Colors of Hydrogen [1) 2)] 26.11.2021/AR

I. Green Hydrogen

Certified green hydrogen requires an emission reduction of >60-70% (depending on the certification body) below the benchmark emissions intensity threshold (= GHG emissions of grey hydrogen, for example benchmark values according to the renewable energy directive RED II). [2)]

Production method: Green hydrogen is generated entirely by renewable energy. 'Green' hydrogen is produced by electrolysis using low- or zero-carbon electricity. [2)]

Green house gas emissions: > 0.45 kg CO_2e per kg H_2; [1)]

II. Grey Hydrogen

Grey hydrogen has significantly higher carbon emissions than green hydrogen. It is produced by steam reforming of commonly natural gas and represents 95% of the market. 2)
Methane is 86 times more powerful a greenhouse gas compared to CO_2; An average of 2,3% of the methane produced leaked to the atmosphere. [1)]

Production method: steam methane reformation:

$$CH_4 + H_2O \Leftrightarrow CO + 3\ H_2$$

1 kg Hydrogen requires 3 kg natural gas (CH4, Methane);
The CO_2 equivalent from methane application is calculated as:

- 2.3% x 3 kg CH_4 *86 = 5,9 CO_2e/kg hydrogen;

The SMR process usually emits

- 9 - 12 kg CO_2 per kg hydrogen;

- **Total CO_2e: 15 – 18 kg CO_2 per kg grey hydrogen**

III. Blue Hydrogen

Hydrogen produced by steam methane reformation is termed “blue hydrogen' when the carbon dioxide from SMR is (mostly: 70- 85%) captured and stored geologically.

Production method: steam methane reformation + Carbon Capture and Storage (SMR + CCS);

1 kg Hydrogen requires 3 kg natural gas, equal to

- 5,9 CO_2e;

Beyond capture and storage of CO_2 emissions from the SMR process:
(70-85% from 9-12 kg CO_2 per kg hydrogen)

- 1,3 – 3,6 kg of CO_2e per kg hydrogen.

- **Total CO_2e: 7,2 – 9,5 kg CO_2 per kg blue hydrogen**

Blue hydrogen produced through more energy intensive autothermal reforming enables 98% of CO_2 emissions to be captured;

IV. White Hydrogen

Manufacturing of 1 kg white Hydrogen requires 15 – 25 kg waste. Alternatively, such waste would have to be landfilled or incinerated/gasified for electricity production – in all cases releasing CO_2e.

The Los Angeles County Greenhouse Gas Emission Report [3)] compares transport and disposal of 1’000 tons per day MSW in a modern sanitary landfill to the treatment in a conversion technology like THERMOSELECT. According to the report 1’000 tons of landfilled waste would emit 1’640’000 tons of CO_2e.

In other words: 1 kg waste landfilled emits 1’640 kg CO_2e , which can be avoided if the waste is used as feedstock for white hydrogen manufacturing.

Production method: Syngas produced from waste (H_2 + CO + CO_2) undergoes water-gas-shift reaction to enlarge hydrogen content:

$$CO + H_2O \Leftrightarrow CO_2 + H_2$$

(This is no methane reformation process !).

The shifting process creates about 1 kg CO_2 per kg waste, equal to 15-20 kg CO_2e per kg hydrogen. Beyond Carbon Capture and Storage (70-85%):

- Release of about 4 kg CO_2e per kg white hydrogen;
- Avoidance of about 24'600 – 41'000 kg CO_2e from landfilling per kg white hydrogen;
- **Net avoided Greenhouse Gas emissions as compared to landfilling of waste: average about 30'000 kg CO_2e per kg white hydrogen;**
- Comparing White Hydrogen Manufacturing to the production of electricity from waste also results in substantial avoided greenhouse gas emissions.

White Hydrogen Manufacturing is a Negative CO_2 Emission Technology.

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Sources:

1) https://www.rechargenews.com/energy-transition/new-clean-hydrogen-production-tax-credit-of-up-to-3-kg-approved-by-us-house-paving-way-for-cheap-green-h2/2-1-1102245
2) Wikipedia: Hydrogen
3) County of Los Angeles Greenhouse Gas Emissions Report Jan. 2016