



UH Energy
UNIVERSITY OF HOUSTON

TIEEP

TEXAS INDUSTRIAL ENERGY
EFFICIENCY PROGRAM

**Highlights from the Texas Industrial Energy Efficiency Program
Newsletter Volume 7, Number 5, January 2026**

Greetings from the Texas Industrial Energy Efficiency Program!

Upcoming Events

Industrial Energy Efficiency Podcast

New episodes and archive here: [Texas Industrial Energy Efficiency Program \(TIEEP\) Podcast Archive | University of Houston](#)



Energy in Action Seminar Series - AI and the Net-Zero Journey with Shell

Friday, February 13, 2026 | 4:00 - 6:00 PM

UH Sugar Land Campus Brazos Hall Room 103 A&B

Energy in Action Seminar Series - Artificial Intelligence in Energy Processes

Friday, February 27, 2026 | 4:00 - 6:00 PM

UH Sugar Land Campus Brazos Hall Room 103 A&B



Energy Transition Webinar Series - Speakers to be announced.

Tuesday, January 27, 2026 | 12:00 - 1:00 PM

Tuesday, February 10, 2026 | 12:00 - 1:00 PM



SPEER

Be sure to check out the South-central Partnership for Energy Efficiency as a Resource (SPEER) website for events across Texas and Oklahoma [Home - SPEER Energy Efficiency](#).

Hydrogen Production Energy Efficiency from Fossil Fuels

By Carla Romero & Hisham Habli

Introduction

In our November 2025 newsletter (Volume 7, Number 3) we discussed the many different colors of hydrogen production in the article "The Variety of Hydrogen Production and Its Energy Efficiency". In this article we will look at three chemical processes at the heart of these various colors of hydrogen production. The three main industrialized processes for hydrogen production from fossil fuels are Steam Methane Reforming, Coal Gasification, and Methane Pyrolysis. We can compare these processes using two metrics: energy conversion efficiency and capital cost. For energy conversion efficiency, these processes can be assessed based on first law efficiency via the ratio of the total energy output (heating values of products) to the total energy input (LHV of feed and energy requirement) .

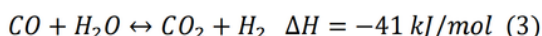
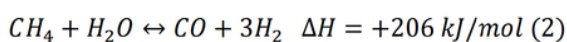
$$\eta_x = \frac{\text{Useful energy output}}{\text{Total energy input}} \quad (1a)$$

$$\eta_x = \frac{\text{LHV of hydrogen produced}}{\Sigma \text{ Energy inputs}} \quad (1b)$$

For capital cost, we compare the cost for each kg of hydrogen produced each day. To put the capital cost on the same basis, carbon capture is included where applicable.

Steam Methane Reforming (SMR)

Methane is the dominant feedstock used to produce hydrogen, which is commonly known as gray hydrogen (or blue when produced through carbon capture). Two main reactions occur to produce hydrogen: steam methane reforming (reaction (2)) and water gas shift (reaction (3)) [1].



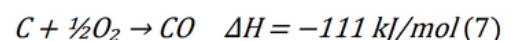
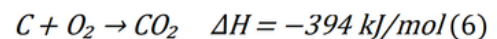
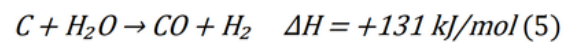
Energy Conversion Efficiency:

As seen in the chemical reactions, overall, one mole of methane produces four moles of hydrogen. The useful output is the four moles of hydrogen; the useful input is the one mole of methane plus the 0.26 moles of methane to supply the 206 kJ of heat required to convert methane to hydrogen and carbon monoxide. With the methane being used as feedstock and energy source, 10 kg of CO₂ is produced per kg of hydrogen produced.

Combining this, we calculate the energy conversion efficiency:

$$\eta_{SMR} = \frac{4 * \text{LHV}_{\text{Hydrogen}}}{\text{LHV}_{\text{Methane}}} = \frac{4 * 242 \text{ kJ/mol}}{1.26 * 802 \text{ kJ/mol}} = 96\% \quad (4)$$

This presents high energy conversion efficiency, assuming minimal heat loss. It is estimated that gray hydrogen (SMR) costs \$900/kW (\$650 per kg per day) of hydrogen energy capacity produced while blue hydrogen (SMR + Carbon Capture) costs \$1,100/kW (\$790 per kg per day) of hydrogen energy capacity produced [2]. This suggests a \$140 per kg per day capital cost associated with carbon capture. Coal Gasification Coal gasification is a well-established method of producing hydrogen and is commonly practiced in China and South Africa. Coal gasification involves several simultaneous reactions. The primary gasification reactions are:



In practice, gasifier operators balance oxygen supply to maximize carbon conversion to syngas while generating sufficient heat. More complete combustion provides more heat but wastes carbon as CO₂; less complete combustion (partial oxidation) improves carbon utilization but requires external heat input [3]. To further produce more hydrogen, the carbon monoxide is reacted with water in a water gas shift reaction.

Energy Conversion Efficiency:

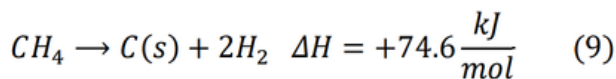
Based on a national energy laboratory report, typically 1.24 moles of hydrogen are produced per mole of carbon consumed [3]. Using heating values, energy conversion efficiency can be calculated:

$$\eta_{coal} = \frac{1.24 * LHV_{H_2}}{LHV_{Coal}} = \frac{1.24 * 242 \text{ kJ/mol}}{394 \text{ kJ/mol}} = 76\% \quad (8)$$

Finding a comparable capital cost versus SMR is difficult since different countries practice this process. However, the capex is estimated at \$1,800/kW of useful energy output from hydrogen (\$1300 per kg per day) [4], including the cost of carbon capture. In coal gasification, about 17kg of CO₂ is produced. With no emissions control, the cost is estimated to be 20–40% less, or approximately \$910 per kg per day capacity.

Methane Pyrolysis

Methane can be thermally decomposed in the absence of oxygen to produce hydrogen and solid carbon [5]



While the enthalpy requirement is low, this process has a high activation energy of 420–450 kJ/mol without the use of a catalyst [6]. This results in the temperature requirements ranging from 800–1600°C. However, with the use of catalysts, this activation energy could possibly be cut by more than 50% and temperature requirement could be as low as 800°C [7].

Energy Conversion Efficiency:

In terms of heating value efficiency output, some simplification is made for the solid carbon, also known as pyrolytic carbon. Since the method of heat supply alters the structure of pyrolytic carbon (graphitic, amorphous, nanotubes, etc.), this means the heating value of the carbon byproducts is not uniform [8]. Hence, we use the value 394 kJ/mol lower heating value of carbon as part of the useful energy output.

$$\eta_{Pyrolysis} = \frac{LHV_{H_2} + LHV_C}{\Delta H + LHV_{CH_4}} = \frac{2 * 242 + 394 \text{ kJ/mol}}{74.6 \text{ kJ/mol} + 802 \text{ kJ/mol}} = 100\% \quad (11)$$

In our referenced example, the carbon produced is combusted for its heating value. The capital cost for this process is estimated at €2,404/kW (\$2,000 per kg per day) [9]. This includes the capital cost associated with carbon capture since there is carbon dioxide produced from burning the carbon deposits.

Conclusion

Based on the heating values of energy inputs and outputs, methane pyrolysis is the most energy efficient fuel conversion process at 100%. This is closely followed by steam methane reforming at 96%, but at 76%, coal gasification lags far behind. For capital cost, SMR has the lowest cost at \$790 per kg per day with carbon capture. This is followed by coal gasification at \$1,300 per kg per day with carbon capture and the highest cost is from methane pyrolysis at \$2,000 per kg per day. These two metrics highlight the trade-offs associated with each process. However, it does not entirely narrow the choice for deciding which process is better overall. For that, many other factors such as feedstock cost and supply, location, value of coproducts, and other various economic variables would need to be considered.

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