REVEAL

REVOLUTIONARY ENERGY STORAGE CYCLE
WITH CARBON FREE ALUMINIUM

Aluminium as an Energy Carrier...

... for heat and electricity in winter

Michel Haller, SPF, Univ. of Appl. Sciences Eastern Switzerland (OST)

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NASA ARTEMIS II MOON MISSION AND EU REVEAL-STORAGE PROJECT

WHAT DO THEY HAVE IN COMMON?

Aluminium Energy Carrier

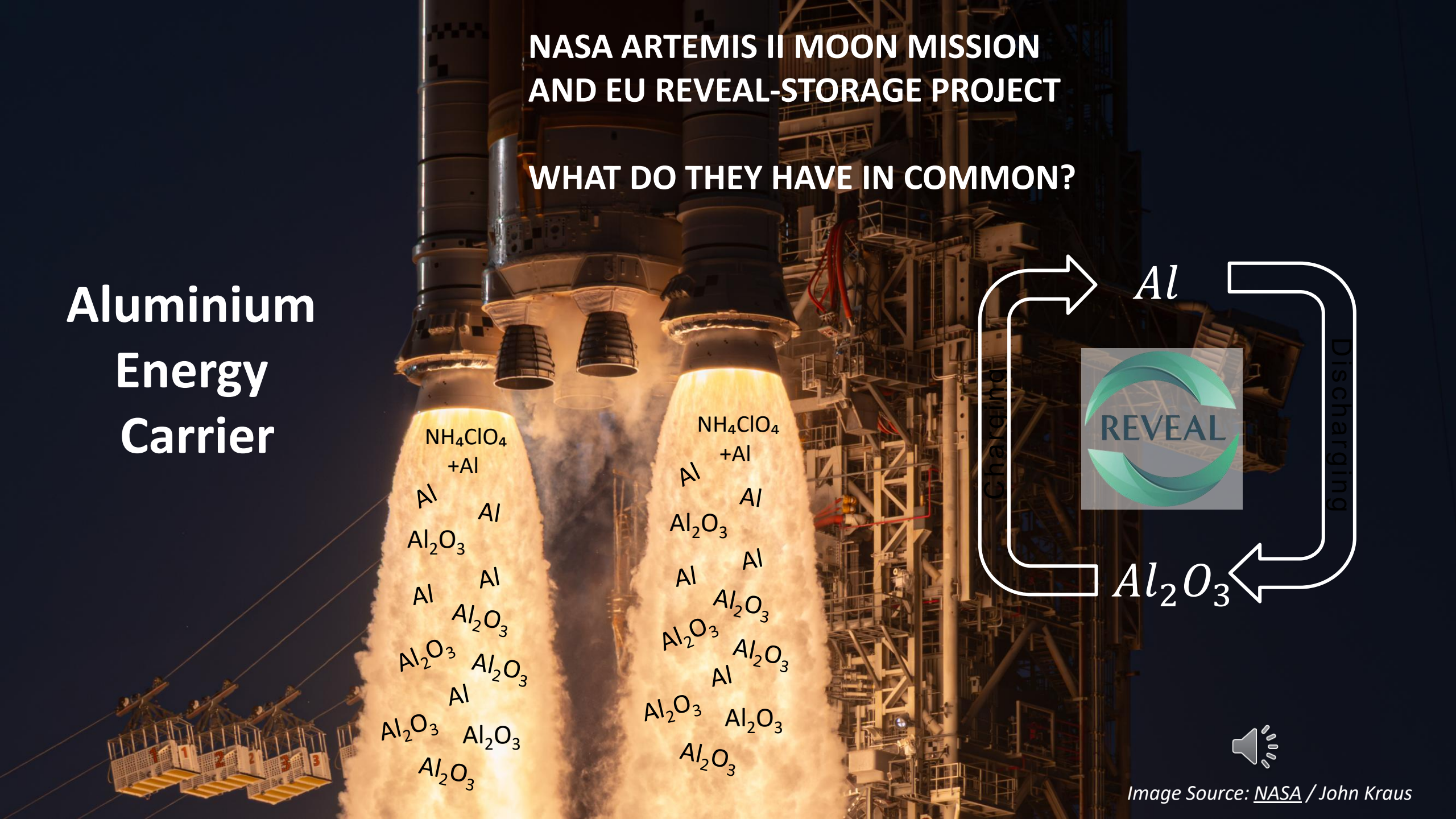
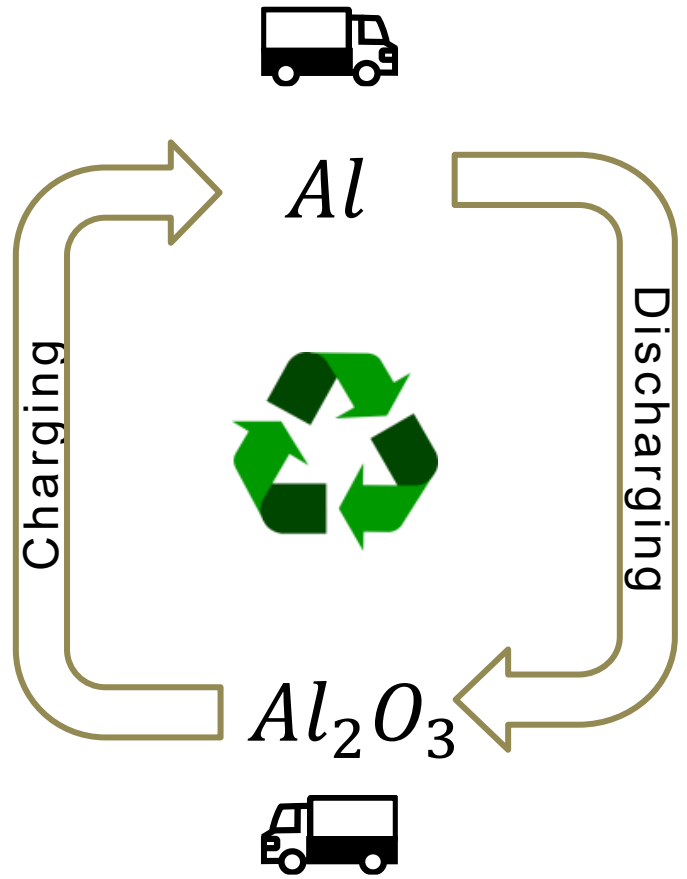


Image Source: NASA / John Kraus

OVERVIEW

1. Why Aluminium?
2. Power-to-Aluminium (Storage / Fuel Charging)
3. Alu-to-Energy (Storage / Fuel Discharging)
4. Closing the Material Cycle
5. Life Cycle Assessment



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1. WHY ALUMINIUM?

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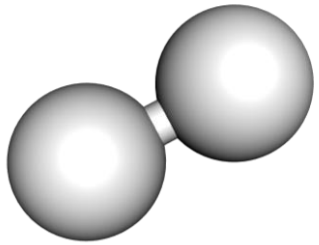
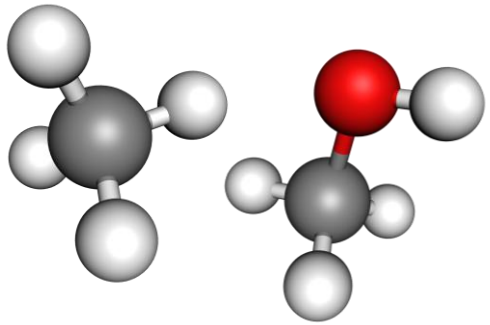
OPTIONS FOR SEASONAL STORAGE OF ENERGY

Hydrogen



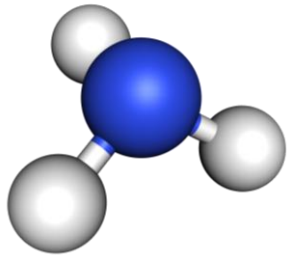
Disadvantage:
vol. density / storability

Carbohydrates Methane / Methanol



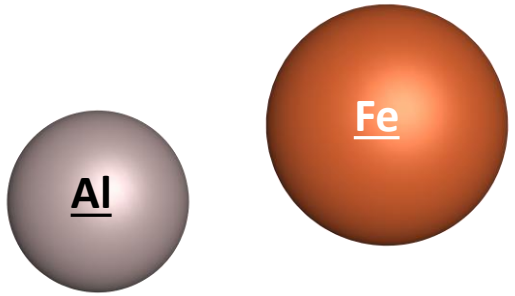
Disadvantage:
carbon:
where from and where to?

Ammonia



Disadvantage:
toxicity

Metal Energy Carriers: Al, Fe



Disadvantage:
technology readiness

Molekülle aus: molview.org

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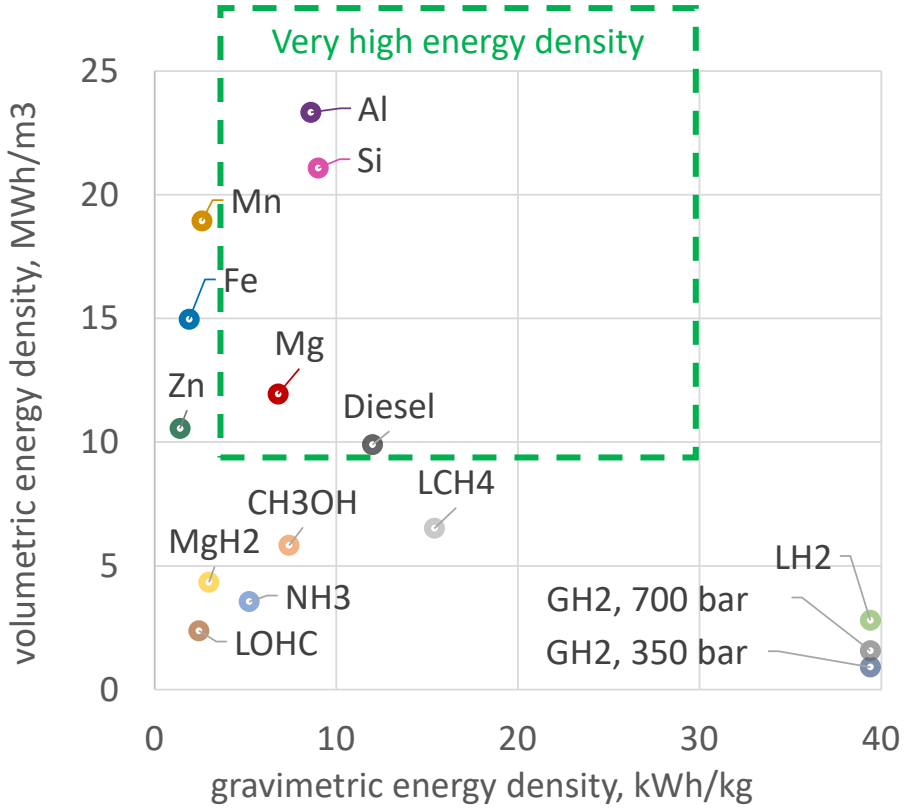
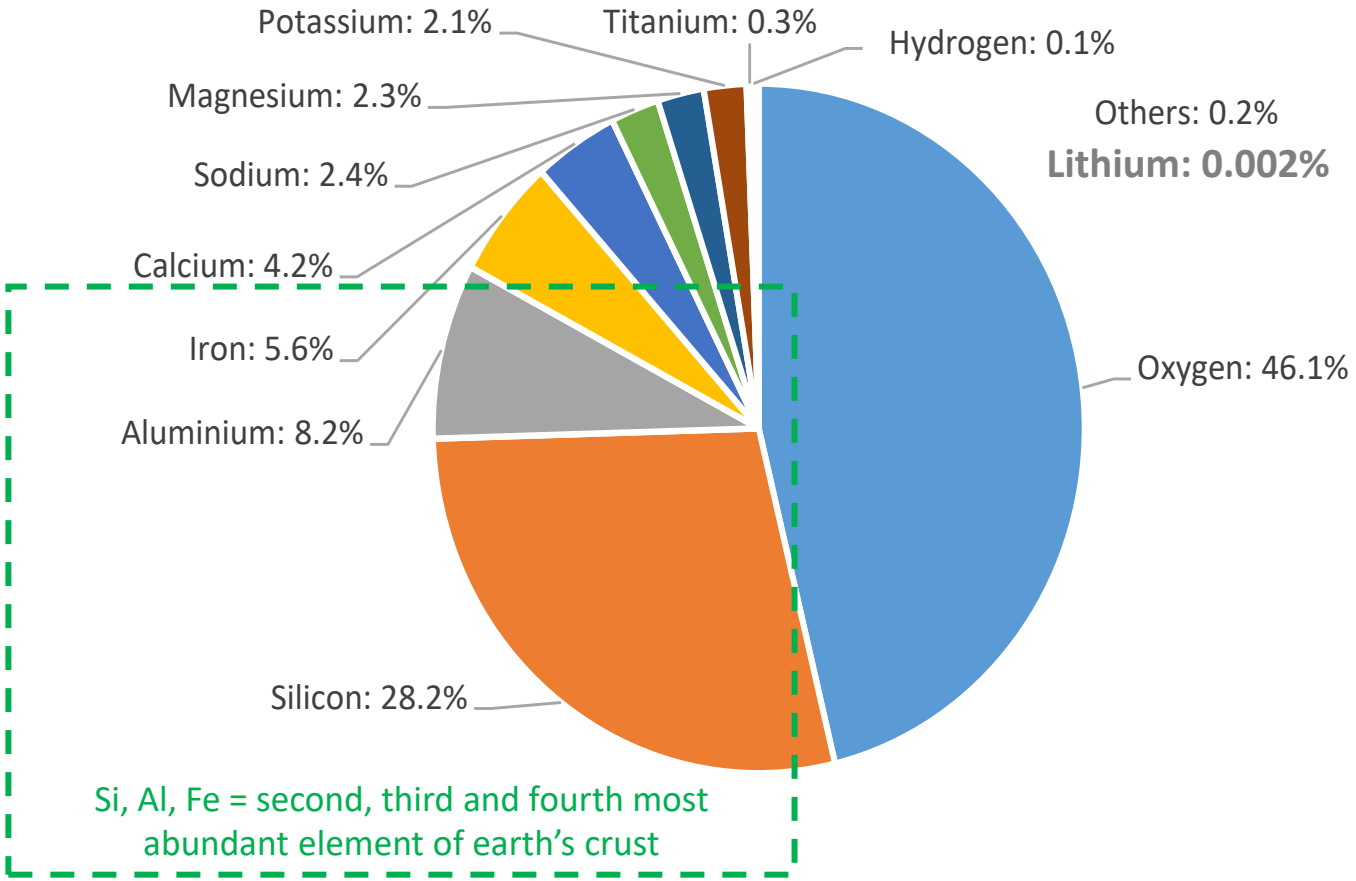
ENERGY DENSITY, AVAILABILITY, LOW COST



Elements in the Earth's crust



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2. POWER-TO-ALU

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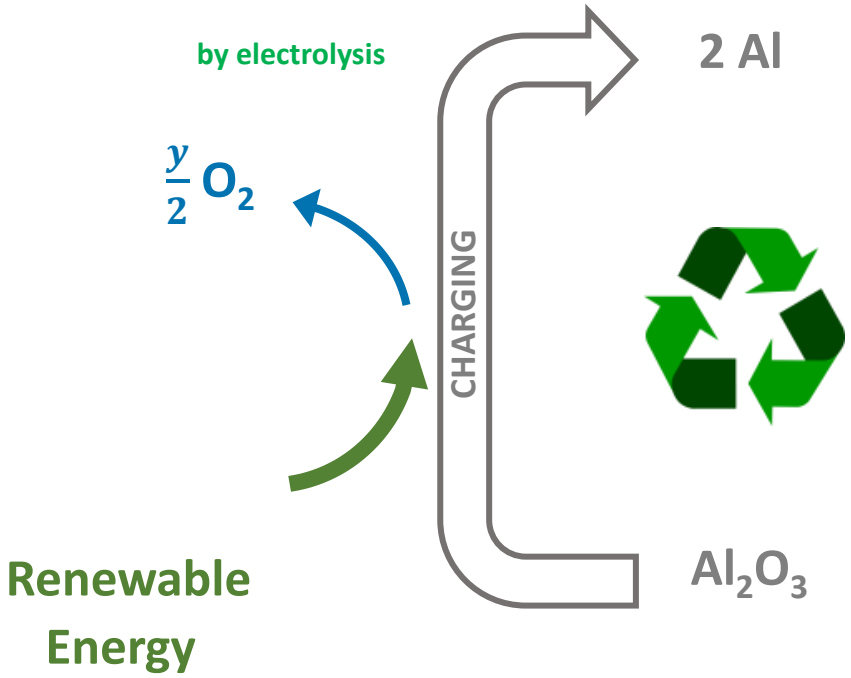
POWER-TO-ALU: REDUCTION OF ALUMINA

Power-to-Metal:



Source: SPF 2024, PeakMetal

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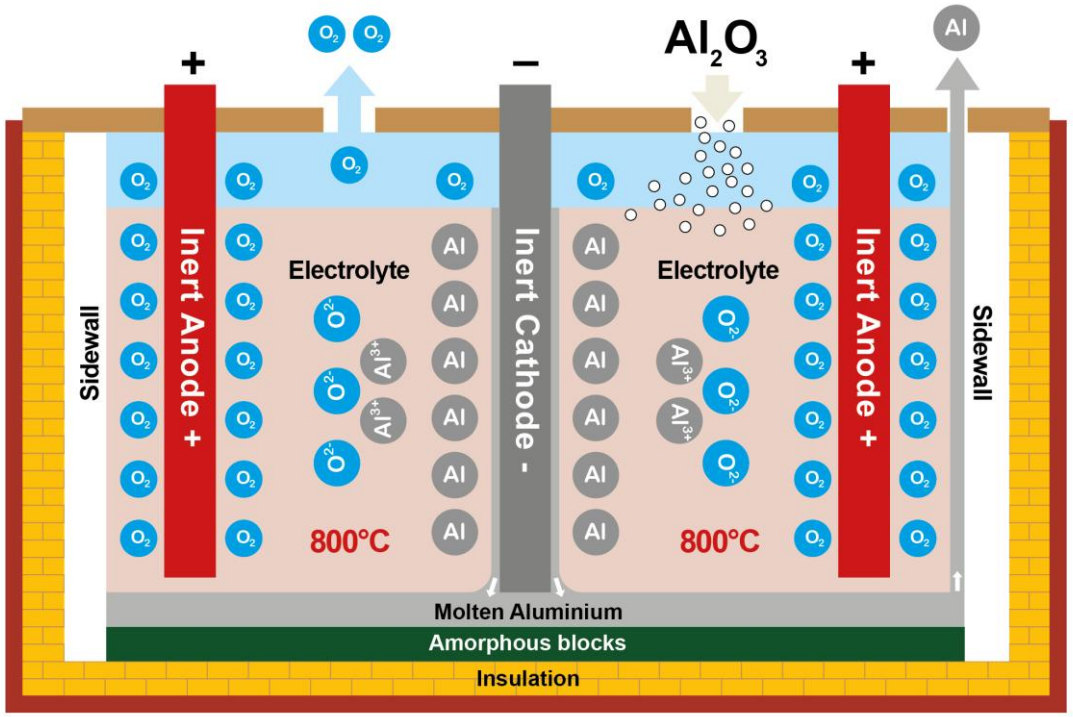
POWER-TO-ALU: INERT ANODE PROCESS

$$2\ Al_2O_3 \longrightarrow 4\ Al + 3\ O_2$$



Vertical Inert Anode and Cathodes in low temperature electrolyte

Source: Copyright© Arctus 2025, published with permission

Benefits compared to traditional Hall Héroult process:

- **No emissions of CO_2, CF_x, SO_2, cyanides**
- **20% less energy demand**

- Zero CO_2 compliance costs & taxes
- Modular power feeding during peak hours & power shortage periods for optimal power price
- 50% less space required for same production capacity
- 40% less investment cost
- 30% less operation cost and no carbon anodes

IceTec Arctus aluminium

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3. ALU-TO-ENERGY

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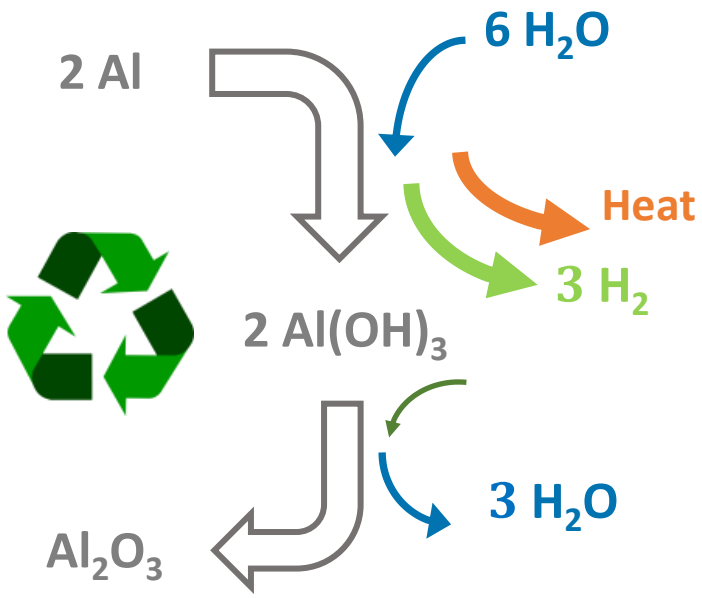
PATHWAYS FOR ALU-TO-ENERGY

Metal-Water Reaction
~20 – 150 °C



Reaction with liquid water
(e.g., with sodium hydroxide):
occurs at **ambient to ~150 °C**

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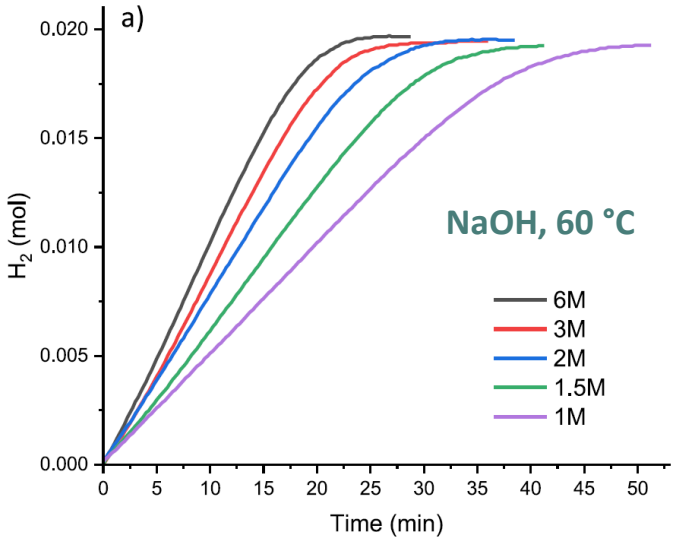
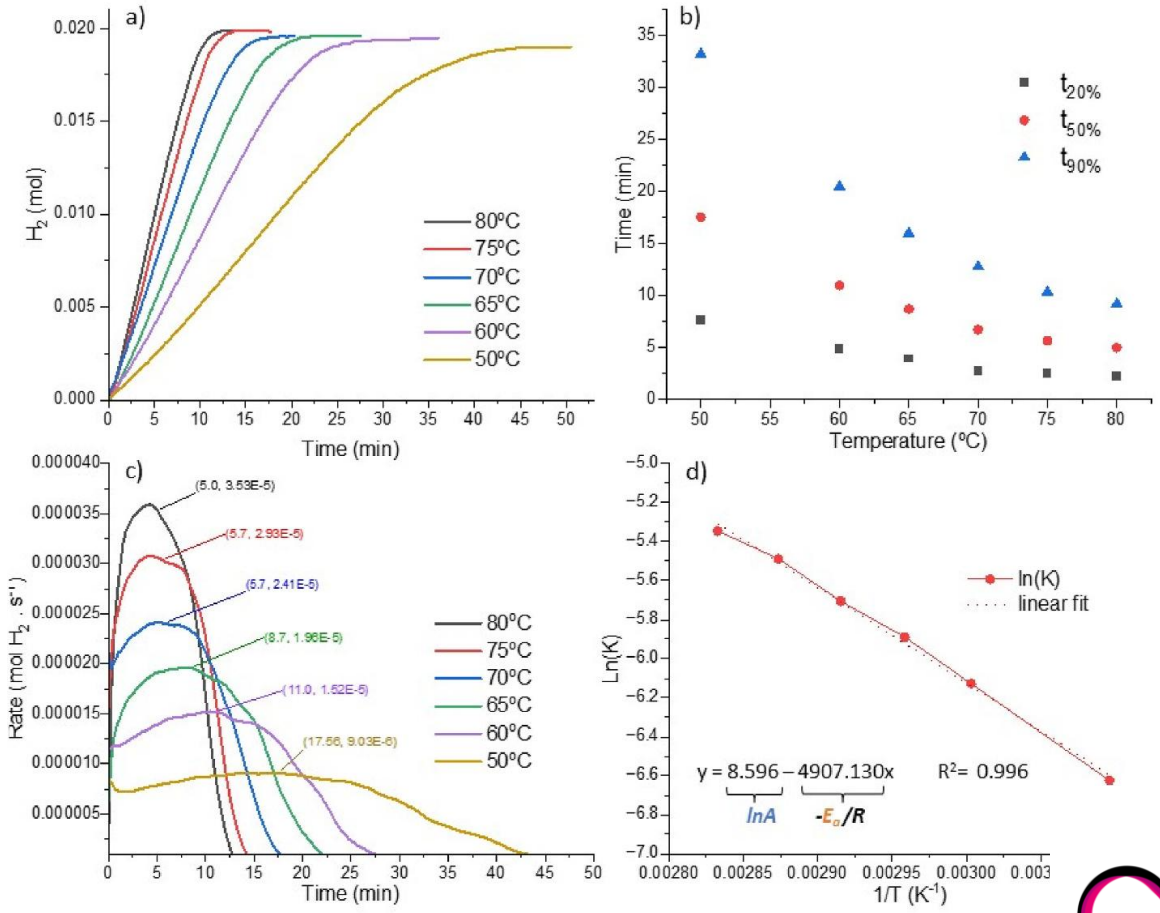
ALU-TO-ENERGY: LOW TEMP. WATER

Low temperature aluminium water reactions depend on **alloy, production process, pH** and **temperature**



Source: Agote-Arán et al. 2025, International Journal of Hydrogen Energy



Results shown are for **cylindrical Al-6060 cut-wire samples** of around **1 mm** in size.

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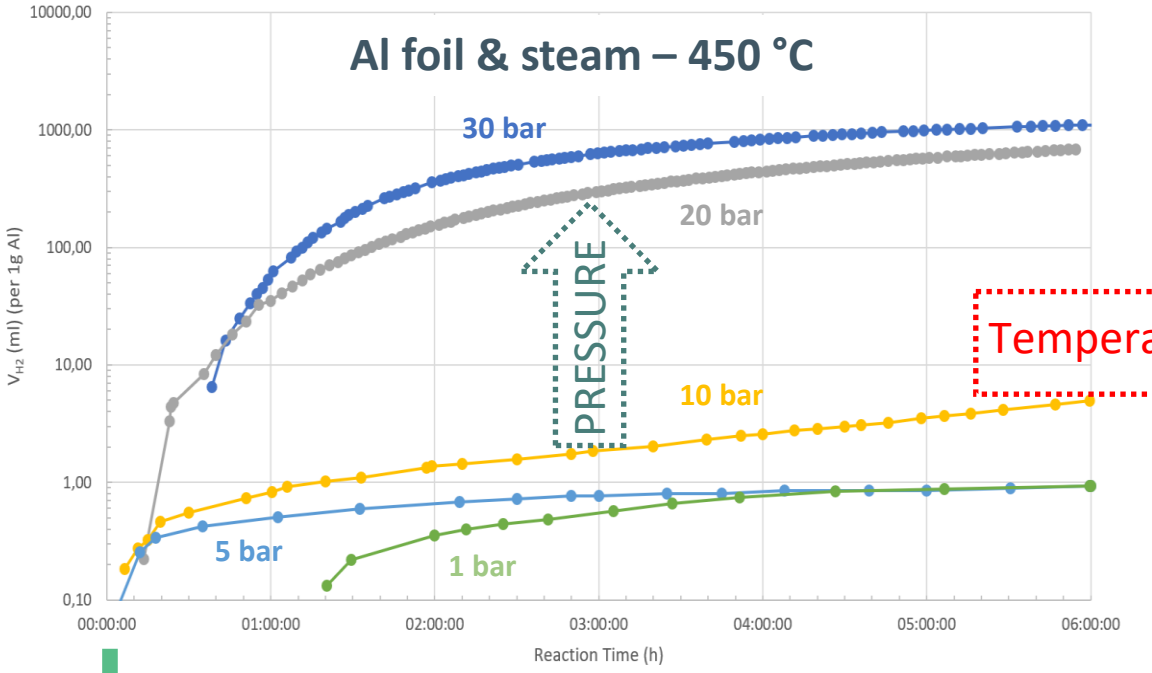
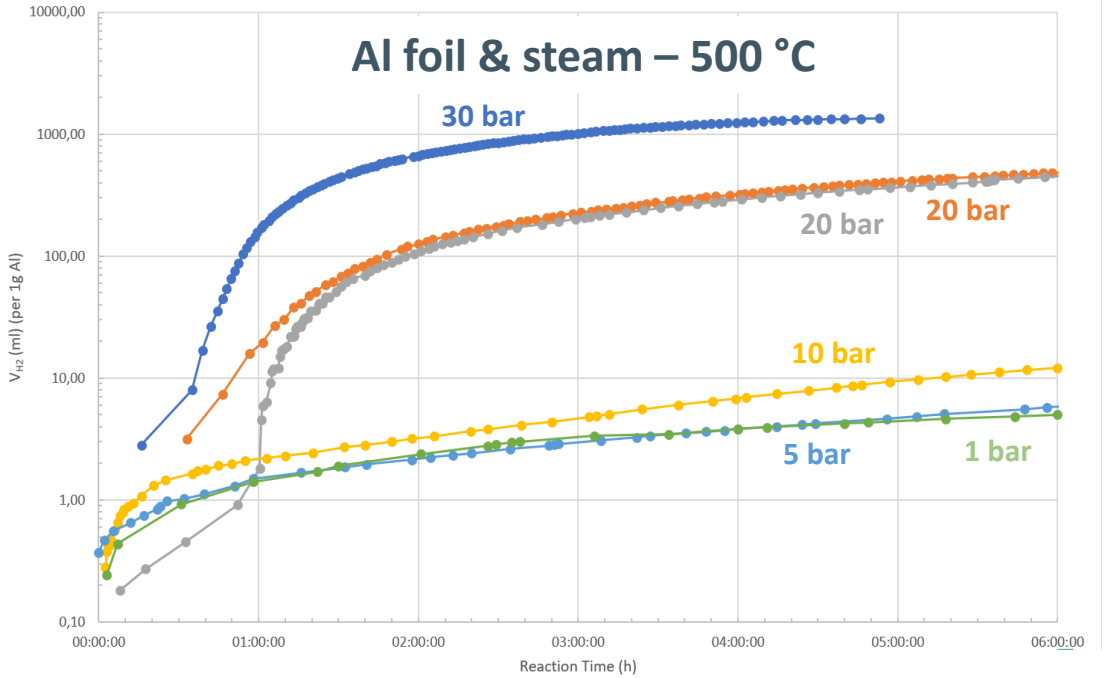
ALU-TO-ENERGY: STEAM

- **High temperature aluminium & steam reactions depend on alloy, production process, temperature and pressure**
- Shown experiments are with A**l-foil, 1 g, 20 µm, for fast energy transformatio**n with this material it needs **≥ 350 °C at 20 bar**





Hydrogen yield rises sharply with temperature and pressure, especially from 10 to 30 bar at 450–500 °C.

Source: van de Velde, NIC

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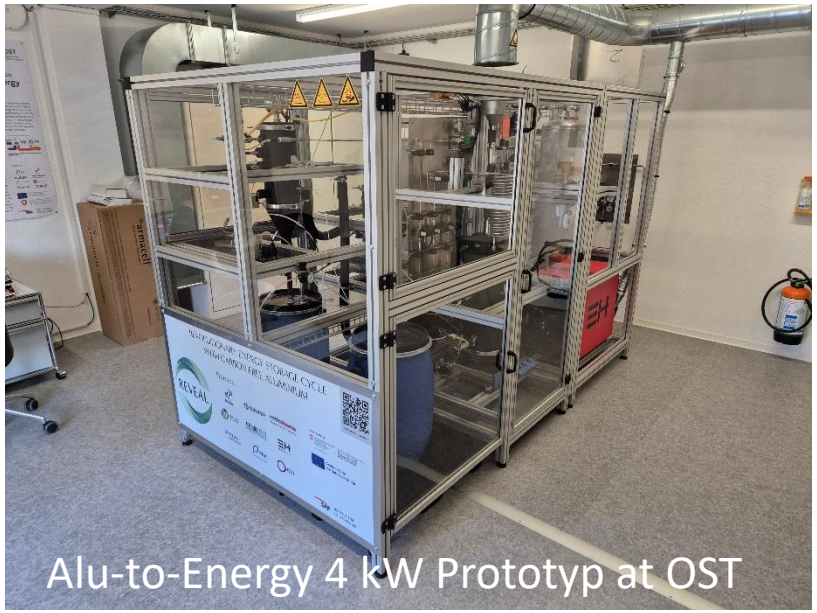
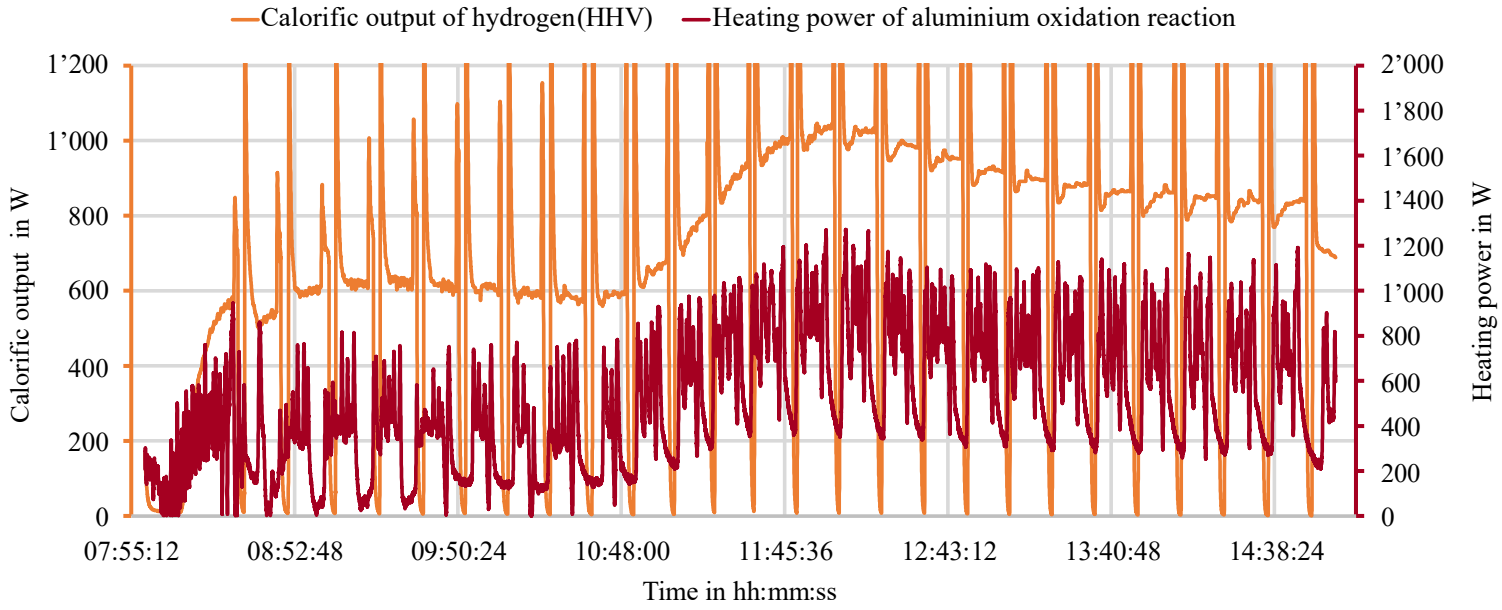
ALU-TO-ENERGY: 4 kW PROTOTYPE


Alu-to-Energy 4 kW Prototyp at OST



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LIFE CYCLE ASSESSMENT

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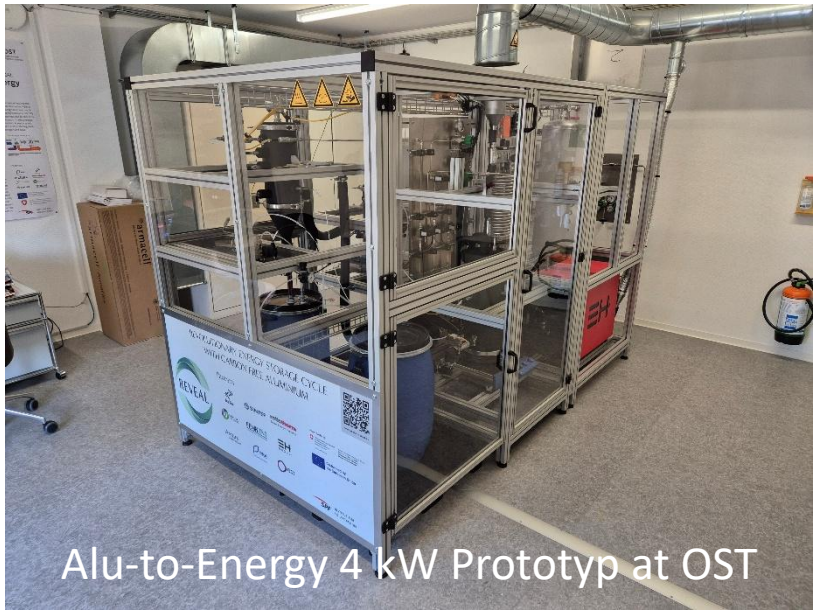
ALU-TO-ENERGY: CLOSED CYCLE

Aluminium granules



Alu-to-Energy 4 kW Prototyp at OST

Power-to-Alu at Arctus/IceTec

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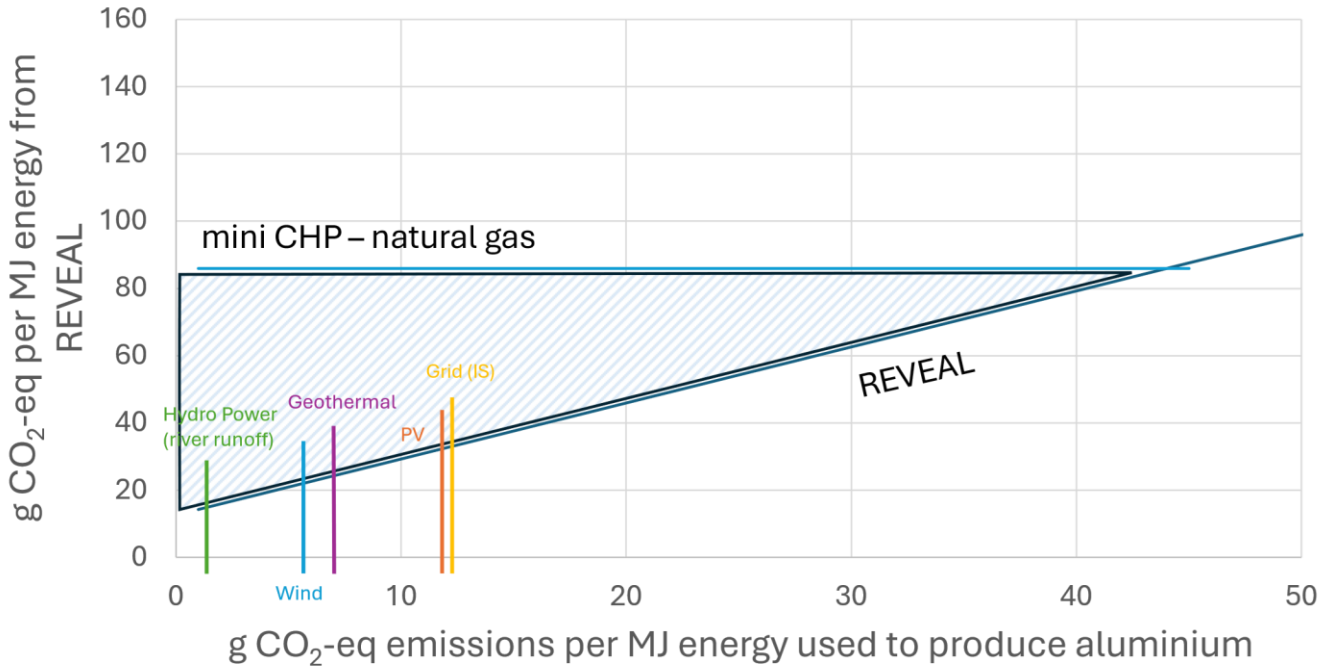
LIFE CYCLE ASSESSMENT

Global Warming Potential: CO_2 free aluminium cycle

- **No direct CO_2 emissions** from the aluminium production.
- **~60% of GHG emissions** from **electricity** input with PV-GWP of 10 g CO_{2eq}/MJ (dominant factor is Al electrolysis)
- **Transport between IS ↔ CH** via cargo ship, electric train, and last-mile diesel trucking accounts for only **~7% of total GWP**
- **Total aluminium cycle GHG emissions** are estimated at **15-34 g CO_{2eq} per MJ, depending on** electricity from wind, hydro or geothermal, grid (IS)



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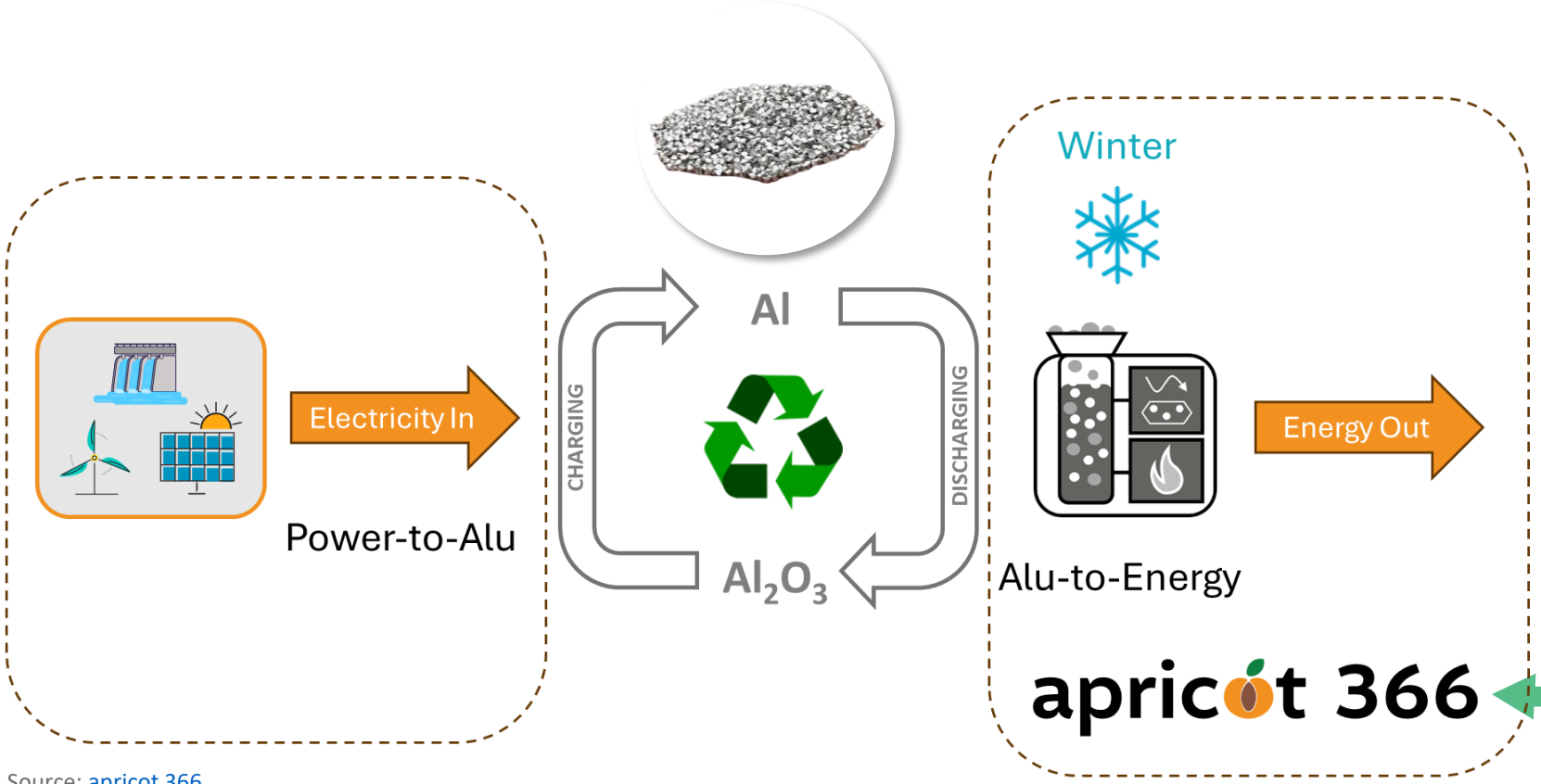
CLOSING THE MATERIAL CYCLE

Energy from CO_2-free aluminium: Circular economy



Source: apricot 366

apricot 366 is a **start-up** out of the REVEAL project, which uses aluminium from the inert anode process for producing hydrogen and heat.

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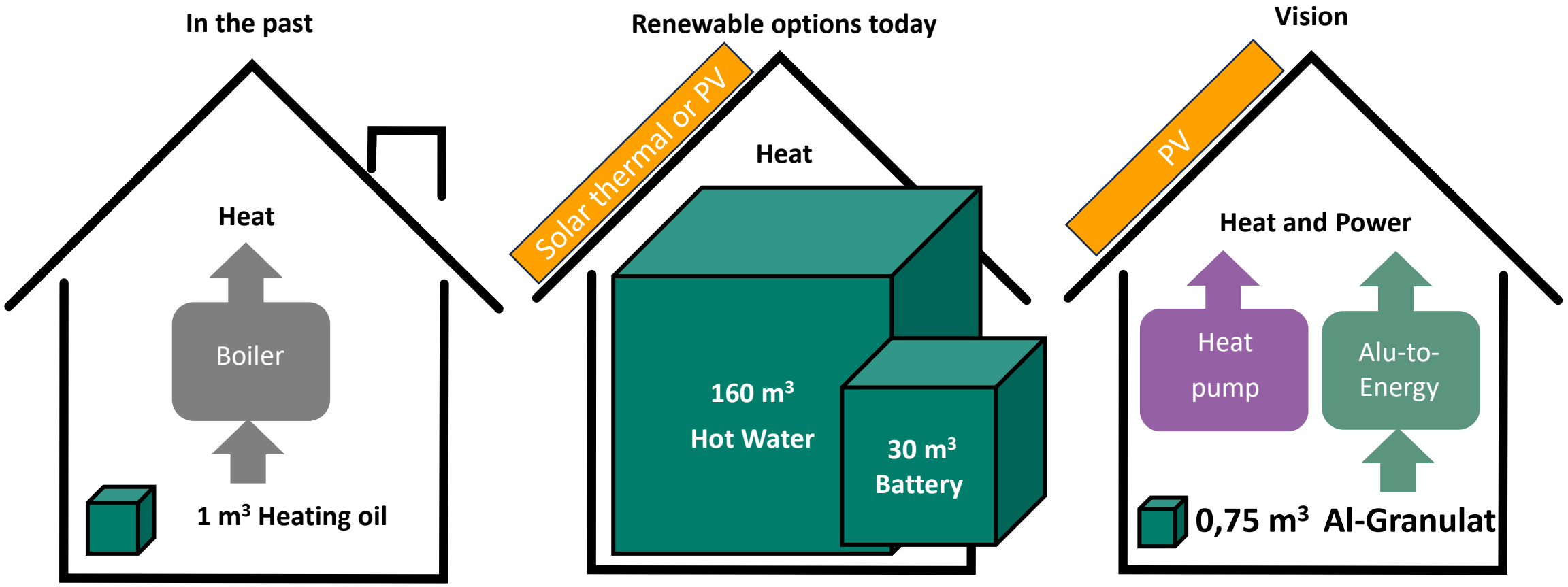
APPLICATION FOR HEAT AND ELECTRICITY



Storage volume requirement to provide a winter heat demand of **11 000 kWh.**

Source: OST-SPF

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THANK YOU!

REVEAL

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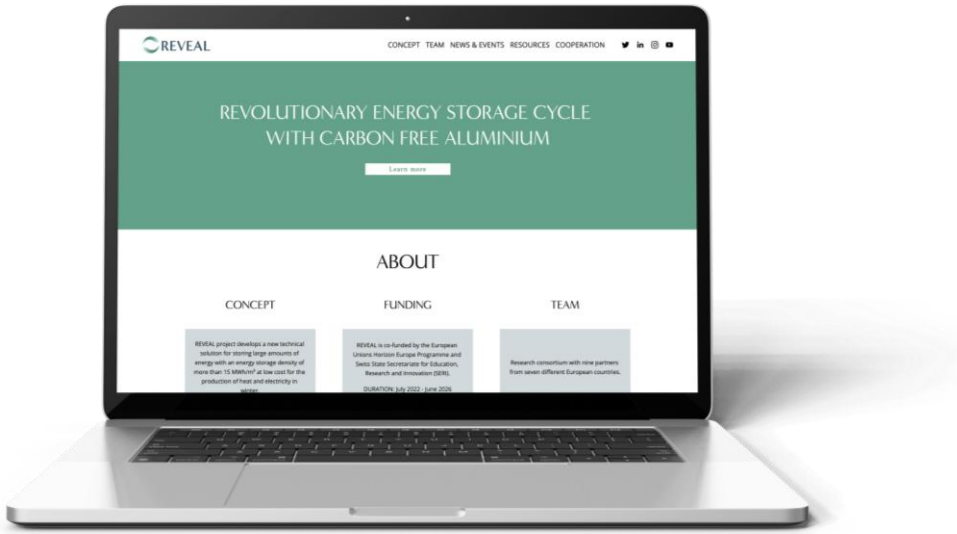

Authors and Contributors: Miren Agote Arán, Yvonne Bäuerle, Michel Haller, Simon Meier, Samuel Senanu, Nigel Van De Velde

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