UH Energy
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TIEEP

TEXAS INDUSTRIAL ENERGY EFFICIENCY PROGRAM

Highlights from the Texas Industrial Energy Efficiency Program

Newsletter Volume 7, Number 3, November 2025

Greetings from the Texas Industrial Energy Efficiency Program!

Upcoming Events

Coogs for Energy Hackathon

November 21-22, 2025
Student Center South | University of Houston

Power Hour Social: Energy Coalition Year-End Social

Thursday, December 4, 2025, 7:00 pm - 9:00 pm

Energy in Action Seminar Series

Tuesday, December 9, 2025, 4:00 pm - 6:00 pm
Student Center South, Bayou City Room | University of Houston

Industrial Energy Efficiency Podcast

Stay tuned for our upcoming new podcast launching this month!

Last Month’s Events

Energy Transition Institute (ETI) Webinars are back, and better than ever! Here are three past webinars with strong industrial energy efficiency content:

“ETI Energy Transition Commercialization Opportunities at UH," Webinar
November 13, 2025

This session was hosted by Dr. Haleh Ardebili and featured a panel of pioneering University of Houston inventors—Dr. Venkat Selvamanickam, Dr. Yan Yao, and Dr. Mim Rahimi—who explored how their groundbreaking research in superconducting materials, battery technology, and electrochemical processes are being transformed into real-world solutions to advance the energy transition.

The panelists talked about three different technologies that they are working on. The first is an electrochemical carbon capture system that replaces energy-intensive thermal processes with modular electrochemical cells. This would been abling integrated capture concentration at lower footprint and projected costs below $50 per ton of CO_2. This is driven by membrane-free cell design, improved current density, and reduced energy load. The second innovation is a high performance superconducting tape manufactured via an advanced Metal Organic Chemical Vapor Deposition (MOCVD)process. By being 300–600 times the capacity of copper with minimal resistive losses, it’s manufactured for higher throughput, lower cost per kiloamp-meter, and transformative efficiency impacts on power cables, motors, generators, and compact fusion magnets. Lastly, Dr. Yao described next-generation sodium-ion batteries using high-compaction density NAP cathodes and anode-free, nonflammable electrolytes that achieve high coulombic efficiency, fast-charge capability, and wide-temperature operation. This would enable lower-cost, domestically sourced, high-efficiency storage ideal for grid applications.

“Materials Powering the Energy Revolution” Webinar

October 14, 2025

This session featured Dr. Hadi Ghasemi and emphasized three innovations designed to remove major efficiency barriers in carbon capture, hydrogen storage, and solar-thermal systems. Dr. Ghasemi talked about a graphene–aerogel/ionic-liquid sorbent that captures CO_2 with high selectivity and converts it directly into calcium carbonate. This enables low-energy, cost-effective retrofits for heavy-emitting industries. He also introduced engineered porous materials (Z3 and SLSM) that store hydrogen as hydrates at near-ambient temperatures and low pressures. These, on the other hand, offer a far more energy-efficient alternative to cryogenic liquefaction. Lastly, he described a full-spectrum solar-thermal storage design that combines photo-switching materials with phase change media to deliver high round-trip efficiency heat storage and 24/7 output power.

“Electrified Steam Methane Reforming for More Sustainable Hydrogen Production” Webinar

September 16, 2025

This session featured Dr. Michael P Harold who outlined a novel electrically heated (instead of fired) approach to steam methane reforming (SMR) aimed at improving the energy efficiency and carbon footprint of hydrogen production. Instead of supplying the reaction’s substantial endothermic heat through high-temperature combustion, which would generate large CO_2 emissions, Dr. Harold’s team coats electrically resistive FeCrAl wires with Ni–ZrO_2 catalyst layers to perform SMR using Joule (ohmic) heating powered by electricity. His experiments revealed an unexpected efficiency behavior, including an ignition-like jump in conversion and hysteresis that appear only with zirconia-supported catalysts. This suggests an electrocatalytic mechanism in which zirconia’s semi conductivity enables in-situ electron-driven reduction of Ni species to their more active metallic state. This would allow the electrically heated catalyst to outperform conventional furnace heating over a key temperature window, which would then increase methane conversion per unit energy input. Early reactor-scale simulations further indicate that dense arrays of heated catalyst wires could achieve high hydrogen productivity at lower CO_2 intensity, pointing to a promising pathway for electrified, energy-efficient SMR in the energy transition.

Texas Energy Summit

2025 November 4-6, 2025
Texas State Capital Building, Austin, TX

The focus of the Texas Energy Summit was policies and priorities. So, it was unsurprising that there were no presentations or discussions specifically on industrial energy efficiency.

However, the overall theme of the three-day event, which featured fourteen workshops, five presentations, and five panel sessions, was clearly Reliable, Affordable, and Clean energy in Texas. Almost all the talks and presentations, including the one by the CEO of the ERCOT Board, incorporated discussions on all these three aspects of energy supply.

One of the more interesting discussions revolved around the misaligned incentives of landlords and renters of apartments and commercial buildings, which hinders energy efficiency upgrades. More on this in the TIEEP Podcast and UH Energy blog coming soon. At the Summit, a helpful distinction emerged between reliability and resiliency. The Department of Defense and Texas regulations define resiliency as the ability of a facility to operate in a self-sustaining manner for 14 days without support from the electrical grid, water supply, gas pipeline, or other external energy sources. Reaching this level of independence is definitely not easy, and in many cases, improving energy efficiency proves to be a cheaper and thus more attractive option than installing additional on-site generation or storage. Fortunately, there are many low interest financing options available for both the public and private sectors to support energy efficiency projects. This will be the subject of a future article or webcast.

On the final day of the summit, the major topic of discussion was the anticipated surge in energy demand from data centers. Earlier conversations about the impacts of electric vehicles on the grid also re-emerged in the context of demand response. Just as some utilities already offer incentives for residential customers to shift usage away from peak times, including encouraging EV charging during off-peak hours, data centers are similarly encouraged to reduce consumption during high-demand periods. Senate Bill 6 even allows ERCOT to require mandatory reductions from large loads, such as data centers. While not strictly energy efficiency, this type of demand reduction can help to manage grid stress.

(A complete agenda is available at https://www.texasenergysummit.com/agenda.)

Technical Article

The Variety of Hydrogen Production and Its Energy Efficiency

By Hisham Habli

Introduction

While Hydrogen is the simplest and most abundant element, it is also the most difficult to produce, store, and utilize since it is not found readily in the atmosphere. Depending on how difficult it is to produce hydrogen, it is assigned a color, as given in Figure 1. Of course, the produced hydrogen does not actually exist in these various colors. However, the color assigned to generated hydrogen influences how it is stored and utilized, but in different aspects depending on the purpose for which hydrogen is produced. The traditional route of hydrogen production, which began in the mid-1800s, mostly uses bituminous (black) coal or lignite (brown) coal and produces what is called brown or black hydrogen. Later in the mid1900s, gray hydrogen produced from natural gas became the dominant hydrogen source. Then, expanding gray hydrogen, blue hydrogen production came about, which recaptured the CO2 produced. Ever since the 2000s, various other colors have been assigned to hydrogen, such as green (produced by water splitting achieved with renewable energy), yellow (produced via electrolysis performed using power from the grid, originating from solar sources), red/pink (produced through electrolysis achieved through nuclear energy), turquoise (generated using methane pyrolysis), white/gold (produced from geological sources), and purple (generated through electrolysis and thermolysis from nuclear sources)[1]. The last two decades have been referred to as the “Renewable

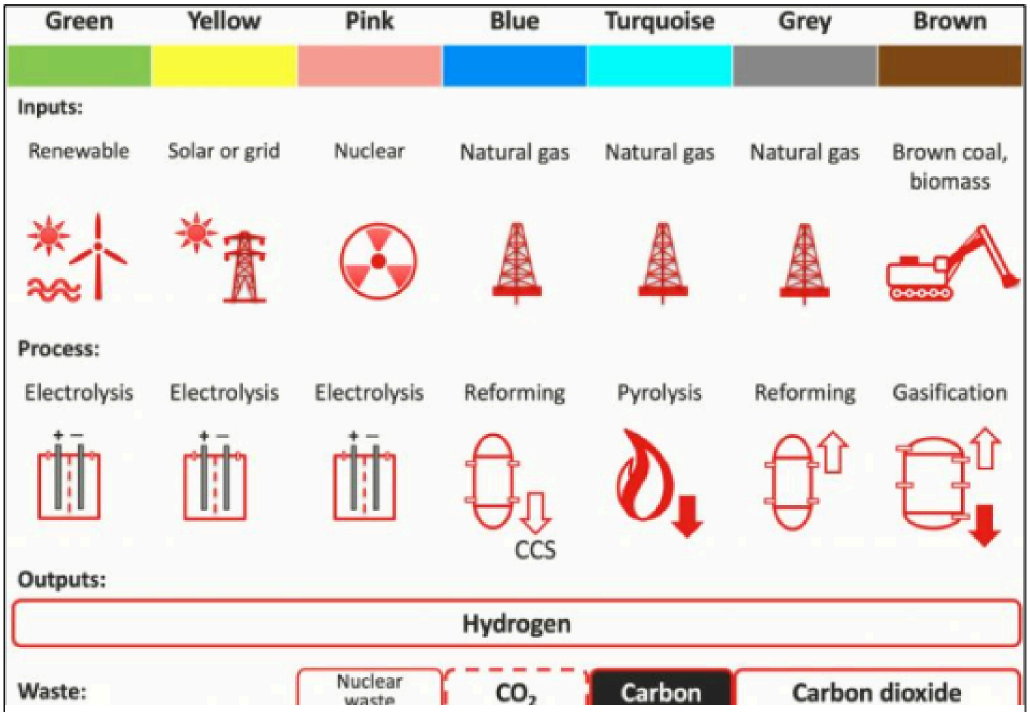

Figure 1 - Summary of Hydrogen Colors (ref. 5)

Energy Era," a time when renewable resources technology has grown tremendously [2]. As hydrogen production expands rapidly in the 21st century, it is crucial to determine the most efficient and sustainable method for hydrogen production.

Methods

To assess the efficiency of each hydrogen production method, the technoeconomics of each must be compared. This evaluation of the Life Cycle Assessment (LCA) includes the Levelized Cost of Hydrogen (LCOH), Green House Gas (GHG), and other more specific assessment methods that pertain to a particular production method such as thermal efficiency, carbon capture efficiency, and electrolyzer efficiency. Hydrogen is produced by any of the following: coal, natural gas, water, or biofuels, which largely differentiates energy efficiency. While some colors of hydrogen share the same feedstock, others vary.

Life Cycle Analysis

Brown Hydrogen:

Coal Gasification is the primary method of obtaining hydrogen from coal. It involves heating coal to over 900°C with steam and limited oxygen, to avoid combustion . Lignite is the preferred type of coal since it contains more hydrogen than bituminous coal, but bituminous coal is more energy efficient. This is due to the rank of coal where lignite (lowest rank) has a higher hydrogen content and lower carbon content and vice versa for bituminous. While both types of coal have the lowest estimated LCOH of \$1–2 in China, it has the highest GHG emissions of about 15–20kg of CO_2 per 1kg of hydrogen produced [3]. A major point that bears noting here is that the estimated LCOH excludes the cost associated with emission control. This process LCOH is largely determined by emissions control cost, which the U.S. has to increase the LCOH; hence, it has low rates of production in the U.S. Since China has more numerous coal mines and natural gas is expensive, it thrives on brown hydrogen [1]. In the U.S. gray hydrogen has largely overtaken the more traditional brown hydrogen.

Gray Hydrogen:

Steam Methane Reforming (SMR) is the dominant hydrogen production method in the U.S., accounting for almost 95% of hydrogen produced in the country, due to many economic factors such as available technology and access to natural gas reserves [1]. These benefits ultimately determine the LCOH of gray hydrogen, which is around \$1.50–1.80 per kilogram of hydrogen as of early to mid2025[4]. As a result of these factors, gray hydrogen is considered the most conventional form of produced hydrogen in the U.S. Other major benefits of this production choice are the efficiency of hydrogen obtained from 1kg of natural gas, energy efficiency, and GHG. Black/Brown hydrogen is estimated to be 30–60% efficient for conversion while for gray hydrogen it is 70–85%. Moreover, the GHG for SMR is about 10–13kg of CO_2 for every 1 kg of hydrogen produced. Overall, the LCA for gray hydrogen tramples that of black/brown hydrogen, making it the major hydrogen production method. The reliability and sustainability of gray hydrogen is improved upon by blue hydrogen.

Blue Hydrogen:

Blue hydrogen is produced in the same way as gray hydrogen, but for blue hydrogen, carbon capture utilization and storage technology (CCUS) is used as well. While it involves adding an additional process for capture and utilization or storage, the CO_2 emitted can be used as feedstock for urea or methanol production or it may be sequestered. Since current CCUS technology can achieve up to a 90% capture rate, it makes blue hydrogen a more sustainable option compared to gray hydrogen [5]. The LCOH for blue hydrogen is estimated to rise to \$2.10–2.40 in the U.S., when compared to gray hydrogen, but this may not be entirely accurate[4]. Furthermore, the GHG ranges from 3.97–6.87kg of carbon dioxide per kg of hydrogen at a CCUS efficiency of 55–88%.[6] However, this range could be wider, as it depends on the CCUS used. Now, leading into the “Renewable Energy Era”, the nature of feedstocks shifts from fossil fuels to more renewable options, starting with green hydrogen production.

Green Hydrogen:

Pioneering renewable hydrogen production, green hydrogen refers to hydrogen produced through several types of “green” processes that result in zero CO2 emissions. Most often green hydrogen production refers to the direct electrolysis of water by energy derived for solar, wind, hydro or geothermal sources, but it can also refer to the use of biomass as a feedstock for gasification. Due to the wide range of costs of electricity from renewable sources, the cost of green hydrogen is uncertain and varies more than black, brown, gray, and blue hydrogen. While there are hundreds of projects to implement green hydrogen production strategies, many companies have opted to invest in blue hydrogen to make the transition to green hydrogen smoother [2]. According to one source, the LCOH ranges from $3.20–8.50 per kg of hydrogen produced,[3] which makes investors uncertain. However, due to the tremendous environmental benefits and potential energy efficiency of the process, some companies see it as an “untapped” market for major growth. Although green hydrogen is still in its beginning stages of growth, it still has a positive outlook.

Yellow Hydrogen:

Taking a leaf out of from green hydrogen production, yellow hydrogen is produced by the electrolysis of water using mainly solar power for energy. It may seem redundant to differentiate yellow hydrogen from green hydrogen, but yellow hydrogen is not always netting zero carbon emissions. This is because while solar power is intended to be the major source of energy, fossil fuels may be used as well to power the grid. Since electrolysis is so energy intensive, the LCOH for yellow hydrogen ranges from $2.56–8.62 per kg of hydrogen produced in Western countries, which largely depends on the energy price per kWh and the type of electrolyzer used[7]. There are two main electrolyzers discussed for yellow hydrogen production: the Alkaline Exchange (AE) and Proton Exchange Membrane (PEM). The PEM is noted to have better efficiency but high capital cost as well as operating cost while the AE is noted to have lower capital and operating costs but not as high efficiency as the PEM [8]. Other details that largely affect the electrolyzers' efficiency and the LCOH are out of the scope of this article. This also pertains to the methodology that detail the LCOH and efficiency for other hydrogen colors such as green, pink, and purple hydrogen, which utilize electrolysis. Compared to green hydrogen, yellow hydrogen is on average more expensive due to the location of the plant, which creates variance in the power mix[9]. Even though the LCOH for yellow hydrogen is higher than other colors of hydrogen, improved energy prices and electrolyzer technology are predicted to allow yellow hydrogen to flourish within the next 10– 20 years.

Red, Pink, and Purple Hydrogen:

The production processes for all three of these hydrogen colors derive from nuclear energy but is provided with energy to split water into hydrogen and oxygen in different ways. Red hydrogen Is produced by using thermal energy from a nuclear reactor to split water in a process called thermolysis; pink hydrogen production uses nuclear generated electricity for electrolysis, and purple hydrogen is generated using a combination of both. According to one source, the LCOH for these three colors of hydrogen is around $2.70–5.50 per kg of hydrogen produced[3]. This LCOH is lower since there are no nuclear plants that exist to mostly produce hydrogen; rather, it is an additional product from some existing nuclear plants. That makes it a relatively affordable, renewable, net zero carbon process compared to that of green hydrogen.

However, some factors limit the growth of these hydrogen production methods. For instance, the efficiency of thermolysis in red hydrogen can range from 15–50% due to heat loss, which makes it inefficient [10]. With pink hydrogen, its efficiency can reach upwards of 90%, and purple hydrogen has a 70–85% efficiency [11]. Even though pink and purple hydrogen have higher efficiency, the nuclear reactors required for it produce hazardous waste and are a huge safety risks in the public's eye. This, however, does not discredit the efficient use of nuclear heat and energy that already exists for such an energy-intensive process.

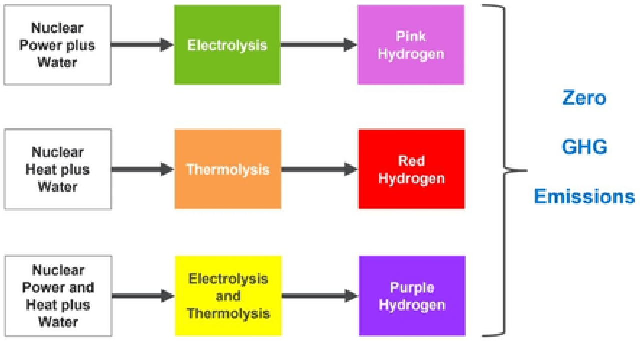

Figure 2 -from ref 12

Turquoise Hydrogen:

This unique color was chosen due to the similarities in the production processes between green and blue hydrogen. The production process itself is methane pyrolysis, which uses natural gas and produces a viable carbon by-product as in the blue hydrogen production process, but it has zero GHG emissions like every green hydrogen production process. Simply put, methane pyrolysis is the decomposition of methane into hydrogen and elemental carbon at high temperatures in the absence of oxygen. Its energy requirement is astonishingly low compared to green hydrogen production processes: requiring roughly 70% less energy [13]. Since this process is not new, major developments in pyrolysis technology have achieved nearly 100% theoretical energy efficiency and have achieved over 90% conversion of methane [13]. Furthermore, even newer advancements in Korea have combined methane pyrolysis, CO_2 reforming, and oxyfuel combustion to reduce the LCOH from $2.20– 3.50 to less than a dollar per kg of hydrogen produced [14]. As long as the price of natural gas does not become too high, the LCOH for turquoise hydrogen could prove to be even cheaper than gray hydrogen.

White/Gold Hydrogen:

This is the most novel type of hydrogen, and it has not been fully developed [15]. It refers to the naturally occurring hydrogen that is found within the earth's crust. These hydrogen deposits form from water reacting with iron-magnesium minerals in a process called serpentinization. While there is no clear LCOH for it yet, the expected GHG is less than 1kg of CO2 [1]. The main challenge is effectively extracting hydrogen from rocks. Most of the difficulty is due to hydrogen being so small, explosive, and being able to easily escape cracks and crevices. There are a few start-ups that may soon hit the ground attempting the extraction, but more research is needed to make white/gold hydrogen more commonplace.

Conclusion:

With so many recent advancements in hydrogen production and so little literature that discusses them on the same basis, the LCOH and GHG assessments on the colors of hydrogen is not entirely accurate. However, it is a good starting point to make decisions in order to direct the future of hydrogen. This topic will be discussed further in next month's article. With many novel hydrogen production methods to choose from and the current economic and political state of the world, the future of hydrogen 20 years from now is uncertain. However, from projections, we do see that the use of fossil fuels to produce hydrogen will continue. There are many directions for the "Renewable Energy Era" to head in, so any pathway using renewables points to a more sustainable future

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