DIGITAL INDUSTRIES SOFTWARE

Making the energy transition

Leveraging the digital twin to empower the route to sustainability

Executive summary

The impact of human-caused climate change is already playing out in front of our eyes. Extreme weather events linked to climate change, such as floods, heat waves, droughts and storms, are occurring with increasing frequency and intensity around the world, causing harm to people, damage to infrastructure and destroying ecosystems. This is a code red situation. Growing awareness of the potentially devastating impact of failing to make fundamental changes in our way of living is pushing the world into a race to decarbonize. Energy transition has a critical role to play because generating and using energy accounts for close to 75 percent of all greenhouse gas emissions.

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Introduction

It is time to rethink our approach. The earth is warming, rainfall patterns are changing and sea levels are rising. These changes are threatening the sustainability of life on earth.

In some areas ferocious storms are destroying lives, homes and infrastructure. In others, a lack of rainfall means deserts are expanding, reducing land for growing food. Across the world many people now face the threat of drought and climate-induced famine.

In the face of the potentially catastrophic effects of continued warming of the earth's surface, we need to rethink all aspects of the energy system, including the sources of energy, its generation, distribution, storage and efficiency at every step of the way.

We need new ways of thinking and working because no single technology can solve our decarbonization challenge. The future of energy depends on a new range of integrated technologies and people working together.

This disruption in our physical world brings with it risks, but also opportunities – including shifts in demand, the development of new energy resources and innovations arising from the need to tackle emissions and manage carbon.

"The energy sector is responsible for almost three-quarters of the emissions that have already pushed global average temperatures 1.1 °C higher since the preindustrial age, with visible impacts on weather and climate extremes."

World Energy Outlook 2021, International Energy Agency

Solving the energy trilemma

The transition to energy sustainability is a necessity if we are to reduce the global carbon footprint and sustainably meet growing energy demand in many parts of the world. But it is also an opportunity to transform societies and grow economies.

To build a strong basis for future prosperity and competitiveness, we must balance the three core dimensions of what Oliver Wyman and the World Energy Council have defined as the energy trilemma: affordability and access, energy security and environmental sustainability.

- **Affordability and access:** Energy we need and use in our everyday lives is affordable and accessible to everyone
- **Energy security:** There is uninterrupted availability of enough energy to meet current and future demand, and the system can respond to changes in supply and demand through the day and the seasons
- **Environmental sustainability:** Develop energy supply from renewable and other low-carbon sources to limit greenhouse gas emissions and prevent further damage to the environment

It is important to find a balance between all three points of the trilemma without sacrificing one to achieve another at every stage of the transition and beyond.

The time to act is now

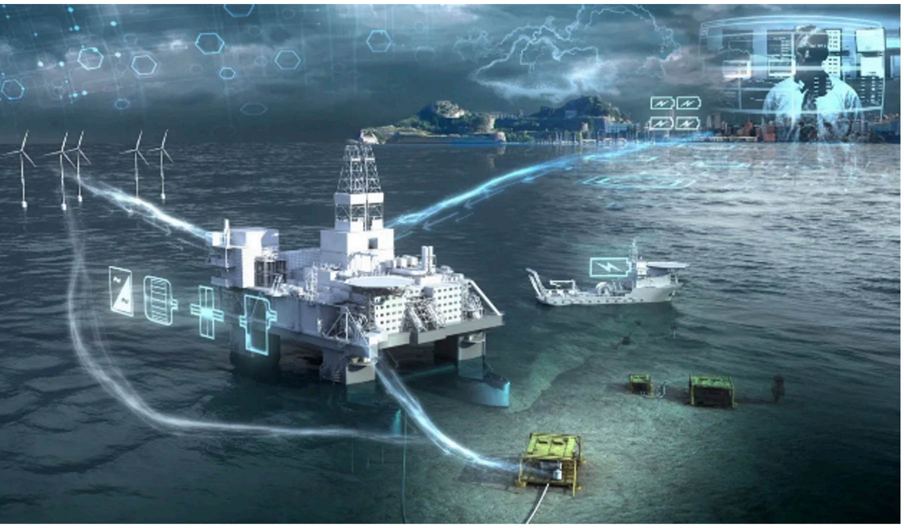
The Intergovernmental Panel on Climate Change (IPCC) warns that between 3.3 and 3.6 billion people already live in areas highly vulnerable to climate change.

In addition, multiple recent events – such as the pandemic, the war in Ukraine, soaring oil and gas prices – have accentuated the cost to the global economy of a centralized energy system highly dependent on fossil fuels, and highlights the pressing need to accelerate global energy transition.

> "Even if all countries with net-zero commitments deliver on their aspirations, global warming is projected to reach 1.7°C by 2100 [...] To keep the 1.5° Pathway in sight, the global energy system may need to accelerate its transformation significantly, shifting away from fossil fuels toward efficiency, electrification, and new fuels, quicker than even the announced net-zero commitments."

McKinsey & Company, Global Energy Perspective 2022, April 2022

The landscape of change



The energy sector has essentially evolved as a range of interlinked but largely independent consumer delivery channels for fuel, heat and electricity. But the energy system of the future will consist of a much more complex web of interactions.

The IEA Net Zero by 2050 roadmap predicts that around 40 percent of primary energy will be converted at least twice before reaching end users:

> "Energy travels through batteries and electrolysers, undergoes conversions from electricity to heat or fuels, and back again. Such conversion processes are essential to provide the system flexibility needed to match the supply of variable renewables and demand for electricity at least cost."
>
> *Net Zero by 2050: A Roadmap for the Global Energy Sector, International Energy Agency*

Achieving this kind of flexibility requires a complete reappraisal of how we generate, manage and distribute energy. In moving away from fossil fuels to renewables, the industry must find solutions for managing and balancing a fundamentally different mix of assets. We see industry responding in three waves, each with a focus on different disciplines:

Engineering innovation

Electricity is taking an increasingly central role in the lives of consumers and is a major focus for developing sustainable energy generation. We need to innovate to transition to technologies that do not emit carbon dioxide (CO_2) and, by extension, greenhouse gases.

Key technology areas in current engineering research include development of advanced batteries to offer more effective energy storage; development of low-carbon fuels, such as hydrogen; hydrogen electrolyzers; direct air capture and carbon capture and storage (CCS) systems as well as next-generation nuclear.

Rapid decarbonization of the electricity sector requires a massive surge in the deployment of low-emissions generation. In most regions, solar photovoltaics (PV) or wind already represent the cheapest available source of new electricity generation. The challenge is to scale and optimize these new technologies to provide energy security and stability – especially as worldwide demand for energy continues to grow as living standards rise.

In this context it is equally essential that we find ways to become more efficient in our use of energy – doing more with less and reducing waste – as well as being more efficient in energy generation.

Managing the transformation

In recent years we have seen many former energy specialists evolving into multi-energy companies. For example, transitioning from an international oil company to an integrated energy company. In conjunction with this transformation, designers and operations teams are updating their skills to meet the demands of the more complex, integrated energy landscape and the changing asset mix.

Due to the magnitude of the challenge and the speed of transition required, this new environment rewards partnerships over traditional supplier relationships: Partnerships that enable integration across disciplines and collaboration between globally distributed teams to build in the flexibility and capabilities required to unlock robust, new design solutions.

Ops integration
The radical acceleration in the pace of development in the energy sector is also bringing about fundamental change at the operational level. The market demands greater efficiency, durability and cleaner, more sustainable energy solutions.

Unlike siloed specialists, engineers are becoming more generalist, with skills in multiple disciplines to enable a faster response to business needs across the supply chain.

Whether developing advanced new materials and processes or optimizing the performance of existing infrastructure, a new, concurrent type of workflow is required. What is required is a framework in which information can flow naturally and transparently across the traditional silos of design, performance analysis, approvals, manufacturing, supply, installation and ongoing service upgrades.

Re-use of design insights in the operations phase
To provide the necessary transparency and greater efficiency, the software tools to support engineering design and optimization must be capable of being used across the multidisciplinary team. Ops engineers must be able to re-use the models and benefit from the insights gleaned from design phase.

This opens the door to better monitoring, control and ongoing optimization to prolong the life and efficiency of plant and equipment and, wherever possible, make the process greener.

Digitalization: the key solution strategy

How to unlock the potential of these new technologies? How to develop new solutions in the short time available to prevent further damage to the environment and to meet stricter regulations for reducing emissions being introduced in almost all industries?

Traditional processes such as spreadsheets for comparing and evaluating hypotheses are cumbersome and limited. Relying on building prototypes is too slow and costly. The complexity of the emerging integrated energy landscape and the urgency of the situation requires use of state-of-the-art digitalization and the digital twin.

The digital twin

A digital twin provides a virtual representation of real-world products and systems. By collecting real-time data from installed sensors, the digital twin provides an accurate and continuously updated representation of the real asset.

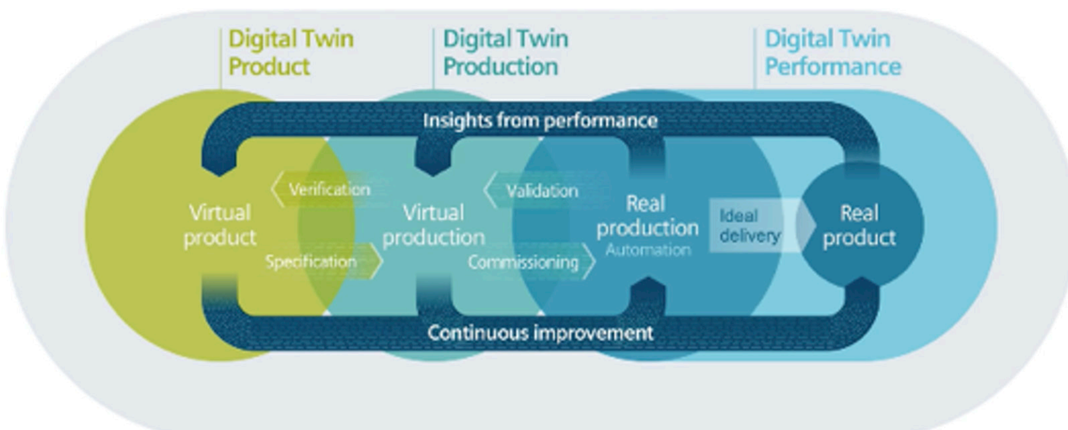
This integration of data in real and virtual representations provides a platform for optimizing product design and performance at every stage of the lifecycle. For example:

- In development, simulating and testing a product's behavior prior to building a physical prototype
- In production, simulating and testing any element, from individual machines to entire factories
- In operations, predicting potential problems, testing potential solutions and optimizing product performance within the constantly evolving real environment

Digitally represent what is real, simulate what is possible

The digital twin not only showcases form, but analyses functions, from the rotation of a shaft to thermal conductivity and the interaction of different components. Furthermore, with the continual flow of data, user experience feedback and new input, the digital twin continuously evolves.

The most holistic digital twin



Only through continuous improvement can we achieve the best result possible.
This creates a complete picture and closes the loop.

Cape Horn Engineering creates a highly accurate digital twin to study WASP energy savings

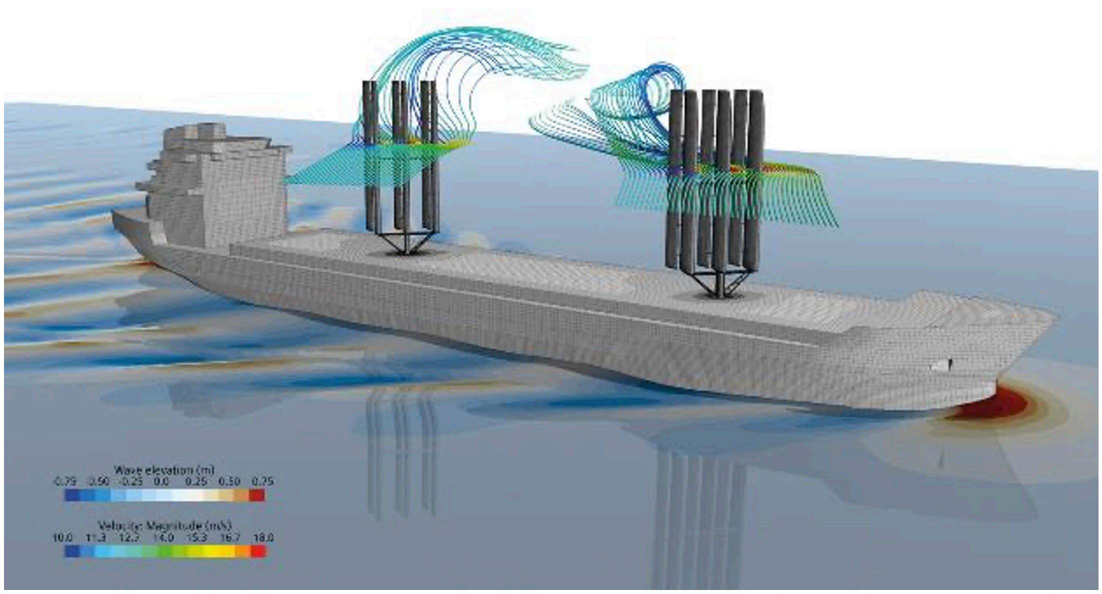
There can be millions of extremely large and complex parts, components and systems to integrate on something as vast as a cruise ship. But every cent that you can save by enhancing energy efficiency contributes to reducing the overall cost of operation and long-term sustainability of the vessel – not to mention the overall environmental impact of reduced emissions and global warming.

Some ship owners are considering wind assisted ship propulsion (WASP) devices, such as wing sails, suction sails or Flettner rotors, to reduce operating costs and ensure that a ship design meets or exceeds the upcoming Energy Efficiency Existing Ship Index (EEXI) regulations.

WASP devices can be used to cut fuel costs by up to 30 percent, but they are highly complex systems to model. Both the hydrodynamic and aerodynamic effects need to be modeled simultaneously in a single simulation.

“Our simulation workflow allows us to directly compare WASP device efficiency and determine potential savings,” explains Dr.-Ing. Azcueta of Cape Horn Engineering, U.K.-based consultancy that specializes in computational fluid dynamics (CFD). “Wind conditions above the water surface are modeled with an accurate wind profile, taking into account the atmospheric boundary layer wind gradient.”

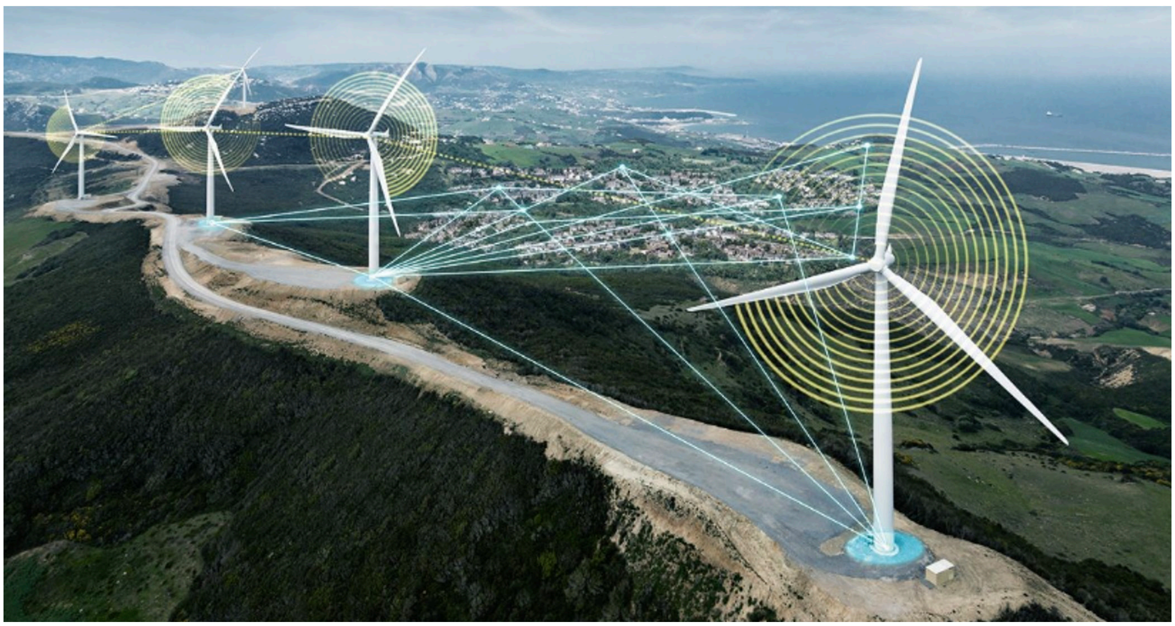
The consultancy is now working on models that incorporate artificial intelligence (AI). “Incorporating AI into the picture opens up vast possibilities to optimize the wing sail design and develop intelli-gent control systems to ensure the largest possible reduction in emissions,” adds Azcueta.



The executable digital twin

The executable digital twin (xDT) extends the usefulness of the simulation models created during the design stage into the operational life of the products. It's a way of extending measurement and test throughout the lifetime of a product.

Further, it's a way of combining simulation and test inside a dynamic model that learns and evolves from the conditions that it experiences in the field – or, for that matter, in the middle of the ocean.



Reducing the risk of subsea tree operation

Subsea compression increases the amount of gas that it is possible to extract from a well. For example, the Jansz-lo field located off the coast of Australia, features three 12-megawatt compressors operating in parallel.

How do you test for design purposes a system at full scale that weighs more than 4,000 tons and feeds a iquefied natural gas (LNG) plant producing 16 million tons per year?

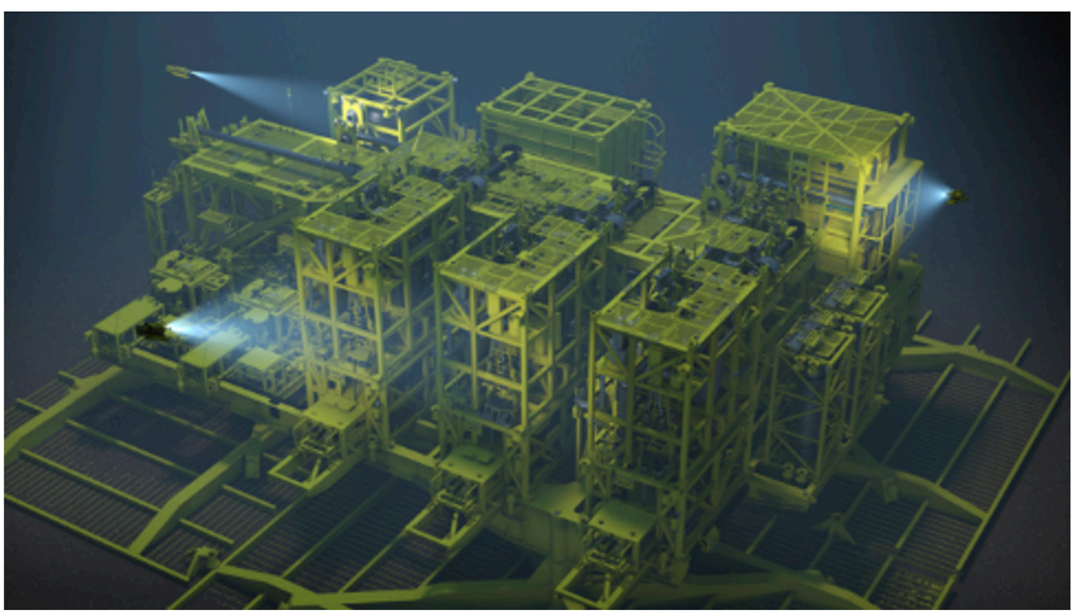
The first opportunity to physically test the full system will occur on the seabed at a depth of 1,300 meters (m). There is no room for error down there. Failure is simply not an option. All systems need to be verified beforehand. But how?

Hybrid, multiphase CFD simulation
Digitalization and the use of digital twin technology allows engineers to test all the equipment numerically before it goes down to the seabed. With three compressors, the Jansz SCSt Inlet Scrubber is by far the world's largest high-pressure scrubber. What’s more, it’s designed to operate autonomously at 1,400m below the surface and suction pressures in excess of 100 bar in a maintenance-free environment for 50 years.

"The engineering of the inlet scrubber demonstrates the effectiveness of computational fluid dynamics simulation," says Henrik Alfredsson of Aker Solutions. "The hybrid multiphase model in Simcenter STAR-CCM+ is tailored to our applications, fluids and pressures to make sure that it replicates real behaviors.

“We validated the model against test data obtained from separate test loops around the planet. Therefore, we can use our numerical test benches to qualify the technology. So the first time we start up the station, we are already certain of its performance."

Simcenter™ STAR-CCM+™ software is part of the Siemens Xcelerator portfolio, the comprehensive and integrated portfolio of software, hardware and services.



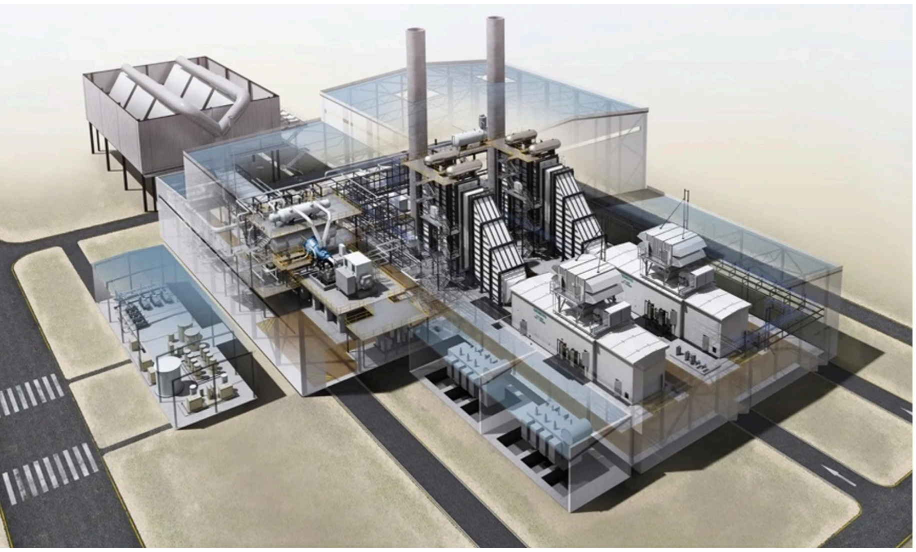
Predicting turbine blade failure

Once the model (xDT) of the turbine blade has been created from multiple sensors embedded in a test blade, just two or three sensors are required on the production blade in the field. From this, the physics-based xDT model can predict response data at any number of virtual sensor locations, and thus predict the likely failure of the real component.

As a result, this allows significant savings in time and resources otherwise tied up in regular maintenance checks of ocean-based wind farms. Furthermore, as more data comes in from that turbine's daily operation, the xDT updates itself, adapting to and learning from its environment.

Instead of traditional algorithmic extrapolations from limited, typical data, the xDT runs real-time simulations in the background, which allows it to reconstruct data across the entire model that corresponds with the known data measured at the limited number of actual sensors.

The digital twin: optimization across the entire power plant



The digital twin enables companies to optimize their transformation with the tools and capabilities to deliver:

- Digital lifecycle management
- Integrated design and configuration
- Advanced engineering simulation
- Operational excellence

Digitalization and the digital twin can be used to achieve multiple goals at scale, from optimizing the performance of a single piece of equipment to the entire plant and multiple installations across an organization.

As systems become more complex, the digital twin enables teams to factor in and correlate multiple complex performance variables and operator experiences to achieve maximum performance to increase productivity, improve energy efficiency and streamline operations.

For example, in a power plant, precision laser measurements give operators a detailed picture of combustion processes as a first step toward getting the most output and profitability from their assets.

By digitally optimizing the combustion parameters, operators can significantly boost efficiency; in turn, reducing coal consumption, raising profitability and scaling back emissions.

Transition technologies for the gas turbine
A gas turbine is a thermodynamic masterpiece. Delivering high power output and thermal efficiency, it is one of the most compact ways to generate electricity. Now advanced design and simulation software is enabling companies to further optimize turbine efficiency and reliability.

Siemens Energy is taking its use of simulation technology to the next level, combining combustion and turbine simulations for more accurate temperature predictions. This allows operators to increase efficiency by reducing cooling air consumption.

The two major emissions from a gas turbine are water (H^2O) and CO_2. But does a gas turbine have to run on natural gas? Siemens Energy is now ready to use hydrogen and can blend high amounts of hydrogen with natural gas – allowing gas turbine plants to reduce emissions by using a blend of the gases.

Developing pure hydrogen solutions
B&B Agema and Kawasaki Heavy Industries used Siemens Digital Industries Software simulation technology to design and optimize the world's first gas turbine to run on pure hydrogen. That means the only emission will be water.

The digital twin provides a single source of truth to optimize design, management and maintenance of assets at scale and in real time.

Digital twin: the single source of truth

Ultimately, operations, maintenance, energy efficiency, security and all other areas of power plant functionality interconnect. A comprehensive data ecosystem can provide complete access to all plant information and support continuous improvement.

The digital twin brings together and unlocks actionable data across all the functions and processes of a plant. This enables complete visibility into operations and the development of proactive strategies for optimization based on predictive analytics.

Improving reliability, resilience and security
The digital twin can provide a real-time dashboard for plant emissions and limits, as well as support automated monitoring of incidents, documentation and root-cause analysis.

In addition, digital twin technology allows engineers to monitor equipment remotely. By bringing together resources and knowledge from numerous geographical locations, expertise can be shared across the organization.

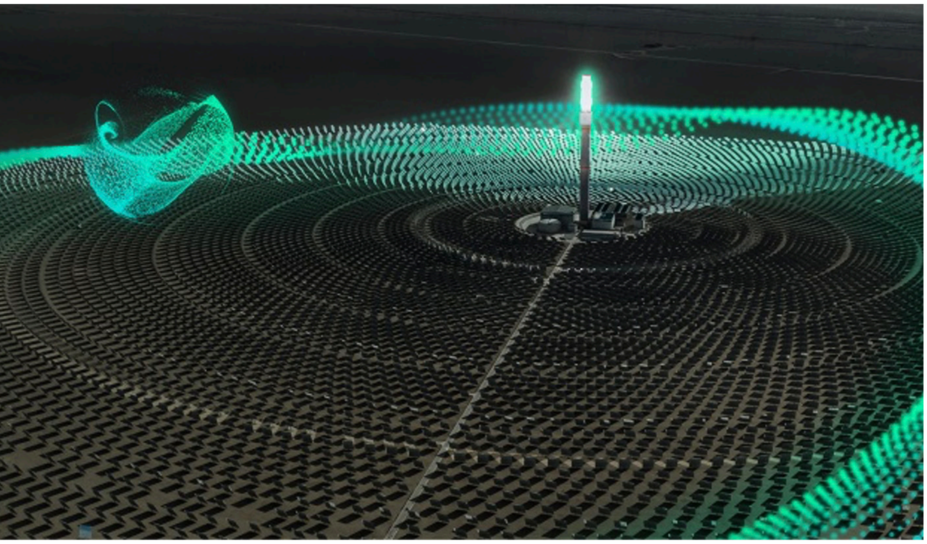
The power of digitalization and a single source of truth
Operations: With a single repository for all relevant information, stakeholders can access the data they need quickly and simply and share knowledge efficiently across the organization.

Maintenance: Managers and the maintenance team can easily view records and conduct analyses to mitigate risk and improve future performance, such as reducing downtime.

Energy efficiency: Digitalization enables real-time analysis of efficiency metrics – so there are no more delays for data gathering and analysis to identify an issue. Instead, engineers can receive immediate notifications of parameters that have been exceeded and other key indicators and begin to resolve issues immediately.

Health, safety and environment (HSE):
Automated data collection and greater sharing of information allows a more complete analysis of incidents and better safety outcomes with the ability to develop better strategies to prevent future occurrence of issues.

Siemens: Advanced engineering simulation for the digital twin



Powered by Siemens simulation technology, the digital twin enables customers to engineer specific performance characteristics into their products, plants and processes. It serves as a virtual test platform where design space can be narrowed down in a systematic and efficient way.

Fostering collaboration across the disciplines
What's more, once developed, the virtual models can be re-used by nonspecialists at any point in the product lifecycle on any certified device. The Siemens simulation environment provides a technology-neutral platform that enables users to explore domains they are unfamiliar with.

Teams with diverse skill sets and domain expertise can work together to innovate, experiment and create. The low-risk virtual environment means that imaginations can be stretched to their fullest and the potential outcomes are limitless.

Conclusion

Using the digital twin, the innovation backbone of the future, breaks with traditional paradigms and opens up extraordinary possibilities for operating, developing and producing products in the energy sector. In fact, the future is now as manufacturers are already merging the digital twin with artificial intelligence to independently design advanced products.

Every step toward lower emissions counts. Every effort to reduce our reliance on fossil-based energy brings us closer to our critical net-zero goal. Act now.

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For additional numbers, click here.

Siemens Digital Industries Software helps organizations of all sizes digitally transform using software, hardware and services from the Siemens Xcelerator business platform. Siemens' software and the comprehensive digital twin enable companies to optimize their design, engineering and manufacturing processes to turn today's ideas into the sustainable products of the future. From chips to entire systems, from product to process, across all industries, Siemens Digital Industries Software – Accelerating transformation.

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