IONIC
MINERAL TECHNOLOGIES

September 9, 2022

ATTN: Deputy Assistant Secretary Alejandro Moreno
U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy
Forrestal Building
1000 Independence Avenue, SW
Washington, D.C. 20585

Re: DE-FOA-0002794: Request for Information on the Department of Energy's Critical Materials Research, Development, Demonstration, and Commercialization Application Program

Dear Deputy Assistant Secretary Moreno and Colleagues,

It is with great enthusiasm and civic pride that I welcome the opportunity to respond to the U.S. Department of Energy (DOE)'s request for information on the Department's Critical Materials Research, Development, Demonstration, and Commercialization Application Program (hereinafter, "the Program").

The Program's timing is perfect. As President Biden has said, climate change is an "existential threat." Slowing, arresting, and ultimately reversing climate change is going to require a rapid, massive shift to renewable energy and a related surge in battery production and, ideally, battery performance (i.e., energy density, charge and discharge rates, cycle life, calendar life, etc.). Given the passage of the Inflation Reduction Act (IRA), demand for batteries, solar panels, and other tools of the renewable energy revolution is already skyrocketing.

Unfortunately, critical minerals and materials are the "Achilles' heel" of the economy-wide transition to renewable energy and more efficient modes of energy consumption. As we stand today, the United States has far too little owned or controlled supplies of both raw critical mineral resources and the value-added critical material processing capacities needed to accommodate the burgeoning domestic demand for batteries and solar panels or even compete in the global marketplace for these technologies. As an increasingly antagonistic competitor—namely, China—has nearly cornered the global supply of critical minerals and value-added processing capacities, it is essential that the Program galvanize a robust cluster of domestic critical minerals extraction, beneficiation, and value-added processing industries as quickly as possible. These industries must be innovative, cost-effective, scalable, and resilient. As Americans, we need to innovate. We need to think out of the box to lead this effort. We need to explore unconventional resources that are abundant in this country. We need to find new ways to develop the materials we need.

As the Founder and CEO Ionic Mineral Technologies, I know we can. Indeed, our company has done just that. We are a Utah-based manufacturer producing nano-silicon anode powders and critical mineral byproducts that will power the next generation of advanced lithium batteries, I believe the Program, combined with the IRA and the Bipartisan Infrastructure Legislation (BIL), provide a once-in-a-generation opportunity to strengthen the American economy, alleviate our dependence on increasingly aggressive foreign competitors, and accelerate the delivery of an affordable and resilient energy transition. **Taking advantage of this opportunity, however, will require the United States:**

1. **Encourage the development and expansion of as many domestic critical mineral and value-added critical material producers as possible. The United States' supply must catch up with both its competitors and domestic demand; we must therefore invest in as diverse a portfolio of affordable, effective, and scalable projects as possible. We must aim for the greatest possible volume of critical minerals, as well. Simply put, the demand for critical minerals vastly outweighs supply; Ernst & Young projects the lithium deficit alone to reach 700kt by 2030. Indeed, I was pleased to see "Scale Up" as an explicit goal of this RFI.**
2. **Invest in silicon-based technological solutions, specifically nano-silicon, which is an advanced material that can either augment the graphite-intensive anodes ubiquitous in today's lithium-based batteries—particularly those installed in electric vehicles (EVs)—or implemented as an outright drop-in substitution for graphite. This innovation empowers far more powerful lithium-based batteries which, in the case of EVs, can increase charging speeds eight-fold and battery energy density ten-fold. As such, the wide-scale integration of nano-silicon in the anodes of lithium batteries for commercially available EVs could effectively eliminate "range anxiety," a key inhibitor to these vehicles' mass adoption by the American consumer. Further, they would increase charging speeds, making EV charging more like the familiar experience of filling up a gas tank. Silicon-based solutions are how we can leapfrog competitors, rather than simply reaching parity.**

3. **Designate halloysite a critical mineral and invest in domestic procurement. Producing halloysite-derived nano-silicon emits the least carbon and is the safest and most scalable way to manufacture the nano-silicon that our**

rapidly electrifying economy needs. Further, the United States has a large raw domestic supply.

Below, please find our reasoning for these recommendations, as well as answers to a selection of your specific questions.

Encourage the development and expansion of as many domestic critical mineral producers as possible: I recommend DOE take an "as much as possible as quickly as possible" approach when it comes to critical minerals. Twin forces are pushing the global market—and, even more acutely, the U.S. market—towards such an approach. First, global demand is exploding. According to Bloomberg, 60% of new vehicle sales will be EVs by 2030, a more than six-fold increase over current percentages. That's to say nothing of the millions more commercial vehicles and the potentially billions more electric mopeds, motorcycles, scooters, and three-wheelers, all of which will require advanced batteries. The smartphone market will also keep growing quickly; in 2021 alone, 1.4 billion phones were purchased worldwide.

The IRA will similarly intensify demand. The more than $350 billion now available for microgrids, clean energy, and EVs will create ever-greater demand for deep-cycle batteries (i.e., EV batteries, long-duration energy storage systems, etc.), solar panels, and other critical mineral- and material-intensive technologies. To be clear, this is a "good problem;" the transition to clean energy is essential. Nevertheless, meeting increased demand will be a challenge for the critical minerals and materials industries.

The second issue is that our critical mineral and materials supplies are vulnerable. China controls over 80% of the market. As China's reaction to Speaker Nancy Pelosi's visit to Taipei demonstrates, China has an increasingly adversarial posture towards the U.S. and its allies. It has also demonstrated it is willing and able to cut critical mineral supplies for political and/or mercantile reasons. Should China choose to do so now—as it could at any time—huge sectors of the American economy would be in serious jeopardy. And that's to say nothing of the Biden-Harris administration's emissions-reduction goals, which largely depend on the rapid operationalization of a domestic critical minerals and materials supply chain.

As such, the Program must prioritize both speed and scale. We need to increase domestic supplies immediately, thus mitigating the short-term risk should China restrict international supply. Long-term, we need to embrace a diverse set of approaches and foster as large a critical minerals supply and as robust materials production capacity as possible. We are very far from saturating the market. For the foreseeable future, there is ample room for many large critical mineral and value-added critical material producers.

Invest in nano-silicon: Nano-silicon is the most promising critical material advancement for batteries in the U.S., and it is available today. When incorporated into the anodes of lithium-based batteries, this advanced material yields superior performance outcomes across a range of metrics. In the case of EVs, the outperformance of lithium-based batteries with nano-silicon anodes over those with anodes reliant on graphite and even micro-silicon is unmistakable. Moreover, these advantages can be captured by incumbent and emerging EV manufacturers alike with surprising ease, particularly if the nano-silicon material they are sourcing is produced with the appropriate feedstock (more on that below).

Nano-silicon anodes have a multitude of benefits. Whereas conventional graphite in lithium-based battery anodes leads to battery swelling and cell rupturing—phenomena that effectively “break” the battery—nano-silicon anode powder can withstand far greater performance demands before it will allow battery swelling or cell rupturing, extending the cycle and calendar lives of the lithium-based batteries in which this advanced material is incorporated.

Nano-silicon powder could also replace all graphite in a battery, enabling far higher capacity batteries. In recent tests, batteries with nano-silicon anodes had a charge capacity of 3600 mAh/g, compared to 372 mAh/g for graphite anodes. Such capacity growth could empower EVs with far greater range. Further, nano-silicon powder enables batteries that charge far faster than those with graphite anodes. Another recent test demonstrated that a nano-silicon anode battery reached 80% power after just five minutes of charging, compared to 40 minutes for lithium-based batteries with graphite-intensive anodes.

Certain types of nano-silicon may be even more effective. Nano-silicon derived from halloysite, for instance, can enable a further 50% improvement in battery capacity, above and beyond the already large gains enabled from conventional nano-silicon, which is typically derived from silane gas.

Halloysite-derived nano-silicon, then, can advance the performance of lithium-based batteries over their full lifecycle. At scale, nano-silicon has the dual potential to dramatically reduce not only our dependence on overseas sources for critical minerals (i.e., lithium and graphite) and critical materials (i.e., battery-grade graphite and carbon powders), but also the need to invest in domestic capacity-add for critical mineral and material recycling and reuse—all while empowering the next generation of battery technology. It could also have an enormous impact on the electric vehicle industry. Range anxiety is the second biggest reason people hesitate to buy electric cars –

according to *Consumer Reports*, 55% of people have that fear. Nano-silicon technology can eliminate that concern.

Name halloysite a critical mineral and invest in domestic capacity: As nano-silicon creates much more powerful batteries, battery manufacturers are eager to move to silicon-based solutions. The issue is supply. Silane gas, the conventional feedstock for nano-silicon, as well as nano-silicon's technological predecessor, micro-silicon, is expensive, rare, toxic, and combustible. It is prone to spontaneous combustion. Silane gas does not occur naturally and, in turn, must be synthetically produced. This is a process with evidently firm technical limitations which, at present, is only capable of producing approximately 2,000 tons per year globally. Relatedly, it costs roughly $25,000 per ton to manufacture, which can translate into exorbitant costs for end-users of the anode materials that the synthetic compound is used to produce.

America's opportunity lies instead in a new feedstock, namely halloysite. America has copious halloysite resources *and* reserves. Our flagship Utah facility alone contains millions of tons of halloysite ready for extraction, and we will be able to process 3,000 tons per year by the end of 2023. We can produce halloysite powder (our nano-silicon feedstock material) for roughly 1% of the cost associated with the synthetic silane gas-derived nano-silicon feedstock material.

As a bonus, the halloysite-derived nano-silicon process creates byproducts that are themselves on the critical minerals list, including high-purity alumina, and magnesium hydroxide. These byproducts are used as everything from catalysts and high-density magnetic data storage media to steel production, LED lights, and scratch-resistant glass.

DOE can galvanize the production of halloysite-derived nano-silicon by naming halloysite to the critical minerals list. Naming it to the list would both spur commercial interest in purchasing halloysite-derived nano-silicon—in effect, it would let private markets know that the solution is a safe investment—while also encouraging new producers to look for more halloysite deposits and build production capacity.

Halloysite is also plentiful in the U.S. indeed, our Utah sit is the world's largest high-purity halloysite deposit in the world.

Halloysite is an American competitive advantage. We should invest accordingly.

Below, please find our answers to a selection of your specific questions. Our thinking on these questions, however, is based on the strategic framework presented above.

I believe, along with the entire Ionic Mineral Technologies team, that we have a once in a generation opportunity to save the planet, leapfrog our competitors, and show that American innovation and manufacturing are alive and well. We have an opportunity to prove we can solve hard problems–all on our own home turf.

Yet such an opportunity is also a responsibility. It demands we not squander the opportunity. It demands we rise to the occasion. We have a will and a way to do just that.

We are eager to be of service and are happy to answer any further questions you may have.

Sincerely,

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Responses to Specific Questions:

C1.1: How should Program applicants be asked to demonstrate potential for and, if selected, measure progress toward the Administration's goals of producing clean energy products; supporting community and economic development; creating or retaining good-quality jobs, including efforts to attract, train, and retain a skilled workforce; providing specific benefits to underserved and disadvantaged communities; securing domestic clean energy supply chains; building the technologies of tomorrow; achieving the goals of the Justice40 Initiative; and transforming the economy by 2050 to achieve net-zero emissions goals?

Funded programs should be measured by their outputs, not their inputs, particularly when considering securing domestic supply chains, building the technologies of tomorrow, and transforming the economy by 2050 to achieve net-zero emissions goals.

Specifically, in the case of critical minerals, programs should be measured by how many batteries or other climate change mitigation tools use the products they produce and how powerful those batteries and tools are. They can similarly be measured by how much carbon they prevent from entering the atmosphere. Depending on measurement timelines, they should also be measured against how much they can continue to produce, i.e., if they will be able to produce battery materials for the foreseeable future, or if they will run out of supply and thus be a stopgap solution.

C1.5: What are the ideal timing and desirable features, terms, and conditions of off-take agreements that would stimulate the private sector investment necessary to achieve BIL provision-related infrastructure and long-term sustainability?
Given the tremendous domestic demand, offtake agreements should be available on the fastest possible timeline and on relatively generous terms, at least for the short-term. DOE should understand that, with scale, prices will come down, but for the time being, offtake agreements will need to outpace the market to generate the sort of supply America needs. Offtake agreements, however, cannot be “one-size-fits-all.” If a company is providing an objectively better product, the price per unit must be higher. That is how DOE can spur innovation; if it is “one-size-fits-all,” DOE will be in effect only subsidizing the lowest-quality products, as the private market will pay more per unit than government offtake agreements for higher-quality inputs. Accordingly, the government offtake agreements will be essentially extraneous to the higher-quality market.

C1A.10: What are the most high-impact opportunity areas to diversify supply, develop substitutes, increase material and manufacturing efficiency, and drive reuse and recycle of critical materials for energy technologies described above in the next 5 years? Please describe which critical materials/energy technologies and type of research project should be targeted (e.g., research stage, supply chain stage, specific research opportunity) as well as what metrics should be used to determine success.
The most high-impact area warranting further investment is halloysite-derived nano-silicon anode powder. It empowers far more high-capacity and fast-charging batteries than does graphite or even micro-silicon.

C1A.12: What are the barriers to commercialization of technologies that have been demonstrated at an industrially relevant scale?
Nano-silicon powder’s primary barrier to commercialization has been lack of government recognition. DOE and future Executive Orders from the White House should recognize nano-silicon anode powder as a critical material and, in turn, halloysite clay (i.e., the primary feedstock for nano-silicon production) as a critical mineral.

C1A.15: What research areas or topics are sufficiently mature that they do not merit federal investment through the Critical Materials RDD&CA Program?
The “bottom up” processes of producing nano-silicon material wherein silane gas is the primary feedstock do not merit federal investment through the Critical Materials RDD&CA Program. While certainly capable of producing nano-silicon, the scalability of these processes is limited by the supply and, in turn, the cost of the feedstock; and there is a surfeit of evidence demonstrating how “top down,” halloysite-derived nano-silicon production are not affected by these limitations.

C3.50: What can DOE provide/do that would be helpful to a project to facilitate its collaborations with potential financing partners?
The DOE, in tandem with other pertinent federal agencies, can improve the bankability of halloysite-derived nano-silicon material processing facilities by designating halloysite a critical mineral. This will give capital markets, namely institutional investors, the certainty they need to underwrite the construction and/or operationalization of these facilities.

This will prove vital in the immediate and near-terms especially. Because while EV manufacturers are evidently bullish on nano-silicon, the ability of these manufacturers to incorporate this material into their products without compromising their products’ fulfillment of the battery assembly and critical mineral sourcing requirements of the IRA’s EV tax credit is severely limited. The trouble has to do with the domestic halloysite-derived nano-silicon production industry’s current capacity to accommodate a surge in long-term offtake agreements, a limitation that may disrupt end-users’ adoption of this advanced, proven superior material.

To that latter point, we further recommend that the DOE, to the extent possible, work with policymakers to refine the eligibility criteria for the IRA’s EV tax credit in a manner that explicitly incentivizes the production of EVs with a designated minimum of nano-silicon in their batteries anodes. Otherwise, we urge the DOE to coordinate with pertinent federal agencies and policymakers in Congress to incentivize at least the allocation of capital by EV manufacturers toward either the procurement or incorporation of domestically sourced, halloysite-derived nano-silicon into their production processes.