



bGen™ - E2E-7000

Utility scale storage solution Brenmiller Energy bGen™

Electricity to Electricity



The need

The need for storage does not end with shifting energy from off peak to peak demands, but also to provide stability, availability and other services that provide diverse revenue streams.

Services and Revenue Streams

- 1 **Energy Arbitrage** – Shifting cheap energy to peak demand
- 2 **Demand Response** – Manage high wholesale price or emergency conditions on the grid by shifting electricity demand
- 3 **Frequency Regulation / Inertial Response** – Provide immediate power to maintain generation-load balance and prevent frequency fluctuations
- 4 **Spinning Reserve** – Maintain electricity output during unexpected contingency event
- 5 **Resource Adequacy / Capacity Payments** – Provide extra capacity to meet projected load growth for reducing investments in distribution system



Technology

Clean, Low-cost, durable storage



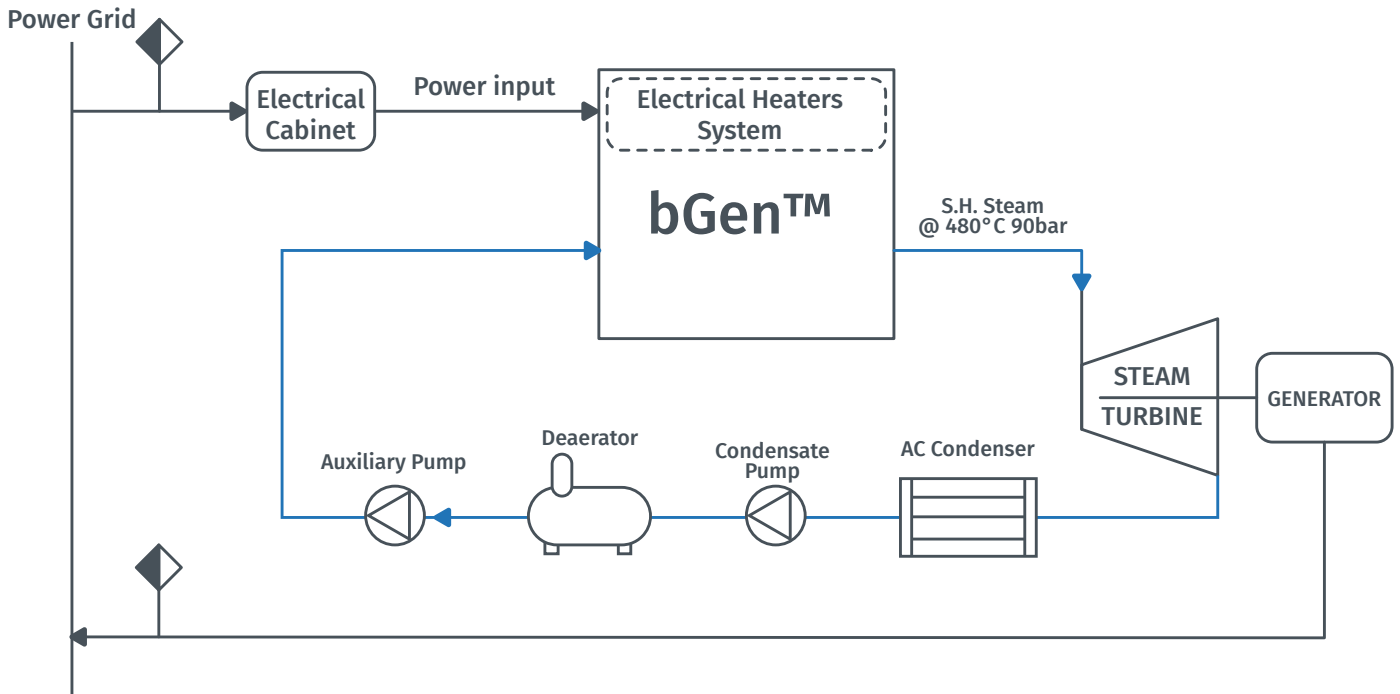
bGen™ is a patented thermal energy storage generation unit based on crushed rocks which combines three elements: Heat exchanger, thermal storage and steam generator.

The bGen has electrical heaters embedded inside. Heat is stored in modular sub-units, filled with crushed rocks which allows to conduct tens of thousands of charge/discharge cycles with no degradation in performance. The unit produces superheated steam, using its inherent steam generator. When the unit is charged, a controlled temperature profile is maintained, transforming the feed water flow into a steady and stabilized superheated steam. The system controls the pressure and temperature of the generated power, assuring a steady output flow, regardless of the unit charging level.

The bGen™ is coupled with a standard steam turbine to produce electricity. The bGen™ thermal storage unit, which is inherently a passive device, creates a highly reliable and stable source of energy. The electricity production system is versatile and reacts quickly to the needs of electricity demand.

There is no degradation with every charge/discharge cycle and no need to replace the equipment. The bGen™ system is considered a 'green engineering' unit, as no hazardous materials and chemicals are used as a storage medium. Accordingly, there are ZERO EMISSIONS when using our system.

Process flow diagram of the bGen™ system:



Technical and Performance

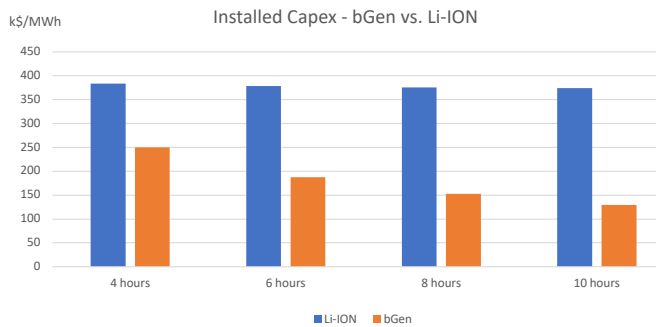
Key characteristics for 20MW electricity generation

	4 hours	6 hours	8 hours	10 hours
Storage capacity electricity [MWhe]	80	120	160	200
Storage capacity thermal [MWht]	216	324	432	540
Discharge thermal Power [MW]	54	54	54	54
Pressure [Bar A]	90	90	90	90
Temp steam out [C]	480 (°C)	480 (°C)	480 (°C)	480 (°C)
Daily Heat loss %	3.1	3.0	2.9	2.8
Max elec. load [MW]	23	33	40	46
Dimensions (m) – (H X W X L)	8x14x14	12x14x14	15x14x14	18x14x14

Pricing Comparison

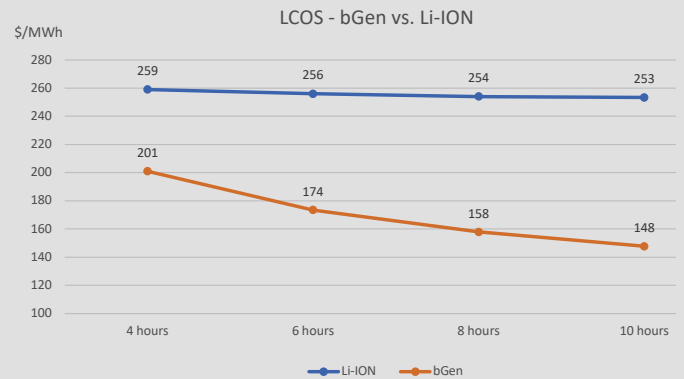
Capex

In comparison to batteries, the price difference increases if using longer duration storage units as we better utilize the steam turbine.



Levelized Cost of Storage

While the bGen's efficiency is lower than Li-ION - due to higher charging costs, the cheaper CapEx, O&M and augmentation costs result in lower LCOS for the bGen, ranging from 21% difference in 4-hours storage systems and up to 37% in 10-hours systems.



Pricing assumptions based on "Lazard's levelized cost of storage analysis, Nov 2018" and U.S. Department of Energy

	Module	Inverter	Power station	EPC
Li-ION	315k \$/MWh	55k \$/MW	-	16.7%
bGen™	66k \$/MWh	-	571k \$/MW	16.7%

Modelling assumptions for 20MW/160MWh storage system

	Li-ION	bGen
Installed Capex	\$60.1m	\$24.4m
Total Annual expenses	\$5.8m	\$5.3m
<u>Annual expenses breakdown</u>		
Efficiency	87%	42%
Annual Charging cost (\$3.3c)	\$2.1m	\$4.4m
Annual O&M (1.3%, \$1c/kWh)	\$0.7m	\$0.6m
Annual Warranty (1.5%)	\$0.8m	\$0.3m
Annual Augmentation (4.2%)	\$2.2m	0

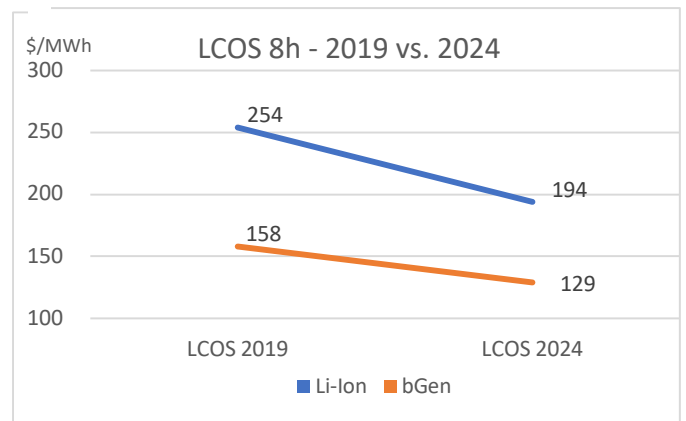
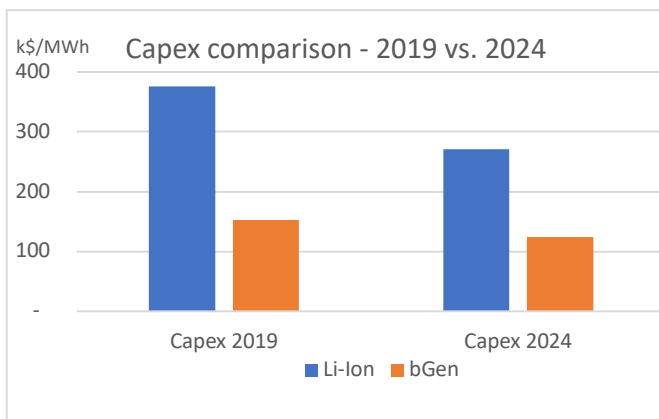
* Project lifetime 20 year, 350 cycles per year, 3.3¢ charging cost, 20% debt, cost of debt 8%, cost of equity 12%, accelerated depreciation 7 year MACRS, 40% tax rate

bGen will remain cheaper than Li-ION

Lazard estimates a Capex drop of ~28% for Li-ION batteries in the next five years. Their projection that Flow-Batteries should drop at ~38% within the same period.

Brenmiller projects a drop of 15% in capex for the bGen storage

system whilst improving system efficiency. We present here comparison of these technologies for 8-hour storage system today (2019) vs. projected pricing and LCOS for 2024.



Company Profile

Brenmiller Energy, based on its unique storage technology, provides sustainable energy solutions to the distributed generation market.

The company was founded in 2012 by Avi Brenmiller, former CEO of Siemens CSP and Solel, and a team of experts in the field of renewable energy. Brenmiller Energy's knowledge and expertise are well-grounded and are based on years of field experience in designing, building and operating solar power plants in Spain and in US of over 500MW.

The company has raised over \$60m and employs 40 people in Rosh Ha'ayin, Israel.



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