Electrical Safety Across the Global Hydrogen Market

In this white paper Emerson explores the current use of hydrogen in Europe, as well as hydrogen's prominent role in the European Union's transitioning to a net zero economy. We provide insights into emerging opportunities and challenges, explain recent EU mandates on clean hydrogen, and explore the ATEX requirements for electrical equipment in hydrogen facilities. We also address how Appleton can help industry stakeholders as they face mounting pressure to scale up hydrogen production, storage and transportation systems.

Currently, 95% of Europe's hydrogen is categorized as "brown hydrogen." Brown hydrogen is produced from natural gas or oil and results in the emission of 70-100 million tons of CO_2 into the atmosphere annually. The EU has recently proposed a comprehensive framework to encourage the use of low-carbon and renewable hydrogen, which will help it become less dependent on imported fossil fuels and decarbonize in a cost-effective way. This framework calls for more than doubling European hydrogen consumption by 2030.

Regardless of its production pathway or end-use, hydrogen remains a highly flammable gas that can cause fires and explosions if not handled properly. Consequently, correctly certified and tested Explosion Protected ("Ex") electrical equipment is required at every point across its value chain, upstream and downstream. Within the EU, EFTA and UK, electronic or electrical equipment of any kind that is intended for use in a potentially explosive zone must be ATEX-certified.

The Appleton A.T.X.™ line of ATEX certified products by Emerson are proven solutions in optimizing the efficiency of hydrogen-based technology while controlling costs and maintaining the highest standards of safety.

The Hydrogen Market

Hydrogen makes up less than 2% of Europe's total energy consumption with demand in 2022 amounting to 8.23 metric tons (Mt). The largest share of demand originates from refineries and ammonia (fertilizer) producers that consume 81 percent of the total, most of which is produced and consumed on-site. This is confirmed by the European Hydrogen Observatory, a research group co-funded by the European Union, that reported that 87% of total hydrogen production capacity in Europe is dedicated to onsite captive consumption, indicating that it is primarily produced and used within the facility.

Another 12 percent of hydrogen demand in Europe is for methanol production and various chemical processing applications. Of the remaining four percent, only a small portion is currently allocated to clean hydrogen applications, notably driven by the mobility sector.

As of the end of 2022, 476 hydrogen production facilities were in operation throughout Europe, with a total capacity of about 11.30 Mt. Notably, Germany, the Netherlands, Poland, Italy, and France contribute the most to this capacity, making up a total of 56% of the hydrogen capacity available. Conventional hydrogen production methods, encompassing reforming, by-product production from ethylene and styrene, and by-product electrolysis, collectively yield 11.28 Mt of the 11.30 Mt hydrogen capacity, according to the European Hydrogen Observatory.

EU Hydrogen Strategy

Aiming to bring clean hydrogen from "niche to scale," the EU established a roadmap in 2020 to enable the bloc to reach 20 million tons of renewable clean hydrogen within a decade, equally split between domestic production and imports from non-EU sources. Clean hydrogen would be for use in heavy industry and transport sectors that are traditionally reliant on coal, natural gas, and oil.

It is very important to note here that the EU's definition of "clean hydrogen" refers to both the hydrogen produced through electrolysis powered from renewable sources and to hydrogen produced from natural gas by steam methane reforming in conjunction with Carbon Capture and Storage (CCS), also known as blue hydrogen.

In 2023 the EU's 27 member states approved the Renewable Energy Directive (RED III), which includes mandatory usage for clean hydrogen and its derivatives. RED III effectively signed into law aggressive clean energy targets with member states agreeing that 42% of hydrogen used by industry and 1% of transport fuel must be clean by 2030. RED III establishes ambitious sector-specific targets in transport, industry, buildings, and district heating and cooling, some of which will positively impact the hydrogen industry.

Member states now face a tight turnaround to meet these targets for building out infrastructure for the processing, storage, transportation and dispensing of clean hydrogen.

Appleton A.T.X. Products

A.T.X. D Series Aluminum Control Stations

A.T.X. JBES Pre-Drilled 316L Stainless Steel Junction Boxes

A.T.X. FDBAES LED Series Self-Contained Emergency Luminaires

A.T.X. DB Series IIC Elbows

As daunting as this task may seem, results of the EU's push towards clean hydrogen are beginning to emerge, for instance:

- There are currently more than 500 new hydrogen projects ongoing in Europe, including about 300 transmission and distribution plants, fifty hydrogen storage facilities, and twenty new hydrogen terminals and ports.
- Thirty-eight hydrogen-powered clean-steel factories are already operating in Europe or have plans to operate.
- Hydrogen startups, those working on hydrogen vehicles, fuel cells, storage and electrolysis, brought in $437m in funding in 2021 — a 592% increase from 2020
- Total installed electrolysis capacity grew from 85MW in 2019 to 191 in 2023.
- 15 EU member countries included hydrogen in their Covid-19 recovery plans, unlocking investments of €9.3 billion.
- Hydrogen transportation options are now being offered in several countries led by Germany with 93 hydrogen fueling stations.

Achieving the ambitious goals set forth by the EU's Hydrogen Strategy and RED III will be an enormous feat. Ramping up will require significant investments in Ex equipment for the many potentially explosive areas within new and existing hydrogen production plants, transportation systems, storage facilities and dispensing operations.

Hydrogen Color Codes

Different methods of producing hydrogen are often referred to by certain colors:

- Brown hydrogen — Produced from the gasification of coal. Releases large quantities of CO_2.
- Gray hydrogen — Steam refined methane production. Releases large quantities of CO_2.
- Blue hydrogen — Steam refined methane production with carbon capture and storage. Releases around 10% CO_2 emissions.
- Green hydrogen — Hydrogen produced by electrolysis, powered by renewable energy sources like wind and solar. Release of emissions is close to zero.

- Yellow hydrogen — Hydrogen produced by electrolysis, powered by existing grid sources like coal and natural gas. Releases typical CO_2 emissions associated with power production, but cam be limited by relying on production overages.
- Pink or Purple hydrogen — Hydrogen produced by electrolysis, powered by nuclear energy. Release of emissions is close to zero, but nuclear waste is produced.
- White Hydrogen — Hydrogen mined from underground sources. The CO_2 emissions come from the mining process.

Hydrogen Production Methods

HHydrogen is the simplest and lightest of all Earth elements, consisting of only one proton and one electron. It is also the most abundant element in the universe, yet rarely in its pure state. Instead, hydrogen covalently bonds to one of three elements: fluorine, oxygen, or nitrogen.

To produce hydrogen, it must be separated from the other elements in the molecules where it occurs. Technologies enable the separating of hydrogen gas from its companion substances in purities in the order of 99.999%.

Reforming Production

The least expensive method of hydrogen production is "reforming" which is used for 91 percent of total hydrogen production in Europe. Reforming refers to the generation of hydrogen through processes like steam reforming, partial oxidation, gasification, and autothermal reforming of fossil fuels. Additionally, this category encompasses hydrogen produced as a by-product within refineries, such as during catalytic reforming.

Although reforming is very cost-effective, this "brown hydrogen" requires fossil fuels as feedstock and to produce heat. In fact, for every kilogram of hydrogen produced in reforming, seven kilograms of CO_2 are released into the environment. Because of this the EU is seeking alternative production methods.

Clean and Green Hydrogen Production

An alternative pathway to reforming is water electrolysis. This pathway splits hydrogen from water using electrical current, effectively converting electrical energy into chemical energy. Like reforming, however, water electrolysis largely relies on fossil fuels. In fact, approximately 60% of the cost of producing hydrogen by electrolysis is electricity.

The only way for electrolysis processes to be truly "green" (CO_2 neutral) is if no greenhouse gases or other pollutants are generated. This requires the use of renewable energy sources such as wind or solar power, instead of fossil fuels to generate the needed electricity. Because green hydrogen is considerably more expensive to process, it constitutes a very small portion of all hydrogen produced in Europe. EU hydrogen initiatives including the Clean Hydrogen Partnership, European Clean Hydrogen Alliance, and the Hydrogen Public Funding Compass are exploring more cost-effective technology and processes to produce CO_2 neutral hydrogen as part of their objectives.

Hydrogen Storage in Europe

Hydrogen storage is crucial to developing secure renewable energy systems. Meeting the EU's hydrogen goals of 45 TWh (Terawatt Hours) of long-term hydrogen storage by 2030 will necessitate a significant increase from the current state of 9.1 TWh.

Energy storage in Europe is now dominated by subsurface hydrocarbon storage and this is where the EU sees the greatest potential for its ambitious storage goals. To achieve a stable supply of blue hydrogen, the EU is relying heavily on Carbon Capture and Storage (CCS) in underground storage. Depleted gas fields, saline aquifers, and artificial rock caverns, often in salt rocks, can be used for these subsurface storage operations.

Hydrogen Transportation in Europe

Approximately 50% of the EU's future demand for clean hydrogen will need to be met through imports to complement its domestic supply. For that reason, plans are in place for a dedicated hydrogen transport network spanning 21 countries, which could see up to 53,000 kilometers of hydrogen pipelines in place by 2040. More than 60% of this network would repurpose existing natural gas infrastructure.

Marine pipelines have also been proposed to import clean hydrogen, such as the one spanning the North Sea in Scotland that could supply ten percent of Europe's imports by the mid-2030s. These ambitious projects and many others are dependent on whether the EU can mobilize additional support for procurement and end use.

Hydrogen Dangers

When developing electrical systems for a hydrogen application, engineers must be aware of its associated dangers. Make no mistake — there are serious safety concerns when hydrogen is released in sufficient concentrations, a situation made even more precarious because hydrogen is both colorless and odorless.

Hydrogen's wide flammability range (4% to 74%) means the energy needed to ignite it can be very low, like that generated by a small spark or an electrostatic discharge. Another danger is that hydrogen flames burn at extremely high temperatures (500 °C, 932 °F) yet mostly outside of the visible light spectrum, making hydrogen fires nearly impossible to initially detect. Furthermore, at concentrations of 18.3% to 59%, hydrogen will explode. Blast waves from hydrogen explosions have resulted in very serious damage to surrounding buildings and led to multiple injuries and deaths. For example, in August 2023, a hydrogen tank explosion occurred in an industrial building in Leibnitz, Austria; the explosion produced a massive pressure wave that was sensed over three kilometers away. Explosive forces vary depending on several factors, such as the quantity and concentration of gas, the presence of any other materials, and the physical conditions under which the explosion occurs.

Hydrogen has one safety advantage over other flammable fuels: hydrogen is 14 times lighter than air and rises six times faster than natural gas, which means that it disperses rapidly when released. Unless contained by an overhead structure, a hydrogen leak will quickly disburse before it reaches a flammable concentration. The laws of physics prevent lightweight hydrogen from lingering near a leak unlike heavier propane or gasoline fumes. Recent incidents inform us that Hydrogen explosions and fires are most likely to occur in confined, poorly ventilated spaces where hydrogen is processed or stored in very large quantities.

A key takeaway here is that, regardless of how clean or green a hydrogen process is, there is always the very real potential of a fire or explosion at the site if improperly approved electrical equipment is being used. Clean hydrogen is more sustainable, but it remains just as explosive.

Mitigating Risk with ATEX Certified Equipment

General requirements for the design, testing, and marking of electrical devices, components, or equipment meant for operation in explosive environments are outlined in a set of European Union regulations known as the ATEX Directives. ATEX is an abbreviation for “ATmosphères EXplosibles”. ATEX directives are based on the International Electrotechnical Commission System for Certification to Standards Relating to Equipment for Use in Explosive Atmospheres or simply, IECEx. The main difference between IECEx and ATEX is that ATEX certification only applies for countries in the EU whereas IECEx certification is accepted globally. With the UK’s exit from the European Union, UK Ex replaced ATEX 2014/34/EU as the new product scheme in January 2021. Technical standards and procedures are the same as those of the EU ATEX standard, however, UKCA branding and a Declaration of Conformity to UK Statutory Instruments must be assessed and issued.

Products that are ATEX compliant have proved safe to use in specific environments with explosive atmospheres, according to the Zone they are certified to be used in. ATEX classifies Zones by the frequency of the presence of explosive gases in an area, with Zone 0 being gases continuously present, Zone 1 being gases intermittently present, and Zone 2 being gases present abnormally or infrequently present. (A separate ATEX Zoning classification is used for explosive dusts.)

Depending on an area’s Zone level, it will require a specific ATEX equipment protection category:

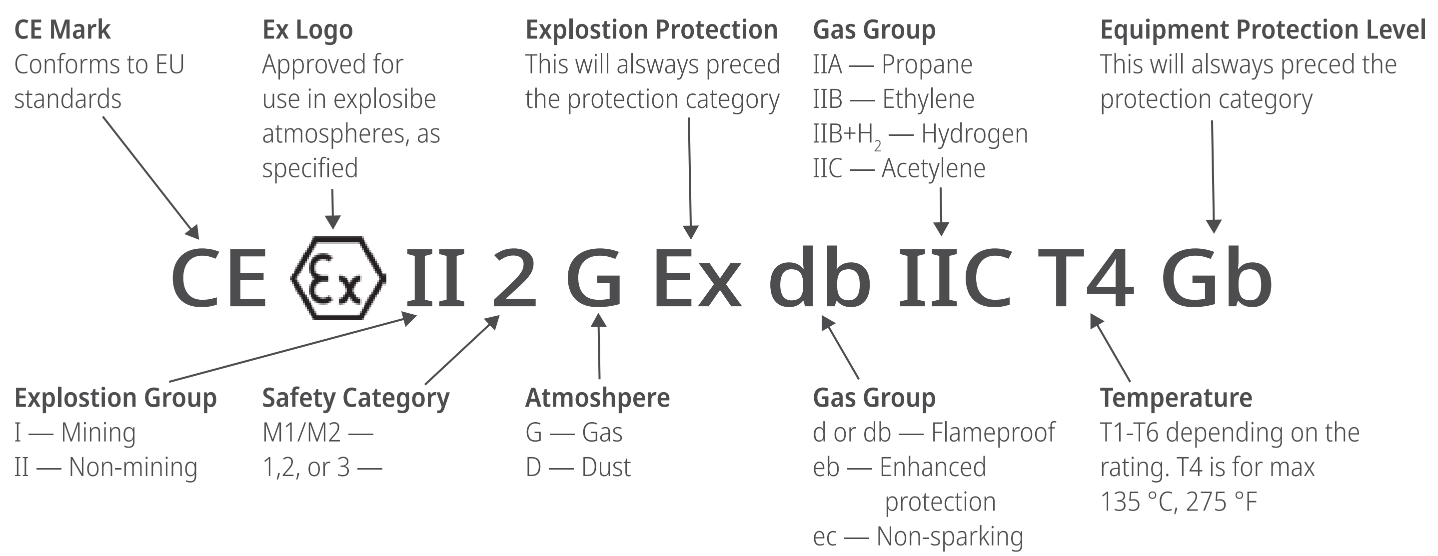
- Zone 0: Category 1 (very high)
- Zone 1: Category 2 (high)
- Zone 2: Category 3 (normal).

Hydrogen is classified by ATEX as a gas group IIC gas (“Atmospheres containing acetylene or hydrogen, or gases and vapors of equivalent hazard”) and belongs to the T1 (450° C) temperature class making it one of the hottest, most dangerous gases used by industry.

Equipment intended for use in a Zone containing hydrogen or other explosive gases is also assigned an Equipment Protection Level of EPL Ga/Gb/Gc. Ga refers to a very high level of ignition protection (two faults), Gb is a high level of protection (one fault), while Gc is a low level of ignition protection (normal operation).

ATEX ID Marking

The ATEX directive requires identification markings indicating a product’s equipment group, category, and flammable atmosphere. Additional ATEX and IECEx markings indicate protection types, gas/dust groups, temperature classifications, and equipment protection levels, as shown in the example below.



Installing Electrical Equipment in Hydrogen Facilities

Below is a basic process for installing electrical equipment in areas with explosion risks. The manager of the installation is solely responsible for:

1. Determining hazardous areas.
2. Defining Zone boundaries - volumes.
3. If necessary, delimiting Zones.
4. Knowing the characteristics of flammable substances present on the site.
5. Defining the temperature class and the explosion group of the equipment.
6. Choosing equipment depending on :
    - the temperature class and the explosion group
    - environmental constraints specific to the site such as corrosion, exposure to UV, mechanical strength
    - protection indexes
7. Installing equipment.
8. Commissioning.
9. Checking the installation.

Emerson Solutions for Hydrogen

The Appleton A.T.X. line of products by Emerson represents a wide variety of ATEX-certified explosion-proof LED lighting fixtures, power distribution panels, enclosures, fittings, junction boxes, cable glands, and connectors for facilities processing, handling, storing, or consuming hydrogen. Certified to ATEX/IECEx standards, A.T.X. Flameproof and Increased Safety products ensure reliable and safe operation of electrical systems in explosive environments. Robust engineering also means a longer service life and reduced downtime.

In Conclusion

Hydrogen is regarded by the European Commission as the cornerstone of its future clean energy strategy. As a global leader with a strong presence throughout Europe, Emerson is uniquely positioned to assist in this strategy with engineering expertise and an array of hydrogen fuel production solutions to drive energy transformation and decarbonization. Partnering with Appleton, as well as with other Emerson brands such as ASCO, Fisher, Micro Motion, Rosemount and TESCOM, means you can expect innovative products designed specifically for demanding hydrogen fuel applications.

Appleton A.T.X. Products

A.T.X. ACSEW-X Cast Junction Boxes

A.T.X. Linmaster LED Zone 1 and 2 Series Non-metallic Luminaires

A.T.X. PRE Series Plugs and Sockets

A.T.X. DB Series Fire Retardant Seal

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