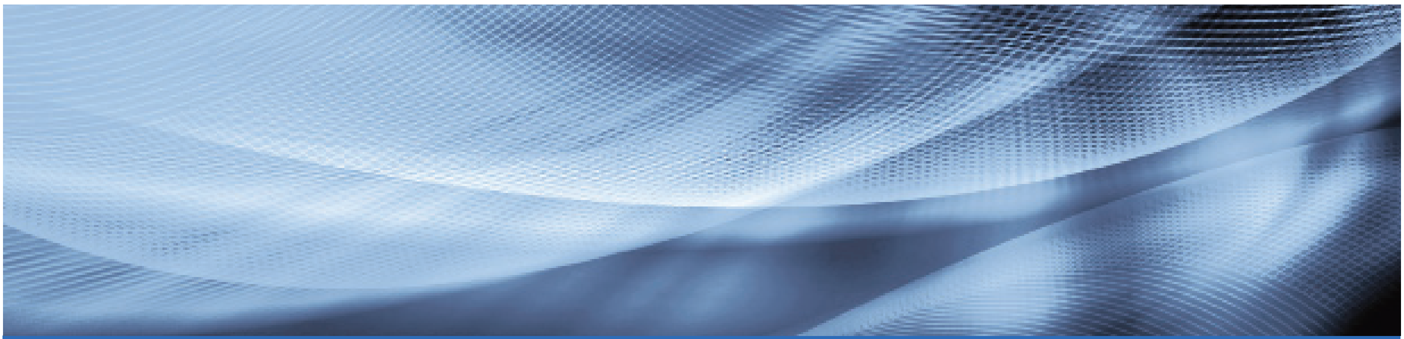
Metal-Air Battery

European Association for Storage of Energy



Electrochemical Energy Storage

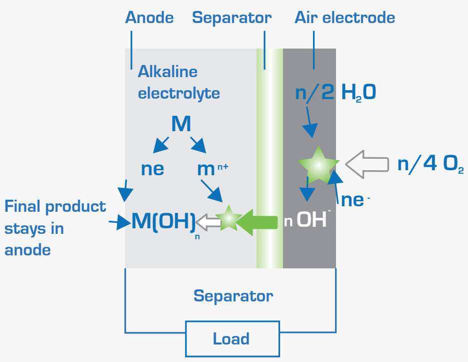
1. Technical description

A. Physical principles

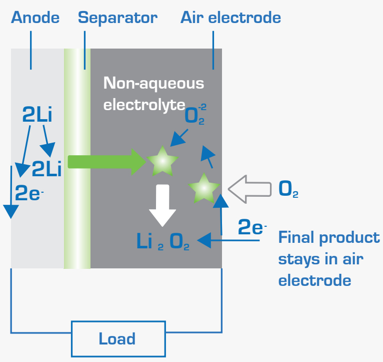
A Metal-Air (M-Air) battery system is an energy storage system based on electrochemical charge/discharge reactions that occur between a positive "Air Electrode" (cathode) and a negative "Metal Electrode" (anode). The negative electrode is typically made of metals such as Li, Zn, Al, Fe, or Na, while the positive usually contains some form of porous carbon material and a catalyst. The electrolyte can be of aqueous or non-aqueous nature as is typical for Li-Air systems.

Oxygen from the atmosphere diffuses through the porous carbon electrode, where a catalyst facilitates its reduction while the metal is oxidised in the anodic reaction. In the M-Air concept, most of the cell volume is occupied by the anodic material itself, thus leading to high energy densities.

Illustration: Charging principal of Metal-Air



$$M + N/4\,O_2 + N/2\,H_2O \rightarrow M(OH)_N$$



$$2Li + O_2 \rightarrow Li_2O_2$$

B. Important components

The main components are the following:

- Elementary cell composed of an assembling of electrodes, electrolytes and separators
- Modules composed of serial or parallel assembling of cells
- Battery systems composed of a large assembling of cells or modules and of a control system
- Power Conversion System (PCS)

C. Key performance data

Power range	Up to some Mw
Energy range	Up to some Mw
Discharge time	
Cycle life	
Life duration	
Reaction time	
Efficiency	75%
Energy (power) density	
CAPEX: energy	$ 160/kWh
CAPEX: power	$ 1,000/5Wh

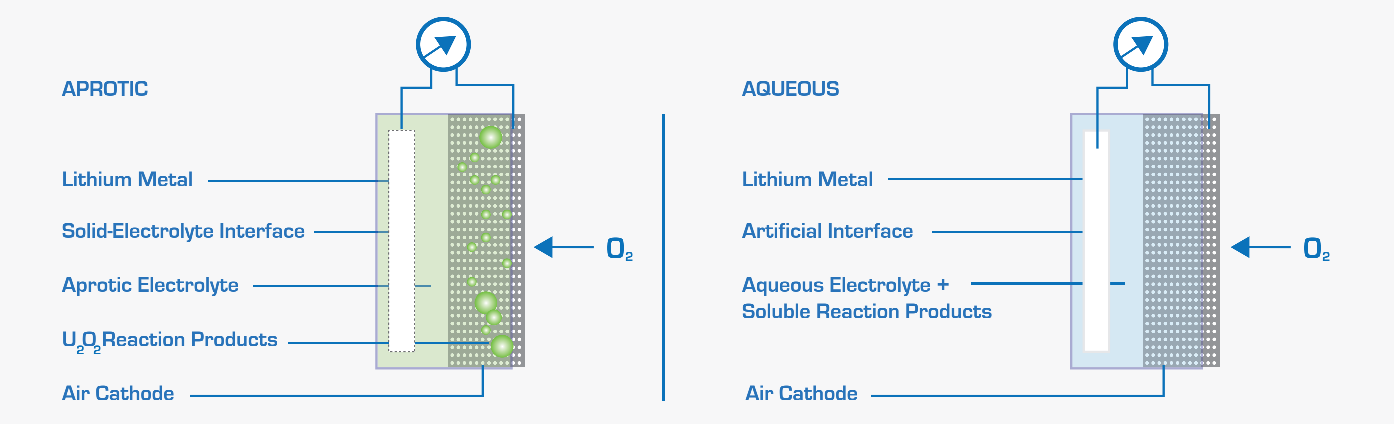
Not available at the commercial level for the energy storage application. Performance data depends on the used metal.

D. Design variants (non exhaustive)

The following design variants can be found:

- Different Metals: Li, Zn, Al, Mn, Na, Fe, etc.
- Different electrolyte type: aqueous or non-aqueous
- Different battery systems according to their size: case up to container

Illustration: Design variants



2. State of the art

M-Air battery systems have the highest energy density (Wh/kg) potential and prompt a lot of R&D work all over the world.

Some M-Air primary batteries are already developed and being marketed. Zn-Air has been commercially available for decades for consumer (e.g. hearing aids) and industrial applications.

The development of electrically rechargeable M-Air batteries is an attractive goal although it has not been fully proven yet. Other alternatives such as mechanical recycling are also being investigated, either by direct substitution of metal anodes in the form of solid sheets, or by regeneration of metal-rich anodic slurry that circulates through the cell via a pumping system.

Today, the M-Air technology is considered as one of the alternatives and successors for the Li-Ion battery and especially in the automotive industry. Some start-ups and companies in Israel and in the USA have developed prototype products.

A one MW DC battery system providing four continuous hours of discharge is expected to be sold at a price of around €150/kWh in volume.

State of the art

Metal-Air Battery	Calculated OCV, V	Theoretical specific energy, Wh/kg	
		Including oxygen	Excluding oxygen
Li/O_2	2.91	5,200	11,140
Na/O_2	1.94	1,677	2,260
Ca/O_2	3.12	2,990	4,180
Mg/O_2	2.93	2,789	6,462
Zn/O_2	1.65	1,090	1,350

3. Future developments

Future developments are mainly devoted to the following points:

- Improvement of the current performances of Zn-Air & Li-Air systems (Set-Plan Materials)
- Study & Development of new M-Air systems: Al-Air, Fe-Air, V-Air, Na-Air (SET-Plan Materials)
- The development of electrically rechargeable M-Air batteries
- Improvement of the reversibility of the Metal-Oxygen reactions
- Demonstration projects

4. Relevance in Europe

M-Air technology can be considered one of the candidates to succeed Li-Ion in the upcoming (10 to 15) years. Because of its high energy density perspective, it will be able to contribute to the European Low- Carbon Energy System.

5. Applications

Due to their high scalability and energy density, M-Air batteries can be used in a large variety of applications:

Large-scale stationary energy storage applications - preferably in combination with renewable wind or solar power systems to compensate the intermittent nature of these renewable power sources

Transportation: due to its high energy density, M-Air batteries would increase the autonomy of the current electric vehicles.

Renewable generation: smoothing and shaping functions associated with voltage and frequency support to ensure better integration of large renewable plants into the electricity system

6. Sources of informations

- EASE Members
- DOE (ARPA-E)
- MIT Technology Review
- Cegasa
- EOS Energy Storage
- IK4-CIDETEC

Avenue Lacombé 59/8 - B - 1030 Brussels - tel: +32 02.743.29.82 - fax: +32 02.743.29.90 - info@ease-storage.eu - www.ease-storage.eu