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Hydrogen firing: UK's Lucideon works with ceramics industry on hydrogen-firing trials

By Andrew Norwood

Hydrogen fuels can help the energy-intensive ceramics industry drive to net zero emissions. U.K.-based Lucideon started using hydrogen fuel mixes in its test kiln.

Burning fossil fuels such as natural gas releases carbon dioxide and other greenhouse gases into the atmosphere, causing climate change. To mitigate these changes, the world will need to reach an equilibrium between greenhouse gases emitted and removed from the atmosphere, a state referred to as reaching "net zero" emissions.

The Net Zero World initiative[1] stresses the importance of transitioning to global net zero by 2050, and meeting this deadline will require countries around the world to work in partnership. Organizations such as Lucideon, a testing, characterization, and consultancy company headquartered in the U.K. and with additional sites in the United States, bring a global presence and expertise across multiple regions, which will be crucial to the collaborative effort required.

Hydrogen fuel is expected to play a significant role in achieving net zero. Hydrogen fuel is a cost effective, highly sustainable, clean source of energy, provided it is manufactured using non-polluting energy sources.

The world has witnessed a significant increase in announced and planned national hydrogen policies in the last couple of years. Countries' geographical locations factor critically in the development of national hydrogen strategies. The local availability and ease of access to hydrogen are vital for assessing potential supply. Demand will be dictated by a country's industrialization, energy needs, and dependencies. Together, these factors will dictate the potential opportunities and challenges that a country may face.

Careful study and anticipation may allow for a potential strategy that leads to success in becoming a large-scale energy exporter or importer. The legislation circulating around the world in the global push to net zero means that, while challenges are present, there can be opportunities for organizations that are able to rise to the task.

Global ambitions

The German Hydrogen National Strategy, for example, recognizes that a large portion of its hydrogen demand targets will have to be met by imports. Likewise, the Netherlands identified the potential for hydrogen imports into the Dutch and European markets as part of its hydrogen strategy. It foresees the Port of Rotterdam playing a key role in facilitating the supply of imports and distribution of hydrogen across the continent.

Chile has the most ambitious plans for embedding hydrogen in its future energy mix. It aims for 25 GW of green electrolysis by 2030 and 25 million tonnes of green hydrogen per year by 2050. Chile's National Green Hydrogen Strategy also calls for the country to become a major exporter of green hydrogen and its derivatives.

One angle of approach for using hydrogen to support existing energy networks is to transition the current natural gas network toward implementing a blend of hydrogen gas and natural gas. As hydrogen is a clean source of energy, this approach could significantly reduce greenhouse gas emissions—especially if the hydrogen is produced from renewable energy sources such as wind or solar. Table 1 details projects currently underway on the feasibility of hydrogen and natural gas blends.[2]

Proposals currently under consideration in the United States could see hydrogen blended into the existing natural gas pipeline network as a means of increasing the output of renewable energy systems, such as large wind farms. If implemented, initial concentrations would start at 5–15% of hydrogen by volume.

This strategy would go some way toward solving the issue of effectively and efficiently storing and delivering renewable energy to markets, and it appears to be viable without significantly increasing risks associated with the use of the gas blend in end-use devices (such as household appliances), overall public safety, or the durability and integrity of the existing natural gas pipeline network.[3]

More significant issues must be addressed for higher blends in the range of 15–50%, for example, conversion of household appliances or an increase in compression capacity along distribution mains serving industrial users.[4] Blends of more than 50% face more challenging issues across multiple areas, including pipeline materials, safety, and modifications required for end-use appliances or other uses.

The manufacturing capabilities and costs of hydrogen must also be considered, as there are no high-volume production facilities in place. These capabilities will inevitably take time to develop. That said, hydrogen can be deployed on a small scale immediately, and it can be produced on manufacturing sites, ideally using renewable energy. The MyKonos[5] and Iris group[6] developed such a capability by installing a 2.5-MW photovoltaic plant, an electrolyzer, and sufficient hydrogen storage.

The ceramics industry, as a large consumer of energy, will need to adapt as many countries begin to transition toward hydrogen/natural gas blends in their supply networks. Both challenges and opportunities will be presented by this change; for example, as part of the industry-wide reaction to the 2050 Net Zero initiative, the potential use of hydrogen to fuel kilns for the ceramics industry would significantly reduce CO_2 emissions. However, the industry will also need to understand the safety implications and any effects it may have on product performance, aesthetics, or other key quality considerations.

Table 1. Hydrogen blending projects currently underway[2]

No.	Project	Country	Blended Hydrogen [%]
1	HyDeploy	UK	20%
2	Fort Saskatchewan Hydrogen Blending Project	Canada	5%
3	H21	UK	100%
4	Hyblend	US	-
5	GRHYD	France	20%
6	Snam	Italy	10%
7	HyP SA	Australia	5%
8	Enbridge and Cummins	Canada	2%
9	Hy4Heat	UK	100%
10	Hydrogen injection in the gas grid	Denmark	15%
11	Cleangas Turkey	Turkey	20%
12	EN-H2 (Portugal National Hydrogen Strategy)	Portugal	15%

Prototype trials

Phases one and two of HyDeploy,[7] a U.K. program that aims to blend hydrogen in the U.K. natural gas network, have been completed successfully. The initial phase was conducted on Keele University's (Keele, U.K.) campus natural gas network from November 2019 to March 2021, where 20% hydrogen by volume was mixed with natural gas. This test led to the second phase,[8] where a larger trial was conducted between August 2022 until June 2022 using the U.K. Northern Gas Network for a larger volume. This trial supplied 668 houses, a school, several businesses, and a church and provided further evidence to support the safety of blended hydrogen in a gas network. The outcome of this work will assist the U.K. government in forming hydrogen/natural gas blending policies for the wider U.K. network.[8, 9]

Successful trials have also been conducted at Pilkington Glass (Lathom, Lancashire, U.K.) and Unilever (London, U.K.). If deployed at scale, hydrogen blending at 20% concentration could unlock 29 TWh per year of decarbonized heat, which could provide a roadmap for deeper savings. The carbon savings of a national roll-out of a 20% concentration hydrogen blend would be equivalent to removing 2.5 million cars from the road. Further details regarding these blending trials are available.[9]

For industrial applications, a series of in-depth trials will need to be completed to ensure safety at the points of production and consumer use. To this end, HyDeploy worked with Lucideon to demonstrate how 20% blended hydrogen can be used in the ceramics industry safely and to determine the performance of safety-critical ceramics when firing using a hydrogen/natural gas blend (Figure 1).[10]

The trial used Lucideon's state-of-the-art kiln (Figure 2), capable of blending up to 20% hydrogen with natural gas by volume.[10] The kiln has a temperature rating of 1,750°C and is capable of reduction firing. The kiln's burner system and flame velocity are very important, as is the adiabatic flame temperature.

Figure 1. A pipe supplying Lucideon's hydrogen kiln with a hydrogen/natural gas blend.

Credit: Lucideon

Figure 2. Lucideon's hydrogen kiln at Stone, North Staffordshire.

Credit: Lucideon

Lucideon–HyDeploy trial results

As part of the trial, a representative variety of safety-critical ceramic products were fired, including bricks; roof tiles; shaped refractories; and ceramic cores and shells used for metal alloy casting, for example, turbine blades, water purification filters, flame arrestors, and filters for metal casting. A range of standards testing was conducted and compared to existing production standards. The results showed some variation with regards to density, hot modulus of rupture, pore size, and creep, although generally the results were found to be within acceptable tolerance.

Notably, there was increased cristobalite formation with increased water vapor, volatilization of silica during sintering, increased propensity of carbon monoxide attack in reducing conditions, and reduction of iron oxides to metallic iron in reducing conditions. Firing with 20% hydrogen concentration used 86.4% of the energy for the same total volume of combustion gas, and an additional 15% total gas volume was used to match expected heat energy of natural gas. Additionally, the nitric oxide, nitrogen dioxide, and sulphur dioxide emissions were higher when firing with a 20% hydrogen blend when compared to natural gas; however, CO_2 emissions were higher during natural gas firing.

Though significant progress has been made, additional R&D is needed to address issues such as autoignition, flashback, thermoacoustics, mixing requirements, aerothermal heat transfer, materials issues, turndown/combustion dynamics, NO_x emissions, and other combustion-related phenomena. In addition, when hydrogen concentration exceeds 75%, there is a significant change in combustion behavior, requiring new combustor designs, different sensor locations, and new control schemes.

These enhancements will allow for limiting NO_x emissions to single digit (ppm) levels, improved flame detection, and monitoring for flashback and thermoacoustic instabilities. NO_x emissions control while firing hydrogen requires micromixer combustor technology, which is a refinement of today's premixed dilution technologies for low NO_x natural gas firing. Higher flame temperatures and increased water content could also reduce the lifetime of metal and ceramic parts exposed to hot gases, thereby increasing the need for new materials and thermal barrier coatings as well as improved cooling schemes.

Lucideon continues to support the ceramics industry and the journey to net zero by developing new capabilities that enable up to 100% hydrogen firing, eschewing natural gas entirely while also addressing effects it may have on kilns, products, and safety considerations during production.

An industry-wide effort

Everywhere you look, it is becoming clear across the entire ceramics industry that the challenge of adapting to a net zero world is being accepted with ambition and enthusiasm. For example, Michelmersh (Michelmersh, U.K.) has its Hybrick project to conduct a feasibility study to replace natural gas with hydrogen in the brick-making process, aiming to produce "the world's first 100% hydrogen-fired clay bricks."[11] The Italian Iris Ceramica Group, mentioned previously, is also working to adapt their processes to create a production site that, in the long term, is designed to run on 100% hydrogen, using a blend of green hydrogen with natural gas as an intermediary solution. Schott, the German speciality glass manufacturer, reported successful trials of using 35% hydrogen for industrial-scale glass production, with plans to use 100% hydrogen in future lab-scale tests.[12]

The efforts of the ceramics industry demonstrate that even energy-intensive industries may have opportunities to cut emissions. What might be considered marginal gains percentage-wise can be leveraged to achieve significant actual carbon savings, and business incentives are aligning to reward and assist the pursuit of net zero. We are confident that the entire ceramics industry will be able to take the initiative to meet the challenge ahead of us, and we are ready to help.

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