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Good morning, Madame Chair and Committee members. Thank you for inviting me to speak today on this very important topic of minerals and chemical processing especially as it relates to growing technologies such as lithium-ion batteries.

I have been in the U.S. advanced battery industry for over ten years and spent nearly 20 -years in the automotive industry. I currently serve in several roles: first, as Chief Customer Officer for a lithium-ion battery pack start-up company called American Battery Solutions; second, as the current Chairman of the industry trade group National Alliance for Advanced Technology Batteries; third, I serve on four different standards committees with SAE International; fourth, as an author of two books on lithium-ion batteries; and fifth, as a user and advocate for these technologies. These different roles have offered me some unique perspectives which I would like to share with you today.

Throughout history there have been several technologies that have helped to shape the direction of mankind, beginning with the taming of fire to the invention of the wheel, and later the telegraph, the steam engine, long-range electrical transmission, personal computers, the internet, space travel, cellular phones, and electrochemical energy storage – the modern battery. Today I will focus on this last one, the battery and its supply chain as it is truly the technology that has enabled of modern life. The modern advanced lithium-ion battery is perhaps *the* most important technology of the 21st Century.

In my new book I describe the last 150 years of battery development as falling into three eras: the Industrial Era, focusing mainly on lead acid batteries for automobiles and industrial equipment; followed by the Portable Era which began with the introduction of the modern lithium-ion battery; and today we are in what I refer to as the Mobile or Autonomy Era wherein energy storage truly enables a world of true freedom and mobility. The world today would be a very different place without these advanced battery technologies, for example imagine a world without our ever-present Smart Phones which grant us not only immediate communications, but access to a world of information and resources

at our fingertips. And as we move farther into the 21st Century advanced batteries, in many cases lithium-ion batteries, are the foundation for an entire new generation of technological disruptions such as the IoT, advanced robotics, the smart home, Smart Cities, blockchain, AI, autonomous vehicles and many other applications. These disruptor technologies fundamentally assume at least the following: resilient grid/energy source, cybersecurity & network security, and high speed (5G / rural broadband) communication. Lithium-ion manufacturing ability – fundamentally depending on access to requisite raw materials – is key to those baseline disruptor-enabling technologies by facilitating resilient energy sources.

The United States is largely responsible for the invention of the lithium-ion battery based on work done by innovators such as Dr John Goodenough and Dr Stan Whittingham. Yet the manufacturing of lithium-ion batteries and, increasingly, expertise in lithium-ion batteries, is now becoming centered in Asia. China is making a massive investment in lithium-ion battery technology estimated by some to be more than $60B and today, by most estimates, accounts for 60-75% of all lithium-ion battery manufacturing in the world today. In order to support these manufacturing efforts China is also aggressively acquiring sources of energy materials around the world and domesticating the processing of those materials into complex battery cathodes and anodes. The European Union/European Commission has also officially identified batteries as a Strategic Technology and are putting regulations in place to ensure sustainable sourcing of raw materials, development of the specialized skills needed in the industry, and the need for a developed recycling infrastructure.

While the “know-how” and innovations has largely being done here, most of the chemicals processing is being done offshore. Based on the 2016 U.S. Geological Survey Minerals Yearbook both the largest mineral reserves and the largest minerals processing for lithium-ion battery chemicals are being done in China, Australia, Brazil and Chile. More than 67% of the world’s supply of cobalt, a key chemical in batteries using lithium-cobalt oxide (LMO), nickel-manganese-cobalt (NMC) and nickel cobalt aluminum (NCA) was mined in the Democratic Republic of the Congo and more than 70% of the cobalt processing was done in China. Lithium presents a somewhat better story since it is more widely geographically distributed throughout the world. However, more than 98% of it is mined and processed in Chile, China, Argentina and Australia. The vast majority of the chemicals being used in lithium-ion batteries, regardless of where they are mined, are being processed in China today due to low environmental standards and strong governmental support.

This points out the complexity of the battery supply chain. For a U.S. company to build lithium-ion cells would require lithium mined in Chile or Australia; cobalt coming from the DRC; graphite coming from Austria, Brazil, Canada, or China; manganese coming from South Africa; copper from Chile; and Nickel from Australia, Brazil or Russia. These materials would then be shipped to other countries such as China where they can be processed into battery grade chemicals. These U.S. cell makers would then need metal foils to coat these materials onto from Korea and Japan, polyethylene separators from China, Korea and Japan to prevent the electrodes from touching. This largely Asian centric supply chain promotes and supports the development of the Asian manufacturers while putting U.S. based manufacturers at a disadvantage.

The energy materials supply chain challenge in North America consists of two problems, which may at times be related but are best thought of separately: The market price problem and the geopolitical problem.

The market price problem exists, and exists inevitably, because the timing of the cycles of energy materials supply and energy materials demand are different. The supply cycle is longer than the demand cycle. It takes a long time to explore, develop and finance new mines for energy materials in many cases up to five years. The rise and fall in demand for electric vehicles and lithium-ion batteries, which drive much of the demand for energy materials, occurs more rapidly. When these cycles become out of balance, prices rise (in times of supply shortage) and fall (in times of oversupply). This is as true in all industries. We can simply look at the price of cobalt over the past few years to see this in action. Cobalt prices in 2016 were about $25,000 per ton, by March 2018 prices had jumped to more than $94,000 per ton and in 2019 have now dropped back down to about $35,000 per ton.

The reason why the supply price problem should be a public policy concern is because in the global competition for advanced battery manufacturing capacity and expertise, the ability to guaranty reasonably stable (and ideally low) energy materials prices to manufacturers is a considerable advantage. Chinese companies, acting almost certainly at the behest of the Chinese government, are buying up energy materials supply sources around the globe in order to ensure that battery manufacturers based in China have access to reasonably stable supplies of low cost energy materials. This strategy will serve China well in times of shortage and will be very costly in times of surplus. But the Chinese are focused on dominating a handful of strategic industries and are willing to pay the cost to do so (i.e., the Chinese are willing to bear the cost of 1,000 Solyndra's in order to dominate the solar industry and solar technology).

The public policy question the United States must answer is what strategic industries is it willing to invest in in order to regain leadership and dominate the market? It is wrong to suggest that the United States does not have an industrial policy that contemplates making such investments. The defense and aerospace industries in the United States are heavily if indirectly subsidized. As a direct consequence, the United States dominates those industries and technologies. The question to the Congress and the Administration is: to maintain the United States' leadership in the world economy of the 21st Century, are there other industries that the United States must invest in and try to dominate as well? NAATBatt and its members would argue strongly that the answer is yes and that one of those strategic industries in which public investment should be made is the industry of advanced battery technology, materials, processing and supply chain.

The second problem is the geopolitical problem. This is the threat of physical disruption of supply by foreign actors. The geopolitical problem likely terrifies the Chinese government and explains at least in part why it views advanced batteries and electric vehicles to be a strategic industry. The ability of the U.S. Navy to disrupt China's supplies of petroleum in a crisis doubtlessly looms large in its strategic thinking. Accordingly, China has invested heavily in electric vehicle technology and is willing to suffer the environmental degradation necessary to mine energy materials and rare earth metals in order to have a source of domestic supply. The United States socializes its investment in geopolitical energy security differently, through heavy expenditures on defense. But increasing Chinese interest in blue water naval technology may indicate that it is considering a different approach and calls into question whether the United States should consider additional approaches to energy materials security that would provide for more redundancy.

Another related topic is the subject of lithium-ion battery recycling and reuse. A recent DOE analysis concluded that by 2040 a full 60% of U.S. requirements for energy materials could be provided by the recycling of lithium-ion batteries already in the market in North America.

Recycling lithium-ion batteries is, at the moment, difficult and uneconomic. The Chinese, again, are leading in this area as a result of heavy recycling infrastructure investment. But there is new technology being developed in the United States that could make profitable lithium-ion battery recycling a possibility in North America. A profitable and robust system of recycling lithium-ion batteries in North America could go a long way towards moderating possible market price problems in future years and provide some redundancy in our defenses against geopolitical disruption.

Why should Congress care? Ordinarily it should not. Today's economy is global. We no longer manufacture t-shirts in the United States. That is not a crisis. But losing the lithium-ion battery race and the race for dominating the lithium-ion supply chain would be a crisis for three reasons:

First, the loss of U.S. leadership in lithium-ion technology may well lead to the loss of U.S. leadership in other important technologies. The ability to supply electricity to a device without a power cord will be fundamental to most of the major new technologies of the 21st Century. If you lose expertise in battery technology, you risk falling behind those other technologies as well. Congress recognized these phenomena in the 1980's when it funded SEMATECH in order to address the threat to U.S. leadership in semiconductor manufacturing and by extension the threat to U.S. leadership in the entire computer hardware industry. A similar threat exists today in batteries and electrochemical energy storage. Last year, it was reported that the first operational high energy rail gun was deployed on a military vessel. That vessel belongs to the Chinese navy, not our navy. And that is just the tip of the iceberg.

Second, losing control of lithium-ion manufacturing and manufacturing technology will disadvantage U.S. workers in the global competition for high-paying jobs. Vehicle technology is moving increasingly towards electrification, for a number of different reasons. NAATBatt believes that he who makes the batteries will one day make the cars. In my main area of focus, the mobility sector, we today see electrification reaching into some all new segments that many are not familiar with including the marine and maritime segments; construction, mining, forestry, and agricultural vehicles; industrial vehicles; aerospace, drone and satellite; robotics; and is now even entering the medium and heavy truck segments. Each of these segments are creating new industries, new technologies, new high-tech and skilled jobs, and new revenue streams within the United States. Electrification is also the major power source for the emerging autonomous vehicle markets, be they land, air or sea based. It is electrochemical energy storage, the batteries, that power these applications. Current forecasts by companies such as Avicenne Energy estimate that the global lithium-ion market will be nearly $55B by 2025 and nearly $75B by 2030. The vast majority of that market is now based in Asia and the current U.S. portion of that market is only between 1-2%.

Third, lithium-ion batteries are, and will increasingly become, a strategic commodity. The Chinese recognized this fact several years ago and are aggressively securing their own lithium-ion battery supply chain, both foreign and domestic. Today, the United States can rely on the U.S. Navy to protect its access to lithium-ion batteries and energy materials, just as we have relied upon it for the

past half century to protect our access to petroleum supplies. The 21st Century may see the rise of new threats to our ability to protect our strategic materials supply chains. Developing domestic supplies of strategic energy materials and lithium-ion battery components would add an important redundancy to future U.S. energy security.

Finally, let me leave you with a thought from one of the earliest and greatest American battery innovators, Mr. Thomas Edison whose first battery patents were issued in the late 1890's, Edison says "I don't think Nature would be us unkind to withhold the secret of a good storage battery if a real earnest hunt for it is made. I'm going to hunt". This is a belief that most of us in the advanced battery industry maintain to this day. It is this spirit of the hunt that drives American innovation, leading to creating new markets, generating new high-tech jobs, developing new supply-chains, enabling the technologies of the 21st Century and beyond, and securing America's future.