



PROCESS INSTRUMENTATION

Three Ways Greater Digitalization in Shale Oil Plays **Can Amplify Capital Efficiency and Investment Returns**

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As shale-oil operators adopt manufacturing models and mindsets to lower the costs of completions and production, they are deploying more and more digital technologies in diverse applications, many of which Siemens pioneered years ago. This paper offers a wide range of examples of how digitalization can drive more efficiency, visibility, and reliability in the digital oilfield to improve capital efficiency and returns.

If one word might describe the mindset of today's E&P operators in U.S. shale plays, especially the Permian Basin, it's urgency. Time is everything. Uptime. Downtime. Time to first oil. Time to cash. That urgency has sent drilling intensity and production from the nation's tight oil formations soaring.

But while the industry's cash is indeed flowing, drilling and completion (D&C) costs are rising sharply as supply shortages emerge in equipment, labor, and even fracking sand. Takeaway pipeline infrastructure for both production and disposal of used proppant is limited, so those costs are growing fast, too.¹

These issues are also pushing out D&C schedules, which is as much a problem for operators as costs. As one analyst recently said, "Once you're losing time, you're losing return."²

That's why, even as more capital spending pours into the ground, productivity has started to lag. According to Rystad Energy consultants, E&P capital budgets in the Permian rose by 8 percent in the first half of 2018, yet oil production volumes grew by just 1.4 percent.³

The implication is a decline in the industry's overall capital efficiency — how well capital is employed to drive production. Compounding that are accelerating declines in legacy well production.⁴

The result? E&P operators must drill faster and faster just to keep pace with their debts to service and dividends to pay. They need ways to cut their operating expenses to boost profitability without affecting output, safety, or compliance.

Digital oilfields: Manufacturing models optimize completions and production

One proven approach to cutting expenses and faster project executions is to better optimize both completions and production. How? With digital technologies proven in sophisticated manufacturing industries, such as aerospace, automotive, pharmaceuticals, and semiconductors, to name a few.

While the digital oilfield concept isn't new, its time has come — especially in tapping shale oil formations faster, safer, and more economically. Digitalization also has a critical role to play in helping to manage an emerging trend that takes drilling intensity to much higher levels but with much greater complexities.

It's called "the cube." It refers to a 3D model of all the shale layers lying under a producer's acreage and uses manufacturing concepts to tap multiple layers in a shale play simultaneously. So, while many multi-well operations may have 6–8 wells per pad, others, such as Encana, Devon Energy, and Concho Resources, have gone big with 10 or more wells and up to 28 wells on a pad.⁵

Three ways digitalization can amplify capital efficiency and returns

As the world's leading provider of digital manufacturing technology, Siemens welcomes this thinking as a sign of the shale-oil industry's growing sophistication.

In fact, we pioneered the application of proven manufacturing technologies — electrification, automation, and digitalization — in shale oil E&P just as we have in conventional E&P activities globally. For decades, we have provided and serviced these technologies to the world's oil and gas industry in the Americas and Arctic, plus the Middle East, Europe, and Asia, for both onshore and offshore requirements.

In shale-oil applications, greater digitalization can provide three big benefits to help operators accelerate execution speeds, optimize completions and production, and amplify their capital efficiency and returns:

1. Efficiency, for greater productivity and faster execution

Oil and gas operations need more than incremental efficiency improvements; they need quantum gains like what the latest digital automation technologies can deliver.

Consider, for example, the savings from deploying a variable frequency drive (VFD) in a fluid flow control application versus the pairing of a fixed-speed motor with a regulatory control valve. By using the VFD to control the flow rate directly, as much as 50 percent less energy is needed.

Also, with service intensity increasing, complexity is increased that must be managed digitally because manual methods simply can't scale, not to mention they're labor-intensive and error-prone.

2. Visibility, for actionable insights and better decisions

Historically the industry has been slow to deploy advanced automation, especially smaller onshore operators with fields that may be easier to reach, even if remote, than those of their offshore counterparts. Many may still use time-tested methods and technologies, often manual and no matter how outdated. If automation is employed, it often consists of localized, standalone mechanical and relay-based solutions.

In contrast, modern automation technologies use intelligent sensors and can be networked, often via highly secure, encrypted wireless communications. Many feature onboard web servers, so they can deliver real-time operating data not only to someone sitting in a driller's chair on-site but also to supervisory personnel thousands of miles away on their tablet, computers, or even smartphones.

Producers can use these capabilities to derive insights for making better, more informed decisions at all management levels — field office, corner suite, or boardroom — about how to improve asset utilization while gaining more operational visibility and information-sharing across a much wider reach of their oil and gas enterprises.

3. Reliability, for greater asset utilization and fewer forced outages

Downtime is costly. But because it happens, it must be minimized in both frequency and duration as the costs of unplanned disruptions can be extreme. An idle rig can cost upwards to \$16,000 a day in mid-2018.⁶ That doesn't count idle labor costs and lost output, the latter of which can dwarf all other costs.

Lack of reliability also can have consequences aside from costs, such as life and habitat safety. These impacts can make lost production a secondary concern and spur much greater costs in remediation, reparations, reputation, litigation, and penalties. Even without them, regulatory violations due to equipment breakdowns can prompt penalties and even shutdowns for non-compliance.

Fact is, regulators and the fates don't care that oil and gas facilities are inherently hazardous. Nor do they care that production is often located in remote, hard-to-reach

places, subject to some of the worst weather and environmental conditions possible.

That’s why it’s critical to deploy ruggedly engineered systems and components with safety built-in, not built-on. Digital self-diagnostics and performance alerts must be able to support predictive maintenance so that engineers can schedule upkeep and repairs proactively, instead of reactively.

If service is needed, knowing in advance what’s wrong can reduce or eliminate troubleshooting time. Plug-and-play modularity and self-configuring components further reduce the time needed on-site and minimize the skills required for making repairs. Service intensity makes this more critical than ever.

Halliburton reports that service intensity in shale-oil plays is shortening equipment lifecycles and raising maintenance costs. Sand volumes pumped in 2018 are three-to-four times what they were in 2014, and slickwater fracs are replacing gel-based ones, increasing equipment abrasion even more.⁷

Figure 1 below illustrates the classic “bathtub” curve of component and system failures over time due to early-life burn-in, random lifecycle failures and physical, end-of-life deterioration. Beneath the illustration are ways to mitigate failures in these phases using digitalization to maximize uptime.

Examples of digitalization solutions in shale-oil operations

What follows are examples of advanced digitalization that are available to enhance shale-oil operations with many of them adapted from technologies proven for years in other advanced manufacturing industries.

Electrified pressure-pumping. Electrified pressure-pumping shows how Siemens is bringing proven manufacturing technology to meet the requirements of unconventional E&P enterprises.

As laterals stretch 10,000 feet or more, today’s operators face a big challenge with limited horsepower on pumping trucks, plus high associated maintenance costs. Next-generation pressure-pumping equipment needs greater horsepower to push proppant that far.

Unfortunately, current diesel drivers, whether mechanical or for power generation, fall short of those needs. And that’s not to mention diesel fuel costs that have risen steadily by nearly 30 percent between January 2017 and late 2018⁸ — and are expected to rise even further in the future.⁹

The other challenge is regulatory limits on flaring produced gas, which is burned because remote production wells often lack the gathering pipeline infrastructure to get it to market. This has caused some unconventional producers to ramp down production because they would otherwise exceed their flaring permit limits.

To address these issues, Siemens introduced electrified pressure-pumping capabilities that consist of rugged, severe-duty, and outdoor-rated Siemens traction motors and drives

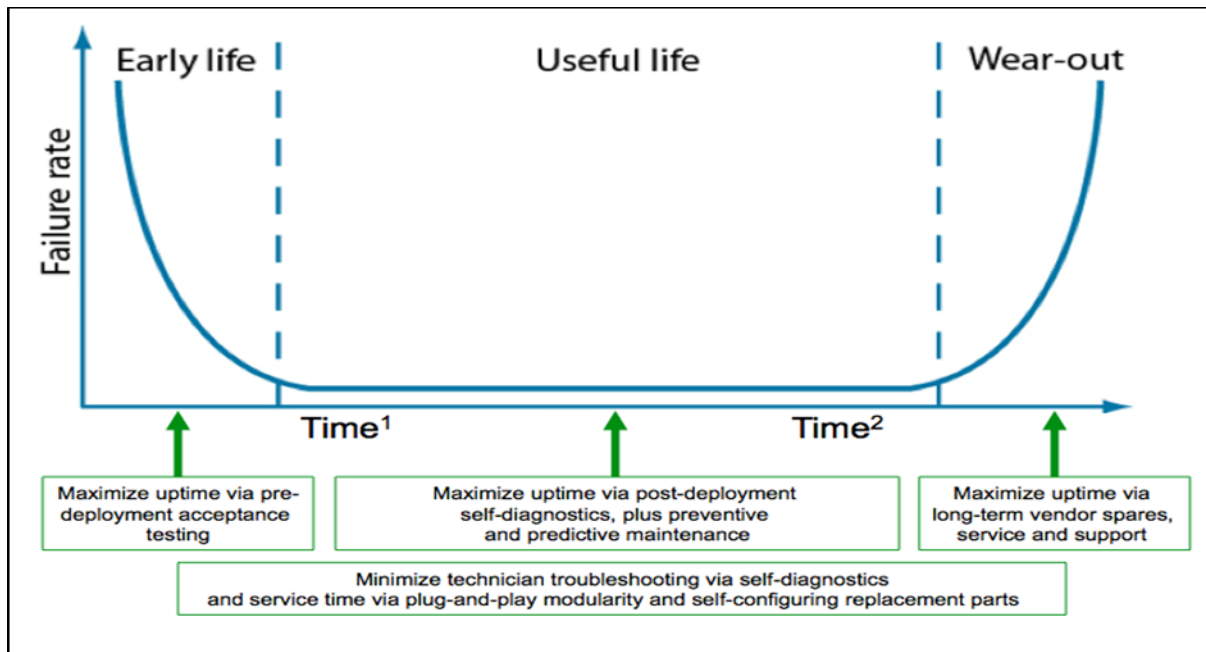


Figure 1. “Bathtub” curve showing failure rates over the time of a system or component lifecycle, while under that curve shows ways digitalization can help extend useful life to lower total cost of ownership.

that have been operating reliably in the mobile mining industry for nearly 20 years.

Their industrial turbines are similar to Siemens models used in the manufacturing and process industries, and their digital sensors can provide real-time operating visibility.

Truck-borne or available on skids, they are compact, turbine-based drive trains. Some can be rigged up and down in 4 hours or less, and be started in less than 8 minutes. Modular in design for easy scalability, they're equipped to safely provide both onsite power and mechanical drivers economically and safely by using produced gas or other fuels more cost-effective than diesel.

ESP condition-monitoring and predictive maintenance.

Another example of adapting manufacturing digitalization to oil and gas applications is the use of artificial intelligence (AI) to enable the condition-monitoring and predictive maintenance for fleets of electrical submersible pumps (ESPs) providing artificial lift for wells.

In collaboration with a global independent E&P operator, Siemens recently conducted a successful trial of 30 ESPs, with pumps ranging from 200–500 kW in power, installed in a medium-depth onshore oil field. It supports a predictive maintenance model that can accurately identify abnormal ESP operating behaviors in advance before an ESP can fail and disrupt production.¹⁰

OEM E&P solutions support. Siemens supports many shale-oil OEMs in their digitalization efforts, too. Delaware-based Teksoyl, for example, uses Siemens advanced digital automation technology — adapted from industrial water treatment applications — in its award-winning HydroWatch solution.

Originally deployed in the Marcellus and Utica shale fields, HydroWatch automates every step in a fracking well's water management. Among its many capabilities are extraction control; impoundment monitoring; real-time water truck GPS tracking; frost control; report generation; security camera integration; and optical character recognition of truck license plates. These and many more features are accessible on site via an HMI or remotely with a web browser, all with the highest levels of security.¹¹

More ways digitalization can benefit shale-oil operations

In effect, digitalization can be extremely transformative by tightly integrating engineering and operations — helping to optimize completions and production.

Plus, with more digital automation, operators can eliminate the time, cost, and error potential of manual collection, collation, and normalization of data from across many disparate sources. This can support better decision-making using deeper, data-driven insights and more actionable intelligence that are just minutes or hours old versus days or weeks.

Digitalization Benefits for Midstream Pipelines

Digitalization is underway in the oil and gas midstream segment for the same reasons it is in the upstream segment: greater capital efficiency and faster returns. The benefits that help drive these impacts are the same, too: More efficiency, visibility, and reliability.

Given the distributed nature of pipelines, especially their pumping facilities as well as terminals and storage tanks, IoT and cloud-based technologies and applications are proving themselves ideal for the segment's requirements, including cybersecurity.

In addition to the Siemens MindSphere cloud-based IoT operating system, the Siemens Drive Train Analytics (DTA) service offers midstream operators integrated condition monitoring, advanced data analytics, machine learning, and human expertise to enable improved reliability, availability, and performance of VFD and motor assets.

It works by pushing a highly-secured stream of operational data to the cloud, where the data is analyzed 24x7 and compared against acceptable operating envelopes developed from the asset itself and similar assets. Siemens, for example, has more than 15,000 of its medium-voltage drives installed worldwide, yielding hundreds of thousands of operating years of accumulated knowledge around drive operation and performance.

If a drive-train's operating data shows variances outside of its parameters, the DTA service can issue alerts so issues can be investigated for mitigation, remediation, or management until the next planned shutdown. Assigned Siemens engineers can pre-screen the variances before alerting customer operators, to prevent false-positives from being passed along.

With DTA, operator personnel are alerted to issues before disruptions, effectively predicting maintenance needs based on actual operating conditions and preventing costly disruptions. They can choose to immediately escalate issues for expert 24x7 support, shrinking the mean-time-to-repair (MTTR) cycle for drives to a fraction of before.

That's because both an operator's and Siemens' staff can view the same fault data simultaneously, while the latter can also quickly access and push to field service staff the relevant documentation they need to troubleshoot and fix the problem. This can be especially valuable for resolving issues that may well be unfamiliar, as they don't often have the necessary internal expertise to address them.

Integrated engineering and operational intelligence.

Integrated engineering via standardized configurators and interfaces offers a common data platform from which all relevant engineering disciplines can access the same pool of data, ensuring consistent data management and reporting.

This enables much of the work done by individual disciplines involved in engineering shale-oil completions and production to be done in parallel, saving dramatic amounts of engineering time and costs and accelerating times to first oil and cash flow.

For example, Siemens XHQ Operations Intelligence software is used in upstream applications to tie together oilfield, reservoir, and corporate data into single, customizable dashboards, as in Figure 2 below.

Advanced instrumentation. In digital oilfields, same as in manufacturing, advanced and reliable instrumentation is necessary to gain greater transparency and visibility into a wide range of operations, helping to find new efficiencies. Process variables, such as pressure, flow, temperature, and others need real-time monitoring to ensure optimization of completions and production.

Take, for example, keeping track of proppant sand levels — an important consideration as shortages loom and costs rise. With accurate data on the sand levels and weights, as it's delivered, trans-loaded, and stored, the effectiveness of its processing and storage operations can be continuously improved. The Siemens SITRANS LR560 two-wire, 78 GHz FMCW radar level transmitter provides continuous monitoring of sand levels.

Accurate weighing is also important to validating inbound frac sand shipments. Siemens Milltronics single-belt scales can weigh how much proppant is being delivered by a rail car or truck. While a single belt scale can achieve +/- 0.5% accuracy, doubling the number of belt scales improves accuracy to +/- 0.25%.

Enabling the digital twin. Another manufacturing concept with relevance to shale-oil completions and production is the digital twin. This is a software-based, 3D virtual proxy for all physical assets, such as tools, materials, and products used in production. The digital twin has special relevance for shale-oil operators.

For example, manufacturers use digital twins to model and monitor their end-to-end production processes, from the receipt of raw materials through shipment of finished goods.

And, because most of these assets are in motion at any point in time, many are using Siemens SIMATIC RTLS (real-time locating systems) to add real-time temporal and spatial dimensions that answer the question, "What's where and when?" Also, for the sake of personnel safety, digital production twins also must answer, "Who's where and when?"

Siemens SIMATIC RTLS solutions can provide those answers. Using specialized wireless technology coupled with intelligent location software, it delivers location data of objects or personnel tagged with transponders within centimeters and with latencies of less than one second.

Cloud-based IoT applications. No oilfield digitalization discussion today can avoid addressing the growing influence

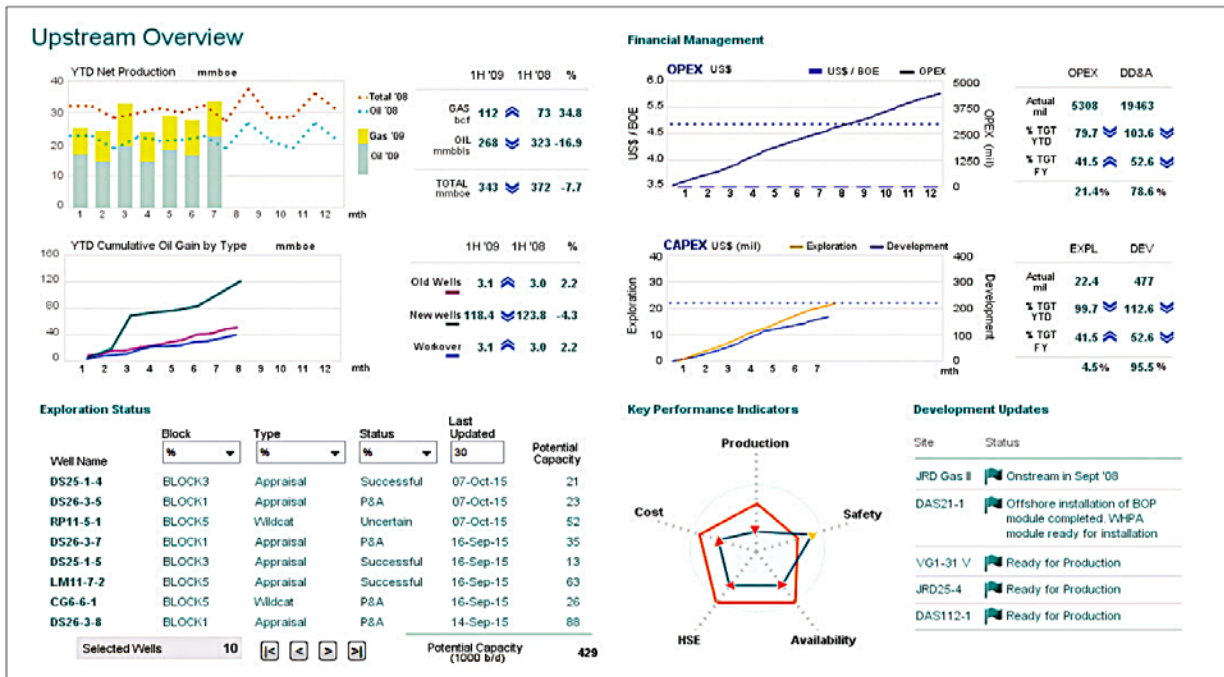


Figure 2. Siemens XHQ Operations Intelligence software provides advanced decision support for shale-play E&P operators by aggregating data from disparate sources into easy-to-read operational dashboards.

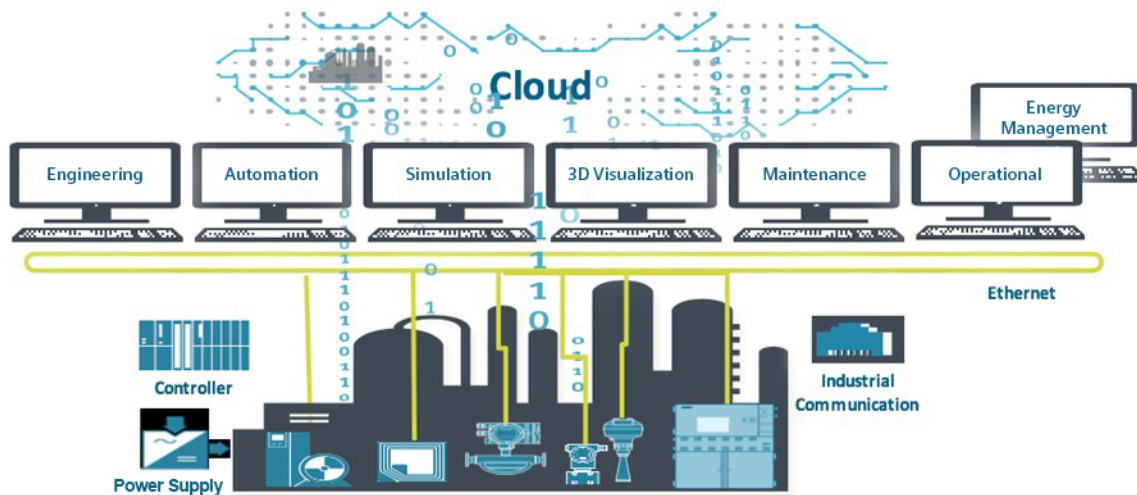


Figure 3. How digital oilfields can use on-premise and secure cloud connectivity to integrate various disciplines and equipment, resulting in a common data platform for greater operational efficiency, visibility, and reliability.

of cloud-based, Internet of Things (IoT) applications and operating models.

IoT all depends on secure and ubiquitous connectivity: satellite networks for the most remote shale-oil sites, 802.16 WiMAX for terrestrial applications, and legacy 3G and today's 4G LTE networks for rural developments. Within a particular site is 802.11n Wi-Fi for internal communications. Then there are emerging 5G cellular networks, which will offer speeds as high as 20 times those of today's 4G networks.

Siemens has developed — specifically for industry and with huge potential for shale-oil operators — its cloud-based, open IoT operating system called MindSphere. It offers access to a growing constellation of industrial monitoring and analytics applications. Figure 3 shows how digital oilfields can use on-premise and secure cloud connectivity to integrate various disciplines and equipment, resulting in a common data platform for greater operational efficiency, visibility, and reliability.

What's more, MindSphere's highly secure, scalable-on-demand, and pay-as-you-go subscription model eliminates the cybersecurity concerns, capital costs and ramp-up time of do-it-yourself approaches.

For example, operators can send field data securely to a cloud-based application to monitor valve performance. The application can use existing diagnostics and process data for anomaly detection and predictive maintenance from existing valve positioners.

In addition, the application makes planning and scheduling maintenance much easier. It also enables the data to be accessed whenever and wherever a technician and other stakeholders (e.g., an OEM) wants it, thanks to the application's secure connectivity to the cloud.

Cybersecurity A Top Digitalization Priority

Siemens' digitalization solutions are often deployed in the world's most critical infrastructure, such as oil and gas, which can offer hackers big targets. The industry can also suffer internal sabotage and compromised technology infrastructure.

Either way, oil and gas production can potentially be disrupted. Intruders can use an operator's routes to exfiltrate intellectual property, private data, and other digital assets of value.

For these reasons, Siemens has developed a rigorous, end-to-end security model that safeguards for the connectivity needed by E&P operators using our connected solutions.

Siemens protections are in accord with the most current global cybersecurity standards, including ISO 27001, IEC 62443, and NERC CIP. All of our components with connectivity ports have firewalls, for example. And firmware is designed with cybersecurity in mind.

Some of the benefits in this example are that unplanned downtime can be avoided or, if mitigation or remediation is necessary, the right set of skills can be dispatched along with required parts. Also, this approach can help to optimize maintenance resources, further reducing costs and boosting capital efficiency.

Driving digitalization deployments in shale-oil operations now

Fully implemented, digitalization can dramatically transform completions and production in the shale-oil industry by tightly integrating engineering and operations disciplines, while also providing a common data platform for faster and better-informed decision-making.

Enabled by such technologies as described in this paper, these capabilities can deliver fundamental benefits of greater efficiency, visibility, and reliability. Taken together, these can help shale-oil operators improve the deployment of their capital, so they can retire debt sooner and ensure a steady stream of healthy dividend payouts to their shareholders.

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² David Deckelbaum, analyst at KeyBanc Capital Markets Inc., as quoted in "Five potential risks lurking in the Permian Basin, America's hottest oilfield," the Dallas News, February 27, 2018. <https://www.dallasnews.com/business/energy/2018/02/27/five-potential-risks-lurking-permian-basin-americas-hottest-oilfield>

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⁸ U.S. Retail Diesel Price, as of September 17, 2018. https://ycharts.com/indicators/us_diesel_price

⁹ "Why Diesel Prices Are Set to Soar" by Robert Rapier. Forbes magazine. August 26, 2018. <https://www.forbes.com/sites/rrapier/2018/08/26/why-diesel-prices-are-set-to-soar/#2fda77c11f0c>

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