engineering.com

The Definitive Guide to Digital Twins for the Energy Industry

Unity

This white paper is sponsored by Unity Technologies.

This white paper describes the value of digital twins in the energy industry. It also lists many successful applications for your consideration. Some of these applications will advance your digital transformation. Others respond to the external pressures the energy industry is facing.

The white paper concludes with a brief discussion of implementation of best practices and risks to avoid.

INTRODUCTION

As more companies in the energy industry adopt digital twins to manage their essential assets, it's worth examining this trend and the value it delivers. Digital twins help management, engineers, technicians and operators better understand how their complex assets are performing now and how they will perform in the future.

Tactically, digital twins help companies improve decision-making, reduce costs, reduce cycle time and become more efficient. Strategically, digital twins help energy companies become more productive, increase profitability, maintain a competitive advantage and meet environmental, social and governance (ESG) goals.

Digital twins can help energy companies respond to societal expectations, reducing environmental footprint, responding to activist pressure, capital market demands, improving low-confidence ESG estimates and identifying opportunities to transition to a lower-carbon economy. This can be achieved by using digital twins in combination with digital transformation, artificial intelligence, cloud computing, simulation and machine learning.

"Unity is an important part of a large ecosystem of tools helping energy companies advance their digital transformation initiatives," says Scott Hamilton, Vertical Lead - Energy Americas at Unity Technologies. "Digital transformation is the next revolution defining how we interact with data. It's driving patterns and behaviors for how most disciplines are starting to work."

WHAT PROBLEMS DO DIGITAL TWINS ADDRESS?

The energy industry is grappling with a wide range of problems. Employing a digital twin can help with a few, such as high development cost, elapsed time for complex facilities, unplanned equipment failures, sustainability, operating costs and energy consumption.

"Digital twins enable system thinking," says Scharl Scott, Senior Sustainability Program Manager at Unity Technologies. "Our customers encounter a wide range of technical circumstances and business issues that digital twins and system thinking can resolve more efficiently than other approaches."

Digital twins help companies in the energy industry address these problems and many others by modelling the design and operation of related equipment and systems.

WHAT IS A DIGITAL TWIN?

Digital twins are digital representations of real-world physical objects using data, modelling and visualization. Digital twins are dynamic and real-time. They are much more capable than static representations like a blueprint, a schematic, a picture, a scale model or even an animation. Examples of digital twins in the energy industry include electricity production equipment and an oil or natural gas processing system. The physical object can be any asset, such as an industrial battery, a natural gas compressor, a crude oil refinery or an electricity distribution grid.

Digital twin models represent all the necessary features of the physical object. The characteristics include thermal, mechanical, electrical, chemical, fluid dynamic, material and economic properties.

WHAT VALUE DO DIGITAL TWINS PRODUCE?

"What used to take ten people a week to figure out, one person can now complete in a couple of days with Unity digital twin software on a laptop," says Matt Grant, Senior Program Manager at Unity Technologies. "That person doesn't need to be an expert in thermal dynamics, complex machinery or process flow diagrams. Their advanced software incorporates the knowledge and experience of the 50 years of many professionals who've come before them."

As physical equipment and facilities become more complex, expensive and dimensionally larger, the value of digital twins increases. For example, consider the increase in the number of components in a modern drilling rig, a wind farm or a compressor station compared to its predecessors a few decades ago.

A digital twin can help with strategies such as scenario planning for an energy transition and increasing throughput, revenue and profitability. When it comes to design, a digital twin can reduce the cost and elapsed time of equipment research and shorten development cycles by eliminating or reducing the cost of building physical prototypes or models. This lowers the manufacturing cost of equipment and reduces capital expenditure.

Operationally, a digital twin can improve equipment efficiency and reliability, reduce cost and elapsed time of equipment inspections, improve occupational and process safety while improving operating costs and energy efficiency. Maintenance will be reduced and so will downtime. A digital twin will be able to help predict equipment failure. Mean time between planned maintenance events will increase. Environmental effects will be positive: reduced equipment emissions and lead to improved decommissioning and recycling processes.

This wide variety of benefits is accelerating the adoption of digital twins in the traditional and renewable energy industries and speeding the evolution of multiple types of digital twins.

ARE DIGITAL TWINS SIMPLY ANOTHER TYPE OF SIMULATION?

Digital twins and simulations both utilize digital models to replicate the capabilities of physical objects. However, a digital twin is a virtual environment that adds scale and capability beyond what simulations can do. Digital twins can study multiple processes concurrently whereas simulations typically study one process at a time. They provide real-time 3D (RT3D) information about physical objects whereas simulations typically predict performance or explain past events.

TYPES OF DIGITAL TWINS

A digital twin's type is defined by its scope. Digital twins that can handle increasing scope also deliver more valuable insights while requiring more resources to function.

Component twins are the basic unit of digital twins. Studying a component produces insights into the performance of variables such as strain or heat. Examples are a sliding sleeve, a valve actuator or a compressor blade.

Asset twins consist of two or more component twins used to study the interaction of those components. This study simulates performance data under various operating conditions for actionable insights. Examples are an electric motor, a drill bit or a gas turbine.

System twins show how different assets come together to form a functioning system or physical object. System twins provide visibility regarding the interaction of assets and often suggest optimization enhancements. Examples are the compression or amine tower portion of a natural gas processing plant or the emulsion separator at a crude oil terminal.

Process twins reveal how systems work together to create an entire production facility. Process twins can determine bottlenecks that influence overall effectiveness. Examples are an oil refinery, a natural gas pipeline or a petrochemical plant.

WHY ARE DIGITAL TWINS RECEIVING MUCH MORE ATTENTION NOW?

The profile of digital twins has become much more prominent recently, even though simulations have been used routinely for decades. Many reasons explain why.

The main business reason is a continuing desire to exploit all technologies to improve product and service performance and reduce costs in a competitive environment.

The generation entering the workforce, often called Generation Z, has grown up immersed in information technology and expects to find it in the workplace.

Technically, the digital twin has matured and therefore, makes itself more usable. A digital twin ecosystem has emerged after many years of significant investments in the foundational software for digital twins. Software has been developed that can produce digital twin applications more efficiently.

Digital capture of the data that digital twins require has increased by leaps, primarily due to the expanding use of SCADA/IIoT in many industries.

Specific to the energy industry, the capability of digital twins has advanced enough to provide a net benefit for oil and gas producers who can now think more about cost management and emission reduction than in the past.

Renewable electricity producers know that their businesses will grow more quickly if they can compete effectively against fossil fuel-fired generators.

DIGITAL TWIN MATURITY MODEL

The digital twin maturity model helps assess where an organization currently sits along the path of digital twin adoption. The assessment helps the organization determine the next steps to increase the value of digital twins.

Virtual Digital Twin

The Level 1 twin is a physically accurate, realistic digital representation of an asset, facility or product that emulates its real-world counterpart.
An energy industry example is an accurate representation of a crude oil refinery.

Connected Digital Twin

The Level 2 twin integrates real-time and right-time data to provide insights into the performance of an asset at specific points in time.

An energy industry example is an accurate representation of the current performance of a nuclear reactor.

Predictive Digital Twin

The Level 3 twin leverages data to predict the outcomes and problems for complex facilities and equipment operations.

An energy industry example is accurately identifying the mean times to critical equipment failure at a hydroelectric electricity generating station.

Prescriptive Digital Twin

The Level 4 twin leverages advanced modeling and real-time simulation for potential future scenarios to produce prescriptive analytics and recommendations.

An energy industry example is accurately predicting the electricity production capacity of a solar facility for the next week by the hour, taking weather, time of year and the operational status of the panels into consideration.

Autonomous Digital Twin

The Level 5 twin uses multiple real-time data feeds to learn and make decisions to correct issues automatically and enable predictive and prescriptive analytics.

An energy industry example is accurately adjusting the operating parameters of the steam turbines at a natural gas-fired electricity generating station without operator intervention.

DRIVERS FOR THE ADOPTION OF DIGITAL TWINS

In the energy sector, the emergence of renewable energy sources to advance the energy transition has created competitive pressure and investment opportunities. Volatile commodity pricing makes margins and earnings challenging to predict and more valuable, creating a drive to improve reliability and resiliency.

Corporate management, pushed by investors into recognizing the value of digital transformation initiatives, are starting to deliver on promises of increased margins and productivity through operating cost reduction.

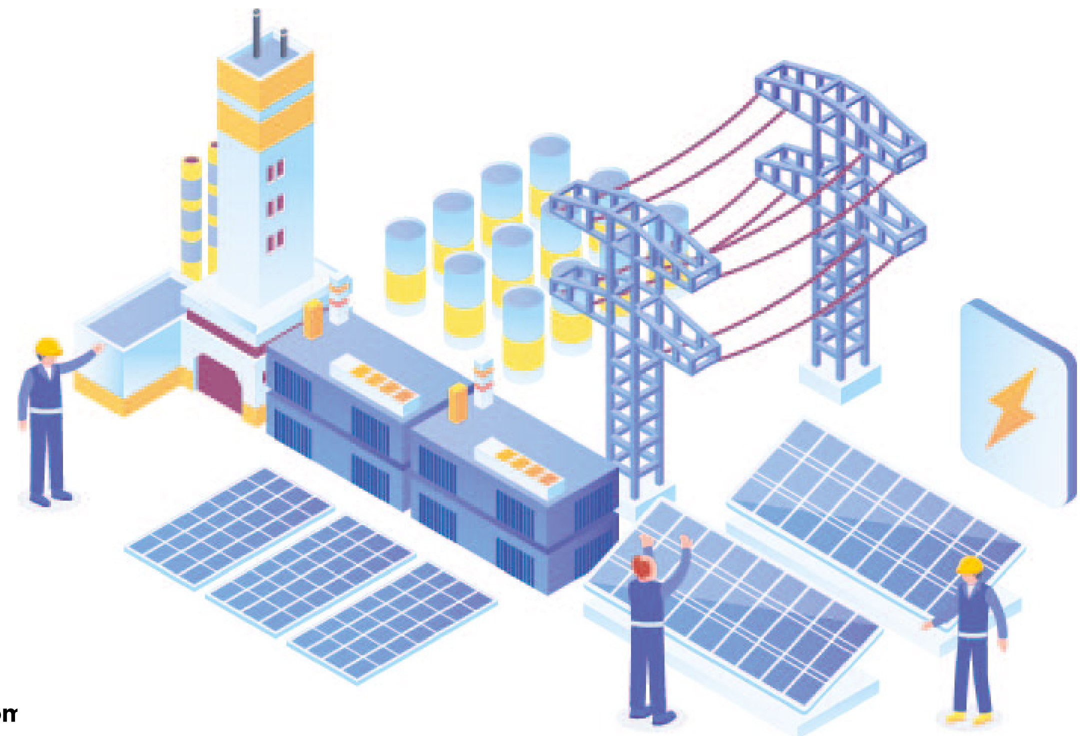
Exploration and production technology is rapidly changing and has created ongoing pressure for experimentation and adoption.

Societal pressures for safety, sustainability and reduced carbon footprint of operations create a need to measure ESG performance more accurately. Government added pressures such as carbon taxes or cap and trade schemes are also increasing.

DRIVING INNOVATION WITH DIGITAL TWINS

Innovation is difficult to define and typically emerges in surprising, unplanned ways. Innovation isn't only about creating new products or services. It's also about finding new ways to revise existing processes and workflows to be better, faster and cheaper. Digital twins can nurture innovation when organizations:

1. Provide time and space for employees to experiment with digital twins to explore ideas and scenarios.
2. Invest in digital twins and supporting data resources to advance innovation.



3. Encourage collaboration among employees, suppliers and customers when reviewing digital twin results and generating new ideas.
4. Reward employees for their ideas that are confirmed by digital twin analytics.
5. Implement recommendations from digital twin analytics as soon as possible. Often speed involves minimizing bureaucracy.
6. Offer digital twin training to employees that will inspire new thoughts and approaches to the business.
7. Make innovation a core value by removing boundaries and providing freedom to explore ideas without fear of retribution for wasting digital twin resources.
8. Maintain a positive atmosphere and avoid assigning blame. Employees feeling stressed or under pressure are not in a mental space where they can innovate.
9. Remove toxic employees.
10. Support diversity and inclusion by hiring culturally and demographically diverse employees.

WHAT ARE SOME EXAMPLES OF DIGITAL TWIN APPLICATIONS?

"In the energy industry and the wider AECO space, digital transformation and digital twins are scorching hot topics," says Grant. "While digital twins are not a new construct due to the long familiarity with CAD, the industry is excited by the concepts of real-time 3D visualization, decoupling data from software and data interoperability offered by the Unity ecosystem."

"The big business trend we're observing is the energy transition," says Hamilton. "It encompasses renewable energy generation, emission reduction, carbon capture and ESG. Unity digital twins are playing an important role in helping energy companies devise feasible and cost-effective solutions."

"The energy industry deploys Unity digital twins for many applications," says Hamilton. "For example, confirming safety in operations, construction progress and variance tracking, offshore subsea well planning and maintenance turnaround planning."

"Unity's oil and natural gas producer clients understand that the digital twin is the end construct of an engineering model," says Grant. "The model enables multiple use cases. For example, construction engineers use the digital twin to plan the replacement of a power generator because it's an expensive and dangerous job on an offshore platform. The facilities engineers use it to manage a complex crude oil refinery maintenance turnaround. The maintenance workers use the digital twin to organize maintenance tasks."

ENERGY INDUSTRY APPLICATIONS

There are many applications for digital twins in the energy industry including design visualization, facility construction, operation and maintenance, field service and education/training.

"Multiple advances are improving the sophistication of digital twins and reducing their cost," says Hamilton. "The introduction of 5G is reducing the cost of data gathering while increasing its volume. Computing hardware is becoming cheaper and more reliable in the data center and the field. Unity introduced the concept of real-time 3D visualizations on any end-user device."

"Our clients' challenge is to keep a digital twin up to date so that it's the most useful for the engineers who need to use it," says Grant. "Unity's energy clients choreograph, rehearse and practice planned work before they go out in a ship at $1 million a day. Out in the middle of the ocean, no one wants to discover they forgot something, or that this isn't going to work."

The larger digital twin applications are listed below by industry segment.

Renewable Energy Applications

Industry	Where Used	Digital Twin Applications Use
Renewable energy "Sustainability is not limited to environmental sustainability," says Scott. "For Unity customers that are for-profit companies, sustainability includes their fiduciary duty to be profitable to sustain the business."	Electricity generators using solar, wind, hydroelectric, nuclear and storage technologies	Solar generation, wind, hydroelectric, nuclear, geothermal, battery facilities, hydrogen production, pumps, turbines and generators.
Energy Transition The energy transition will reduce greenhouse gas (GHG) emissions, reduce other air pollutants and dramatically increase electricity production from renewable energy sources.	Carbon capture and underground storage (CCUS) facilities, direct air capture (DAC) facilities for removing CO2 from the atmosphere, carbon capture at coal and natural gas-fired electricity generation stations and systems to reduce GHG emissions at fossil fuel production and processing facilities.	CCUS facilities, DAC facilities, electricity generation stations, systems to reduce GHG emissions.
Electricity Distribution	Long-distance high-voltage electricity transmission and low-voltage distribution to consumers.	Transmission lines, sub-station, transformer distributions and control systems.
Upstream Conventional and Unconventional Energy	Exploration for energy resources, drilling and completion, crude oil production, raw natural gas production and gathering pipelines.	Seismic data gathering, horizontal well drilling, well completions.
Oil and Mining	Mining, separation and upgrading.	Surface mines, overburden and tailing ponds, separation facilities, hauling trucks, draglines, blending facilities and water management.
Midstream Oil and Natural Gas	Processing crude oil, processing raw natural gas and large pipelines.	Natural gas processing facilities by representing sulfur handling facilities, blending facilities, rail and truck loading facilities, crude oil pumping stations, natural gas compressor stations, tank farms, underground storage facilities and crude oil and natural gas pipelines.
Downstream Energy	Crude oil refining, distribution of refined products and retail sales to consumers.	Refineries, refining slate optimization, product tank farms, rail and truck distribution terminals and refined product pipelines.
Petrochemical (crude oil and natural gas)	Intermediate chemicals and final products such as detergents, fertilizers, floor covering, insecticides, perfume, plastics and textiles.	Chemical production facilities, production optimization, product tank farms and rail and truck distribution terminals.
Smaller Applications	Drill bits, completion tools, pumps, compressors, meters and valves.	[1][RT2]Small applications are an effective, low-cost way to ease into the use of digital twins.

BEST PRACTICES TO OVERCOME IMPEDIMENTS TO IMPLEMENTING DIGITAL TWINS

Organizations should be aware of various impediments when implementing digital twins and solutions to ensure a successful project.

"Sometimes customers buy a digital twin solution and think it will solve all their problems," says Hamilton. "They don't realize that it's actually siloed, inconsistent data that impedes their ambitions to scale solutions and drive down costs across the enterprise."

Focus Your Proposal on Tangible Business Benefits

Digital twin projects can only proceed if management approves and funds them. It should come as no surprise that management will only fund projects they understand, and which are financially and strategically justified. Highly technical projects, including digital twin projects, can be challenging to present in terms that management will find appealing.

The solution is to focus the proposal on tangible business benefits and be candid about risks. Minimize discussion of the underlying technical details. Also, plan the project for many releases so that management can visibly observe progress.

Integrate Data Silos Effectively

Most organizations operate with many data silos. Many are associated with software packages such as SAP, Bentley, ESRI or custom applications managed by specific departments. These data silos complicate developing the software for integrating the data to achieve the interoperability digital twins require.

"Unity partners with most software package vendors used in the energy industry," says Hamilton. "To integrate this data, we typically build a real-time interface. Often the vendor handles the discipline-specific calculations, and Unity contributes the data visualization."

Examples include enterprise data from ERP and manufacturing systems and IIoT data from SCADA systems that monitor production and fulfillment equipment. This data is buried in many databases, spreadsheets, CAD, BIM and GIS models.

The solution to better integrate data is establishing a data lake and developing custom extract, transform and load (ETL) software.

WHAT CAPABILITY DO DIGITAL TWINS HAVE?
A digital twin helps designers, engineers and facility operators understand how various physical objects are performing now and how they will perform in the future. The ability to predict future performance helps manufacturers and engineers accomplish a great deal by understanding the interaction of disparate systems and predicting performance under revised operating conditions. Also, a digital twin will enable the visualization of physical objects in operation in real-time and help in troubleshooting far-away equipment.

Improve Data Quality

Organizations experience various data quality problems. Data quality lapses quickly undermine the value that digital twins can deliver.

Management can defend their organizations by educating their employees that with digital twins, accurate and complete data is possible. A data steward for every IT system must supply reports and charts that monitor data quality, ensure data integration, produce exception reports that reveal data problems, enact data governance processes, create data quality measures and share status and trends using dashboards.

Close Skills Gaps

Projects to implement a digital twin can be challenging for staff because the organization lacks the requisite software development and operation skills. Organizations can start with small projects that focus on individual pieces of equipment and only require a few data sources. They may want to consider engaging a consultant at this point, and should be prepared to pay for training for developers and end-users.

Invest in People Change Management

When introduced to new technology like digital twins, staff will be unfamiliar and apprehensive. This situation creates an adoption challenge.

The solution is ensuring people change management is an implementation project component comprising messaging, mentoring and training. This work will turn an impediment into a confidence-building experience.

WHAT CAPABILITY DO DIGITAL TWINS HAVE?

A digital twin helps designers, engineers and facility operators understand how various physical objects are performing now and how they will perform in the future. The ability to predict future performance helps manufacturers and engineers accomplish a great deal by understanding the interaction of disparate systems and predicting performance under revised operating conditions. Also, a digital twin will enable the visualization of physical objects in operation in real-time and help in troubleshooting far-away equipment.

HOW TO GET STARTED WITH A DIGITAL TWIN

Building and operating a digital twin is appropriate in the energy industry when the physical object is complex enough that significant performance improvement opportunities exist. Examples of physical objects that are sufficiently complex are listed above.

The complexity creates a net benefit from applying a digital twin. With complexity, the benefit of a digital twin is sufficient to offset its high cost of development and operation.

The cost is a function of the complexity of a physical object, the effort required to gather and manage real-time sensor data produced and the number and complexity of the simulations conducted.

The development of digital twins is based on sensing, data and modeling strategies required to achieve business and technical goals. Available data resolution, software capabilities and system coverage constrain digital twins.

To create a digital model, designers use a variety of software packages.

Typically, the starting point is the data on blueprints, scans, bills of materials or digital models created in other

Pay More Attention to Sustainment

Successful digital twins evolve and grow as end-users identify new opportunities. Without ongoing sustainment efforts, digital twins will wither into irrelevancy.

The solution is to budget resources to maintain the digital twin ecosystem.

"Unity is moving toward a platform solution for real-time 3D digital twins operating at scale," says Hamilton. "Our customers will benefit through lower cost of sustainment as version upgrades are dramatically simplified, revising applications becomes cheaper and adding new data sources is much easier."

CONCLUSION

Digital twins have demonstrated their value in the energy industry by increasing throughput, revenue and profitability. This white paper lists many successful applications for your consideration that improve facility reliability, reduce cost and improve safety.