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Panel III: China's Capabilities and Export Ambitions in New Energy, Nuclear Power, and Energy Storage

Introduction

My name is James Greenberger and I am the Executive Director of NAATBatt International. NAATBatt is a trade association of advanced battery manufacturers and their supply chain partners doing business in North America. Today, NAATBatt has 110 corporate members, including major automobile manufacturers, electric utilities, equipment manufacturers, battery cell and pack manufacturers, chemical companies, energy materials suppliers and professional service firms. Our organizational mission is to support developments in the science of and markets for advanced electrochemical energy storage technology in North America consistent with the goals of enhancing energy efficiency, reducing petroleum dependence and enabling carbon-free electricity generation.

I apologize for the rough nature of these comments. I am a last minute substitute for NAATBatt's Chairman Emeritus and Chief Technology Officer, Robert Galyen, who had originally been scheduled to testify today. Mr. Galyen, who also serves as the Chief Technology Officer of CATL, the largest lithium-ion battery manufacturer in the world based in Ningde, Fujian Province, China, has a unique perspective on Chinese capabilities and ambitions in advanced battery manufacturing. Mr. Galyen asked me to express his deep regret at being unable to be here today.

Of necessity, my remarks will focus a little less than Mr. Galyen's would have on what is going on in China and a little more on the prospects for the U.S. advanced battery industry in light of the large and growing investment that China is making in lithium-ion battery technology. The views I express are my own and are not the official position of NAATBatt International.

The Importance of Battery Technology

Advanced battery technology, or more precisely the technology that stores and delivers energy to an electrical device in precise amounts, at precise times, and at precise locations, is and will continue to be one of the most important technologies of the 21st Century. If the United States wants to remain a leading economic power, it is essential that U.S.-based companies master this technology and maintain leadership in its innovation, manufacture and deployment.

Advanced battery technology is a strategic technology in that it touches upon and provides spin-out opportunities into most of the other technologies that will shape human society in the 21st Century. Vehicle technology, stationary energy storage on the grid, consumer devices, implanted medical devices, drones, the Internet of Things, high energy weapons, electrified aircraft, ships

and submersibles will all depend upon the ability to access electric energy at precise times and places that the traditional electricity grid cannot accommodate. In fact, battery technology sets the pace at which many of these other technologies can evolve and come to market. For example, Apple already knows what the iPhone XIV is going to do. It is just waiting for a battery light enough, powerful enough, durable enough and safe enough to power it. The same is true for other technologies such as rail guns, long duration drones and implanted medical devices. Because the battery is such a key factor in these technologies, the battery manufacturer will always have insight into them and the ability over time to enter into their markets.

An advanced battery also provides a substantial value-added component of the manufactured goods into which they are installed. In electric vehicles today, the battery pack accounts for roughly 40% of the vehicle cost. This percentage may fall as the cost of lithium-ion batteries decline. But it will remain a significant part of the overall vehicle bill of costs because the battery substantially simplifies and makes less expensive the balance of the vehicle. The ability to add substantial value to end products is an essential attribute of a manufacturing process that has the potential to provide high wages to its workers and high profits to its owners.

Battery manufacturing provides substantial backward linkages within its supply chain that help stimulate other industries. Manufacturing lithium-ion batteries requires base materials, such as lithium, nickel, copper, and cobalt, as well as the mixing, compounding and formation of those materials. It requires specialized manufacturing and testing machinery, monitoring devices, electrical control devices, software, adhesives, and metal working. Batteries lie at the end of a long and complex supply chain. Stimulate battery manufacturing and you stimulate a wide swath of advanced manufacturing in other industries.

Finally, the process of battery manufacturing involves a lot of "learning by doing". Over the past 10 years, the price of lithium-ion batteries have fallen by about 80%. Almost none of that reduction has come from improvements in the chemical composition of lithium-ion batteries. The vast majority of the reduction has come from hundreds of small improvements made in the design of batteries on the manufacturing shop floor. That is not surprising. Economists increasingly recognize that the vast majority of technology innovations take place, not in a laboratory or classroom, but on a shop floor. Lose the shop floor and you lose an important opportunity to innovate.

Chinese Efforts to Dominate Advanced Battery Technology

China figured out the importance of advanced battery technology to its economic development more than 10 years ago and has been heavily investing in the sector ever since. Unlike the United States, which has a longstanding ideological discomfort with industrial policy (i.e., picking winners in the private sector), China's innovation and investment in the lithium-ion battery industry has experienced strong support from Federal, Provincial and City governments through a variety of methods ranging from incentive programs, licensing programs, allocations in infrastructure development, to actively managing the battery industry.

In 2016 the Chinese National government issued what has come to be referred to as the "White List" of lithium-ion battery companies. This list is made up of entirely domestic cell manufacturers with more than 8GWh of installed capacity. No non-Chinese companies are included on this list.

All electric vehicles sold in China must use cells and packs made by companies on the list or they will not be eligible for any incentives. This has forced out all non-Chinese manufacturers from the Chinese market.

But the primary focus of the Chinese government in its effort to support the manufacture of advanced batteries has been its support of market demand for the vehicles which are powered by lithium-ion batteries. *Forbes* reported that incentives for the production of electric buses propelled electric bus sales in China from just over 1,000 in 2011 to 132,000 units in 2016. Today there are over 400,000 electric buses in the road in China and more than 30 e-Bus manufacturers.

Purchase incentives for light electric vehicles, including cars, have been at least as aggressive. *Forbes* reports that based on an average subsidy of about $10,000 per vehicle, China's central and local governments spent $7.7 billion on electric vehicle subsidies in 2017 alone. Assuming that current subsidies continue (though it is not clear that they will), *Forbes* estimates that subsidy payments would rise to approximately $20 billion in 2020 and $70 billion in 2025.

China's efforts to corner the market on lithium-ion battery manufacturing have been largely successful. Today, approximately 75% of all lithium-ion batteries made worldwide are manufactured in China.

China's success in capturing lithium-ion battery manufacturing stands in unfortunately contrast to the largely unsuccessful efforts of the Obama Administration to promote lithium-ion battery manufacturing for electric vehicles in the United States. Although the American Recovery and Reinvestment Act of 2009 invested more than $2 billion in domestic battery manufacturing, few if any of the funded projects were commercially successful. With the exception of the Tesla/Panasonic Gigafactory in Nevada, no large scale manufacturing of automotive lithium-ion batteries takes place in the United States today. China's demand-pull approach has proven more successful than the limited supply-push initiatives in the United States.

Policy Recommendations

China and its success in lithium-ion battery manufacturing should not be viewed as a threat. The United States should endeavor to learn from the Chinese experience and to employ some of the same tools that China has used successfully to build its own advanced battery industry. Some possible policies would be the following:

1. *Procurement of Public Electric Vehicles for Mass Transit*. The United States should establish a substantial and well-financed "Procure for Innovation" policy. First priority should be the purchase of electric buses for public transport and of light, medium and heavy vehicles for use by public bodies. Today, almost all procurement decisions in the public sector are driven by price, which generally drives purchasers to non-electric vehicles. This makes sense from the standpoint of the locality or agency doing the purchasing. But it is counter-productive on a national level. A robust investment in public electric vehicles, coupled with strict local content requirements that support the development of lithium-ion battery production in the United States, would return to the public treasury in the long run many times the additional expense of acquiring electric buses and other public vehicles today.

2. *Continue and Expand EV Purchaser Incentives*. The United States should double-down on its investment in tax subsidies and other purchaser incentives for private electric vehicles. Any such subsidies should be conditioned on strict domestic content requirements for the battery technology contained in the vehicle. The local content requirement must be carefully specified. It is not just a matter of mandating U.S.-made steel. The battery technology and battery components should be largely of domestic origin. Also, Congress should consider enacting a special funding mechanism to expand existing purchaser incentive programs. A small user fee charged to purchasers of electric vehicles starting in 2028 could be sold to raise funds for the near-term payment of additional purchaser incentives. The fee would end up paying for itself if an increased market for electric vehicles in the short term helps improve battery technology and lowers the cost of electric vehicles during the period in which the fee is charged. Public investments in vehicle electrification are really investments in infrastructure. They can be financed through user fees, in much the same way that toll roads are financed.

3. *Use Public Subsidies to Push the Envelope on Battery Technology*. Any "Procure for Innovation" policy and EV purchaser incentives should be structured to encourage battery manufacturers to push the envelope of battery technology. The availability of public procurements and private purchasing subsidies should depend on the vehicle battery being "state of the art" and addressing specific areas of concern in battery technology, such as energy density, safety, ease of second use and recyclability. These requirements can be staged over time to push manufacturers to innovate, just as is done with fuel economy standards in ICE vehicles today.

4. *Learn from Foreign Battery Manufacturers*. Foreign-based battery manufacturers should be encouraged to locate in the United States and have access to the U.S. market, provided that American workers have the opportunity to learn from the battery manufacturing technology they bring. Foreign-based companies building battery plants in the United States should be required to use some minimum percentage of local suppliers, engineers and manufacturing technology in their factories and products. The opportunity for American workers to "learn by doing" must be jealously protected as a matter of public policy.

5. *Focus Long-Term Research on Disruptive Battery Technologies*. China's decision to make a massive investment in lithium-ion technology was motivated in part by its desire to compete with more established Western vehicle manufacturers by disrupting the internal combustion engine technology that those Western manufacturers dominate. Having made that investment, however, China is now itself vulnerable to a competitor that can disrupt lithium-ion technology with a better energy storage or energy generation technology. Lithium-ion chemistry is unlikely to be the last word in battery technology. New and better technologies will replace it in time. The United States should focus its public research dollars on finding and commercializing that next generation energy storage/generation technology.

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ADDENDUM

Questions Posed by the Commission:

1. *Describe China's current capabilities in battery production. How have they progressed in the last five years, and what has driven this progress?*

a. The stated reason for battery production is a social need for electrified vehicles which help to reduce air pollution. The government has openly stated that the fast-industrial growth in China has contributed significantly to air pollution, which has in turn created unsafe air to breath in many of the large cities. Cost of health care for people in these large cities are sky rocketing putting a large load on medical costs for society. Therefore, the need for energy storage systems, such as batteries are needed. This is creating social instability in the major cities, forcing people to leave the cities moving back to the countryside or other countries.

b. China has aspired to create manufacturing systems to produce cost effective batteries for use in electrified vehicles through new process innovation, better understanding of the chemistries involved and improved internal process flow, inventory management, supplier development and significantly improved quality systems. China has passed Japan and Korea in battery production in the past 5 years. USA runs a distant 4th place in overall global battery production, and this is with foreign domestic manufacturing capacities from Japan and Korea already in place in USA.

c. China manufacturers have must create their own new process and tooling to increase production speed without sacrificing quality. Much of this has to do with designing and building their own equipment as other equipment manufacturers do not have the experience of making such machines to exacting standards.

d. China's premium cell manufacturers are making high quality batteries for these type applications. Individual cell quality must be in the low parts per million failure rates. Multiple industries needs are fueling other developments which can be utilized into other market segments, such as bus cells used in grid energy storage systems.

e. The biggest manufactures like CATL and others are highest tier quality but there are second tier manufacturers and offshore (Korea, Japan) which drive a culture of fast, aggressive technology development, cost reduction and quality improvements.

f. China has been more customer friendly to work with in terms of customizing designs and even chemistries for faster product development.

2. *To what extent is China's innovation in batteries driven by spillover from its manufacturing capabilities in electronics, as well as government support for developing advanced manufacturing facilities?*

a. There is no "spill over" from electronics in terms of helping the manufacturing processes of batteries. Actually, the battery industry is driving the electronics industry. However, there are two significant factors in how the electronics industry plays a key role in manufacturing of batteries. First, sophisticated electronics for controlling these complex electrochemical cells

during charge and discharge is required. Due to the complexity of the chemical reactions these cells must be "balanced" by highly accurate electronic measurements and control. Secondly, the consumer electronics industry started the revolution of using advanced battery technologies due to size and weight requirements for handheld devices. This same approach in technology was adopted into the transportation sector. Although electronics play a significant role in these battery systems for all applications, the electronics industry did not drive the battery production, it was the battery technology which drove the electronics industry by enabling dispatch-able energy.

b. The battery industry did not have the right equipment for high precision battery technology manufacturing. The battery manufacturers had to design the equipment themselves, then farm it out to companies to make the equipment for them.

c. The Chinese governmental incentives packages drove the industry but not direct investment. The stated purpose of these incentives were to improve air quality in the large cities by utilization of electric vehicles. This was done in harmony with reducing coal burning plants or cleaning up the coal burning. This pushed and encouraged innovation in battery manufacturing technology. These incentives drove cooperation between vehicle manufacturers and battery manufacturers to achieve common goals of production and profitability. The incentives targeted the automotive and bus market segments directly, not batteries.

3. *How does production in the United States compare to production in China, both in the level of technological sophistication and overall manufacturing capabilities? How is it likely to evolve in the next five years?*

a. The manufacturing technology in most U.S. plants is old compared to that of China. Typically, technologies of domestic battery companies in the U.S. are more than 8 years old, the majority built during the Obama Administration from U.S. government funding.

b. China's level of manufacturing technological sophistication in the larger corporations is at or beyond MES (manufacturing execution system) 3-4 level. Human hands do not touch the product. Automation is nearly 100% in cell manufacturing, and most module manufacturing, and even prevalent in battery pack systems manufacturing. Traceability and quality systems are already in place for complete raw materials, process monitoring, process control and record retention for 15 years. Some of the most sophisticated gaging systems are in place for assuring precision and accuracy in process control measurements.

c. The likelihood of accelerated evolution in China is very high due to high market demand. This is expected to accelerate during the next five years as shown by many consulting forums predictions. In China many battery manufacturers are now consolidating into a few large battery manufacturers.

d. The growth of battery manufacturing sophistication in the United States over the next five years will be largely dependent upon governmental policy and market demand for electric vehicles. The China governmental policy is called "Double Credit Policy" which requires car manufacturers to "balance" the ICE vs EV cars with increasing the balance towards EV's over the next several years.

e. The level of technical sophistication in lithium-ion cell manufacturing in the United States is generally low and the installed capacity within the U.S. is now only about 2% of the total global capacity.

f. The manufacturing capacity that was installed as part of the 2009 ARRA Act was entirely based on Japanese and Korean equipment manufacturers and has not progressed much since then. Significantly, the U.S. government did not require that auto manufacturers in the United States use cells from any of the facilities funded by ARRA grants. So almost the entire manufacturing capacity funded by the ARRA sits idle today with the exception of the LG Chem plant in Holland, Michigan.

4. *Outside of the United States and China, who are the major global players in battery production, and how do their production capabilities compare? How dependent is the United States on imports from these countries, as well as from China? How dependent is China's battery industry on other countries?*

a. Outside of USA and China there are only three major global players, which are located in Japan and Korea. Those players are LG Chem and Samsung of Korea, and Panasonic of Japan. It hard to compare the manufacturing technology due to the stringent security of these manufacturers' plants, just like the Chinese plants. This industry is rich in manufacturing trade secrets.

b. It is true that the U.S. consumer electronics industry is highly dependent upon batteries from offshore. But a significant piece of the consumer electronics business is also offshore, meaning the batteries are already installed before hitting U.S. soil. On the EV front, nearly all batteries are manufactured by foreign own domestics or imported from offshore to service the automotive OEM's in the United States.

c. China is not dependent on other countries for battery supply. There has been a significant effort in the past decade to become independent from outside country sourcing due to the multiple industry needs within China's society. Raw materials sourcing, manufacturing equipment, research and development are all well self-contained within China. Only a few raw materials need to be imported into China to complete the battery bill of materials.

d. In the lithium-ion battery space the major players are CATL (China), LG Chem (Korea), Samsung SDI (Korea), Panasonic (Japan), and BYD (China). The U.S. is entirely dependent on China, Japan and Korea for our lithium-ion cells. With very few exceptions, even battery packs that are assembled in the U.S. are made with cells that are sourced from somewhere in Asia. Today, China accounts for about 75% of all lithium-ion cells manufactured in the world. Korea and Japan combined account for about 25% of all lithium-ion cells manufactured in the world with the EU and the U.S. accounting for 1-2% each. However, recent plans and announcements in the EU will increase the lithium-ion cell manufacturing there. In his latest book, "Lithium-ion Battery Chemistries: A Primer" (2019) Dr John Warner estimates that there is about 265GWh of globally installed capacity, and of that only about 25-28GWh are installed in the U.S., and about 22GWh of that is the Tesla/Panasonic Gigafactory. Dr Warner goes on to write:

> China has been very actively working to grow and manage the lithium-ion battery manufacturing industry within its borders. The 13th Five Year Plan that was issued in 2015 for the period of 2016–2020 with areas of lithium-ion battery focus including "Use of new energy vehicles to be promoted and the industrialization of electric cars improved" as well as "Clean production to be promote and green and low-carbon industry systems set up. Green finance to be promoted and green development fund established" (Xinhuanet, 2015). In 2016 China's Ministry of Industry and Information Technology (MIIT) created a "White-List" of approved lithium-ion manufacturers for xEV (transportation) applications. In order for a lithium-ion battery manufacturer to be included on the list and be eligible to be used in a xEV application, it requires that 100% of the manufacturing is done in China and was updated in 2017 to include a requirement to have at least 5GWh of installed capacity to be eligible to be on the list. This rule has effectively closed the lithium-ion market for all non-Chinese manufacturers.

The European market has also been moving quickly to install lithium-ion battery capacity. Initially, it was mostly the Asian manufacturers such as Samsung SDI, CATL, and LG who were installing new capacity. However, today there are several new domestic EU lithium-ion battery plants in the works. One is the Swedish firm Northvolt, who broke ground in mid-2018 for a 32GWh plant in northern Sweden. Another was Terra-E, which was a consortium of German manufacturers who had planned to build a 34GWh facility in Germany.

e. France has been putting together a new consortium to support Saft, their domestic lithium-ion cell manufacturer.

5. *Aside from new energy vehicles, what emerging industries are highly dependent on batteries or poised to develop rapidly with improved (e.g., lighter or with greater storage capacity) battery technology? Is the United States competitive in those industries? How is the United States faring vis-à-vis China (including in third country markets)?*

a. Several markets are emerging which can and will utilize advanced battery technology. Those include: marine, rail, drone, mining, agriculture, sensors, micro-mobility, aerospace and many others. ESS, or Energy Storage Systems, is an expression used for grid electric energy storage which is becoming prevalent in the USA due to the increase of renewable energy. All of these are becoming reality as the energy density of the batteries increase and battery prices decrease.

b. Ancillary technologies supporting battery technology cannot be overlooked. Several US based affiliates in China create value in battery technology with their specialty products as suppliers to the big battery manufacturers, whose revenues flow back to the U.S. corporations.

c. Lithium-ion and other advanced battery technologies are now powering a wide range of technologies and markets that have historically used other technologies, including agriculture, mining, and forestry equipment; marine and maritime vessels; buses, ranging from small six person buses up to transit buses; light, medium and heavy duty trucking and delivery vehicles are all experiencing a rapid growth of electrified options; the emerging autonomous vehicles (AV) market

will be powered by lithium-ion based technologies. In the aviation space, autonomous and unmanned drones; aircraft; and satellites all use lithium-ion or advanced technology batteries.

e. In addition to these many new and emerging markets, virtually all consumer electronics use a lithium-ion battery technology. Robotics ranging from warehouse stocking robots to military grade explosive detection robots all use lithium-ion batteries. In the medical field more and more new technologies are being enabled by lithium-ion batteries. With the introduction of battery power equipment is now becoming mobile, where it can be brought to the patient rather than bringing the patient to the equipment. This has also enabled telecommunications solutions that allow medical experts to be able to evaluate patients from great distances through wireless, mobile technology. The markets for smart phones, smart devices, the IoT, telecommunication backup centers are all powered by lithium-ion batteries. And increasingly, power companies are installing lithium-ion based energy storage on the grid, with about 95-98% of all new grid energy storage being based on lithium-ion batteries.

f. With new battery developments occurring almost daily and technologies such as solid-state batteries, lithium-sulfur, and others rapidly coming to fruition many of these industries are set for rapid growth, once the energy storage technologies have evolved to a point where power is no longer the limiting factor. And while the U.S. may be competitive in these markets, the batteries for all of these are coming from non-Domestic, and almost entirely Asian, sources.

6. *Where is China putting the most effort into developing new battery technology? What are the advantages and possible applications of these new technologies? What is the state of development in these industries in the United States?*

a. China has a multi-front effort in developing advanced battery technology.

i. First is the chemistry technology of the battery. Chemistry is the heart and soul of battery technology in its ability to store energy in a chemical form and release it upon demand. China, like the rest of the world, could not wait on academicians to spawn new chemistry technology, so most major battery companies have their own internal Research Institutes.

ii. Second is packaging technology which is a critical aspect of battery technology as you must be able to contain the stored chemical energy safely. The higher the voltage the more difficult packaging becomes. All of this is safety related yet influences energy density and charging infrastructure. This involves other aspects such as thermal management, serviceability, recyclability and first responder's accessibility.

iii. Third is measurement and control technologies of these sophisticated battery cells are critical for safety, performance and life of the battery. Since no two cells are ever exactly the same, these minor differences are compensated by electronics.

b. The advantages and possible applications are already emerging. Here are a few examples:

i. In the aerospace industry nearly 100 companies have sprouted in the past couple of years to develop short range aircraft utilizing advanced aerodynamic electric prop aircraft with passenger loads of 6-12 passengers for short commuter flights of less than 500 kilometers.

ii. In the material handling equipment industry, there is a fast change-over of fork trucks to lithium batteries. Dock cranes are now being equipped with batteries to take advantage of "what goes up must come down" concept. Even elevator technologies are investing wide spread use of batteries for energy recovery.

iii. Several agriculture and construction equipment companies have active projects to investigate electrification to reduce or eliminate in some cases the use of hydraulics. Many have found maintenance and serviceability improvements. It also enables autonomous equipment to do work and return for recharge automatically without operator intervention, such as farming.

c. In some cases of the aforementioned examples U.S. companies are on par, or ahead of other, other companies, but the battery technology in most cases are coming from offshore or foreign owned domestics.

d. The trends in China appear to be heading in several directions. First and foremost, Chinese companies are investing in ways to make their products lower cost as price has always been the main reason for non-adoption. This will allow Chinese companies to effectively "buy" the market and force out non-Chinese companies. Second, China is investing in an entire suite of "Beyond Lithium" chemistries with Solid-State Batteries at the forefront. The promise of low cost, high energy density solutions that can reach 500Wh/kg and 1,000Wh/L may require some form of solid-state battery technology. Third, there is significant interest in multi-valent ion technologies. These are elements such as Aluminum which can transport more than one electron (lithium can only transport a single valence electron). These hold much promise but require much additional work to bring them to fruition.

7. *The Commission is mandated to make policy recommendations in its Annual Report to Congress. What other recommendations do you have for policy that could strengthen the United States' competitiveness in battery production and innovation and reduce its dependency on China?*

Please reference the five policy recommendations made in the main body of my comments.

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