Chinese Battery Manufacturing

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Chinese Battery Manufacturing Commentary

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This is an attempt to sort out the confusing status of LiFePO4 production in China and the shifting assortment of companies and factories involved in delivering large prismatic cells to the U.S. Differences in business practice, legal structure, and language can easily lead to errors, misunderstandings, and worse, so read this summary with that in mind.

Factories in China are established in a different manner than those in the U.S. They tend to be intimately connected to local economic development committees – an extension of centralized Chinese authority – and thus have a sort of independent status. Companies are formed around factories – often a single facility – in a production-centric model. In contrast, most U.S. manufacturing is finance- or sales-centric and the factory itself has no independent status. Thus, a U.S. company can simply close a factory unilaterally; in China, productive capacity is viewed more "collectively".

With a production-centric system, factories can "flip" from company to company is what appears to be an incomprehensible organization from a U.S. business model perspective. This seems to be what has happened in terms of Chinese LiFePO4 battery manufacturing.

The father of the Chinese LiFePO4 industry is Winston Chung King-ha (Chung), an inventor and entrepreneur. In 1998, Chung founded Thunder Sky Battery as an R&D company to exploit lithium chemistry research from the U.S. The company name appears in various forms, mostly due to "lost in translation" variances, but commonly is known as *Thundersky*.

Winston Chung

Between 2000 and 2008, Chung and his research team filed 15 patents related to battery chemistry, design, and manufacturing. Eight patents have only a 10-year life (and the earliest patent for a "solid state" battery has already expired), while the remaining portfolio offers 20-year intellectual property protection. Chung aggressively expanded his patent protection to at least 26 countries (the U.S. perspective that China "ignores" intellectual property is an unsophisticated and erroneous view).

Over an eight year development period, a number of prismatic form factors and chemical formulas were tested, all apparently in relatively small batches using manual assembly. In late 2006, Thundersky moved into a proper factory in Lisonglang, Shenzhen to commercialize output using automated equipment with a capacity of 150 million amp-hours (Ah). Capacity estimates are based on two shifts per day and generally characterize a theoretical maximum output.

This capacity is equivalent to 750,000 200Ah prismatic cells, or enough to power 15,000 electric vehicles. However, capacity was split between various products – 3.6, 12, 24, and 48 volt ranges as well as a variety of form factors. Therefore, it is reasonable to assume that production runs of any particular size, say the 200Ah cell, were modest, perhaps in the range of 1m Ah/5,000 cells/100 vehicles each.

In any event, output through 2006 was small, a product in search of an application; a few U.S. enthusiasts tested the early formulations, some with negative reviews.

Lisonglang, Shenzhen battery factory in 2006 with large "Thundersky" sign indicating company control

By early 2007 Thundersky had arranged to distribute batteries in the U.S. through International Battery (IB), a battery management system (BMS) developer. This relationship apparently evolved by early 2008 when IB opened its own Allentown, PA plant to manufacture large format LiFePO4 cells. Today IB makes 40, 60 and 160 amp cells in a green plastic case that resemble Thundersky cells (see battery specification sheet in Appendix), but now targets utility storage applications.

IB opened the first U.S. large prismatic lithium battery plant in 2008

Thundersky also arranged a venture with Finnish Electric Vehicle Technologies Ltd. (FEVT) and coordinated distribution out of a Hong Kong office.

In 2008 Thundersky became involved with a factory known as the Green Power Source Company **宁波雷天绿色电动源有限公司** located in Yuyao, Zhejiang province, Ningbo perfecture.

Green Power Source facility in Zhejiang

By 2009 Thundersky had become something of an umbrella trading company for various battery factories, an arrangement that seems strange from a U.S. perspective. In addition to the IB license deal and production at both Green Power Source -Yuyao, Zhejiang and Lisonglang, Shenzhen plants, the following factories were also marketed under the Thundersky umbrella:

- Sky Energy Company, Luolang, Henan province
- New Energy Company, Liaoyuan, Jilin province

Sky Energy facility, Luolang, Henan

The fact that Sky Energy, now branded and sold separately as CALB (China Aviation Lithium Battery), appeared to be "owned" by Thundersky (at least from

our U.S. perspective in 2009) was due to an easy-to-misinterpret Chinese "partnering" trading company process. The factories are managed independently under the watchful eye of local government committees, and not literally owned outright by corporations as they are in the U.S.

Complex relationships continued to evolve. The Great Recession of 2008 must have had an impact. With CALB (Sky Energy) products from the Luolang factory now distributed outside of the Thundersky channels, Chung sought additional expansion (or perhaps survival) capital using U.S. investment bankers.

Opening ceremony at New Energy Jilin factory

In December 2009 Jia Sheng Holdings Limited, a public company traded on the Honk Kong exchange, agreed to acquire Thundersky with stock and a convertible bond deal valued on paper at $355 million. Due to the structure of the stock swap, owners of Jia Sheng retained operating control. In May 2010 Jia Sheng, a Bermuda corporation, changed its name to *Thunder Sky Battery Limited* (not to get ahead of a convoluted story, but the name was changed yet again to *Sinopoly Battery* in April 2011).

Prior to the Thundersky deal, Jia Sheng was what we in the U.S. would call a paper or shell corporation with virtually no revenues. What Jia Sheng actually acquired in the stock deal will be ultimately decided in Chinese courts since things began to unravel almost immediately (see discussion of Chung legal dispute in Appendix). A key asset in question is the 15-patent portfolio developed by Chung up to 2008 (see Appendix). Another important issue is what production capacity, if any, the new entity controls.

In the immediate aftermath of the acquisition, Jia Sheng outsourced battery cell manufacturing and distribution to PRC Operating Companies, a newly created entity controlled by Chung that produced batteries in the Shenzhen facility. This suggests that the acquisition did not actually transfer operating control of factory production to any degree. From the U.S. perspective, this seems strange, if not silly. But again, from the Chinese collectivist "socialism with capitalistic characteristics", this acquisition was a trading company combination that did not involve the underlying manufacturing assets directly.

The PRC outsourcing arrangement by Sinopoly (Jia Sheng prior to the name change to Thundersky) included an interesting provision: the internal transfer price of battery production was fixed at $0.50/Ah. Apparently, this was conceived – at least by the Jia Sheng executives – as a "no profit" transfer arrangement. They must have thought that until they could complete a separate negotiation regarding independent factory production, the deal was to use Chung's existing factory output from Shenzhen at its cost without any benefit accruing to Chung in terms of trading company profit. Part of the current legal dispute is whether, in fact, profits were made at the $0.50 Ah transfer price level.

Sinopoly

Sinopoly became the new trading company after the Jia Sheng/Thundersky stock swap deal

In any event, the $0.50 Ah factory price provides some useful guidance about the internal cost structure of LiFePO4 production.

After the stock acquisition closed in mid-2010, Thundersky (now Sinopoly) arranged for production at a "new" battery factory in Liaoyuan (Jilin). Actually, this appears to be the "old" New Energy Company plant that had been part of the Thundersky collective back in 2009. The plant, controlled by an entity

called Liaoyuan Liyuan, was put back into the Sinopoly camp with a $10.4m cash payment and a $4.6m loan from a local bank. Chung apparently no longer had any direct control over the Jilin facility at this point.

By February 2011, Sinopoly resumed production at the Jilin facility with a reported capacity of 70m Ah. This is basically half the capacity that Thundersky had back in 2006 at its Shenzhen plant.

As stated above, some Sinopoly output was outsourced to PRC Operating Companies temporarily pending the addition of new capacity in Tianjin. Meanwhile, the original Shenzhen factory remained under Chung's control.

Chung, using proceeds from sale of his Sinopoly stock (some of his holdings were subject to lockup restrictions and could not be sold), purchased a controlling interest in Balqon, a struggling U.S. manufacturer of large industrial electric vehicles, and transferred U.S. distribution rights to this restructured entity. He also created a new brand, Winston Battery.

In effect, the old Thundersky brand was "split" into two new brands – Sinopoly and Winston – but the underlying factory production remained unchanged.

If this seems completely confusing, it is. Although Jia Sheng "acquired" Thundersky, the deal did not include factory capacity. This runs counter to American business thinking, but makes sense in the Chinese context.

Factories are independent entities, linked to trading companies via output distribution deals, but basically tied into local economic committees and central Chinese authorities. All the battery companies we know in the U.S. - Thundersky, CALB, Sinopoly, et.al. – are essentially trading companies; that is, they specify the product, provide brand marketing and documentation, and then ship the output of independent factories to their own customer base.

Finally, we can begin to understand 2010 production capacity, as follows:

Trading Company	Associated Battery Plant	Max Capacity
Sinopoly (Jia Sheng/Thundersky)	Liaoyuan, Jilin (former New Energy)	70m Ah
Winston (Chung/Thundersky)	Lisonglang, Shenzhen (former Thundersky)	150m Ah
CALB (Sky Energy)	Luoyang, Henan (China Aviation Lithium Battery)	30m Ah

It seems that Chinese battery capacity for these large prismatic cells has not significantly expanded since 2009, and for good reason: there is significant excess capacity. Assuming that the estimates above are in the ballpark, total Chinese industry capacity is about 250m Ah, enough to power about 25,000 electric cars.

As we know, the U.S. market is nowhere near this level. The Chinese government has ambitious plans to promote non-polluting electric vehicles, an effort that is somewhat opaque to us here in the U.S. But according to recent Sinopoly financial disclosures, the domestic Chinese market for lithium cells is even smaller than the U.S. export business.

Best current estimates put the U.S. market for LiFePO4 large prismatic cells at between 5m and 6m Ah, which is a small fraction – 2% to 3% - of hypothetical Chinese Ah capacity. It appears that the U.S. export business is about 40% of Chinese output, so overall LiFePO4 production is around 15m Ah. In order words, the Chinese battery industry (at least the large prismatic sector) is running at ***only 6% of existing capacity***!

At this early adopter stage of market development, excess capacity is no surprise. But there is a chicken-and-egg dilemma. Without significant volume, battery costs will not decline, but without significant cost reduction, demand for batteries will not increase since the economics remain prohibitive.

Current battery pricing reflects this condition. Landed U.S. LiFePO4 cell prices in 2011 are "stuck" at, or even above, 2009 levels. With only "hobbyist" interest, there is not sufficient volume to really drive down production costs. As a result, trading company entities experience financial difficulties.

The fact that Chung "sold" to Jia Sheng in late 2009 suggests a need for survival capital that could not be generated by operating cash flow. Minor players, like China HiPower and Headway have failed, it seems, to gain real market positions.

Meanwhile, Sinopoly (the Jia Sheng entity) has reported large financial losses that has significantly impacted its stock performance.

Sinopoly Battery stock performance (July 2008 to June 2011)

As the market develops over time, this situation will certainly rebound, but for now – in 2011 – the U.S. is left in a kind of limbo: high prices and a slower development cycle since high volume production has yet to kick in.

The Chinese are planning – or at least have announced – huge (almost irrational) capacity increases. Sinopoly, for example, plans to go from its current 70m Ah capacity to 190m Ah by adding new space in aTianjin facility before the end of 2011. By 2016, Sinopoly forecasts a need for a *2 billion Ah capacity*!

Recent statements by Winston Battery in connection with the January 2011 U.S. distribution arrangement with Balqon Corp indicate a planned 2011 capacity of about 160m Ah. Future expansion plans have not been disclosed. CALB has announced that its 2011 capacity is 60m Ah.

Given large Chinese LiFePO4 capacity, what demand can be expected from the U.S. hobbyist market? Historically, U.S. imports have been extremely small, about 10m – 12m Ah cumulative purchases between 2009 and 2010.

Data is fragmented, but EVAlbum.com maintains an informal directory of about 3,300 EV projects (projects are worldwide, but most are in the U.S.). Of this total, there are some 1,400 car conversions and builds. About 15% of the car projects use LiFePO4 technology, or roughly 200 cars. Assuming an average 7500 Ah per vehicle, this equals 1.5m Ah.

EVAlbum is only a sample of conversions, but it provides some data for a useful projection. Market share by battery brand for the 200 known LiFePO4 EVAlbum car projects is:

74% Thundersky (includes Winston and Sinopoly)
22% Sky Energy (CALB)
4% other brands including China HiPower and Headway

EvAlbum isn't a census of U.S. EV conversion activity. For a market size estimate, assume that 1 in 8 projects were documented on EVAlbum. This would imply 1,600 LiFePO4 vehicles were converted in the U.S. during 2009 and 2010, or 800 per year. The 800 vehicles would require, at 7,500 Ah each, some 6m Ah. If Thundersky held 75% of the market, the company would have exported 4.5m Ah to U.S. hobbyists.

Fortunately, due to public company disclosure rules, we know that Sinopoly FY2011 battery sales were $9.6m (from April 2010 through March 2011). Average FOB plant wholesale prices are approximately $0.90/Ah, so this equates to 10.7m Ah during the past 12 months. Sinopoly reports that 41% of battery sales went to the U.S, or roughly 4.4m Ah. This matches the analysis in the prior paragraph quite well.

An EV project that uses LiFePO4 cells at their current retail price level between $1.10 and $1.40 per Ah implies a direct battery investment of $8,000 to $12,000, and perhaps even more. One might assume that only high end cars – either recent models or prestige brands like Jaguar, BMW, and Porsche – would dominate conversions. In fact, the opposite is true. Based on EVAlbum data, only 10-15% of U.S. EV conversions use a relatively expensive donor or base vehicle. The majority of the hobbyist market abides by strict budgets and, even when expensive LiFePO4 battery are deployed, the finished electric vehicle is typically extremely modest in terms of style and appeal.

The high end EV conversion market – Porsche Speedsters, 550s and 911s, AC Cobra Roadsters, and so on - is vanishingly small; less than 200 such vehicles (using a rather generous definition) are on U.S. roads today.

For the reasons set out above, the U.S. market is unlikely to be a major driver of LiFePO4 pricing; volume demand is simply too small compared to overall Chinese capacity. Instead, we need to hope for an explosion in demand in emerging markets – China, India, Pakistan, Brazil – where government-directed adoption of small EVs may generate sufficient production volume to enable the battery industry to "work down the experience curve".

If the Chinese can grow twelve-fold over the next five years, from around 200m to 2.5b Ah, the impact on pricing will be significant. Experience curve economics suggests that each doubling of industry volume equates to a 10-20% unit cost reduction. To be conservative, assume 10%.

Here is a pro forma cell experience curve (FOB USA wholesale price).

Year	Volume (m Ah)	Ah price
2012	200	$1.00
2013	400	$0.90
2014	800	$0.81
2015	1600	$0.73
2016	2500	$0.69

This pro forma exercise predicts that a 200Ah cell will cost, at wholesale, about $138 in 2016. Using 36 such cells in a Porsche Speedster replica would then cost under $6,000 versus $10,000 today. While an impressive cost reduction, this is still not enough to tip economics into a huge mass market without significant government incentives or directives. A significant premium versus ICE will remain for a long while yet.

Even with huge expansion in the Chinese LiFePO4 industry, it is likely that the early adopter stage will still be here in 2016.

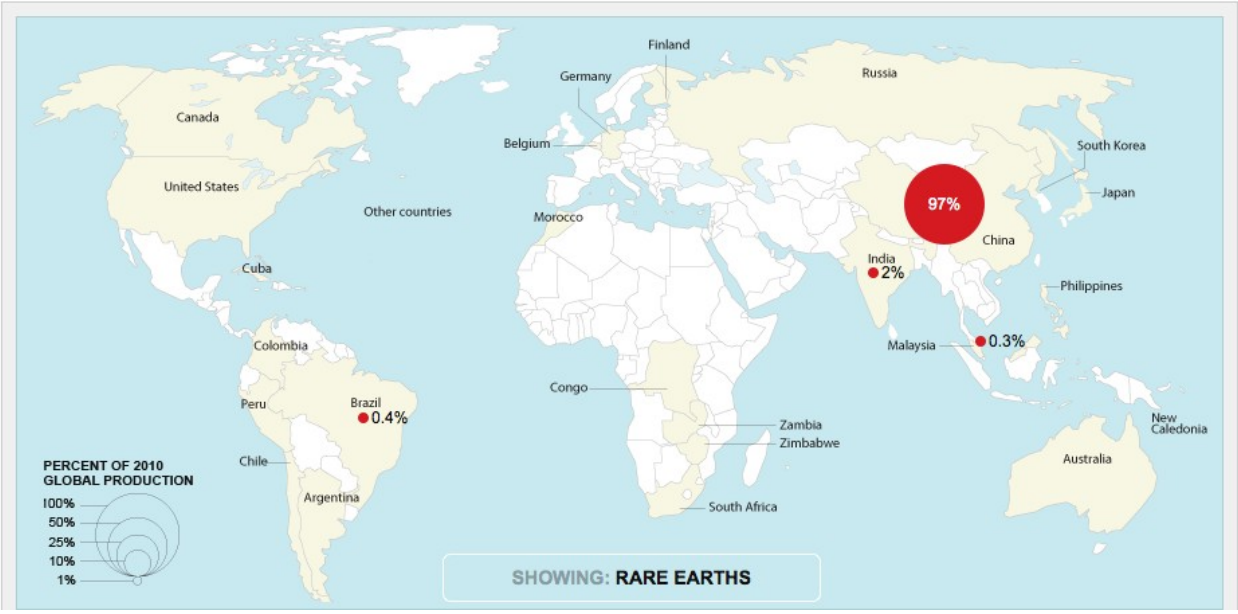
The good news? *There is still plenty of time to get in on the ground floor of EV development!*

So what do we know at this point?

A few things …

1. Chinese LiFePO4 theoretical capacity is 250m Ah, potentially much higher
2. Chinese LiFePO4 factories are running at very low utilization, around 6%
3. LiFePO4 prismatic market is at an early stage, dominated by U.S. hobbyists with a 40% share
4. U.S. hobbyists are budget restricted, and their collective volume is not large enough to drive cell pricing down a meaningful experience curve
5. High end lithium-based conversions in the U.S. are just emerging, and have not yet caught the eye of kit car and hot rod enthusiasts; the 2008 Great Recession didn't help
6. Cost structure of LiFePO4 can be reasonably estimated: $0.50 Ah manufacturing cost including factory overhead; $0.90 Ah FOB plant wholesale price; $1.10 -$1.40 Ah FOB USA retail price
7. Distribution and technical support will remain confusing until the Chinese trading companies establish real U.S.-based sales offices
8. Battery brands matter less than the factory the cells come from

Given the infancy of the prismatic lithium-iron battery business, why are Chinese companies talking about such huge – in excess of 2 *billion* Ah – capacity? The answer lies in these two maps (courtesy of *Technology Review*, MIT):



Two key ingredients are required to make lithium batteries (apart from the copper and aluminum of course!): lithium and the so-called rare earths (not really rare, and not earth in the dirt sense of the word). A glance at the maps tells all.

China produces 18% of the world's lithium, but the balance resides in countries – Australia and South America – that have no world class industrial base or domestic demand. And China controls 97% of the world's rare earths. What this means is that China is destined to control world battery production from a strategic viewpoint. The Chinese government has recognized this fact (and recently restricted exports of rare earths), and will take steps to buttress domestic manufacturers as part of a larger national energy policy.

Sadly – from a U.S. perspective – we don't produce much lithium or rare earth. For the indefinite future, we will be battery *importers*, not manufacturers. Knowing a little Chinese may be helpful in the future.

The U.S. role in EV development must come from another direction: innovation in design, electrical/electronic components, information systems, and so on. And for a long while yet, the key U.S. market will likely be high end – sensitive to design and performance – more like the upcoming Tesla Model S sedan than the Chevy Volt.

Hopefully, a high end entrepreneurial conversion business will evolve in the U.S., much like the custom hand-crafted vehicles that come out of Britain today. But the U.S. regulatory environment is not friendly to this concept, and vehicle safety requirements may retard U.S. innovation during this early transformative period. Crash testing, airbag, and tire pressure monitoring is especially onerous for small converters, and kit car exclusions may not survive the political pressure from entrenched (and failing) ICE manufacturers like General Motors.