space, and for good reason. For one, RD provides a lower-carbon, renewable-based alternative to petroleum-based diesel; for another, it’s a chemical twin of and therefore a “drop-in” replacement for ultra-low sulfur diesel. But, most of all, there are the large financial incentives provided by California’s Low Carbon Fuel Standard, the U.S. Renewable Fuel Standard, the U.S. Biodiesel Tax Credit, and other programs, which can make RD production highly profitable. Driven by these factors, there’s a lot of renewable diesel production capacity under construction or on the drawing board: everything from greenfield projects to expansions of existing RD refineries to conversions of old-school refineries so they can make RD. Today, we put the spotlight on RD and discuss how it differs from biodiesel, how it’s produced, and the new RD capacity coming online in North America.

Our blog series on low carbon fuel policies in the U.S. and Canada has garnered a lot of attention. There’s no doubt about it, energy folks want to learn all they can about alternative fuels, including the impact that low carbon fuel standard (LCFS) programs could have on refined products markets. To quickly recap what we’ve said so far, in Part 1 we provided an overview of various policies that have been adopted to reduced greenhouse gas (GHG) emissions from the transportation sector, such as fuel economy standards, renewable blending requirements, zero emission vehicle mandates, and LCFS programs in locations such as California, Oregon, British Columbia, and Canada generally via its Clean Fuel Standard.

In Part 2, we focused on California’s LCFS, which was implemented in January 2011 and which grew out of a number of earlier efforts there to improve air quality and, more recently, reduce GHG emissions. The LCFS assigns a carbon intensity (CI) target value for petroleum-based gasoline and diesel fuels, as well as their substitutes, such as ethanol, biodiesel, and renewable diesel. (CI is an assessment of the GHG emissions associated with producing, distributing, and consuming a fuel, and is measured in grams of carbon dioxide equivalent per megajoule, or gCO_2e/MJ.) The LCFS then sets maximum CI limits on finished gasoline and diesel fuel consumed in California each year on a gradually declining scale to meet the 2030 goal of a 20% reduction in the carbon intensity of motor fuels consumed in the state.

In Part 3, we turned our attention to ethanol, the use of which in gasoline has been prevalent for many years. Ethanol is a biofuel that is found in nearly 98% of the gasoline purchased at retail stations in the U.S., in most cases accounting for 10% of the gasoline at the pump. This high-octane biofuel has grown in popularity around the world, particularly over the last 20 years, due to regulations that require or incentivize its use. As governments continue to evaluate regulations to control GHG emissions, ethanol has been overshadowed by some other biofuels lately, but it is expected to continue to play an important role as a pathway for meeting low-carbon mandates. Last time, in Part 4, we looked at biodiesel. We noted that while the incentives for producing biodiesel are substantial, there are two big catches with the fuel: a limited supply of feedstocks and properties limiting how much can be blended with petroleum-based diesel.

And that's a perfect segue to renewable diesel, which has no such "blend wall" — and which has been receiving a lot of press the past couple of years, including in the RBN blogosphere. In Playin' by the Rules in December 2019, we covered some of the basics behind RD and noted that at the time about 2.9 billion gallons per year (gal/yr) of RD production capacity was either in operation or under development in the U.S. and Canada. Today, the amount of operating and planned RD capacity is 7.2 billion gal/yr, or 2.5 times where we stood a year and a half ago. Last July, in Green Grow the (Refineries), we zeroed in on HollyFrontier's plan to shut down its petroleum-based Cheyenne, WY, refinery and convert it into an RD facility. Here we are in the summer of 2021 and the excitement around RD has not waned — if anything, the momentum toward low carbon transportation fuels in general, and RD in particular, has accelerated.

Renewable diesel, like biodiesel, is a biomass-based fuel that can be burned in diesel engines or used as home heating oil. However, there are unique aspects of RD that have given it an edge over biodiesel as a substitute for petroleum-based ultra-low sulfur diesel (ULSD; Figure 1). Renewable diesel meets or exceeds the fuel specifications of ULSD, thus is considered a "drop-in" replacement, whereas biodiesel (from FAME, or fatty acid methyl ester) is typically limited to blends of 5% (a diesel/biodiesel blend known as B5) to 20% (a.k.a. B20). In fact, unlike biodiesel, which has poor cold-flow properties and risk of contaminants, RD generally has a higher cetane value (an octane-like measurement of diesel and diesel alternatives) than ULSD, promotes more complete combustion and higher engine efficiency, and has comparable or better cold-flow properties than petroleum-based diesel.

	ULSD	Biodiesel (FAME)	Renewable Diesel
% Oxygen	0	11	0
Specific Gravity	0.84	0.88	0.78
Sulfur Content, ppm	<10	<1	<1
Heating Value MJ/kg	43	38	44
Cloud Point, deg. C	-5	-5 to +15	-20 to +20
Cetane	40	50-65	70-90
Stability	Good	Marginal	Good

Figure 1. Quality Comparison of ULSD, Biodiesel, and RD. Source: UOP

How RD Is Made

There are several technologies available to produce renewable diesel, each with its own proprietary combination of catalysts and equipment layouts. But the basic design reacts a renewable feedstock with hydrogen (H_2) at high pressure over a catalyst bed (see diagram in Figure 2). The process produces RD, renewable naphtha, and renewable propane (LPG), plus water and carbon dioxide (CO_2).

Renewable Diesel Production Unit

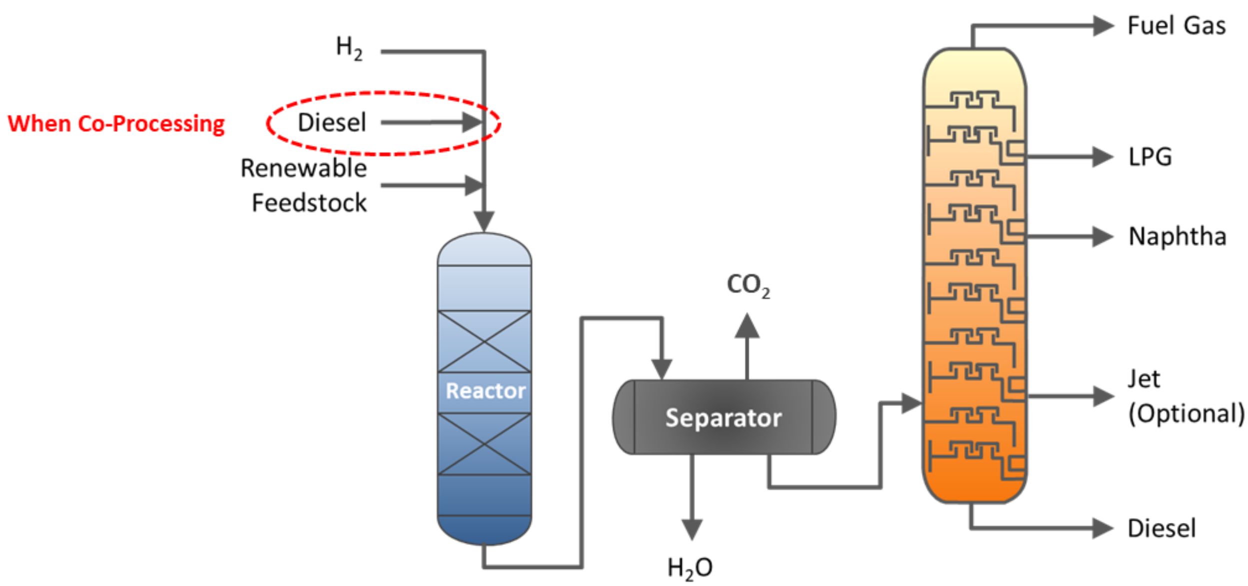

Figure 2. RD Manufacturing Processes Utilizing Hydrotreating Technology. Source: Baker & O'Brien

Each RD technology provides a unique set of yields, but typical yields are 90-92% renewable distillate (mostly diesel) and 3-7% renewable naphtha, with the balance going to renewable propane. The process can be adjusted to produce renewable jet fuel — now often referred to as sustainable aviation fuel (SAF) — at the expense of lower production of diesel and higher production of less valuable naphtha and propane. (We will discuss SAF in the next blog in this series.)

In many cases, renewable diesel is produced at (or near) an existing crude oil refinery. Refinery complexes provide infrastructure for utilities and logistics and generally have access to — or produce their own — hydrogen. Also, the equipment required to produce RD is similar to existing distillate hydrotreater units, which remove sulfur to produce ULSD.

Due to its similarity to ULSD, renewable diesel can be co-processed with petroleum-based diesel in a refinery's distillate hydrotreater. For typical co-processing applications, relatively minor modifications are required to provide the additional hydrogen and water handling that is needed for the renewable feedstocks. Co-processing renewable feedstocks in existing facilities does have its challenges, however. For example, the unit is more susceptible to corrosion due to the additional water production; also, processing capacity may be limited due to increased hydrogen requirements. Another downside: co-processed RD does not qualify for the U.S.'s lucrative $1/gal Biodiesel Tax Credit (BTC). However, the overall co-product does see an increase in the cetane and, in some cases, improved cold-flow properties.

Another co-processing production path is to feed the renewable feedstock (such as pyrolysis oil derived from forest residue) directly to a Fluid Catalytic Cracking (FCC) unit's reactor riser, where it is "cracked" with vacuum gas oil (VGO) feed to produce renewable diesel, naphtha, and olefins (see Figure 3). In this case, the renewable feedstock is typically limited to 5-10% of the feed rate because at higher percentages it lowers the overall FCC conversion yields. While this path results in lower yields of the desired diesel product, it provides another pathway to produce renewable fuels while providing feedstock to underutilized FCC units and lowering the overall CI of fuels in the refinery.

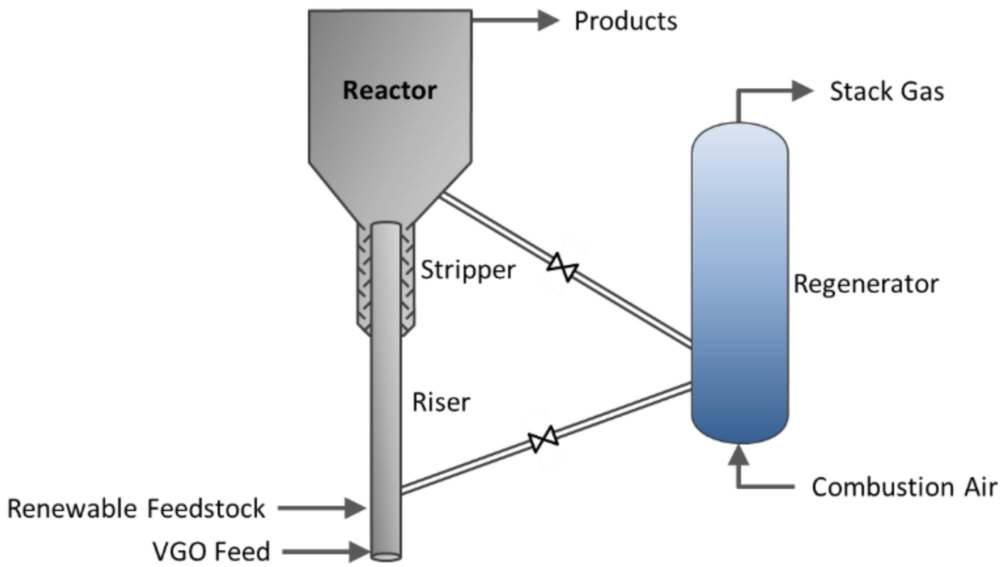

Figure 3. RD Manufacturing Utilizing an FCC Unit. Source: Baker & O'Brien

RD feedstocks

The same renewable feedstocks — whether they are soybean oil, canola oil, used cooking oil (UCO), tallow, or distiller's corn oil (DCO) — can be used to produce both biodiesel and RD. In either case, the feedstocks must be pre-treated prior to conversion. Lower-quality feedstocks like UCO, tallow, DCO, or pyrolysis oil are typically less expensive and have lower carbon intensity values since they are "waste" products. We won't be discussing pre-treating in this blog, but we should note that lower-quality feedstocks can require a more rigorous pre-treating process due to their higher level of impurities, which can lead to higher capital and operating costs. As with biodiesel, the renewable diesel CI value is based on the type of feedstock and can vary depending on the location and source. For example, in California's LCFS program, the certified CI values for tallow-based renewable diesel range from 19 gCO_2e/MJ for feedstock that is produced in California to 52 gCO_2e/MJ, for feedstock produced in Finland — that's quite a range!

RD production demand and capacity

Renewable diesel demand in the U.S., specifically the West Coast, has skyrocketed due to a trifecta of incentive programs: the federal RFS and BTC, and LCFS policies in certain states (see Part 1). But none of the policies has had a more profound impact on renewable diesel demand than the California LCFS program, given the state's population (see Part 2). Similar programs in Oregon and British Columbia only add to the demand, and more demand is on the way, with Washington State approving an LCFS law in May and Canada's Clean Fuel Standard program scheduled to be implemented in December 2022. Additionally, several more states and regions within the U.S. — New Mexico, Colorado, New York, the Northeast, and the Midwest — are in various stages of considering LCFS-type programs (see Figure 4). With ethanol and biodiesel blending in LCFS regions at their saturation points (again, see Part 2), renewable diesel, with its "drop-in" blending capability, is a logical choice to meet increasingly lower transportation fuels CI requirements.

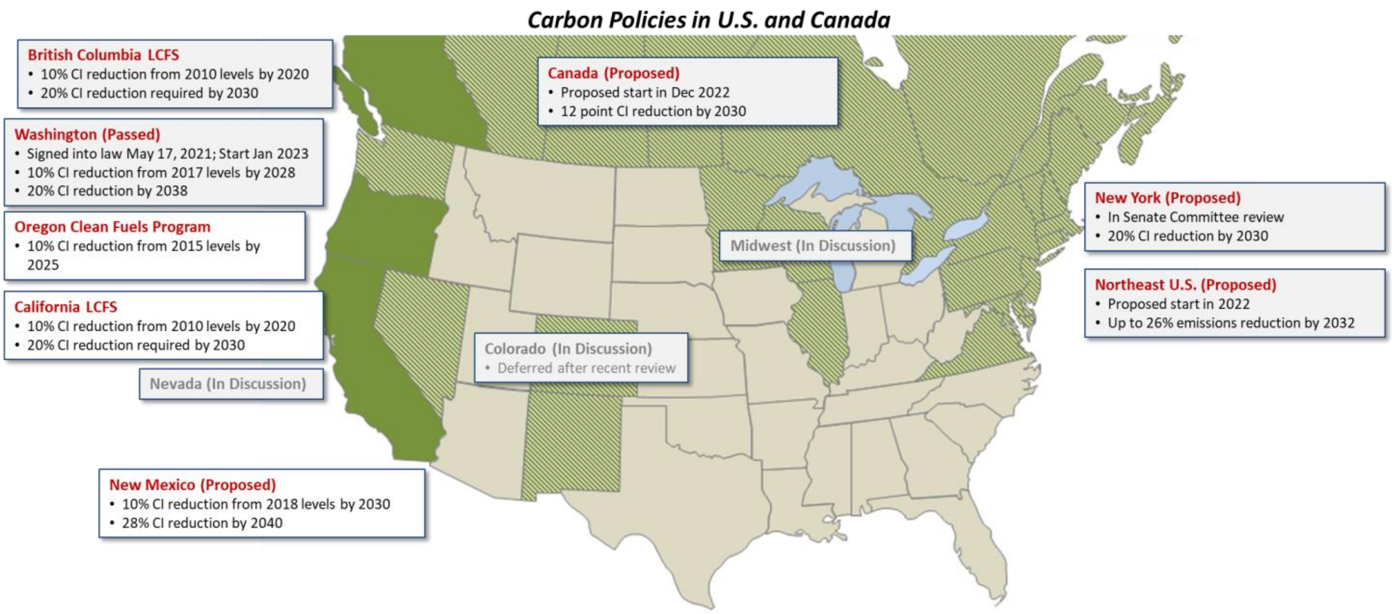

Figure 4. Low Carbon Fuels Policies in the U.S. and Canada. Source: Baker & O'Brien

Stand-alone RD unit capacity in the U.S. stood at about 37 Mb/d at the end of 2020, and another 21 Mb/d has started up so far in 2021: Phillips 66's 9-Mb/d Rodeo facility in northern California and Marathon Petroleum's 12-Mb/d Dickinson facility in North Dakota. By the end of this year, another 44 Mb/d of RD capacity is expected to come online, boosting total U.S. capacity to more than 100 Mb/d (see Figure 5). Most of the incremental production is slated to be shipped to California or other jurisdictions with programs to capture LCFS credits. However, as we've said in earlier blogs, renewable diesel producers also capture RIN (Renewable Identification Number) credits under the U.S. Renewable Fuel Standard (RFS) and a $1/gal tax rebate under the BTC — a pretty lucrative business! At present, these tax incentives make producing RD economically compelling, which in turn is leading to even more production capacity to be planned. Another 86 Mb/d of capacity is scheduled to come online in 2022, and by 2025 total U.S. capacity may approach 500 Mb/d. To put this into perspective, total 2019 diesel demand in California, Oregon, and British Columbia combined (the jurisdictions with LCFS programs at the time) was just over 300 Mb/d (blue line in Figure 5), and when Washington state and the rest of Canada are added to the mix, the diesel demand totaled about 680 Mb/d (orange line).

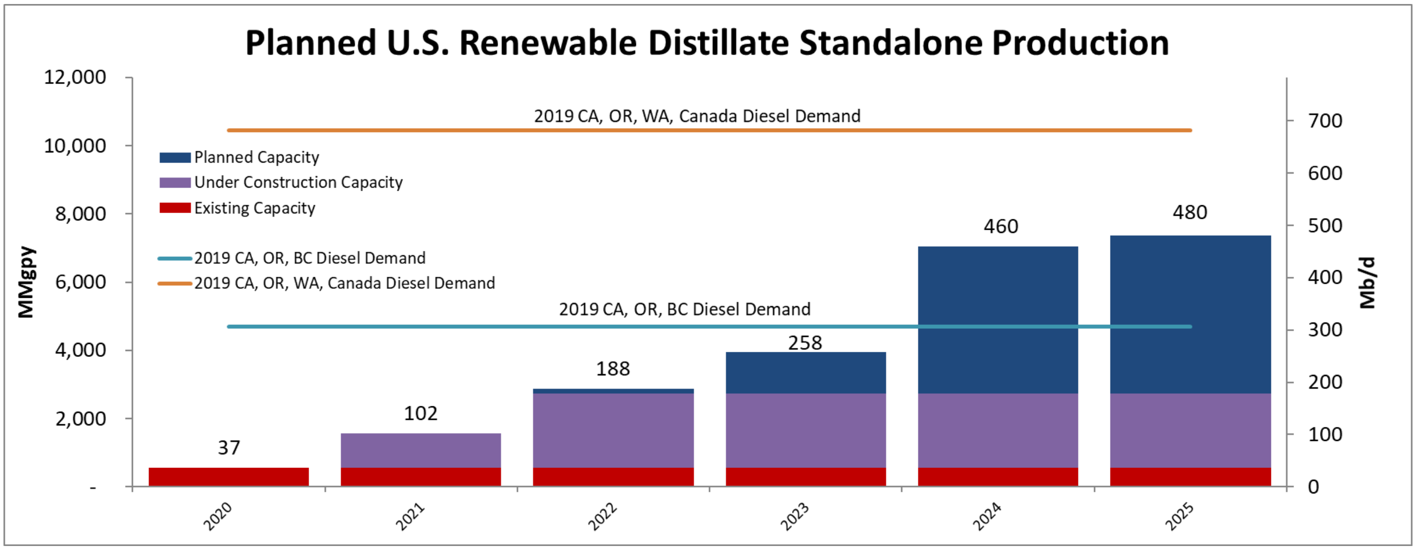

Figure 5. Planned U.S. Renewable Distillate Stand-alone Production. Source: Baker & O'Brien

Figure 5 includes neither RD production that is currently being imported (mostly from Neste's facility in Singapore, which is expected to double its capacity by the end of 2022) nor co-processed renewable diesel within the U.S. We estimate that 5-10 Mb/d of RD is currently being co-processed in refineries in the U.S. with another 15-30 Mb/d planned over the next 18 months. In recent years, more refineries have started-up or announced plans to co-process RD, with the majority of the production likely to be shipped to California. As we said, a downside of co-processed RD is that it does not qualify for the $1/gal BTC. As this chart highlights, without expansion of LCFS-type programs, we have the potential to overbuild RD capacity in the short to medium term.

In Part 4, we said that the feedstocks for biodiesel coming to California consist mostly of UCO and vegetable oils (DCO, soybean, and canola oils) and are relatively unchanged over the last five years. As for renewable diesel feedstocks, an entirely different story is unfolding. Tallow, due to its low CI value (current average CI of 34 gCO_2e/MJ) and large-capacity units in Louisiana and Singapore utilizing it as a feedstock, has dominated the California renewable diesel landscape from the beginning (orange layer in Figure 6), reaching its volumetric peak in 2017 before leveling off in recent years. Over the past five years, UCO (with an average CI of 22 gCO_2e/MJ; purple layer) and DCO (with an average CI of 45 gCO_2e/MJ; light blue layer) have been taking larger shares, growing to a combined 50% of California's renewable diesel pool.

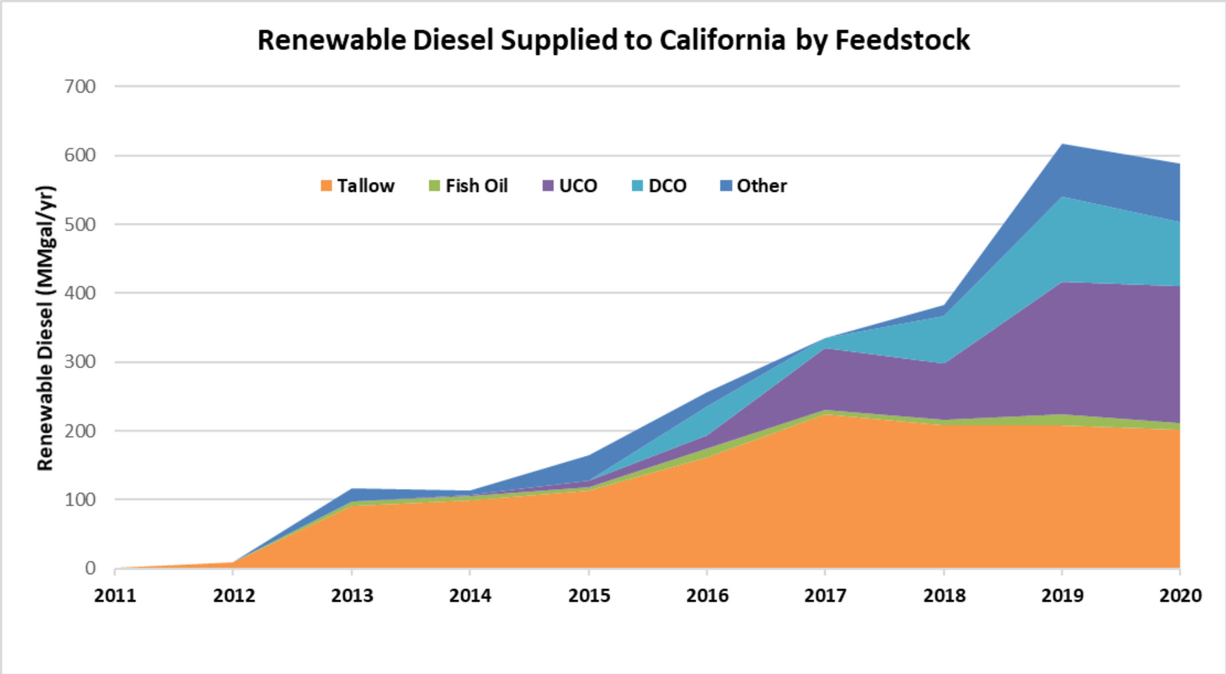

Figure 6. Renewable Diesel Supplied to California by Feedstock. Sources: California Air Resources Board, Baker & O'Brien analysis

There is a finite supply of low-CI feedstock like tallow, UCO, and DCO, however, and as supplies tighten and additional renewable diesel production capacity comes online, other, higher-CI feedstocks such as soybean oil (with an average CI of 56 gCO_2e/MJ) are becoming more commonplace in the market.

So where does all of this leave renewable diesel? No question, RD has been making waves in a big way and continues to pique investors' interest as a pathway to help meet greenhouse gas-reduction goals without making major changes to vehicle fleets. Will the current regulatory financial incentives be enough to keep the growth going or will it require more LCFS-type programs to continue the current trend? We'll continue watching the space and provide another update on the regulations and projects in the future. As we said, in the next blog in this series, we'll look at another popular commodity on the renewable fuels front: SAF.

Note: The article was authored by Kevin Milburn of Baker & O'Brien and published on RBN Energy's Daily Energy Post on June 27, 2021.

"Come Clean" was written by Kara DioGuardi and John Shanks and in January 2004 was the second single released from Hilary Duff's second studio album, Metamorphosis. Produced by John Shanks, the song peaked at #35 on the Billboard Hot 100 Singles chart in the U.S., but broke into the Top 20 in the UK and Australia.