Advocacy Brief

HYDROGEN MADE FROM WASTE — IS IT GREEN OR IS IT RED?

Hydrogen is being proposed as a "carbon-free" fuel for transportation, heavy industry, and other places where fossil fuels are currently used. Although hydrogen produces no CO_2 when burned, the vast majority of hydrogen is produced from fossil fuels, particularly fossil ("natural") gas, which has a massive carbon footprint throughout its lifecycle.[1] The rise of "green" hydrogen begs the perpetual question: which energy sources count as renewable?

What is green hydrogen?

Most hydrogen is made from fossil gas or other fossil fuels.[2] The two most common methods for producing hydrogen are methane reforming and electrolysis.

- **Methane reforming**: high-temperature steam (700°C–1,000°C) is used to produce hydrogen from a methane source, such as fossil gas. Other pre- and post reforming stages are needed to increase the yield. During this process, CO_2, CO, and other greenhouse gasses are released as byproducts, and it relies on high external energy inputs, which are also typically supplied by fossil fuels.[3]

- **Electrolysis**: An electric current splits water into hydrogen and oxygen. The electricity can be from renewable or non-renewable sources.

Hydrogen production is referred to as 'gray hydrogen' when the energy source comes from fossil fuels. When the electrolysis uses electricity produced by renewable sources, such as solar or wind, the resulting hydrogen is considered renewable; this is called 'green hydrogen'.

The term green hydrogen is sometimes misused to refer to non-renewable energy processes such as:

- **Hydrogen production using electricity produced by waste-to-energy incineration**: waste is incinerated, some electrical energy is recovered and used for electrolysis of water.

- **Waste gasification/pyrolysis (also known as waste-to-hydrogen)**: waste (primarily plastic waste) is subject to high-heat thermal processing such as gasification or pyrolysis and the resulting syngas undergoes steam reforming and further treatment steps to increase the hydrogen yield.

We use the term "red hydrogen" to refer to all waste-to-hydrogen processes.

Red hydrogen: burning waste to produce hydrogen

	PROCESS	FEEDSTOCK	ENERGY SOURCE	BYPRODUCTS
GRAY, BLACK, BROWN HYDROGEN	Steam reforming	Methane	Coal, methane, oil and gas (fossil fuel)	CO_2, and other pollutants (CO, PM, SO_x, NO_x), CH_4 leaks
GREEN HYDROGEN	Electrolysis	Water	Solar, wind, etc.	O_2
RED "WASTE-TO-HYDROGEN"	Electrolysis	Water	Burning waste (WTE, pyrolysis, or gasification)	CO_2, and other pollutants (CO, PM, SO_x, NO_x, metals, dioxins and furans, PAHs, VOCs, and other POPs, acid gasses, particulates, etc.), CH_4 leaks.
	Pyrolysis/ gasification followed by steam reforming	Waste, primarily plastic	Burning waste (WTE, pyrolysis, or gasification) and additional fossil fuels	

Is waste-to-hydrogen green?

The short answer is no, for the following reasons:

1. It is another form of fossil fuel. Most of the energy in municipal solid waste comes from plastic waste, which is made from fossil fuels. Large quantities of CO_2 are released during the steam reforming process, from converting the feedstock and for additional energy use that is required for high-temperature processing.[4]

2. The processes have high GHG footprints. Producing hydrogen from plastic is a carbon-intensive process, which includes two main steps: pyrolysis of plastic and catalytic steam reforming of pyrolysis gasses and vapors. The technologies used to turn plastic waste into syngas, usually gasification and pyrolysis, are high-temperature thermal processes - powered by fossil fuels - which require heavy energy input during pre-treatment, processing, and post-processing.[5] No existing plastic-to-fuel technologies can currently offer a net-positive energy balance, and there is no evidence that this can improve in the foreseeable future.[6]

3. Energy efficiency is low. Most of the energy in waste is lost during pyrolysis/gasification or combustion. Additional energy is lost in electrolysis and steam reformation, while even more energy is lost in compression and transportation of the hydrogen. This results in very low overall energy efficiency.[7]

4. Material efficiency is also low. The yield rates mentioned in promotional materials range from 4% to 16.6%, according to the companies' own estimates. The rest of the material is wasted in the process.

Ways2H — a joint venture between US-based Clean Energy Enterprises, and Tokyo-based Japan Blue Energy Corporation (JBEC) says, for **every tonne** of dry waste put into the system, roughly **40-50 kg** of hydrogen is produced. **Yield rate** 4-5%	Ways2H's facility in Tokyo will process **1 tonne** of dried sewage sludge per day, to generate **40 to 50 kg** of hydrogen per day. **Yield rate** 4-5%
H2-Industries proposed a 490-foot ship that is designed to collect and process marine plastic waste with thermolysis. For every **600 kg** of plastic waste collected, approximately **100 kg** of hydrogen can be produced. **Yield rate** 16.7%	H2-Industries is developing a 1-gigawatt liquid organic hydrogen carriers (LOHC) Hydrogen Hub, which will process **4 million tonnes** of organic waste and non-recyclable plastic per year to produce **300,000 tonnes** of green hydrogen. **Yield rate** 7.5%

Where is “waste-to-hydrogen” being pursued?

A number of hypothetical or proposed projects are emerging in different parts of the world. **Egypt** has seen the waste-to-hydrogen hype with construction approval granted to a US-based company H2 Industries. The company plans to build the world's first and largest plant that aims to convert organic waste and plastic waste into hydrogen.[8] Targeting Egypt for such “waste-to-hydrogen” projects is especially concerning for large leaks from fossil fuel operations and water scarcity that the country has historically dealt with.[9] Among other US-based companies, Ways2H has a mobile demonstration unit in **Japan**, and is looking to expand to California and South America,[10] and a California-based company, Raven SR, has raised $20 million for its technology to convert mixed waste into hydrogen.[11]

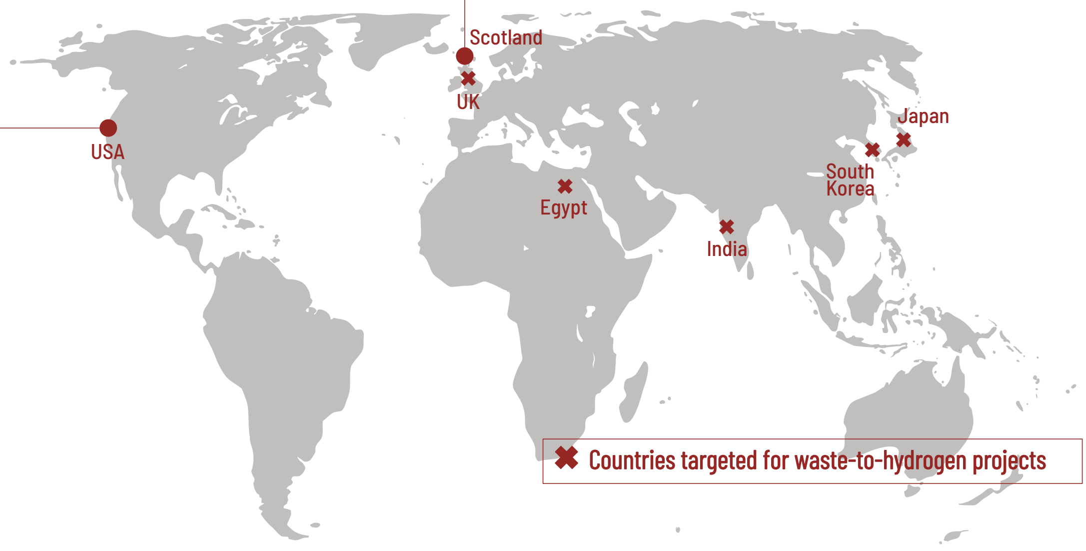
Several **UK-based companies** have been aggressively seeking public funding for their waste-derived hydrogen businesses. Compact Syngas Solutions has secured nearly £300,000 from the Department for Business, Energy and Industrial Strategy for their proposed gasification facility that would use bales of dried, compacted municipal waste as a feedstock.[12] Advanced Biofuel Solutions plans to build five plants to turn refuse-derived fuel into hydrogen or methane, and one facility is funded by a £2 million grant under the government’s Green Fuels, Green Skies program. H2Upgrade, the University of Cambridge’s waste-to-hydrogen venture, secured £245,302.[13] A British infrastructure and property investment business named Peel NRE has also signed a collaboration agreement with Powerhouse Energy Group to develop 11 waste plastic-to-hydrogen facilities across the UK over the next few years, with an aim to build a total of 70 facilities (see below for the latest failure of one of the planned projects).

In Asia, **Japan** and **South Korea** are among the most eager to promote such waste-derived hydrogen technologies. The Ways2H project in Japan is a facility in partnership with the City of Tokyo that will turn sewage sludge into hydrogen, reportedly as part of the nation’s strategy to scale up renewable energy.[14] Samsung, one of the biggest corporations in Korea, also invested a large sum in “green hydrogen” projects that aim to convert household waste such as plastic waste, food waste, sewage sludge, and waste wood into hydrogen, including a joint venture with the California-based Raven SR.[15] **Pune, India** has also entered into a 30-year-long agreement for the country’s first waste-to-hydrogen plant in 2023.[16]

Several countries, including the U.S., Canada, and South Korea, also included expansion of green hydrogen projects as a climate strategy in their recent climate plans (Nationally Determined Contributions or NDCs); Among them, the U.S. specifically mentioned waste-derived “green” hydrogen in its NDC.[17]

Examples of Failed Waste-to-Hydrogen Proposals

While industry seeks to classify "waste-to-hydrogen" as green energy, there are numerous examples of governments and civil society blocking these attempts. For example, the Scottish government recently withdrew support for what would have been the largest waste-to-hydrogen facility in **Scotland**. The £20 million plant developed by Peel NRE would have burned 13,500 tonnes of plastic waste each year. The proposal was dropped in December 2022, however, for several reasons: Scotland's moratorium on building of new waste incinerators that was announced in June 2022, the Scottish Government's policy requirement for hydrogen plants to include carbon capture, and issues regarding the claimed GHG benefits of the proposal.[18] Local residents also persistently voiced their concerns about the lack of public consultation and the risk of turning the town into a plastic waste dumping ground.[19]



In **California**, waste-to-hydrogen company, 'H Cycle' asked to be classified as a methane climate solution under the state's landmark methane prevention law. The state denied the application due to lack of data.[20] H Cycle is approaching cities across the state to build facilities that appear to be based on gasification incineration technology from the bankrupt incinerator company Plasco, and could apply again for this classification.

So, what should we do about waste-to-hydrogen?

Producing hydrogen from plastic, a fossil fuel byproduct, results in using fossil fuels to create another form of fossil fuel. As with other false solutions and greenwashing schemes, waste-to-hydrogen is not green. We should steer clear of any waste-to-fuel or plastic-to-fuel processes, whether the final product is pyrolysis oil, syngas, hydrogen, or something else. The real solution to plastic pollution lies in drastically curbing plastic production, and decarbonization through renewable energy is the most effective way to make the energy sector green.

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Glossary

- **Electrolysis**: a process of using electricity to split water into hydrogen and oxygen
- **Gasification**: a chemical recycling process based on pyrolysis where oxygen is restricted so that the input thermally decomposes but does not combust.
- **Gray hydrogen**: hydrogen derived from natural gas and produced from fossil fuels.
- **Pyrolysis**: a process of heating an input with limited oxygen to produce a liquid or gaseous fuel.
- **Refuse-derived fuel (RDF)**: solid fuel typically made from dried municipal waste shredded and compacted into pellets or bricks.
- **Steam reforming**: a method for producing syngas (hydrogen and carbon monoxide) by reaction of hydrocarbons with water at heightened temperature and pressure.
- **Fossil gas (also called natural gas)**: an odorless, gaseous mixture of hydrocarbons, consisting primarily of methane and ethane.

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