

Made in Europe: hydrogen and critical raw materials from methane pyrolysis

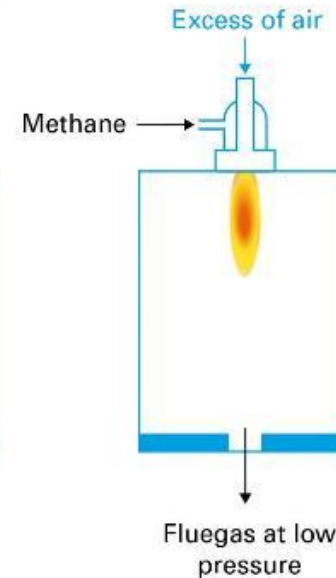
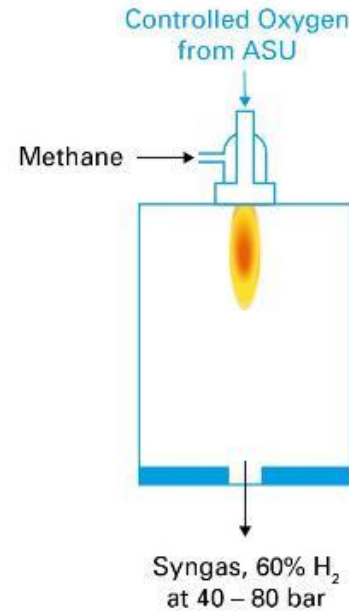
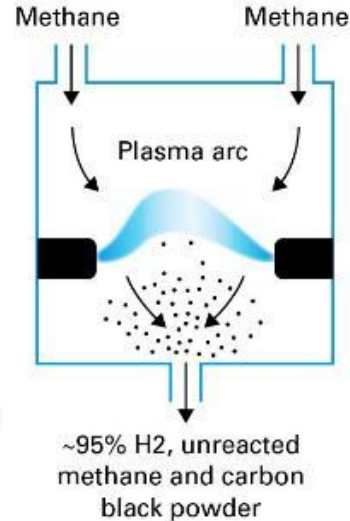
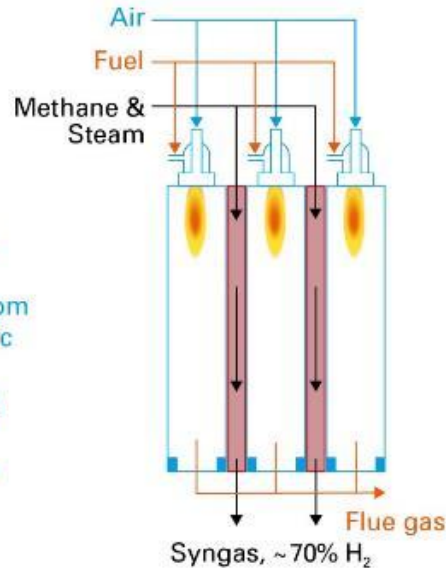
I support investors with due diligence, operators with decarbonisation initiatives and startups with strategy.

Stephen B. Harrison, sbh4 consulting



Notes:

- Energy for pyrolysis may be from combustion of fuel, or from an electric plasma arc
- Pyrolysis diagram shown is for thermal plasma pyrolysis
- POX diagram shows non-catalytic POX



Process	Steam Methane Reforming	Methane Pyrolysis (Methane splitting or cracking)	Methane Partial Oxidation – POX (Gasification)	Methane Combustion (Thermal oxidation)
Oxygen feedstock	Oxygen is supplied as part of the water molecule with the steam	None, oxygen-free process	Oxygen from ASU	Air fed in excess
Catalyst required	Yes, generally Nickel	No	Not for thermal POX	No
Energy required/released	Endothermic, requires heat input	Endothermic, requires heat input	Exothermic, steam generation	Exothermic, steam generation
Chemical reaction	$\text{CH}_4 + \text{H}_2\text{O} \rightarrow \text{CO} + 3\text{H}_2$	$\text{CH}_4 \rightarrow \text{C} + 2\text{H}_2$	$2\text{CH}_4 + \text{O}_2 \rightarrow 2\text{CO} + 4\text{H}_2$ (ideal case)	$\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$ (ideal case)
Carbon product	CO and CO_2	Carbon black powder	CO and CO_2 from side reactions	CO_2
Hydrogen content in product gas	~70%	~95%	~60%	Zero, complete oxidation to CO_2 & H_2O is ideal case
Product gas pressure	15 to 40 bar	Atmospheric pressure	40 to 80 bar	Atmospheric pressure
Product gas temperature	~850 °C	~1700 °C	~1400 °C	~1400 °C

What is methane “Pyrolysis”?

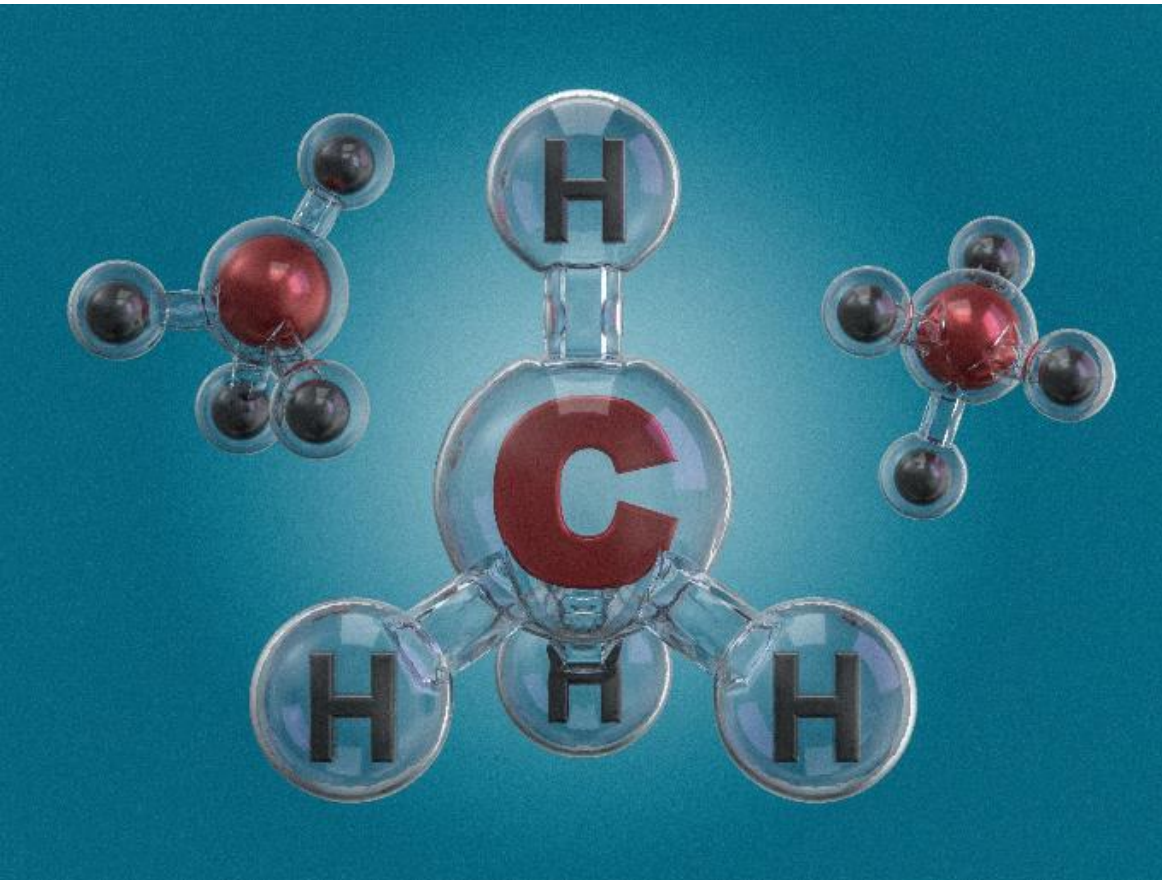
- Pyrolysis takes place in the absence of oxygen.
- Reforming takes place in the presence of steam.
- Gasification takes place with a precise amount of oxygen.
- Combustion uses an excess of oxygen.
- Plasma is one of several ways to perform methane pyrolysis



What is Plasma and “Plasmalysis”?

- Plasma is a ‘gassy cloud’ of ions and electrons
- Plasma is one of several ways to perform methane pyrolysis
- Alternative techniques...
 - Thermal
 - Catalytic
 - Microwave
- Plasmalysis is a word that has been introduced to refer to methane pyrolysis using plasma

By mass, methane pyrolysis releases mostly solid carbon



4 tonnes of methane produces 1 tonne of
turquoise hydrogen and 3 tonnes of solid
carbon



$$16 \rightarrow 4 + 12$$

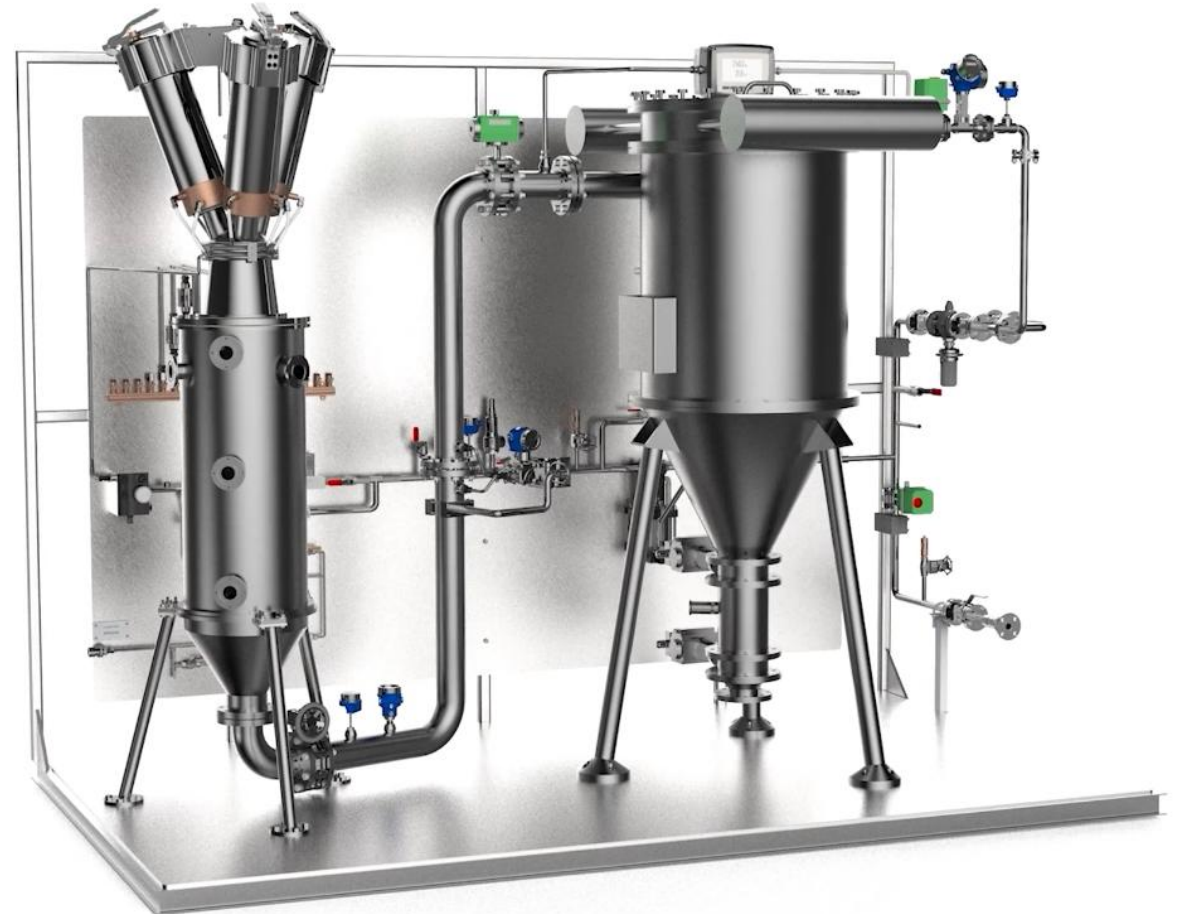


Solid carbon exists in many forms. Some have high value, others not. Some forms can be transformed to others using additional energy.

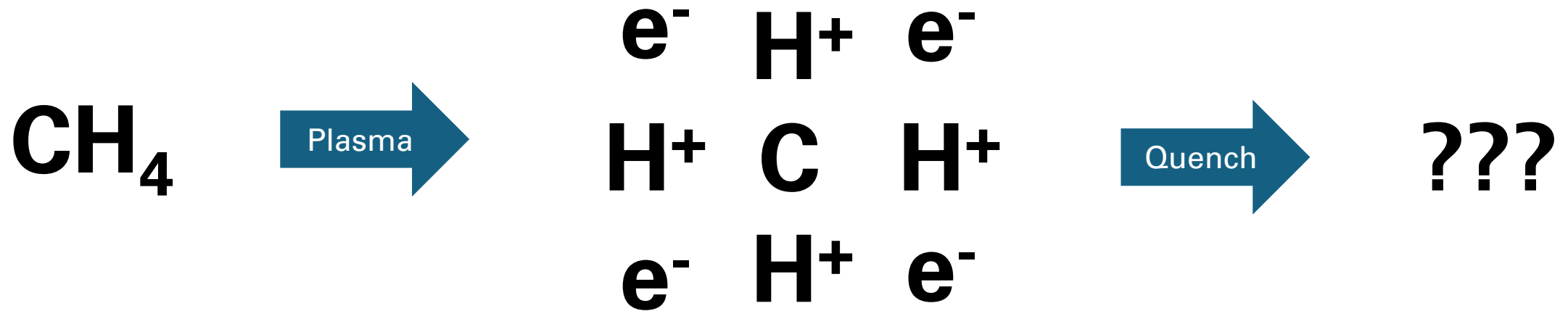
1. Diamond
2. Graphene
3. Battery grade graphite
4. Carbon nano tubes
5. Activated carbon
6. Tyre grade carbon black
7. Raw graphite
8. Pigment grade carbon black
9. Coke
10. Soot



Plenesys AC Plasma Methane Pyrolysis. Making their own plasma torches, continuous electrode feed for un-interrupted operation and operating with AC, not DC plasma. Targeting carbon black. Commercial deployment at Turquoise Group (Pure Hydrogen Corporation) at Brisbane, in Australia.



Methane pyrolysis tries to re-create order from chaos



Methane molecule

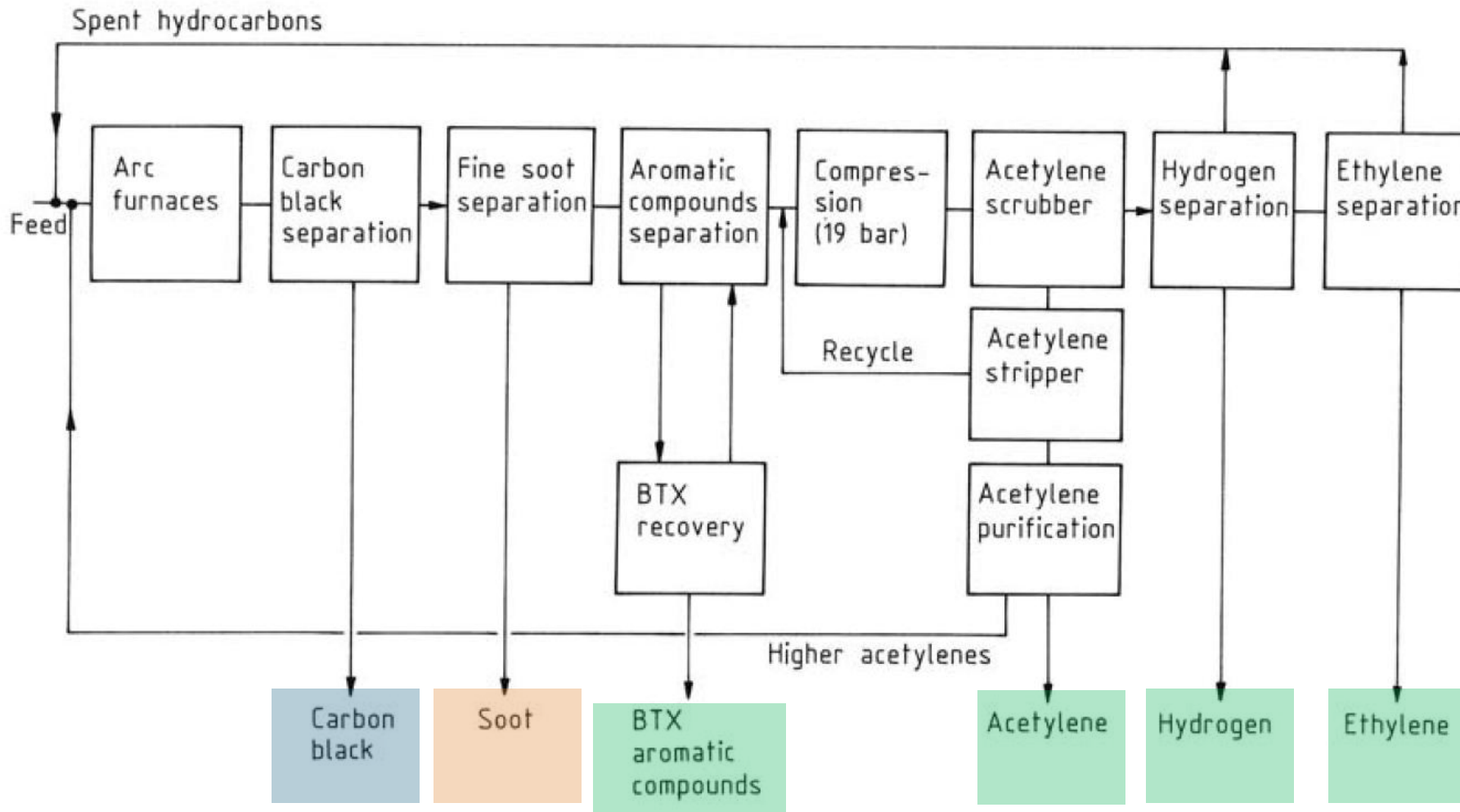
C and H ionic cloud

**C and H
ions combine
to form???**

INEOS Solvents, Marl (formerly Evonik / Ashland). High temperature thermal plasma
Hüls process for acetylene, solid carbon and hydrogen production.



Hüls plasma arc reactor with downstream processing / purification. In addition to hydrogen several liquids and gases, carbon black (up to €2,000 per tonne) and soot (sold at the value of coal) are produced. This process was designed for methane pyrolysis but now runs on a C4-C5 liquid hydrocarbon mix.





1. Methane pyrolysis converts natural gas, or biogas, to hydrogen and solid carbon (and other chemicals!)
2. The chemistry looks simple but consistently achieving high value products is complex
3. In addition to the methane feedstock, energy (eg from electricity) is required for pyrolysis
4. The type, value and market for the solid carbon will heavily influence the business case
5. Several methane pyrolysis technology categories exist, including the use of plasma
6. Various technology providers are emerging and validating their process at demonstration scale

Commercial opportunities for EVOLEN members will exist

- EPC contracting
- Technology licensing
 - Natural gas supply
 - Biomethane supply
- Solid carbon production
- Investment in technology startups / scaleups

Introduction to Stephen B. Harrison and sbh4 consulting

Stephen B. Harrison is the founder and managing director at sbh4 GmbH in Germany. His work focuses on the energy sector, decarbonisation and GHG emissions reduction. Hydrogen, ammonia and CCU/S are fundamental pillars of his consulting practice.

Stephen has extensive investment due diligence advisory experience in methane pyrolysis and the broad clean-tech sectors. Corporate venture capital funds, and other investors are regular clients.

He also supports operating companies in their mission to decarbonise their scope 1, 2 and 3 GHG emissions. Additionally, Stephen assists startups and scaleups with their strategic development and “Tech to Market” activities.

In 2023, Stephen evaluated seven CCTUS, hydrogen and e-fuels submissions to the European Commission’s Third Innovation Fund. Again in 2025, Stephen assessed seven Innovation Fund applications related to e- and bio-methanol production.

With a background in industrial gases, including 27 years at BOC Gases, The BOC Group and Linde Gas, Stephen has intimate knowledge of hydrogen, ammonia and carbon dioxide from commercial, technical and operational perspectives. For 14 years, he was a global business leader in these FTSE100 and DAX30 companies.

