HYDROGEN FOR INDUSTRIAL PROCESS HEAT

Prospects

POOR

This fact sheet is part of an Energy Innovation paper assessing clean hydrogen's value for cutting climate pollution from 12 end uses. The full report includes context, analysis, policy recommendations, and citations—see QR code or link at bottom.

Hydrogen may be limited to opportunistic retrofits for providing high-temperature heat.

CONTEXT: More than 90 percent of combustible fuel use in U.S. industry (i.e., excluding fuels used as feedstocks) is used to provide heat to alter materials or manufacture goods. Different industrial processes require different temperatures of heat, categorized loosely as low (below 100-200°C), medium (from 100-200°C to 500°C), and high (above 500°C). Particularly for high-heat processes needed to make steel, cement, glass, and chemicals, industrial stakeholders often look to lower-carbon fuels like hydrogen to reduce their emissions. This is because hydrogen readily achieves high temperatures and—as a fuel—is a more familiar concept that might not require as many changes to equipment and processes (relative to electrification).

INFRASTRUCTURE NEEDS: Hydrogen is not a "drop-in" fuel replacement for natural gas; equipment designed to burn fossil fuels may need modifications before it can use significant shares of (or 100 percent) hydrogen. This is due to hydrogen's unique properties, including a fast flame speed (increasing the risk of "flashback" that can damage equipment), high flame temperature that increases harmful nitrogen oxide (NOx) emissions, low volumetric energy density (meaning you must burn more hydrogen than methane to get the same heat output), and small molecule size (worsening risks of leakage, explosions, and embrittlement of pipes and other equipment). With the right upgrades and technological advancements, it may be possible to account for these differences, but it may also require a large investment by facility owners, whether for retrofits or replacements of equipment with very long service lives.

Industrial heat—particularly at high temperatures—requires a lot of energy, whether through hydrogen or electricity. As discussed below, electric technologies own a significant efficiency advantage. Hydrogen may hold an edge for a given facility if it's easier to build pipelines to deliver fuel than an energy-equivalent amount of electric transmission, or if it's much easier to reconfigure the facility to use hydrogen. However, this may require new, dedicated hydrogen pipelines, as natural gas pipelines are not suited to handle high shares of hydrogen.

SOCIAL IMPACTS: Burning hydrogen for industrial process heat primarily carries public health risks related to its potential for worsened NOx emissions. Industrial facility owners can install equipment and modify operations to mitigate these emissions—such as by premixing fuels, adjusting airflow, and using post-combustion controls—though they would not be expected to do so absent regulation. Such measures can reduce NOx emissions below that of natural gas combustion, but because these facilities are often in communities that have long borne the brunt of harmful air pollution, the residual NOx may still be unacceptable.

COMPETING TECHS: The main competitor to hydrogen for cleaning up industrial process heat is electric technologies, which can collectively meet any temperature requirements at higher efficiencies and with no air pollution. These technologies vary in market readiness, meaning some industrial sectors can switch to electric heat today (e.g., food, paper), while others need research and development before they'll be available (e.g., cement). One study finds commercialized technologies could electrify 78 percent of non-feedstock industrial energy demand in Europe, rising to 99 percent when including technologies under development.

Electric technologies providing industrial heat include electric boilers, heat pumps, resistance heating, induction heating, plasma torches, electric arc furnaces, and shock-wave heating. **Heat pumps** are notable for moving rather than generating heat, allowing them to use 1.5 to five times less energy to provide the same amount of heat as perfectly efficient combustion. However, they are limited to lower temperatures (up to 200°C) and lose efficiency when generating higher temperature increases. **Thermal batteries** convert electricity into heat (using resistance) and can store this heat for days at temperatures up to 1,700°C in a thermal storage medium (e.g., graphite blocks) surrounded by insulated casing. This means electricity can be procured when it's clean and low-cost, with heat then available on demand, all while maintaining a high round-trip efficiency of around 95 percent. Other technologies are also under development that replace the need for high-temperature heat altogether, helping to clean up trickier sectors like cement production.

Due to losses from electrolysis and combustion, hydrogen for industrial heat is generally far less efficient than electric alternatives, requiring on the order of 1.5 times as much clean electricity to play the same role. However, electric technologies can require larger, more complex retrofits or replacements of existing equipment than hydrogen. They may also require grid upgrades to permit higher power draws. While hydrogen may use more electricity overall, it may be situationally easier to deliver (via new pipelines) than electricity.

TAKEAWAY: There may be opportunities for hydrogen in a few niche high-temperature heat cases, such as in retrofitting newer combustion equipment, using hydrogen to serve multiple roles (e.g., as a feedstock), or when building hydrogen pipelines would be much less expensive than new transmission lines. However, directly electrifying industrial process heat should be prioritized wherever possible due to its higher efficiency and lack of harmful air pollution.

FURTHER READING:

- Fraunhofer ISI, "Direct electrification of industrial process heat: An assessment of technologies, potentials, and future prospects for the EU," on behalf of Agora Industry, June 2024, https://www.agora-industry.org/publications/direct-electrification-of-industrial-process-heat
- Nora Esram, Anna Johnson, and Neal Elliott, "How to Decarbonize Industrial Process Heat While Building American Manufacturing Competitiveness," American Council for an Energy-Efficient Economy, April 2024, https://www.aceee.org/policy-brief/2024/04/how-decarbonize-industrial-process-heat-while-building-american-manufacturing
- Jeffrey Rissman, "Climate's industrial-sized problem calls for electrification," Latitude Media, March 4, 2024, https://www.latitudemedia.com/news/solving-climates-industrial-sized-problem-requires-electrification
- **Featured story:** Maria Gallucci, "Southern California adopts landmark rule to electrify industrial heat," Canary Media, June 7, 2024, https://www.canarymedia.com/articles/clean-industry/southern-california-adopts-landmark-rule-to-electrify-industrial-heat
- **Full report:** https://energyinnovation.org/publication/hydrogen-policys-narrow-path-delusions-and-solutions