Greening Circular Economy by Innovative transformation of Reuse Recycled Aluminium into Green Hydrogen

Acknowledgements

The present project (COM-CONCEPT ENERGY/0624/0004/HY-CIRCULAR, "Greening Circular Economy by Innovative transformation of Reuse Recycled Aluminium into Green Hydrogen", **Hystore Tech Ltd**, April 1, 2025 to March 31, 2026) was funded by the Research and Innovation Foundation, under the «Commercial Proof of Concept - Energy» Programme and through the Recovery and Resilience Facility of the NextGenerationEU instrument

Participants:

Hystore Tech Ltd

General Objective:

To reuse recycled Aluminium metal collected in neighbourhoods, industrial areas, hospitals and elsewhere, to, in-situ, produce green Hydrogen and other value-added useful products.

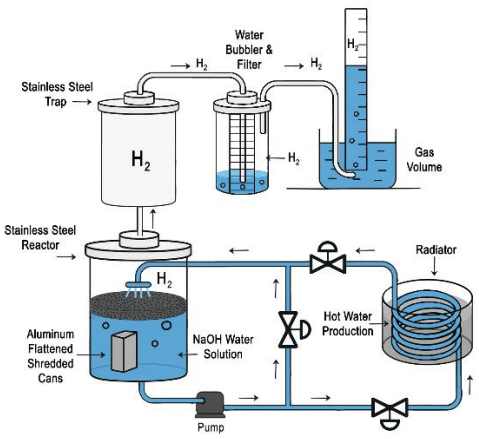
Specific Objectives:

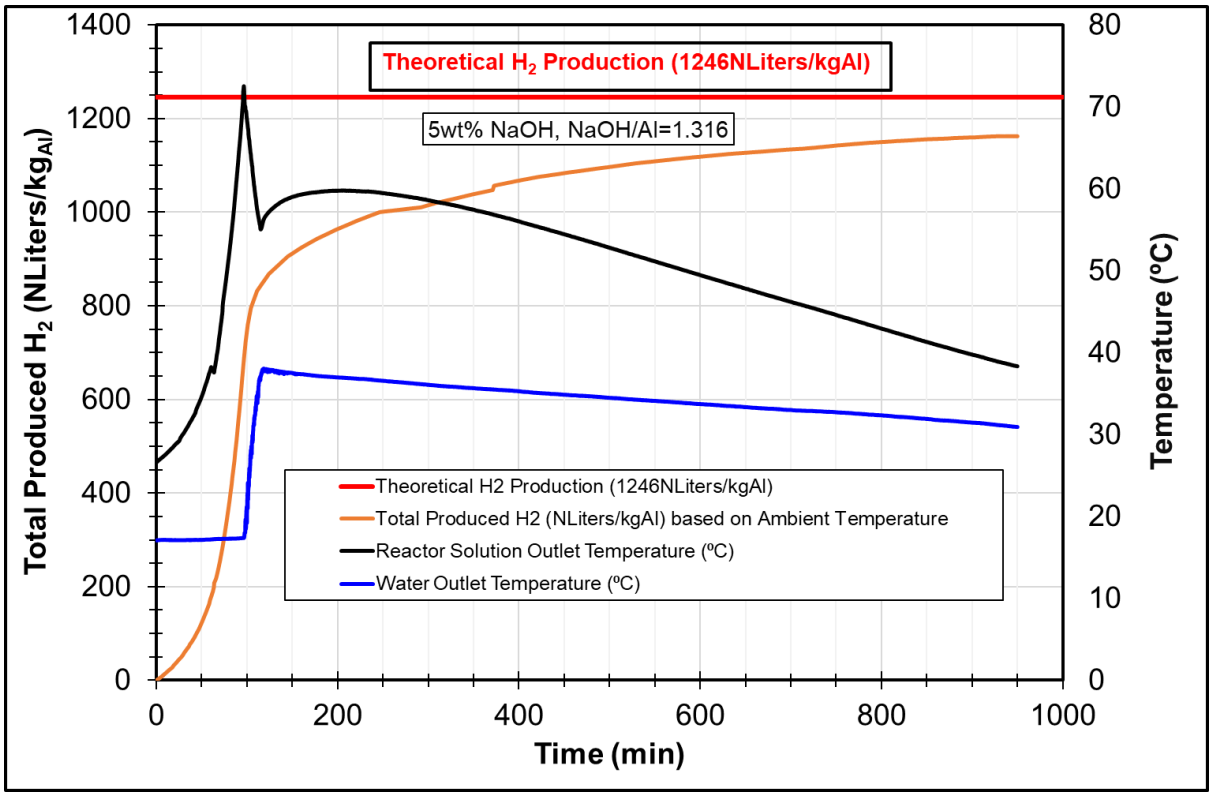
To design, construct, operate and demonstrate a simple, final **prototype unit** utilizing directly recycled Aluminium Scrap metal (Shavings, Cans and Slabs) without any pre-alloying, melting, pre-treatments, etc., in order to produce:

- Pure green hydrogen gas (potentially to be used for electricity production)
- Thermal energy (hot water for central heating and other uses)
- Value-added by-products, such as $NaAl(OH)_4$ and/or $Al(OH)_3$ powder for the Aluminium production companies and/or for other uses (water purification, polishing pastes, abrasive detergents, abrasive particles for water jets cutting, etc.)

Experimental Results:

Design and Construction of a large-scale final prototype unit




Theoretical H_2 Production (1246NLiters/kgAl)
5wt% NaOH, NaOH/Al=1.316
Theoretical H2 Production (1246NLiters/kgAl)
Total Produced H2 (NLiters/kgAl) based on Ambient Temperature
Reactor Solution Outlet Temperature (ºC)
Water Outlet Temperature (ºC)
Total Produced H_2 (NLiters/kg_{Al})
Temperature (ºC)
Time (min)
0
200
400
600
800
1000
1200
1400
10
20
30
40
50
60
70
80

Conclusions

- **Small and Medium Experimental prototype units** were constructed and operated smoothly obtaining results on the production of green H_2 gas by using recycled Aluminum Shavings, Cans and Slabs.
- The **H_2 production rate is higher** by using Recycled Aluminum Shavings, Cans and Slab respectively, due to their higher specific surface area.
- The H_2 production was found to be **very close to the theoretical 1246NLH_2 per kgAl** (3H/Al atom/atom ratio), within +2% to -10% depending on the purity of the recycled Aluminum and taking into consideration the experimental error involved.
- It was found that as the NaOH wt% concentration increases the **reaction rate increases**.
- For **high NaOH wt%** concentrations, the produced **$NaAl(OH)_4$ remains in solution** whereas for **low NaOH wt%** concentrations, it further **decomposes into $Al(OH)_3$ precipitates** (white precipitate) and regenerated NaOH catalyst.
- A **Final Prototype Unit of 50kg** recycled Aluminium per day was successfully designed, constructed and operated.
- For the smooth operation of the large Prototype (Reactor), a molecular ratio **R=NaOH/Al of 1.25** (equivalent of a mass ratio R=NaOH/Al of 1.853) is used in order **to avoid any precipitation** (crystallization) of **$Al(OH)_3$** onto the Reactor internal surfaces, which may create maintenance problems.
- The **mass of NaOH-water solution** of concentration of >2.5wt%NaOH depends on the initial amount of Aluminum scrap and the molecular ratio R=NaOH/Al. **It is such that keeps the Aluminum scrap wet at any time**. In other words, the level of the liquid containing the NaOH catalyst to cover the Aluminum scrap and keep it wet at any time. This is estimated in a custom-made developed software.
- The **Green H_2 production** was found to be **very close to the theoretical 1246NLitersH_2 per kg of pure Al**. Indicatively, Slabs, Shavings and Cans contain 97.5%Al, 94.5%Al and 95%Al, respectively. The extent of the rection is usually about 95%. Based on the above Al-purity and extent of reaction the **H_2 production** was 112.07tonH_2/tonAl-pure, or **101.14kgH_2/tonAl-Cans**
- The **by-product** is a slurry of $NaAl(OH)_4$/NaOH solution, inorganic compounds (Mg, $Mg(OH)_2$, Fe, Fe_2O_3, MnO_x (x=1-2)) and plastic coatings/paints. **The plastic coatings/paints are screened-separated**, **the inorganic compounds (Mg, $Mg(OH)_2$, Fe, $Fe(OH)_3$, Fe_2O_3, MnO_x (x=1-2)) are filtered-separated for proper disposal**.
- The **decanted solution of $NaAl(OH)_4$/NaOH (Bayer Liquid)** can be further treated to produce **2.09ton $Al(OH)_3$ per tonAl-Cans**, a useful value-added product as well as NaOH/catalyst water solution to be reused.
- A **larger-scale production unit** can be designed, constructed and operated, depending on the desired Aluminum scrap capacity.

- **Green H_2 production from recycled Aluminum** metals **without any electricity offers an environmentally friendly, alternative method** for handling Aluminum Scrap within a **Circular Economy.**

Publications

1. Christina Ch. Christodoulou, Demetris Hadjipetrou, Christodoulos N. Christodoulou, Kypros Demetriou, George Karagiorgis and Michalis Menicou, "Demonstration of a Prototype Unit Producing Green Hydrogen, Heat and Alumina by Catalytic Water Decomposition With Recycled Aluminum Metals", Conference on Advancements in Sustainable Engineering 2025, Frederick University, Limassol, Cyprus, September 11-12, IOP Conf. Series: Earth and Environmental Science 1558 (2025) 012012, doi:10.1088/1755-1315/1558/1/012012 (Attachement#1)

2. Demetrios Hadjipetrou, Christodoulos N. Christodoulou, George Karagiorgis and Michalis Menicou, "Green Hydrogen Production by Using Recycled Aluminum Metal Without the Use of Electricity", Conference on Advancements in Sustainable Engineering 2025, Frederick University, Limassol, Cyprus, September 11-12, IOP Conf. Series: Earth and Environmental Science 1558 (2025) 012013, doi:10.1088/1755-1315/1558/1/012013 (Attachement#2)

3. Christina Ch. Christodoulou, Christodoulos N. Christodoulou, Kypros A. Demetriou and Demetrios P. Hadjipetrou "Environmental alternative of processing recycled Aluminum metals to produce simultaneously value-added products such as, Green H2 Gas, Heat and NaAl(OH)4", to be presented at the 13th International Conference on Sustainable Solid Waste Management, June 24-27, 2026, Kos Island-Greece (Attachement#3)

Presentations

1. "Demonstration of a Prototype Unit Producing Green Hydrogen, Heat and Alumina by Catalytic Water Decomposition With Recycled Aluminum Metals", Conference on Advancements in Sustainable Engineering 2025, Frederick University, Limassol, Cyprus, September 11-12, (Attachement#4)

2. "Green Hydrogen Production by Using Recycled Aluminum Metal Without the Use of Electricity", Conference on Advancements in Sustainable Engineering 2025, Frederick University, Limassol, Cyprus, September 11-12 (Attachement#5)