EBOOK

HOW TO MAKE MONEY MANUFACTURING BATTERIES

VOLTAIQ

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I. Introduction

By 2030, the global lithium-ion battery market is expected to reach $180 billion, according to Grand View Research. As a result of this dramatic market expansion, numerous OEMs are looking to enter the battery manufacturing industry.

However, before these companies can effectively compete and take advantage of the available opportunity, they need to understand how challenging it is to make money in this sector, owing to the huge upfront capital investment and the long time needed to reach profitable production.

This eBook lays out the challenges new entrants to battery manufacturing will face, and some guidance for achieving profitability as quickly as possible.

Batteries are complex, temperamental and potentially dangerous if not handled properly.

II. The Battery Manufacturing "Boom"

News from the battery ecosystem speaks to severe supply constraints and dozens of companies seeking to fill the coming supply gap by building gigafactories and cranking out lithium-ion cells by the billions.

Indeed, Benchmark Mineral Intelligence projects global battery manufacturing capacity to grow sixfold by 2030 to a staggering six terawatt-hours per year (that's 6,000 GWh, from a baseline of under 1,000 GWh in 2021). Even with anticipated cost declines, the projected production level will create a market size for battery cells in the hundreds of billions of dollars.

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Existing Tier 1 battery providers, new entrants such as Auto OEMs trying to vertically integrate battery supply, and ambitious startups with promising technology and tons of capital are in for a difficult ride, according to our predictions.

The State of Battery Manufacturing

On paper, it may seem possible to achieve the frequently proposed timeline of "two years from breaking ground to full production" for a new battery factory. However, the recent experience of two of the most prominent players in the industry, Panasonic and LG Energy Solution, suggests a sobering dose of reality may be in store for those with such aggressive timelines. (The other "Big Six" Tier 1 battery suppliers are CATL, Samsung SDI, SK Innovation, and BYD.)

Looking at the launch timeline of the Panasonic gigafactory outside Reno, Nevada, we note the following milestones:

- July 2014: Gigafactory announced
- January 2015: Construction begins
- January 2017: Production begins
- 2017-2021: Production quality issues & financial losses
- Q1 2021: First (announced) profitability

Bear in mind — this is the company whose battery cells enabled Tesla's meteoric rise. They should be the best in the world at battery factories (and they may very well be). Yet, it took them four years to ramp up the production lines to achieve profitable operation.

The LG Energy Solution battery factory in Poland reveals a similar narrative, with production shortages forcing their major auto OEM customers to delay deliveries and shut down production lines (with Jaguar, Audi, and Mercedes suffering delays, to name a few) as that battery plant ramped up.

The chart in Figure 1 illustrates the challenges from a financial perspective.

> **If you can maintain sufficient throughput and yield, you'll eventually reach the point where the initial large investment has been repaid ("breakeven point").**

From the day you break ground, it takes enormous cash outlays just to get to the point where you can start the production lines (more on why below). Once you actually begin production, it can again take multiple years (as illustrated by Panasonic and LG) to reach the point where you are making enough cells (throughput) with high enough quality ("yield" percentage, i.e. the portion of cells that are good enough to sell to someone else), that the factory is neutral from a cash flow perspective. On the chart, this is marked as the "self-funding point." If you can maintain sufficient throughput and yield, you'll eventually reach the point where the initial large investment has been repaid ("breakeven point").

Continue along that path, and you'll start to see a positive net return on this initial investment. The key takeaway is that you want to get to the self-funding point as quickly as possible so cash starts coming in and your massive investment starts paying off.

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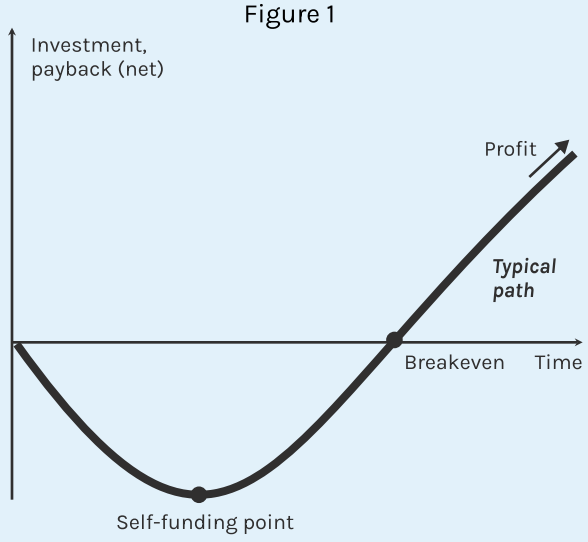
Figure 1



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III. The Challenges of Building a Gigafactory

The question remains: Why is it so hard to make money manufacturing batteries? Getting to profitability in battery manufacturing is a multi-stage challenge — from building the factory, to ramping production up to a profitable level of throughput and yield, to maintaining quality and profitability over the long run.

Building the Factory

The "fun" begins when you start building your battery factory. Here are some of the biggest challenges you're likely to encounter:

1. Sourcing Equipment.

With over 80% of anticipated battery manufacturing capacity yet to be built, it's no surprise that the production equipment to fill all those factories will be in short supply. Unlike other more mature high-tech manufacturing sectors like semiconductors or pharmaceuticals, advanced lithium-ion battery manufacturing production equipment continues to evolve rapidly.

New production techniques driven by innovative cell designs or processing steps mean that your equipment may not exist and will need to be custom-built. The supply base for this equipment is also highly varied, comprising a mix of multinational industrial companies and mom-and-pop outfits.

Like many other industries, the global Covid-related supply disruptions have also impacted this sector. The bottom line is it will likely take over a year just to equip your factory.

2. Sourcing Materials.

In addition to production equipment, you also need the materials to make the batteries themselves. If you're planning to start production at any time in the next couple of years, you should already have your materials supply locked in by now. With global production increasing sixfold over the next several years, it's safe to assume that materials supply will tighten accordingly.

Add in complications around geographic concentration around sourcing and processing of key materials, geopolitical instability, and ethical sourcing concerns. Securing a steady supply of high-quality materials for your factory is an enormous challenge in and of itself.

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3. Sourcing Talent.

Let's assume you've locked in supply lines for your production equipment and materials. Who is going to run your plant? A future with six times the global battery production will require roughly six times the number of people working in battery manufacturing today. It is safe to say that those people don't exist yet, or more precisely they haven't been trained and lack the experience needed to spin up a battery factory and keep it running.

Indeed, at a recent battery manufacturing panel at The 2022 International Battery Seminar, the consensus across the panel of experts was that finding people would end up being the biggest challenge in getting a new gigafactory up and running. The key takeaways here are that:

- You will need to look more broadly for talent — food manufacturing and pharmaceuticals have been mentioned as potential sources.
- You need to equip your people with force-multiplier tools that will make them maximally productive and effective.

Ramping Up the Factory

When we talk about "ramping up" a battery factory, we're referring to the process of starting up production lines, fine-tuning your production process using limited production runs in pursuit of your yield target, and then increasing production until you reach the point where your factory is profitable on a per-unit-manufactured basis (the "self-funding point"). The chart in Figure 2 illustrates the link between ramping up manufacturing capability and the investment payback timeline shown in the earlier diagram in Figure 1.

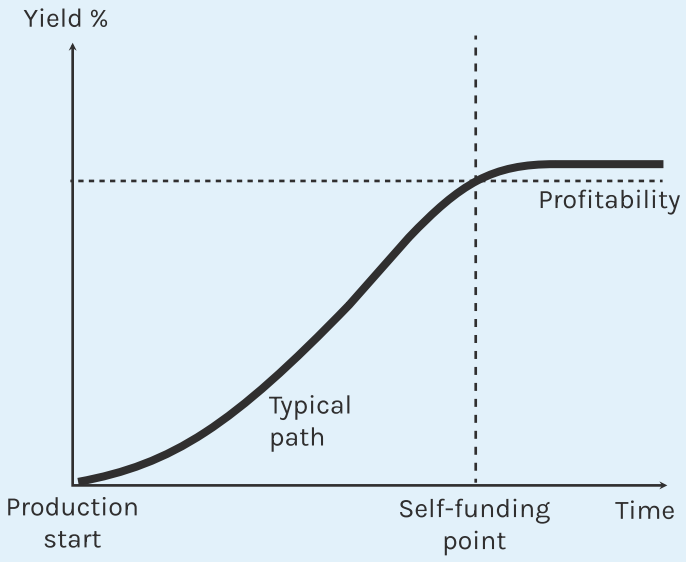
Winning in battery manufacturing is all about getting the combination of throughput (number of units you make) and yield (percentage of production that passes quality control and can be sold to customers) to a profitable state as quickly as possible. Even once your factory is fully built and equipped, this process can take years, as illustrated by the Panasonic and LG cases mentioned above.

Battery Manufacturing Is Complicated

At a high level, battery manufacturing comprises three main stages — electrode fabrication, cell assembly, and end-of-line. However, each stage comprises dozens of individual steps and hundreds (if not more) of equipment settings: speeds, temperatures, pressures, and so on.

Figure 2 here illustrates the link between ramping up manufacturing capability and the investment payback timeline shown in the earlier diagram in Figure 1.

Figure 2



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Achieving profitable production throughput and yield requires precise orchestration of these parameters into a recipe that will produce a commercially viable battery. It's just plain hard to get all of it right and can take years of iteration when bringing up a new factory. This challenge is compounded when building a factory to support the latest and greatest cell technologies — which have not yet been mass-produced.

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Cycle Times Are Slow

When running at full speed, it only takes a handful of hours for a production line to transform a batch of raw materials into a fully assembled battery. However, it actually takes days or weeks longer to determine if that battery is any good. This delay comes down to two final steps in the manufacturing and quality control process, formation and aging, together commonly known as "end-of-line". Formation cycling (a.k.a. "formation") is the slow, careful charging and discharging of a finished battery cell over a handful of cycles to form and lock in the vital internal structures and interfaces that ensure the cell's performance and longevity. Each and every battery cell goes through formation cycling, and the process typically takes a few days.

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Formation is also the first time the battery produces any sort of electrochemical data, and as such is really the first indication as to whether the cell is any good. Thus, when ramping up a new factory, formation necessarily implies that the minimum feedback cycle time for any tweaks to your production recipe is at least three or four days, realistically more like a week.

But it gets worse. After formation, a cell goes through "aging" in which newly produced cells are stored in a warehouse for anywhere from a week to a month, after which each cell's voltage is measured and compared to its voltage when it finished formation.

If a cell's voltage declines too much during this aging period, some undesirable self-discharge is occuring (an internal short or similar). That cell ends up getting rejected by quality control. A longer aging period indicates more rigor in the quality control function of a battery manufacturer. However, the tradeoff further extends the feedback cycle needed to determine if a given production recipe will produce the desired results.

Systems Are Immature

Manufacturing lithium-ion batteries at the planned scale is unprecedented, and companies are still figuring out the best practices in real time.

One implication of this immaturity is that the computer systems that link together all the equipment in a factory and record process parameters and similar continue developing. Many of these Enterprise Resource Planning (ERP), Manufacturing Execution Systems (MES), and Product Lifecycle Management (PLM) software packages are custom-built or adapted from other industries and may or may not be capturing the most valuable and relevant information from the production line.

Production iteration cycles can stretch to several weeks when combined with the delays inherent to formation and aging.

Even less mature are the tools manufacturers use to analyze all the data from the production line, formation, and aging to determine what makes a suitable cell and ultimately increase production and optimize yield. It can take weeks or longer to analyze the data from a production run, connect the dots across disparate systems, and determine what to try next. Production iteration cycles can stretch to several weeks when combined with the delays inherent to formation and aging.

In light of these challenges, most notably the iteration cycles denominated in months and not days or weeks, it is actually not that hard to understand why it can take multiple years to ramp up a new factory to full production. These challenges also put in perspective the ambitious timelines being proposed by new entrants who plan to fully ramp up in a year or less. In all likelihood, it will take substantially longer.

Running in Steady State

If you get to the point where your primary concern is running a battery factory at a steady state in full production capacity, then you have overcome a multitude of major obstacles that continue to trip up some of the most experienced companies in the field. Well done!

You'll still be faced with the ongoing challenges of continuing to source an adequate supply of high-quality materials, and retain enough experienced staff and institutional knowledge to keep things running smoothly in an extremely tight market for battery expertise. But if you've come this far, you probably have a good handle on those things as well. Production issues will inevitably arise, however. And when they do, those same issues around immature and inadequate data and analytics systems can severely hamper root-cause analysis and lengthen response times.

Both of these can be disastrous to your cash position when running a high-volume, commodity manufacturing business, particularly if you have to stop production or recall batteries. Having access to the best modern tools for gathering and analyzing all of this data, from mixing electrode slurries all the way through to formation and aging, is ultimately vital to dispatching production issues quickly and resuming profitable operations.

IV. How to Properly Monetize Battery Manufacturing

In presenting these many daunting challenges to starting up a new battery factory, the goal is not to discourage anyone but instead to generate awareness. With global demand for battery cells skyrocketing, there is a massive and lucrative opportunity for companies that get it right — and many will.

On the chart in Figure 3, the path highlighted in green illustrates the potential benefits of accelerating the production ramp, namely:

- **Faster time-to-market and time-to-self-funding.** The sooner you get yield up, the sooner you can actually start selling batteries. The faster you ramp throughput, the more revenue you'll make.
- **Greater profitability in the long run.** Again, a higher yield means more saleable batteries, and thus more profit for a given production throughput. Happily, increasing yield also tends to increase throughput due to less overall downtime and time spent troubleshooting.
- **Faster and larger return on investment.** The area between the two curves represents the massive lost time, lost revenue, and increased expense that results from taking the default path (grey) as opposed to the optimized one (green).

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And likewise, let's take one more look at the more financially oriented chart in Figure 4, to observe these impacts in terms of payback on investment.

Here, you can see how ramping up throughput and yield faster gets you to self-funding and breakeven sooner, meaning you can raise less money for each factory, and enjoy greater profitability over the long run.

Figure 3

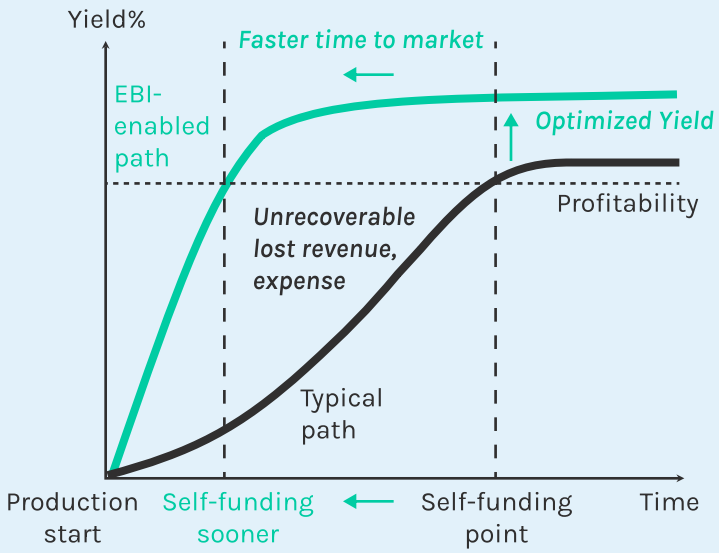
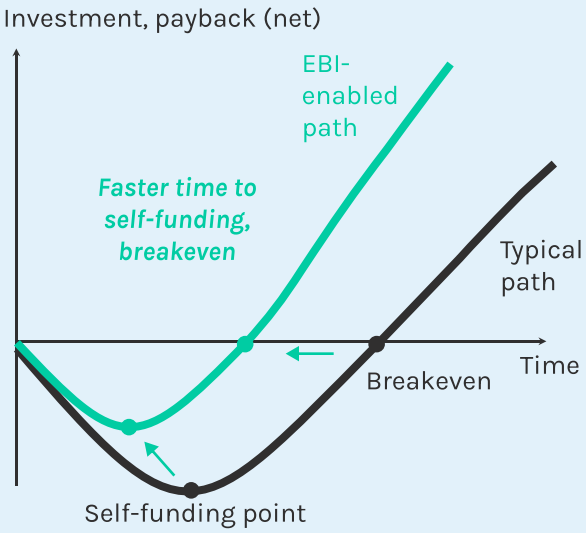


Figure 4



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V. The Key to Speed: Enterprise Battery Intelligence™

You'll see on these last two charts that the more optimal green path is labeled the "EBI-enabled path". EBI here stands for Enterprise Battery Intelligence, an emerging category of data infrastructure and analytics software specifically targeted to helping battery-powered businesses achieve profitability and success in the marketplace.

In battery manufacturing, an EBI system provides an analytics layer that automatically aggregates data from across the production line — materials batches, equipment setpoints, formation cycling, and end-of-line quality control information.

An EBI solution applies battery-specific analytics to make critical correlations and actionable insights instantly available across your organization. This capability brings the following range of benefits to a battery manufacturer.

Accelerated Production Ramp

By shortening the feedback loops between production runs, an EBI system can detect problems early in formation and alert you to issues in real-time. Correlations to materials and process information can quickly identify which parts of your recipe need fine-tuning. You no longer have to wait days for formation to complete or to prepare all data for analysis. The critical information is immediately at your fingertips, so you can iterate quickly and reach profitability faster.

By shortening the feedback loops between production runs, an EBI system can detect problems early in formation and alert you to issues in real-time.

Improved Yield

EBI analytics can use formation cycling data to derive much deeper insight into battery quality than the current industry-standard practice. Let's use a medical analogy: Most formation cycling analysis measures a battery's "height" and "weight" (voltage and capacity). By contrast, EBI is like an automated cardiologist examining the battery's charge-discharge "heartbeat" like a detailed EKG, identifying more subtle clues as to how a battery will perform over the long term. Over time, these insights can help further optimize your production process to drive even higher yields than the base case would permit.

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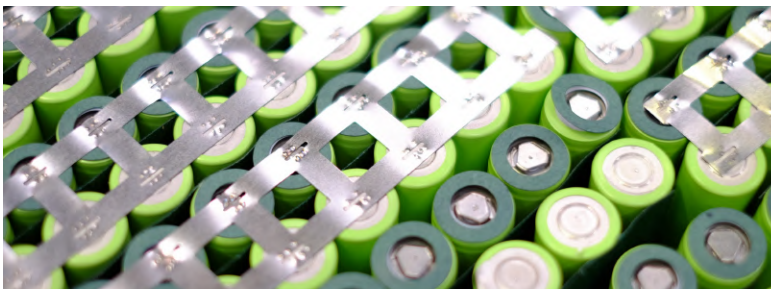
Faster Response to Production Issues

Production issues will inevitably arise. EBI can quickly alert you to end-of-line quality problems and facilitate rapid root-cause analysis through its materials and process tracking functionality to get you back to full throughput and yield faster. EBI can also help you avoid recalls by detecting issues before faulty batteries find their way into customers' hands. In the unfortunate event that you do need to recall the product, EBI can help you limit the scope of any recall by isolating the problem to the affected batches or production lines.



VI. Discover the Difference With Voltaiq's Enterprise Battery Intelligence

Voltaiq's EBI platform is a powerful software tool that can assist battery manufacturers in optimizing their manufacturing processes and improving product quality.

EBI provides manufacturers with real-time battery performance data and detailed manufacturing process information. This enables manufacturers to identify potential problems early on and take corrective action before they become serious problems. The software can track trends in battery performance over time, assisting manufacturers in continuously improving the quality of their products.

EBI can also help you avoid recalls by detecting issues before faulty batteries find their way into customers' hands.

An EBI system integrates with and runs alongside your existing tooling (MES, formation data capture, etc.), allowing you to get up and running quickly and iterate toward success. This level of data agility and depth of analysis is a must-have for any company that currently manufactures batteries or plans to do so in the near future. Voltaiq provides a comprehensive view of the battery manufacturing process, resulting in higher product quality and customer satisfaction.

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Voltaiq is proud to work with companies at various stages of the battery manufacturing journey as the company pioneered EBI. We'd love to hear about your challenges and see if we can assist you.

Schedule a free demo today.

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REQUEST DEMO

About Voltaiq

Voltaiq has built the industry's first Enterprise Battery Intelligence (EBI) software platform, helping its customers optimize battery performance, reliability and financing, while avoiding costly recalls and catastrophic battery fires. Voltaiq's EBI platform is the only purpose-built, fully automated software solution that marshals vast quantities of battery data from across the full product lifecycle, providing a window into real-time battery function and a detailed view into future performance and behavior. Founded in 2012 by veteran battery and software entrepreneurs, Voltaiq's global customer base includes industry leaders in transportation, consumer electronics, energy storage, and the full battery supply chain. For more information, please visit www.voltaiq.com.