

Digital solutions to advance the energy transition



An energy transition report by Shell Catalysts & Technologies

SHELL CATALYSTS & TECHNOLOGIES
TRANSFORMING ENERGY TOGETHER

Digital solutions for the energy transition

As the world transitions to lower-carbon energies, the hydrocarbon processing industry is integrating advanced digital solutions to accelerate learnings, lower costs and improve safety. Shell is leading in the development of digital solutions that support operations and facilitate the journey to deliver its net-zero emission ambitions. In this report, we will share insights into the expertise Shell has gained in building upon its digital solutions to support energy transition applications. We also show how Shell Catalysts & Technologies is integrating that wealth of knowledge into its products and offerings such as:

Seamless user experience via real-time connectivity.

Real-time performance optimisation through digital twin technology.

Enhanced safety and support flexibility through VR & robotics.

Software solutions that maximise the value of integration across the energy value chain.

At Shell Catalysts & Technologies, we state through our *Make Every Molecule Matter* campaign that we are at the beginning of the energy transition journey and there is much to learn. As you dive into this resource, you will also gain perspective on where Shell Catalysts & Technologies is in the development of these digital solutions and the questions we look forward to discussing with customers as you join us on this journey.

Seamless user experience via real-time connectivity

- How can asset performance data be fully utilised?
- Will around-the-world, 24/7 technical customer support be possible through a data-sharing platform?

The traditional process behind our technical services for assets employing our catalysts and technologies has been based on periodic reporting. Each quarter, for instance, customers send completed spreadsheets documenting performance data to our technical experts. Our teams analyse the data and create graphs to demonstrate how the asset is operating.

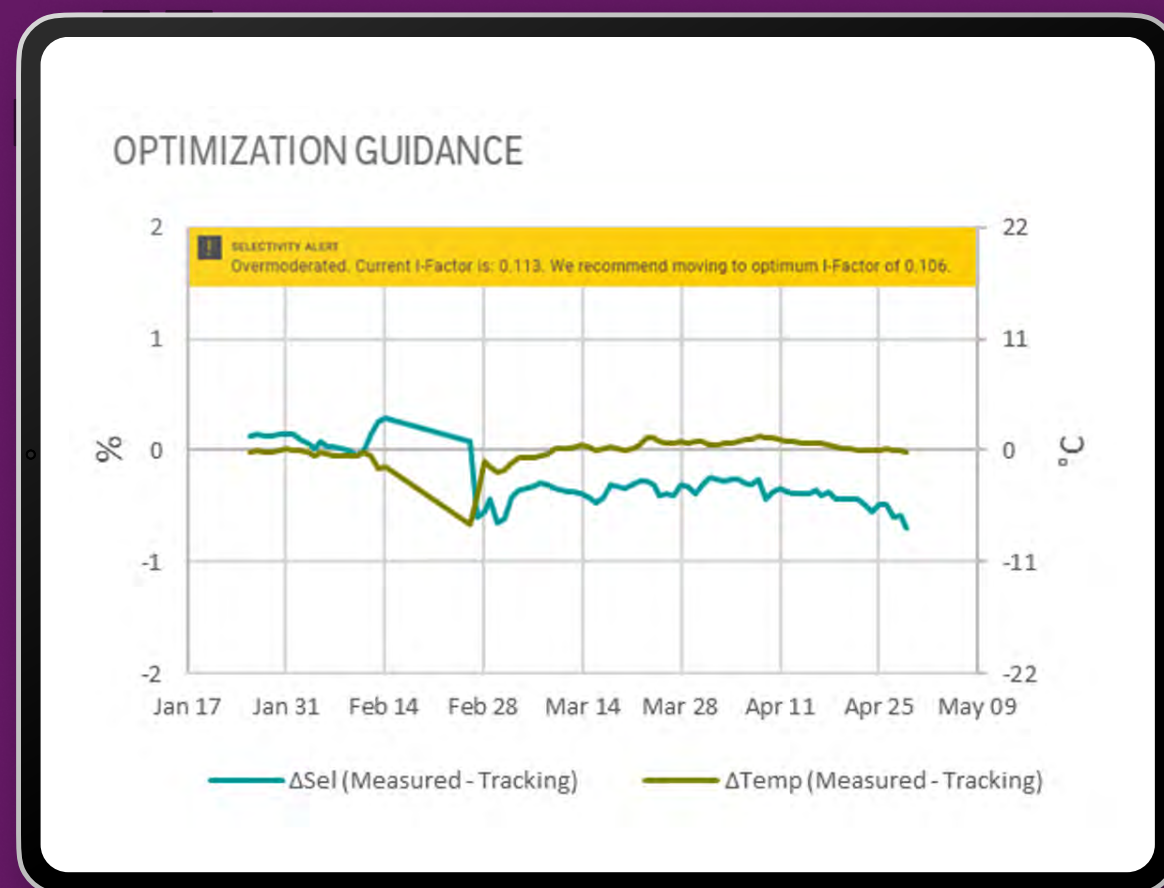
With the digital portal CatCheck Connect, customers can access live support by enabling real-time data sharing directly to a secure cloud database. CatCheck Connect not only enables data sharing with Shell Catalysts & Technologies, but it combines cutting-edge artificial intelligence (AI) and machine learning technologies with our proprietary process models and vast operational results database to generate meaningful reports, monitor key performance indicators and provide recommendations to the plant operators and engineers.



Real-time access to data for selectivity and margin improvements

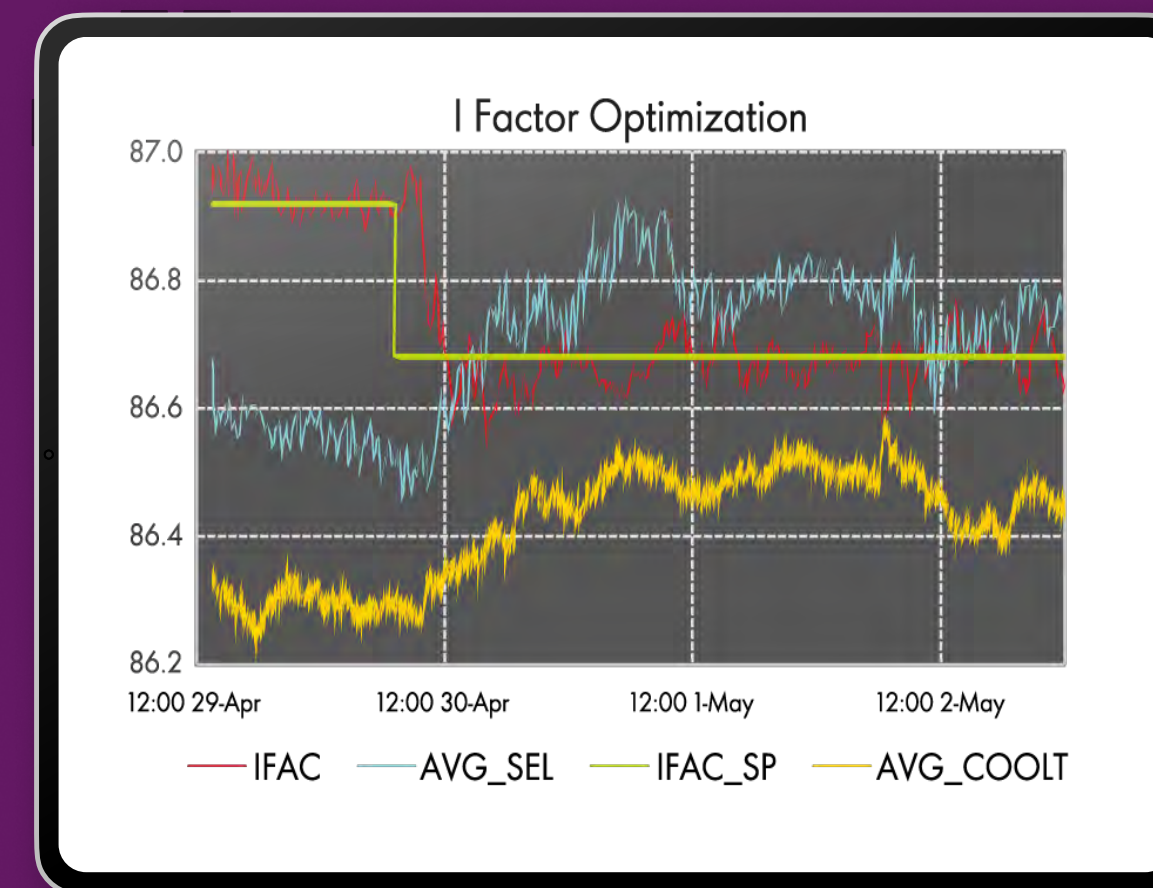
Our global team of technical experts can access the data in real time and make recommendations to improve performance, reliability and safety. Ultimately, these improvements result in higher efficiencies in operations, better monitoring of energy utilisation and reduced carbon intensities.

Below is an example of CatCheck Connect in action at an ethylene oxide (EO) plant where real-time monitoring and advice was implemented and resulted in significant cost savings and CO₂ reduction.



Real Time Advice

- Plant was considering reoptimising following process disturbances
- CatCheck Connect™ detected suboptimal feed conditions and sent a signal recommending set point changes



Real Time Impact

- Process engineers & TSE decided to implement advice
- Positive impact on selectivity observed: +0.2 to 0.3%



Global experts providing best-in-class services

Building on the success of CatCheck Connect, Shell Catalysts & Technologies is now working on bringing a true global, round-the-clock customer support experience. With over a thousand technical experts in refining, petrochemicals and natural gas across the globe, we are uniquely positioned to provide round-the-clock, best-in-class services when you need it the most. Our team of global experts is ready to assist you with services such as troubleshooting a complex issue with your plant, reducing risks during a plant outage and safely restarting a plant overnight.

As we look to connect customers with our global experts through real-time data access, these are some of the discussions we look forward to having:

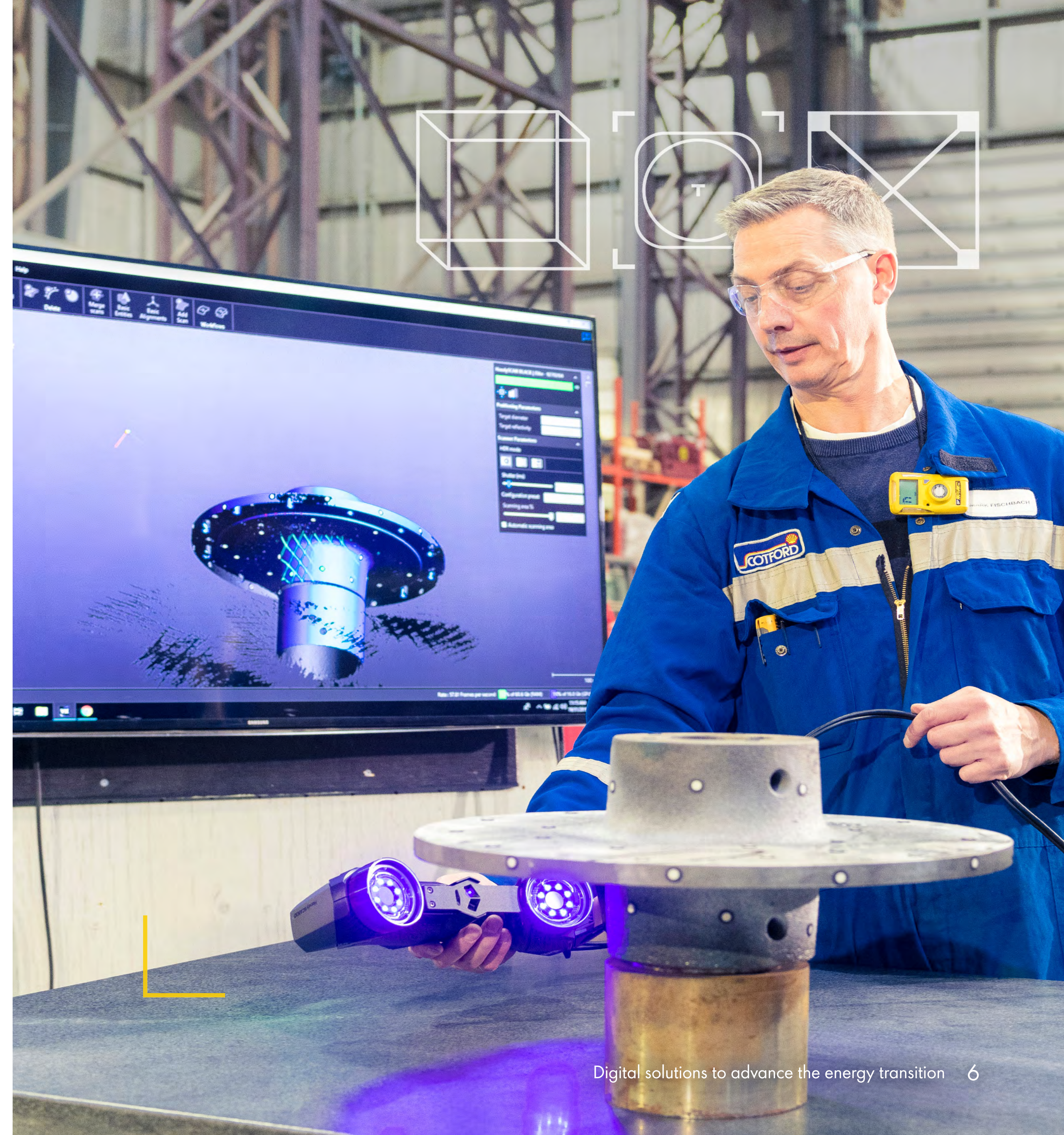
- What are the key barriers preventing you from optimising the performance of your plant?
- How could data integration result in a lower carbon intensity for your asset?

Real-time performance optimisation through digital twin technology

- What else is possible with asset data sharing?
- Can performance data be applied to what-if models?

Shell uses digital twin technology, a dynamic computer model that replicates how a plant is behaving through real-world data. A digital twin is the virtual representation of the physical elements and dynamic behaviours of an asset over its lifecycle. It can be of the whole asset (e.g. drilling platforms, refineries) but also at the equipment level (e.g. valves). It is built combining data from various sources – such as asset operations, maintenance, engineering and real-time data series – into visualisation and models.

Digital twins, which are used by Shell, are also being integrated into Shell Catalysts & Technologies' process technology offering, building on the capability of CatCheck Connect. A digital twin is used to simulate how changes will impact a facility's operation or equipment in real time to improve yield and margins, while also reducing safety risks for operators when applying parameter changes.

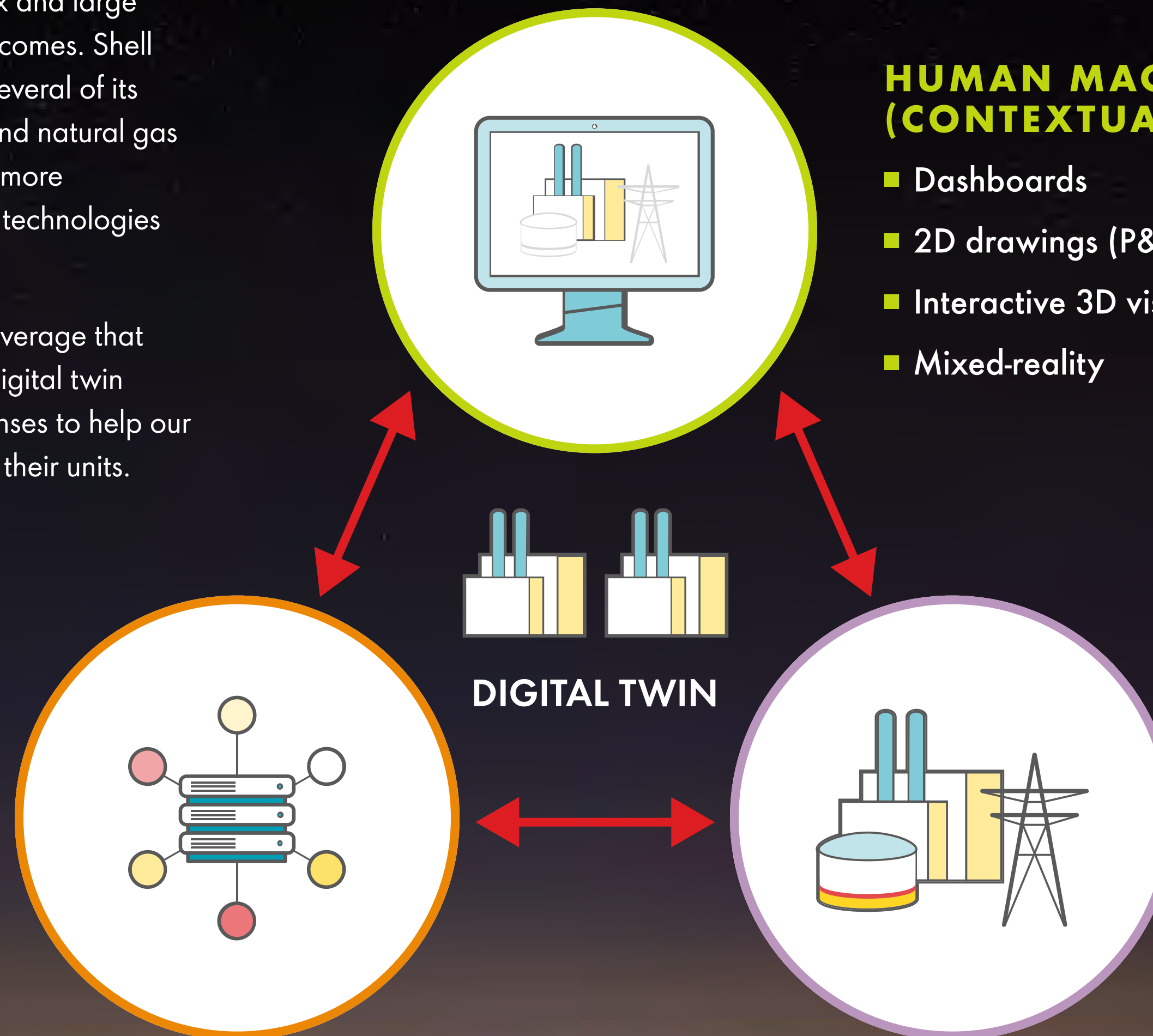


A digital twin should only be as complex and large as is required to achieve the desired outcomes. Shell has applied digital twin technology at several of its world-scale refineries, chemical plants and natural gas processing facilities to deliver safer and more transparent operations while optimising technologies in real time.

At Shell Catalysts & Technologies, we leverage that industry-leading expertise to integrate digital twin models into our technology process licenses to help our customers maximise the performance of their units.

DATA

- Operations
- Engineering (incl. documents)
- Maintenance
- Subsurface & wells



HUMAN MACHINE (CONTEXTUALISATION) LAYER

- Dashboards
- 2D drawings (P&IDs, PFS)
- Interactive 3D visualisation
- Mixed-reality

MODELING

- Past – Review performance, diagnose and learn
- Present – Operate and optimisation
- Future – “What if” and predictive all

Full digital twin representation at an integrated oil-and-petrochemicals site

The Shell Pulau Bukom refinery in Singapore is piloting digital twin technology. It is one example of a digital twin being used at a Shell site, from which Shell Catalysts & Technologies can apply learnings to implement this technology at customer sites. In fact, for some opportunities in the Americas, our experts have had preliminary discussions with customers looking to leverage a digital twin not only to maximise performance but also to use as a training tool for operators as the plants get built.

By 2025, the Bukom refinery project aims for the digital twin to be a complete virtual representation of the physical site and for all critical operations to be performed through tablets. The digital twin will enable operators to respond dynamically to conditions based on data from over 20 different technology platforms and provide them with live information via AR and VR. Operators can then test various options to troubleshoot an issue before deciding on a solution. This can improve operational efficiency, prevent downtime, reduce maintenance cost and allow real-time collaboration.

The Bukom refinery represents a forward-looking integration strategy that many refiners today are considering through the energy transition. It is an integrated oil-and-petrochemicals site with manufacturing facilities for fuels, lubricant base oils and speciality chemicals. By integrating assets, refiners can maximise the economic and efficiency benefits in terms of feedstocks, operations and logistics. Feedstock flexibility helps the site maximise returns as economics shift between hydrocarbon streams and provide greater security of supply.





Digital twin technology can also support refinery cost-savings through increased operational efficiency

At the Bukom refinery, digital twin benefits include increased efficiency and reduced operating costs through:

- Increased asset availability through minimised unplanned downtime.
- Reductions in electrical failures and repair.
- Reductions in breakdown corrective cost.

Shell's technology and process learnings are continuous. Shell Catalysts & Technologies is currently offering digital twin technology as an add-on offering for select technology licenses. As we expand the use of digital twins in other applications in Shell, we will continue to expand this as an offering in other process technologies. These are some of the discussions we look forward to having:

- How can digital twins make data useful to increase human efficiency?
- How can we create a unified model that can be accessible by all platforms so everyone is on the same page?

Enhanced safety and support flexibility through VR & robotics

- How can machines assist in human safety and efficiency?
- How can safety be improved in the implementation of new energy transition technologies?

Advanced robotics and VR can help reduce the amount of human exposure to risks. Shell is committed to the safety of personnel and works in partnership across the industry to improve safety performance. As industry experts gather learnings about new applications that support the energy transition, advancements in VR and robotics can help them to ensure safer operations.



Shell is developing several digital solutions to support safety

Some of Shell's technology offerings are not yet used as part of Shell Catalysts & Technologies' operations, but are positioned to help our customers in the future. Our experts are working to embed advanced digital tools as part of our base catalyst and technology offerings to support safer operations during catalyst and equipment installations and inspections.

- **Smart helmets** include a tracker for where personnel are located on a particular site. In the case of a safety incident, the control room can identify where everyone is at any given time to help in evacuation protocols and detect whether anyone requires assistance.
- **Drones** can reduce the manpower required for inspections within confined spaces. A traditional method for inspections within reactors and towers has required a team of personnel to perform a task while ensuring safety. One staff member is stationed outside the confined space to monitor the interior air quality, while a second staff member enters the enclosed area. Shell's drone development can help to replace the requirement of staff members entering potentially hazardous areas for inspections.

Due to COVID-related travel restrictions, Shell Catalysts & Technologies has successfully deployed the use of VR headsets at several locations to support remote installation and inspection of Shell Catalysts & Technologies' licensed reactor internals.

- **VR headsets** can be critical in situations where multiple staff members are required to enter a confined space. A VR headset can allow only one staff member to enter the space while others remain outside or in the office. These staff members can see what is happening and communicate efficiently in real-time, thereby quickly assisting the staff member who has entered the confined space and reducing the time the staff member must remain inside.

An additional value of a VR headset is enhanced technical support. In cases where there is a very challenging issue with a particular reactor, the engineer on-site may need to leverage the support of a particular expert engineer who is in a different country. Through the VR headset, the expert engineer can observe what the on-site engineer sees and provide assistance.



Enhancing safety through digitalisation

Enhanced digital safety tools allow for some work to be conducted remotely and can support safer implementation and operations. In addition, smart applications can connect experts stationed around the world to particular sites, which can lead to time and cost savings, faster decision-making and higher productivity in the assets. Smart applications can also reduce required travel, hence reducing carbon footprint.

As we look to advance new technologies and processes through the safest methods available, these are some of the discussions we look forward to having:

- What types of complex site problems do you experience that could be solved by remote experts?
- How can technology improve the safety at your site?

Software solutions that maximise the value of integration across the energy value chain

- How can software solutions help to prevent unplanned downtime, reduce working capital and improve integration across the energy value chain?
- How is the energy and process industry working together to leverage AI to meet energy transition goals?

Shell has a strong legacy in the development and implementation of digital tools and software that optimise integrated value in the oil and gas industry. Many of these were developed by Shell for its own assets and later sold or licensed to others for commercialisation via Shell Catalysts & Technologies or authorised licensors and partners.



Examples of software solutions that Shell has developed, licensed out and continues to optimise in owner-operated assets include:

ROMeo Process Optimisation – Real-time optimisation software that ensures operational excellence and enables offline decision-making and analysis.¹

PACE (Platform for Advanced Control and Estimation) – Advanced process control software that simplifies complex maintenance into one application and reduces deployment time.²

Shell Inventory Optimiser (SIO) – Decision-support tool for inventory analysis that recommends re-order points for all stock based on usage, criticality and lead time.³

Just Add Water System (JAWS) – A software application that uses historical vessel data to reduce ship fuel consumption through the optimisation of vessel draft, speed and trim.⁴

Smart Torque System (STS) – A patented end-to-end quality and productivity management system that connects, collects and manages mission-critical work, providing a single source of truth for quality assurance and progress tracking.⁵

Hydrocor – A Shell proprietary web-based engineering application for quantifying the corrosivity of the operating conditions associated with the production and transportation of corrosive, water-wet hydrocarbons in carbon steel facilities.⁶

Sources

¹ "ROMeo Process Optimisation", AVEVA, 2018, https://www.aveva.com/content/dam/aveva/documents/datasheets/Datasheet_ROMeo-Process-Optimisation_EN.pdf.coredownload.inline.pdf. ROMeo is marketed by AVEVA.

² "Platform for Advanced Control and Estimation (Advanced Process Control)", Yokogawa, accessed 4 November 2021, https://www.yokogawa.com/us/solutions/products-platforms/solution-based-software/optimization/advanced-process-control-platform-for-advanced-control-and-estimation/#Details__Multivariable-Control-Quality-Estimation. PACE is marketed by Yokogawa.

³ Malory Davies, "Revealed: Supply Chain Excellence Award winners", Logistics Manager, 7 November 2018, <https://www.logisticsmanager.com/revealed-supply-chain-excellence-award-winners/>.

⁴ "Kongsberg and Shell Sign Jaws Agreement", Kongsberg, 2 September 2020, <https://www.kongsberg.com/maritime/about-us/news-and-media/news-archive/2020/kongsberg-and-shell-sign-jaws-agreement/>. JAWS is marketed by Kongsberg.

⁵ "Smart Torque System™", Cumulus Digital Systems, accessed 7 December 2021, <https://www.cumulusds.com/smart-torque-system/>. STS is marketed by Cumulus.

⁶ "Hydrocor", Cenosco, accessed 28 February 2022, <https://cenosco.com/hydrocor/>.

Shell recognises that many of the challenges we face today are similar to ones facing our peers

That is why, in partnership with C3.ai, Baker Hughes and Microsoft, we have launched the **Open AI Energy Initiative (OAI)**, an open ecosystem of AI-based solutions for the energy and process industry. The solutions Shell Catalysts & Technologies has brought to market via OAI include:

Predictive Maintenance (PdM) software – Uses advanced data analytics to predict the early signs of an upcoming failure of critical equipment in assets. PdM is part of Proactive Technical Monitoring, a work process that involves operators' understanding and action regarding potential problems in a timely manner to prevent failure or lost production. Operators also utilise PdM to optimise asset equipment care strategies, reduce maintenance costs and prevent unscheduled deferment or unplanned downtime.

Shell Process Optimiser for LNG, internally known as **RTPO (Real-time Production Optimisation)** – Brings together engineering models and data analytics to enhance asset production by helping engineers close the gap between current and optimal production ("gap to potential") by changing operating conditions.

Shell Corrosion Advanced Risk Modelling and Analytics (CARMA) – Makes use of novel data analytics techniques to predict internal corrosion and erosion to better prioritise and target inspection and maintenance activities. By leveraging a variety of collected site data, and with the help of artificial intelligence (AI), the software provides new insights to predict corrosion and erosion and identify degradation before leaks happen.

Shell Autonomous Integrity Recognition (AIR) – Allows inspectors to quickly and easily make use of automated image capture and evaluation to support execution of external integrity inspections.

By processing data in the cloud coming from inspections carried out with handheld devices, drones and robots, the solution enables inspectors to objectively evaluate issues, identify items that have been overlooked, reduce the time needed at the desk to generate reports and improve inputs to maintenance planning.



Key digitalisation questions to ask:

- Do you face challenges in predicting failures of critical equipment resulting in unscheduled downtime?
- How could we leverage advanced data analytics to ensure that the right amount of spare parts are available to you when you need it the most?

The digital solutions that have been discussed help customers through the energy transition with improved productivity, better performance of assets and increased integration through the value chain.

As we look to advance new technologies and processes through the safest methods available, we look forward to continuing the discussion.

Continuing the conversation

on digitalisation and the energy transition

Our experts at Shell Catalysts & Technologies are starting conversations and taking action – both on and offline – to power the transformations that will shape tomorrow's energy, petrochemical and industrial sectors.

Our commitment to **Make Every Molecule Matter** means that we apply the knowledge of our molecular science and digitalisation experts to create the processes that will power the energy transition. But this is just the beginning and we still have many questions to answer. We hope you will join us on this journey by getting involved, starting these important conversations and working with us to develop more and cleaner energy solutions.

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