Increase safety and achieve optimum quality of green hydrogen

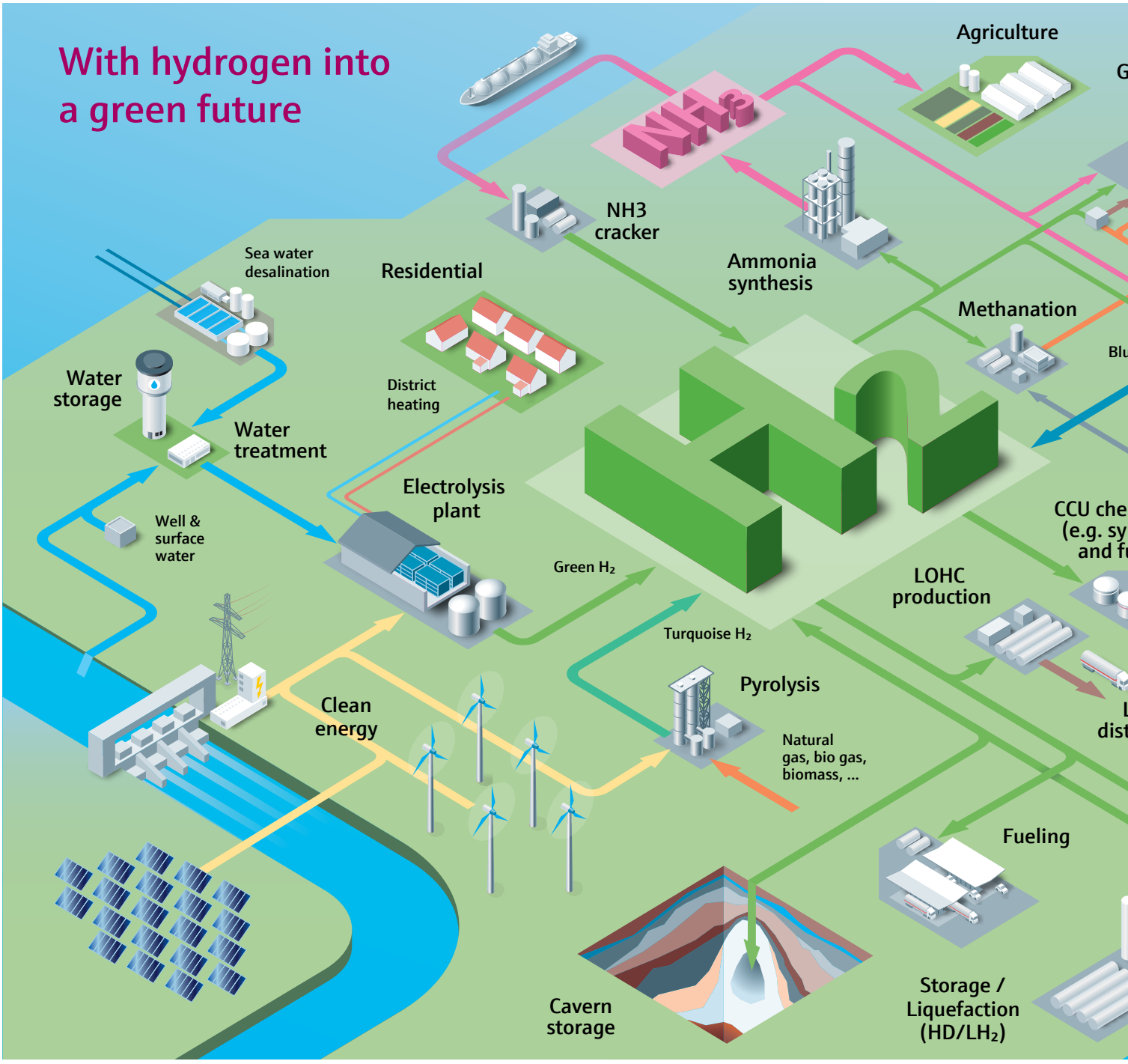
Reduce your levelized costs of H_2 (LCOH) along the H_2 value chain

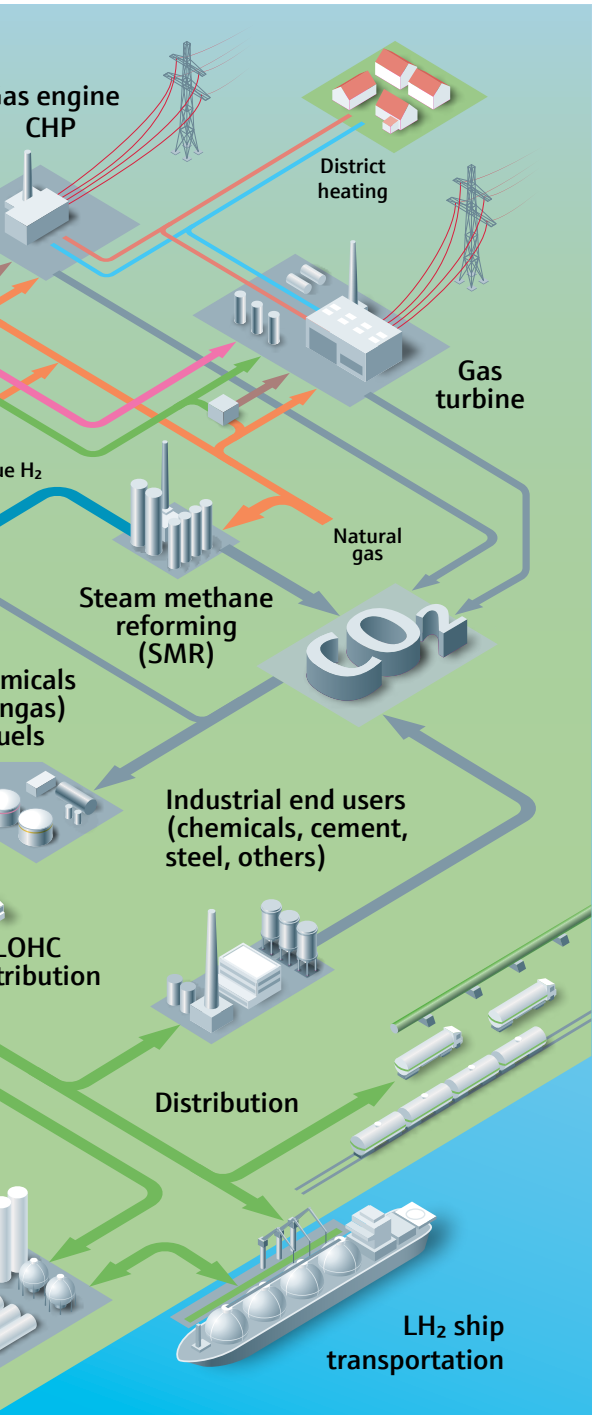
Increase safety and achieve optimum quality of green hydrogen

Endress+Hauser
People for Process Automation

Serving the energy transition across the full ecosystem

Drawing on years of experience in instrumentation, Endress+Hauser offers a comprehensive range of solutions across the entire value chain of hydrogen.





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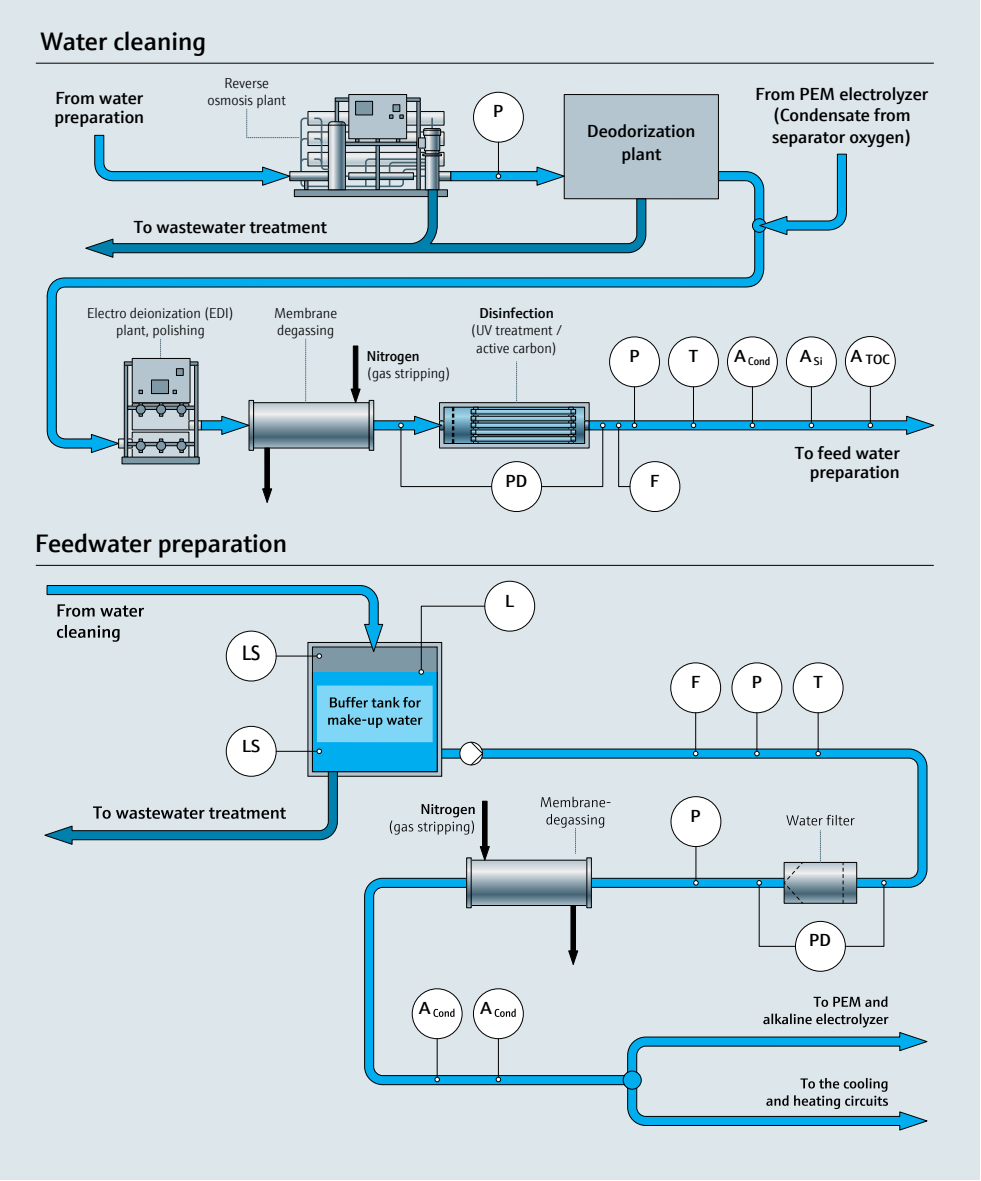
Enhance efficiency and safety of green hydrogen production

Industry Applicator

Water preparation

Water is the fuel for electrolysis and critical for the production of green hydrogen

Water preparation is key for electrolyzers, whether the water is to be mixed with KOH for alkaline electrolyzer, or to be ultrapure for PEM or SOEC. With a full portfolio and industry expertise, Endress+Hauser can support the measurements needed to ensure plant reliability and uptime.



Electromagnetic flow measurement – Proline Promag

Useful flowmeter for raw water intake or electrolyte flow with unrestricted installation measurements

- **Version 0 x DN with full bore**: without any upstream or downstream lengths and no pressure loss
- **Easy commissioning**: thanks to the touchscreen via smartphones using Bluetooth® with the SmartBlue App
- **High rangeability and measurement precision**
- **Embedded Heartbeat Technology** for simplified operational performance monitoring
- Optionally with calibrated conductivity measurement

Vortex flow measurement – Prowirl

Robust and driftfree capacitive sensor for flow measurement of all types of fluids: liquids (ultra-pure water, oxygen...).

- 2-wire technology for simple and cost-effective integration
- Process safety and monitoring with Heartbeat Technology
- Flanged or sandwich-mounted version available
- Optionally with integrated pressure and temperature (multivariable)

Conductivity measurement – Memosens digital sensor with Liquiline Multiparameter transmitter

Conductivity measurement on ultra-pure water for PEM electrolyzers and on potassium for alkaline electrolysis, for optimal quality monitoring.

- Wide measuring range
- Compact design for simplified installation
- Memosens 2.0 technology with data storage and contactless transmission

Differential pressure measurement – Deltabar

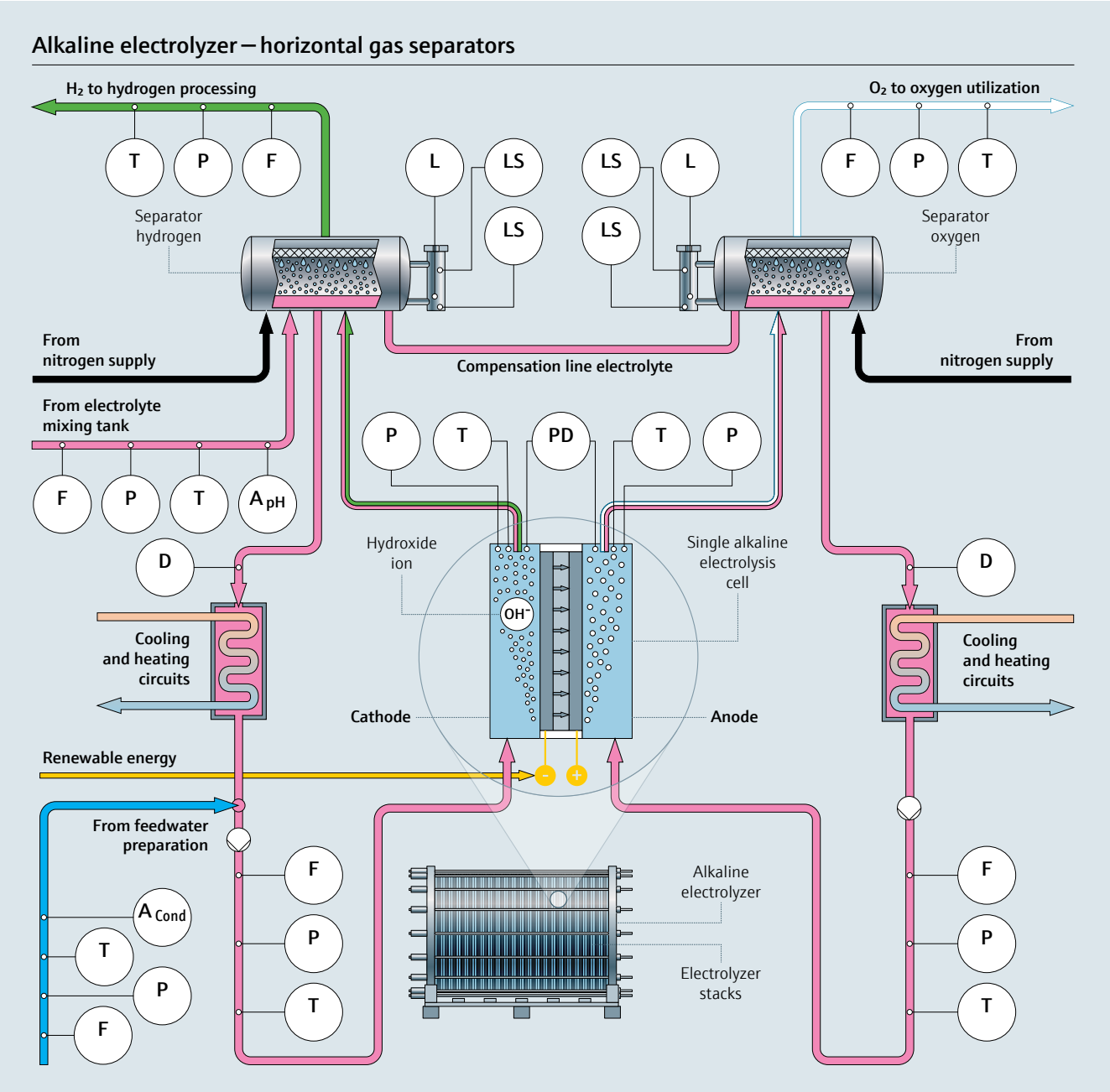
Differential pressure transmitter known for its robustness and reliability, enabling the monitoring of filtration quality throughout the water treatment process.

- Measuring accuracy up to +/- 0.055%
- Compatible with smartphones through secure Bluetooth connection using the SmartBlue App
- Enables condition-based maintenance

Electrolyzers

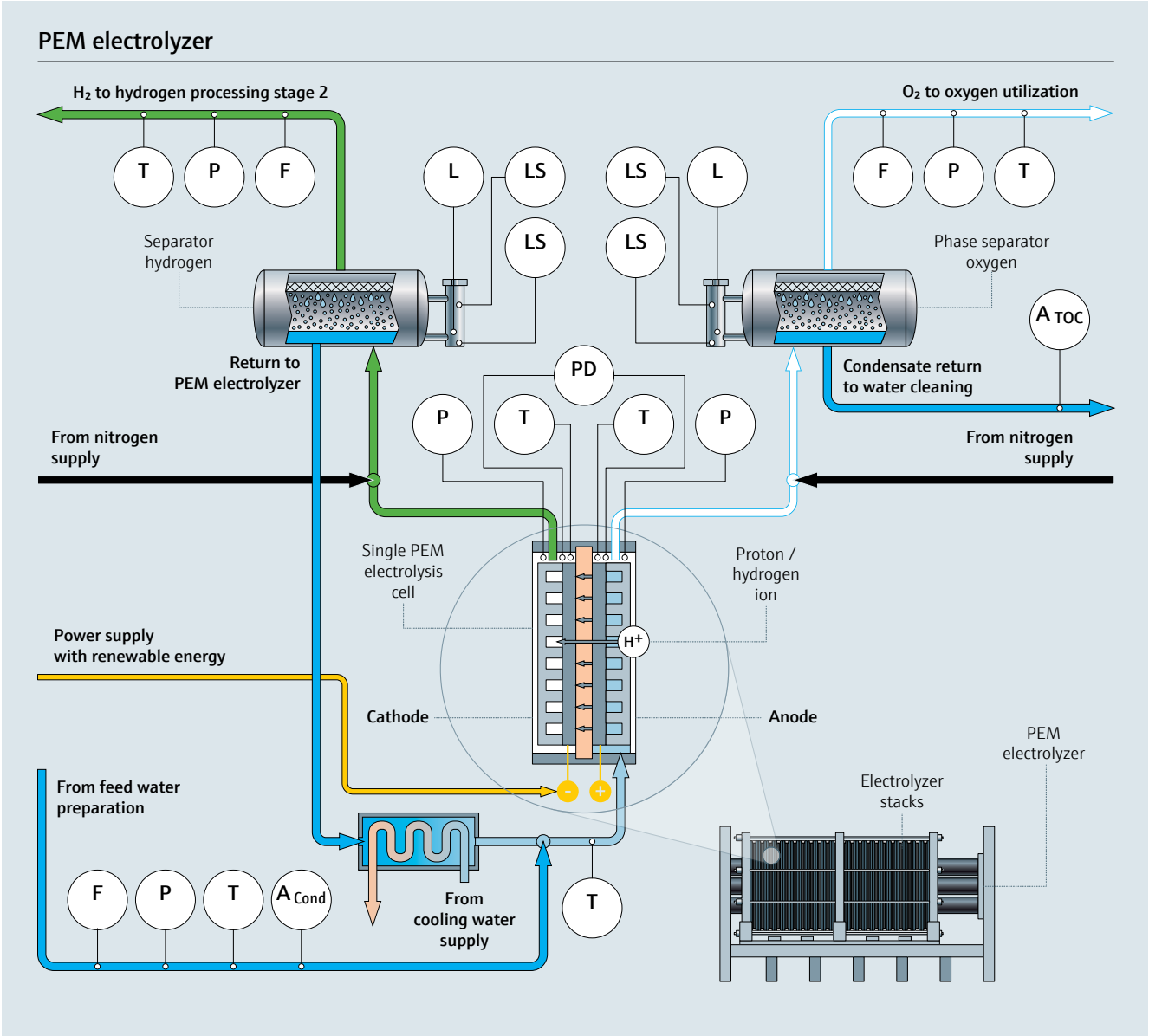
Alkaline electrolyzer

For the production of green hydrogen, the alkaline electrolyzer is currently the most widely used technology. To optimize and ensure better production efficiency, the following parameters need to be measured: flow, level, temperature, pressure and liquid analysis like pH and conductivity. All these parameters are available from Endress+Hauser.



PEM electrolyzer

Like the alkaline electrolyzer, the PEM electrolyzer is also widely used for the production of green hydrogen. As with the alkaline electrolyzer, precise measurements of the parameters are crucial to maximize the efficiency of this process. Endress+Hauser offers a comprehensive portfolio of measuring devices that are specially tailored to the requirements of PEM electrolyzers.



Instrumentation for electrolyzers

Guided wave radar level measurement – Levelflex

Technology suitable for liquid level control in hydrogen and oxygen separators, highly resistant to corrosive substances.

- Reliable measurement even in narrow measuring ranges
- Optional supply of the measuring chamber (bypass)
- Certified according to IEC 61508 for maximum safety – SIL2/3 applications
- Certified cleaning for oxygen applications

Pressure transmitters – Cerabar and Deltabar

Pressure measurement on all fluids present such as ultra-pure water, brine, hydrogen, oxygen and nitrogen.

- Measurement accuracy up to +/- 0.025 %
- Gold-coated membrane for hydrogen and degreased for oxygen
- Remote configuration via Bluetooth and SmartBlue App
- Verification of proper functioning through embedded Heartbeat Technology

Temperature sensor – iTHERM SurfaceLine

Increase safety and availability without compromising accuracy and response time by measuring temperature non-invasively.

- No contact, no compromise
- Fully tested on electrolyzers
- Reduce mechanical components and welds
- Non-invasive thermometer
- Increased safety

Conductivity measurement – Conductivity sensor Condumax with Liquiline transmitter

Robust conductivity measurement set consisting of a conductive sensor, a cable and a field transmitter usable in demanding environments.

- Measuring range from 0.04 to 20 µS/cm or from 0.1 to 200 µS/cm
- Optimized for high pressures (40 bar/580 psi)
- Reliable and accurate measuring values at low conductivities
- Easy cleaning thanks to stainless steel body and removable outer electrode

Liquiphant point level switch

Secure your processes with Liquiphant which has more than 3,000,000 applications worldwide. Benefit from the expertise of a sensor developed and patented by Endress+Hauser.

- Certified to IEC 61508 fox maximum safety – SIL2/3 applications
- Advanced diagnostics and self-testing functions with Heartbeat Technology
- Simplified loop control, even remotely via Bluetooth
- Certified cleaning for oxygen applications available

Temperature Sensor – iTHERM ModuLine

Pt100 sensor with an integrated thermowell, suitable for both hazardous and non-hazardous zones.

- Pt100 sensor range -328 °F to +1112 °F (-200 °C to +600 °C)
- Vibration-resistant version up to 60g (iTHERM StrongSens) or fast response time of 1.5s (iTHERM QuickSens)
- Dual Seal: containment enclosure for process safety with corrosion/leak detection within the thermowell — protects against hydrogen leakage
- iTEMP temperature transmitter, HART with options SIL certification, dual channel inputs for delta-T or redundancy

Coriolis mass flow measurement – Promass

Mass flowmeter renowned for its robustness, reliability and precision in measuring liquids and gases.

- High precision
- Multivariable version integrating mass flow, temperature and even density for liquids
- No required straight inlet and outlet lengths
- Embedded Heartbeat Technology for operational performance monitoring
- Certified cleaning for oxygen applications available
- Fully welded design for additional safety

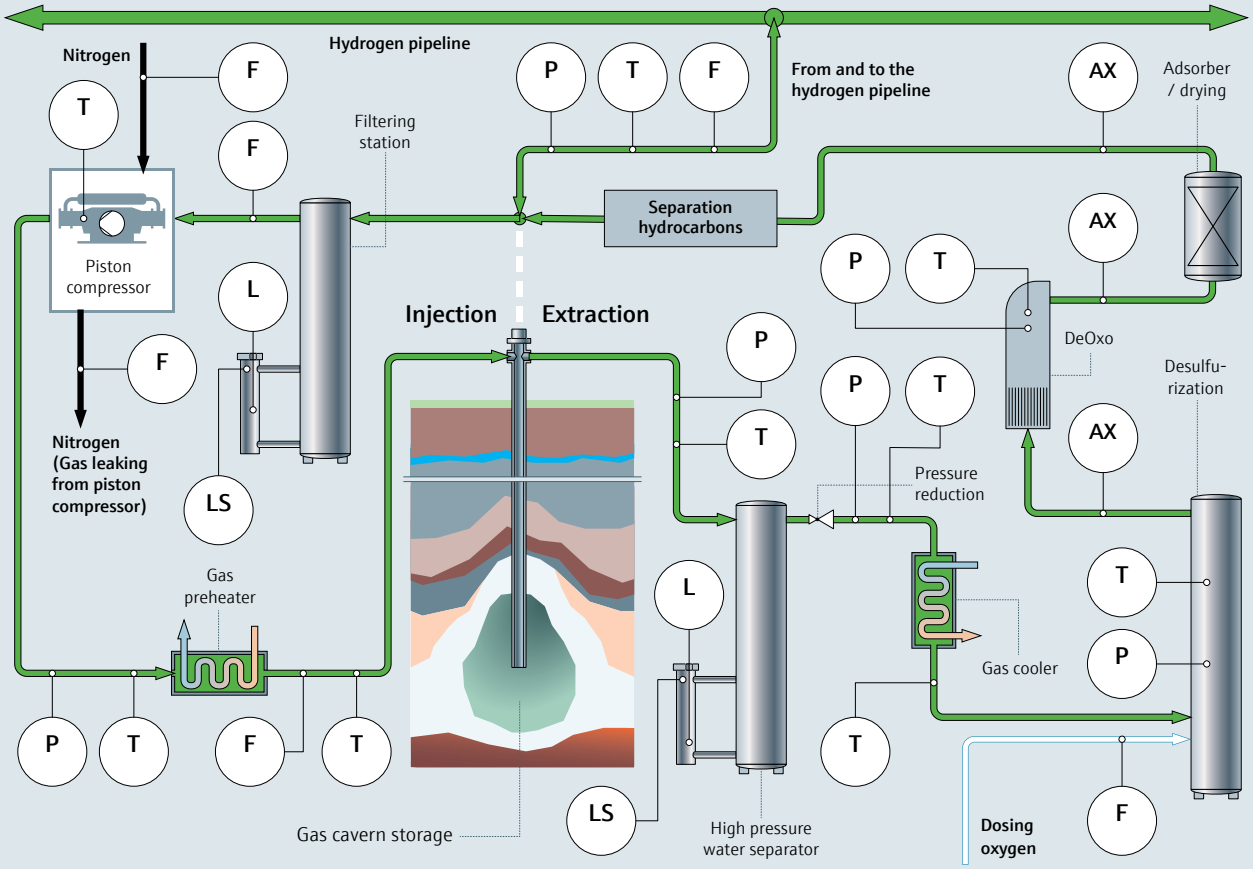
Measurement solution to test the process in an anion exchange membrane (AEM) electrolyzer.

Example of installation on an AEM electrolyzer.

Hydrogen cavern storage

Hydrogen can be used as a form of energy storage, harnessing excess renewables or low-cost power for electrolysis. Endress+Hauser offers reliable instrumentation, however the hydrogen is stored. Salt cavern storage is an essential part of a hydrogen network for the expansion of the hydrogen infrastructure.

Gas cavern storage injection and withdrawal



Relative or absolute pressure transmitter – Cerabar

Pressure sensor with gold-coated metallic membrane for measurements in hydrogen applications.

- Measurement accuracy up to +/- 0.025 %
- Measuring range up to 700 Bar
- Remote configuration via Bluetooth and SmartBlue App
- Verification of proper functioning through Heartbeat Technology

Temperature probe – iTHERM ModuLine

Pt100 sensor with an integrated thermowell, suitable for both hazardous and non-hazardous areas.

- Pt100 sensor range from -328 °F to +1112 °F (-200 °C to +600 °C)
- Vibration-resistant version up to 60 g (iTHERM StrongSens) or with fast response time of 1.5 s (iTHERM QuickSens)
- Dual Seal: Containment enclosure for process safety with corrosion/leak detection within the thermowell
- Transmitter TMT82, HART with optional SIL certification

Coriolis mass flowmeter – Promass

Mass flowmeter renowned for its robustness, reliability and precision in gas measurement.

- High precision
- Multivariable version integrating mass flow and temperature
- No required straight inlet and outlet lengths, all-welded design
- Embedded Heartbeat Technology for operational performance monitoring

dP flow with primary element – Deltabar

Wide choice of orifices, nozzles, venturis or pitot tubes with differential pressure transmitter.

- Technology recognized and standardized since 1929 (ISO5167)
- Replacement or recalibration of the delta P without stopping the installation
- Suitable for extreme process conditions (<420 bar/6100 psi)

Ensure hydrogen quality

Depending on its use, the required quality of hydrogen gas varies. Producers and users can measure impurities in the hydrogen stream using two distinct measurement technologies: TDLAS analyzers or QF analyzers.

Measurement of H_2O traces: J22 TDLAS gas analyzer

The required quality of hydrogen gas varies based on its use. Producers and users can measure H_2O in the Hydrogen gas stream with the J22 H_2O analyzer. They then can determine the quality and purity of the Hydrogen stream through the understanding of the volume of H_2O in it.

- Laser measurement (tunable diode laser absorption spectroscopy)
- Trace H_2O measurements: 0...10/200/500 ppm
- Sample conditioning system included
- Easy installation with analyzer and sample conditioning supplied together
- Non-contact optical measurement requires no calibration
- Low maintenance with no consumable components
- Heartbeat Technology: built-in gas validation and reporting tools
- Available with global hazardous area certifications

Measurement of O_2: OXY5500 oxygen analyzer

Measuring trace oxygen concentration helps verify the proper functioning of electrolyzers or ensure the quality of hydrogen distributed at injection points in distribution networks. For example, excess oxygen in hydrogen is an early sign of electrolyzer membrane degradation.

- Optical measurement using fluorescent quenching technology
- Trace O_2 measurement: 0–10 ppmv / 0–1,000 ppmv
- No interference with moisture, nitrogen, CO_2, H_2S, or other contaminants
- Fast response time
- Automatic operation with minimal maintenance
- Available with global hazardous area certifications

Measurement of H_2S (hydrogen sulfide): JT33 TDLAS gas analyzer

Measuring H_2S traces can be essential to ensure the quality of hydrogen that has been derived from fossil fuels, biomass or other waste processes and can be detected in underground storage.

- Laser measurement (Tunable Diode Laser Absorption Spectroscopy)
- Trace H_2S measurements: 0–10 ppmv / 0–1,000 ppmv / 0–5,000 ppmv
- Indoor and outdoor installation
- Patented differential technology removes measurement error in changing gas backgrounds
- Available with global hazardous area certifications

Integrated and turnkey solutions are tailor-made by our Project team

Turnkey integrated solutions are custom designed by our project team or production center. The integration of our optical technologies into Analytical solutions is carried out in France or the US for customers around the world. We support our clients in the realization of their projects according to the application specifications and the applicable industrial standards, while guaranteeing maximum performance and longevity of our solutions. We are involved from the design phase, through the production of the Integrated solution to the factory acceptance tests (FAT), and provide support during commissioning on-site.

Hydrogen utilization

Whether it's for decarbonizing industrial sites or producing e-methanol or e-fuel, hydrogen is now a promising molecule for achieving zero greenhouse gas emissions by 2050. Our hydrogen measurement and quality control solutions are designed to meet these diverse applications.

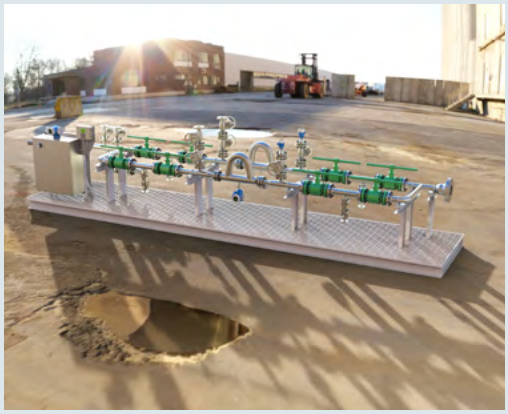
Proline Promass Q Coriolis flowmeter

The Proline Promass Q Coriolis flowmeter directly measures the mass balance of transferred quantities. These devices are renowned for their robustness, reliability and precision in gas measurement.

- Low maintenance cost: These meters have no moving parts
- Lower pressure drop compared to volumetric meters
- Simultaneous measurement: Transfer quantities in mass and volume compared to some volumetric meters under measurement conditions
- Minimal measurement uncertainty, maximum repeatability, long-term stability
- MI002 for light industrial processes (depending on process conditions)

Turnkey metering solutions

- Integrated metering system: Incorporates our Coriolis flowmeters and hydrogen purity solutions for fiscal measurements or custody transfer
- Scalable and modular system
- Quick installation and commissioning
- Reduced billing losses thanks to the performance of Endress+Hauser Coriolis meters

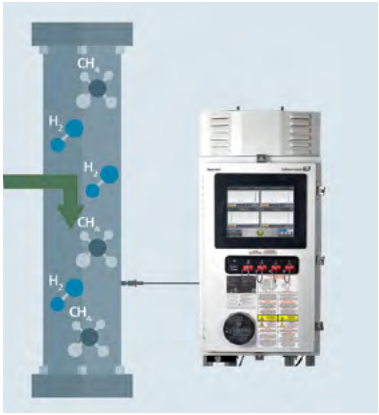


Hydrogen and natural gas mixture metering and analysis

Proline Prosonic Flow ultrasonic flowmeter

This ultrasonic flowmeter is suitable for various gas applications and is insensitive to gas composition, making it ideal for blending applications up to 50% hydrogen.

- Direct measurement: Measures flow, pressure and temperature
- No pressure losses
- Factory calibrated with air: Can be transferred to other gases



Fuel composition analysis (hydrogen and natural gas mixture) – Raman Rxn5 analyzer

This Raman analyzer, paired with the Rxn-30 probe, allows simultaneous measurement of different parameters: H_2 (0.1 to 100%), N_2, CH_4, C_2H_6, CO_2, $C3H_8$, C_4H_10, O_2, Btu and Wobbe index.

- Fast measurement: Continuous detection of hydrogen composition variation
- Non-destructive measurement: Gas can return to the process
- Up to 4 measurement channels simultaneously
- Reduced operating costs: Maximum analyzer availability with minimal maintenance required

Example of Implementation at Long Ridge Energy (USA)

The goal of this solution was to inject a mixture of 5% hydrogen, sourced from a local chemical manufacturer, into natural gas to fuel a gas turbine. The solution included a Coriolis flowmeter to measure the amount of combustion gas and a Raman Rxn5 analyzer to measure the gas composition.

Our offering:

- Turnkey solution provision
- Supply of proven Endress+Hauser sensors: Flow, pressure, differential pressure and gas analysis

Functional safety and explosion protection

In hydrogen production applications, safety is a crucial element. Whether it involves personnel, facilities or the environment, it adheres to strict regulations and standards that evolve over time, requiring investments. However, we strive to ensure that safety does not compromise productivity for your plants.

Functional safety

- **IEC 61508 – Functional safety of electrical/ electronic/programmable electronic safety-related systems**: This generic standard provides specifications for the design of safety-related systems.
- **IEC 61511– Functional safety - Safety Instrumented Systems for the process industry sector**: This international standard for process industries establishes best practices in engineering systems to ensure the safety of an industrial process through instruments. These systems are referred to as Safety Instrumented Systems (SIS).

Explosion protection

- **EX, FM and IECEx**: In electrical engineering, a hazardous area is defined as a location where concentrations of flammable gases, vapors or dust may occur. Electrical equipment intended for installation in these areas is specially designed and tested to ensure that it cannot trigger an explosion due to contact with an electrical arc or a high surface temperature of the equipment.
- Endress+Hauser instrumentation is offered across a wide variety of protection concepts including intrinsically safe, explosion proof, non-incendive and more.

Innovations in the service of safety

Intrinsically safe iTHERM ModuLine temperature sensor with dual-seal technology

High-performance temperature sensor technology (e.g. RTD or thermocouple) combined with innovative safety features guarantee the highest plant safety and availability. The integrated pressure switch allows for process leak detection, which can be communicated to the control system to alert personnel.

Liquiphant point level switch for liquids for FailSafe overfill protection

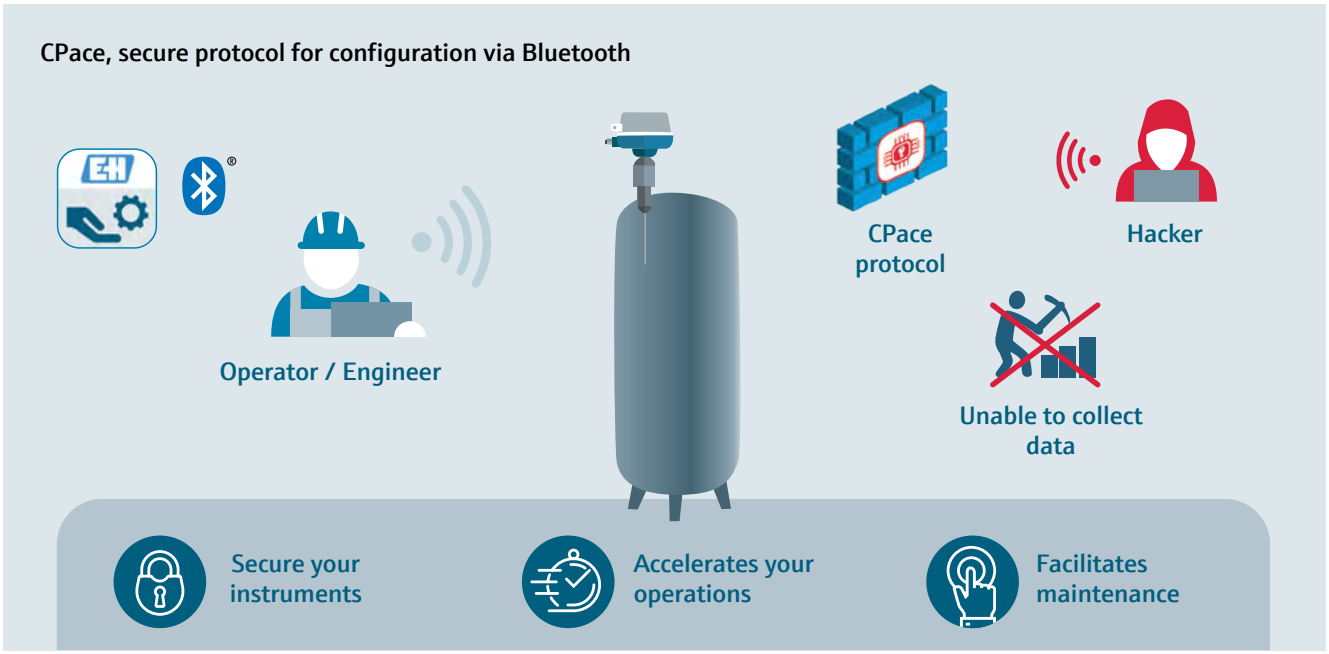
Thanks to its self-diagnostic functions allowing it to achieve a SFF (Safe Failure Fraction) > 99% as well as its innovative system of internal redundancy, it is possible to implement it in a SIL 3 loop single track. Its 12-year test interval allows you to optimize your maintenance operations safely.

The challenge of cybersecurity

With the advent of digitization and the presence of so-called 'connected' instruments on industrial sites, the threat of a cyber-attack is a very real risk that should not be underestimated. At Endress+Hauser, we take this risk very seriously, which is why we are certified in both the design of our connected products (IEC62443), the security of our Netilion cloud solution (ISO 27017) and the data management of our production centers (ISO 27001).

Furthermore, we have aimed to position ourselves as a global player in cybersecurity with the development of a unique encryption protocol for password-free wireless communications. This protocol, already approved by the German Fraunhofer Institute, was selected following an international competition by the EITF as the basis for future standards and is already used by all our Bluetooth devices* to ensure optimal security!

*Bluetooth option is enabled by chip and can be physically removed by the device or left off of the bill of materials for all associated transmitters.



Our experts are here for you

Have a question or uncertainty about a standard? Trust our expertise:

- Qualified and certified personnel (SIL, DESP, FM, IECex, ATEX, CRN, INMETRO, NAMUR)
- Utilization of databases and useful software

Use ExiCalculator for your calculations of intrinsically safe loop Ex "i".

Download the application from the Apple Store or Play Store.

Applicator, for the selection of your devices, stress calculations, sizing and corrosion resistance.

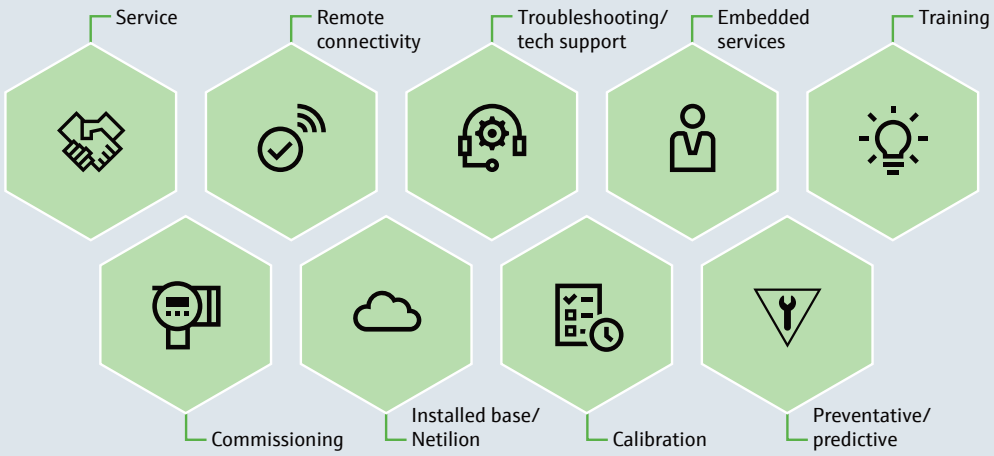
endress.com/applicator

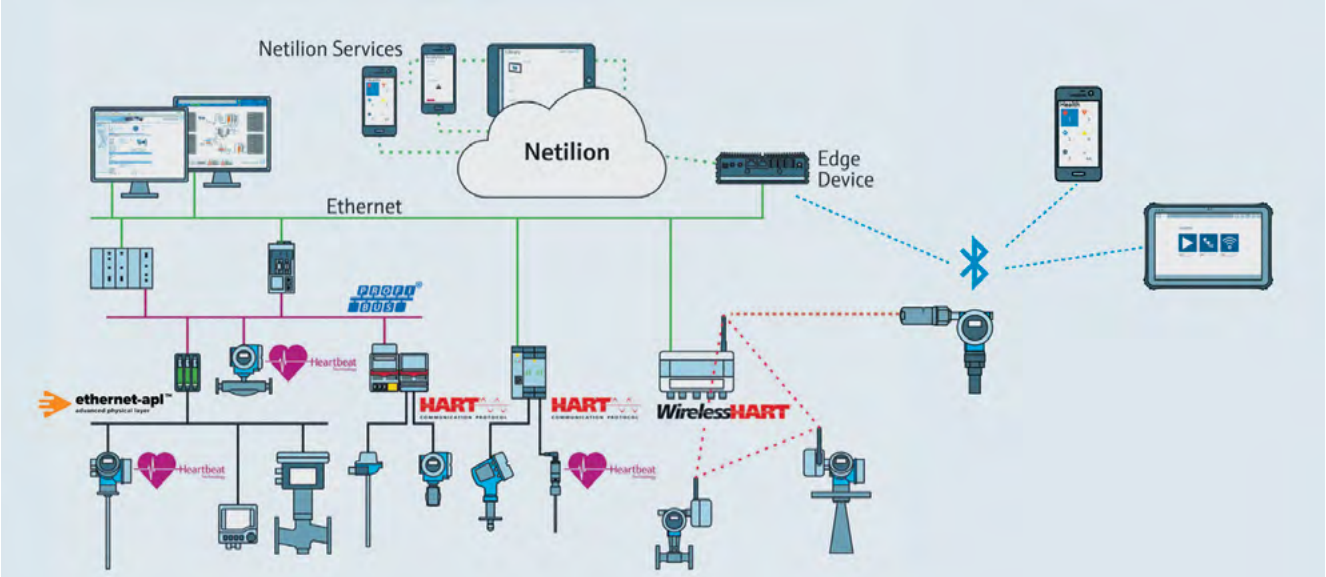
Digitalization is at the heart of the energy transition

Today, sensors have multiple pieces of information that are not fully utilized. Digitalization allows for optimizing the monitoring and maintenance of your process.

Regardless of the chosen communication networks, Endress+Hauser is here to support you at all levels: sensors, converters and gateways.

Predictive and preventative maintenance through verification, monitoring and diagnostics





Example of the different possible communication networks (HART, Profibus, EtherNet/IP, WirelessHART, Bluetooth, Cloud)

Cerabar pressure transmitter

Proline Promass coriolis flowmeter

Micropilot 80 GHz radar

iTEMP temperature transmitter

Memograph data manager

Field Xpert tablet PC

FieldPort converter

WirelessHART adapter

FieldGate gateway

Optimize your maintenance, improve your process

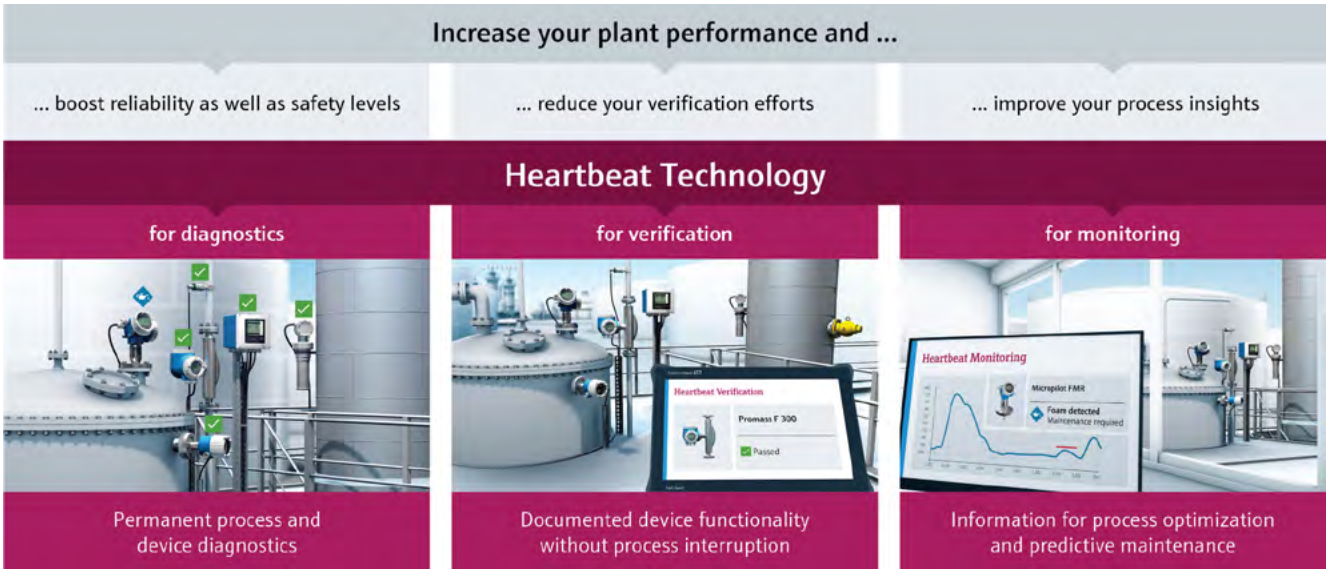
Do you want to increase the availability of your facility and reduce your costs?

With Heartbeat Technology, Endress+Hauser offers the widest range of devices with an innovative diagnostic and verification concept.

Heartbeat Technology enables cost-effective and safe operation of the installation throughout its lifecycle via its comprehensive diagnostic, verification and monitoring functions.

Digital reporting with Heartbeat Verification can reduce paper use in plant shutdowns or maintenance checks while offering a pathway for partial proof testing to provide confidence that safety loops are working properly.

More straightforward and efficient control of your measuring points.



- Explicit and standardized **diagnostic messages** with clear operation instructions facilitate maintenance
- **Permanent self-diagnostics** of the device enables safe operation with extended verification cycles

- The automatically generated **report of proper functioning** assists users in meeting regulatory demands
- The measuring point can be **verified *in-situ* and documented** at any time
- The simple and guided verification procedure yields clear verification results

- **Coriolis flowmeters:** Abrasion detection – corrosion or tube fouling detection – entrained gas detection
- **Vibrating fork level detection:** Corrosion or abrasion detection of the forks
- **Pressure/differential pressure:** Detection of blocked impulse lines, water hammer, corrosion in the current loop

endress.com/Heartbeat-technology

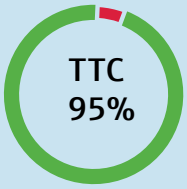
Heartbeat Verification: Improve production and maintenance efficiency in a comfortable, safe and compliant manner

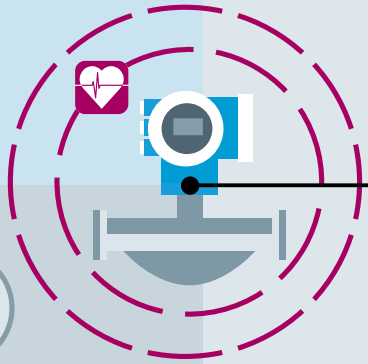
With Heartbeat Verification, the functionality of your measuring device can be assessed at any time, in-situ, and in a very short time, without the need for external tools or interrupting the process. Verification not only involves checking whether the components of the device still conform to their original reference values but also indicates the presence of systematic faults that could have a negative impact on the device or process performance, such as corrosion, abrasion or fouling.

95% total test coverage (TTC) in a successful verification – What does this mean?

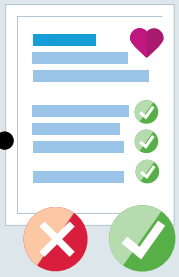
Random failures
(sensor features)

In the highly unlikely event of a random device failure, Heartbeat Technology detects it with a very high probability of 95%.





Heartbeat Technology verification report



Systematic defects
(related to the process)

Heartbeat Technology is also capable of indicating the presence of specific systematic applicationrelated faults, such as corrosion, abrasion and fouling.

"Everything is ok"

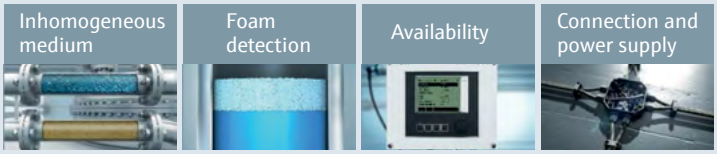
"Trend"

Heartbeat Monitoring: Be efficient and proactive in your operations

In particularly challenging process conditions, certain events can occur and influence the performance and reliability of a device. Examples of such events include corrosion or abrasion of parts of the sensor in contact with the fluid or the appearance of foam in a tank. These events will influence the physical responses of the device. Heartbeat Technology detects these events and converts them into easily understandable information by providing insights into the process and the device.

Monitoring operating conditions enables predictive maintenance by identifying process conditions that may have a negative impact on the integrity of the instrument or on process performance.

Support for **process optimization** enables the identification of anomalies (non-critical to the integrity of the instrument but potentially affecting its performance) and monitoring the **state of the instrument installation** enhances the reliability of the measuring point.



Value-added services for plant availability

The performance and compliance of your installations and measuring points require a rigorous and systematic approach to monitoring the critical instrumentation fleet. Call on us during your shutdowns or other maintenance activities.

Commissioning: your guarantee for operational instruments

Benefit from Endress+Hauser's expertise to commission instruments optimally. Take advantage of the extended warranty to cover any unforeseen costs and reduce the total cost of ownership.

Support and maintenance contract

With the service contract, you optimize your instrument fleet without the risk of additional costs. The implementation of a contract provides you with additional peace of mind.

- Be sure that maintenance services are carried out on time
- Receive regular visits from a technician who provides maintenance advice
- If you wish, spare parts can be included in the contract
- Contracts can also include equipment from third-party manufacturers

Accredited laboratory calibration

Temperature, pressure, flow, physico-chemical analyses (conductivity, pH).

- A single provider for all types and brands of equipment
- Services performed according to metrology standards and references (NF EN ISO/IEC 17025, NF EN ISO 10012, NIST, ASME MFC-9M)
- Accredited laboratories AL2A, COFRAC, SCS, SIT or Dakks (DKD)

Custody transfer and fiscal measurements available according to local regulations

Remote services for plant reliability

Develop technical expertise and maximize your plant availability with Smart Support

Gain direct access to Endress+Hauser expertise via our online knowledge base and remote support sessions with technical engineers who ensure availability and prompt response times.

Maximize process availability and meet production objectives

Support services enable fast identification and resolution of issues through remote expert guidance and preventive maintenance advice. This ensures high process availability and helps you meet production targets in decentralized energy supply.

Minimize field travel to ensure the safety of the plant and operators

With Smart Support, your service operators will only need to travel to the field when necessary and will be equipped with the required knowledge and tools to service the installed base. This minimizes their exposure to hazardous conditions in power and energy plants.

Customer benefits

- Access immediate remedy information from our comprehensive knowledge base on Endress+Hauser instruments, software and applications
- Maximize expert support through live video streaming or remote screensharing
- Track support performance and benefit from guaranteed availability with priority callbacks

Reduce carbon footprint

Smart Support reduces unnecessary travel, enhancing safety while also advancing your sustainability goals and emission targets.

Process uptime

- Maximize the availability of assets and processes to ensure the safety of products and operators in the field
- Restore operations quickly in case of failure and minimize risk of non-compliance

Operational efficiency

- Extend the lifecycle of instrumentation
- Expedite diagnostics and troubleshooting to keep the maintenance budget under control

Access to knowledge base

- Acquire the necessary technical skills to service the installed base
- Transfer knowledge to local operators

Streamline

- Limit control routines, especially in remote locations
- Reduce costs associated with travel

Sustainability

- Reduce the environmental impact of service operations which contributes to emissions targets

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The new features transform endress.com into a powerful and intelligent cooperation platform that connects you directly to us and our extensive network of sales representatives. Your personalized space allows you to perform your operations in just a few minutes. Manage your transactions, purchase products, order spare parts, download documentation and access your contacts – at the office, in the field or on the go, all with My Endress+Hauser.

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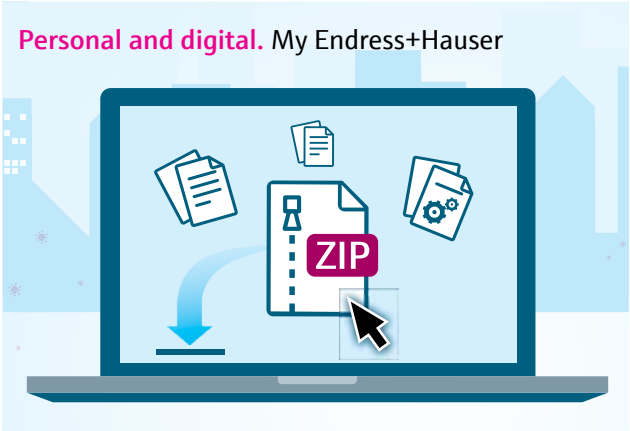

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