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Energy Storage Innovations to Support Grid Reliability Concept

Additional submitted attachment is included below.

Solicitation Questions and Responses

Please find answers to selected solicitation questions below, followed by a summary of our technology which we believe will provide relevant background and detail to our answers.

General

1. Do the Project Groups described in Section IV.A address the primary objectives of the solicitation to enable more strategic and high-value implementation of energy storage to support grid reliability?

Yes.

2. In addition to the target performance metrics outlined in Section IV.A regarding LCOS, calendar life, and roundtrip efficiency, what other metrics should be reported?

N/A.

3. CEC is considering releasing this funding opportunity as a two-phase solicitation that includes a Pre-Application Abstract phase and Full Application phase. Projects that are successful in the Abstract phase will have two months to prepare a Full Application. Is this approach preferable to applicants or should the CEC consider a one-phase solicitation without the Pre-Application Abstract phase?

We believe feedback from a pre-application abstract is helpful to inform application materials.

4. Are the draft funding levels and match requirements appropriate to achieve the desired outcomes of each Group?

Yes.

Group 1

1. Is a three-year project timeline feasible for Group 1 projects to meet the objectives of the solicitation? Are there any potential barriers or challenges in implementing these types of projects over three years?

We believe this is a feasible timeline.

2. What level of analysis would an applicant be able to provide to demonstrate supply chain sustainability improvements of a proposed innovation? For example, could applications be expected to describe the source and lifecycle impacts of relevant materials, ethics or workforce implications, and/or manufacturing scale-up capabilities?

This is a fair expectation for the depth of applicant analysis.

3. What emerging technologies can be demonstrated to further reduce energy storage safety risks?

Discussed in our technology overview below.

4. Are there additional energy storage applied R&D or innovation opportunities not captured by this Group 1 concept?

N/A.

Group 2

1. Is the minimum scale of demonstration (>100 kW capacity) reasonable?

Yes.

2. Do the Group 2 requirements sufficiently encourage projects to be in and benefitting disadvantaged communities, low-income communities, or Native American tribes?

Yes.

3. Is the 12-month minimum demonstration period requirement reasonable for Group 2 projects?

Yes.

Introduction to Zēlos Technology

We believe batteries for the long duration energy storage (LDES) Market should have the following qualities:

- Manufacturable from abundant, inexpensive materials
- Manufacturable from materials easily sourced within global network of strategic allies
- Inherently safe (water based)
- Long cycle life (2,000+)
- Low self-discharge rate (<1% per month)
- High temperature range (-40C to +60C)
- Recyclability and ability to use existing recycling infrastructure
- Low environmental footprint (1/5 of other chemistries)
- Low cost compared to Lithium or Lead-Acid systems (1/2 cost or less)

Zēlos' Zn alkaline rechargeable batteries correspond to all these requirements.

Overview

Zēlos developed a unique patented battery architecture that stabilizes traditional single-use alkaline (Zn-Mn02) electrodes, enabling extensive rechargeable capabilities. Zēlos demonstrated over 1,400 deep cycles at 1 hour charge, 1 hour discharge, a highly demanding test regimen. Zēlos is in the process of developing a residential LDES solution that has the potential to set a new standard in terms of cost, safety, and environmental performance. Zēlos's zinc-manganese dioxide battery has the potential to realize high cycle rates and deep discharge levels, making them suitable for a wide range of applications, especially where safety and cost are of importance. The Zēlos battery is built using water-based, non-flammable electrolytes and non-toxic earth-abundant electrode materials such as zinc (Zn) and manganese dioxide (MnO2). All materials are highly energy dense and low cost.

Development of Zēlos's rechargeable alkaline battery technology will enable environmentally friendly, safe, low-cost, and high-performance energy storage products to California's ratepayers, notably the 2.7 million Californians in fire safety electrical outage risk areas and the 9 million in SB 535 disadvantaged communities.

Advantages Over Lithium Systems

Today 70% of Li-Ion battery costs are in the electrode active materials, and Lithium systems materials are largely controlled by foreign powers, namely China. The price of these commodities has increased significantly in recent years as the Lithium supply chain struggles to meet increasing global demand. The average price of Lithium batteries has increased for the first time in 2021 as chemistry improvements no longer make up for the commodity price increases.

Zinc and Manganese dioxide, by contrast, can be sourced across North America and strategic allied nations at very low costs of about $2,000-3,000 per ton; a mere fraction of the cost of electrode material used in Lithium systems. Non-flammable materials and an aqueous electrolyte eliminate multiple safety issues that plague Lithium batteries with manufacturing complexities, transportation limitations, site safety hazards, and recycling costs.

Low Carbon Footprint Recyclable Battery

The low carbon footprint of the Zēlos electrode materials, the low toxicity of its contents, and the relatively low amount of energy required to make the battery make the CO_2 payback period only 5 months for Zēlos compared to 24-34 months for Lithium based systems. Our system therefore has a much higher impact on CO2 emission reductions than any Lithium or Lead Acid based system by a significant margin. A CO_2/GHG performance comparison of our system vs Lithium and Lead Acid can be seen in the figures below as uncovered by a peer-reviewed 3rd party partial LCA analysis. It is key to note that there are no significant end-of-life concerns for alkaline systems, as they are easily recyclable, using infrastructure that is already in place globally for household AA, AAA alkaline batteries.

Background: Meeting California's Clean Energy Goals

As California procures increasing amounts of renewable energy to reach its SB 100 goal of 100% GHG-free electricity by 2045 (60% by 2030), the state will need significant deployment of energy storage. Renewable power such as wind and solar is intermittent, meaning it is not able to continuously generate power all the time, such as when the air is still or the sun sets. Energy storage allows renewable power to be captured when it is produced and dispatched later when it is needed. Thus, energy storage is necessary to fully enable solar and wind power as part of California's goal of 100% renewable energy by 2045 (SB 100) and for additional key applications such as back-up power.

Market Overview

Current State of the Market

Energy storage plays a pivotal role in enabling power grids to function with more flexibility and resilience. At the end of 2021, about 540 grid-connected energy storage systems[1] were operating in the United States.[2] A further 160 projects were either announced, contracted, or under construction. The maximum energy that could be stored at the operational energy storage sites (energy capacity) was about 234 gigawatt hours (GWh), and the maximum power that could be provided to the grid from these sites at any given moment (power capacity) was about 24 gigawatts (GW).[3] California leads the U.S. in energy storage capacity and projects with over 200 operational projects totaling about 4.2 GW.[4]

Price and Performance

Zēlos' rechargeable alkaline battery chemistry offers 30% or more savings over lithium-ion (Li-ion) and lead acid batteries at the pack level; the Zēlos battery is about $70 per kilowatt-hour whereas lead acid and Li-ion batteries are about $100 per kilowatt-hour and $100-200 per kilowatt-hour, respectively. Additionally, Zēlos' rechargeable zinc-manganese (Zn-Mn) technology can run for hundreds to thousands of cycles, overcoming the typical service lifetime constraints for Zn-Mn. The cycle efficiency of the Zēlos battery is comparable to that of a Li-ion battery and greater than that of a lead acid battery. The Zēlos battery cells can last two to three years with regular charge-discharge, and for ten years or more under occasional use, such as for backup power. Zēlos' products also feature the inherent safety of Zn-Mn and aqueous electrolytes, raw material abundance, and ease of manufacturing (no dry rooms needed). New generations of the Zēlos battery will have further improved product specifications – cost, lifecycle performance, energy density, and efficiency – and will become even more competitive with traditional technologies.

	Lead acid (PbA)	Li-ion	Zēlos Gen1	Zēlos Gen2	Zēlos Gen3
Technology	Lead acid (PbA)	Li-ion	MNO_2 – Zn 1 electron	MNO_2 – Zn 2 electrons	Novel Chemistry
Pack Cost per kWh	$100	$100-200	$70	$40	$20

[1] All grid-connected batteries; not only utility-scale
[2] US DOE Energy Storage Database
[3] Ibid.
[4] Ibid.

Volumetric energy density, Wh/L	100	500-700	85	170	250
Specific energy, Wh/kg	30-50	150-280	40	70	100
Long term lifecycle performance (number of cycles to 80% of initial discharge capacity)	300-700[5] (Most lead-acid batteries experience significantly reduced cycle life if they are discharged below 50%)[6]	500-800[7]	400-600	800	1000
Cycle Efficiency	80%[8]	>90%	>90%	>90%	>90%
Self-discharge (%/month)	Varies greatly depending on temperature – at 80F discharge is 4% per week; at 65F it is 3% per month[9]	5% in 24h then 1-2% per month (plus 3% for safety circuit)	Not measured	2-3% per year (typical for alkaline batteries)	2-3% per year (typical for alkaline batteries)

Health and Safety

Zēlos batteries use safe and abundant materials that mitigate battery hazards, health risks and scarcity concerns. Zinc and Manganese are four and sixty-four times more abundant in the earth's crust, respectively, than lithium and lead.[10] They are also non-toxic substances that can be handled safely by production workers and customers alike. Whereas the Zēlos battery is nonflammable, lithium's reactivity with air and water creates an inherent fire hazard. Additionally, the Zēlos battery composition requires no cobalt usage as required in a Li-ion battery, avoiding human rights concerns with the

[5] Custom Marine Products. 2019. Accessed March 30, 2022. https://www.custommarineproducts.com/uploads/1/4/3/7/1437708/qms_lifepo4_manual_19.pdf
[6] https://www.usbattery.com/wp-content/uploads/2019/11/FLA_DATA_1119-1.pdf
[7] Lupine Lighting Systems. 2022. Accessed March 30, 2022. https://www.lupine.de/eng/service/faq/batteries
[8] https://batterytestcentre.com.au/project/lead-acid/
[9] https://northeastbattery.com/battery-101-three-things-need-know-lead-acid-batteries/
[10] https://periodictable.com/Properties/A/CrustAbundance.v.html

procurement of cobalt in the Democratic Republic of Congo.[11] It also completely avoids the global health concerns of lead exposure. Zēlos battery manufacturing also requires no solvents, unlike lithium-ion and lead-acid battery manufacturing.

	Lead acid (PbA)	Li-ion	Zēlos Gen1	Zēlos Gen2	Zēlos Gen3
Flammability	Gases released during charging cycle are flammable	Flammable electrolyte; lithium is also highly flammable	Non-flammable electrolyte	Non-flammable electrolyte	Non-flammable electrolyte
Thermal Stability	Thermal runaway conditions determined by temperature and float voltage[12]	Thermal runaway followed by explosion may be triggered by temperatures >80C	Stable; not quantified	Stable; to be quantified	Stable; to be quantified
Safety	Must be charged in a vented room to avoid explosion of gases released; electrolyte solution is highly corrosive and poisonous if ingested	Dangerous if damaged, overcharged, or over heated; explosion hazard	Safe; positive initial results in UN 38.3 tests (T1 altitude, and T4 shock)	Safe; to be quantified in standard testing	Safe; to be quantified in standard testing
Toxicity	Toxic; Lead exposure for 6 to 16	Lithium batteries contain potentially toxic materials including	No exposure to toxic materials	No exposure to toxic materials	No exposure to toxic materials

[11] Note that there are multiple commonly used Li-ion chemistries. This statement only refers to Nickel Manganese Cobalt (NMC) Li-ion batteries.

[12] Float voltage is the voltage at which a battery is maintained after being fully charged to maintain that capacity by compensating for self-discharge of the battery.

	million people globally[13] "most polluting industrial process worldwide when ranked by disability adjusted years of life lost (DALY) [...] between 2 000 000 and 4 800 000 DALYs."[14]	metals, such as copper, nickel, and lead, and organic chemicals, such as toxic and flammable electrolytes			

Findings of primary research related to product specifications:
Below is a summary of many conversations Zelos has had with solar installers, potential customers, and utility partners.

The lower price of Zelos batteries is a competitive advantage over current available rechargeable batteries. Most of our interviewees and potential customers agreed that the main barrier for widespread adoption of BTM batteries is their upfront cost. An energy solution provider focusing on low-income communities mentioned that a lower upfront battery price can help increase disadvantaged and low-income communities' access to BTM storage systems, while improving local air quality by displacing current cheap fossil fuel-based back-up options. Another energy solution provider, working on the market rate side, mentioned that often solar installers do not offer storage because it is an expensive add-on that can threaten the deal. Therefore, the lower price of Zelos' batteries can help overcome this barrier and increase adoption of BTM battery storage as well as solar generation capacity. Future partnership opportunities for Zelos are companies working with underserved communities market segments such as Grid Alternatives, Communities for a Better Environment and The Energy Coalition. Other potential partnerships to explore are solar installers that use third-party batteries to offer residential energy solutions.

The use of abundant and non-toxic materials on Zelos batteries is a high selling point. Some interviewees referred to supply chain shortages and stated concerns on the use of scarce materials such as lithium and cobalt for BTM storage solutions. This is a growing concern among different stakeholders,

[13] Ericson, B., Landrigan, P., Taylor, M.P., Frostad, J. and Caravanos, J., 2017. The Global Burden of Lead Toxicity Attributable to Informal Used Lead-Acid Battery Sites. Annals of Global Health, 82(5), pp.686–689. DOI: http://doi.org/10.1016/j.aogh.2016.10.015

[14] Ballantyne Andrew D., Hallett Jason P., Riley D. Jason, Shah Nilay and Payne David J. 2018Lead acid battery recycling for the twenty-first century. Soc. open sci.5171368171368 http://doi.org/10.1098/rsos.171368

which is evident by the rising media coverage of resource scarcity from mining activities and the lack of battery recycling facilities to recover these scarce materials. Zelos battery materials are more ubiquitous and safer to handle than their lithium-ion and lead counterparts, thus making Zelos products more appealing to organizations committed to sustainable practices. Energy solution providers with public commitments in this regard using third-party batteries, are undoubtedly a potential future partner for Zelos.

Fair labor and non-discriminatory practices at Zelos factory can encourage more business opportunities. There is increasing concern among operators in a supply chain to ensure fair labor throughout the system. One of the interviewees highlighted the desire to move beyond Tesla power wall due to racism and other labor malpractice claims at their plants. By ensuring fair labor and non-discriminatory practices, Zelos products can resonate with the growing demand and supply side actors concerned with acquiring products that are responsibly sourced, as well as ethically and sustainably produced.

Zelos modular and stackable battery can provide additional value to the market. An energy solution provider claimed that as energy management keeps evolving, having a 3 kWh battery that can be modular and stackable can significantly add value to the market and help optimize systems, such as solar installations. Additionally, an energy system designer for net zero buildings mentioned the opportunities of different battery sizes under the current California building code for apartment complexes in low rise buildings. For this market segment there is already battery back-up designed into buildings for emergency lighting, hallways, pumps and elevators. The energy system designer highlighted that the new Title 24 building code to be adopted in 2023 will bring more opportunities for battery storage in this market segment and there was interest on his part to partner with Zelos to deploy pilot projects in the future.

Additional comments from interview findings highlighted the high value proposition of a stable battery chemistry with long-lasting usable capacity, and the possibility of interconnection and integrated load control capabilities. The latter is sought by customers as they are interested in keeping specific circuits energized during an outage.

Storage Paired with Distributed Solar

Market Analysis

Declining battery storage costs and the growing emphasis on resiliency and grid services have led to heightened interest in pairing battery storage with distributed solar to provide value to customers and the distribution grid. Storage helps solar contribute to the electricity supply even when the sun isn't shining. It can also help smooth out variations in how solar energy flows on the grid.

In California, the Self-Generation Incentive Program (SGIP) provides millions of dollars to incentivize distributed energy storage. In addition, solar with paired-storage customers under 10 kW receive NEM credits for storage exports that are sent back to the grid.[15] Thus, it makes sense for many SGIP

[15] https://www.sce.com/residential/generating-your-own-power/incentive-program

participants to pair SGIP-eligible technology with distributed solar due to the significant available incentives.[16]

Residential customers who have energy storage systems almost always also have solar panels. A May 2021 report from Lawrence Berkeley National Lab showed that of all the energy generation projects in interconnection queues nationwide, solar accounts for most projects paired with energy storage; 34% of pending solar projects are paired with batteries while 6% of wind and natural gas projects in the queue are paired with storage.[17]

In 2019, about 4% of distributed solar was paired with energy storage. By 2025, SEIA and Wood Mackenzie have predicted that about 24% of distributed solar will be paired with energy storage.[18] It has also been forecast that in 2025, about 750 MW of energy storage capacity will be installed annually in California[19], creating the opportunity for about 180 MW of distributed storage paired with solar to be installed in California annually.

Backup power

Most interviewees agree that backup power is the main reason for BTM storage adoption in California. An increase in PSPS and extreme weather events, where resiliency of the system has been affected and customers have spent hours without power, is the driver of the battery storage market. A market rate residential solution provider shared that there are spikes in customer interest in and deployment of BTM storage right after a wide power system outage. Most interviewees agreed that as PSPS events become more frequent, this increases the likelihood of customers adopting BTM storage. A battery solution with integrated control capabilities, as suggested by the SGIP evaluator, would have a competitive advantage under this scenario.

TOU Arbitrage & Solar plus storage

Interviewees agreed that the second large driver of adoption is bill savings. In the residential sector, the most common business model is to add storage to their existing solar system to extend the use of the renewable resource to cover peak hours of TOU rates (peak shaving). Stand-alone BTM systems are most common in commercial applications as their objective is to reduce demand charges and participate in TOU arbitrage.

Nevertheless, the different market actors interviewed identified that TOU arbitrage in residential is often secondary to having a battery system installed. While the initial reason might have been backup power, once the system is installed, they can stack value streams through TOU arbitrage. As pointed out by the SGIP implementer, storage is most valuable where there are larger price differentials between on- and off-peak TOU rates.

[16] https://news.energysage.com/california-energy-storage-incentives-sgip-explained/
[17] https://emp.lbl.gov/publications/are-coupled-renewable-battery-power
[18] https://www.seia.org/us-solar-market-insight
[19] https://www.seia.org/solar-industry-research-data

Several interviewees stated that energy solution providers are going back to solar customers offering to add BTM storage to the system. For this retrofit scenario, interviewees pointed out that AC coupling[20], although not the most efficient, is the lower cost and less labor-intensive option, making it the preferred option in the market. Once again, all interviewees pointed out the importance of compatibility with available battery inverters.

Finally, the deployment of BTM battery storage whether stand-alone or with a solar system, opens the door for aggregators to come in. Aggregators work with energy solutions providers, which are the ones to recruit their clients to participate in aggregation programs, adding value to the battery product by accessing the wholesale market. Both aggregators interviewed shared that areas with high energy prices and local capacity constraints have high value for aggregation into wholesale market given that local transmission constraints rely on local generation to meet customer demands. They do not require any particular chemistry nor size, and agreed that the most important requirement is connectivity; how is the data shared, what is the IoT solution and what is the frequency of communication.

Economic Analysis

Market Sizing Model

Analysis on market size and projected revenue were conducted using two separate tools. The market sizing analysis was developed using NREL's Distributed Generation Market Demand (dGen) model, an open-source, Python-based model that forecasts adoption of solar and storage across the U.S. under different conditions.[21] It does this through a bottoms-up agent based approach, essentially simulating the decision-making process for a number of representative households based on different economic and behavioral considerations and then aggregating these decisions to arrive at an estimated scale of deployment

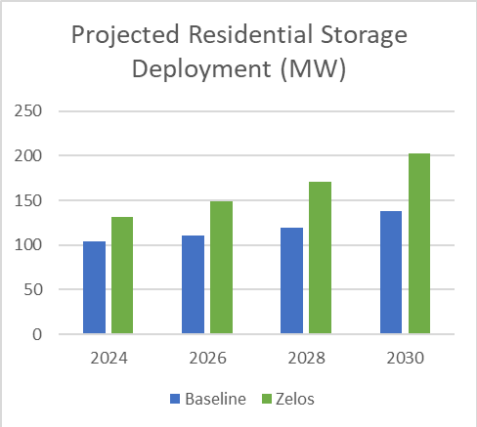
This model comes pre-loaded with several underlying assumptions, most of which were left in place for the purposes of this analysis. This included retail electricity price forecasts, solar + battery system size (based on underlying load data), revenue opportunities for customers, and types of incentives in place (including net metering). It also assigns specific dollar values that customers might assign to the resiliency benefits of batteries, which were taken from an extensive review of existing literature on the value of resiliency in different sectors. These assumptions are available for review through NREL's open-source platform; the only input that was changed from the default was the price of batteries, which was adjusted to simulate the cost declines made possible by Zelos's technology.

[20] AC coupling is when the battery is connected after the inverter of the solar array, having a second inverter to charge the battery with incoming AC power. In a DC-coupled system, solar panels and batteries interact directly with DC power behind the inverter.

[21] Descriptions and download instructions for the dGen model are available at https://www.nrel.gov/analysis/dgen/

We calibrated the model to calculate expected solar + storage deployments in California out to 2030 for two separate technology classes: Li-ion batteries and Zelos' battery product. For the Li-ion projection, we used the medium cost decline scenario for Li-ion batteries provided as part of NREL's pre-loaded input sets, which were developed from the laboratory's Annual Technology Baseline data sets. For the Zelos projection, we used forecasted cost declines provided by Zelos's engineers, with the assumption that the product hits the expected price point of Zelos's Gen 3 model in 2030.

The results of this projection are shown in the graph to the right. Based on the model, the market for residential energy storage (coupled with rooftop solar) in California is expected to reach 138 MW in 2030 at current cost decline forecasts. If cost declines were to accelerate in line with Zelos's projected cost reductions for its alkaline battery product, this market is expected to expand by roughly 50%, to 202 MW. This would translate to an additional 64 MW of behind-the-meter storage deployments in California by 2030.



It should be noted that the cost projections for Li-ion batteries used for this analysis do not include recent cost increases from supply chain challenges. If these challenges are to continue in the future (which is not unlikely given high demand and tight supply of this chemistry's component metals), the gap between battery deployment in a lithium-only scenario and one where Zelos's battery is available will likely be higher than shown in the graph above.

Summary

From a cost perspective, Zelos's battery product shows consistent advantages over Li-ion. Because price is inversely related to market demand, we would expect Zelos's product to expand the market for residential energy storage if it were introduced in California. In 2030, market demand for residential energy storage in California is expected to reach 138 MW, most of which will be paired with rooftop solar. If a battery product at the Gen 3's price point were introduced, this market is predicted to expand to 202 MW.

We would also expect Zelos' Gen 3 model to edge out Li-ion from an economic standpoint for most customers. The NPV of a Gen 3 model installed anywhere between now and 2030 would be between $2,000 and $10,000 in Northern California, and between $2,000 and $12,000 in Southern California. Even before consideration of the additional benefits provided by Zelos's battery chemistry (e.g. safer, more environmentally friendly materials), almost all residential customers considering installing a battery would likely select Zelos's product for this cost advantage alone.

Conclusion

California consumers and businesses will need substantial implementation of energy storage technology to meet the goal of 100 percent renewable energy by 2045. Zelos batteries offer a competitive advantage over current market products such as Li-ion.

Market advantages for the technology developed by Zelos include:

- Disadvantaged and low-income communities' access to BTM storage systems, while improving local air quality by displacing current cheap fossil fuel-based back-up options.
- Concerns on safety and environmental practices, including energy storage solution providers looking to shift away from lithium ion and other scarce minerals-based batteries.
- Ensuring fair labor practices and safe working conditions throughout the value chain, with inherently non-flammable, non-toxic, and sustainably sourced materials.
- If proposed changes under NEM 3.0 come into effect, where a solar array system will require batteries to achieve energy bill savings, lower pricing will have greater importance to solar system buyers.

LDES is an essential building block of the grid of the future, allowing for more integrated use of renewable energy sources, providing resilience, and helping reduce energy costs. It also has the potential to reduce human suffering during periods of power scarcity and lessens the need for emergency travel and other needs when electrical grid connections are compromised.

Please let me know if we may provide further information.

Thank you for your consideration and good luck with the program, it is important work.

Best Regards,

Sebastien Belanger
CEO – Zēlos Energy Ltd