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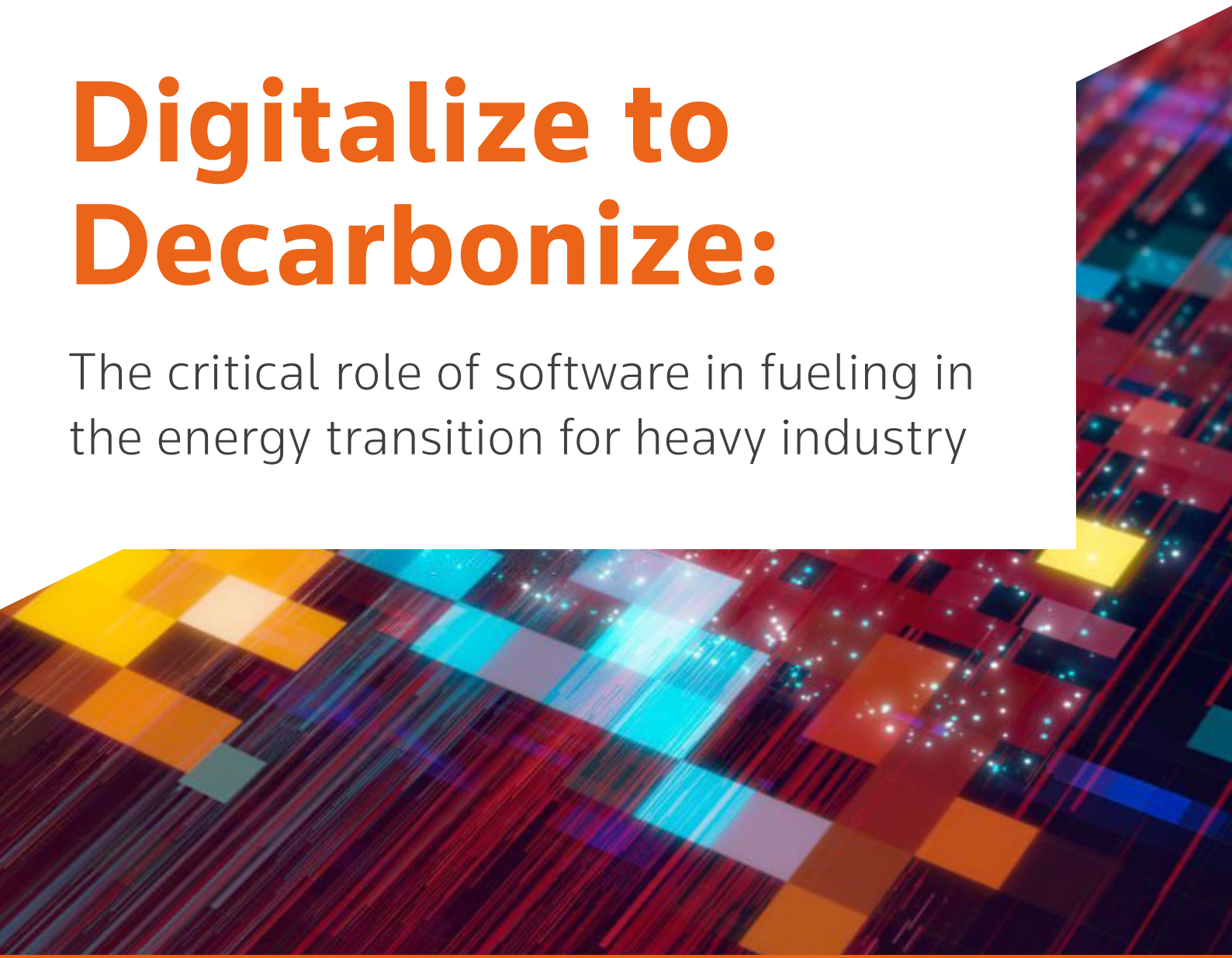
A white paper in conjunction with

Digitalize to Decarbonize:

The critical role of software in fueling in the energy transition for heavy industry



Introduction

As the energy transition takes hold and countries, companies, and consumers alike drive towards decarbonization goals, it's imperative that energy is reliable and affordable. As demand grows, and fuel sources become less secure amid renewed geopolitical tensions, this imperative must be kept front of mind. In a global context of supply chain disruptions and sharp volatility in commodity prices, optimizing the performance of energy assets to increase reliability, minimize costs, and reduce operational risks has become ever more critical over the past few years.

Technology and analytics can boost the overall resilience of the system, enabling companies in energy-intensive segments to get power from different sources in a seamless and cost-effective manner. Artificial intelligence, data analytics and the wider digital transformation provide the speed and scale of changes required to address the climate crisis as well as operational challenges. Whilst often under-represented, they are demonstrably as important as the deployment of renewable energy sources to cut carbon emissions.

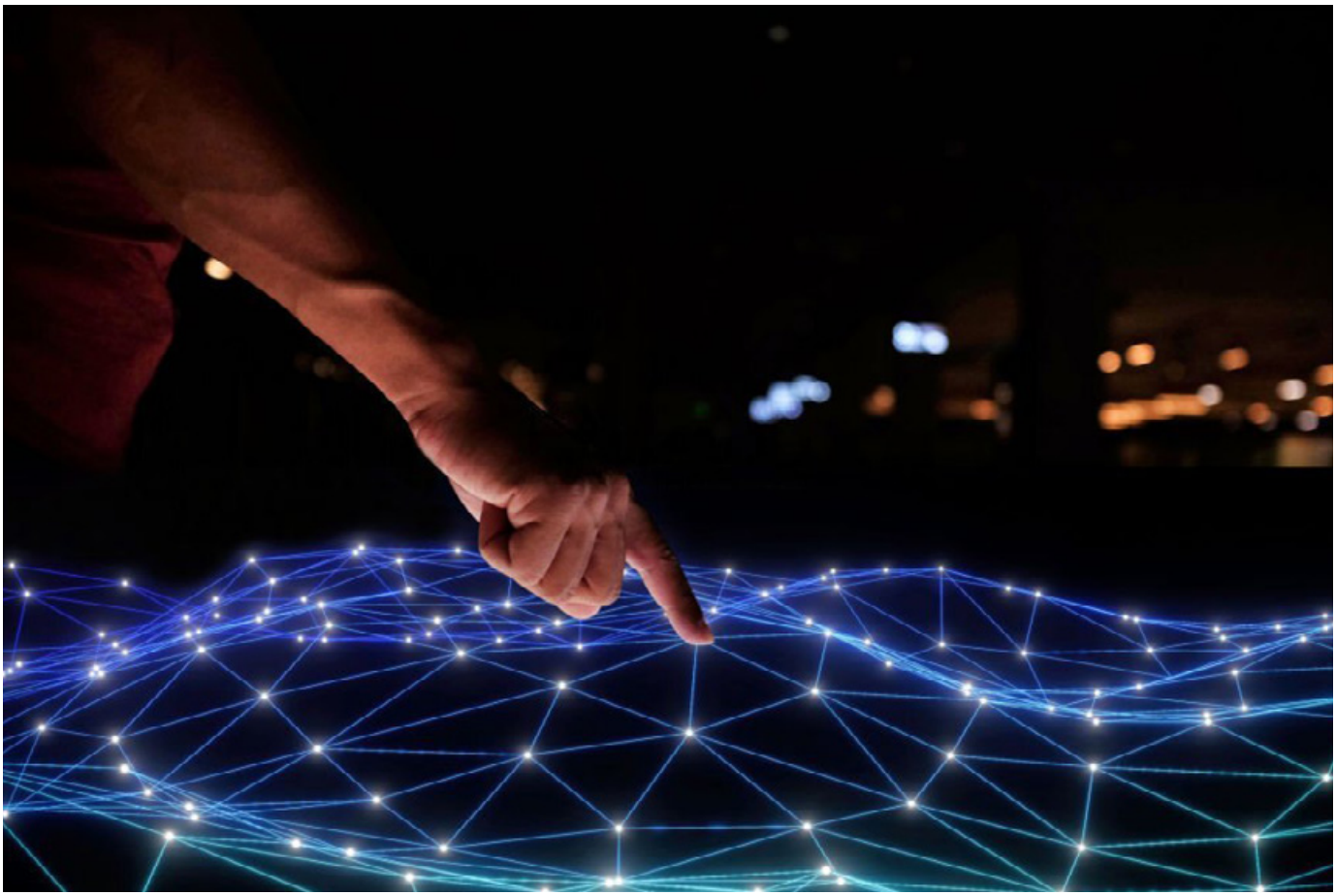
Decarbonization requires a holistic approach that takes different energy sources and ultimately the entire system into account. It means getting the most out of each energy source and making it as clean as possible. To meet rising demand for sustainable energy, the global grid needs to get smarter, more agile, and more resilient to power industry evolutions, consumer behavior patterns, and the accelerated cutover to electrification.

"This is the ultimate multivariable equation, and the equation is getting more complicated because you are adding new fuel sources, there are changing demand patterns, and demand is influenced by the need to move towards electrification," says Linda Rae, General Manager of Power Generation and Oil & Gas at GE Digital.

Even as renewable sources become cheaper and more readily available, the world will have to rely on fossils for decades to come. That said, the industry can continue to make progress towards decarbonization at the same time. Indeed, according to a 2020 report by McKinsey & Company, the oil and gas sector can abate the majority of its emissions — at an average cost of less than US$50 per ton of carbon-dioxide equivalent (tCO2e) — by prioritizing the most cost-effective interventions. Process changes and adjustments that reduce energy consumption will promote the least expensive abatement options. Many companies are implementing interventions that can substantially decarbonize operations. For instance, predictive maintenance can reduce a high percentage of fugitive emissions through maintenance routines based on real-time data that reduce shutdowns and leaks.

While the specific initiatives chosen to lower emissions will depend on factors such as geography, asset mix, access to different energy sources and local policies and regulations, digital solutions will combine all these factors to allow better business decisions and lower operational risks.

Environmental, health and safety workflows can be integrated with emissions management and general operation routines. With artificial intelligence, digitalization and data analytics working toward the same goals, energy-intensive companies will arrive at more sustainable operations in the future, while also achieving economic benefits.



Diverse energy sources strengthen the case for a holistic approach

Along with availability, cost and risk, the carbon footprint has become a new dimension in decision-making by all energy-intensive industries. Pressure by the public, investors and regulators is forcing traditional oil and gas companies to add renewable sources to their portfolios. System operators are receiving power from more diverse sources and must integrate and optimize dispatch of all assets in real time — without disregarding the actual cost of each generation source, including maintenance.

That said, the energy transition is not limited to utilities or oil and gas companies. Mining enterprises moving away from coal must also consider their environmental impact when extracting metals like lithium, copper, and cobalt, which are essential to decarbonization technologies like electrification and battery storage.

Efforts to make the entire energy supply chain cleaner create new challenges because more sources and variable demand mean more intermittency, complexity, and operational risk. Digitalization helps companies in different parts of the energy chain to get the most out of their assets, improve efficiency and therefore to reduce their carbon footprint at the same time.

"We need to think of the transition from a site level to an enterprise level," says Linda Rae. "While there is temptation to implement at the site level, which will provide a short-term gain, implementing at the enterprise level will provide the biggest scale and impact that we need."

Old Assets, New Demands

The world's power infrastructure was designed to last; flexibility was never an embedded feature of this design. However, generators increasingly require agility to ramp output up and down at short notice to meet fluctuating needs and take advantage of low carbon sources when available.

Variable operations compel plants to turn on and off multiple times in one day, forcing the equipment to cycle more, collect more residue, and deteriorate faster. This variability increases operational risks and maintenance costs. One example are modern cars that are pre-programed to shut down at a stop light and turn on when the driver steps on the gas. The technology helps carmakers lower carbon emissions, but also puts more stress on the engine.

Power plants are also running under more challenging conditions. When unplanned shutdowns happen, safety and stability are prioritized, so carbon emissions take a back seat and plants end up, for instance, releasing more methane when valves need to be opened. As operational flexibility becomes more pressing, the energy industry is finding that unplanned outages and shutdowns of refineries, have a higher carbon footprint.

Operators are thus looking beyond single-point digital solutions to integrated workflows and systems to lower their overall emissions. One operator found that 70 percent of all flaring emissions came from nonroutine flaring and cut overall emissions by applying technology to carry out predictive maintenance. Many others are using predictive analytics to reduce the frequency of outages to compressors or other equipment.

"You are trying to plan in advance, trying to predict what will happen and trying to optimize in a constantly moving dynamic environment," says Colin J. Parris, Senior Vice President and Chief Technology Officer of GE Digital. "This is the power of digital and software, it ties all these pieces together."

Using Tech to Get the Most Out of Each Asset

Digital innovation relies on a deep understanding of how each physical asset was designed, how it operates and how it potentially fails.

Digital solutions can make operations more reliable, efficient, and sustainable by predicting and preventing failures in a timely manner. To do that, operators need to continuously collect and manage all the data for each asset to make the best decisions that maximize operational performance.

The foundational elements of the solution are sensors that can extract digital representation of what is physically happening to an asset, covering aspects such as speed and temperature, then turn physical elements of the asset into digital information. Installation of these sensors is not limited to traditional power equipment like boilers, turbines, solar panels, and transformers. It often includes, for instance, large trucks at mining facilities.

Companies own hundreds or even thousands of assets that produce enormous amounts of data that can help them make smarter decisions that balance business needs and sustainability. To achieve that balance, they can deploy integrated processes that collect, analyze, and present the data that determines the status and health of their most crucial assets. Such capabilities predict equipment and process issues with greater accuracy before they occur. Asset integrity is ensured while regulatory compliance is documented for auditing and reporting purposes.

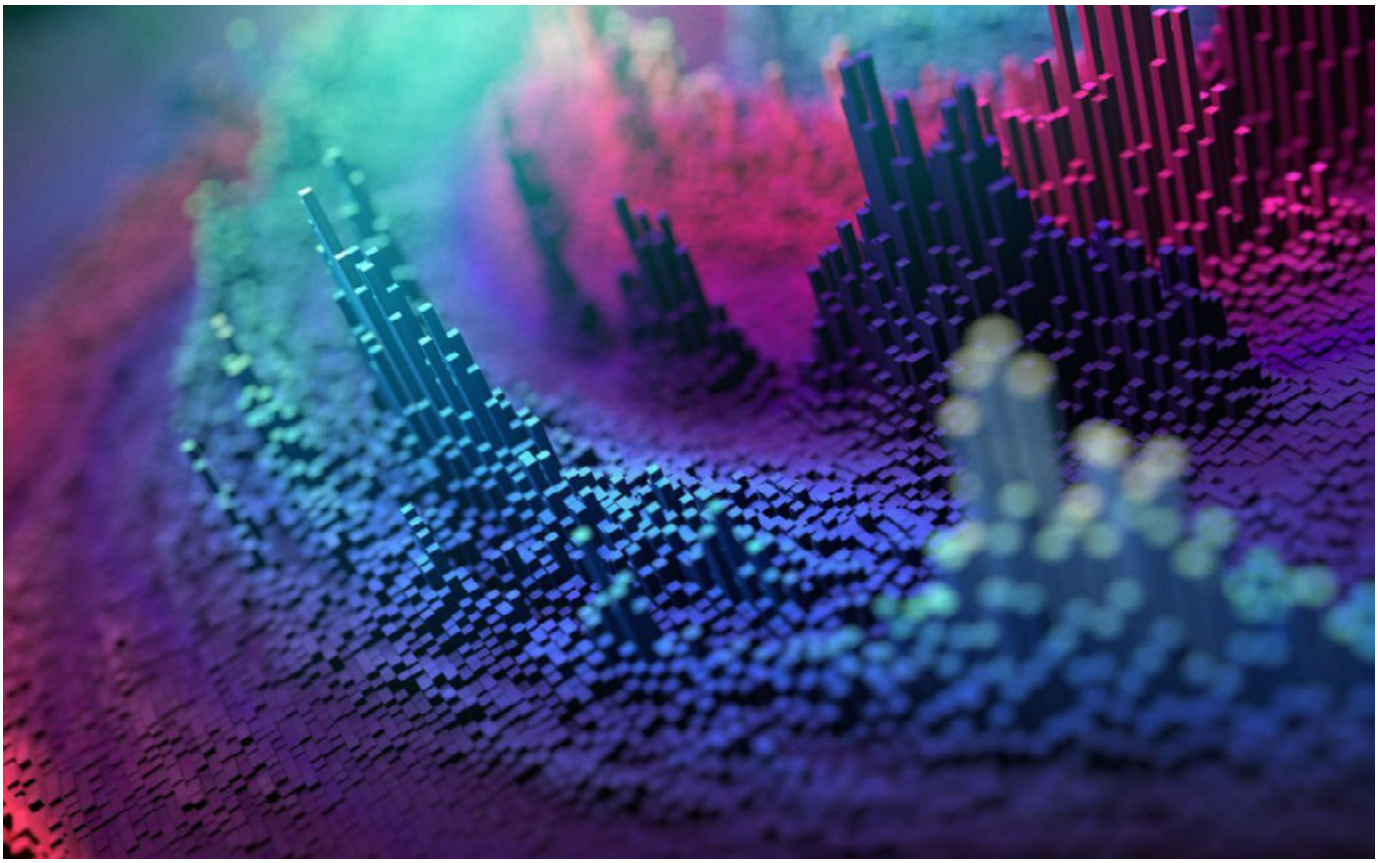
Given the cost of placing sensors and monitoring so many assets, deployment of such solutions involves determining which ones are most critical to the overall health and sustainability of the operation.

"Digital for everything is overkill, the customer looks at the criticality of assets" to decide which ones will provide the greatest results for the entire system, says Steve Deskevich, Vice President of Digital Product Management, Power Generation and Oil & Gas at GE Digital. "Also, if the asset costs a lot, I will want to monitor to prevent failure."

Workforce Empowerment

Digital solutions cut emissions and increase reliability and profitability while also empowering the most critical asset of any enterprise: employees. Workforce productivity is enhanced when operators prioritize activities based on criticality and cost, avoiding unnecessary dislocations and exposure. Professionals can get more done when they work remotely, and companies are able to attract and retain talents who live far away or prefer to work from home.

The past couple of years were marked by enormous changes in the way people work, and energy industry employees are no longer being sent to remote areas to take readings. They are now able to assist remotely and focus on solving difficult problems rather than executing mundane tasks.



Analytics Will Accelerate Decarbonization

Traditional fossil fuel power plants and energy-intensive segments (such as aluminum smelting and steel manufacturing) are using artificial intelligence and machine learning (AI/ML) to significantly lower overall emissions.

AI/ML resources process the growing amount of data collected by these enterprises and deliver increasingly sophisticated strategy options. Continuous, real-time analysis help operators understand their options for mitigating potential problems while balancing related costs, risks, and benefits. These tools can recommend operating parameters to lower emissions and even identify opportunities for further emission reductions.

On a practical level, these solutions will analyze the desired output and suggest the right amount of fuel and ideal temperature and pressure, so the plant does not burn more fossil fuel than it needs to and over time releases less carbon in the air. Such strategies find the ideal flame temperatures and fuel splits for optimal combustion and gas turbine optimization. The system also senses changes in ambient temperature, gas fuel properties and degradation, then sends real-time

adjustments to control apparatus, preventing equipment damages.

In enterprises that are considering substantial operational changes, what-if scenarios allow operators to visualize how their assets would perform when running at 100%, 50% or 0% capacity or with different types of fuels.

Analytic tools are optimizing maintenance routines as well. The new approach delivers cost savings, prevents unplanned outages, and ensures safer and more reliable operations. Instead of scheduled activities, data-driven strategies guide operators to anticipate maintenance in equipment that is undergoing more stress and postpone maintenance in equipment that is running smoothly. Using an example that is understood by consumers, carmakers recommend changing the oil after 10,000 kilometers, but many vehicles can run twice that distance before requiring the maintenance under the best care.

When it comes to complex emerging technologies like green hydrogen and CCUS (carbon capture, utilization, and storage), analytic tools can support much needed performance improvements at every step along the infrastructure and value chain, achieving new levels of operational efficiency in the future.

Digital Solutions are Already Delivering Substantial Results

Powerful digital solutions are already slashing fugitive carbon and methane emissions. Optimized maintenance routines reduce intermittent flaring and improve detection and repair to prevent leaks. Such changes have the potential to curb 62% of all emissions across upstream, midstream, and downstream operations, according the McKinsey.

After implementing GE Digital's Autonomous Tuning solution, one gas-turbine plant reduced carbon monoxide emissions by 14% and nitrogen oxide emissions by 12% as well as achieving 0.5% fuel and CO2 reductions. Manual tuning events were eliminated, and 12 days of downtime were avoided.

Italian giant Enel has been using predictive analytics to address asset issues proactively. Over the course of 27 months, the approach resulted in 750 GWh of avoided downtime and savings of US$3.6 million.

In Argentina, state-owned oil company YPF is extending deployment of monitoring and optimization software to approximately 30,000 assets, encompassing rotating, instrumentation, and electrical equipment. The move is allowing technical knowledge transfer across numerous sites in remote areas of the South American country.

France-based TotalEnergies hasn't recorded a single unanticipated failure of critical production assets since 2013, when it implemented predictive analytics technologies. The center focuses on four key areas: power generation; gas compression; water injection and crude oil export. The monitoring operation across these four areas is extensive, with 30,000 sensors monitoring 260 shaft lines and 540 pieces of equipment. Data is sampled every 10 minutes to limit the burden on data storage without impacting analysis and effectiveness.

Conclusion

Energy-intensive industries around the globe are realizing that digital transformation can reduce their carbon emissions by improving efficiency, saving fuel, and avoiding asset-related incidents and unplanned downtime.

These solutions help companies deliver environmental and economic benefits under changing conditions and find alternatives in a world where energy sources are less secure.

"This is a system, its's not one component," says Colin J. Parris. "It has to work together to have stability to be on all the time, it has to be affordable, it has to be secure, and it has to be efficient. This is where the power of software, analytics, and workflows comes in."

Today, digital technologies already play a vital role in improving the productivity and reliability of energy production. Tomorrow, they will tie disparate workflows and systems together to connect supply chains, assets, emissions, and operations — and accelerate the energy transition.