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THE SILICON BATTERY

This is SILBAT
The Silicon Battery

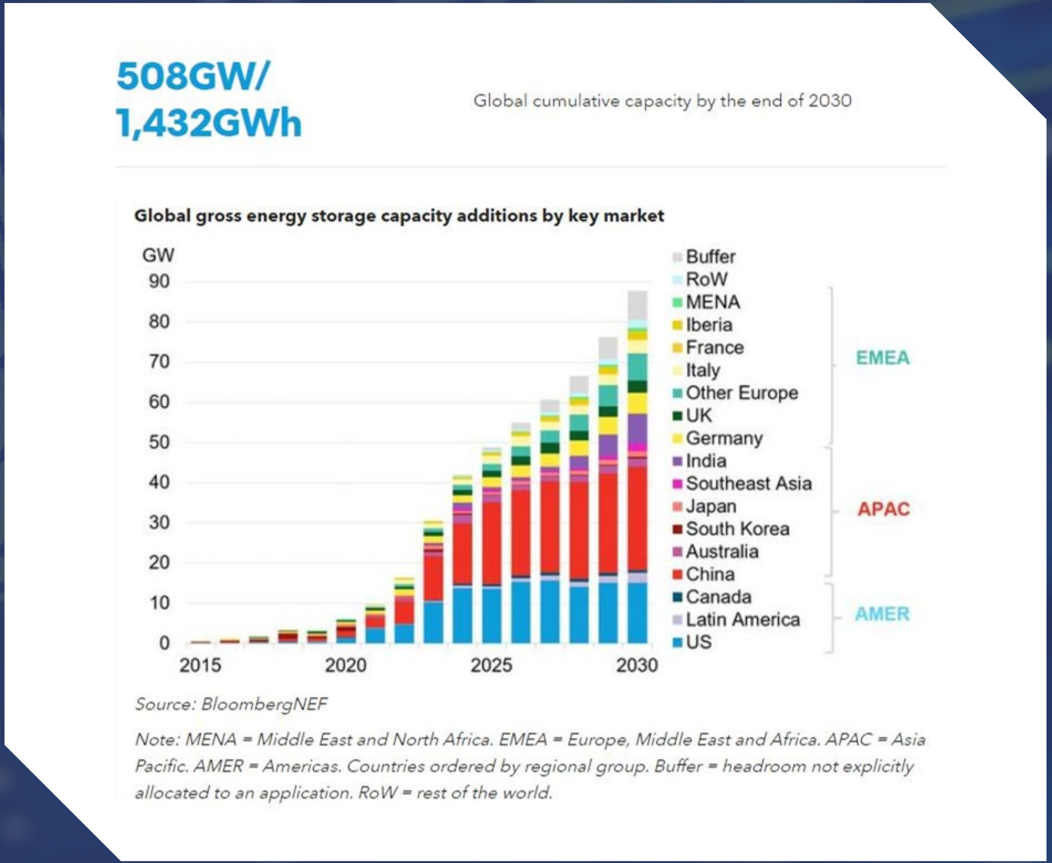
Energy Transition

Novel technologies for intermittent renewable energy sources

By 2050, Renewable Energy Sources (RES), mainly solar and wind, must supply **50% of World's energy consumption** to achieve Net Zero goal (IEA).

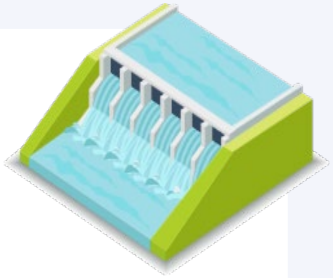
A **massive increase in electricity storage capacity** will be required to make intermittent RES fully dispatchable, meaning available around the clock

To make this feasible and cost-effective, we need **multiday (≈100 hours)** Long Duration Energy Storage (LDES) with energy-related CAPEX **below $20/kWh*.**



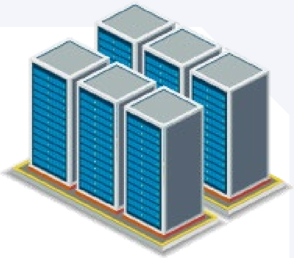
*Research from MIT (Ziegler et al., Joule 3, 2019, 2134–2153)

Current solutions for LDES are ineffective, expensive and unsustainable



Pumped hydroelectric storage (95% LDES)

- Low energy density and high cost ($80/kWh)
- Only suitable in particular orographic and weather conditions
- Large environmental footprint
- Non-modular, non-portable



Li-ion batteries

- Very high installed costs over $200/kWh
- Used for low energy storage duration (< 8 hours)
- Based on critical raw materials that can create social and geopolitical stress.
- Flammable electrolytes susceptible to thermal runaway and explosion

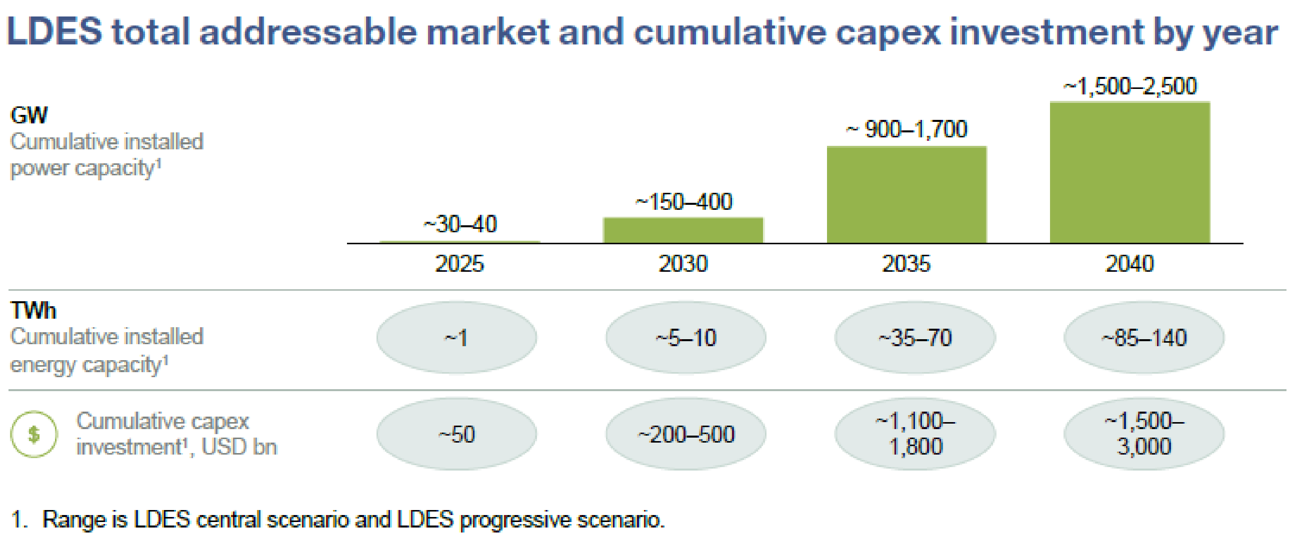
An unsolved problem with a huge TAM

$200–500 billion

According to McKinsey, **LDES is expected to attract $200–500 billion in investment by 2030 and grow 10x by 2040.**

It is primarily a stationary storage market, serving both **off-grid and on-grid applications**

- Energy for industries and critical facilities (hospitals, military, telecom, data centers, etc.) having remote or unreliable grid
- Firming Power Purchase Agreement for RE plants
- Energy shifting, capacity provision, Transmission & Distribution optimization
- Isolated island grid optimization



[20] Central scenario: assumes first-quartile costs for LDES, conservative learning rates, and new-build nuclear capped at previous peak, and retired as planned. Progressive scenario: assumes first-quartile costs for LDES, aggressive learning rates, no new-build nuclear, and retired as planned.

Net-zero power: Long duration energy storage for a renewable grid | LDES Council, McKinsey & Company

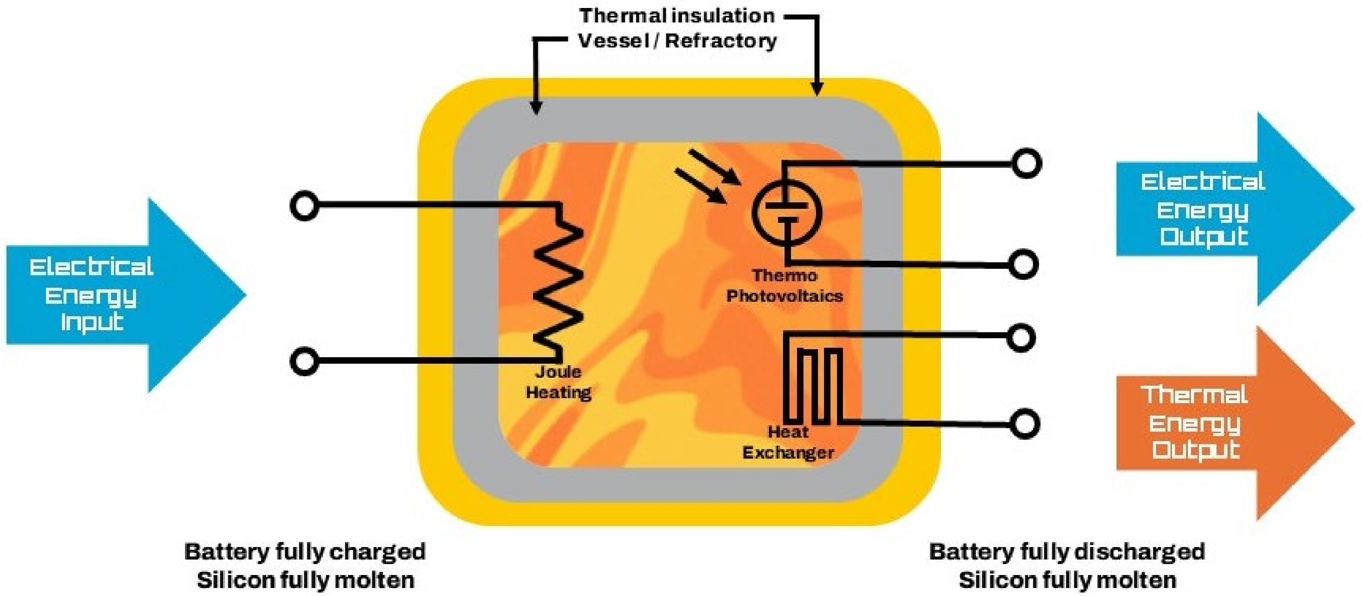
We solve it! The Melting Silicon Battery

P2H2P

Electricity is stored as Latent Heat in melting Silicon with electricity extraction through ThermoPhotovoltaics

P2H

We are developing in parallel a heat exchanger that can be integrated into the main unit and can, ultimately, produce heat for industrial processes



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A Unique Value Proposition

Low cost

Silicon costs $1.2/kg (Oct. 2025), enabling CAPEX as low as <$15/kWh

High Energy Density

Melting point of 1414°C with an extremely high latent heat of fusion (1154 kWht/m3) – 2nd highest after Boron

30 yrs. life-time with low O&M

vs. Li-Ion max. ~20yrs. life-time with 40% degradation

Adaptable: Rating values decoupled

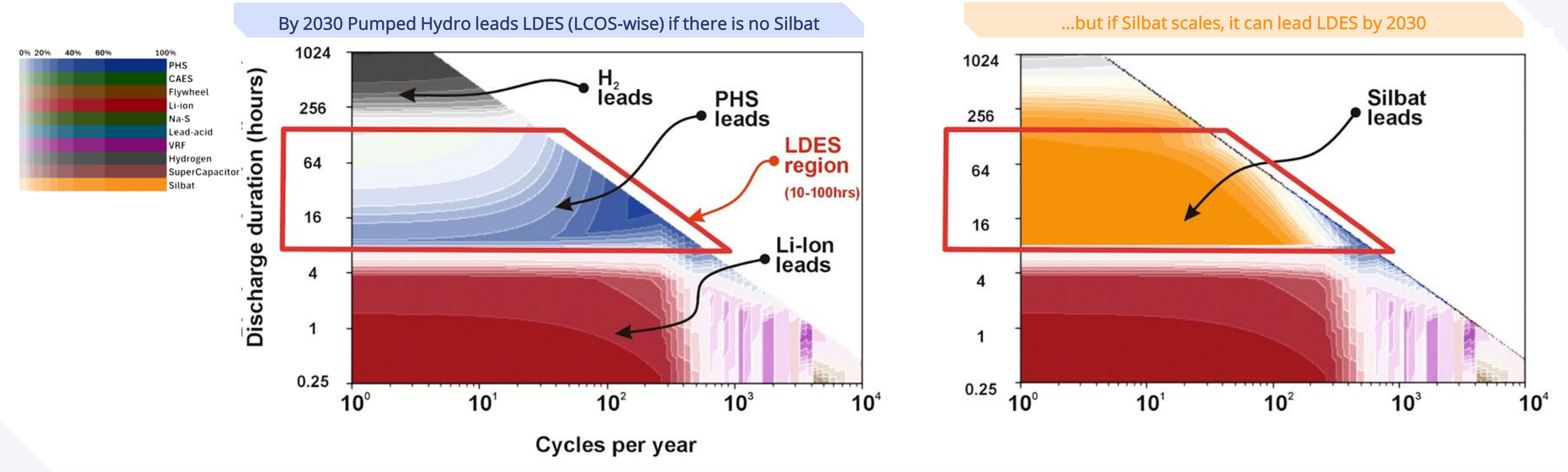
Charge and discharge power, and capacity, can be sized separately and optimally for each application

Highly Abundant & Widely Found Raw Materials

>1000X more than Li-Co-Ni-Mn in mainstream Li-Ion batteries

Size of the opportunity

- **LDES TAM by 2040 85-140TWh and $1.5-3tr** according to LDES Council
- Silbat's LCOS can clearly outperform that of Pumped Hydro Storage (leading commercial LDES now)



We are developing also combined **heat delivery output**: **TAM of 200-400C TES is 3100TWh by 2030**

Who we are

POLITÉCNICA
Instituto de Energía Solar

INSTITUTO DE ENERGÍA SOLAR
Innovation in photovoltaics since 1979

- Technology foundations are set by IES-UPM starting in 2011. **SILBAT is a 2019 startup founded to move technology from lab to market.**

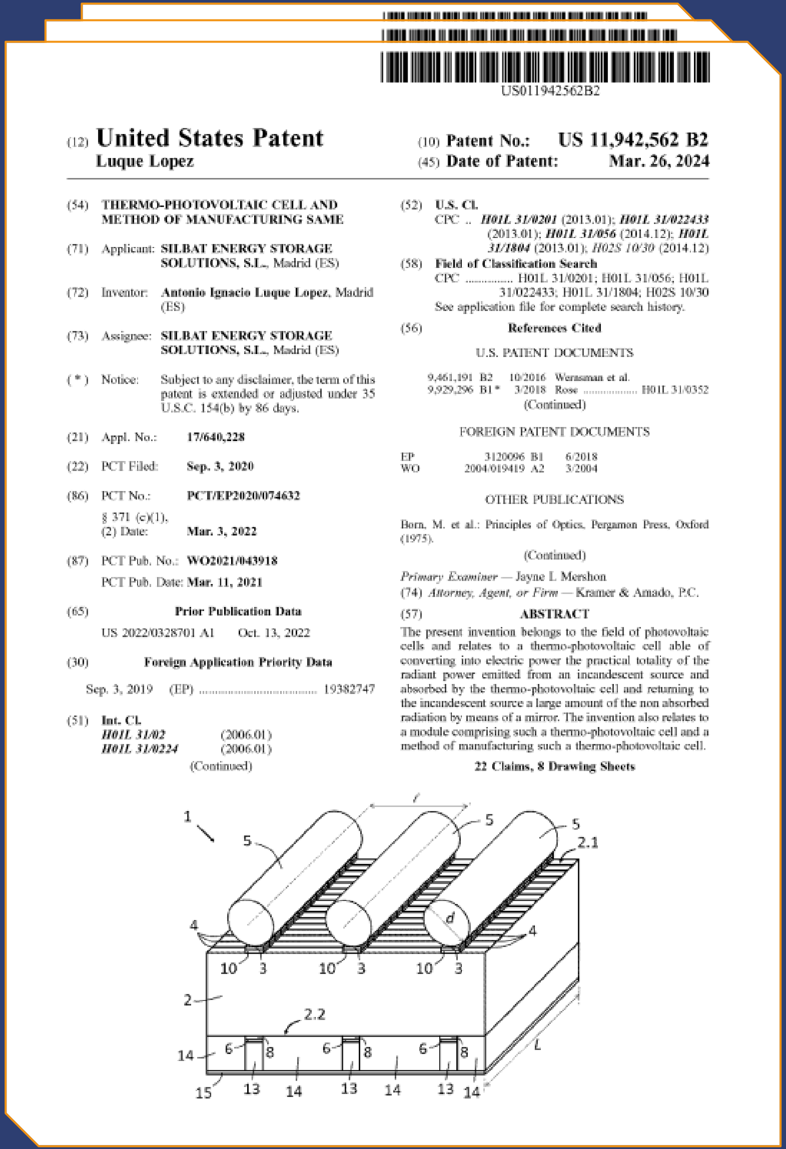
- So far it has obtained **10.5M€ in seed capital + grants.**

IPR assets

- Filed **10 patents**
- **5 regions**

(US, EU, KR, JP, CN)

- 3 patent families
- **8 patents already granted**



US011942562B2

(12) **United States Patent**
Luque Lopez

(10) **Patent No.: US 11,942,562 B2**
(45) **Date of Patent: Mar. 26, 2024**

(54) **THERMO-PHOTOVOLTAIC CELL AND METHOD OF MANUFACTURING SAME**

(71) Applicant: **SILBAT ENERGY STORAGE SOLUTIONS, S.L.**, Madrid (ES)

(72) Inventor: **Antonio Ignacio Luque Lopez**, Madrid (ES)

(73) Assignee: **SILBAT ENERGY STORAGE SOLUTIONS, S.L.**, Madrid (ES)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 86 days.

(21) Appl. No.: **17/640,228**

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§ 371 (c)(1),
(2) Date: **Mar. 3, 2022**

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PCT Pub. Date: **Mar. 11, 2021**

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(30) **Foreign Application Priority Data**
Sep. 3, 2019 (EP) 19382747

(51) **Int. Cl.**
H01L 31/02 (2006.01)
H01L 31/0224 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC .. ***H01L 31/0201*** (2013.01); ***H01L 31/022433*** (2013.01); ***H01L 31/056*** (2014.12); ***H01L 31/1804*** (2013.01); *H02S 10/30* (2014.12)

(58) **Field of Classification Search**
CPC H01L 31/0201; H01L 31/056; H01L 31/022433; H01L 31/1804; H02S 10/30
See application file for complete search history.

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Primary Examiner — Jayne L Mershon
(74) *Attorney, Agent, or Firm* — Kramer & Amado, P.C.

(57) **ABSTRACT**

The present invention belongs to the field of photovoltaic cells and relates to a thermo-photovoltaic cell able of converting into electric power the practical totality of the radiant power emitted from an incandescent source and absorbed by the thermo-photovoltaic cell and returning to the incandescent source a large amount of the non absorbed radiation by means of a mirror. The invention also relates to a module comprising such a thermo-photovoltaic cell and a method of manufacturing such a thermo-photovoltaic cell.

22 Claims, 8 Drawing Sheets

证书号第7927903号

专利公告信息

发明专利证书

发 明 名 称：热光伏电池及其制造方法

专 利 权 人：西尔巴特储能方案有限公司

地　　　址：西班牙马德里

发　明　人：安东尼奥·伊格纳西奥·卢克·洛佩兹

专　利　号：ZL 2020 8 0077036.3　　授权公告号：CN 115004379 B

专利申请日：2020年09月03日　　授权公告日：2025年05月09日

申请日时申请人：西尔巴特储能方案有限公司

申请日时发明人：安东尼奥·伊格纳西奥·卢克·洛佩兹

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局长
申长雨

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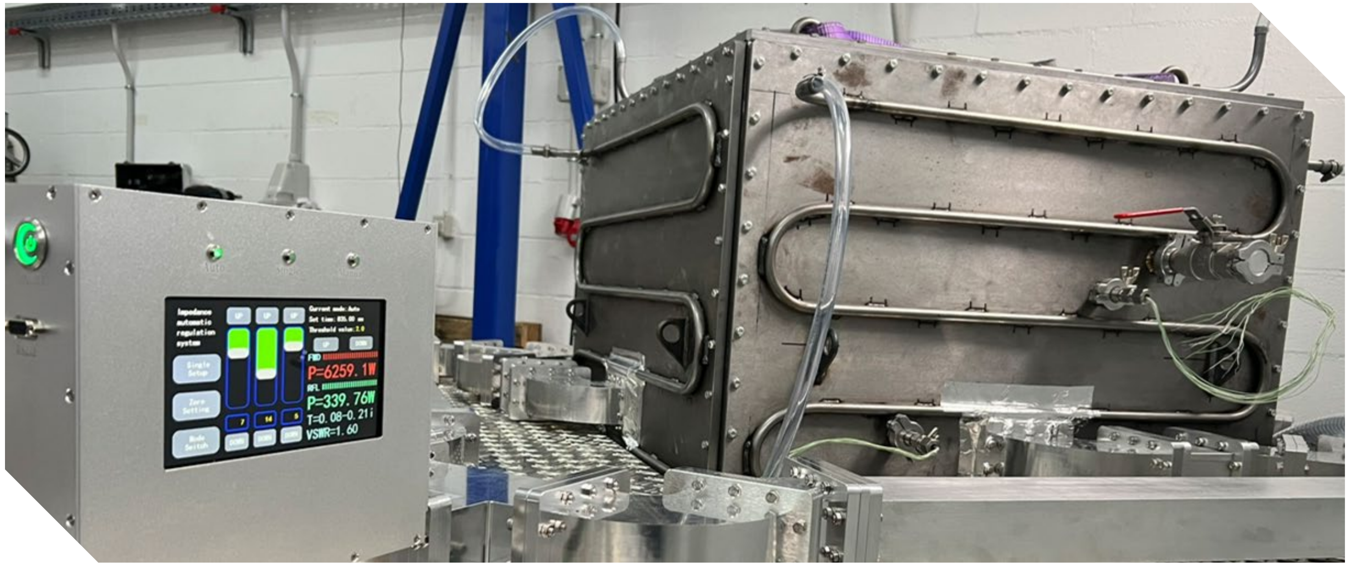
2025年05月09日

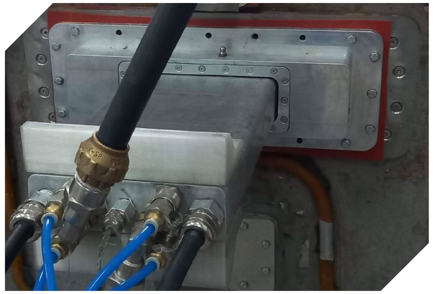
第 1 页 (共 1 页)

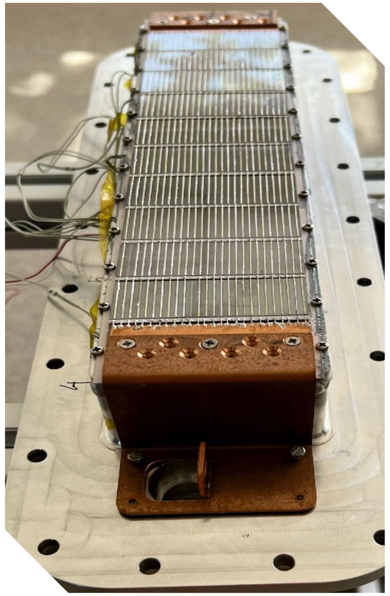
Stage of development

Built and validated PoCs and demos
reaching TRL5

- Small-scale demonstrator built
- Validated under relevant conditions
- Demonstrated power-to-heat conversion
- Integration of TPV module interface
- Successful high-temperature operation (up to 1410 °C)







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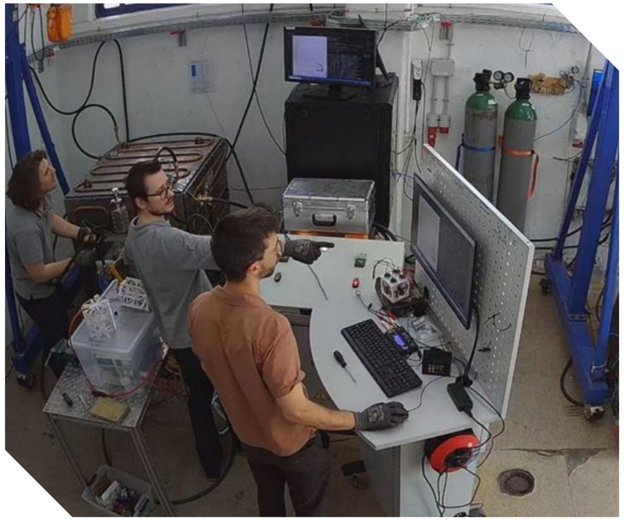
Stage of development

Finalizing TRL6 by Q1 of 2026 with technical and financial support of the Shell Gamechanger programme

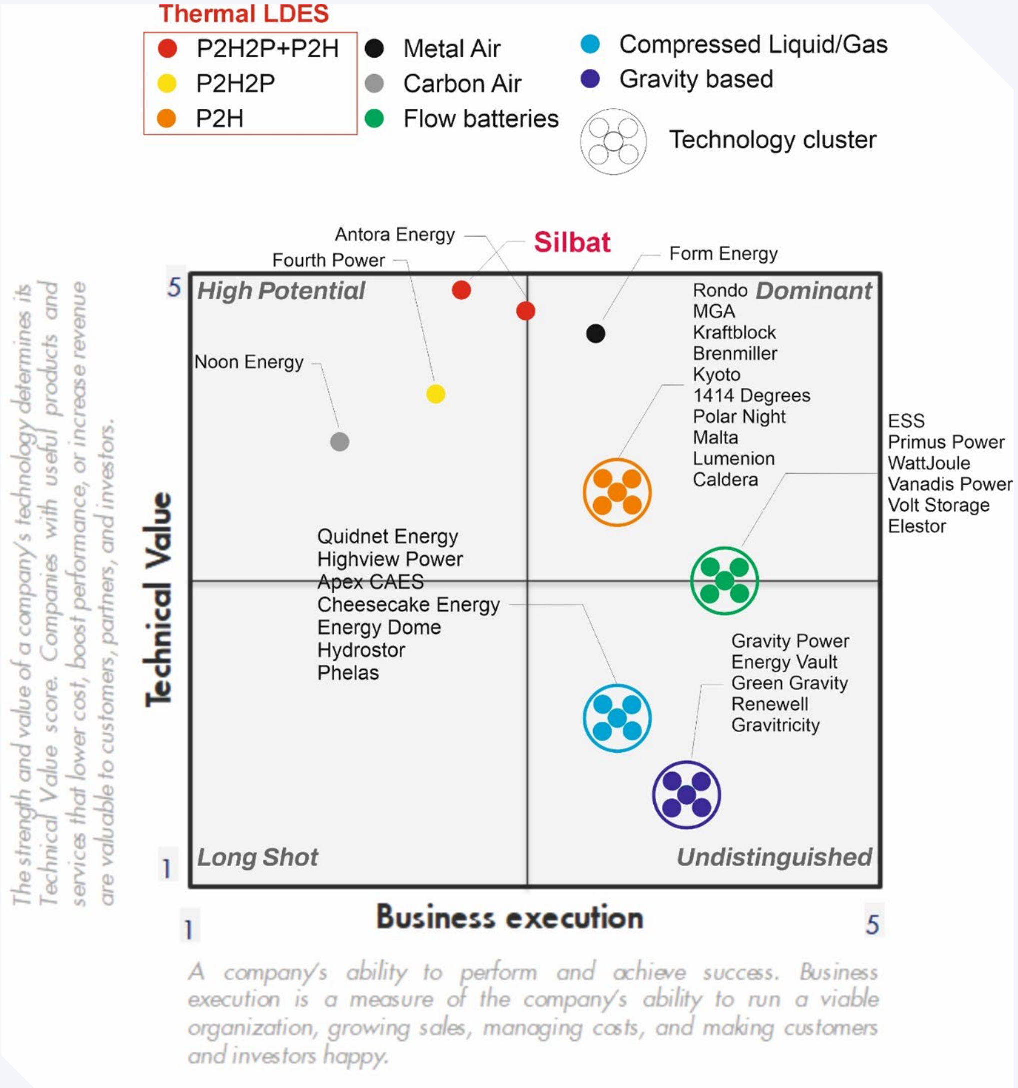


- TRL6 will feature also heat delivery (P2H) process steam at 200°C-400°C.
- It features a volume very close to the commercial target (10’ container)
- Four new 100W improved version of the TPV module

Competition

Lux Innovation Grid

- Most competitors in LDES are still in the product development phase
- Other technology clusters rely more on engineering and systems integration. They are more advanced in business execution but have lower technical and IP value.
- Maximum technical value: only Antora (US) and Silbat would be offering TPV-based output power plus industrial heat delivery.



LDES Landscape

Competition

Company/ Research Center	Thermal storage	Temperature (°C)	Electricity Recovery	How it compares to SILBAT
1414 Degrees	Latent heat Silicon	1414	Stirling	▪ *Moving parts / wearing fatigue* ▪ *Thermal insulation?*
Antora Energy	Sensible heat Graphite	Over 2000	TPV	▪ *Too high temperature: over steel's melting point* ▪ *Variable operating temperature: thermal fatigue, variable source* ▪ *Moving parts to regulate impinging radiation* ▪ *Thermal insulation?*
Fourth Power (M.I.T)	Sensible heat Silicon	1900 to 2400	TPV	▪ *Too high temperature: Over steel's melting poing* ▪ *Variable operating temperature: thermal fatigue, variable source* ▪ *Two tank hot/cold approach: big size, non portable.* ▪ *Thermal insulation?*
SILBAT	**Latent heat Silicon**	**1410**	**TPV**	

The Silbat Team

- Led by a **committed set of first-rate researchers and technology entrepreneurs + a brilliant young team.**
- Supported by **strong corporate shareholders and partners.**

The Engineering team


Rafael Molinero
Growth and applications Strategist


Marius Zehender, PhD
Senior Research Scientist - TPV


Alejandro Benito
Systems Architect Lead


Rishabh Golchha
Analyst Engineer


Javier García, PhD
Senior Research Scientist – Silicon & Containment


Julia Palenzuela
Operations Assistant


Manuel Álvarez-Voykin
Prototyping Support Technician


Vahid Safari, PhD
Senior CAE Engineer


Ignacio Checa
Technical Project Coordinator


Martín Moreno de Barreda
Silicon & Containment Intern

Board of Directors


Prof. Antonio Luque
Founder
One of the fathers of modern photovoltaics


Ignacio Luque, PhD
Founder
Seasoned entrepreneur in PV


Javier Celma
Baker Hughes
Sr. Vice President Origination


Jordi Daunis
EIT InnoEnergy
Investment and Asset Manager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GFM
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Soltec
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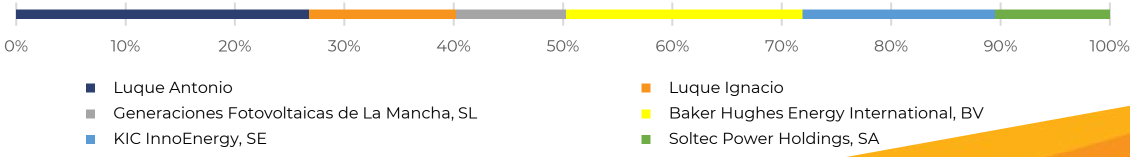
Fausto Rubio, PhD
High Temperature Engineering


Prof. Ignacio Rey-Stolle
Thermo photovoltaics


Iván Fernández, PhD
Plasma Vapour Deposition

Baker Hughes
Soltec POWER HOLDINGS
INNO

Corporate shareholders



Shell GameChanger
repsol

(Non Dilutive) Funding Partners

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Business Model

How Silbat creates and captures value in LDES

Silbat thermal battery system

- Silicon–based latent heat storage (P2H2P)

- Industrial heat: launching with 200-400°C steam co-generation (H2P)

B2B model

Silbat act as system integrator, providing turnkey LDES solutions

Revenue streams:

- Battery sales
- Strategic partnerships
- Licensing

Potential clients

Baker Hughes

REPSOL

Shell GameChanger

We are currently working on our TRL6 activities **with technical and financial support of the** Shell Gamechanger programme and Repsol's Open Innovation

COGS projections:
49.7 €/kWh in 2032

Price point projections:
67.2 €/kWh in 2032

LCOS to end users:
87.9 €/MWh in 2032

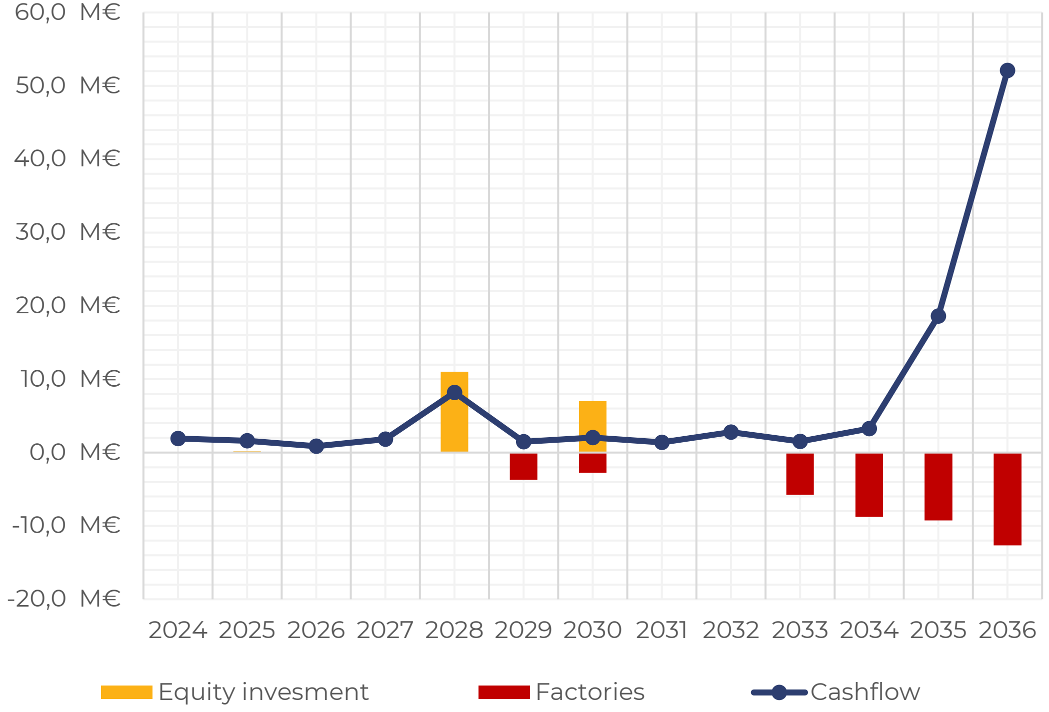
Financial metrics

Revenues
€42 million by 2033

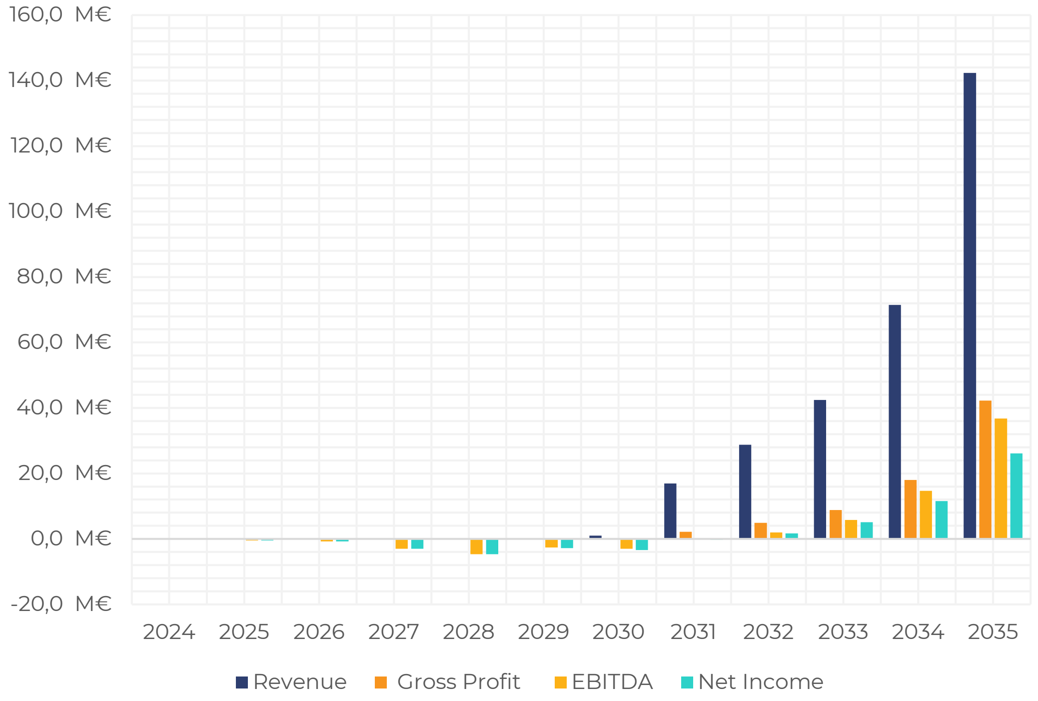
EBITDA-to-turnover (2033)
7%

Productivity (2033)
300 containers

Cash flow projections



Profit & loss projections

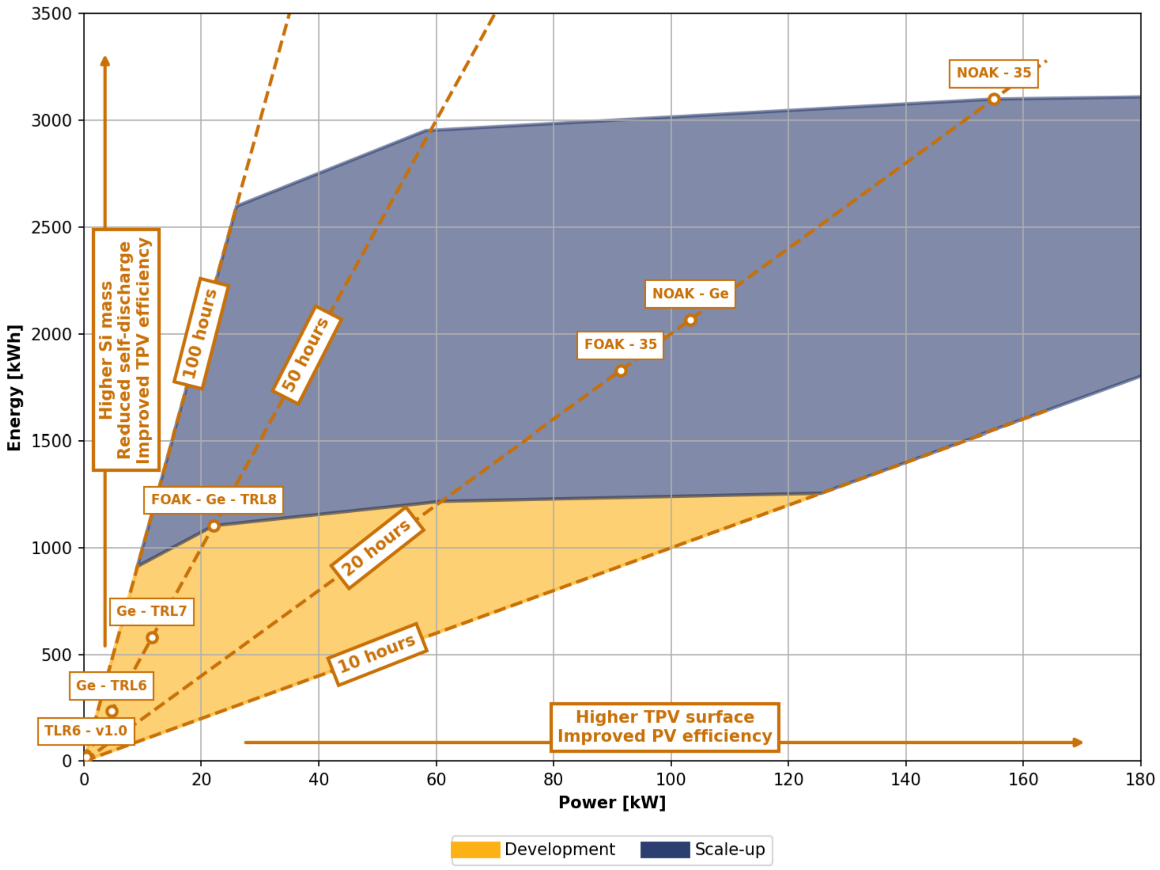


Roadmap

Product development

Development Matrix

TRL6	TRL7	TRL8
Q3 2026	2027	2028
ELECTRICITY OUTPUT		
Input power: 100 kW Output power: 0.5 kW Capacity: 25 kWh Discharge: 50 h	Input power: 300 kW Output power: 35 - 4 kW Capacity: 600 kWh (2500 kWh thermal) Discharge: 20 - 100 h	Input power: 500 kW Output power: 60 - 9 kW Capacity: 1200 kWh (4500 kWh thermal) Discharge: 20 - 100 h
HEAT OUTPUT		
Delivery: 200 °C steam Output power: 20 kW Capacity: 700 kWh Time-limited	Delivery: 250 °C steam Output power: 100 kW Capacity: 3 MWh Time-limited	Delivery: 300 °C steam Output power: 200 kW Capacity: 3 MWh 24/7
CYCLABILITY		
Limited cycling of crucibles	1 year accelerated cycling of crucibles	Full operation cycling of crucibles
Investment 1 M€	Investment 2.5 M€	Investment 1.5 M€



Roadmap

Commercialisation – production scale-up

TRL9	PHASE 3	PHASE 4
2029 – 2030 Tens of units	2031 – 2035 Hundreds of units	2036 - Mass-scale manufacturing

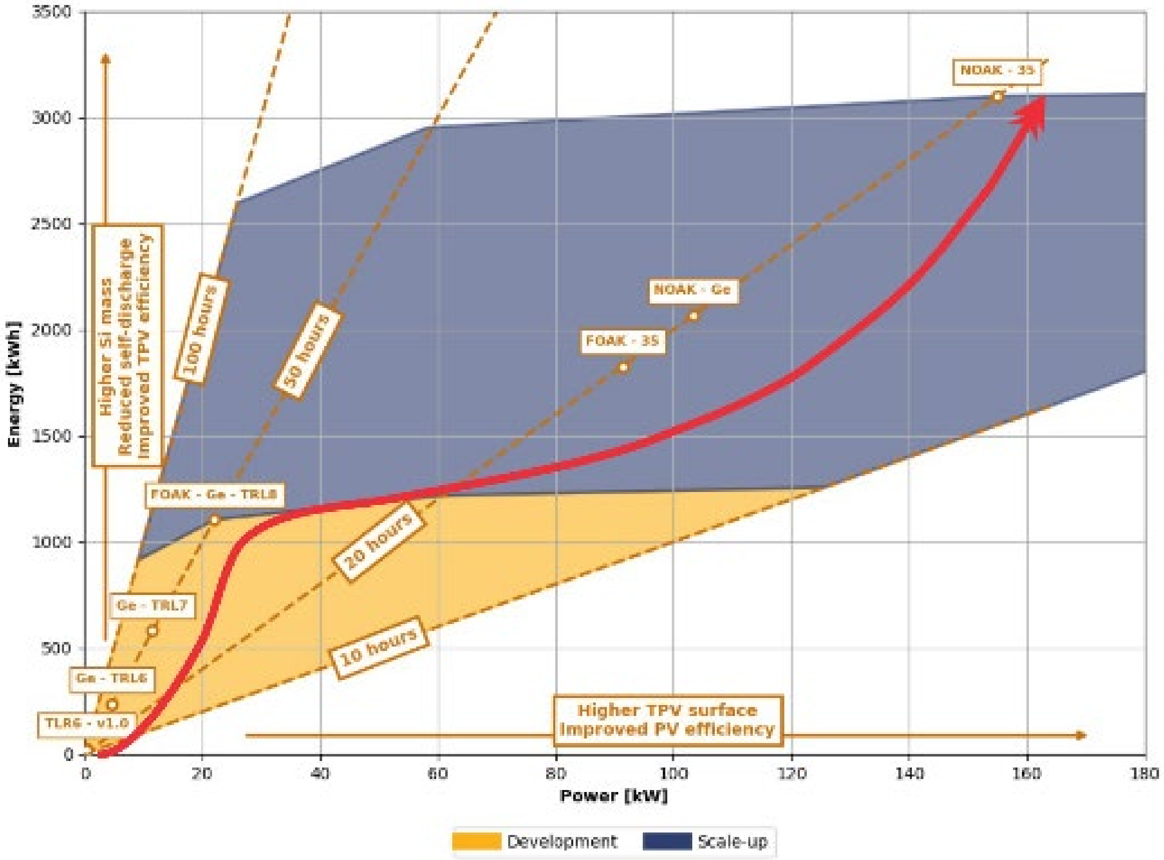
SPECIFICATIONS

TRL9	PHASE 3	PHASE 4
Input Power: 1 MW Output Powe P2H2Pr: 23 kW_e Output Power P2H: 200 kW_{th} Capacity: 1.2 MWh_e (4.5 MWh_{th}) 24/7 Heat Delivery	Input Power: 1 MW Output Powe P2H2Pr: 23 kW_e Output Power P2H: 200 kW_{th} Capacity: 1.2 MWh_e (4.5 MWh_{th}) 24/7 Heat Delivery	Input Power: 1 MW Output Power: 25 - 140 kW_e Discharge: 100 - 20 h 10' container

GROWTH STRATEGY & MARKET APPLICATIONS

TRL9	PHASE 3	PHASE 4
Validation at costumer site TRL9 achievement + safety & quality standards Continued R&D	P2H2P - Off-grid, Resiliency, Backup Power – SAM: 170 GWh P2H: process steam up to 400 °C - TAM: 3100 TWh	P2H2P: 24/7 PPA, T&D network, Arbitrage - TAM (power): 85–140 TWh P2H: process steam up to 400 °C - TAM: 3100 TWh Cogeneration
Investment 11 M€	Investment 7 M€	

Development Matrix



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Take home messages:

Innovative, game-changing LDES technology

A novel long-duration energy storage solution capable of delivering up to **100 hours** of storage at costs **below $15/kWh**, unlocking true renewable potential.

Massive and fast-growing market

The **LDES segment is a critical pillar of the energy transition**, with accelerating global demand for affordable, dispatchable clean energy.

Powered by a strong ecosystem

Best-in-class team supported by industrial partners, R&D institutions, and investors committed to scaling deep-tech innovation.

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