# *Why Turquoise Hydrogen is a Key Element for the Energy Transition*

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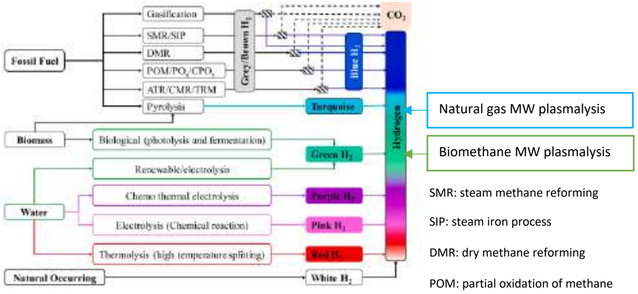
Today more than 90% of the hydrogen is produced from fossil resources, mainly natural gas by high temperature processes. 50% of the annual production of more than 100 Mt is used for the production of fertilizers, and about 45% for petrochemical processes. To achieve the goal of a sustainable energy economy, hydrogen must be used as an energy carrier. To be a long lasting and sustainable solution especially for the industry, it must be produced without greenhouse gas (GHG) emission, from unlimited natural resources with no conflict of use and at affordable cost. Among all known methods for hydrogen production – see **Figure 1**, the direct decomposition of methane into hydrogen gas and solid carbon requires significantly less energy and does not emit $CO_2$. This process, known as methane pyrolysis, is achieved at high enough temperatures; however, it has not been deployed industrially so far and it can best be fulfilled by microwave assisted plasma, potentially coupled to nuclear power, which are able to provide large amounts of hydrogen.



SMR: steam methane reforming
SIP: steam iron process
DMR: dry methane reforming
POM: partial oxidation of methane
POx: partial oxidation of methane
CPOx: catalytic partial oxidation
ATR: auto-thermal reforming
CMR: combine methane reforming
TRM: trireforming methane
WGS: water gas shift
MW: microwaves

**Figure 1**. Hydrogen production methods vs. associated color codes (adapted from [1]).

Since early 2021, the DeepTech Sakowin Green Energy and Microwave Technologies Consulting have been working together to develop an industrial 915 MHz microwave (MW) plasmalysis system to split either natural gas or biomethane into hydrogen and carbon, yielding either turquoise or green hydrogen. Depending on the methane source, natural gas or biomethane, the plasmalysis technology is negative or neutral in terms of $CO_2$ emissions. The technology has the potential of using much less electricity than water electrolysis to produce the same amount of hydrogen at a more competitive cost and without using water, which is recognised as a resource whose conservation is essential in the fight against climate change. The co-production of solid carbon, which can be used in industrial and environmental applications such as electrodes for batteries, building materials and agriculture, together with the use of biomethane, which makes it possible to produce hydrogen that is not only decarbonised but also negative in terms of $CO_2$ emissions, makes this technology a model of energy efficiency, circularity and sustainability.

The use of a MW plasma to achieve methane decomposition allows for an efficient process by delivering energy directly to the gas (plasma) without the use of intermediate heaters or electrodes within the plasma chamber. In addition, the start-up and shut-down times of the process are virtually instantaneous, controlled by the time it takes to turn the microwaves on and off as a function of the downstream process requirements.

In this context, we had the opportunity to present an experimental study of the methane plasmalysis process at the recent 19th AMPERE conference in Cardiff. We presented the results of an optical emission spectroscopy (OES) study of the MW plasma under different pressure, MW power and gas mixture conditions. The results not only allowed a determination of the plasma temperature in the centre of the microwave plasma reactor, but more importantly, it opens the door to future studies where the spatial distribution of the temperature can be determined.

Our presentation was just one of many dedicated to making the industry as a whole more efficient and $CO_2$-free, a quest for which, as we saw during the AMPERE 2023 conference, microwave technology offers enormous potential.

As shown in **Figure 2** Sakowin's equipment is compact, modular and stackable. It can be integrated into existing gas infrastructure, for on-site and on demand hydrogen production, with capacities ranging from 200 kg $H_2$/day to hundreds of tons of $H_2$/day.

For more details: www.sakowin.com; www.microwavetechs.com

**Figure 2**. Photo of the R&D Team at the inauguration of the industrial test site, 27th September 2023.

## For further reading

1. Faisal S. AlHumaidan, Mamun Absi Halabi, Mohan S. Rana, Mari Vinoba (2023) Blue hydrogen: Current status and future technologies, Energy Conversion and Management, 283, 116840, https://doi.org/10.1016/j.enconman.2023.116840.

## About the authors

**Dr. Alvaro Martin Ortega** is a senior researcher at Sakowin Green Energy, France, having joined the company in March 2021. Dr. Martin Ortega obtained his Ph.D. in plasma physics from the University of Grenoble in 2017, while working at The European Synchrotron Radiation Facility (www.ESRF.fr). His professional experience includes two postdoctoral positions at French laboratories in Grenoble (2017-2018) and Toulouse (2018-2020), investigating innovative applications of plasma sources for CVD diamond deposition and electric space propulsion.

**Dr. Marilena Radoiu** is the founder of Microwave Technologies Consulting, France. She has more than 25-year experience in the development of microwave assisted technologies applied to chemical synthesis, biomass extraction, plasma, food etc. Her work has included engineering and development of novel industrial and scientific standard and custom-tailored equipment and processes. Dr. Radoiu is a Chartered Scientist and fellow member of several professional associations, including the Royal Society of Chemistry and the Association for Microwave Power, Education and Research in Europe (AMPERE).