

OUR APPROACH

The **REVEAL** project tackles the challenge of **seasonal renewable energy storage** by developing a breakthrough **Power-to-Aluminium (Power-to-Alu)** technology that converts aluminium oxide into aluminium metal in a **carbon-free process** as well as efficient **Aluminium-to-Energy (Alu-to-Energy)** technology to recover the energy. Thus, **aluminium** becomes a **renewable fuel and energy carrier** with an exceptionally **high density (>15 MWh/m³)**, enabling **large-scale, efficient, and low-cost storage of renewable energy**.

Compared to hydrogen or synthetic fuels, **REVEAL's** solution offers **higher energy density, safer handling, easier transport, and zero emissions**, paving the way for efficient, sustainable, and scalable long-duration energy storage.

GOALS:



Seasonal energy storage cycle

development of breakthrough components and solutions that are needed for an Al electrochemical energy storage cycle



Power-to-Alu (Storage charging)

based on renewable electricity without emissions of greenhouse gases from the Al smelter (Power-to-Alu) process



Alu-to-Energy (Storage discharging)

emission free Alu-to-Energy



Life cycle and economic analysis

for better understanding of environmental impacts to improve economic and environmental performance

PARTNERS

Research consortium with nine partners from seven different European countries:



VISIT WEBSITE:



reveal-storage.eu

PUBLICATIONS:



[zenodo](https://zenodo.org)



@reveal-storage

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REVOLUTIONARY ENERGY STORAGE CYCLE WITH CARBON FREE ALUMINIUM



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OUR RESULTS

Aluminium storage can cover **100 %** of a Zurich home's annual energy needs using **0.2 to 0.5 m³ of Al**

System analyses confirmed that **REVEAL's** aluminium energy storage can supply **100 % of a building's annual energy demand** in Zurich's climate, requiring only **0.2 to 0.5 m³ of aluminium per household**. Inert-anode electrolysis cells enable flexible, carbon-free production, while **Alu-to-Energy conversion** offers adaptable combined heat and power.

Studies show tens of TWh of renewable low cost electricity could be stored in aluminium, representing a **€30 billion annual market potential** by 2050. Surveys with **1,000 homeowners** and **216 experts** reveal strong adoption readiness.

500 A CO₂-free smelter at **<13.7 kWh_{el}/kg Al** with **<1.5 mm/year anode wear**

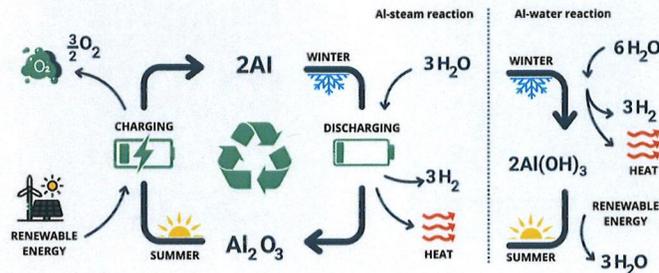
A **500 A CO₂-free aluminium smelter** was developed with **high efficiency (<13.7 kWh_{el}/kg Al)** and **low anode wear (<1.5 mm/year)**. A low-energy, **low-GWP aluminium granulation process** was created, producing highly reactive aluminium. Processing of **Al(OH)₃** from the energy conversion step yielded alumina that can be re-used in smelters for the production of new aluminium, closing the loop for **circular, carbon-neutral aluminium energy storage**.

4 kW Alu-to-Energy prototype in operation (lab scale)

The kinetics of hydrogen producing Al-water reactions were studied in alkaline solutions and superheated steam, revealing correlations between reaction rates, granule properties, and operating conditions. The findings, published in a peer-reviewed journal, guided the design of a continuously operating automatically **4 kW Alu-to-Energy prototype** with advanced discharge handling, efficient heat removal, and **HAZOP-based control**.

Combination with a **Fuel Cell Power System** enables **electricity production for combined heat and power**. The system is under validation, and a patent pending.

ALUMINIUM ENERGY STORAGE CYCLES ①



Power-to-Alu (Charging): Renewable electricity reduces aluminium oxide (Al_2O_3) to aluminium metal, storing energy in a carbon-free form.

Alu-to-Energy (Discharging): Aluminium reacts with water or steam to release heat and hydrogen, operating in high-temperature (Al-steam) or low-temperature (Al-water) modes.

CO₂-free closed material cycle with >15 MWh/m³ energy density

Tests confirmed **>95 % of the theoretical maximum efficiency for Alu-to-Energy**, delivering **4 kW of total output as heat and hydrogen (>2.0 kWh H₂ and >1.9 kWth heat)**. A **CO₂-free closed material cycle** and seasonal storage with **>15 MWh/m³ energy density** were successfully demonstrated.

>60 % lower CO₂ impact compared to natural gas-based Combined Heat and Power (CHP)

Life Cycle Assessment (LCA) framework for REVEAL was established with a clearly defined goal and scope, providing a strong foundation for evaluating environmental performance. Preliminary analysis already highlight promising sustainability insights, confirming the project's potential to deliver deep decarbonisation benefits across the full aluminium energy cycle.

By using low-carbon electricity sources such as PV, wind, or hydro, the **REVEAL aluminium storage cycle reduces the carbon footprint by 60-80% compared to conventional mini-CHP systems** running on natural gas, with even greater reductions possible as **electricity generation continues to decarbonize** – unlike mini-CHP.