Cracking the Code of European Gigafactories

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Local Value Creation and its Unexpected Obstacles.

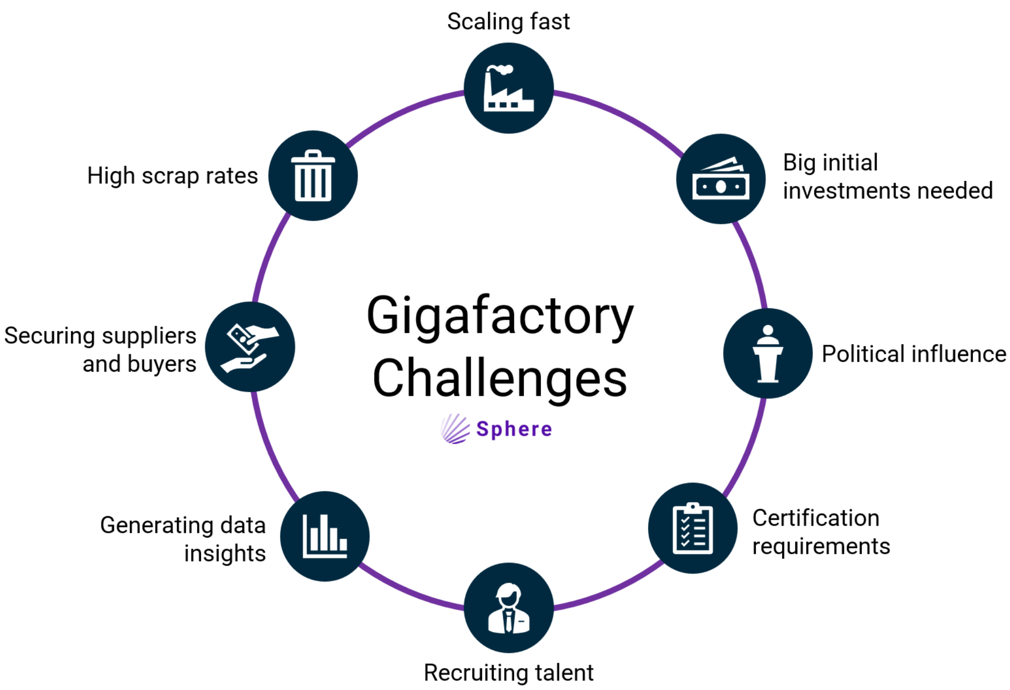
Context

The battery market is the new gold rush. An expected market size of $400 billion in 2030 and staggering annual growth rates of over 30% mean getting in on the action now or risk being left behind in the dust. The emerging battery market is a big opportunity that in times of recession, helps to mitigate the disruption of many classical businesses and provides a ground for new, local value creation.

Besides directly affecting one of Europe's biggest industries - the automotive sector - the battery has further become a strategic value driver and a key differentiator for many other companies that have batteries at the core of their products. For example the power tool industry - a $50 billion market no one talks about.

With such a profound impact on the value chain, the battery has secured itself a place on the geopolitical agendas of policymakers, which aim to secure a fair share in this growing market for their respective countries and reduce their dependence on foreign production. With predictions from the likes of McKinsey and Roland Berger, that foresee potential battery (supply) shortages, the direction is clear. We need local battery production to secure the supply of this critical technology and create local value at the same time.

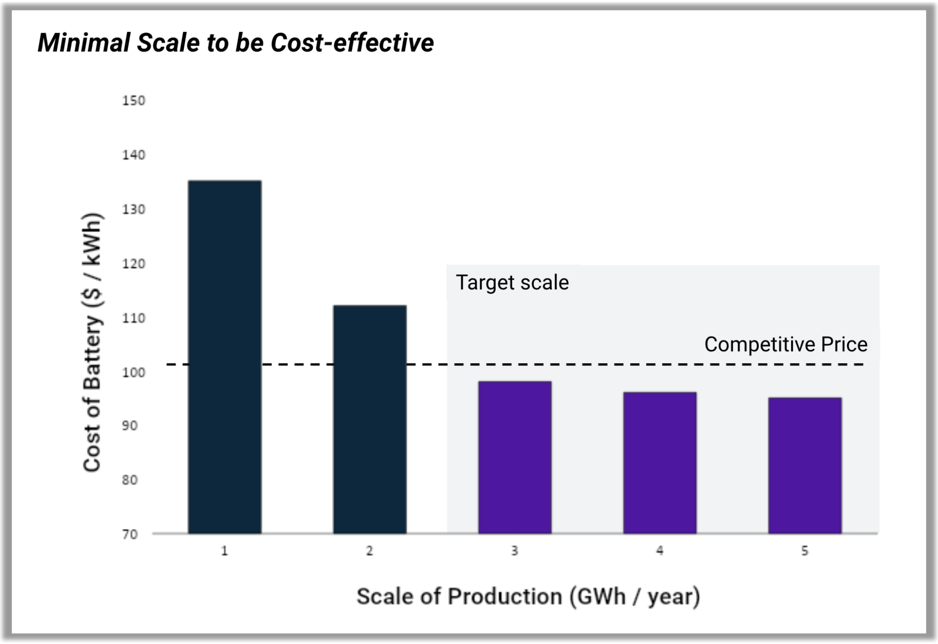
But building a local battery production at the Gigawatt hour scale is easier said than done. In the following, we want to look behind the scenes of glossy announcements and highlight critical success factors to understand why Gigafactory projects are such a challenging endeavor.



> *It's quite easy to make one battery per day, but it is extremely hard to make 100.000 batteries per day and they all perform in the same way!*
>
> *- Nemanja Mikac, CEO at ElevenEs*

First of all - size matters

Let's start with the size and why everyone is actually talking about "Gigafabs". Why giga? Well, there is a reason. To set up a cost-competitive battery plant, one must go big from day one. A big junk of profitability is dependent on massive economies of scale. Despite its high price, the battery is a commodity in a very cost-sensitive market. The expected minimum scale to produce at a competitive price of < $ 100/KWh starts at around 3 GWh of annual production capacity as is shown in the figure below. This number originates from a study of the University of Münster focused purely on the production process of NMC batteries. When one considers other factors such as bargaining power or securing supplier contracts, a production volume of 20 to 35 GWh is more realistic to be competitive. This is reflected in the announced capacities of European Gigafactories. Basquevolt announced 10 GWh, Britishvolt 35 GWh, and Northvolt 40 GWh. Generally, the more the better to fully leverage the economies of scale.



The target scale is also highly dependent on the produced cell chemistry, where e.g. LFP needs around 3 to 4 times larger production to be efficient compared to NMC. While special application batteries for e.g. space shuttles may be sold at a higher price, for all the rest of the batteries, $ 100/kWh is the target.

So when planning such an endeavor one needs big pockets to start with. Just to give you an idea, the required CAPEX investments for production equipment alone, needed to produce 1 GWh of batteries, sum up to around $ 60-90M. And that doesn't include labor and energy. Quite some money...

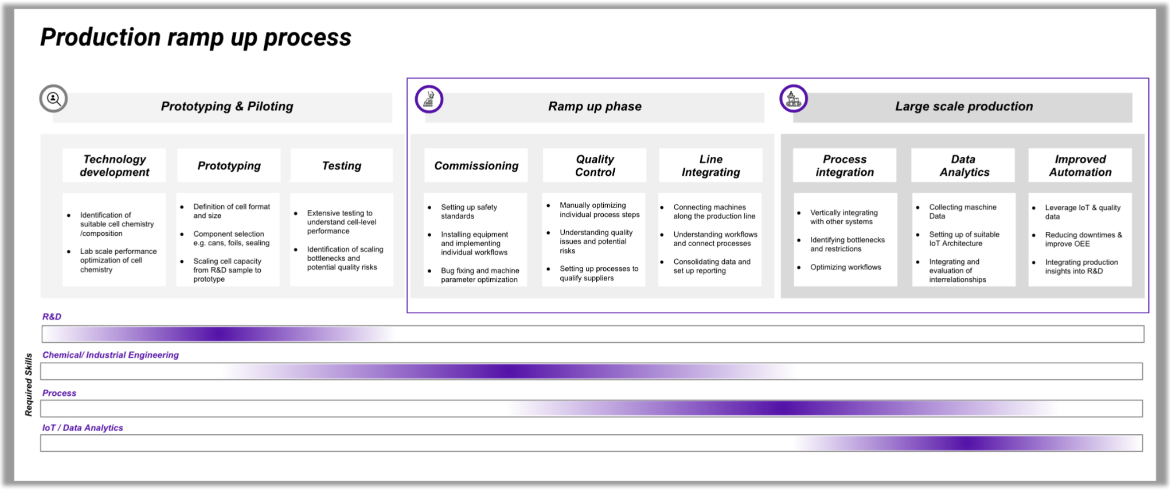
Finding a location to get started

Before you can set up your production, you need to find a suitable location. This depends on various factors. First it needs to fulfill all the legal requirements for producing batteries - clear. But there is also a social aspect. Especially in countries like Germany, neighbors can be kind of a showstopper, as Northvolt has painfully experienced in Grünheide. Second, the location needs to be attractive to talent and ready for an efficient transportation of goods, by land, air or water. And last but not least, as we know size matters - so further growth options should also be planned for ahead of time..

From a first pouch prototype to a manufacturable cell

Scale location and financing secured (since this is a more technical article, we won't go into the details of fundraising here), now one needs to transfer what was learned in the small pre-pilot line to a massive production plant. And it all starts with the design of the cell, which ultimately defines what equipment is needed and how the shop floor will look like.

Traditionally, the cell design is based on expertise that has been gained in projects together with academic partners. But such, often manual labor intensive, processes have little to do with producing millions of batteries in a highly automated production line and it takes years to adapt to industrial scale. No doubt, institutes involved in process research play a central role in bridging the gap between coin cells and small-format pouch cells to multilayer prototype cells. Through the targeted establishment and use of these institutes, the entire process chain of various battery technologies can be researched and scaled up to suit the material. However, scaling up to Gigawatt Hour scale is simply tough.



Coming from the pre-pilot experience, everyone is talking about how the cycling data showing overwhelming (or not, but surely soon) energy and power densities, great coulombic efficiency, and cycle life. Optimizing the active materials: the cathode, anode, and electrolyte is crucial and everyone gets that - even investors. But, a commercial battery is, unfortunately, more than just that.

> ***Institutes involved in process research can be of great help with the scale-up. For this an open dialogue and intensive exchange is necessary.***
>
> ***- Fabian Schatz, CEO TUMint Energy Research GmbH***

Lots of the secret sauce of an industrial-grade battery cell comes from the boring stuff. Optimizing parameters and adjusting machines to achieve the optimal e.g. porosity, thicknesses or mixing speeds. Choosing the optimal current collectors, tabs, or welding processes. Who wants to deal with that when “the real innovation” is happening in cell chemistry? Well, all these unsexy details like surface treatments, adhesion parameters, etc. will screw you over big time when putting it all together. Getting this stuff right is what differentiates the start of a successful production, from the ones that struggle massively when scaling the design of their first 10 Ah, handmade prototype. And this needs skills that an academic battery scientist simply does not have.

But who defines the cell design new? The battery scientists, the engineers, or the quality people? Who is right? Who is leading? Not an easy one to manage. The worst thing though, is that during all these discussions you can’t really engage with the equipment suppliers. They want a partner that has a clear plan since your project is still high risk for them at this stage, and no one has time to waste on a Gigafactory project that maybe won’t happen in the end, it’s tough to partner.

Production equipment off the shelf - not so easy.

But let's get to it - buying the equipment. Shopping, the fun part no? Now that the cell design is clear, more or less, we just need to tell them what we need and buy the machines from the catalog? Well that's a no again, it's unfortunately not that easy.

First one needs to translate the requirements of how your cell should look into a machine that can produce that thing. Good luck doing that yourself. At this point, you need not only a supplier but a partner that helps you design your plant. This may not be the case in other industries, but certainly is for Gigafactories.

So now, do you go to a high-quality European supplier, that potentially is expensive and has often less experience in battery manufacturing, but is keen to design the plant together with you? Or do you choose a cheaper Asian supplier, that has been in the battery game for over a decade with highly standardized machinery? Both options have advantages and pitfalls especially when it comes to quality, communication, customer service, delivery times, or maintenance. The question is often answered when looking at the budget at hand and the timeline to be fulfilled. This doesn't always lead to the best long-term-oriented decisions.

But it's all done. Equipment ordered. Machines commissioned - at least kind of.
Wait a second, did anyone think about spare parts? Cutting blades, notching tools, winding spindles. Aren't these all high-precision tools that are very sensitive to wear and tear, with revision cycles of weeks or more often months? Well yes! And if you now factor in current delivery times, it becomes pretty obvious why spare parts management is something you may want to consider with strategic suppliers early on to ensure a smooth production later on.

Securing a stable supply chain - in both directions

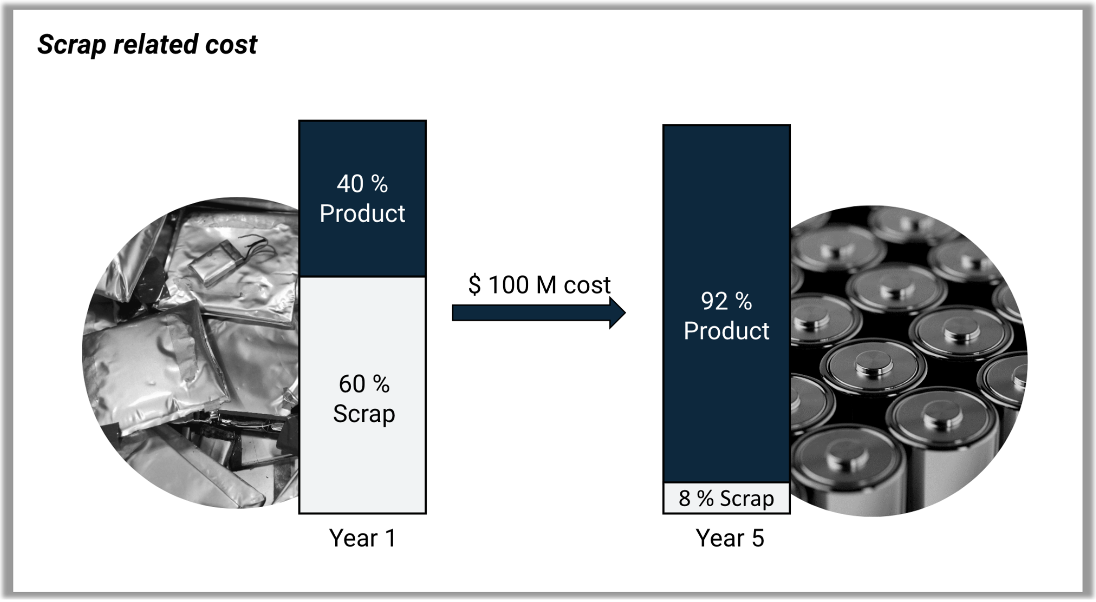
Everything is set up, so let's focus on the supply of raw materials to not jeopardize the operations when it's finally running - because once a Gigafactory is turned on you better not turn it off or slow down! Just to give an example: if your 20 GWh line is not producing for a day, you just burned $2 million. In a day! So the primary objective is to run it at maximum capacity while avoiding any interruptions.

Sustainable, long-term agreements with raw material suppliers have to be put in place. On paper it is easy, but who wants to do that with a Start-Up? Well, most of the Gigafactories are still Start-Ups and many raw material providers are extremely hesitant to engage in business with a new venture unless the ability to procure bulk amounts of materials in the future can be demonstrated. This situation can prove to be an obstacle for companies that lack prior experience in the field, as they find it difficult to convince their partners of their reliability.

And a reliable supply is already important in the earliest stages. The design phase alone requires hundreds of kilos of raw materials that cannot be simply bought online on Amazon. And to make things worse - there is a massive chicken and egg problem here. Securing these long-term supply agreements normally demands backing from potential buyers, which define your cell design, the production planning and have a reciprocal effect on the negotiation with material suppliers. Another really nice challenge. It's actually such a big challenge that some of the large OEMs (e.g. GM) decided to leverage their power and purchase the raw materials themselves to ultimately provide it to their partner/captive battery producers, since they couldn't convince the suppliers themselves.

Reducing scrap rates - fast.
So let's assume you made it to the stage where agreements are put in place and your production is running. Well, now you have to deal with large, not to say massive scrap rates! Scrap rates of around 60 % in the first years are normal. And it's extremely difficult to get down to the desired ~ 8 % that the top players have. Still several orders of magnitude higher compared to traditional industrial processes like metal sheet bending. And to give you an idea of cost: during the first 5 years, a normal timeframe to get down to 8%, a 2 GWh plant will consume roughly $100 million. Money down the drain!

The other problem with battery waste is that it is not only extremely costly, but also highly regulated in terms of recycling, since it contains a lot of precious and toxic materials. So building a recycling plant right next door is your best case. But wait, you wanted to build a battery production not become a recycler. Time to partner up.



Data and insights
And let's not forget all the generated data and its related value.

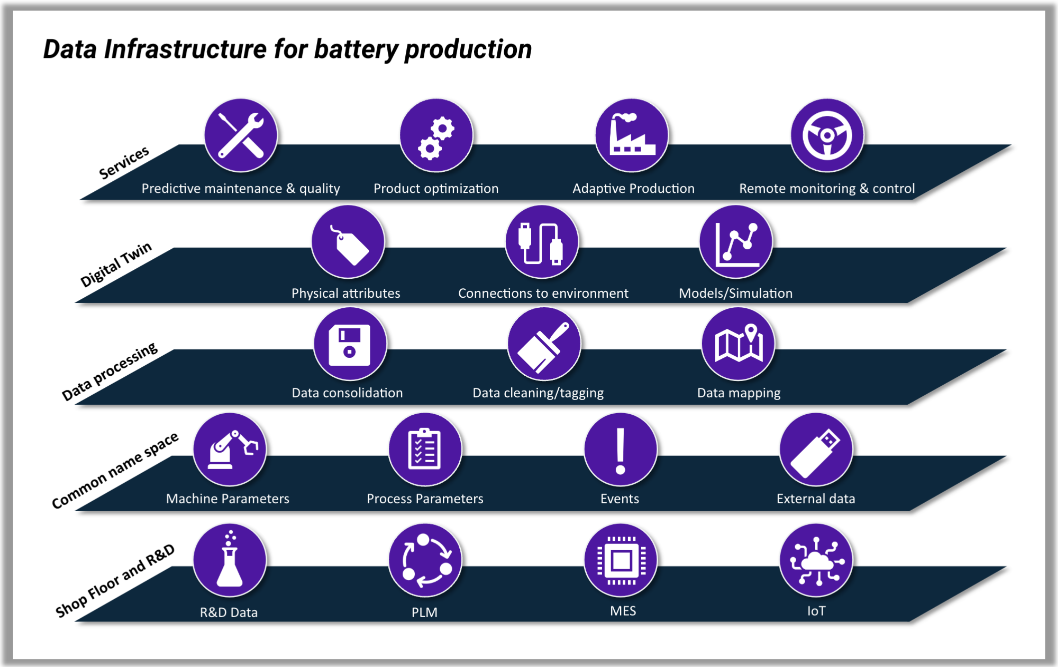
There was a nice quote from Quantum Scape in their early stages, which was along the lines of: "We want to be a data-driven company and will dedicate lots of effort towards setting up the necessary IT infrastructure, even before production starts." So let's talk about the value of data in a Gigafactory. There are many aspects to data here, but let's focus on the most impactful.

It all starts in R&D where experimental results can be used to learn from high volumes of experimental results, be it throughput screening of material combination, or fundamental behavior differences of various chemistries. This alone is generating tons of data, where the valuable information is often hidden in the metadata, which without experienced data analysis, is often uselessly sitting on some hard drive instead of delivering support for complex decisions.

On the other hand, there is the production data. The various systems that leverage production data can be segmented - on a high level - into product lifecycle management (PLM) systems, machine execution systems (MES) as well as more sophisticated internet of things (IoT) or so-called digital twin technologies.
The PLM is used to manage a product and its associated data through all stages of the product life cycle and provides visibility throughout the design process for all stakeholders, e.g. project management, BOM management, and purchase management. The MES is more related to the production itself by monitoring, tracking, documenting, and controlling the manufacturing process, from the raw materials to the final battery cell.

Additionally, you have the possibility to leverage the IoT and related technologies like digital twins, which are a virtual representation of a physical object, e.g. a machine, that reflects all the relevant attributes, connections, and data sources of the physical object in the data space. These technologies extract information from your production line, via new sensors, edge IoT gateways, and communication protocols like MQTT, that then can be used by advanced data analytics to provide real-time insights into equipment performance - identifying potential issues before they lead to downtime. And besides that, seasoned in-line quality control is an essential component to managing highly sensible processes and achieving low scrap rates in the end.

Well and if this alone would not be a headache enough - the holy grail is then to connect the R&D with your production to generate "one intelligence" that helps you leverage the full potential of these technologies and become the most efficient Gigafactory out there. But that's a really really tough one! Here it's not only about skills, it's about the attitude and mindset of your venture. Are you a "data company" or a "battery science company" or simply good at manufacturing? Unfortunately, the answer is not binary, being software and data savvy is not an option, it is a must. Ask any CTO from a successful manufacturing heavy company. Iot and DT are their favorite topics. Key is to find the right balance between over-engineering and being at the top of data to really drive the value of the operation.



Tedious certification requirements

Compliance and regulation: everyone's favorite. Mastering these domains is unfortunately an absolute must when you want to supply the automotive industry. The key market all battery makers want to supply. The battery certification process is regulated on international as well as national levels, with specific standards and guidelines to assure production quality and cell safety, to name only the two most important.

The qualification process for new cells is a multi-year project and typically starts with an A-sample, a prototype cell that is tested for safety and functionality. From there, the cell design progresses through the B-sample and C-sample stages, with a larger number of trial modules/packs assembled and cell series produced. The final

D-sample stage involves producing the battery cells at scale and passing automotive part approval to reach TRL 7 - ready for the likes of the UN 38.3, IEC 62133, IEC 62619, UL 1642, IEC 61960-3, and many more.

Having the right expertise within the team to master such a strict process for both the production as well as the final product, is one thing but providing the necessary financials to surpass this, often > 3 years process, elevates this challenge to another level.

Finding the right talent.

Last but not least, someone needs to do all that work
Besides all the business-related challenges Gigafactories are facing, one of the core success factors is finding the right talent. Unfortunately, experienced battery development engineers and production process experts that know how to ramp up such a facility do not grow on trees. Nowhere! And fresh PhDs or Battery experts with 2 years of experience won't be enough. But it is not only important at the production level to have the necessary battery know-how. The best management skills will be of no use if there is no understanding of the complex processes involved in battery production at the decision-making level.

With all the aforementioned, the availability of such talent is ultimately going to decide if the EU and the US will participate in this new value creation in the long run. And unfortunately, there is no quick fix (e.g.: by throwing money at it) for decades of experience.

Final thoughts

Setting up a new local battery production is not as simple as many would have hoped for. It is actually "rocket science".

It's a massive money drain with terrible yields for many years in a super cost competitive market - that demands a sophisticated long-term plan not only a sparking idea!

And in the end, there are more reasons why a Gigafactory project should fail rather than succeed - like with every other ambitious endeavor. And most likely not all of the announced projects will survive their first year, due to energy prices, blown-up supplier contracts, missed operational targets, or simply not enough talent.

The success factors of a Gigafactory can be viewed as a success chain. If one of the factors is not succeeding, the whole chain breaks and the endeavor fails. There are three critical success factors, that we believe are essential to building an European battery production:

- **Securing long-term contracts** - this is only possible with a certain bargaining power that only comes with the scale of a venture. Long-term investment and commitment are needed.
- **Leveraging the EU (machinery) ecosystem** - we need to capitalize on our vast knowledge in machines, manufacturing, and process engineering and establish partnerships between equipment manufacturers and Gigafactories to master the high levels of required quality.
- **Attracting the right team** - finding the scarce battery talent is a huge challenge, but proper management is just as crucial to put the talent to work. Both are needed: a battery scientist alone won't build a Gigafactory, and neither will a manager that has never assembled a coin cell. There needs to be a talent strategy and educational programs, it's not like battery talent grows on trees.

But there is no time for resentment. Competition is fierce and we need to establish the appropriate awareness and political support to pull this off. Let's get our hands dirty, work together and cut the marketing BS, if we really want to create value here in Europe.

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