Nano4EARTH Roundtable Discussion Summary
Batteries and Energy Storage

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Overview

The National Nanotechnology Initiative (NNI) launched the National Nanotechnology Challenge on climate change (Nano4EARTH) to convene and mobilize the broad nanotechnology community to accelerate solutions for climate change. The NNI, with support from the National Nanotechnology Coordination Office (NNCO), has organized a series of roundtable discussions on promising areas that could have near-term impacts (four years or less). These promising areas were identified at the Nano4EARTH kick-off workshop. Among them was *batteries and energy storage*, which was the focus of the second roundtable discussion.

Widespread electrification could boost U.S. electricity consumption by almost 40% by 2050[1], causing a significant growth in the need for batteries and long-term energy-storage solutions. With that in mind, the NNCO assembled 11 subject-matter experts from different sectors, including academia, national laboratories, small and large businesses, and technology development and finance, to discuss and identify the most pressing near-term needs, opportunities, and challenges.

The moderated discussion focused on brainstorming battery use cases and needs; identifying specific nanotechnologies with untapped potential; and analyzing technological characteristics for needed optimization. Participants assembled scenarios that linked use cases with technologies and characteristics for optimization, producing a collection of specific opportunities. The agenda and list of invited participants for the roundtable can be found here.

Use Cases

A brainstorm yielded a mix of existing and potential uses for batteries, which the group felt could better address climate change in the near term (Table 1).

Table 1. Battery and Energy Storage Opportunities to Address Climate Change

Sectors Identified	Application Areas
Transportation	Battery-electric vehicles, e-scooters/e-bikes, long-haul trucks, ships, off-road vehicles, airplanes
Heavy machinery	Construction, manufacturing, agriculture
Energy storage	Homes, businesses, neighborhoods, utility grids, mobile power sources

1 https://www.nrel.gov/docs/fy18osti/71500.pdf

Household and commercial buildings	Appliances, heating and cooling systems

Discussions addressed the typical pace of change for different industries, relative carbon emissions savings, sensitivity to marginal cost changes, longevity of equipment, the role of government as a customer, battery applications in healthcare or the military as proving grounds, and crossover benefits, such as battery-electric vehicles serving as nodes in a distributed energy grid.

Technological Opportunities and Strategies

Next, participants identified technological opportunities and strategies that they felt represented untapped potential and exciting opportunities for batteries and energy storage to address climate change (Table 2).

Table 2. Nanotechnology-Enabled Opportunity Areas

Categories Identified	**Description**
New battery chemistries and architectures	Sodium, potassium, zinc, lithium sulfur, liquid electrolytes, lithium iron phosphate , lithium manganese iron phosphate, lithium manganese oxide , metal-oxygen, silicon anodes, nickel manganese cobalt, solid state polymers, doped known chemistries, flow batteries
Battery pack design	Separators, interfaces, thermal insulators, structural integration
Battery management systems	Software to maximize efficiency of battery network, energy recovery, safety, battery health
Battery recycling	Reusable materials, disassembly, recyclability by design, earth-abundant materials

Discussions highlighted the importance of incremental improvements over “moonshot” ideas for meeting short- and medium-term goals, the influence of economics for recyclability, the geographical distribution and environmental impact of mining raw materials, the rapid pace of testing software solutions, and links between performance and safety. For example, incremental improvements could be achieved with nanotechnology-enabled drop-in solutions and additives, such as cathode or anode nanocoatings, that would not disrupt existing supply chains.

Technological Characteristics for Optimization

Participants developed a list of technological characteristics that they felt must be considered and matched to applications to optimize battery development (Table 3).

Table 3. Technological Characteristics for Optimization

Characteristics Of Interest	Description
Design	Lightweight, small volume
Performance	High power, quick charge
Durability	Longer shelf life, many cycles, reliability in harsh environments
Production	Low cost, domestic supply chain, fewer critical/rare materials, ease of manufacturing, recyclability
Safety	For workers, consumers, and the environment

Discussions addressed the lack of battery factories in the United States and the need to address domestic workforce development along with export controls; the benefits of a foundry model for the battery industry that is separate from the National Labs; and the challenge of matching funding to the appropriate technology readiness level (TRL) to maximize impacts. Participants argued that a “foundry” model, similar to what is available for micro/nanoelectronics as part of the NNI-supported infrastructure, would be beneficial to quickly iterate different designs and testing parameters and accelerate innovation.

Matching Use Cases, Technology Opportunities, and Characteristics for Optimization

Participants discussed how critical the list of technological characteristics for optimization would be for the success of particular use cases. For example, batteries for heavy machinery would require high power and durability in harsh environments, while batteries connected to the utility grid would prioritize reliability and increased number of cycles.

Subsequently, participants chose a subset of potential technologies and rated each of them according to their ability to contribute to optimizing technological characteristics. For example, silicon-based batteries, which utilize nanostructures in their design and additives, avoid critical/rare minerals but may not function particularly well in harsh environments; while lithium iron phosphate batteries, which may rely on conductive nanomaterials like graphene, enable quick charging and many cycles but are not lightweight or small in volume.

Discussions focused on the comparative advantages in the United States of making high-performance batteries – even as other countries currently lead in total production output – as well as the need for quality assurance and control, which will require innovations in metrology. Participants saw interfacial challenges as crucial to battery improvements but acknowledged that no one solution will be a silver bullet. Interfacial challenges are a prime opportunity for nanotechnology solutions, as the superior contact area of nanomaterials can have a big impact in efficiency without negatively impacting size, weight, and other important performance characteristics.

Nanotechnology-enabled coatings, lubricants, membranes, and other interface technologies were highlighted to be of interest. Safety emerged as important across many domains, with the recognition that when batteries enter a use case, such as battery-electric vehicles, they may disrupt long-standing assumptions about safety standards (e.g., crash testing). The U.S. military, while perhaps more conservative than private industry, may enable substantial investments in strategic technologies, which could then scale up for broader public deployment.

Overall, the roundtable discussion demonstrated promising opportunities for nanotechnology to enhance – and, in some cases, transform – the potential for batteries and energy storage to reduce greenhouse gas emissions across many sectors in the short term. Future efforts might build on this discussion to map more comprehensively the matrix of connections among use cases, technological opportunities, and characteristics for optimization.