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Comments on CECâ€™s EPIC 4 Investment Plan

Additional submitted attachment is included below.

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Via Electronic Delivery to CEC's e-commenting system
Development of the California Energy Commission (CEC) Electric Program Investment Charge (EPIC) Investment Plans 2021-2025
Docket #: 20-EPIC-01

Comments on CEC's EPIC 4 Investment Plan

Gridtential Energy, Inc. is pleased to submit the following commentary to the California Energy Commission in response to the Electric Program Investment Charge (EPIC) Investment Plans 2021-2025. In this response, we will first introduce Gridtential's technology and our approach to energy storage. We will then comment on the research themes and initiatives proposed in the EPIC 4 Investment Plan with specific focus on energy storage. Finally, we will share our experiences in entrepreneurship in California, and some of the things we considered important for CEC and EPIC to do to help the energy storage sector and entrepreneurial ecosystems.

Introduction to Gridtential Energy, Inc.
Gridtential Energy, Inc is a venture-backed private company in CA with the mission to revolutionize energy storage by integrating solar wafer and lead battery technologies. Our unique battery design is capable of achieving cycling performance and cost target for renewable energy storage while meeting safety and sustainability requirements of future energy infrastructures. Since our founding in 2012, we have developed a broad portfolio of intellectual properties spanning areas of substrate material, electrode processing, cell design, and battery packaging. Our approach to technology scaleup and domestic manufacturing is to engage with existing battery producers and leverage their deep expertise in industrial engineering.[1] Over the past 8 years, we have become a leader of advanced lead technology and our innovative approach to energy storage was recognized by the industry in 2018. [2]

Our technology is developed through material and architecture innovations conceived in the Silicon Valley of California, manufactured by US battery makers with domestic recycled components, and will be deployed for different energy storage applications worldwide. The core idea of Gridtential's Silicon Joule technology is the application of solar wafer processing techniques to enable a complete architectural redesign of traditional lead batteries for energy storage applications. In particular, silicon wafers are introduced to replace traditional lead-alloy grid current collectors to reduce weight and therefore increase energy density. Additionally, the battery package is re-engineered into a bipolar architecture which improves, cycle life, charge

[1] https://www.prnewswire.com/news-releases/gridtential-secures-6-million-from-battery-industry-strategics-east-penn-manufacturing-crown-battery-manufacturing-leoch-international-and-power-sonic-inc-300389955.html
https://www.prnewswire.com/news-releases/gridtential-energy-and-crown-battery-build-new-silicon-wafer-battery-that-combines-the-best-of-lead-and-lithium-ion-performance-300942290.html
[2] https://batterycouncil.org/blogpost/1190989/300815/Gridtential-Energy-Receives-2018-Sally-Breidegam-Miksiewicz-Innovation-Award

acceptance, and power performances of traditional lead electrochemistry. More importantly, the battery can be manufactured and recycled at low costs with existing infrastructures: silicon wafer current collectors are fabricated with high-throughput solar equipment; commercial electrode materials are manufactured at traditional lead battery factories; spent batteries can be recycled at existing infrastructures. The Silicon Joule technology is an innovative approach to energy storage that retains the traditional benefits of lead batteries – low cost, safe, and sustainable – with improved energy, power, and cycle life performances to tackle the renewable, distributed and interconnected energy infrastructure in the future.

Lead Batteries for Energy Storage
Lead batteries, due to its simplicity and robustness, has become the most deployed rechargeable energy storage (Figure 1).[3] It is inexpensive compared to newer technologies, generally safe due to its aqueous nature, and almost completely recyclable, which makes it the most sustainable among all battery technologies. Lead batteries are ubiquitous in numerous energy storage and also automotive applications. For energy storage, deep-cycle batteries are widely used in various stationary and industrial applications. Thin-plate batteries, which have high surge current capabilities, are used in automotive as well as backup applications.

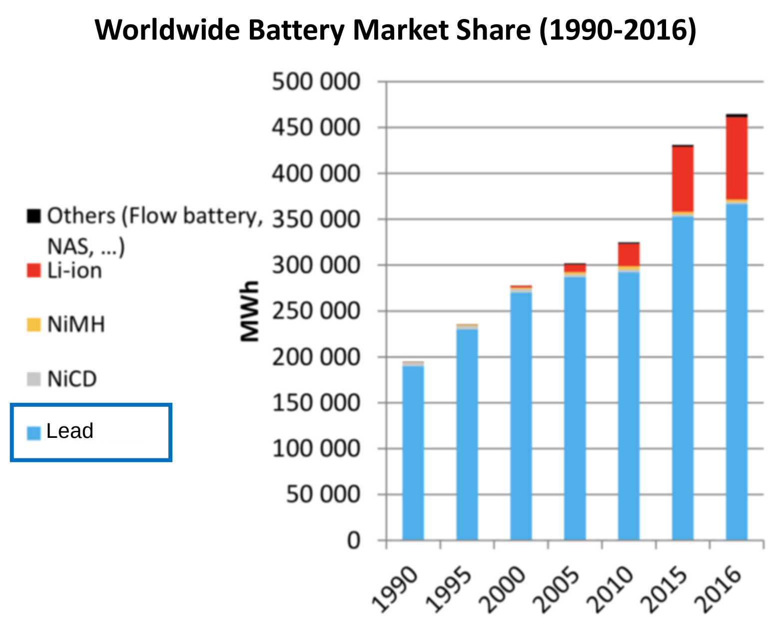

Figure 1: Worldwide battery market share by technologies (1990-2016), lead occupies > 90% market.[3]

Despite its widespread deployment, lead batteries only occupy a small market share in renewable energy storage, especially for grid-connected large-scale systems (Figure 2).[4] Although the capital costs of lead-based systems are among the lowest, their levelized costs of storage increase due to energy throughput issues. Nonetheless, lead batteries have found applications and have active projects in all use cases on the ESGC Roadmap.[5] Lead batteries are

[3] http://www.avicenne.com/pdf/Lithium-Ion%20Battery%20Raw%20Material%20Supply%20and%20Demand%202016-2025%20C.%20Pillot%20-%20M.%20Sanders%20Presentation%20at%20AABC-US%20San%20Francisco%20June%202017.pdf
[4] https://www.eia.gov/analysis/studies/electricity/batterystorage/pdf/battery_storage.pdf
[5] DOE OE Global Energy Storage Database – Global Energy Storage Database Projects https://www.sandia.gov/ess-ssl/global-energy-storage-database-home/

highly competitive in use cases which require good response to shifting capacity needs over a few hours (mid-duration load response); strong initial power input (black start); smooth electricity supply without interruptions (power quality); ability to provide power after inactivity (reliable); high tolerance to mechanical and temperature stresses (robust); simple integration to large systems (scalable); low risks of operation and good recyclability (safe); and cost-effective integration to other energy sources (efficient). These attributes make lead batteries indispensable in several of CEC's proposed research initiatives that require stationary energy storage, such as "Advanced Prefabricated Zero-Carbon Homes" and "Optimizing Long-Duration Energy Storage to Improve Grid Resiliency and Reliability in Under-resourced Communities".

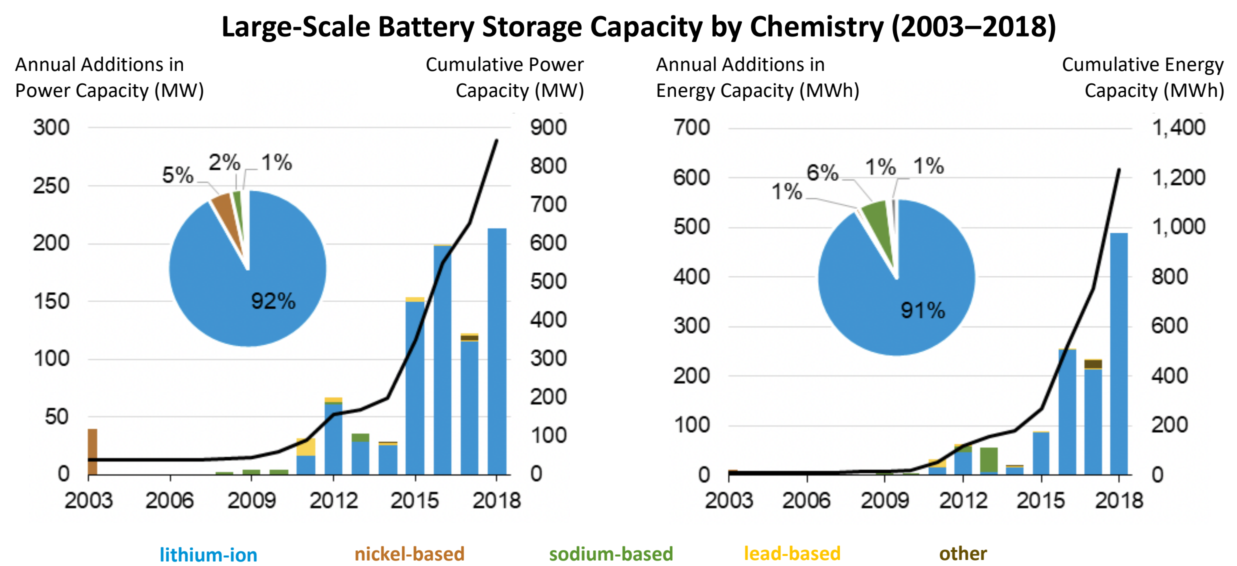

Figure 2: Grid-connected large-scale battery storage capacity by chemistry (2003 – 2018).[4]

As our energy infrastructure advance towards increased variety of power sources and complexity of grid services, emerging use cases are developing rapidly to facilitate the evolving grid for the adoption of renewable sources; increase resiliency of remote communities towards effects of climate change; enable a distributed charging infrastructure of electrified mobility; and further increase energy flexibility of residential, commercial, and industrial facilities. As a result, a spectrum of energy storage technologies is required to balance the intermittent nature of renewable energy sources; connect a distributed grid with nodes of different energy and power requirements; and support off-grid isolated sites with increasing flexibility and resiliency needs.

Potential of Advanced Lead Batteries on DoE's ESGC Roadmap

In order to support energy storage of the future, there is a renewed interest in the development of advanced lead battery technologies to improve their load response from short-to-mid duration; cycle lifetime; and energy density.[6] Fundamentally, these deficiencies are not necessarily inherent to lead electrochemistry, but rather to the architecture of the battery.

Lead Batteries – The Complete Energy Storage Solution (An Interactive Map) https://batteryinnovation.org/interactive-map/

[6] **Past, Present, and Future of Lead–Acid Batteries**. Pietro P. Lopes and Vojislav R. Stamenkovic *Science* **369** (6506), 923-924. https://science.sciencemag.org/content/sci/369/6506/923.full.pdf

Therefore, novel material and architectural innovations designed to improve performance while leveraging existing manufacturing infrastructures, like Gridtential's Silicon Joule technology, will be attractive solutions if technical challenges can be overcome.

The Silicon Joule battery is packaged in a bipolar architecture in which solar wafer current collectors are used to connect electrochemical cells electrically in series. Replacement of lead alloy grids with silicon bipolar plates reduces the overall weight of the battery and increases energy density. The bipolar configuration eliminates non-uniform current density distribution across the electrodes to delay traditional failure mechanisms and extend the cycle life of lead electrochemistry to achieve the requirements of renewable energy. In addition, current conduction in a bipolar lead battery is only limited by the plate thickness and thus much shorter, which leads to reduced electrical resistance to enable higher power and charge acceptance (Figure 3).

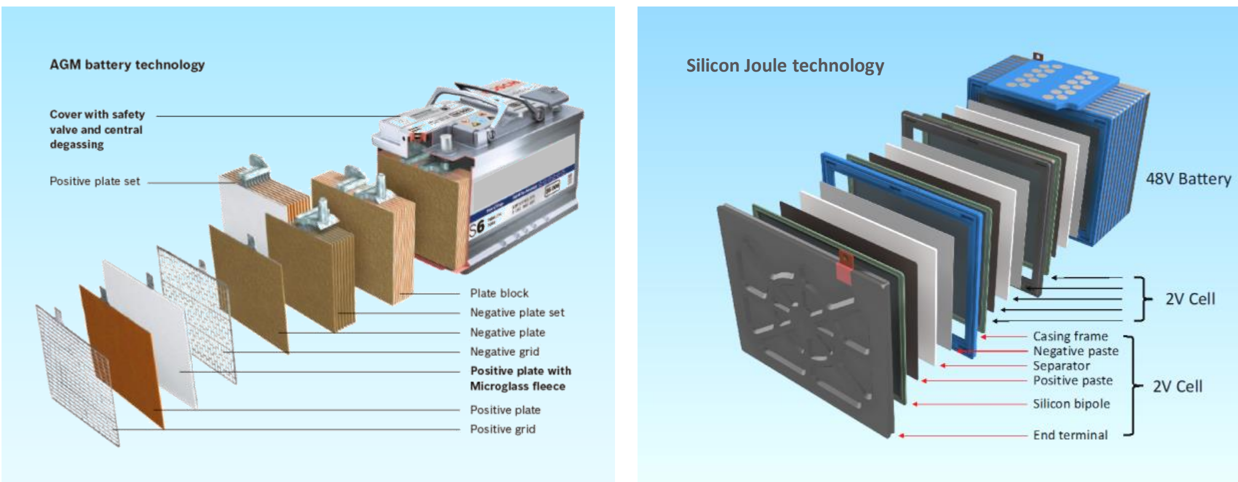

Figure 3: Construction of traditional AGM lead battery and Silicon Joule bipolar technology, in which cells are connected electrically in series and hermetically isolated by the wafer current collectors.

Advanced bipolar lead technologies such as Silicon Joule inherit advantages of traditional lead electrochemistry – black start, power quality, reliable, robust, scalable, safe, and efficient – but also addresses its deficiencies to achieve higher power (faster load response), longer cycle lifetime, and higher energy density (more compact). Adoption and deployment of advanced lead technologies can expand the capability of lead batteries. In particular, advanced lead batteries are well suited to facilitate the evolving grid; serve remote communities; support electrified mobility infrastructures, and further increase flexibility, efficiency, and value of residential and commercial facilities.

The Silicon Joule technology not only improves performance of traditional lead electrochemistry, it is compatible with existing silicon and lead infrastructures. Therefore, commercialization and deployment of Silicon Joule technology can be simplified by exploiting low-cost solar wafer supply chain and partnering with existing lead battery manufacturers in the US. In other words, development of advanced lead technologies can revamp domestic manufacturing technology innovations, revitalize local battery material supply chain, and deliver energy storage to benefit communities around the world.

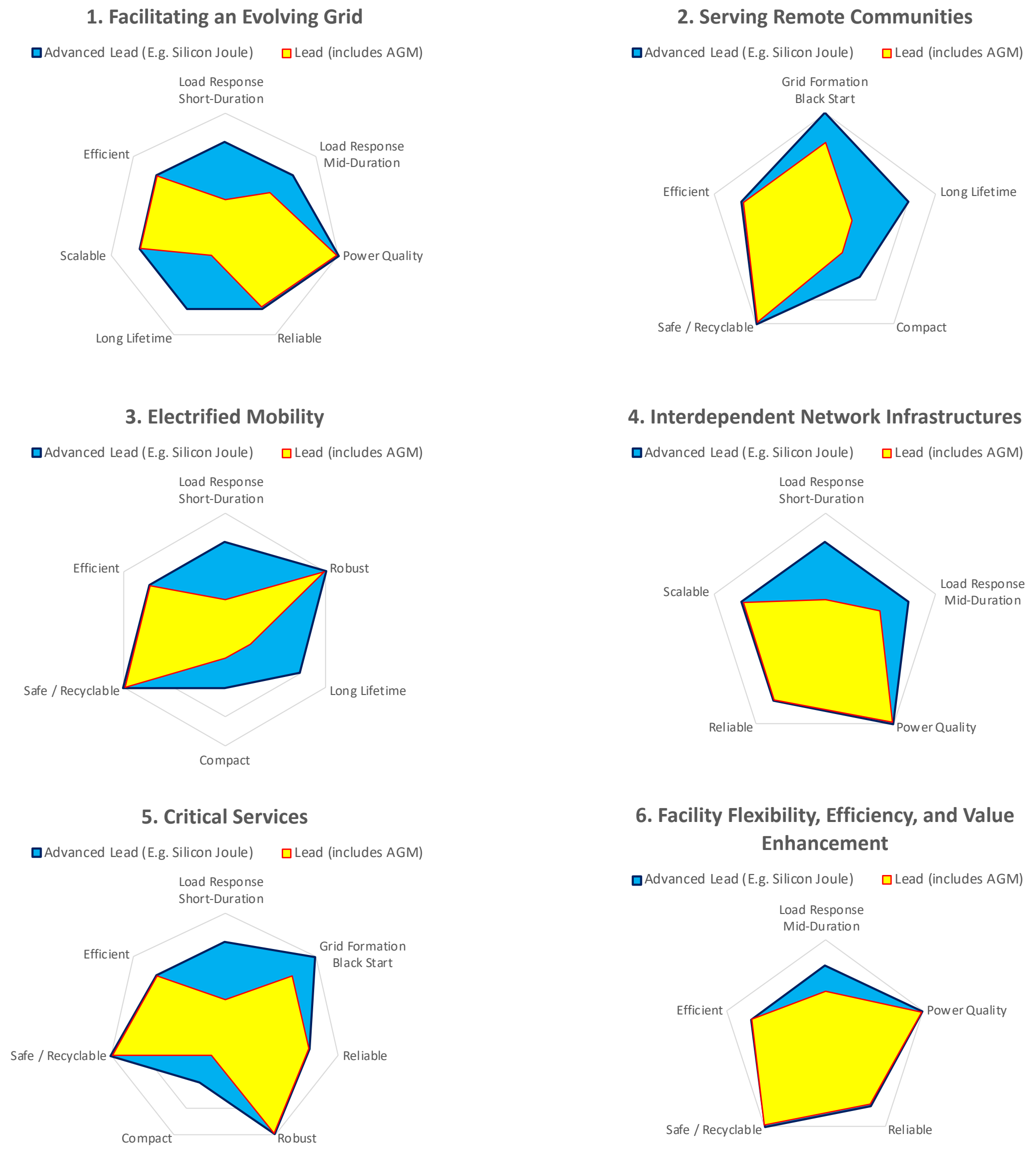

Figure 4: Improvement in performance attributes of advanced lead technologies over traditional lead in each use case on the ESGC Roadmap.

Comments on CEC's EPIC 4 Investment Plan

California is leading the nation in climate change legislations, renewable energy deployment, and clean tech businesses. This is partly because of CEC's continued support of entrepreneurial ecosystems. Gridtential is grateful for CEC's support during its founding stage through the Energy Innovation Small Grant Program (Grant 10-14, Contract 500-98-014). The EISG program kick started Gridtential, and provided much-needed support for us to demonstrate concepts and feasibility of our basic technology.

It is important for the CEC to continue support California's entrepreneurial ecosystem from research and development, pilot demonstration, and manufacturing scale up. Specifically, Gridtential can benefit from GFO's that focus on energy storage, technology agnostic, and target low to medium TRL / CRL / MRL, so call the valley of death. Examples of recent GFO's relevant and appropriate to Gridtential include GFO-19-305 (Gridtential applied but not awarded), GFO-20-301 BRIDGE (Gridtential attempted to apply but was deemed ineligible after an addendum), and GFO-20-302 RAMP (Gridtential applied but not awarded). In Gridtential's experience, the challenges of energy storage development to commercial viability are threefold: technology development, domestic manufacturing, and technology transition, which we will discuss below.

Technology Development

Gridtential's Silicon Joule technology combines innovations in materials, architecture, and also manufacturing. Successful commercial deployment requires development, testing, and pilot scale up. As our technology integrates two different infrastructures (silicon wafer and lead battery), our early efforts were focused on the development and processing of custom silicon wafers and thin film materials that are compatible with lead electrochemistry. Although research work in semiconductor thin films and lead electrochemistry are both plentiful; screening, optimization, and characterization of substrate and thin film materials all require development of specialized equipment and expertise.

To accelerate technology development, entrepreneurs would appreciate support to access the vast technical knowledge and facility resources in the state. For example, high-throughput materials screening and electrochemistry optimization efforts will be much more effective at the SLAC National Accelerator Laboratory at Stanford. In addition, modeling of lead batteries from atomistic to system scale is only possible with supercomputing resources. *It is important that the CEC continues to support both basic and applied research of advanced lead-based technologies for energy storage applications.*

The modular nature of lead batteries (as opposed to bulk-scale energy storage like flow batteries) is most suitable for small-to-mid scale applications in the distributed grid. As the energy infrastructure migrates to distributed energy storage, emerging market opportunities will also shift to smaller-scale, residential, behind the meter applications. In this case, it is better to validate advanced lead technologies first in smaller-scale demonstration sites (residential), followed by system scaleup to mid-scale commercial deployments, and finally to utility-scale system projects. *It would be beneficial to technology developers like Gridtential if the CEC facilitates testing and validation of new technologies in small scale testing sites hosted by institutions, laboratories and incubators; increases support of residential-scale projects on distributed storage; and creates a platform for data collection and analysis of system cost-benefits.*

Domestic Manufacturing

For traditional lead, domestic infrastructures are relatively mature – from raw material supply, manufacturing, and also recycling. In the US, 99% of used lead batteries are recycled,[7] and 93% of the recycled lead are used to produce lead batteries domestically.[8] This is in stark contrast to

[7] https://batterycouncil.org/page/Battery_Recycling

[8] U.S. Geological Survey, 2020, Mineral commodity summaries 2020: U.S. Geological Survey, 200 p. https://doi.org/10.3133/mcs2020

lithium-ion technologies: China manufacturers 62% of lithium ion batteries worldwide in 2016,[9] and China's share is increasing.[10] For Silicon Joule technology, although it is compatible with traditional lead infrastructures, our innovations in materials and architecture necessitates new developments in material supply chain and manufacturing technologies. These development efforts are crucial to address barriers of adoption, and also lower the overall system cost. To illustrate both the potential and challenges reinvigorate domestic manufacturing of energy storage, consider the following comparison between traditional lead and advanced Silicon Joule advanced bipolar (Figure 5). We will discuss the major barriers of deploying our technology in terms of materials processing, manufacturing technology innovations, and supply chain.

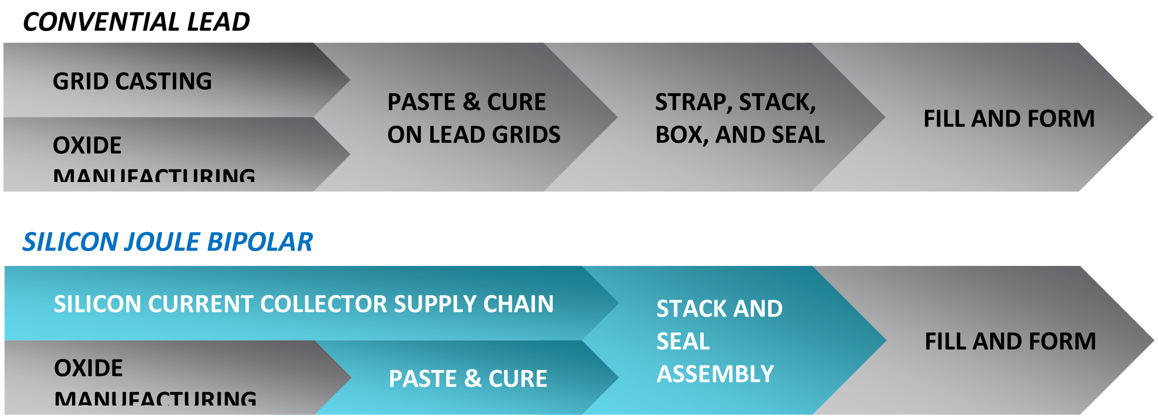

Figure 5: Comparison of conventional lead and Gridtential bipolar battery manufacturing.

<u>Manufacturing Innovations for Materials & Components</u>

The substrate plate material is critical to the performance of bipolar lead batteries. The silicon wafer substrate used the Silicon Joule technology is manufactured by solar processing techniques. Although solar technology has gone through dramatic cost reduction in the past decade, bipolar plate cost is still a major barrier of adoption for domestic battery manufacturers. This is partly because material requirements for solar and lead battery are slightly different. In solar, high purity un-doped silicon must be used to maximize cell efficiency. However, lead, an essential element in lead battery, are not found in solar infrastructures. Deposition processes that hold promise to manufacture low-cost bipolar plates in the US are often not integrated into existing solar process flow and therefore not used. *Manufacturing process innovations supported by the CEC to lower cost of silicon plates for bipolar lead batteries, many of which can be developed by readjusting solar processing towards Silicon Joule technology, will lead to lower cost and increase commercialization of advanced lead battery technologies.*

<u>System-Level Innovations</u>

In addition to battery manufacturing, system-level integration into energy storage systems presents additional challenges for new battery technologies. Whereas it is commonplace for lithium ion battery packs and systems to have built-in charge controllers due to fire hazards,

[9] **The Case for Recycling: Overview and Challenges in the Material Supply Chain for Automotive Li-ion Batteries**. Mayyas, A., D. Steward, M. Mann, *Sustainable Materials and Technologies* **19**, e00087, 2019.
[10] https://www.forbes.com/sites/rrapier/2019/08/04/why-china-is-dominating-lithium-ion-battery-production/#7feb8e373786

lead batteries charge control is often not included because of their inherent safety. On the other hand, it has been demonstrated that optimized charge control can improve cycle life and lower energy storage costs of lead-based energy storage systems.[11] System-level hardware and software are especially important for large-scale battery energy storage systems to facilitate the evolving grid, as well as "multi-purpose" systems – time-shifting, demand charge reduction, backup power – to enhance facility flexibility, efficiency, and value. *Innovations in integrated system design to connect battery control systems can improve performance and lower cost of energy storage, thus maximize the potential of advanced lead technologies.*

Supply Chain Resilience

The Silicon Joule technology is designed to be compatible with solar silicon materials and processing techniques. However, we are facing significant challenge in both silicon wafer supply and solar process options in the US. *Our challenge is evident with the continued decrease of solar manufacturing in the US – the US share of module shipments dropped to approximately 0.5% in 2017[12] – and the US is ceding its leadership in processing the 2nd most abundant element on earth.* In order to promote advancement of energy storage technologies, particularly advanced lead batteries, it is important to rebuild a domestic bipolar substate supply chain that is equipped with flexible manufacturing technologies to compete with low-cost but low-quality suppliers.

Technology Transitions

Gridtential's technology is a perfect example of integrating crossover innovations to revitalize a traditional domestic industry for emerging applications of upmost importance. However, our innovative business model also inherits additional challenges during technology transition. In particular, venture investors prefer "pie-in-the-sky" ideas and generally are not interested in established industries; government innovation programs often overlook opportunities to upgrade mature infrastructures for emerging applications; publicly-funded projects tend to favor large-scale installations with long-term warranty requirements; private industries are sometimes reluctant to invest in disruptive technologies that could displace their own market share. *In Gridtential's experience, California can achieve its renewable energy and decarbonization goals if the CEC will encourage cooperation between technology developers, domestic manufacturers, OEM's and customers; and also stimulate investments from mature industries (like lead) to promising technology ideas (like Gridtential's bipolar lead batteries solution).*

[11] https://batteryinnovation.org/research-targets-intelligent-battery-management-system-for-storing-wind-and-solar-power/

[12] Brittany L. Smith and Robert Margolis, Expanding the Photovoltaic Supply Chain the United States: Opportunities and Challenges. NREL Technical Report TP-6A20-73363, 2019. https://www.nrel.gov/docs/fy19osti/73363.pdf