UN CTCN-UNITAR CIFAL Jeju-Korea Institute of Energy Research
2026 Energy Storage System Workshop and Learning Visit

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Jeju Global Research Center
Korea Institute of Energy Research

History of Energy Storage

What is energy? (In the past) If you needed heat and/or light, you needed fire (exothermic reaction).



energy resources + oxygen (everywhere) + reaction (anytime)



Energy Storage: Bunkering (security)

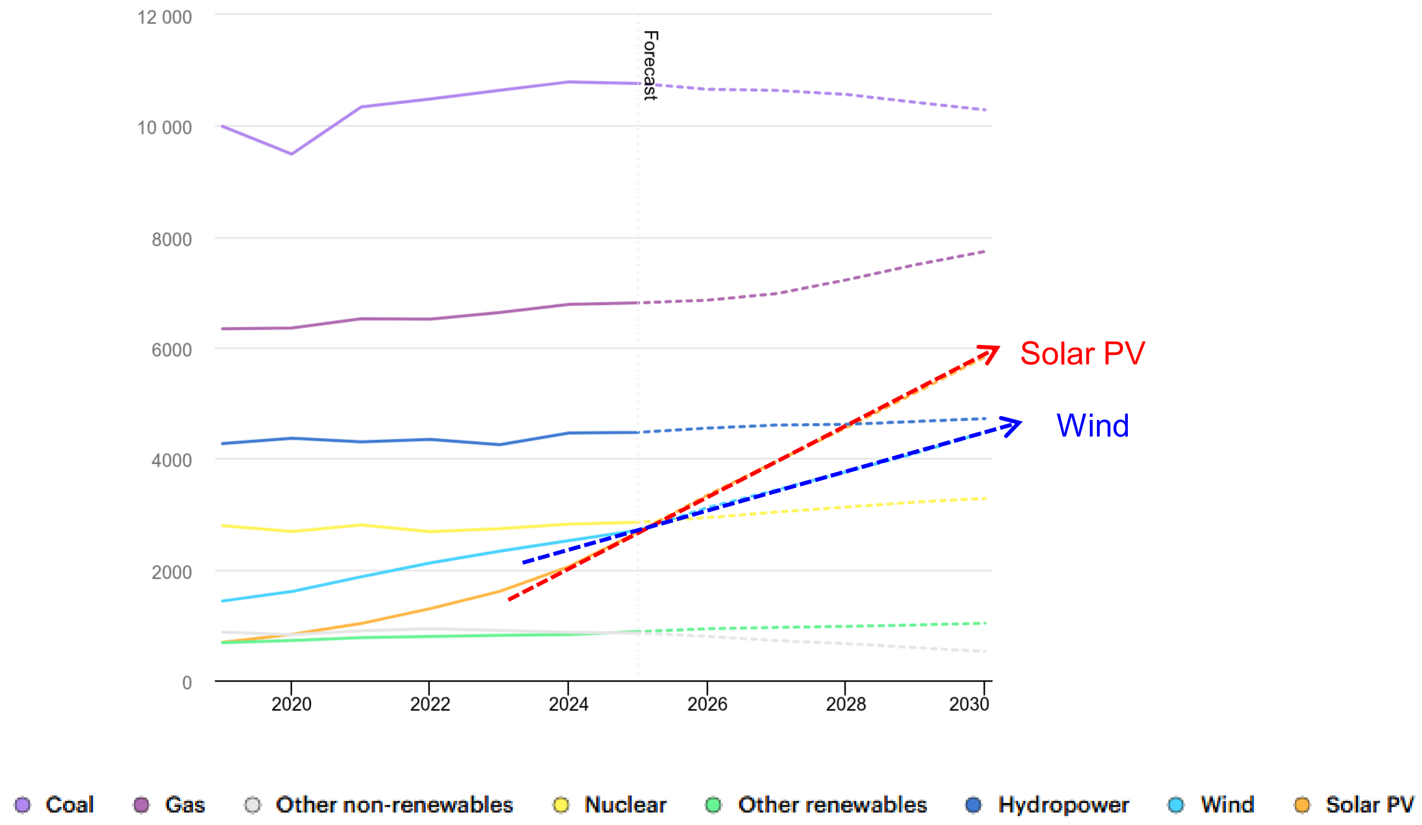
Bunkering: Long-Duration Energy Storage System (National Level)

Bunkering goes beyond simple ship refueling, serving a vital long-duration energy storage (LDES) function within the broader macro-energy system.

- **Physical Fuel Stockpiling**: Serves as a definitive form of long-duration energy storage through the creation of large-scale physical fuel reserves.
- **Market Price Stabilization**: Acts as an economic buffer, securing stable energy costs against market volatility, seasonal fluctuations, and geopolitical supply chain disruptions.
- **Decoupling Supply and Demand**: Eliminates the requirement for instantaneous matching of energy generation and consumption, providing critical time-shifting flexibility for energy grid operations.

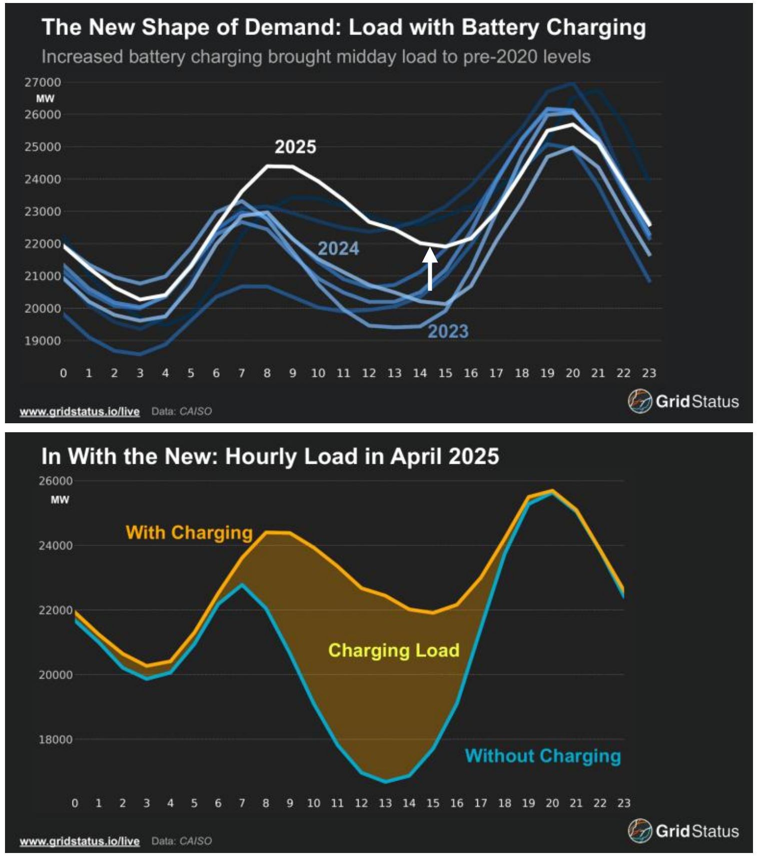
Renewable Energy System

Global electricity generation by source, 2019-2030



RES = renewable energy sources. 'Other non-RES' includes oil, waste and other non-renewable sources. 'Other RES' includes geothermal, bioenergy, concentrated solar power (CSP), and ocean energy. Data for 2026-2030 are forecast values.

The New Shape of Duck Curve – Role of Battery



In CAISO, Solar Generation Jumps Again While Batteries Reshape Demand
([In CAISO, Solar Generation Jumps Again While Batteries Reshape Demand]())

Source: Electricity – 2026 (IEA)

Long-Duration Energy Storage

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NON-EXHAUSTIVE – HYDROGEN AND HYBRID LONG DURATION STORAGE EXCLUDE

Legend: △ Faces geologic constraints[4] · ■ Not enough public datapoints to obtain a reliable value · Less Desirable → More Desirable · Inter-day · Can function as both · Multi-day/week

Duration	Energy storage form	Technology	Nominal duration, hrs	LCOS[5], $/MWh	Min. deployment size, MW	Average RTE, %	TRL
Inter-day	Mechanical	Traditional pumped hydro (PSH) △	0–15	70–170	200 – 400	70–80	9
		Novel pumped hydro (PSH)	0–15	70–170	10–100	50–80	5-8
		Gravity-based △	0–15	90–120	20–1,000	70–90	6-8
		Compressed air (CAES) △	6–24	80–150	200–500	40–70	7-9
		Liquid air (LAES)[1]	10–25	175–300	50–100	40–70	6-9
		Liquid CO2[1]	4–24	50–60	10–500	70–80	4-6
Multi-day / week	Thermal	Sensible heat (e.g., molten salts, rock material, concrete)[2]	10-200[2]	300	10–500	55–90	6-9
		Latent heat (e.g., aluminum alloy)	25–100	300	10–100	20–50	3-5
		Thermochemical heat (e.g., zeolites, silica gel)	XX	XX	XX	XX	XX
	Electrochemical	Aqueous electrolyte flow batteries	25–100	100-140	10–100	50–80	4-9
		Metal anode batteries	50–200	100	10–100	40–70	4-9
		Hybrid flow battery, with liquid electrolyte and metal anode (some are Inter-day)[2,3]	8–50[2]	XX	>100	55–75	4-9

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Economics in LDES

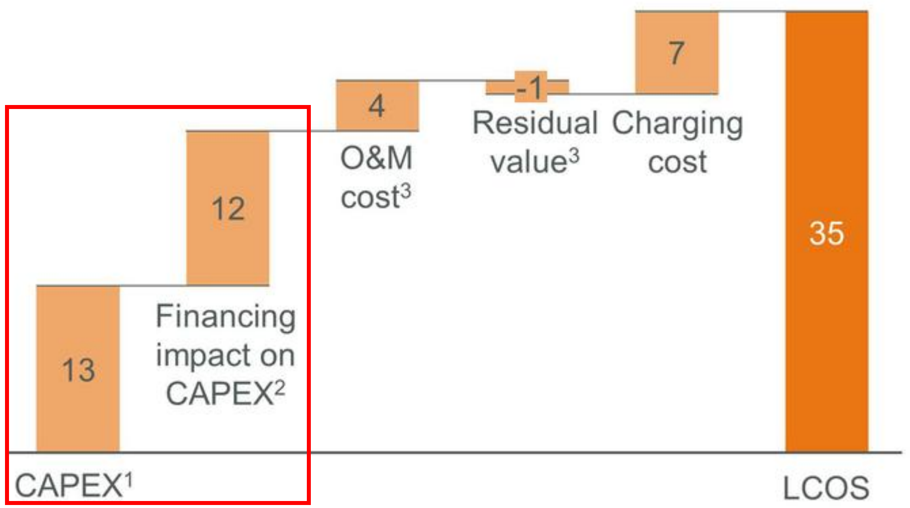
$$LCOS = \frac{CAPEX}{\#cycles * DOD * C_{rated} * \sum_{n=1}^{N} \frac{(1-DEG*n)}{(1+r)^n}} + \frac{O\&M * \sum_{n=1}^{N} \frac{1}{(1+r)^n}}{\#cycles * DOD * C_{rated} * \sum_{n=1}^{N} \frac{(1-DEG*n)}{(1+r)^n}} - \frac{\frac{V_{residual}}{(1+r)^{N+1}}}{\#cycles * DOD * C_{rated} * \sum_{n=1}^{N} \frac{(1-DEG*n)}{(1+r)^n}} + \frac{P_{elec\text{-}in}}{\eta(DOD)}$$

With:

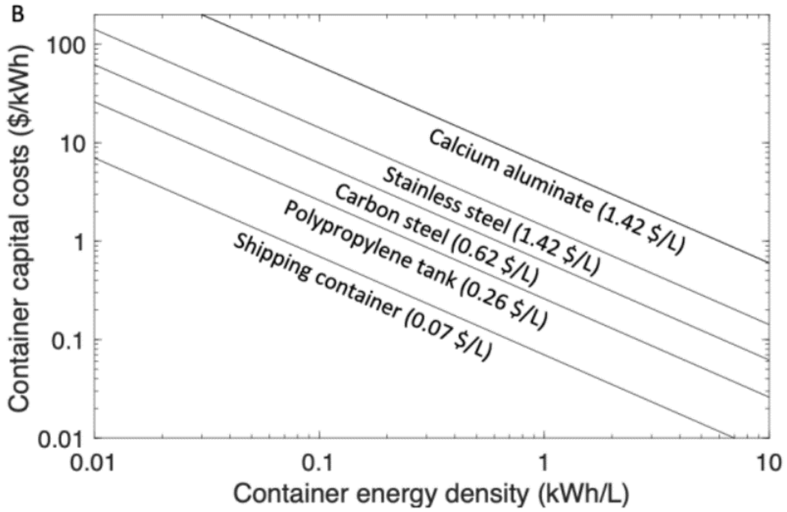
- $\#cycles$ = full charging/discharging cycles per year
- DOD = depth of discharge
- C_{rated} = rated capacity
- DEG = annual degradation rate of capacity[1]
- N = project lifetime in years
- r = discount rate (e.g., weighted average cost of capital)
- $O\&M$ = O&M cost (assumed to be constant)
- $V_{residual}$ = residual value (after project lifetime)
- $P_{elec\text{-}in}$ = charging electricity tariff (assumed to be constant)
- $\eta(DOD)$ = round-trip efficiency at DOD (assumed to be constant)

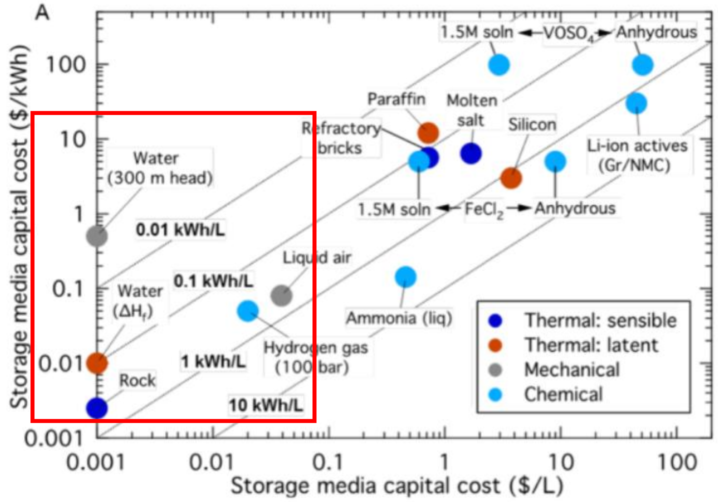
1) Assuming linear degradation

Cost components and LCOS for utility-scale stationary battery storage system for dispatchable PV [USD¢/kWh]



1) Divided by undiscounted total energy; 2) impact of discounting total energy; 3) discounted and divided by discounted total energy
Source: Apricum analysis
Assumptions: Lithium-ion battery technology with CAPEX of 500 USD/kWh; use case dispatchable PV with 350 cycles (80% DOD) per year; project lifetime 15 years; battery lifetime of 6,000 cycles; constant annual O&M cost of 10 USD/kWh p.a. (2% of initial CAPEX); constant charging cost of 0.06 USD/kWh; 10% discount rate (assuming 50% of debt at 8% and 50% equity at 12%); residual value assumed to be 20% of initial CAPEX



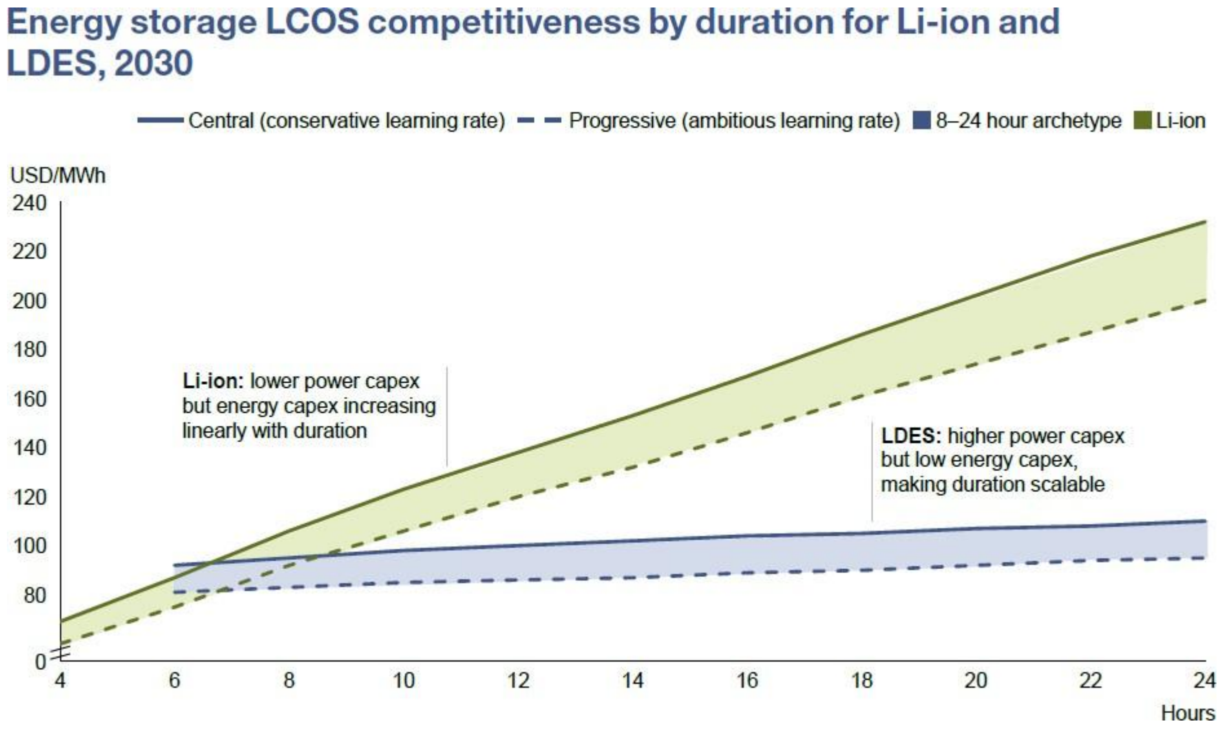


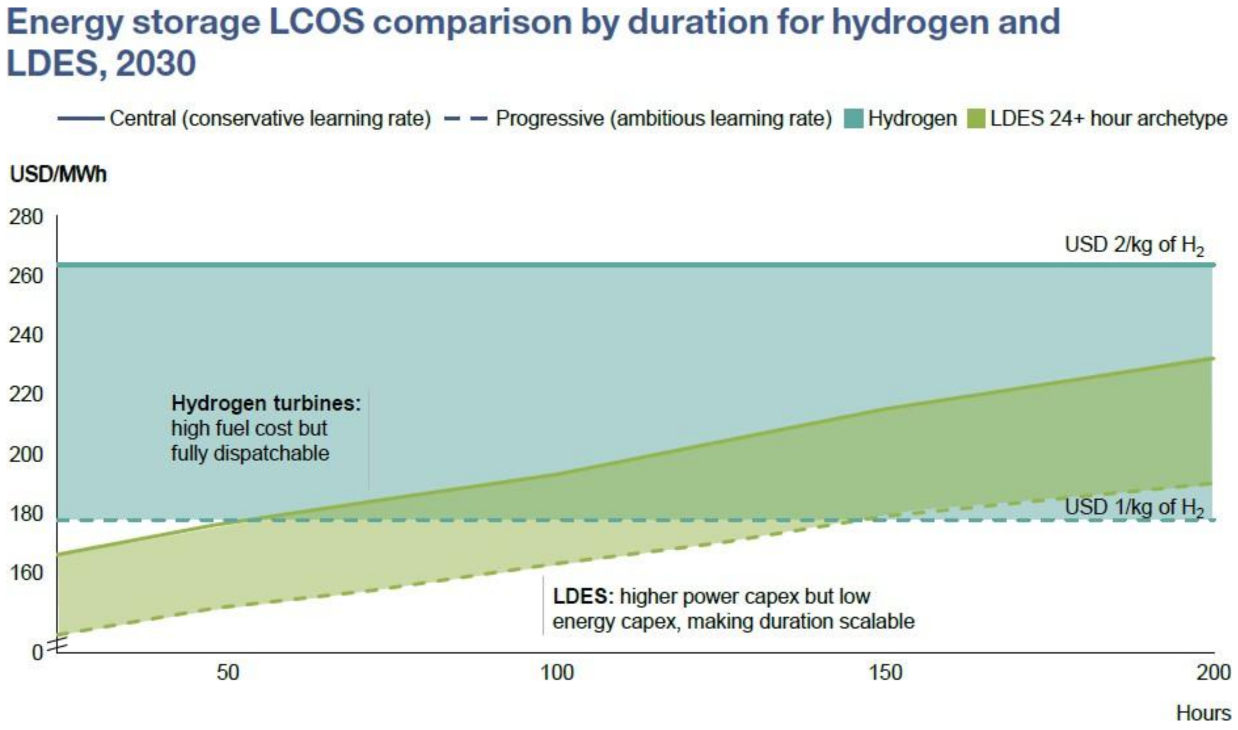
~~Seen through the eyes of a LiB developer….;~~

Economics in LDES

Competitiveness of LDES

- Compared with Li-ion batteries, LDES is more economical for discharge durations exceeding 8 hours.
- Compared with hydrogen (HESS), LDES is more economical for discharge durations under 100 hours.





UN CTCN TA cRD&D : Papua New Guinea

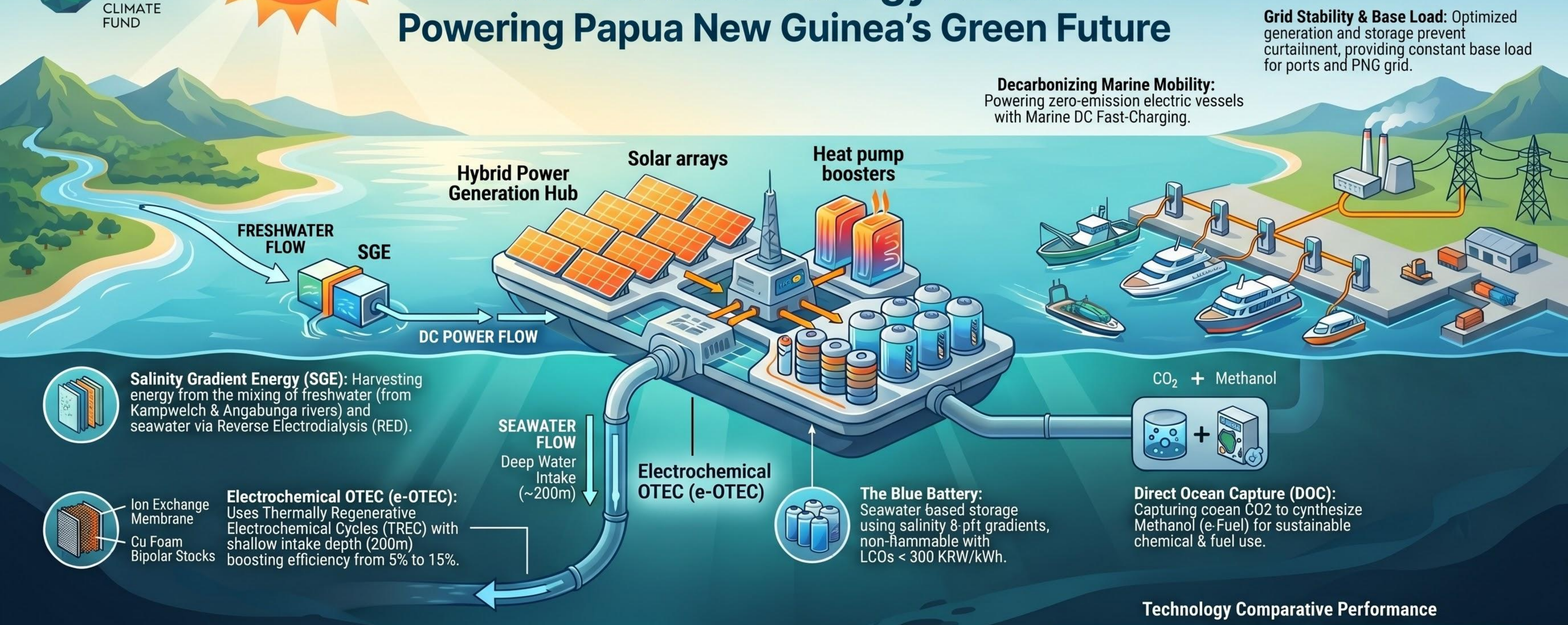
UN CTCN TA cRD&D Project : Papua New Guinea

- Project Title: Pre-feasibility study on **Ocean Energy focusing on Salinity Gradient Energy Technology and Electrochemical Ocean Thermal Energy Conversion (= Seawater Energy Nexus)**
- NDE: CCDA (Climate Change & Development Authority), Mr. Danny Nekitel (Manager Mitigation and Low Carbon Growth)\
- Proponent: National Energy Authority, Contact person: Larsen Daboyan (Manager Research and Statistics)
- Aims of project:
  - To provide essential technical groundwork and knowledge base enabling PNG to utilize its ocean potential effectively
  - To focus on cutting-edge technologies compatible with PNG's unique geographical and environmental landscape
  - To contribute to the nation's renewable energy journey and reinforce its commitments to both national and global climate action.

Source: https://www.solarplaza.com/resource/11498/how-determine-meaningful-comparable-cost-energy-storage/

The Seawater Energy Nexus: Powering Papua New Guinea's Green Future

GREEN CLIMATE FUND



58% Reduction in LCOE

Hybrid systems (Solar + Heat Pump + Thermal Energy Storage) significantly reduce Levelized Cost of Energy.

30.25–30.35/kWh

50.15/kWh

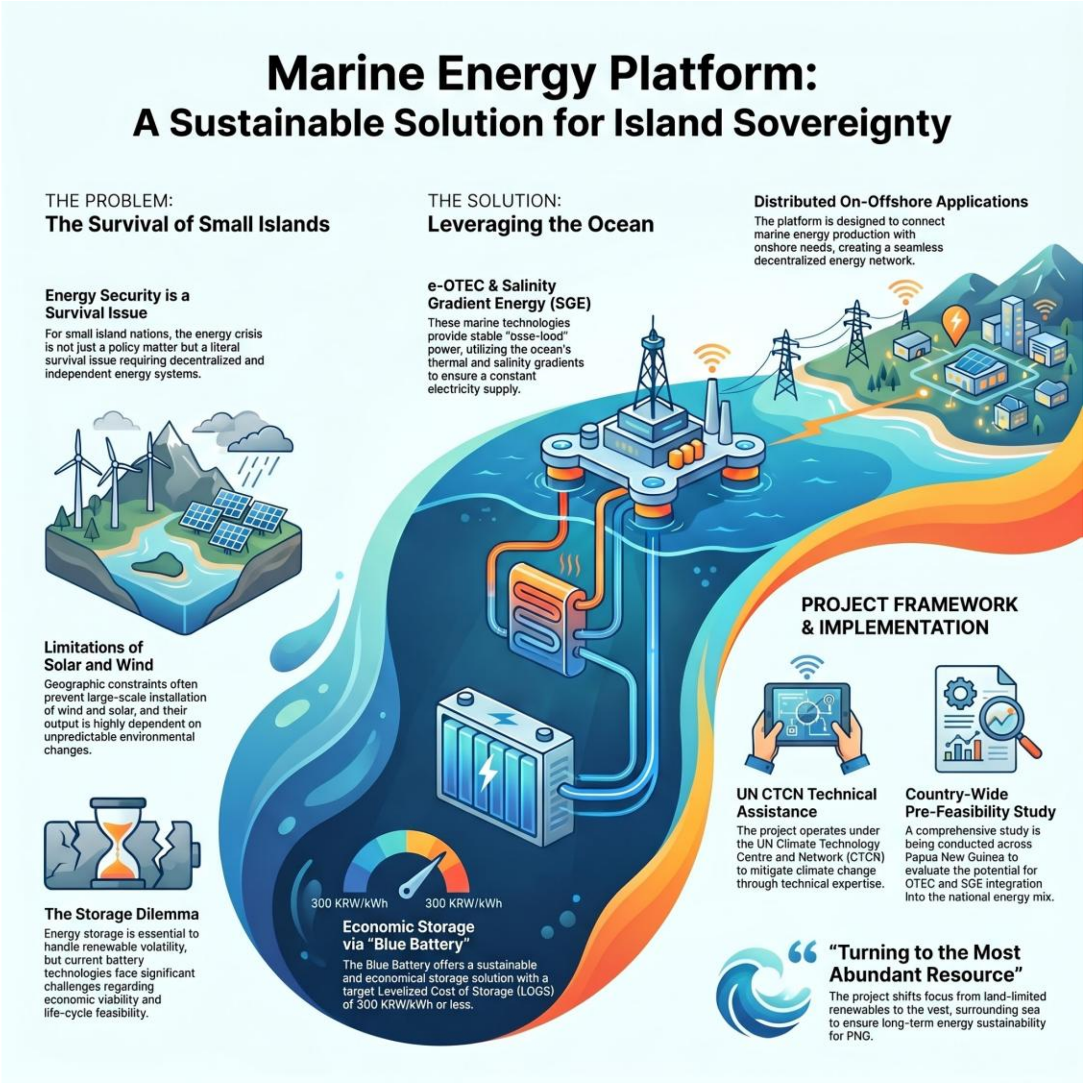
Lower Cost than Fossil Fuels

Massive Scalability: PNG's river discharge offers GW scale SGE potential, and shallow-water intake drastically lowers CAPEX for ocean energy.

Technology Comparative Performance

	Mechanical OTEC	Electrochemical OTEC (e-OTEC)
Thermal Efficiency	~3%	10% – 15%
Required Intake Depth	1,000 m	~200 m
Primary Cost Driver	Deep-water CWP Pipe	Modular Electrochemical Stack
Power Density	Low	High (Reduced Area & CAPEX)

The Seawater Energy Nexus



- **Environmental and energy crisis in small islands as survival issues**
- **Importance of decentralized energy systems in small islands**
  - Challenges in the implementation of independent renewable energy systems
  - The crucial role of the energy mix for independent power systems
  - Unequal opportunities for Solar PV and Wind Turbine (WT) installations in small islands
  - Mutual influence between renewable energy sustainability and surrounding environments
- **Necessity of energy storage** (e.g., batteries) for a stable electricity supply from volatile renewables
- **Key challenges for future energy storage**: economic viability and life-cycle feasibility

New Technology: Seawater-based Energy Storage

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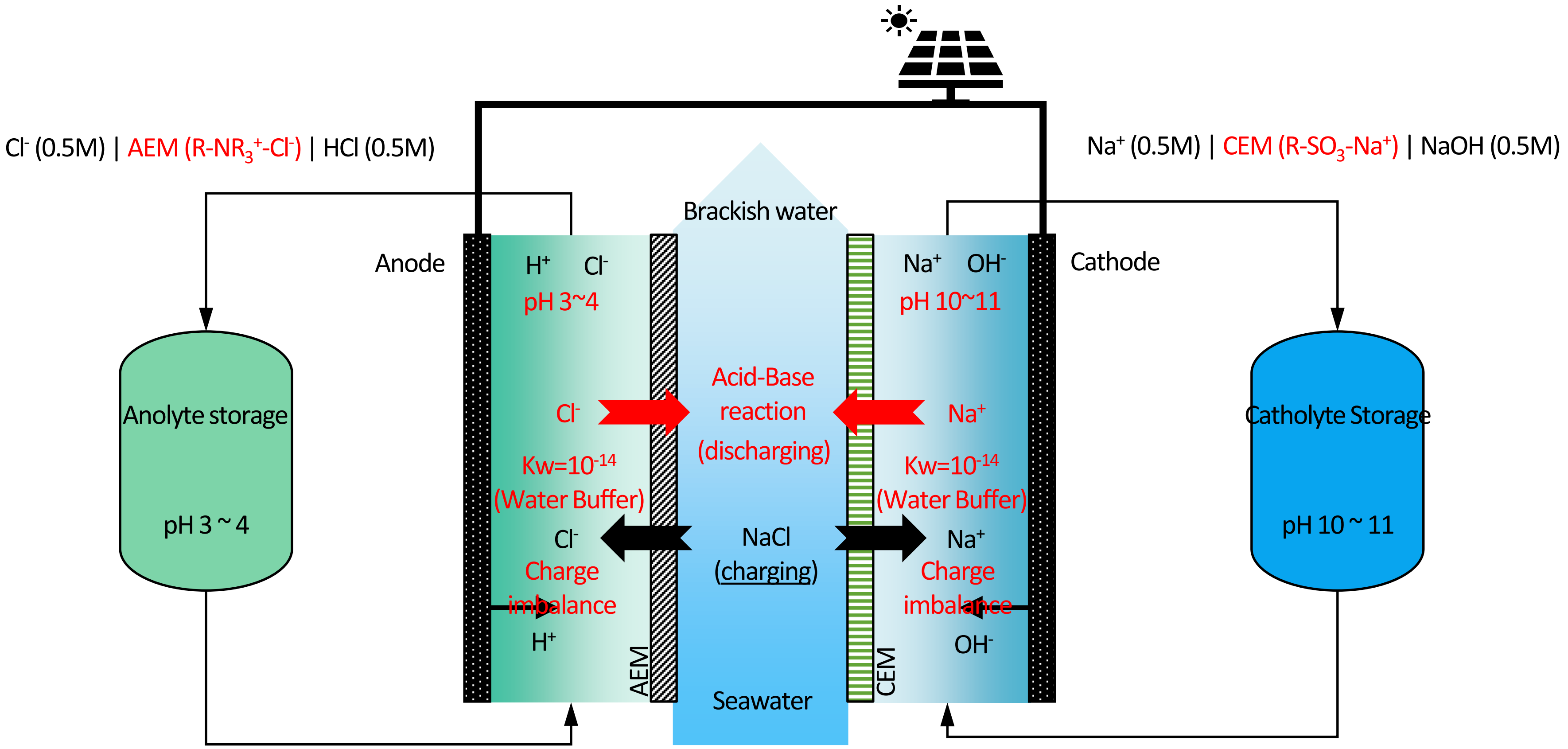
Seawater-based energy storage (Blue-Battery)

- Charging : electrochemically separating ions in seawater (e.g., NaCl) according to its own charges by ion-exchange membrane.
- Discharging : electrochemical reaction by acid-base reaction (NaCl + NaOH → NaCl + H_2O)



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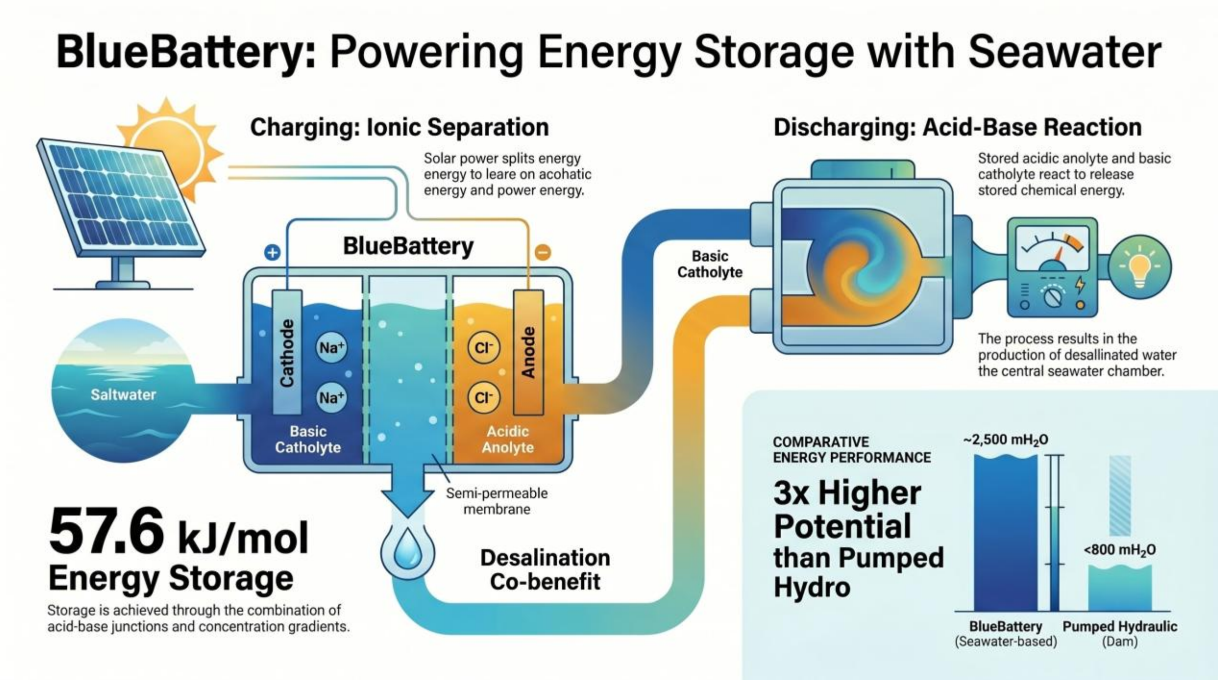
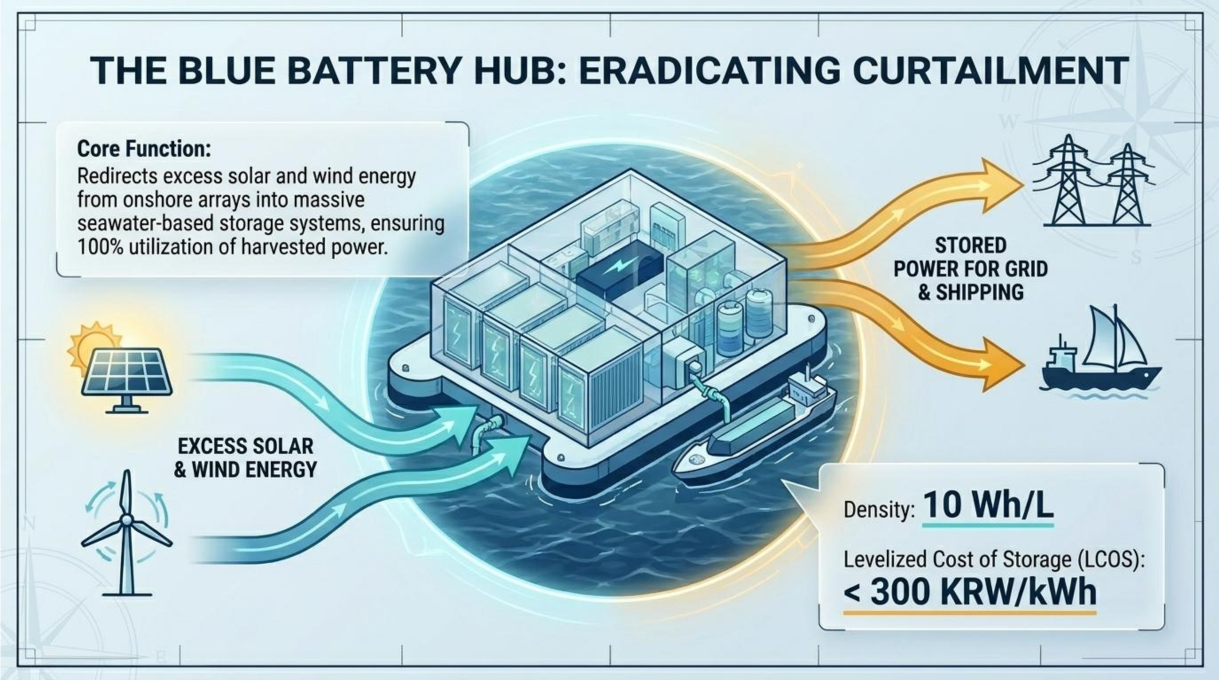
New Technology: Seawater-based Energy Storage





- Eradicating Curtailment & Maximizing Utilization
- Unmatched Economic Viability & Ultimate Safety
- Massive Storage Potential & Grid Stability
- Simultaneous Energy Storage and Desalination (Co-benefit)

"Ultimately, the Blue Battery serves as the beating heart of the 'Seawater Energy Nexus' in Papua New Guinea, leveraging the nation's boundless seawater to economically conquer the curtailment of volatile renewables and accelerate the journey toward complete energy independence and zero-emission decarbonization."

New Technology: Seawater-based Energy Storage

New Technology: Seawater-based Energy Storage

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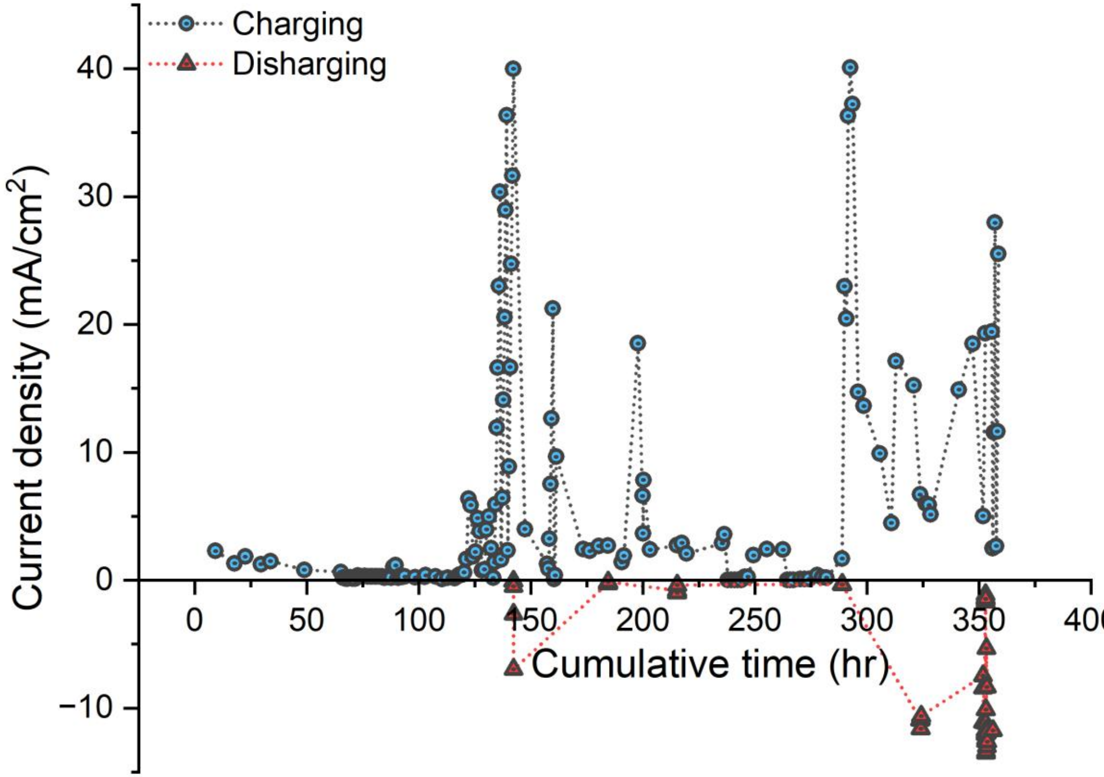

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Blue-Battery Pipelines in Korea

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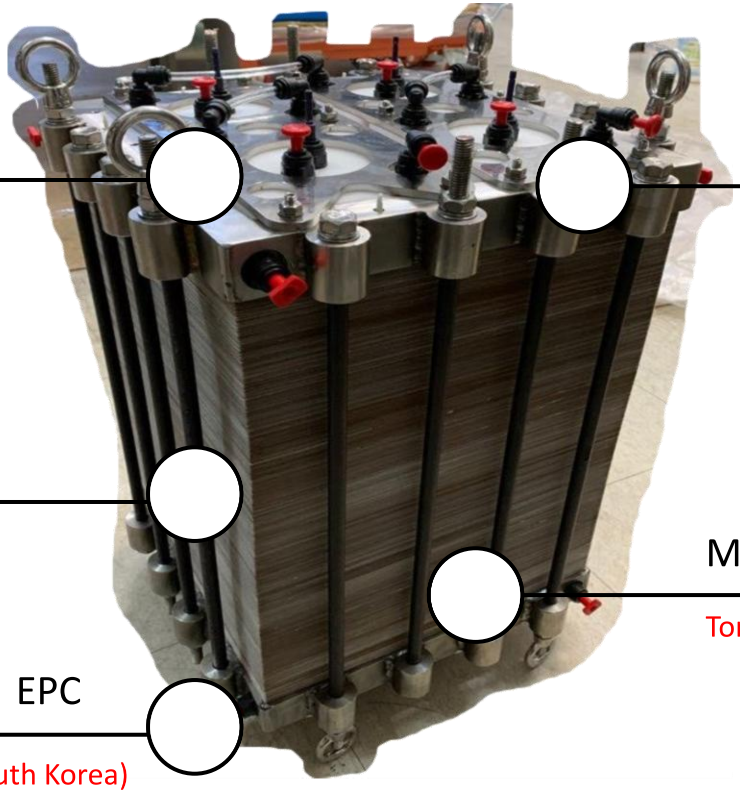

Stack/Module

Korea Institute of Energy Research (KIER)
Innomeditech (South Korea)
Lapinion (South Korea)

PRIONE (South Korea)
OOO (O&M specific company) (PNG)

Electrodes

Wesco Electrode (South Korea)
Innomeditech (South Korea)
POSCO (South Korea)

Seawater

Papua New Guinea (PNG)

Membrane

Toray advanced materials (South Korea)

EPC

RED (South Korea)
Korea Institute of Energy Research (South Korea)
Samsung Engineering (South Korea)
CARBONCO (South Korea)

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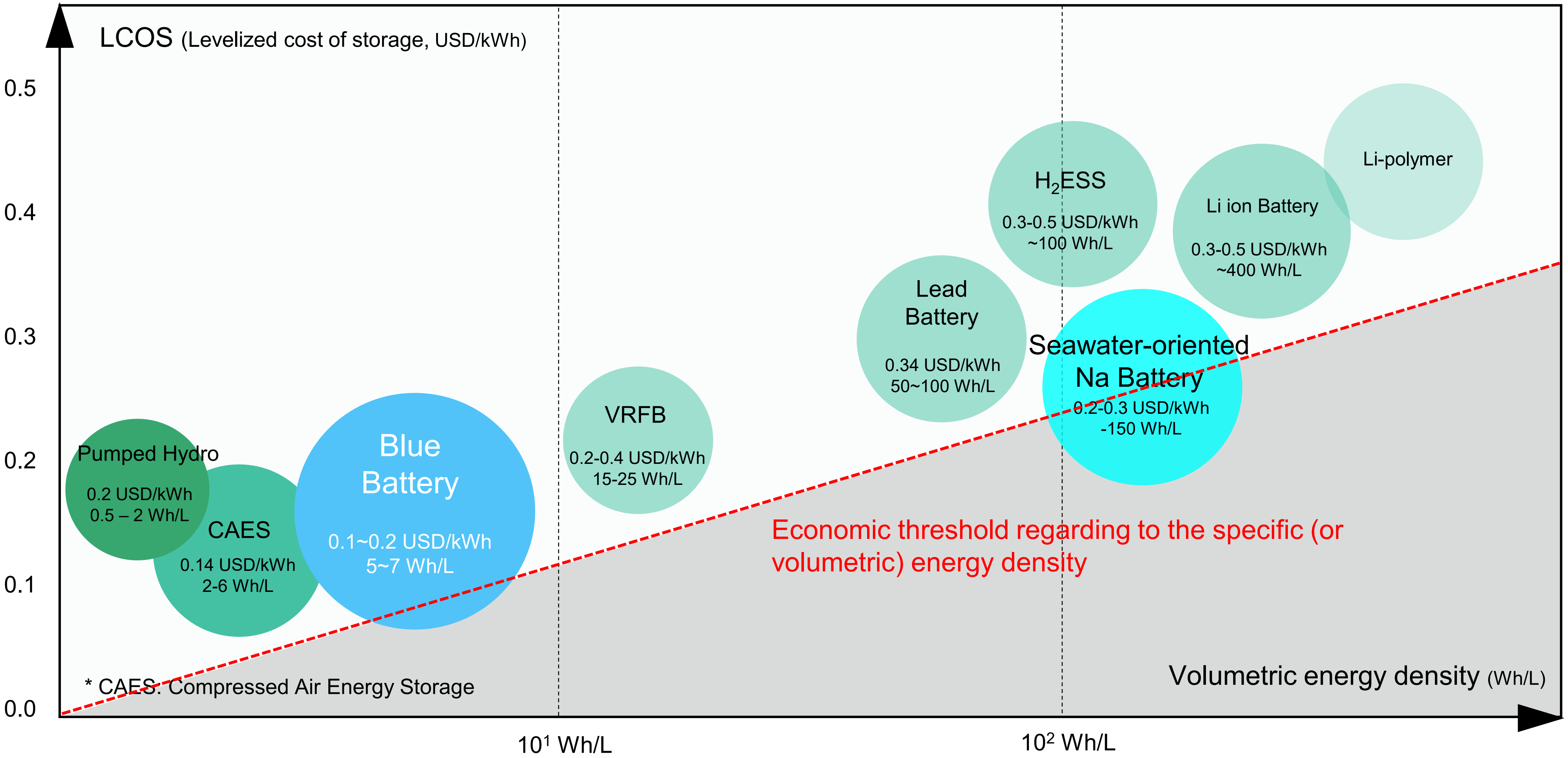
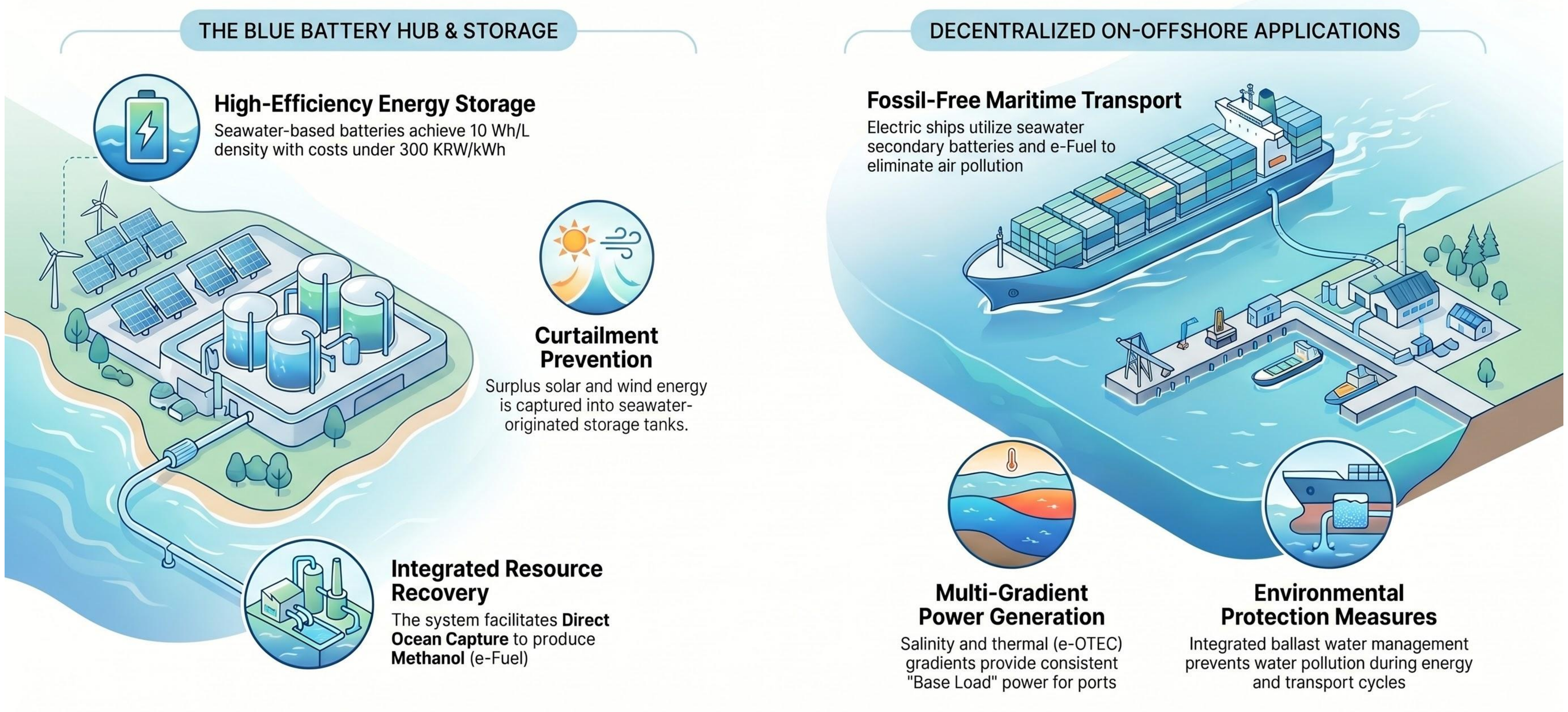
New Technology: Seawater-based Energy Storage



The Seawater-Based Energy Ecosystem: From Storage to Zero-Emission Transport



Implementation Plan

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	Demonstration site specification	Scale (kW)	Budgets	Implementation Partners (in South Korea)	Implementation plan
Salinity gradient power (e.g., RED)	Kalo (river mouth)	100	4 M$ (Installation cost: 2.5 ~ 3.0 M$, Operation cost: 0.5~1.0 M$/3 years)	KIER Lapinion Inomeditech Toray Materials	Step1. Manufacturing in Korea (including FAT) – 6~8 months Step2. CEPA (target: Level 2/3) – 6~12 months Step3. Logistics (Customs clearance)- 6-8 weeks Step3. PNG installation 3.1. Mechanical BOP (Pumps and Pipes) 3.2. Electrical BOP (electrical load) Step4. SAT, optimization (~24 months)
Electrochemical Ocean thermal energy conversion	Port Moresby	50~100	3.0 – 3.5 M$ • Depends on the installation cost of intake pump and pipe system CAPEX • Stack (module): 1.2 M$ • BOP (pump & pipe): 0.8 M$ OPEX: 1.0 - 1.5 M$	KIER Danfoss Korea	
Seawater-based energy storage (Blue battery)	Port Moresby	200 (800 kWh, 4 hrs)	2.5 – 3.0 M$ • Battery pack: 1.2 M$ • BOP : 1.0 M$ • Installation cost: 0.5 M$ • SAT: 0.3 M$	KIER Hanyang University (O&M) Korea University (Capacity building) PRIONE (Electrode) Innomeditech (Stack/Module) CARBONCO (EPC)	

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Implementation Plan

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No.	Task Name	M1	M3	M5	M7	M9	M11	M13	M15	M17	M19	M21	M23	Owner
1	Site Survey & Basic Design	■	■											KR/PNG
2	PNG Environmental Permitting (CEPA)		■	■	■	■	■							CCDA
3	Detailed Engineering (Stack/BOP)			■	■	■								KR
4	Membrane & Stack Fabrication					■	■	■	■					KR
5	BOP & Control System Assembly						■	■	■					KR
6	Factory Acceptance Test (FAT)								■					KR
7	Shipping & Port Clearance									■	■			Logistics
8	Site Preparation (Foundation/Intake)								■	■	■			PNG
9	On-site Installation & Integration										■	■		KR/PNG
10	Commissioning & Training											■	■	KR/PNG