Automation Technology Supports Growing Demand for Green Diesel

As the energy transition continues, green diesel is poised for growth. Digital technologies optimize the return on investment.

The history of alternative liquid fuel development over the last 100 years was primarily driven by availability and cost. To understand this industry, we must first clarify that alternative in this context means liquid fuels (gasoline, aviation fuel, diesel, etc.) that are not produced from conventional refining of crude oil. For example:

- Projects to create gasoline from coal in Germany and South Africa, first begun around 1930, sought to compensate for a lack of domestic oil supplies.
- During the oil shocks of the 1970s, synfuel manufacturing was promoted as a lower-cost alternative to high crude oil prices.
- Growth of the corn-to-ethanol industry started in earnest during the 1970s oil crises, but it continued as a means to add value to surplus corn production and facilitate phaseout of MTBE.

For the last decade or so, the driving factors have changed away from availability to the impacts of carbon footprint and resulting climate change associated with production and consumption of fossil fuels. Any time a fossil fuel is burned or processed into a different form, such as refining crude oil to produce gasoline, carbon dioxide is released into the atmosphere, representing a net negative impact since its source was trapped in the ground for millennia.

Today's alternative fuel projects now hinge on reducing carbon footprint (Figure 1). This is quantified via a carbon intensity (CI) score, calculating all total hydrocarbons consumed, or greenhouse gases (GHG) released, per unit of energy produced (grams of carbon dioxide equivalent per megajoule of energy or fuel produced).

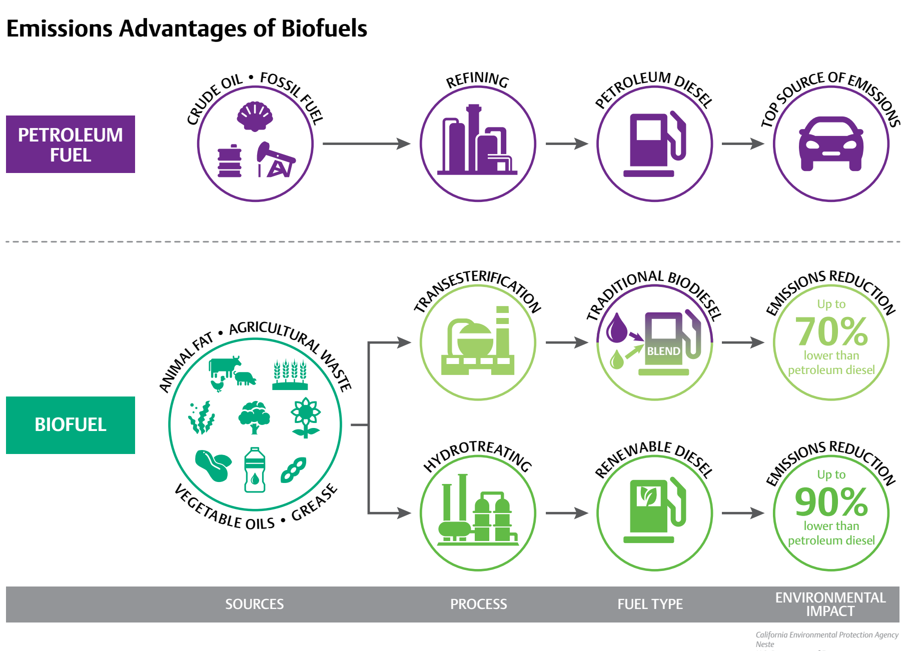

Figure 1: *Alternatives to conventional diesel use the same feedstocks, but with different approaches and results, each with its own characteristics.*

Therefore, the lower the CI score, the better. So, we must ask, when all factors are considered, how much does manufacturing and consumption of an alternatively sourced transportation fuel represent a lower CI score than conventionally produced crude oil? Let’s examine some of today’s options.

Ethanol—Adding ethanol to gasoline is relatively simple, and this technique is used in many places throughout the world to add a renewable component to the fuel, driven by regulations as much as value. It’s addition to the fuel distribution chain is regulated under ASTM D5798: *Standard Specifications for Ethanol Fuel Blends for Flexible-Fuel Automotive Spark-Ignition Engines.* Theoretically, ethanol is fully renewable since it can be made from plant sources—including corn, sugar beets, and sugar cane—and to a lesser extent from cellulosic waste materials such as wood chips and crop residues. As a practical matter, it gives back some of its CI score savings since fossil fuels are used in its production to plant and harvest crops, along with required distillation processes. Use of food stocks for this purpose has also disrupted food pricing and distribution at various times.

Diesel—This is a category of its own (Figure 1) since there are various ways to manufacture fuel that has the basic characteristics of diesel. In the crudest form, some inventive people have modified diesel cars to run on minimally processed restaurant fryer oil.

Biodiesel is a more sophisticated version of the fryer oil approach. Vegetable oils and animal fats are used as feedstocks, which are converted to a product called fatty acid methyl esters (FAME) through transesterification. It is regulated by ASTM D6751-20a: *Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels.* This specification characterizes biodiesel as, “mono-alkyl esters of long chain fatty acids derived from vegetable oils and animal fats.” This process is suitable for large- and small-scale installations, and vehicles can be adapted to run on biodiesel directly with some modifications to the engine, such as might be used in agricultural applications. However, it tends to gel at low temperatures, and if added to the conventional diesel distribution chain, the amount blended in is limited.

Renewable or green diesel starts with the same oils and fats as feedstock, but it uses a complex process more similar to conventional oil refining. It produces fuel indistinguishable from conventional diesel, and it can therefore be used interchangeably or blended without limitations. It is regulated under ASTM D975-21: Standard Specification for Diesel Fuel, which reinforces the point of its interchangeability. It uses a variety of feedstocks, including vegetable oils and animal fats, but also crop residues and other biomass. Byproducts from the process, such as light hydrocarbons and naphtha, can be used as non-fossil fuels to meet processing needs, sold as chemical feedstocks, or added to blending stocks to reduce the CI score of conventionally produced gasoline.

Sustainable aviation fuel (SAF)—Similar to renewable diesel in that it uses a variety of feedstocks to produce a product indistinguishable from conventional fuel and is therefore regulated under ASTM D1655-21c: *Standard Specification for Aviation Turbine Fuels.* However, given the safety considerations of aircraft use, its characteristics must be tuned to fulfill specific attributes outlined in the standard. With the right plant configuration and assets, renewable diesel plants can alter their operations to maximize the production of SAF over renewable diesel.

Economics and Environmentalism

These days, the motivations for alternative fuels are driven first-and-foremost by environmental considerations, whether by force of direct regulation, incentive programs, or to meet demands from shareholders and the general public. The global petroleum supply chain has overcome availability issues, and conventional fossil-based fuels are invariably less costly to produce than anything produced from bio-based sources.

On the other hand, in many situations, there are subsidies and tax incentives to launch and maintain these projects, which can help mitigate the additional costs. Some are based on the CI score of the fuel produced, rewarding carbon reduction directly. Incentives vary widely and are often site-specific, so individual companies must examine the possibilities case-by-case.

Critical considerations in this specific industry segment hinge on several key points:

- The manufacturing processes in use here are relatively new, so many installations lack a deep experience base.
- Markets for renewable fuels are stable or expanding, but regulations and incentives are still in flux in many cases, so producers must be agile enough to respond quickly to beneficial incentives and other opportunities.
- Processes can often use a variety of feedstocks, so a facility processing soybean oil one day may have to switch to used cooking oil the next, due to cost and availability, leaving operators to determine how the process must be adjusted.

Green (renewable) diesel

The process and its associated equipment are normally designed and constructed under the supervision of a technology licensor, resulting in a production unit for the specific purpose. Neste, Axens, Honeywell UOP, and Haldor Topsoe are among leading licensors for renewable diesel. A production unit will include the automation hardware and instrumentation necessary to run the process effectively, but instrumentation choices and automation technologies may not be optimized to meet the specific challenges of future renewable fuel demands.

On the other hand, while it may add to the initial cost, a more in-depth analysis and application of the instrumentation and control technologies available today can improve process flexibility, decrease maintenance costs, and deliver lower lifecycle costs. Many producers find it necessary to make instrumentation and control system improvements incrementally after the unit is in operation, when it would have been better to implement them at the outset.

Emerson's engineers have seen this experience firsthand, working on more than 20 new green diesel projects in 2021 alone. It has helped formulate a growing list of best practices for automating, optimizing, and future-proofing these operations while improving speed to market. Ultimately the process can become more efficient, while reducing the CI score so the fuel produced actually reduces overall carbon footprint, rather than making the problem worse. For the balance of this white paper, we'll look at a few examples of where operational gains can be made using this approach.

Digital advances

Figure 2 illustrates areas where digital technologies work in conjunction with advanced instrumentation to provide capabilities that are unlikely to exist in the basic automation system provided with a licensed production unit.

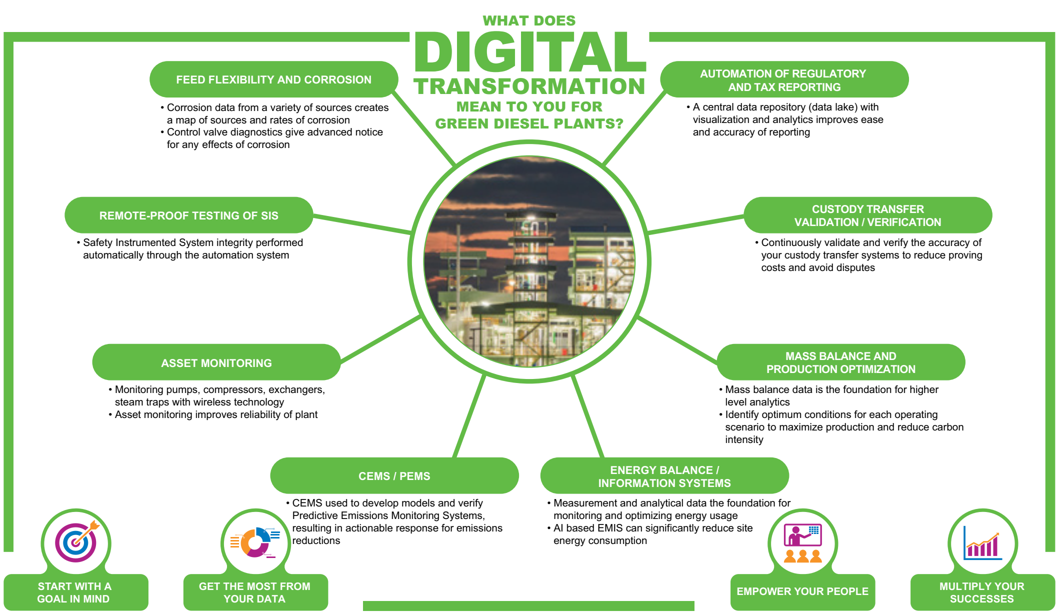

Figure 2: *Improving the performance of a renewable diesel production unit depends on a variety of digital technologies, combining hardware and software.*

Feed Flexibility—One of the risks of working with a variety of feedstocks is that they can have different chemical characteristics and contaminant levels. Feedstocks can often reduce the life of many of the alloys commonly used with piping, reactors, heat exchangers, and control valves. Alloys frequently used in conventional refining are not always capable of standing up as well to feedstocks used for renewable diesel.

Refineries that add green diesel production units discover a variety of new processing challenges not found in conventional refining:

- Oxides and acids in intermediates can produce an elevated level of corrosion.
- Temperatures and pressures can also run higher in a green diesel hydroprocessing unit, creating challenges for instrumentation and control valve selection.
- Paraffin-like components make the process more “sticky,” causing control problems over time.

Ultrasonic thickness sensors (Figure 3), such as Emerson’s Rosemount Wireless Permasense Corrosion Sensors continuously and wirelessly measure wall thickness of piping indicating material losses in real time. Other sensors, such as Roxar Electrical Resistance Probes, measure corrosiveness of the process fluid itself, alerting operators when conditions can cause equipment damage. This data provides direction for when corrosion inhibitors should be added and provides insight to help producers understand the impacts varying feedstocks have to the process to manage asset integrity in downstream processing.

Figure 3: *Some feedstocks used for renewable diesel can present major corrosion problems in specific parts of the plant. The effect can be monitored with Rosemount Wireless Permasense Corrosion Monitoring sensors and Roxar Electrical Resistance Probes.*

The reactor section is the most critical unit for maximizing profitability, with reliable and tight control required for smooth operations. Poor control performance can shorten catalyst life and reduce yield, so picking the right control valves is a crucial step in the design process. Emerson’s breadth of control valves available in a variety of alloys can accommodate the harsher environments of the green diesel plants.

With Emerson’s Fisher™ FIELDVUE™ DVC6200 Digital Valve Controller (Figure 4), control valves offer advanced diagnostic capabilities. These performance diagnostics enable condition and performance monitoring of the entire valve assembly while the valve is actively controlling the process. The DVC6200 uses statistical algorithms to determine condition- and performance-related issues based on live readings from the many on-board sensors. Having diagnostic data to monitor valve health is critical for green diesel processing plants to maximize performance.

Figure 4: *Digital valve controllers help reduce process variability and improve product quality.*

Remote Proof Testing of SIS—Safety instrumented systems must be tested at various intervals to verify their functionality. Usually, these tests are manual procedures, and they often call for process shutdowns. Some tests can be partial tests, reducing their interference with operation. Some partial test procedures can even be programmed into the automation system so they can be performed automatically, without the need for a shutdown and without required operator intervention. DeltaV Lifecycle Services-SIS Functional Safety Maintenance and Proof Testing (Figure 5) does this in accordance with IEC 61511 lifecycle requirements. This reduces the time involved and ensures that procedures are run correctly and reported.

Figure 5: *SIS Functional Safety Maintenance and Proof Testing performs much of SIS partial testing automatically.*

Asset Monitoring—This practice applies a variety of sensor types to monitor the effectiveness and condition of strategic manufacturing assets. Many of these sensors are wireless and some are also non-intrusive to the pipe or vessel, making them easy to install outside of a turnaround. For example, it is a simple matter to outfit a critical pump with sensors to measure vibration, bearing temperature, seal-flushing flow, and other basic functions. These data are presented on an interactive dashboard using Plantweb™ Insight, with warnings sent to the maintenance team when measurements change, suggesting a nascent failure. Similarly, adding sensors to a heat exchanger can indicate its condition and efficiency, also reporting via a dashboard.

CEMS/PEMS—Combustion processes used to drive heaters and boilers in the production of fuels will normally require a continuous emission monitoring system (CEMS) using flue gas analyzers, including Emerson's Rosemount XE10 CEMS with its automated calibration capabilities. In some cases, conventional CEMS can be augmented or replaced by a predictive emission monitoring system (PEMS) that uses a process model to calculate pollutant releases based on operating conditions. This provides critical tools for operators to control conditions and reduce emissions.

Energy Balance/Information Systems—Outside of feedstocks, hydrogen and energy are the largest operating costs for renewable diesel plants. The ability to measure and control energy consumption of the manufacturing process depends on having detailed data and tools capable of providing sophisticated analysis and presentation to operators. While energy management is important in every industry, it is fundamental to the very concept and purpose of sustainable fuel manufacturing. Poor energy management, when fossil fuels are being used to help create sustainable fuels, can greatly reduce any improvement in overall CI score.

Yet for many facilities, energy consumption information is only seen after the fact, summarized in monthly energy reports, making it difficult to pinpoint assets or processes that are running inefficiently. An artificial intelligence (AI) based Energy Management Information System (EMIS) can help provide early detection of poor performance, effective performance reporting, and support for decision making.

Mass Balance and Production Optimization—This capability is especially important in sustainable fuel production where feedstock variability can be very high. One plant reported 132 suppliers of 14 different feed types from 362 different locations during one year. One of the challenges associated with this degree of variability is being able to accurately measure process variables. Without effective measurement, reactor control can be poorly impacted due to feedstock change. Data from Micro Motion Coriolis flow meters (Figure 6) reflect true mass flow measurements and accurate measurements ensure proper reactor control is maintained.

Figure 6: *Coriolis flow meters are ideal for measuring feedstocks since they provide a true mass flow reading, unaffected by changing densities.*

The accuracy of the mass balance meters can be easily verified to ensure plant data is valid. Micro Motion Coriolis and Rosemount Magnetic flow meters can perform self-diagnostics able to verify that their mechanism is working correctly and therefore delivering accurate process data. These online and on-demand verifications simplify agency calibration and reporting compliance requirements without disrupting the process and/or pulling meters offline to send to a lab for testing.

An additional challenge associated with a changing feedstock mix is in understanding operational constraints and identifying optimum operating conditions for each feed type, providing optimum targets, and identifying non-optimum conditions. Software such as Plantweb™ Optics Analytics, has the ability to set dynamic operating targets based on conditional operating scenarios. It also has the ability to identify operational problems, using equipment readings, alerts, and status to generate root cause analysis. This provides a diagnosis of the cause of the problem and required corrective actions to avoid their occurrence while helping deliver the product consistency necessary to remain within the bounds of relevant standards, and historical data useful for future feedstock analysis.

Custody Transfer Validation/Verification—Custody transfer, whether of fuels and feedstocks coming in or product going out, is the point where money changes hands, so both sides of the transaction must agree that the mass or volume stated is consistent and true. Emerson designs and builds complete custody transfer measurement systems (Figure 7) to provide the best possible measurement accuracy and reliability, and in compliance with commercial and regulatory regulations. This calls for flow meters with unquestioned accuracy across a wide range, capable of handling a variety of products. Emerson's Micro Motion Coriolis technology, which uses self-verification via internal diagnostics to prove the flow meter is functioning correctly and delivering an accurate reading, regardless of conditions. These engineered systems are factory tested to ensure measurement confidence and compliance, reduce project risk, and simplify project start-up.

Figure 7: *Emerson's engineered truck/railcar loading and unloading custody transfer measurement systems provide best-possible measurement accuracy and reliability to assure commercial and regulatory compliance.*

Automate Regulatory and Tax Reporting Through Plantweb Optics

Utilizing the best available technologies and systems for custody transfer and mass balance is an important component of the regulatory requirements for a renewable diesel plant, but the needs go beyond that. Reports require extensive data from many sources, including point source feed supplier reconciled pathways, contracts, invoices, transportation information, custody transfer documentation, and others.

Plantweb Optics (Figure 8) provides a cost-effective means to automate data gathering, analysis, visualization, and reporting, while having the added flexibility to adapt to future requirements. Plantweb Optics features a central data repository (data lake) which stores all types of data required for reports and analytics with integrated visualization to significantly reduce the manhours and time to produce highly accurate, yet flexible, reports.

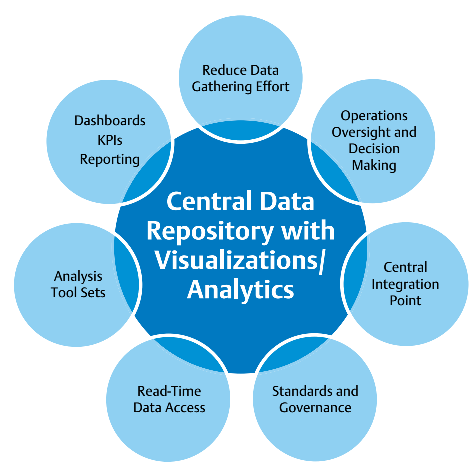

Figure 8: *Plantweb Optics provides the mechanisms to gather and analyze the enormous amounts of structured and unstructured operations data from across the plant or enterprise, including measurements, states, aggregates, alarms, videos, pictures and event data.*

Looking ahead

For the time being in the U.S., renewable diesel production is running in third place behind ***ethanol*** (averaging approximately 1.2 billion gallons monthly) and ***biodiesel*** (averaging approximately 150 million gallons monthly). Domestic renewable diesel production was running at about 72 million gallons per month in late 2021, but this is nearly double the production from a year earlier. The U.S. also imports more than 20 million gallons of renewable diesel each month. These figures fluctuate from month-to-month, but ethanol and biodiesel imports have matured, both remaining flat in recent years. Demand for ethanol, under current regulations, is unlikely to increase, and limitations to the practicality of biodiesel (blending limits, etc.) suggest it has also reached a plateau.

Globally, the picture is more complex as some countries are pushing for advanced biofuels (made from non-food-based feedstocks such as crop residues), and production coupled with carbon capture and utilization or storage. Still, according to the ***International Energy Agency*** (IEA), regardless of how one wants to dissect the larger picture, the aggregate forecast (Figure 9) calls for growing demand with North America remaining the largest market.

Global Biofuel Demand by Region, 2019–2026

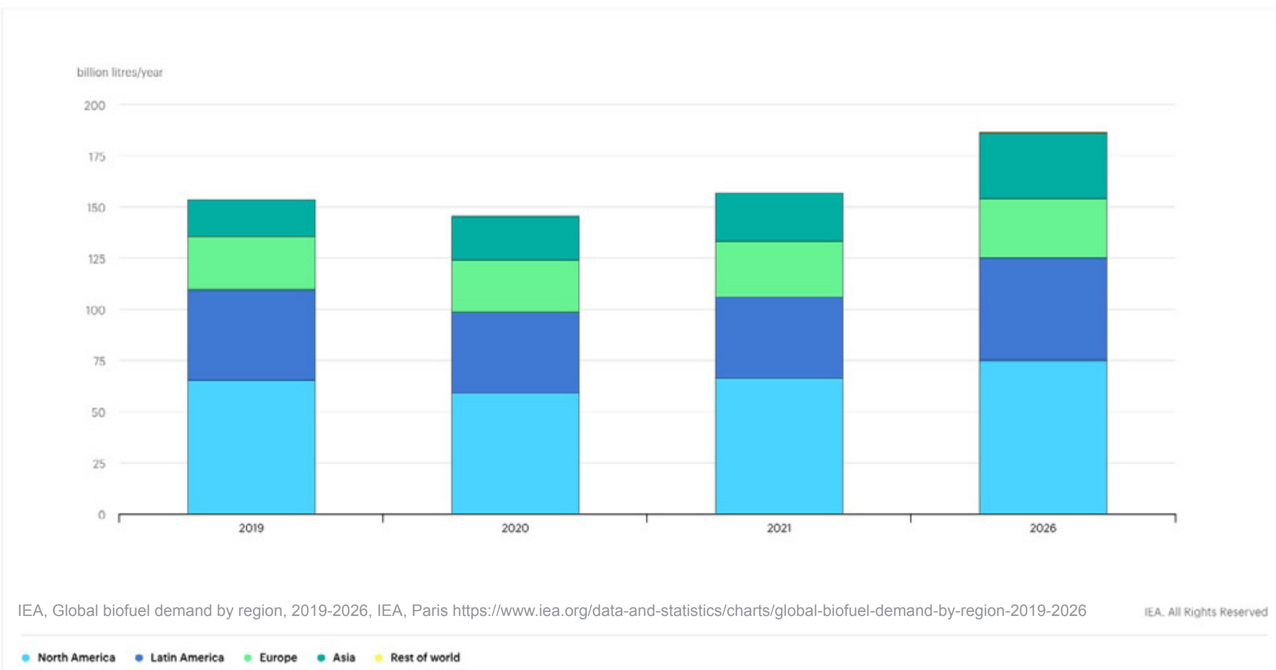

Figure 9: *IEA projections for overall biofuel demand see a recovery from the COVID-19 dip followed by an increase over the next several years.*

Renewable diesel has enormous room for growth since it can be blended without constraints and consumers can use it at 100% without a second thought. It is easy to argue that renewable diesel represents the most practical approach to reduce carbon intensity and replace a significant portion of the conventional diesel available today. Compared to the total amount of diesel consumed in all markets, the potential for renewable diesel is effectively limitless.

Many of the renewable diesel production units in operation today are located on an existing refinery site to take advantage of transport infrastructure and human resources. Some refinery locations have multiple units installed, and others are planning or constructing expansions. To make these projects as effective as possible, engineering teams must examine and consider the improvements possible using the types of digital technologies just discussed. These technologies can be used to maximize efficient use of feedstocks and consumption of fossil fuels during production. When this is done correctly, renewable diesel with the lowest possible CI score can be produced for the greatest effect on carbon reduction.

Any company considering construction of a new unit, or an upgrade/expansion of existing capacity, should take the time to understand all the possible options, evaluate the available digital technologies, and select the best ones for maximum operational improvements. Automation is key to developing smart operations, with the flexibility to switch feedstocks as pre-treatment units and associated automation technologies help plants use various feedstocks without damaging existing refinery equipment.

Emerson offers innovative technological solutions and long-term experience working with renewable fuels. When adopting sustainable technology, a partner with experience can help ensure success. Our deep, global expertise in creating a digital foundation, advanced analytics, and mobile collaboration capabilities for our customers makes the adoption of green fuels production seamless and more cost-effective.

To learn more or to speak with an Emerson expert, ***contact us***.

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