Natural graphite is a critical material with limited supply

Making turquoise hydrogen economics stack up with solid carbon

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Focusing on methane pyrolysis to produce only turquoise hydrogen misses a major value stream from this technology.

The way to make a methane pyrolysis business case stack up without subsidies is to co-produce a grade of solid carbon that can be monetised for circa €2,000 ($2,345) per tonne, or more.

A big ask? No. Higher value grades of carbon black are exactly this price. Battery-grade graphite, graphene and multi-walled carbon nano-tubes are many times more valuable.

Misunderstanding the value streams from methane pyrolysis is a mistake that Modern Hydrogen made and contributed to its collapse in Q4 2025. The carbon it produced was promoted as a low-value bitumen additive for road repairs – not much better than sending it to landfill.

Techno-economic optimisation

Getting the process parameters right to achieve good methane conversion, hydrogen that is easy to separate from the reactant gases, and marketable carbon is a non-trivial task.

In addition to getting the carbon to form as graphite, graphene

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or carbon black, it must also be adequately pure. If the carbon is contaminated with polyaromatic hydrocarbons, it is unlikely to achieve a commercial specification.

Additionally, if the methane conversion is low or the hydrogen is laden with difficult-to-separate gases, the costs of gas separation and feedstock recycle can explode the system capital and operating costs.

Furthermore, to reduce the carbon dioxide intensity of the hydrogen and the carbon, it is favourable to use renewable electricity to provide the high-temperature energy for the pyrolysis reaction and biomethane instead of natural gas as the feedstock. These inputs are more expensive than fossil-generated power and gas.

A thin line between success and failure

Pyrolysis of methane yields turquoise hydrogen and solid carbon. Within this broad statement, many nuances bridge the gulf between economic failure and success.

What form of energy will drive the pyrolysis: microwave, non-thermal plasma, or thermal heat? Some of these require electrical power for the pyrolysis.

In what form of reactor will the pyrolysis take place: catalysed fluidised bed, moving bed, or free space? What type of carbon will be produced: high-value carbon nanotubes, speciality grades of carbon black, graphite, graphene, or worthless soot? Can the process cope with the non-methane components in the raw natural gas?

Graphene from gas

UK start-up Levidian has developed a microwave plasma process to convert methane to graphene. The use of microwaves can generate what is referred to as a 'cold' plasma. Whilst the temperature in the core of the plasma may be more than 700°C, the overall system temperature remains low. This means that speciality grades of carbon, such as graphene, can be produced without being damaged by the high temperatures associated with 'thermal' plasma.

Graphene is composed of a single layer of carbon atoms arranged in a >>

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>> honeycomb pattern. It is incredibly light and is 300 times stronger than steel. It is also an exceptionally good conductor of both heat and electrical current. These properties make graphene a valuable raw material with applications in advanced batteries, tyres and high-performance materials.

In January 2025, Levidian announced the successful installation of its patented Loop technology at Adnoc Gas' Habshan Gas Processing Plant in Abu Dhabi. The Habshan complex processes over six billion standard cubic feet of gas per day.

Completed in collaboration with Baker Hughes, an international energy technology company, the installation was a world-first deployment of Levidian's Loop technology at an operational natural gas processing site. The unit will be capable of producing over a tonne each of graphene and turquoise hydrogen each year.

Carbon black

Plenesys, a French start-up based in Nice, has several unique aspects to its plasma-based methane pyrolysis technology.

Chief Operating Officer Ahmed Kacem said, "We stand out in the field of methane pyrolysis because we manufacture our own plasma torch." This gives Plenesys the ability to rapidly iterate their torch and overall system to optimise efficiency, operational reliability and the nature of the solid carbon product.

"Over time, we have been able to fine-tune our process to generate carbon black," Kacem said. "At around €2,000 per tonne, this product can add significant value to gas that would otherwise be flared. Furthermore, carbon black is easy to transport from remote flare locations to market. And producing solid carbon minimises CO_2 emissions from flaring."

One of the operational issues associated with plasma pyrolysis of hydrocarbons is that the plasma electrodes are eroded by the high-intensity heat and flow of electrons. To ensure their process operates continuously, Plenesys has created and patented an automated electrode replenishment and feeding system.

"Unlike many other plasma torches, we operate with alternating current (AC), not direct current (DC)," Kacem explained. "This enables us to have much better control of the plasma and avoids the cost and complexity of using a rectifier for electrical power conversion from AC to DC. Furthermore, we have proven our system at elevated pressures, which is a significant advantage for plasma methane pyrolysis because hydrogen compression costs are minimised".

Prognosis for the second half of this decade

Green hydrogen economics are tough, and there is always something else that can be done with those renewable electrons.

> "It is now time for turquoise hydrogen with carbon co-production to enjoy the spotlight"

The capital intensity of blue hydrogen makes investment tough until geopolitical and regulatory landscapes settle.

With these concerns, it is now time for turquoise hydrogen with carbon co-production to enjoy the spotlight.

There have been more than 100 start-ups and research groups working on methane pyrolysis this decade. However, this field is likely to thin out to fewer than five technology providers through the end of this decade.

As with electrolysers for green hydrogen, consolidation is beginning to bite. The winners continue to run, and the losers fall by the wayside.

Picking a winner in this race requires market insight, technology awareness, and a detailed appreciation of the business model that lies behind methane pyrolysis. Expert due diligence is the name of the game when investing in first-of-a-kind projects and technology providers.