INNOVATION SPOTLIGHT:

nanoOne

Lithium-Ion Batteries

50 years
BCC Research
Smart Decisions Start Here

Report Code: FCB054A

Sustainability in Electric Vehicles

Lithium-ion batteries have revolutionized many consumer electronics and are a driving force in electric vehicles. BCC is spotlighting one company disrupting their production, cutting costs and boosting performance at the same time.

Some background: Sony commercialized lithium-ion batteries in the 1990s. Today, after decades of development, lithium-ion batteries have grown into a huge industry, reaching a global output of 200 gigawatt-hour (GWh) in 2018. The lithium-ion battery was first used mostly for consumer electronics such as laptops and mobile phones. But motive batteries, a battery type that powers a motor to drive an electric vehicle (EV), boomed in the past decade and now dominate the market. Motive batteries took 53% of the whole lithium-ion battery market, with 106 GWh produced in 2018, compared to the output of 1.1 GWh in 2011, accounting for only 2.4% of the world's total lithium-ion battery output of 46.6 GWh. Steady growth will continue, and motive power applications will continue to be the primary driving engine to the global lithium-ion battery market.

Lithium-ion and lithium-ion polymer batteries now are widely commercialized for use in portable computers, multi-functional handheld devices and cell phones or smartphones. They are also used in other portable battery-powered devices and military applications. They have the potential to displace more traditional battery systems in large stationary and automotive applications and will play a significant role in both the hybrid electric vehicle market and ultimately the market for plug-in vehicles. All batteries, lithium or otherwise, are based on ions. In lithium-ion technology, the use of "ion" emphasizes that the battery's lithium component always is in ionic, and never in metallic, form. As the battery is charged and discharged, intercalation or "rocking chair" transformation, takes place. Here, lithium-ions move back and forth between electrodes.

The last eight years have seen the commercialization of a variety of lithium-ion battery chemistries, some optimized for particular sizes and tasks, and some competing head-to-head. Types of lithium-ion cathodes include:

- Lithium titanium disulfide (TiS_2).
- Lithium iron phosphate ($LiFePO_4$).
- Lithium cobalt oxide ($LiCoO_2$).
- Spinel: Lithium manganese oxide ($LiMn_2O_4$).
- Lithium nickel oxide ($LiNiO_2$).
- Lithium nickel manganese cobalt oxide ($LiNiMnCoO_2$).
- Lithium nickel cobalt aluminum oxide ($LiNiCoAlO_2$).
- Lithium titanate (LTO).

SUMMARY TABLE

Global Lithium-Ion Battery-Powered Electric Vehicle Market, by Vehicle Type, Through 2024 ($ Millions)

Vehicle Type	2018	2019	2024	CAGR% 2019-2024
Passenger	82,697.0	95,028.1	216,543.1	17.9
Bus	39,704.0	48,981.1	127,242.8	21.0
Scooter	1,486.3	1,750.2	3,669.6	16.0
Low velocity	391.0	464.6	1,038.7	17.5
Commercial/industrial	20.5	30.9	130.0	33.3
Niche	—	—	52.2	—
Total	124,298.7	146,254.8	348,676.4	19.0

Global Lithium-Ion Battery-Powered Electric Vehicle Market Volume, by Vehicle Type, Through 2024 (Thousand Units)

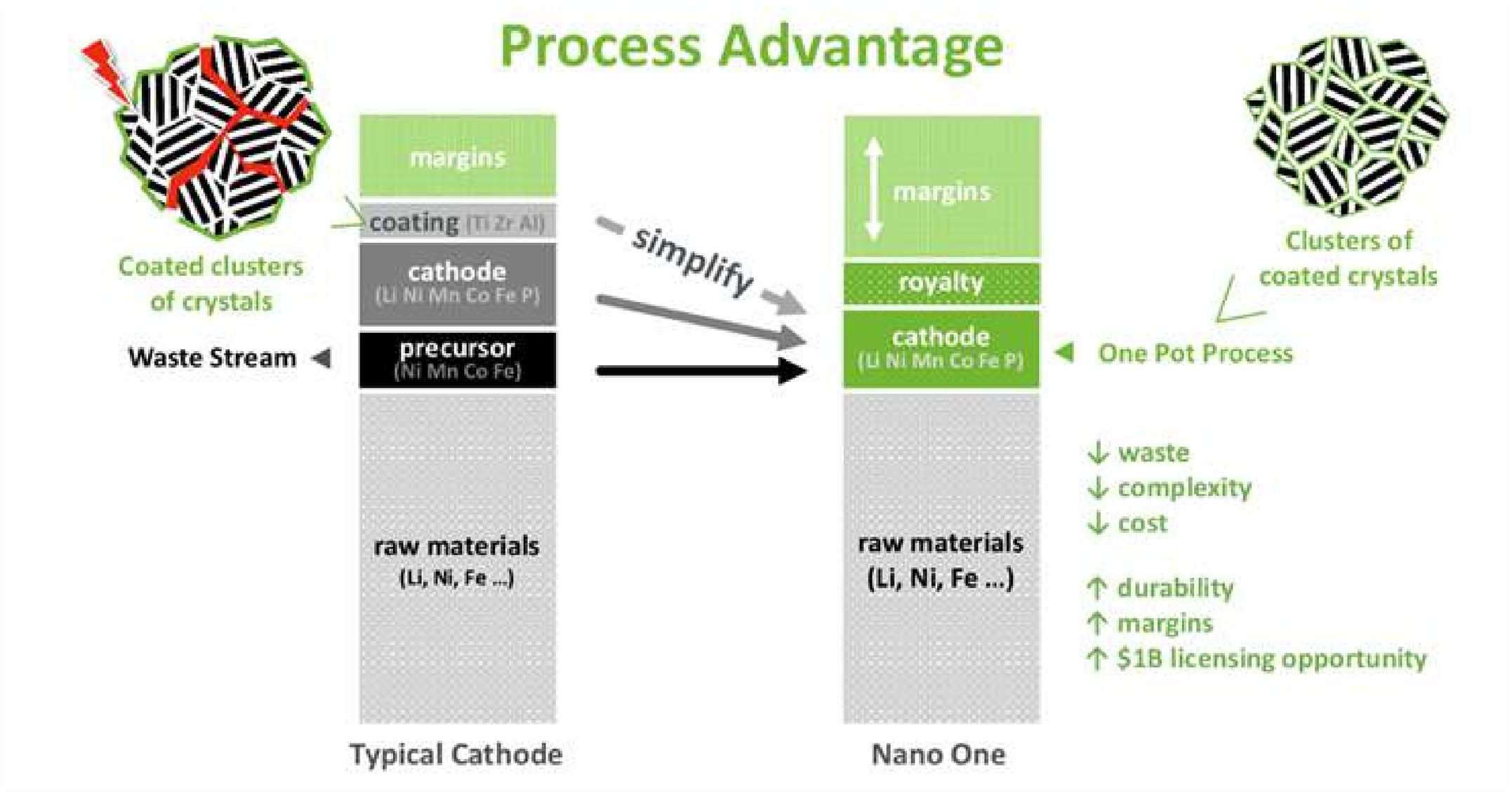
Vehicle Type	2018	2019	2024	CAGR% 2019-2024
Passenger	789.5	1,162.8	5,806.2	37.9
Scooter	1,435.1	1,688.9	3,270.3	14.1
Low velocity	58.8	74	195.2	21.4
Bus	23.6	31.8	116.0	29.5
Commercial/industrial	5.1	5.9	12.1	15.4
Niche	—	—	0.7	—
Total	2,312.1	2,963.5	9,400.3	26.0

BCC's Interview With Nano One Materials Corp.

BCC Research sat down with Dan Blondal, CEO of Nano One Materials Corp. Nano One has developed a manufacturing process that makes the production of a wide variety of cathode materials for lithium ion batteries less costly while boosting performance. Specifically, the company's One Pot Process makes and coats cathode powders simultaneously eliminating waste and steps in the traditional manufacturing of those battery materials. The cathode represents approximately 25% of all battery cell costs.

The technology has application with all manner of batteries, including LFP (energy storage systems, mass transit, mass market EVs), NMC (dominant in auto, largest segment of cathode material market), and LNMO (high voltage spinel, next generation solid state batteries).

Funded in part by Sustainable Development Technology Canada and Canada's Strategic Innovation Fund, Nano One has partnerships with major international EV/battery companies like Volkswagen, Pulead and Saint-Gobain.



BCC: Why are cathode materials and cathode construction so key to lithium-ion battery innovation?

Dan B: The cathode is the most complex component in a lithium ion battery, representing 25% or more of the cost. It is a nano engineered ceramic powder comprised of raw materials such as lithium, nickel, manganese and cobalt plus performance boosting additives and protective coatings. These raw materials are combined and processed to form energy storing grains of crystalline powder, where the quality of each grain of powder is critical to charging, capacity and cycling. The durability and stability of the cathode material is also critical to lifespan, total cost of ownership and safety of each battery cell.

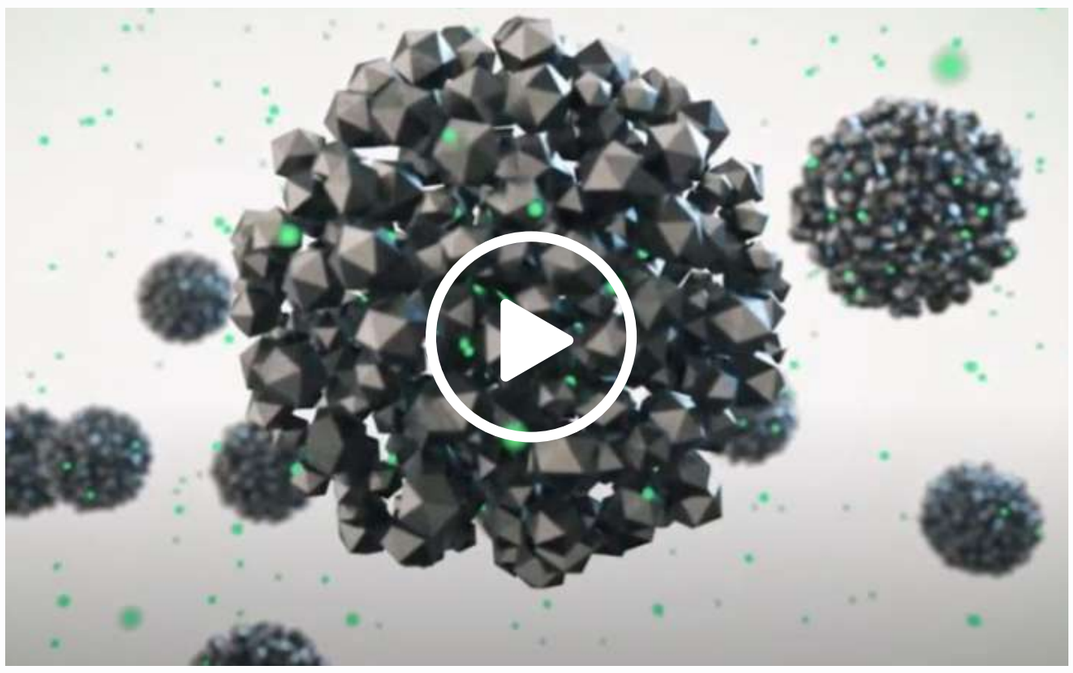
Keiji Kata—EVP and GM of Toyota's battery business recently stated that expansion and contraction of cathode materials leads to deformed particles which results in the degradation of battery performance over time. He stated that developing a material that won't deform easily is key to next generation batteries.

BCC: Can you tell us about your One Pot process and how it differs from current standard practices in the industry?

Dan B: Nano One's patented One-Pot process is ESG inspired technology that simplifies production, reduces operating costs and uses alternative feedstocks to reduce waste, complexity and needless water usage in the lithium ion battery supply chain.

The process combines all input components—lithium, metals, additives and coatings—in a single reaction to produce a precursor that, when dried and fired in a kiln, forms quickly into a single crystal cathode material simultaneously with its protective durability enhancing coating. These tiny grains of powder resist the stresses of repeated charging and preserve an essential protective coating. This enhances durability and enables a low-cost approach to boosting charge, lifetime and range.

In contrast, conventional cathodes are made by converting metal sulfates into a mixed metal precursor powder, with all the sulfate going to waste. The precursor is then milled to mix it with lithium before firing in a kiln. Protective coatings can then be formed by adding additional materials and firing again. However, cathode crystals expand and contract from repeated charging and fractures the protective coatings and leaves individual crystals exposed to side reactions. Here is a simple 2-min 3D video explanation.



BCC: How does your technology play into and improve the supply chain for cathode materials?

Dan B: Nano One has developed IP and filed patents recently to simplify and clean up lithium ion battery supply chain and manufacturing processes. Our patented One Pot process using non-sulfate forms of metal, eliminates sulfate waste, needless water consumption and added process costs.

Furthermore, Nano One uses lithium carbonate and avoids costly, corrosive and hard-to-handle lithium hydroxide. Nano One can also integrate its One Pot process with refiners for further cost reduction, all while forming coated single crystal cathode powders, that bring much needed durability to nickel-rich, cobalt-depleted cathodes.

As background, cathode producers require their battery metals from refiners in the form of sulfate (20% metal, 80% water/sulfate). They mix the metal sulfates in a caustic process to form an intermediate NMC precursor and the sulfate goes to waste adding cost, complexity and environmental challenges. Lithium hydroxide is then milled into the mixture during a prolonged thermal process to form cathode powders, before final protective coatings can be applied. This supply chain is long and complicated with waste handling, sales, support, logistics, shipping and margins added at each stage.

Nano One's approach aligns it with the ESG objectives of automotive companies, investment communities and governmental infrastructure initiatives.

BCC: In addition to electric vehicles, are there other verticals/battery types you see as targets for your One Pot technology?

Dan B: Nano One's technology is applicable to cathode materials for a wide range of lithium ion batteries used in electric vehicles, consumer electronics, power tools, e-busses and grid storage. Estimates for the total addressable market in cathode materials are bracketed between $25 to $45 billion per year by the end of this decade. To give this context, it represents up to 3 billion kilograms of cathode powder and 40 million electric vehicles per year.

BCC: What's your commercialization plan in such a competitive space?

Dan B: Our strategy is to collaborate and partner with industry through licensing and joint venture. As an example, we are working with automotive OEMs to define the next generation battery chemistry and create demand for our technology, while at the same time collaborating with battery materials companies to integrate our technology for the low-cost fulfillment of this demand. By reducing costs and increasing performance, we are aiming to improve margins for our partners while leaving room for a healthy licensing fee for Nano One. The total market in terms of cathode royalties, is estimated as a $1B opportunity.

BCC: What do you think the next couple of years could look like for Nano One?

Dan B: Nano One has come a long way over the past couple of years. We are well funded having recently completed a heavily oversubscribed $11 million private placement which unlocked $8 million in non-dilutive government funding to give us a multi-year runway. We have global partnerships with Volkswagen, Pulead, Saint-Gobain and a recently announced global cathode producer (currently anonymous for competitive reasons). We also have a growing pipeline of strategic relationships being developed with various companies in the lithium ion supply chain under NDA (more than 20). Nano One has a solid foundation to advance its technology and business plans towards meaningful commercial agreements in the next couple of years.

What Does BCC See Ahead?

- The global electric vehicle (EV) market was worth an estimated $224.9 billion in 2018 and is projected to reach $550.4 billion by 2024. This market is expected to grow at a CAGR of 16.4% between 2019 and 2024.

- BCC Research projects a $354.3 billion revenue for passenger EVs market by 2024. Although electric scooters have the largest share in terms of unit sales in overall EV market, passenger EVs holds the highest share in terms of revenue among all EV segments. The major growth of the EV market in terms of revenue is from the increasing passenger vehicles due to the increasing unit sales and higher unit sale cost compared to the electric scooters.

- In 2018, it is estimated that nearly 37 million battery-powered scooters and e-bikes were sold. This figure is significantly higher than unit sales of all other segments. Shipments of scooters/e-bikes are expected to grow to 46.8 million units by 2024, mainly based on expanded sales outside of China, especially in India. As of 2018, an estimated total of over 300 million electric scooters were on the road, most of them powered by lead-acid batteries.

- In geographic terms, Asia-Pacific leads the global electric vehicles market. China leads the Asia-Pacific region as well as the world market in terms of unit sales of electric cars/passenger cars. It is followed by Europe and the United states in terms of passenger car unit sales. China also leads the world market in electric scooters market in terms of unit sales and revenue.

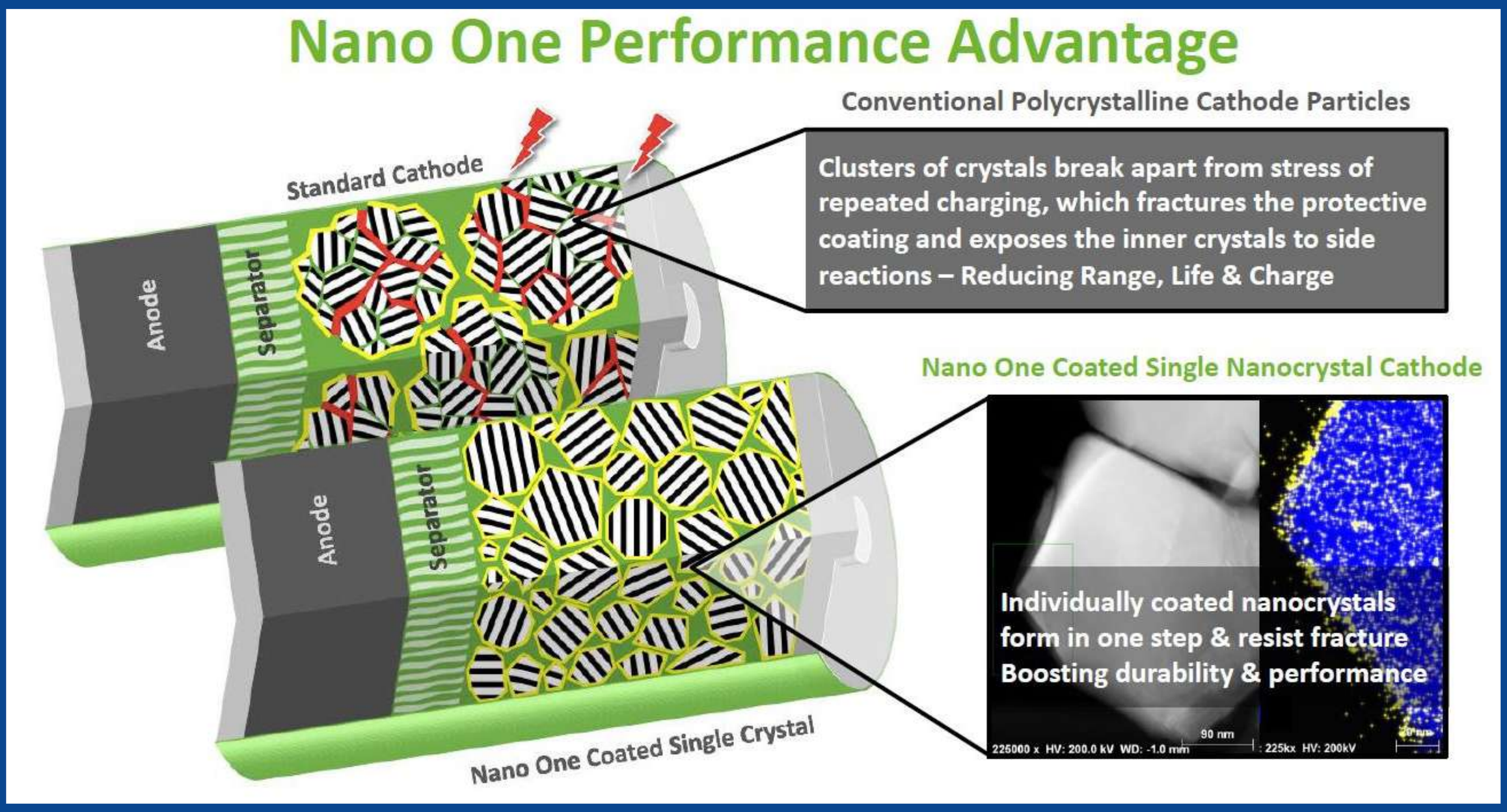
- Much of this value and growth is based on various types of passenger vehicles (pure electric, hybrid and plug-in hybrid), other forms of transport, and portable devices (personal electronics, portable tools and military equipment). The market for advanced batteries in passenger vehicles is expected to grow at a CAGR of 11.6% over the next five years to reach $60.9 billion in 2024. The market for advanced batteries in other ground, marine and air transport applications, meanwhile, should grow at a CAGR of 9%, approaching $13.2 billion by 2024.

- Large and advanced batteries represented a $61.5 billion global market in 2018. The overall market is projected to grow at a compound annual growth rate (CAGR) of 11.4% between 2019 and 2024, making it one of the largest and fastest-growing, technology-driven electrical/electronic sectors. BCC Research projects a market of $109.9 billion by 2024.

- Portable devices such as computers, tablets, smartphones, power tools and military equipment batteries form another large segment, with total sales of $10.2 billion in 2018. This market is predicted to grow to nearly $20.3 billion by 2019, a CAGR of 12.0% between 2019 and 2024.

- The market for large and advanced batteries in stationary applications such as uninterruptible power supplies, emergency lighting and electricity storage systems, meanwhile, should increase from $7.9 billion in 2018 to $15.3 billion in 2024, a CAGR of 12.1%.

- Lithium ion batteries accounted of over half of the total market in 2019, a share that BCC Research expected to increase to more than 60% by 2023. These gains will come at the expense of other first- and second-generation batteries such as lead-acid, nickel-cadmium and nickel-metal hybrid batteries. Other emerging battery types such as sodium-sulfur and vanadium redox batteries should capture an increasing share of the market.



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