elestor

electricity storage at an unrivalled cost level

Content

WINNER Best Technical Development in Energy Storage
IDTechEx AWARD

Electricity storage at an unrivalled cost level

Only the storage technology offering operational costs low enough to create an attractive return on investment has sufficient leverage to boost the energy transition.

Elestor's breakthrough flow batteries store electricity at only a fraction of the costs of conventional batteries, safely and with a very long lifetime.

"With Elestor's technology an **LCoS below € 0.05 per kWh is achieved**"

Triple cost reduction strategy

Elestor introduces a storage technology able to reduce the cost of electricity storage to an absolute minimum. This is why low cost and abundant active materials are used, in combination with a patented, simplified system design and easy to manufacture compact cells. This triple cost reduction strategy results in the lowest possible cost for storing electricity.

The keys to the ultra-low cost of storage are:

1 The flow battery concept

2 The choice for hydrogen and bromine

3 Elestor's patented system design

Cost of Storage below € 0,05 per kWh

Impact on the energy transition
To prevent the energy transition from coming to a halt, a huge capacity of electricity storage is required. It is, however, decisive for the adoption of a storage technology, and thus for its impact on the energy transition, to create viable business cases around storage. To accomplish this, a storage technology must offer very low storage cost per kWh. It is Elestor's mission to reduce these costs to an absolute minimum.

Levelized Cost of Storage (LCoS)
Storage costs, also known as Levelised Cost of Storage or LCoS, define what it really costs to store 1 kWh of electrical energy. In the LCoS calculation the properties Capex (€), Lifetime (cycles), Efficiency (%) and usable Capacity (%) are taken into account. All these factors must be included in the calculation in order to come to a true figure for storage costs per kWh.

With Elestor's technology an LCoS of as low as € 0.05 per kWh is achieved and with larger capacity-to-power ratios even beyond. This figure is based on a lifetime of 10,000 cycles, full use of capacity (100% Depth of Discharge), and a round-trip system efficiency of 65-75%.

The LCoS is defined as:

$$\text{LCoS} = \frac{\textbf{Total costs during the system's lifetime (€)}\ \text{(Investment + Maintenance)}}{\textbf{Total delivered energy during the system's lifetime (kWh)}\ \text{(Lifetime (cycles), Capacity (kWh), Roundtrip Efficiency (\%))}}$$

FACT:

With an unrivalled low cost of storage, **Elestor's solution changes storage from a pure cost factor into viable business cases**

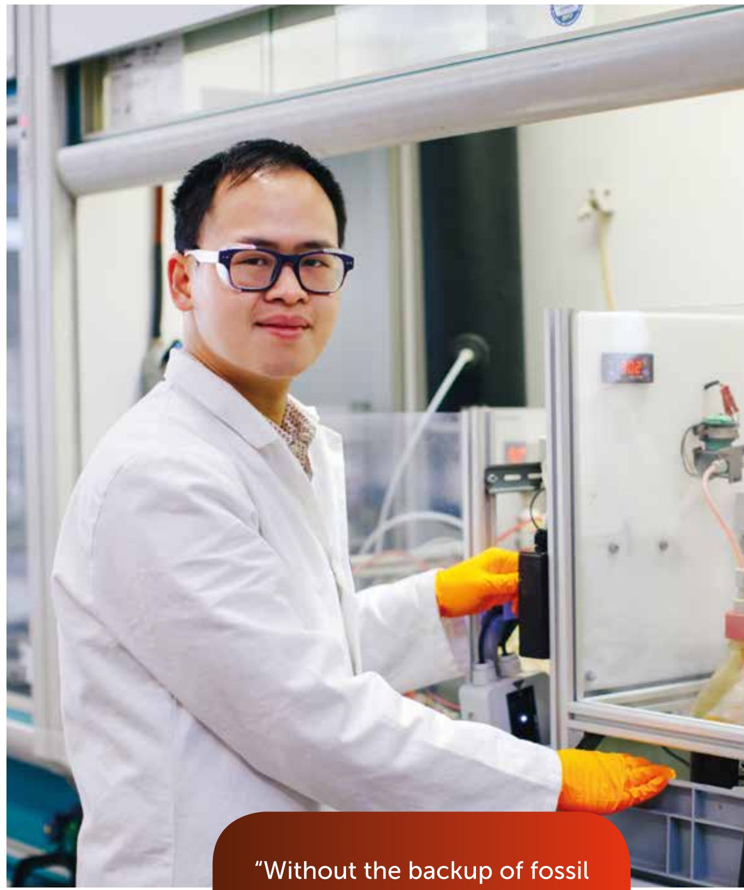
Elestor perfectly matches the changing world

Climate targets
To reach climate targets, fossil power plants will progressively be shut down and the dependency on intermittent sources, like sun and wind, will largely increase. This is where storage of electricity comes in: Storage guarantees continuous availability of electricity, irrespective of when the electrical energy is generated.

But not just any storage technology will do that job...
Without the backup of fossil power plants, the world increasingly needs storage systems with a large capacity (MWh) rather than with a high power (MW). Conventional storage technologies immediately become far too expensive to fulfil these changing needs: As power and capacity scale up simultaneously, a battery with a very high capacity also comes with a very high power.

Scalable
In contrary to conventional technologies, Elestor offers the freedom to choose any desired combination of power and capacity. Due to its modular concept, both power and capacity can be adjusted independently to fit possible changing needs in the future.

With this unique property, Elestor introduces a technology that secures long term supply of electricity, on a very large scale, and in the most cost-effective way.



"Without the backup of fossil power plants, **the world needs storage with very large capacities**"

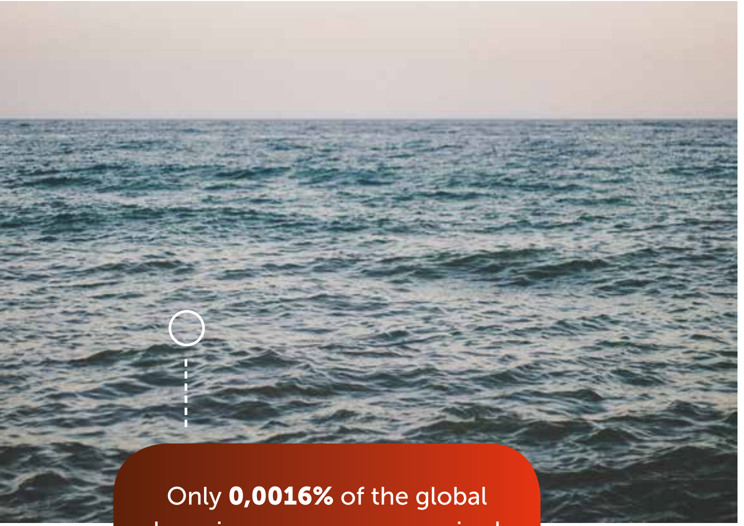
FACT:

Elestor's flow battery technology offers independent selection of storage power and capacity, and **any thinkable combination is possible**

Bromine: Global availability at virtually unlimited quantities

Based on the huge growth of renewable energy systems, a global storage capacity of 500 TWh (see text frame) will have to be installed to create a fully decarbonized electricity supply by 2050. The only way to, also economically, realise this capacity is to select active materials with tremendous global reserves.

The element Bromine as selected for Elestor's Hydrogenbromide (HBr) flow battery is found in seawater, evaporated (salt) lakes and underground brines. Free bromine does not occur in nature, it only occurs as colourless soluble crystalline salts, analogous to table salt.



Only **0,0016%** of the global bromine reserves are required for a **100% decarbonized electricity suply**

Advantages of Bromine

The high solubility of bromide ions has caused its accumulation in all oceans worldwide. As such availability is not limited to specific geographic locations around the world.

Bromine is cost-effectively extracted on a very large scale and does not involve polluting processes or severe, even torturous, working conditions.

Seawater contains about 65 parts per million of bromine, resulting in reserves of approx. 100 trillion tons worldwide, a quantity millions of times larger than any of the materials used in conventional batteries.

From all materials that in theory could be used to design a flow battery, Elestor selected hydrogen and bromine, based on Elestor's mission to introduce a storage system with ultra-low storage costs per kWh. This can only be accomplished with abundant, inexpensive materials, available throughout the globe without geographic constraints.

Other advantages of bromine are that it enables a high power density [W/m^2] as well as a high energy density [kWh/m^3], both further contributing to the reduction of storage costs per kWh.

Due to its high reactivity, bromine is extremely well suited for electricity storage and enables system designs with ultra-short reaction times. Being a chemical element, bromine can be fully recycled, which contributes to creating a full circular society.

Estimation of the required global storage capacity in 2050:

- The global energy consumption tripled between 1965 and 2015 to a total of 50.000 TWh per year
- Until 2050 electricity consumption is to double to 100.000 TWh, due to:
  - Further electrification (electrical vehicles, heat pumps)
  - Population growth (7,2 billion in 2012 to 9,6 billion in 2050)
  - Higher average living standards worldwide
- For reserves covering at minimum 2 days, during which hardly or no electricity is generated, a storage capacity of at least 500 TWh is necessary

Scarcity leads to large cost increases

Conventional storage technologies based on materials with limited reserves will simply not be able to create sufficient storage capacity to accelerate the energy transition. Already today scarcity leads to large cost increases, causing an increase of cost of storage rather than the much needed decrease. A second important cost driver of these materials is formed by constraints in geographic availability, creating large dependencies on a limited number of locations.

Material	Global reserves (Kilotons)	Usage (kg/kWh)	Sufficient for ...% of required capacity	Supply & cost contraints
3 Li Lithium Li-ion batteries	16.000 [2]	0,9 [3]	4%	- >90% of global reserves in 4 countries: Chile, China, Argentina, Australia. - Oligopoly, no price pressure - Mining creates large scale depletion and pollution of groundwater
27 Co Cobalt Li-ion batteries	7.100 [4]	0,2 [5]	7%	- Approx. 60% of global reserves in 1 country: Congo, extreme geographic dependency - Mined under torturous labour conditions
23 V Vanadium Vanadium Redox Flow batteries	20.000 [7]	4,4 [8]	1%	- 85% of the global supply comes from China, Russia, South Africa - Cost increased >400% from US$ 13.50/kg in 12-2015 to US$ 68/kg in 5-2018 - 90% of the Vanadium supply is used for hardening steel
35 Br Bromine Hydrogen Bromine Flow batteries	100.000.000.000	3,2	100%	+ Only 0,0016% of the global bromine reserves are sufficient for a 100% decarbonized electricity supply

[1] www.earthmagazine.org/article/mineral-resource-month-bromine
[2] investingnews.com/daily/resource-investing/battery-metals-investing/lithium-investing/lithium-reserves-country/
[3] www.deingenieur.nl/artikel/lithium-and-cobalt-shortage-by-2050
[4] investingnews.com/daily/resource-investing/battery-metals-investing/cobalt-investing/cobalt-producer-cobalt-reserves/
[5] energypost.eu/the-rush-for-cobalt-and-what-it-means-for-evs/
[6] www.chemistryworld.com/news/battery-builders-get-the-cobalt-blues/3008738.article
[7] investingnews.com/daily/resource-investing/battery-metals-investing/vanadium-investing/vanadium-reserves/
[8] www.bushveldminerals.com/wp-content/uploads/2018/11/Energy-Storage-Vanadium-Redox-Flow-Batteries-101.pdf

FACT:

Cost of bromine is not an issue today **nor will it ever be in the future**

The Hydrogen Bromine Flow Battery

Elestor's storage systems are based on Hydrogen Bromine Flow Battery concept. Originally developed by NASA and already in the 1980's proven to last for more than 10,000 charge-discharge cycles, Elestor has matured this technology, enabling cost-effective storage for a large variety of stationary industrial applications.

"The active materials are only used, **not consumed**"

Elestor's proprietary system and stack design offers a unique set of advantages:

Nothing goes in or out… except electricity

Since the chemical (dis)charge reactions are 100% reversible, the storage capacity remains unchanged during lifetime. The active materials are only used, not consumed. This implies that the system's storage capacity remains unchanged during its lifetime.

No self-discharge

As the electrical energy is not stored in electrodes but in separate tanks, the system does not show self-discharge. This allows storage of large capacities over very long periods of time without losing energy.

100% Depth of Discharge

With a Depth of Discharge of 100%, the system's storage capacity can be fully utilized without affecting its lifetime.

Replacing stacks gives a system a full 2nd life

At end-of-life (10,000 cycles), the stack modules can be replaced, while the system itself including active materials remains unchanged. With new stacks, the system is given a full 2nd life.

Electrolyser and Fuel Cell with one single membrane

Elestor's cell design combines 2 electrochemical processes with 1 single membrane: The cell is operated as an electrolyser during charge and as a fuel cell during discharge.

Above properties – unique for Elestor's flow battery – add up to unprecedented low storage costs, significantly lower than can be reached with any of the conventional batteries.

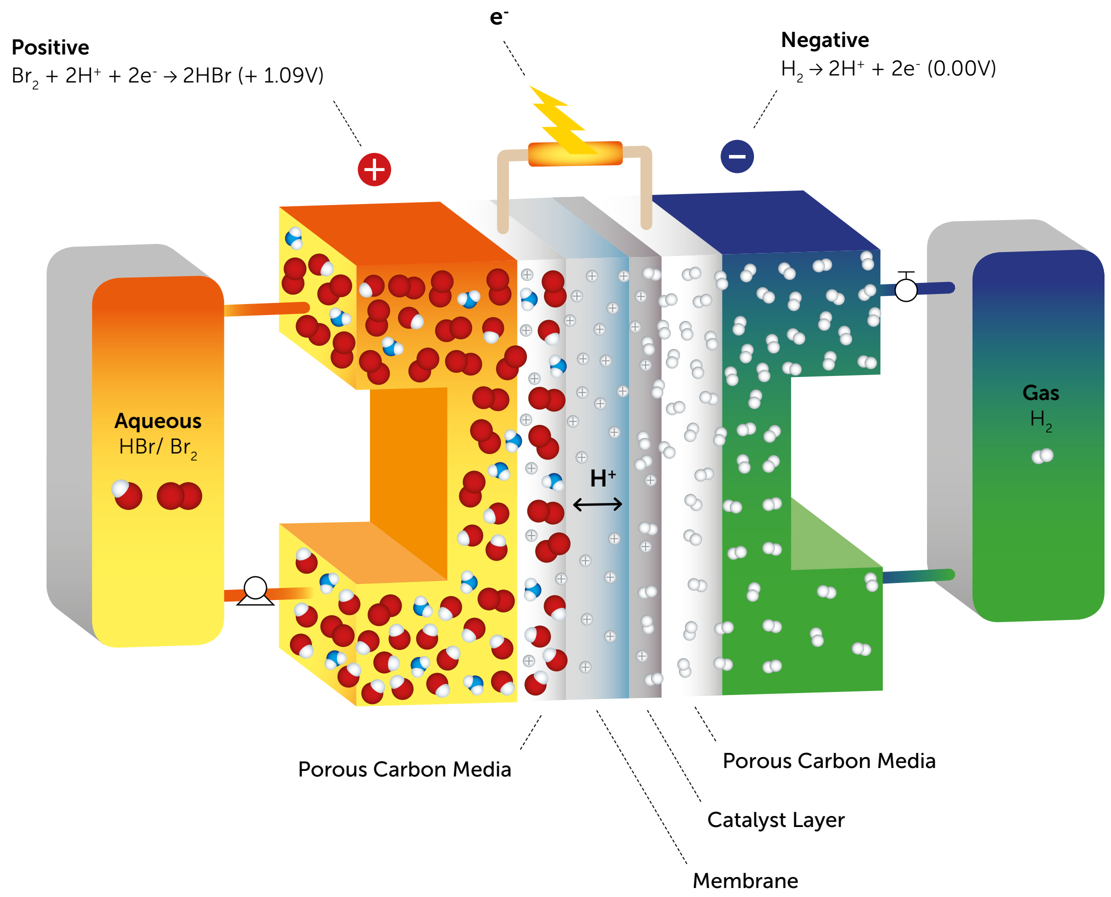
Working principle

A hydrogen bromine flow battery is a rechargeable storage system in which HBr serves as the system's electrolyte. The assembly in the centre of below image depicts Elestor's electrochemical single cell, which is the heart of the storage system. In practice, a so-called stack is assembled, consisting of a large number of such cells, stacked and connected in series.

The membrane surface area determines the power (MW) of the system and the tank volumes the capacity (MWh). Both can be chosen independently in any desired combination.

- During the charge cycle, HBr is split in H^+ and Br^- ions. The H^+ ions cross the membrane, absorb an electron, and are stored as hydrogen gas (H_2) in a separate tank. The resulting bromine (Br_2) is dissolved in the same tank as the HBr.
- During the discharge cycle H_2 is recombined with Br_2, forming HBr again, while the stored energy is released.

Elestor's HBr flow battery combines electrolyser and fuel cell functionality with 1 single membrane. The (dis)charge processes do not suffer from degradation and the system is self-contained with no emissions.



FACT:

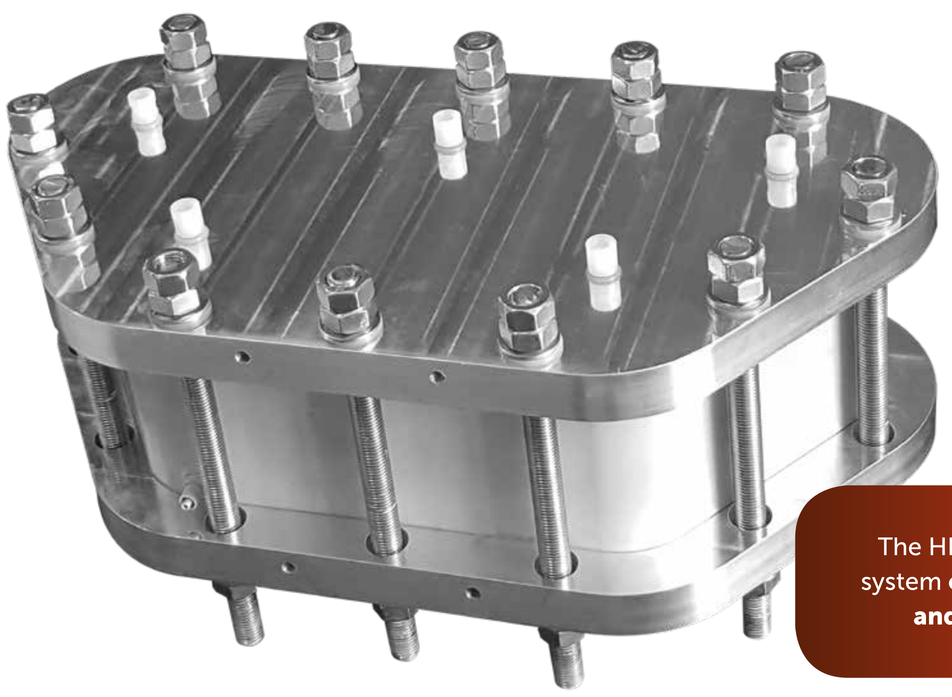
Originally developed in 1961 by NASA, **already in the 1980's more than 10,000 charge-discharge cycles were demonstrated**

A unique and patented system design

A simple yet robust membrane stack
The patented cell design offers following advantages:

- The system does not require a compressor to generate H_2 pressure. A H_2 compressor is costly, consumes energy and requires maintenance.
- The stacks are simple yet robust and easy to manufacture. Already in the design phase, high volume automated production was anticipated.
- With the stack design, manufacturing costs are largely reduced.

Accessible and Upgradable like a Machine
The Elestor system shows a high resemblance with a machine rather than with a closed battery pack. All parts (stacks, circulation pumps, valves, control electronics etc.) are easily accessible for maintenance. Unlike the typical closed battery packs of conventional storage technologies, the HBr flow battery system can be serviced and upgraded.



The HBr flow battery system **can be serviced and upgraded**

FACT:

Exchange of membrane stacks **gives the system a full 2nd life**

Technical details

General

Storage system

Technology	Hydrogen Bromine flow Battery
Power range	50 kW to 50 MW
Capacity range	250 kWh to 250 MWh
Power-Capacity combination	Free selectable

Performance

Lifetime	10,000 charge-discharge cycles
Depth of Discharge	100% (not affecting lifetime)
Self-discharge	Negligible
Roundtrip efficiency	65-75% (total system including inverters)

Control & Monitoring

Ability to remotely monitor and control the storage system
Automated safety system including H_2 and Br_2 detection
Ability to connect with local on-site alarm system

Energy Management System connection

Accepts a large range of Energy Management Systems
Communication with various industrial protocols, e.g. TCP/IP, Modbus, MQTT
Input: Selection of charge or discharge power
Output: Actual power, System status, State of charge, Max. available charge / discharge power

Electrical connections

Power connection	400VAC 3P+N+PE *(other outputs, incl DC, on request)*
Frequency	50/60 Hz
Includes net protection relay	
Safe state mode with power shutdown	

Housing and environmental conditions

Enclosure	IP54
Ambient temperature	0 to 45°C
Ambient temperature with cold pack option	-25 to 45°C

Marking

CE; IMO CSC 2012

Site requirements

Concrete slab-on-grade foundation

Typical storage system (example)

Container 1: Hydrogen tank

Container 2: Stacks and electrolyte tank

Configuration

Power	200 kW
Capacity	2,000 kWh

Physical properties

• 2 each 40 ft high cube containers	
Size LxWxH [m]:	12.2 x 2.4 x 2.9 each
• Container for hydrogen	
Tare weight [tonnes]:	14
• Container for stacks and electrolyte tank (reinforced)	
Tare weight [tonnes]:	17
Gross weight [tonnes]:	42
Transportable as standard 40ft ISO container	

System configuration

Hydrogen tank volume [m^3]	45
Max. hydrogen pressure [Bar]	20
No. of stacks	25

“**We will make electricity so cheap** that only the rich will burn candles”

Thomas A. Edison

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