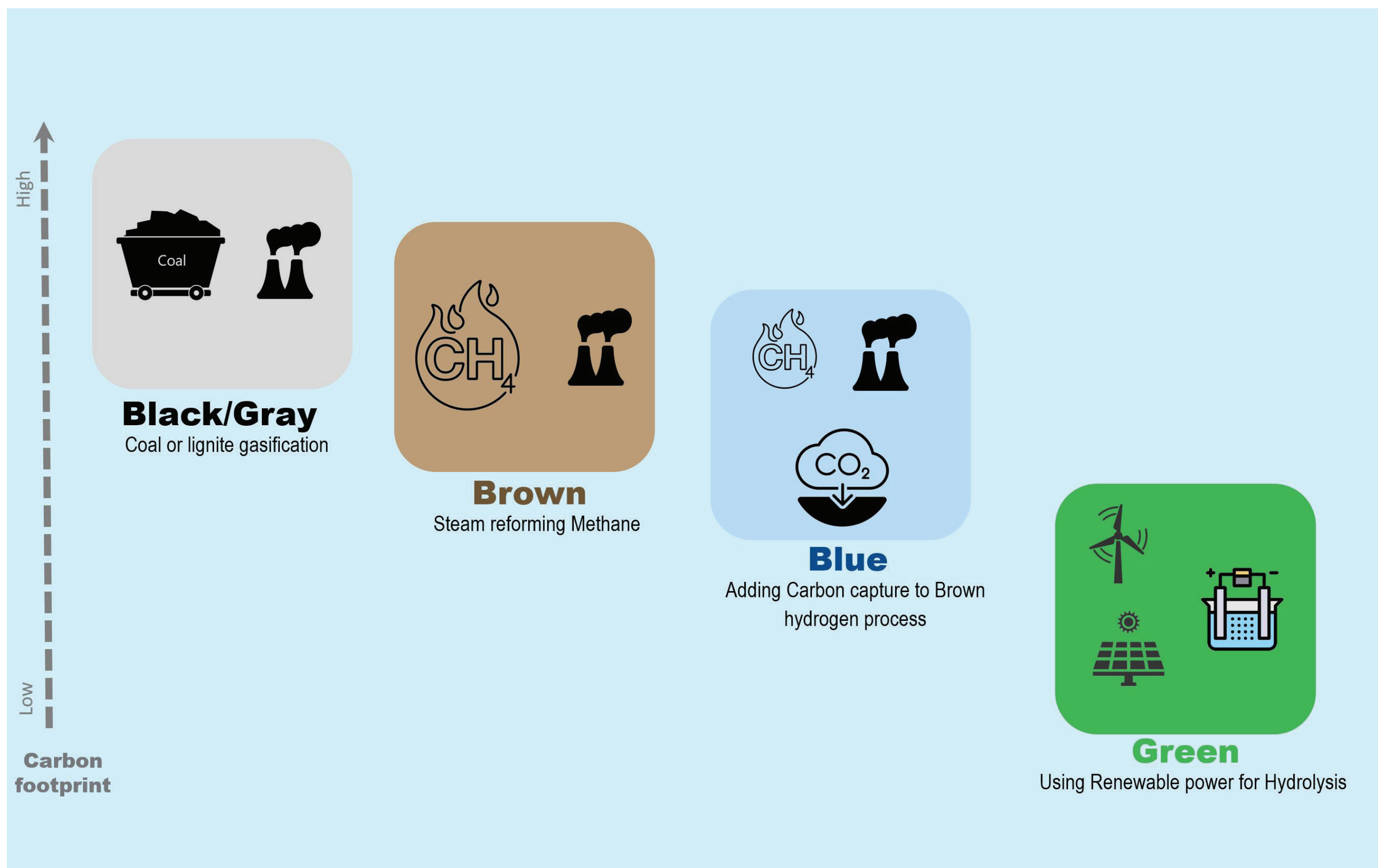
The Role of Hydrogen in Carbon Reduction:

Key Questions & Answers on Technology Trends

Hydrogen fuel technology has the potential to drive sustainability and carbon reduction objectives in many industries. The substitution of coal or crude oil-based fuels with hydrogen will increasingly lead to a decarbonized world where 'water' is the new crude oil and 'hydrogen' is the new gasoline or diesel.

By Manish Sharma, Global Industry Marketing Leader, Energy and Water – Emerson



The hydrogen industry has developed a color scale to label how clean each of the extraction process are.

Q: What role can hydrogen play in global efforts to decarbonize energy sources?

Hydrogen fuel technology is a promising decarbonization opportunity for three main reasons.

First, on the supply side, hydrogen can be produced from most primary energy sources. This diversity of supply sources is one of the key reasons hydrogen is such a promising pathway. Using low-carbon energy sources (e.g., wind, solar, nuclear and hydropower) coupled with electrolysis is the focus of current policies and worth exploring further.

Second, on the demand side, hydrogen is gaining momentum in new applications. In its molecular form, it is an industrial raw material and serves as an energy carrier. It can also be combined with other molecules to produce hydrogen-based fuels and feedstocks like ammonia, which is used for various processes in petrochemical industry or fertilizer manufacturing. When it is not used as an input for chemical processes, hydrogen can be a source of thermal energy or electricity in several ways (e.g., gas turbines, gas grid blending, boilers and in fuel cells).

Thirdly, hydrogen acts as an 'energy storage' medium. Renewable energy is being used to store energy in the form of hydrogen, which is in turn substituted for traditionally hydrocarbon-based fuels in gas turbines, transportation systems such as personal and commercial vehicles, marine vessels, and railways.

Q: What are the different 'colors' of hydrogen and why is it important to understand how they are produced?

Although hydrogen is the most abundant element in the universe, it must be extracted from more complex molecules. Industry has developed a color scale to label these extraction processes, in terms of how clean they are: black/gray, brown, blue, and green.

Currently a large percentage of hydrogen is produced from fossil fuels. 'Black' and 'gray' hydrogen is a byproduct of coal or lignite gasification. This process is being steadily replaced, with 'brown' hydrogen being produced from a methane source, such as natural gas, using a process called steam-reforming.

While they yield clean hydrogen, these processes produce significant amounts of Earth-warming CO_2, so they do not really contribute to decarbonization.

'Blue' hydrogen uses the same steam-reforming process as brown but adds carbon capture technology to the process to eliminate the greenhouse gas emissions.

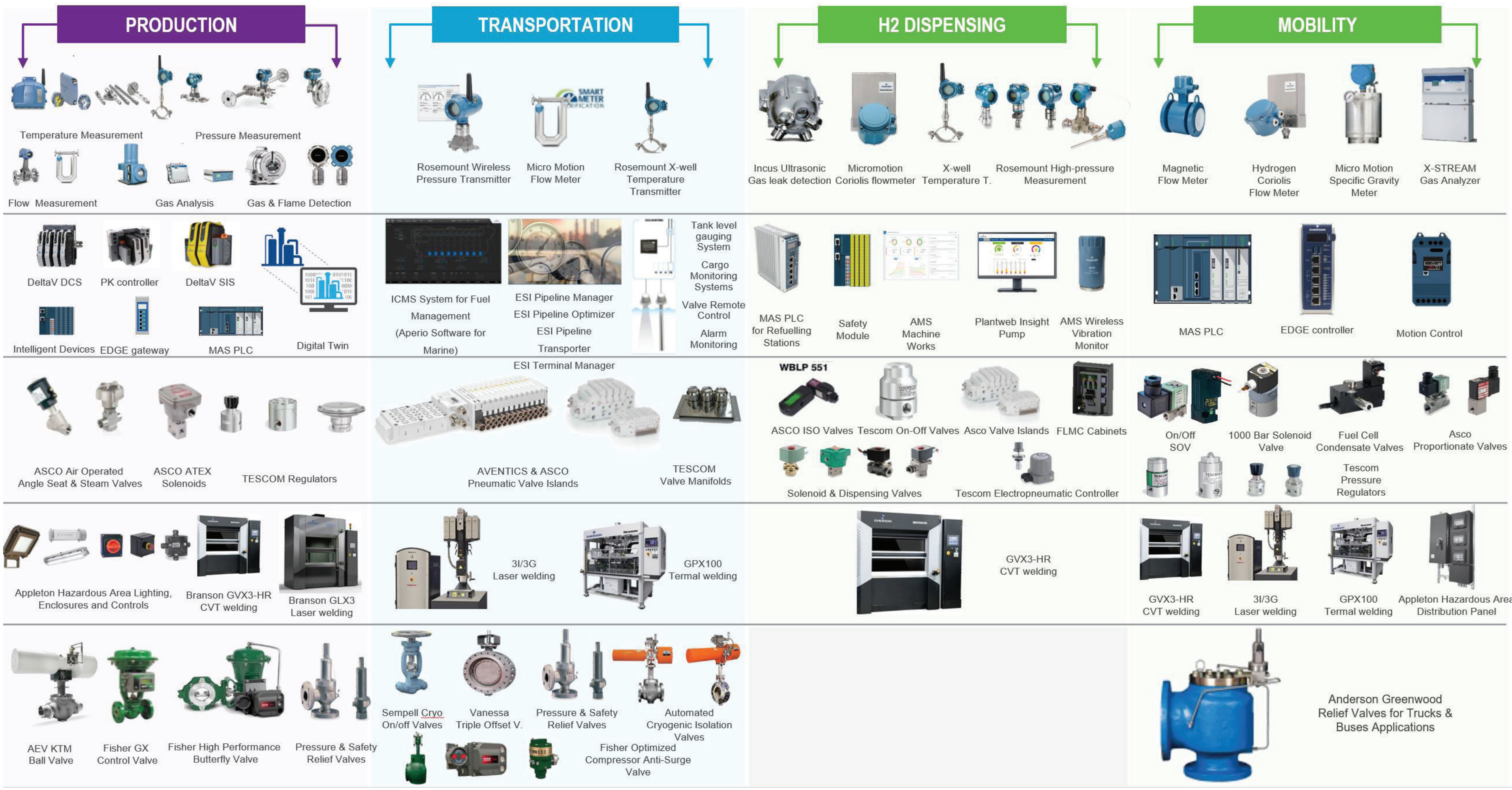
'Green' hydrogen involves no carbon release at all, using industrial-scale electrolysis to separate water — H_2O — into oxygen and hydrogen.

Q: Why is there growing attention to hydrogen processing now — what is driving the attention?

Global governments are setting ambitious net-zero goals and introducing legislation to prevent the most extreme effects of climate change. This is being done as part of the efforts to fulfill the 2015 Paris Climate Agreement, when the European Union and 195 countries signed on to a single, sweeping agreement that aims to keep global warming to well below 2°C (3.6°F) — and make every effort to go below 1.5°C (2.7°F).

Governments in many regions are backing the renewable hydrogen industry through substantial subsidies as they seek to reach net-zero targets. In the U.S., the 2022 Inflation Reduction Act provides incentives with up to USD $3 per kilogram of production tax credits for green hydrogen. It also authorizes USD $1 billion for research, development, demonstration, and deployment activities to reduce the cost of clean hydrogen produced via electrolysis and USD $500 million for research, development and demonstration of improved processes and technologies for manufacturing and recycling clean hydrogen systems and materials.

Along with investments, there have been dramatic reductions in the cost of wind and solar energy installations. The reduced cost is helping bring down the electricity cost of industrial-scale electrolysis operations.



Scaling up the green hydrogen infrastructure will require a broad range of technologies, some widely used in current applications and others only now being developed, combined with deep experience in developing solutions across the entire hydrogen value chain.

These conditions are creating the conditions for some of the most rapid growth in hydrogen electrolysis plants ever seen. One 2022 industry report noted that the global green hydrogen project pipeline exceeds 250 gigawatts, 200 times the power produced in 2020.

In Canada, an 88-megawatt water electrolysis plant for Hydro-Québec, an energy firm backed by the provincial government, is being developed, and will be able to generate 11,100 metric tons of green hydrogen per year; there was a similar-sized project recently announced for South Korea.

This improved production is being stimulated in part due to improvements in hydrogen fuel cell technology. According to a recent fact sheet from the U.S. Department of Energy, high-volume automotive fuel cell costs have been reduced by 60% since 2006, and their durability has quadrupled in the same time frame.

Q: What is unique about hydrogen processing and scaling up of hydrogen infrastructure?

The hydrogen fuel infrastructure needs major investment and scaling up to provide a viable and robust clean fuel option and power the expanded use of hydrogen fuel cell technology. Companies across the hydrogen value chain are working on large-scale projects to advance hydrogen fuel's availability, its ease of use, and expand its contribution to decarbonization.

These projects include electrolyzers for producing green hydrogen, refueling stations for dispensing it, and fuel cells for converting it into electricity. With these foundations in place, people can use hydrogen as fuel for stationary power units and hydrogen-powered transportation. Scaling up each area presents major challenges, in terms of efficiency, process control, safety, and reliability.

As it moves throughout the value chain, hydrogen is subject to pressures of up to 15,000 pounds per square inch (psi), or 1,000+ bar, and, like many fuels, can be explosive when not handled properly. To achieve a landscape that can effectively and safely meet demand, it is critical that companies identify technologies that can reliably and efficiently control hydrogen fuel, from production through end use.

Q: What challenges are there to scaling up green hydrogen processing?

Green hydrogen is produced through alkaline or polymer electrolyte membrane (PEM) electrolysis, powered by renewable energy sources such as hydropower, wind or solar. Once it is isolated, hydrogen can be stored, transported, and distributed. If transported over large distances via pipelines or gas tankers, it is done so by converting hydrogen to ammonia, which is safer and more energy dense to ship.

For an electrolyzer to work effectively and safely, the flow of all three fluids — water, hydrogen, and oxygen — must be precisely controlled. Reliable valves, back-pressure regulators, and an intelligent programmable logic controller (PLC) with SCADA can provide four layers of media control, preventing leaks and minimizing maintenance time and costs while protecting the plant at large.

The first layer is any valve controlling the flow of media — oxygen, water, or hydrogen — and includes both back-pressure regulators and pneumatic shut-off valves. The second layer is the actuation layer, which includes valve islands and solenoid pilot valves. Both components have the same function, to actuate the pneumatic shut-off valves that handle the process media.

The PLC has the control algorithm to manage the pilot valves' operation and control the process media. Safety-certified PLCs ensure that a plant undergoes a safe, controlled shutdown in case of a hazardous event like a gas leak or fire. The fourth layer is a SCADA system that collects all plant data, providing operators and process managers with engineering displays, trends, notifications, and analyses that guide real-time refinements and improvements in the electrolyzing process.

Another layer must be added to this traditional model, the 'floor to control room'. The new layer is composed of industrial edge computing and cloud processing. This industry is in a unique position to have digital transformation specified into projects, rather than retrofitting it. Edge computing provides a superior model called Floor to Cloud™ which provides various benefits like predictive diagnostics, fleet management, better process visibility and control and much more.

Transportation is one of the key segments that utilizes hydrogen fuel, and the scale up of hydrogen fueling stations is critical for the segment's success.

All these layers working together, engineered with expertise by technology suppliers with strong backgrounds in hydrogen production processes, are critical elements in the efforts to scale up green hydrogen. Today, only 0.2 gigawatts of green hydrogen are produced; the investments targeted to rapidly expand that number need strong, safe, efficient control technologies and philosophies to ensure that the scale-up delivers the growth cost-effectively.

Q: What major challenges are associated with expanding the hydrogen fueling infrastructure?

Transportation is one of the major segments where hydrogen fuel and the hydrogen fuel cell are rapidly offering an effective, carbon emissions-free option in parallel with the expansion of battery electric vehicles (BEVs). To help drivers adopt fuel cell electric vehicles and hydrogen combustion vehicles, it is critical that hydrogen dispensers are working when drivers need to refuel. That means real-time, completely reliable visibility of fueling station inventory levels and responsive supply chains to replenish stock. Additionally, hydrogen fueling times must be comparable to gasolines.

In hydrogen refueling stations, hydrogen is stored as either compressed gas or liquid in a pressurized tank. When a customer activates the dispenser, fuel is drawn from high-pressure storage to flow through the system and into the lower-pressure vehicle tank. Many devices and components work together to control the flow of hydrogen and help to ensure safe, precise, and quick operation when operators arrive at the dispenser.

Fueling for multiple pumps at a fueling station can be controlled by a PLC, which can be configured to manage multiple fueling pumps simultaneously. This PLC can handle other key tasks, such as controlling hydrogen dispensing from the fueling station's main storage tank and communicating via network or cloud with a company's master control room. It can also be the source of inventory, billing, and process reports on the fueling stations' performance.

Managing multiple pumping stations located across geographically disparate locations and monitoring their inventory levels, operational parameters and equipment health from a central remote location requires a cloud-based edge controls solution. This is critical for fleet maintenance of assets at the corporate level for business and technical purposes.

Q: What kinds of control technologies can help improve hydrogen fuel cell efficiency and performance?

When designing a fuel cell system, it is important to maximize fuel usage. The hydrogen storage tanks cannot be run to empty due to pressure constraints, so enabling efficient fuel delivery to the fuel cell stack with minimal losses is critical. The system must be able to operate consistently across a range of operating modes — acceleration, deceleration, stopping and idling — which all require varying hydrogen flow demands. This stable system operation is aided through a design employing positive, high-pressure fuel shut-off and is achieved through use of a reliable hydrogen regulator.

Hydrogen regulators with a two-stage tied-valve design can provide a steady flow of hydrogen to the fuel cell stack while minimizing the chance of hydrogen fuel leakage, enabling electricity to be effectively generated to power vehicles or stationary power units. The steady fuel delivery can help extend the life of fuel cells by ensuring they have an even amount of hydrogen disbursed across them while in use. For hydrogen-powered vehicles, this allows their drivers to maximize their fuel usage and reduce maintenance frequency.

Q: How can technology help ensure that hydrogen fuel is produced, delivered and used safely?

To prevent leaks and explosions, electrolyzers and hydrogen fuel dispensing stations should be installed into shelters with proper ventilation and protective systems. These include relief valves and bursting disc systems, as well as safety system shut-off valves. In addition, ultrasonic gas leak detection systems can provide early warning of unsafe conditions.

To further improve safety while guaranteeing gas purity and precise metering, fueling stations can utilize a PLC with integrated edge gateway capabilities. Edge controllers offer control by accurately predicting dispensing level as well as executing predictive analytics, which simplify supply chain logistics and reduce costs and unplanned downtime. Connecting reliable pressure transmitters and flow meters to the gateway can help manage high pressure and flow applications more effectively and issue real-time alerts for a higher level of safety. Furthermore, Safety PLCs can be used for critical process to ensure safe shutdown and revert to safe state in case of anomalies.

Q: What is the most effective way to advance the contribution hydrogen fuel cell technology can make to decarbonization and address climate change challenges?

The future of green hydrogen depends on the success of each stage of its ecosystem. From production to distribution and conversion, high-pressure solutions can safely, effectively, and efficiently control hydrogen and other media as the fuel moves through the value chain.

Advanced technology platforms can greatly improve operations throughout the hydrogen value chain. They provide valuable data and insights that empower informed decision-making, to improve operational safety and reliability, optimize production, and energy use and reduce emissions.

These solutions can monitor the wear of pneumatic valves and actuators, detect compressed air leaks in pneumatic systems and optimize compressed air consumption. In addition, flexible and scalable software technology, backed by suppliers with rich domain and application expertise, can provide users with finer levels of control and relate critical device process and diagnostic data.

There are advantages to working with companies such as Emerson with decades of experience developing products and helping manufacturers in the hydrogen processing and fuel cell development industries. By providing a broad portfolio of valve control products and control systems (PLCs, SCADA, edge computing) that offer proven performance in electrolyzers, fueling stations and hydrogen fuel cells, companies like Emerson can help work through the scale-up challenges in the hydrogen fuel value chain, find efficiencies and solve roadblocks to the kind of fast buildout now underway in the industry.

ABOUT THE AUTHOR

Manish Sharma is a global marketing and business development leader for Emerson's Discrete Automation business and is responsible for its portfolio targeting Energy Transition across industries like Power, Renewables, Hydrogen, Hydrocarbons, Semiconductor, water. He has 20 years of experience in marketing, product management and control systems and R&D.