Digital technologies supporting the pathway to develop green hydrogen & fertilizers

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Hydrogen Production

Gaining momentum with companies all across the process industries

Renewable electricity

Green hydrogen as a clean energy vector

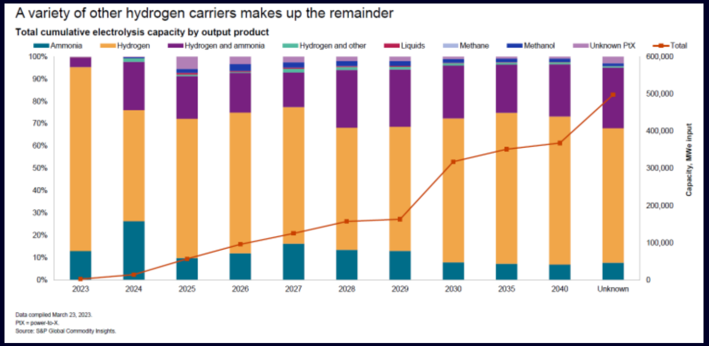
498 GW

Pipeline of electrolysis projects worldwide, with 18.7 GW announced in Q1 2023

Source: S&P Global Commodity Insights

Clean hydrogen market growth

Clean hydrogen as a feedstock in traditional processes



9.2%

Expected growth per year of hydrogen production market value

Source

Novel technologies

Adapting processes to use cleaner feedstocks

2050

Hydrogen demand expected to grow from 87 million MT in 2020 to 500-680 million MT by 2050

Source

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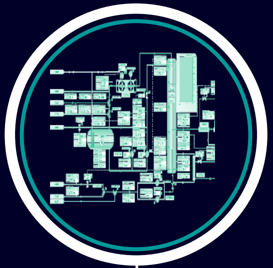


Integrated Design and Configuration

Digital Lifecycle Excellence

Operational Excellence

DESIGN

Research & Development

Requirements

FEED
Front End Engineering Design

Detailed Eng

FID
Final Investment Decision

Procure

Construct

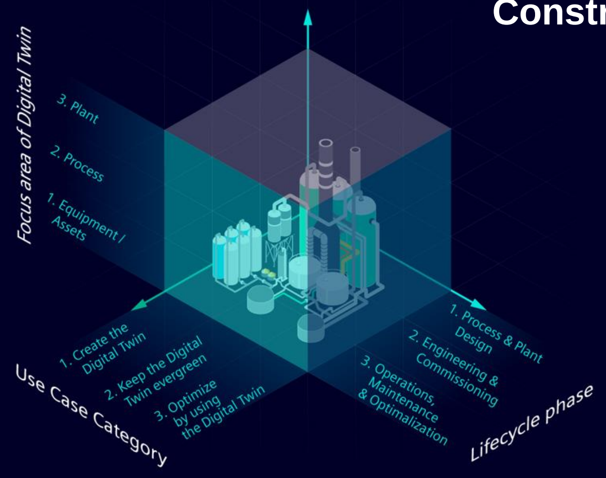
BUILD

Commission

Start-up

Operate & Maintain

OPERATE



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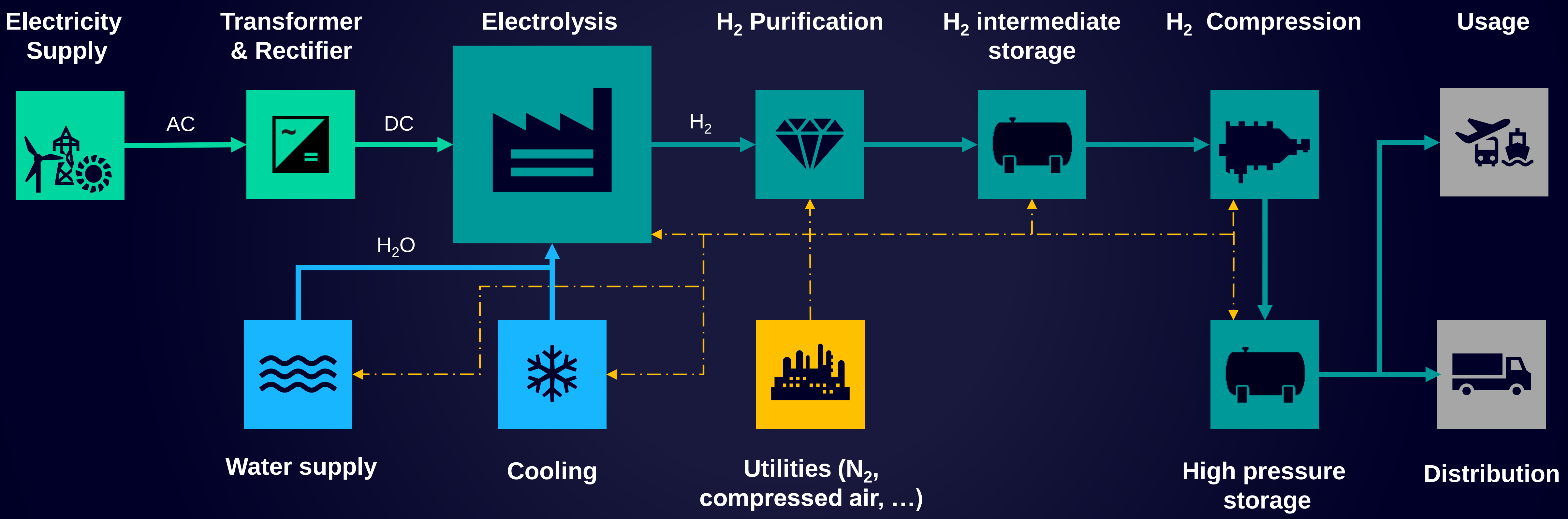
Typical component structure of a hydrogen plant – The Digital Plant Emerge



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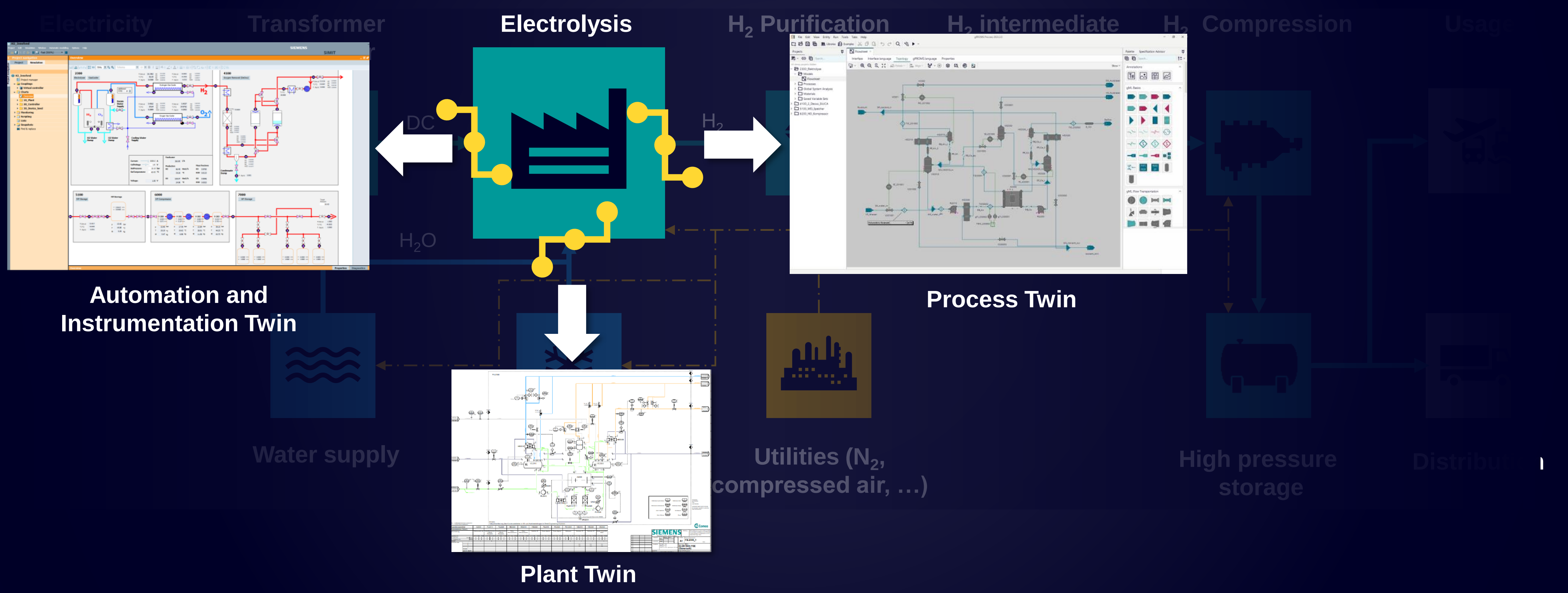

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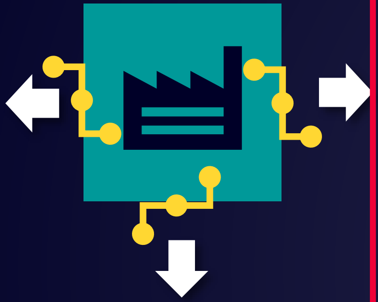
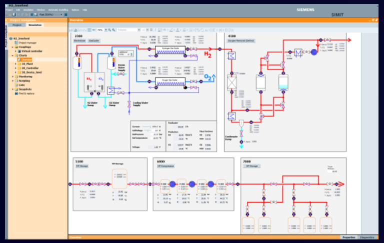
OEM | Operator | Integration: EPC/SI | **Investor/owner**

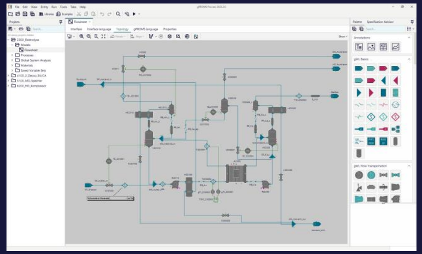
Conceptual process design

Electrolysis

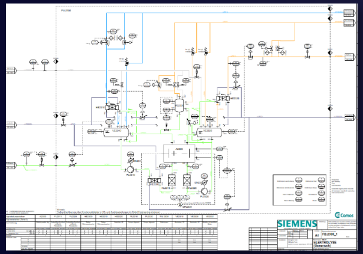




Automation and Instrumentation Twin



Process Twin



Plant Twin

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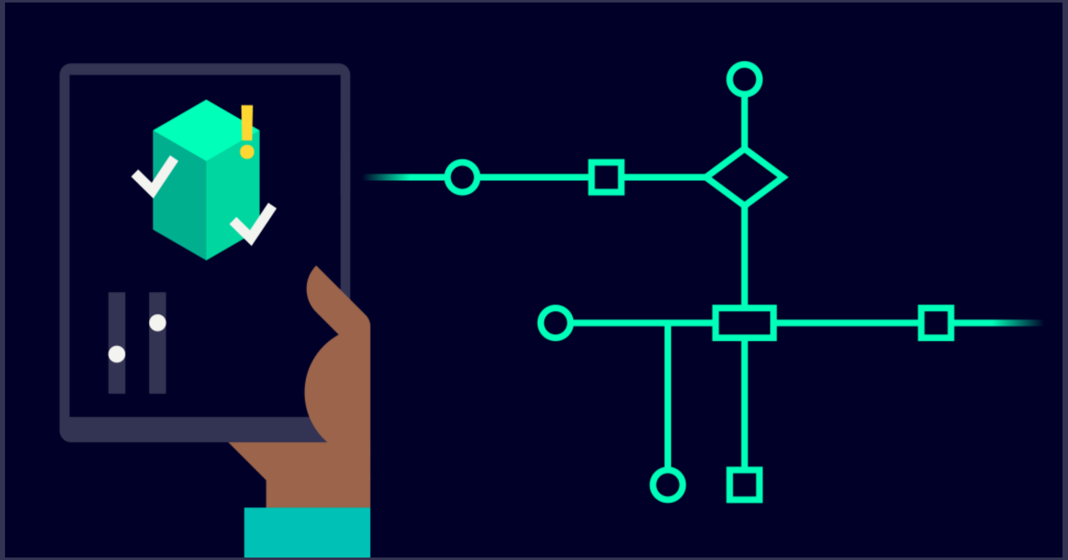
Conceptual process design



Shortage of expert knowledge

Limited information and data

Growing number and complexity of projects

Challenge

Initial project planning

- **Defining process configuration:** Identifying necessary procedures and stages for project initiation
- **Calculating energy and mass balances:** Estimating vital process parameters using available data

Navigating preliminary hurdles

- **Decision-making before supplier selection:** Undertaking critical calculations before finalizing vendors, based on the best possible information
- **Mitigating expertise limitations:** Addressing the challenge of scarce specialized knowledge

Impact

Risks to the FEED phase

- **Inaccuracy concerns:** Employing oversimplified models for quick calculations can lead to misleading results
- **Limited process insights:** These models offer scant process details, necessitating numerous assumptions for further analysis

Standardization and efficiency issues

- **Duplication of efforts:** Without a unified approach, repetitive tasks are common across different projects
- **Inconsistencies in output:** Varying results hamper the ability to standardize workflows, impacting later project stages

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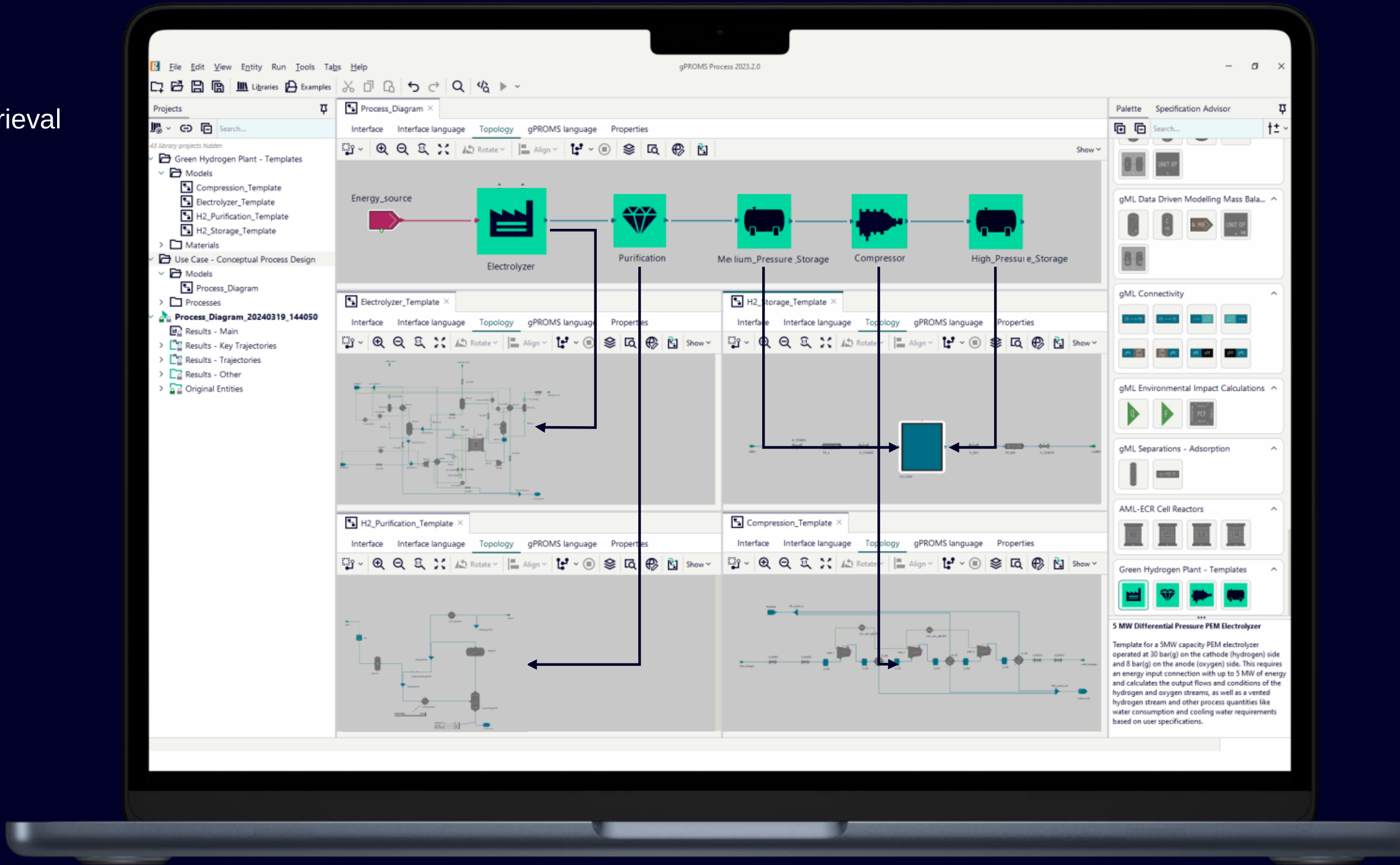
Elevating hydrogen plant development
Advancing hydrogen design with gPROMS

Enhanced process design

- **Validated templates:** Utilization of models that accurately predict individual process behaviors
- **Efficient design and information extraction:** Facilitates rapid overall process design and data retrieval

Foundation in physics

- **Physics-based equations:** Core reliance on scientific principles ensures accuracy
- **Efficient data utilization:** Enables the derivation of extensive information from minimal data inputs



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Elevating hydrogen plant development
Conceptual design of a hydrogen plant

Use case description:
Efficient plant modeling

Modular integration using pre-built templates:
Simplifies construction of a comprehensive plant model by utilizing templates for individual plant sections, enhancing the integration of green hydrogen technologies

Implementation steps:
Creating and analyzing process models

1. Constructing the process model: Drag and drop sections such as energy supply electrolyzers, purification, storage, compression, and off-take to outline the entire process
2. Process exploration: Analyze results to examine various configuration possibilities
3. LCOH calculations: Perform calculations to determine the levelized cost of hydrogen (LCOH) based on certain assumptions
4. Configuration and uncertainty analysis: Finalize the plant setup and evaluate the impact of potential uncertainties

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Elevating hydrogen plant development
Navigating design with uncertainty

Use case description:
Assessing impact of assumption uncertainties

Understanding the impact of variable assumptions:
Emphasizes the importance of evaluating how deviations in initial assumptions (energy supply, pricing, hydrogen demand) affect project forecasts, aiding in risk assessment for the chosen process design

Implementation steps:
Analyzing uncertainties and risks

1. Initiate with a conceptual model: Start with a plant model developed during the conceptual design phase
2. Identification of key inputs: Determine inputs for analysis, including decision variables and uncertain factors
3. Selection of calculation criteria: Choose specific metrics or quantities for evaluation
4. Risk and uncertainty analysis: Examine process metrics under various uncertainties to gauge potential risks

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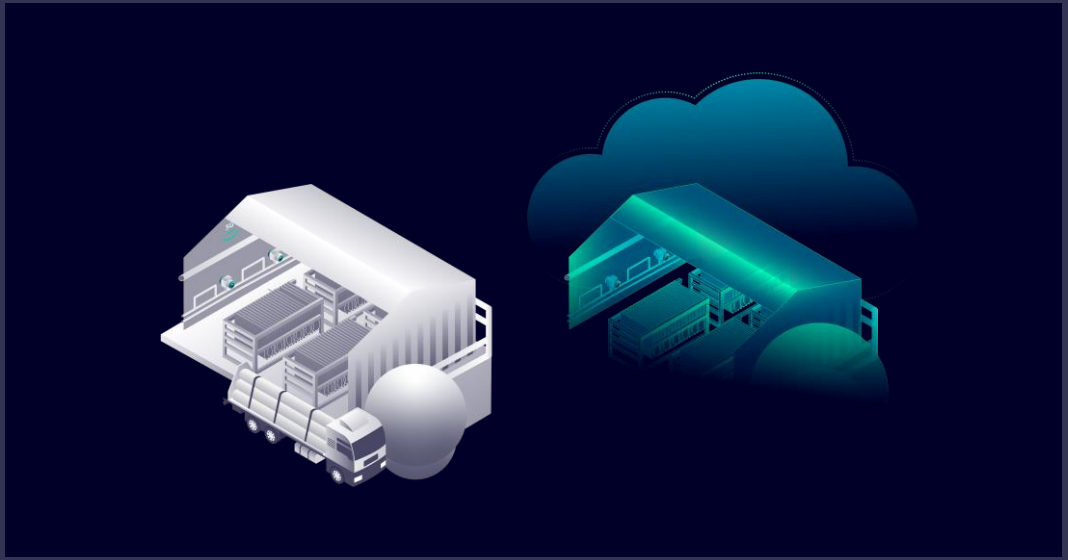
Conceptual process design



Operational efficiency

Cost savings

Safety and compliance

Benefits

Comprehensive process analysis

- Detailed assessments for the process of interest
- Clear rationale for each decision
- Thorough evaluation of uncertainty-related risks
- Applicable in energy and process sectors

Enhancing project viability and efficiency

- **Scalability:** Offers a flexible solution tailored to meet specific business objectives, applicable across various projects
- **Workforce efficiency:** Streamlines the workload in conceptual design and pre-FEED stages, optimizing team productivity
- **Risk management:** Provides insights into how uncertainties in initial design assumptions may affect critical performance metrics, enhancing strategic planning
- **Cost reduction:** Facilitates informed process design decisions, significantly reducing engineering efforts and, consequently, the overall project costs

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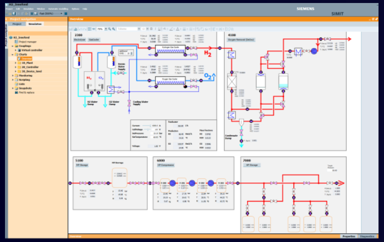
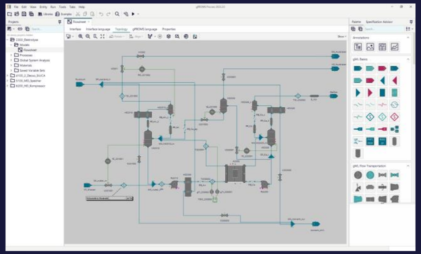
Modular sales configurator

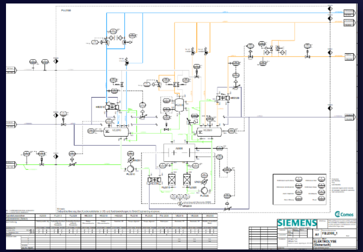
Electrolysis



Automation and Instrumentation Twin



Process Twin



Plant Twin

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Modular sales configurator for H_2 plants

Limited expert knowledge for proposal making

Time pressure and high costs for proposals

Low hit rate

Challenge

Proposal data sharing
- Sharing proposal data globally and early in sales without technical barriers
- Preventing information loss in transition from sales to detail engineering

Tackling technical complexity
- Addressing technical complexity effectively
- Utilizing product and process knowledge from aging workforce

Accessibility and configurator solutions
- Ensuring global accessibility
- Configurator solution meeting specific requirements without technological complexity

Impact

Manual proposal processes
- Verifying information manually leads to decision delays or uncertainties
- Speculative decisions increase project and NCC costs

Impact on customer response and market shares
- Risks of no or delayed customer response
- Potential loss of market shares due to inefficient processes

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Modular sales configurator for H_2 plants
Technology

Description of the technology

- The Modularized Engineering Web Configurator (“ME Web Configurator”) is a cloud native app integrated in the plant engineering software COMOS. It helps to improve the efficiency and effectiveness of engineering processes for creating proposals and bidding for plants, products and machines
- The configured product in the ME Web Configurator is transferred to COMOS for detail engineering
- Deep integration with COMOS Modularized Engineering which enables the reuse of legacy knowledge and processes involved in product configuration, without much of technical expertise

Integration leads to more efficiency

- Updated functional documentation in real time which can be shared with stakeholders
- Secured handover from sales to engineering, maintaining the confidentiality and ensuring zero loss of information

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Modular sales configurator for H_2 plants
Use case

Use case description:
Configuration hydrogen plant

Modular sales configurator
- The sales engineer can configure a standardized hydrogen plant based on captured design knowledge stored in rulesets
- The configured hydrogen plant can be visualized and verified by sharing documents with stake holders
- Variants with design options of the H_2 plant can be configured in real time

Implementation steps

- The configuration will be sent back to COMOS for detailed engineering.

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Modular sales configurator for H_2 plants

Optimized business workflows from sales to engineering

Reduced NCC costs

Higher efficiency in sales phase

Benefits

Improving sales and engineering processes

- Shorter lead time for bids
- Faster response to change processes
- Sales not required to master technology or product details
- Efficient sales and engineering cooperation

Enhancing customer experience and accessibility

- Customer requests directly visualized
- Worldwide use via cloud solution
- Better data handover
- Enhanced user experience

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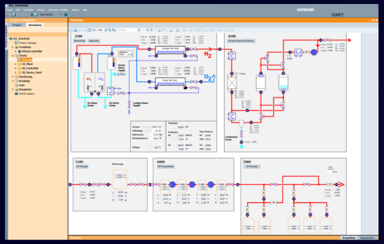
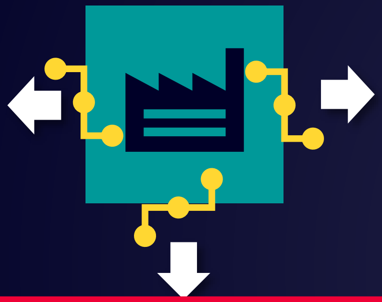
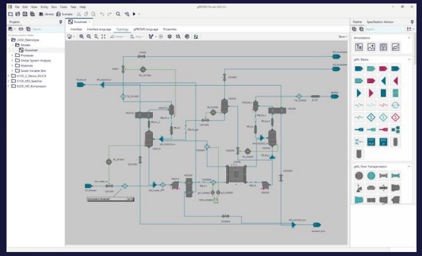
Engineering Digital Twin

Electrolysis

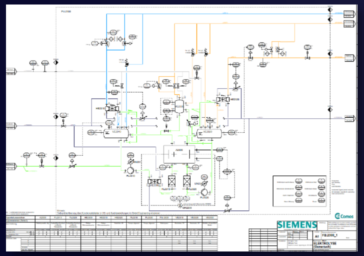






Automation and Instrumentation Twin

Process Twin



Plant Twin

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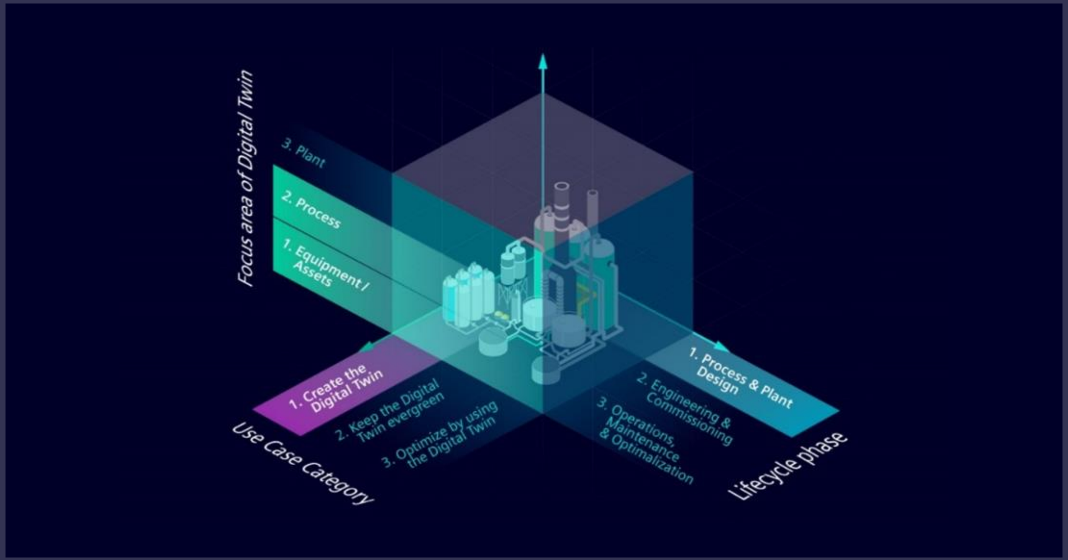
Enablement of the engineering digital twin for H_2 plants



Standardized & reproducible solutions

Time & cost savings

High flexibility in plant design

Challenge

Data integration
- Many different data formats in the engineering process
- Disconnected data silos leading to inaccessibility of information
- Missing data standards enforcement

Global accessi-bility needs
- The need for accessibility across the globe
- Compliance with BIM standards and methodology

Knowledge utilization
- Challenge for site engineering and maintenance staff to utilize the product and process knowledge from aging workforce
- Finding the correct information of the asset

Impact

Effort and verification
- Enhanced design and engineering effort
- Enormous efforts are made to verify and synchronize the information
- Longer search times to get correct asset information

Cost and risk implications
- Decisions made based on this speculative information then lead to increased and unplanned project and NCC costs
- Risk of production stoppage due to incorrect or missing asset data

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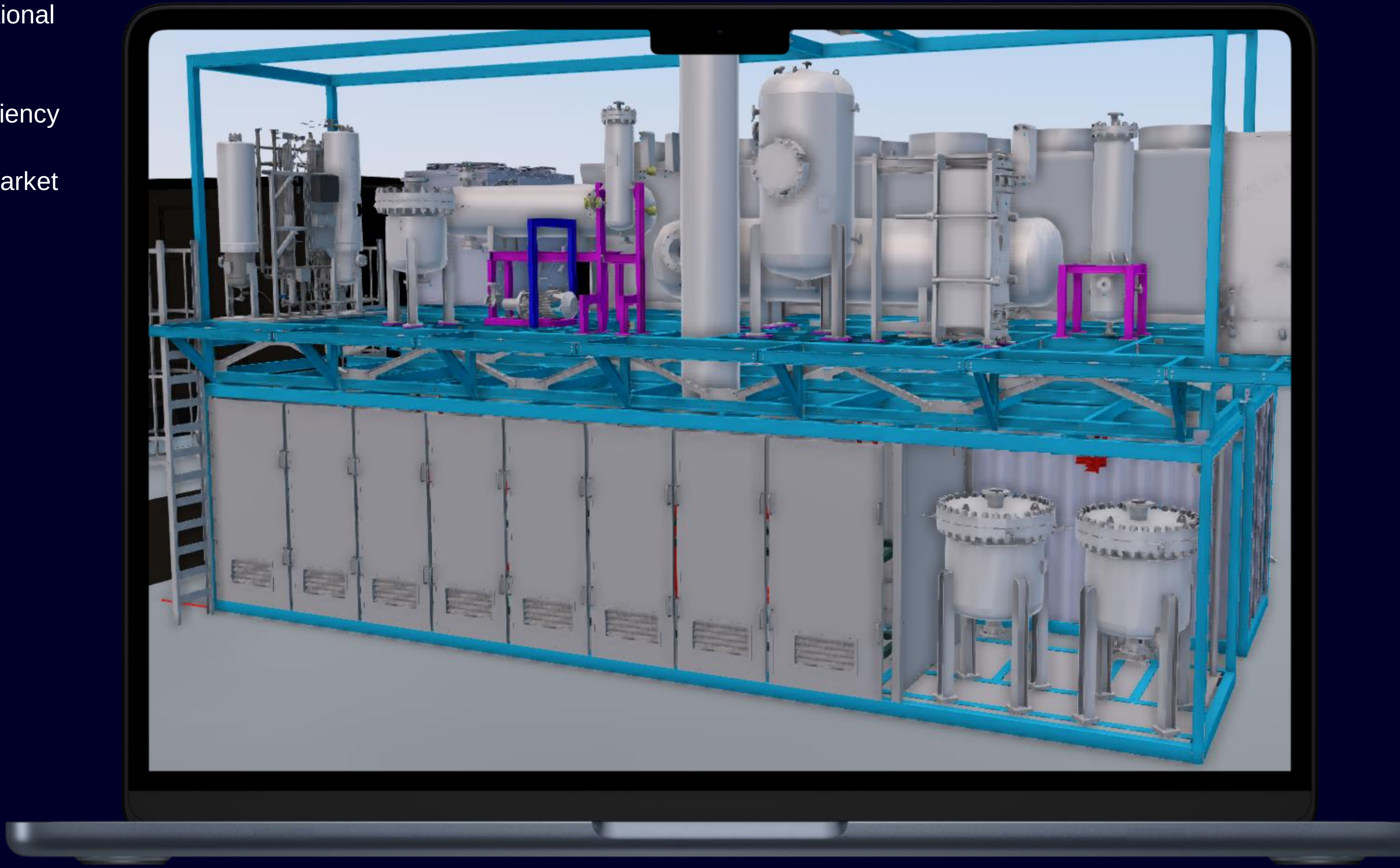
Enablement of the engineering digital twin for H_2 plants
Technology

Description of the technology

- Solution features: Connects and synchronizes 2D functional data with 3D plant model
- Integrated engineering approach: Utilizes modularized engineering for green hydrogen market, enhances efficiency and flexibility in site engineering processes
- Utilizes modularized engineering for green hydrogen market
- Enhances efficiency and flexibility in site engineering processes
- Improved information availability: Provides enlarged information for maintenance activities

Enhanced maintenance efficiency

- Integration of 2D functional data with 3D plant models streamlines maintenance
- Integrated engineering approach enhances site engineering flexibility
- Improved information availability enables proactive maintenance strategies



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Enablement of the engineering digital twin for H_2 plants
Use case

Use case description:
Synchronize 2D data to 3D model

Aligned view on engineering data

The plant operator wants to connect and synchronize 2D functional data with 3D model of my process plant in order to build an aligned view on engineering data for further maintenance activities.

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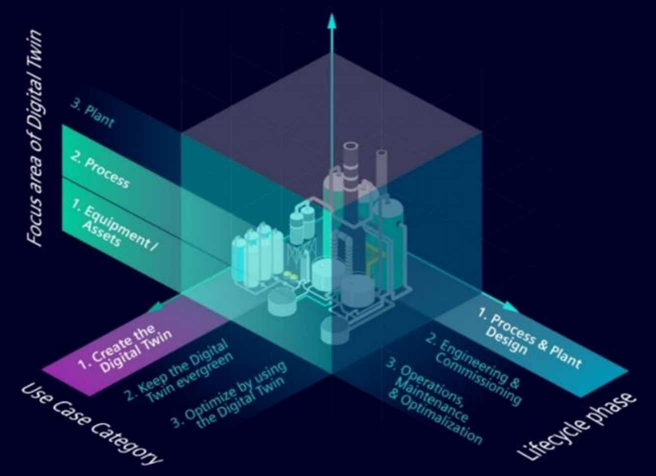
Enablement of the engineering digital twin for H_2 plants



Scalable digital twin solution

Time & cost savings

High flexibility in plant mainte-nance and site engineering

Benefits

Maintenance optimization

- Precise maintenance planning
- Reduce downtime
- Reduce incidents
- Deliver reliable and consistent data

Data accessibility and reporting

- Provide access to consolidated information for Siemens and other 3rd Party products
- Allow consistent and reliable reporting over the entire lifecycle of the plant to deliver a stable base for faster, precise, and safe decision-making

Efficiency and engineering streamlining

- Reduced design and engineering effort through quicker access to reliable information

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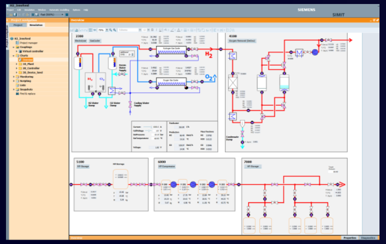
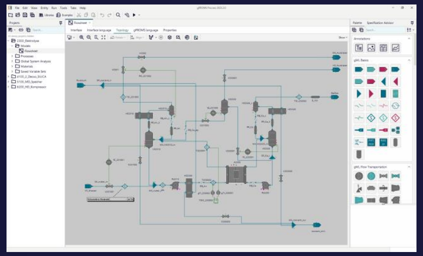
Unified Operations and Performance Management



Automation and Instrumentation Twin

Electrolysis



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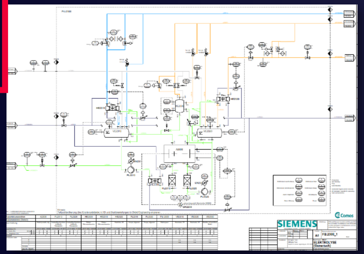
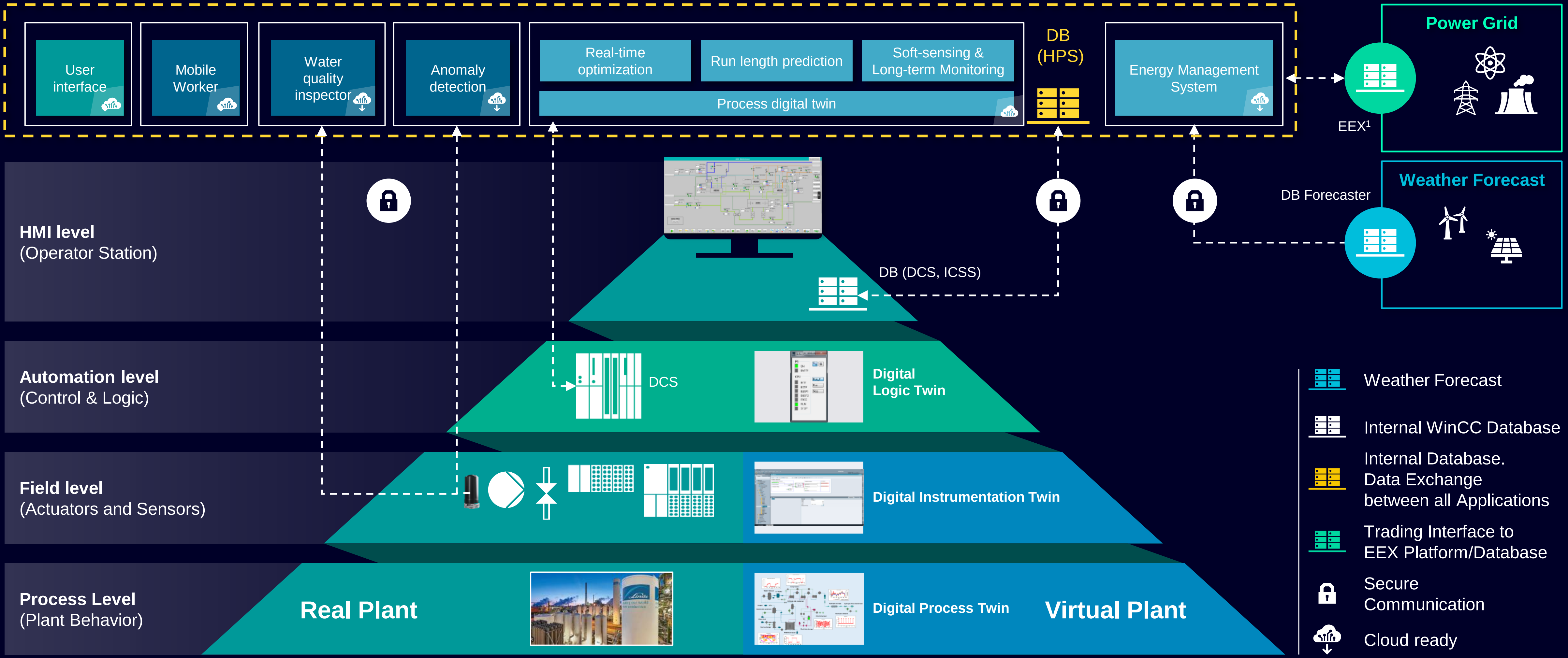


Plant Twin

The Hydrogen Performance Suite – Unified Operations and Performance Management for Hydrogen Plants



[1]EEX (European Energy Exchange)
[2]HPS is independent from DCS vendor

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Real-time optimization

Complex decisions

Continuously changing requirements

Managing equip-ment degradation

Challenges

Renewable energy integration and planning

- Hydrogen plant relies on a mix of renewable energies and electricity from markets
- Planning is crucial for cost-efficient operation, particularly without storage capacity

Storage for operational flexibility

- Storage bridges the gap between electricity availability and hydrogen demand
- Provides flexibility in operation, reducing operational expenses

Optimal set points

- With the need to optimize based on forecasts it is not simple to know what the best operating set points are for the current operation

Impacts

Unoptimized planning

- Sourcing electricity during high-priced periods to meet hydrogen delivery contracts raises production costs significantly
- Increased OPEX contributes to a larger share of the overall levelized cost of hydrogen

Equipment lifetime and shutdowns

- Unoptimized planning may result in more frequent plant shutdowns, potentially reducing equipment lifetime

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Real-time optimization
Technology

Description of the technology

- Accesses plant data
- Validates and updates the model to reflect current operation
- Utilizes state-of-the-art optimization algorithms for multi-period optimization
- Optimizes production plans for enhanced efficiency

Complexity of operational decisions

- Operators face challenges due to the complexity of decisions
- Large amounts of data must be considered to determine optimal operations

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Real-time optimization
Use case

Use case description:
Optimizer View Access

Hydrogen Performance Suite xHQ

- Operators access the optimizer view in the Hydrogen Performance Suite xHQ dashboard
- Dashboard updates production plan based on new information and reruns optimization
- System can function as an advisory or closed-loop system, sending production signals to the process

Implementation steps

1. Provides holistic view of plant's energy usage, integrating real-time data and analytics
2. Serves as central hub for monitoring energy efficiency and informed decision-making
3. Offers real-time updates on renewable energy availability and H_2 demand forecasts
4. Synthesizes data periodically to recommend actionable strategies for effective energy use and meeting production goals

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Real-time optimization

Optimal utilization of production capacity

OPEX reduction

Sustainable operation

Benefits

Efficiency and cost reduction

- Optimized planning ensures efficient use of resources like water, energy, and labor
- Reduces energy consumption and increases capacity utilization for cost-effective operation
- Maximizes utilization and improves production process efficiency
- Results in significant savings on water, energy, and maintenance costs

Reliability and demand fulfillment

- Careful planning leads to consistent quality and rate of hydrogen production
- Crucial for meeting customer expectations and maintaining market reputation
- Enables effective response to demand fluctuations

Environmental sustainability

- Increases efficiency and reduces waste for sustainable production
- Minimizes carbon footprint in green hydrogen plants

Adaptability and flexibility

- Provides flexibility to adapt to market and regulatory changes
- Enables quick adjustments to maintain competitiveness

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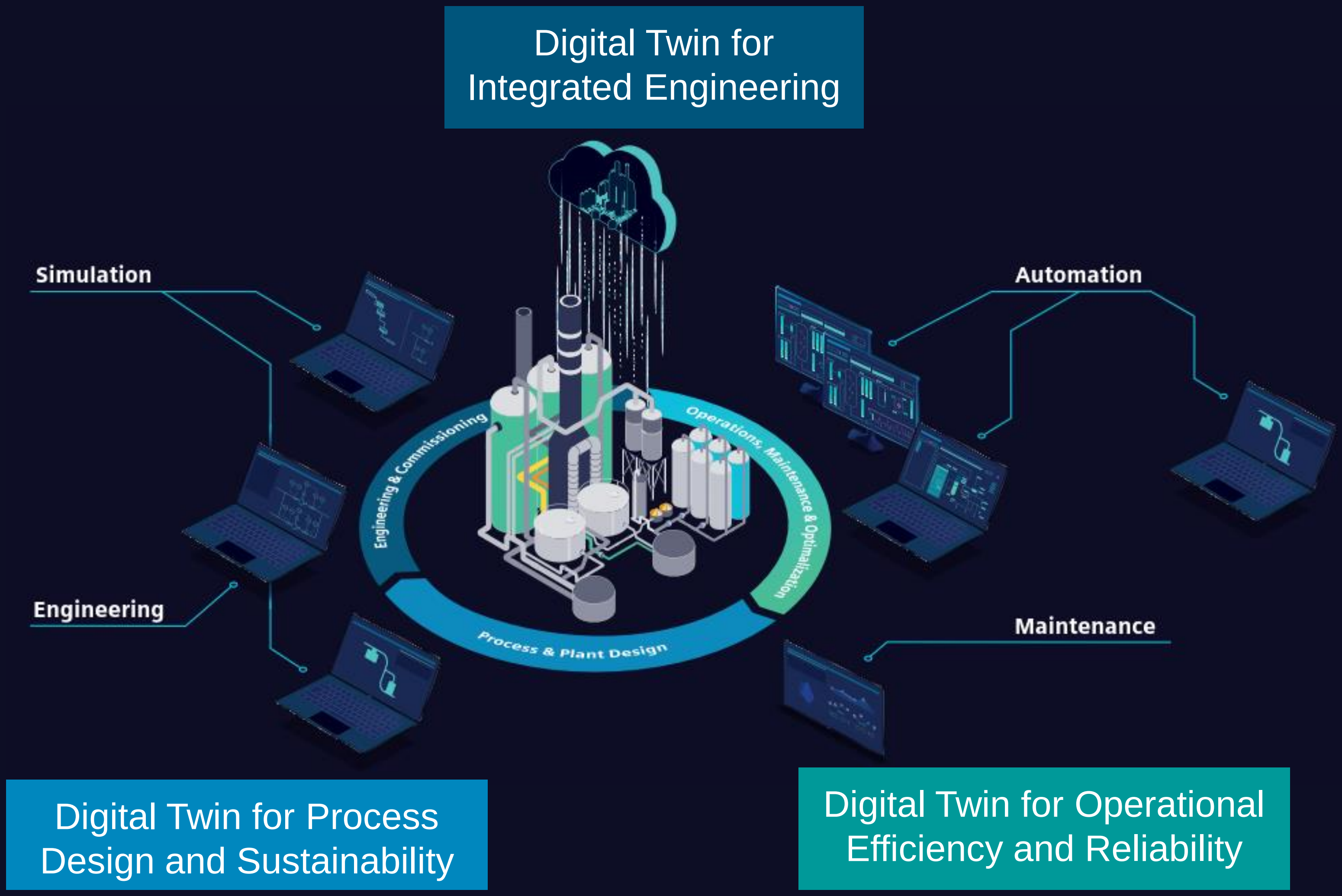
Software for Process Industry
A holistic Digital Twin over the entire lifecycle



WHY?
Digitalization is critical for customers sustainability, decarbonisation, efficiency, and optimization goals.

HOW?
We enable companies to digitally design, operate, and maintain their operations for maximum sustainability and performance.

WHAT?
Value-based use-cases in the context of the customers industry challenges.

Thank you

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