Be the zero hero: Improve project economics when transitioning to 100% hydrogen firing

BY MATT MARTIN, CLEARSIGN TECHNOLOGIES CORPORATION CASE STUDIES & SOLUTIONS AUGUST 7, 2024 9:44 AM

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Hydrogen as fuel in fired heaters

Hydrogen produces no CO_2 when burned. This simple fact makes it an attractive fuel for organizations who either have ESG goals or regulatory obligations to reduce their greenhouse gas emissions.

The fuel for fired heaters in refineries and petrochemical plants already contains a significant amount of hydrogen, often ranging from 20 to 80%. Given that the infrastructure is already available to deliver hydrogen bearing fuel to these heaters, the plant has already made the investment to build them, and the temperatures required make the electrification of the processes difficult, it is reasonable to increase the hydrogen content of the fuel to reduce CO_2 emissions.

Burners supply the heat to these heaters. Many burners will require some degree of modification to fire hydrogen. Generally, typical burners cannot fire fuels ranging from 100% natural gas to 100% hydrogen, so the burners are generally designed for a narrower range of fuel compositions. Most burners, including new burners designed to fire 100% hydrogen, will have increased NO_x emissions of 20% or more when firing fuels with an increased hydrogen content compared to operation with the current fuel gas.

Higher hydrogen, higher NO_x: Why it matters

Nitrogen oxides (NO_x) form smog and ground level ozone, react to produce particulate, may contribute to respiratory problems, and contribute to the formation of acid rain. The EPA regulates NO_x and ozone emissions in the United States [1]. A State Implementation Plan (SIP) submitted by each state and approved by the EPA regulates implementation [2].

The details of each SIP mean that the trade-offs and incentives vary by region, State, and locality when considering NO_x abatement. For example, in the South Coast Air Quality Management District (SCAQMD) in California, when the emissions from a heater increase either from capacity increase or due to a change in operating conditions, one must calculate the Average Cost Effectiveness of a NO_x control and the Incremental Cost Effectiveness compared to other NO_x controls. If the Average Cost Effectiveness is less than the threshold value set by the SCAQMD, then one must implement the NO_x control. If there is a more effective control and the calculated Incremental Cost Effectiveness is less than the threshold value, then one should implement the more effective control [3].

In Texas, the Emissions Banking and Trading (EBT) Program allows for the trading of Emissions Reduction Credits (ERCs). These credits can be sold on a market or used to allow for capacity increases. In non-attainment zones, there is typically a NO_x offset requirement of 1.2 to 1 for new or modified major sources of equipment [4].

In most cases using hydrogen as a fuel will increase NO_x emissions beyond the operating permit. The modifications and new equipment required to use hydrogen as a fuel alone may trigger a required reduction in NO_x. Any plans for capacity increases will also require a reduction in NO_x emissions.

Sourcing hydrogen: Are you near a hydrogen hub?

Hydrogen is predominantly produced in natural gas reformers, which emit CO_2 (gray hydrogen). Firing hydrogen in heaters will reduce CO_2 emissions from your organization (Scope 1) but will not reduce emissions used to create the final product (Scope 2). There are several projects that have been announced that will supply hydrogen from reformers where the CO_2 is sequestered (blue hydrogen) dramatically reducing Scope 2 emissions[5] [6].

Plants that already have high hydrogen concentration in their fuel gas system may opt to separate their hydrogen from the fuel stream and incorporate a reformer for the remaining hydrocarbon portion of their fuel gas such that they have on-premises hydrogen production. However, the CO_2 from the reformer must be sequestered for Scope 1 emissions to be reduced.

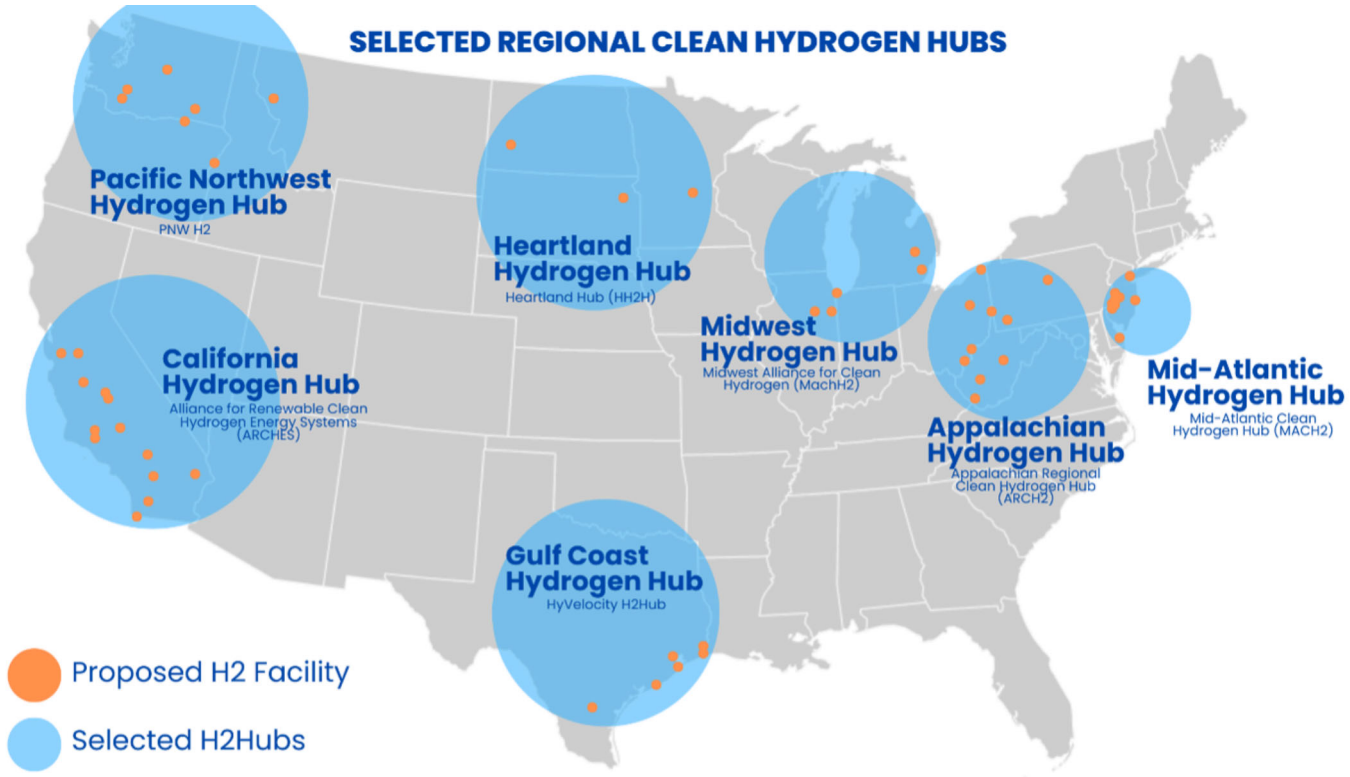

Figure 1 - Regional clean hydrogen hubs

On October 13th, 2023, the United States announced its selection of seven regional hydrogen hubs. Most of these hubs are located near hard-to-decarbonize industries. These hubs are to provide clean (green) hydrogen to industry in the area [7]. Adjacency to these hubs may result in a supply of CO_2-free hydrogen in quantities large enough for industry.

Proper selection of emissions control improves capital and operational expenses while reducing secondary environmental effects

Owners that select the proper emission controls can reduce both capital and operational expenses both for hydrogen implementation and non-hydrogen NO_x reduction projects.

When NO_x is reduced without an SCR there is no ammonia needed, there is no additional particulate emission caused by ammonia slip, and the equipment and catalyst associated with the SCR is eliminated.

SCRs reduce emissions by a catalytic reaction with NO_x and ammonia (NH_3). A small fraction of the ammonia will bypass (slip) the catalyst and exit into the atmosphere. Once in the atmosphere the ammonia and other pollutants react to form particles that can be smaller than 2.5 µm (PM 2.5). Once inhaled, particles of this size can be trapped in human lungs [8]. Meeting required NO_x emissions without ammonia eliminates the contribution of ammonia slip to PM 2.5.

By eliminating the SCR, all capital and installation costs and operational expenses are eliminated. The ductwork, catalyst bed, ammonia storage tank, ammonia vaporizer, ammonia injection grid, and – perhaps most importantly – the support structure is no longer required. The ammonia handling and catalyst reloads with the associated labor is also no longer required as an ongoing operational expense.

ClearSign's 100% hydrogen burner

ClearSign Technologies has developed an innovative burner capable of 100% hydrogen firing while achieving near-selective catalytic reduction (SCR) level NOx emissions. Figure 2 shows a picture of the burner operating with 100% hydrogen fuel. The NO_x production from the burner is lower when firing 100% hydrogen than when firing natural gas. Performance testing already has shown NO_x as low as 4 ppm for natural gas and 3 ppm for hydrogen operation. While still under development, there may be the ability to reduce NO_x below 2.5 ppm with relatively small modifications to the operation of the burner.

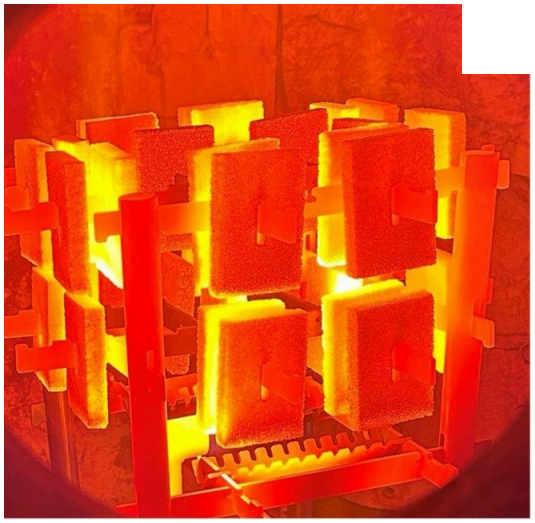

Figure 2 - ClearSign's Core Burner Technology operating with 100% hydrogen fuel.

Quantifying the benefit

Justifiable NO_x projects

Using the cost from an air permit filed with the EPA as a basis, the total installed cost of either an SCR or the installation of ClearSign burners was calculated for 25, 50 and 100 MMBtu/h heaters. The 25 and 50 MMBtu/h heaters are of particular interest because prior NO_x reduction efforts typically did not include heaters with such a small heat release, but NO_x reduction may be required when changing to hydrogen fuel in the current regulatory environment.

NO_X production from burners is variable depending on the heater in which the burners are operating. The ClearSign burners are no different in this regard, but the current test data supports that ClearSign burners in typical refinery heaters would result in NO_X emissions near 0.005 lb/MMBtu.

The current NO_X emissions required to meet first quarter 2024 SCAQMD Average Cost Effectiveness threshold of $39,100/ton of NO_X reduced for each size of heater is shown in Table 1 as well as the anticipated NO_X for ClearSign burners and assumed NO_X for a high-performance SCR used in subsequent calculations [9]. For smaller heaters higher NO_X production from the current burners is required to justify a NO_X reduction project because the economies of scale make larger projects more attractive. However, many smaller heaters are now justifiable when using ClearSign burners where they were not when only SCRs were available.

Table 1 - Baseline NOx required for 2024 Q1 SCAMD Cost Effectiveness for ClearSign Burners and assumed SCR NO_X used in subsequent calculations.

Baseline NOx Required to Meet the Q1 2024 SCAQMD Average Cost Effectiveness Threshold				
Heat Release [MMBtu/h]	Current Burner NOx [lb/MMBtu]	Burner NOx with Hydrogen Fuel [lb/MMBtu]	ClearSign NOx with Hydrogen Fuel [lb/MMBtu]	SCR NOx with Hydrogen Fuel [lb/MMBtu]
25	0.035	0.042	0.005	0.003
50	0.028	0.034	0.005	0.003
100	0.023	0.028	0.005	0.003

Capital cost savings

The anticipated capital cost savings for installing ClearSign burners compared to an SCR are shown in Table 1. Note that in each case the equipment cost is only a small fraction of the total installed cost. Efficient project execution could potentially reduce the cost from those shown. Conversely, variable labor rates and the specific implementation difficulty could increase the cost significantly from those shown. SCR systems being inherently more complex than a burner retrofit may be more prone to unforeseen cost escalation. Note that as the heater size approaches 100 MMBtu/h in fired duty the cost savings from implementing the ClearSign burner solution are such that an additional 50 MMBtu/h heater could be retrofitted.

Table 2 – Total installed cost for ClearSign burner, SCR, and the difference for various size heaters.

Total Installed Cost and Cost Savings for ClearSign Burners vs an SCR			
Heater Fired Duty [MMBtu/h]	ClearSign Burner Retrofit Total Installed Cost [MMUSD]	SCR Retrofit Total Installed Cost [MMUSD]	Cost Savings [MMUSD]
25	1.72	3.79	2.07
50	2.79	6.15	3.36
100	4.54	12.16	7.62

NO_x credits

ERCs in Texas trade for approximately $100,000 per ton [10]. For large NO_x sources these credits can offset a sizable portion of the project cost. Table 3 lists the ERC value for each size of heater evaluated as well as the percentage of the total installed cost that this ERC value represents. Using ClearSign burners the ERC value offsets 26.5 to 28.0% of the project cost. The relative offset for an SCR installation is substantially smaller at 10.3 to 13.5% of the total installed cost.

Table 3 - Emissions Reduction Credit value for ClearSign burners, SCRs, and the percent offset of the project cost.

Baseline NOx Required to Meet the Q1 2024 SCAQMD Average Cost Effectiveness Threshold				
Heat Release [MMBtu/h]	ClearSign ERC [MMUSD]	SCR ERC [MMUSD]	Percent of ClearSign Project Cost [%]	Percent of SCR Project Cost [%]
25	0.481	0.513	28.0	13.5
50	0.756	0.819	27.1	10.4
100	1.202	1.328	26.5	10.3

With the likely escalation of labor cost and ERCs in the future, it may be preferrable to incur the expense in today's dollars and hold the value for future capacity expansions or credit sales. Retrofitting fired heaters for hydrogen capability and NO_x reduction now. If ERCs do not increase in price the capital could gather a better rate of return elsewhere from immediate sale and re-investment.

Bringing the benefit to your team

Whether you are tasked with your organization's ESG goals, manage environmental compliance, are running capital projects, or are the fired equipment subject matter expert, the

benefits of correct technology selection can be delivered across your organization. ESG managers can drive change that also has operational and capital benefits. Project managers can reduce capital cost by significant amounts while also delivering ongoing cost reduction and ease to operations. Fired equipment experts can bring forth significant cost savings with relatively minor risk.

Refueling with hydrogen is likely to be capital intensive and environmentally sensitive. NO_x reduction projects can bring benefits regardless of hydrogen adoption. Awareness of the current technology options can deliver results now and in the future.

For more information, visit clearsign.com

References

—[1] United States Environmental Protection Agency, "Basic Information about NO2," [Online]. Available: https://www.epa.gov/no2-pollution/basic-information-about-no2. [Accessed 09 07 2024].

—[2] United States Environmental Protection Agency, "About Air Quality Implementation Plans," [Online]. Available: https://www.epa.gov/air-quality-implementation-plans/about-air-quality-implementation-plans#what-is-a-sip. [Accessed 09 07 2024].

—[3] South Coast Air Quaility Management District, "Cost Effectiveness and Calculations," [Online]. Available: https://www.aqmd.gov/home/permits/bact/cost-effectiveness-values. [Accessed 10 08 2024].

[4] Texas Commission on Environmental Quality, "Emission Reduction Credit Program," [Online]. Available: https://www.tceq.texas.gov/airquality/banking/erc_program.html. [Accessed 10 07 2024].

[5] D. Woods, "Low-carbon hydrogen: Fueling our Baytown facilities and our net-zero ambition," [Online]. Available: https://corporate.exxonmobil.com/news/viewpoints/low-carbon-hydrogen. [Accessed 10 07 2024].

[6] Air Products, "Louisiana Clean Energy Complex," [Online]. Available: https://www.airproducts.com/energy-transition/louisiana-clean-energy-complex. [Accessed 10 07 2024].

[7] Office of Clean Energy Demonstrations, "Regional Clean Hydrogen Hubs Selections for Award Negotiations," [Online]. Available: https://www.energy.gov/oced/regional-clean-hydrogen-hubs-selections-award-negotiations. [Accessed 10 07 2024].

[8] United States Environmental Protection Agency, "How Does PM Affect Human Health?," [Online]. Available: https://www3.epa.gov/region1/airquality/pm-human-health.html. [Accessed 10 07 2024].

[9] South Coast Air Quality Management District, "2024 South Coast Air Quality Management District BACT Maximum Cost Effectiveness Values ($/Ton)," [Online]. Available: https://www.aqmd.gov/docs/default-source/bact/cost-effectiveness-values/2024q1_equipment_cost_index.pdf. [Accessed 10 07 2024].

[10] TCEQ, "Emission Credit Trade Report," [Online]. Available: https://www.tceq.texas.gov/assets/public/permitting/air/reports/banking/ectradereport.html. [Accessed 10 07 2024].

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