<Prediction 3>

"Battery Competitiveness:
Determined by Scale, Materials, Structure and Safety"

Low Ratio Labor Cost

While the cost reduction of energy storage technology (secondary batteries) is driven by the lithium- ion (Li-ion) automobile battery, what determines cost-effectiveness? The primary factor is in the "scale" of production, which is due to the cost-structure of an automobile battery.

For instance, there are various kinds of Li-Ion batteries for use with cell phones. As the size and electrical capacity vary between batteries, the manufacturing process is more efficient through manual labor than through automated processes. The reason why Chinese battery manufacturers, including BYD, have been able to enter into the cell phone device market is that they took advantage of low labor cost in production processes that requires significant manual labor.

On the other hand, the "18650 model" battery, which is typically used for laptop PC's, requires standardized manufacturing facilities, and the use of an automated process yields much higher productivity. Chinese manufacturers have adopted automated production in all of their production lines for the "18650 model," and the difference in labor cost would provide very little advantage. It is estimated that the ratio of labor cost to total manufacturing costs is lower than 5%.

As the inconsistent qualities in battery manufacturing affect the safety of automobiles, the production line for automobile batteries needs to be automated as much as possible to minimize factors that could cause inconsistencies. While facilities have yet to become standardized, similar to the "18650 model", the ratio of labor costs to total costs is low. The operation of automobile battery factories requires a capital intensive model based around manufacturing facilities, and the large production scale operates to lower the cost per battery as the scale of production increases, known as the "economies of scale." Further, by expanding the production scale, it also becomes advantageous in regards to negotiating reductions in the supply cost of materials and parts used for battery cells and systems.

Manganese based Cathode Materials Becoming Mainstream

The second main factor determining cost competitiveness is "materials." As stated above, once economies of scale comes through, the difference in cost of raw materials will start to make a difference. Among all the materials used for batteries, the decision on the material used for the cathodes has the largest impact on the cost. The two most dominant cathode materials, among all the material choices, are the Manganese (Mn) and Iron (Fe) bases (**See Diagram 1**). With the Mn base, it is incomparably more cost effective when compared to other materials used in Li-ion batteries, such as Cobalt (Co) and Nickel (Ni) bases. It is said that when the Nissan Motor Company took attention to the significant cost reduction potential, they were determined to make use of Mn-based batteries, no matter the challenge.

Main manufacturers using Mn-based batteries	Main manufacturers using Fe-based batteries
Nissan Motors(AESC, Japan), LG Chem (South Korea), SB LiMotive (South Korea), GS Yuasa (Japan)	BYD (China), Tianjin Lishen (China), Wanxiang Group (China)

Diagram 1: The main manufacturers that provide the Mn- or Fe-based automobile batteries, classified by the materials used for the Li-ion battery cathode.
Prepared by TechnoAssociates, Inc.

Initially, there were drawbacks in the Mn-based cathode material ($LiMn_2O_4$), including that Mn melts into the electrolyte solution at high temperature. However Nissan, in collaboration with the NEC group, has already solved this issue. Currently, aside from Nissan, South Korea's LG Chem Company and South Korea's Samsung group (SB LiMotive) have announced their adoption of the Mn-based cathode materials. Having both cost effectiveness and technological maturity with cathode material, there is a high possibility that the Mn base could see mainstream use for automobile batteries.

On the contrary, there are those that feel that Li-ion batteries with an Fe-based cathode ($LiFePO_4$) will never become less expensive, as its conductivity and ability to diffuse Li, which affect the performance of electrodes, are low. To offset these weaknesses, it demands microparticulating Fe, and coating the particles with the conductive Carbon. Furthermore, preventing the addition of impurities in the process of material synthesis for $LiFePO_4$ is necessary. With various designs of these processes in place, it is possible that material costs could "leap to at least twice the cost." (A battery manufacturer)

The Laminate Model Structure Becoming Mainstream?

The third primary factor is the battery's "structure." In addition to the generic "18650 series," automobile batteries can be generally classified as an oblong shape utilizing a metal can or as a laminate structure utilizing aluminum film. The battery jointly developed by Nissan and NEC utilizes a laminate structure. Battery manufacturers that are considered to be main players for automobile batteries, including LG Chem, have opted to use the laminate structure design.

The reason that battery manufacturers give for their adoption of lamination is its "structural simplicity." Automobile batteries demand a flow of large electrical currents, and the laminate model allows for a sufficient terminal width, making it easy to design, and requiring fewer parts. This "structural simplicity" creates high productivity at a favorable cost. Additionally, as the battery cell area has a large and comfortable space, its heat dissipation is superb, as is the heating uniformity. As the Li-ion battery can easily deteriorate under high temperatures, this can increase the battery's lifespan, and this also makes it unnecessary to build a cooling system for the battery, contributing to a system-wide cost reduction (**See Diagram 2**).

However, manufacturers who support the oblong model often question the reliability of the laminate structure, with comments such as "Is the sealing airtight enough?" or "Isn't its mechanical strength weak?" Those who have adopted the laminate structures say, "Of course, we recognize these challenges and have already developed solutions for them." At this point, one can only observe how the technology turns out once batteries are released into the market. If the laminate structure battery is able to gain credibility in the market, it will immediately lead to mainstream use.

Main Manufacturers using the laminate structure	Reason for use
Nissan Motors (AESC, Japan) LG Chem (South Korea)	・Good heat dissipation (uniform heating) ・simple in structure (few parts)

Diagram 2: Battery manufacturers which adopted the laminate structure and their reasons for doing so, in the case of automobile batteries.

Prepared by TechnoAssociates, Inc.

Cost for Ensuring Safety Becoming Imperative

The year 2013 brought attention to the safety of Li-ion batteries to the world. On January 7th, a GS Yuasa-made Li-ion battery on board Boeing's state-of-the-art "787" passenger plane ignited at Boston's Logan International Airport. The following January 16th, another 787 with a smoking Li-ion battery made an emergency landing at Takamatsu Airport in Japan. On March 21st, one of the Li-ion batteries in Mitsubishi Motors Corporation's SUV, "Outlander PHEV," melted.

In response to the first two incidents, the FAA (Federal Aviation Administration, USA) approved the resuming of operations on April 19th, though they had yet to ascertain the root cause of the problem; it is still not clear whether it was the problem of the battery itself or the battery management system. The cause of the Mitsubishi incident was concluded to be that of human error during production, and counter-measures are being applied.

Li-ion batteries utilize organic solvents, which differ from nickel-cadmium batteries and nickel-hydrogen batteries, among others, which use water-soluble electrolyte solutions . Because of this, there is a high risk of igniting the battery at high temperatures. For Li-ion batteries, safety measures are taken into consideration through the material development process and the design of protection circuits. However, due to poor usage and defects in manufacturing, incidents of heat generation and ignition continue to occur. Going forward, safety measure costs and the safety of the battery itself will particularly influence the Li-ion battery's competitiveness in the market.

[Expert comments]

"Ensuring the quality of automobile batteries absolutely requires automated manufacturing processes, and the labor cost makes up only a few percent of the entire manufacturing cost. For example, the labor cost for the "18650 series" is less than 5% of the total cost. Cell phone batteries, even for just one company, can have dozens of different sizes. This means that even changing to complete automation would prove quite difficult, and that manual labor would be a much more viable option. In the case of automobile batteries, there are not nearly as many variations, and manual labor would cause an inconsistency in product quality."

(Ener1 Group, USA)

"We use the Fe-based Li-ion battery for automobiles. It is safe, and while production costs are still high, from a materials standpoint, it could still theoretically be cheaper than the Mn- and Co-based batteries."

(BYD, China)

"Why the Mn base? The first reason is its reliability. The Mn base has a stable crystalline structure. Changes in the crystalline structure that are caused by charging and discharging can be controlled, so naturally its reliability is considered high. The cost of the raw materials can also be noted. Compared to the Co and Ni bases that have been primarily used in the Li-ion battery up until now, it is evidently more affordable. The automobile parts need to be manufactured at a unit price of 1 yen/g. When materials match this price point, an automobile company would have no choice but to choose this."

(Nissan Motor, Japan)

"The laminate structure is not only more cost effective than the metal can type, but the manufacturing technology is also simple. For relatively smaller batteries geared towards products such as cell phone devices, the metal can type is still good. However, for automobiles and other applications that require high energy capacity, a laminate structure that utilizes lamination layered electrodes is advantageous."

(Battery manufacturer outside of Japan)

"For cathode materials, in the next several years there will be two options available: the ternary compound base (Mn, Ni, Co), and the Mn base. In 2013, we plan to use both options, and the weight energy density will average at 130wh/kg. The ternary compound base has the advantage in energy density, while the Mn base has the advantage in safety.

(Battery manufacturer outside of Japan)

"If you only look at the cathode, you can say Fe-based batteries are safer, however the cathode is not the only determinant for safety for the overall battery. Also, more than the cost per cell, the cost per Wh is most important. The Fe-base has an energy density lower than the Mn-base by 20-30%, and therefore its merit in cost per Wh is rather weak."

(Battery manufacturer outside of Japan)

"If you are afraid of risk and refrain from making an investment, battery costs will never decrease. What determines battery cost is the materials themselves. These are still too expensive. Without a certain level of scale, the cost will not become lower, creating a vicious cycle that leads to customers becoming unable to accept [our product]. Eventually, to truly commit to this, it will be necessary to think about adjusting the scale of investments to a certain degree."

(Nissan Motor, Japan)

"In China there are many battery manufacturers eager to delve into automobile batteries. Sadly, the near future will see but a few large companies remaining. The archaic manual labor system and semi-automatic production line will make it impossible to develop a vast amount of batteries."

(China Tianjin Institute of Power Sources)