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Mechanical and plant engineering: A strategic component of the European battery ecosystem

Cooperation as a key to success?

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1 EXECUTIVE SUMMARY

In establishing battery cell manufacturing and building a functioning battery ecosystem in Germany and Europe, collaboration between cell manufacturers and mechanical and plant engineering offers numerous innovation potentials and thus opportunities to counteract existing disadvantages in competitiveness against Asian competitors.

Compared to Asian competitors, to date the European mechanical and plant engineering has achieved limited success as a supplier for Europe's emerging battery industry. In addition to a lack of references in the battery industry, the mechanical and plant engineering sector in Europe has relatively little experience in the manufacturing of turnkey solutions for the battery industry. However, these solutions are of interest, in particular for European cell manufacturers, that are new to the market, as they can partially compensate for the lack of practical knowledge and low personnel capacities for system integration. To meet these requirements, it is essential for German mechanical and plant engineering to develop a broad process knowledge along the production chain for the manufacturing of lithium-ion batteries. Cooperation between machinery and plant manufacturers enable a rapid enhancement of competencies and expertise.

To assess the current situation, interviews were conducted with machinery and plant manufacturers as well as battery cell manufacturers. The key finding of this study is that cooperation between machine and plant manufacturers can be advantageous in competing with Asian manufacturers. Advantages include the synchronisation of interfaces, synergy effects and the accumulation of know-how through joint research and development, as well as the ability to offer turnkey solutions for larger plants more quickly. Some core requirements for cooperation must be met to make it successful. These include a clear division of work, mutual trust and active participation.

However, the dynamic battery cell market makes cooperation more difficult and the antitrust law can be an additional obstacle. Nevertheless, machinery and plant manufacturers increasingly seek out cooperation with manufacturers from adjacent production steps, beyond the usual supplier or integrator relationship. This is because cooperation in combination with quality assurance can strengthen the competitiveness of German mechanical and plant engineering against Asian manufacturers.

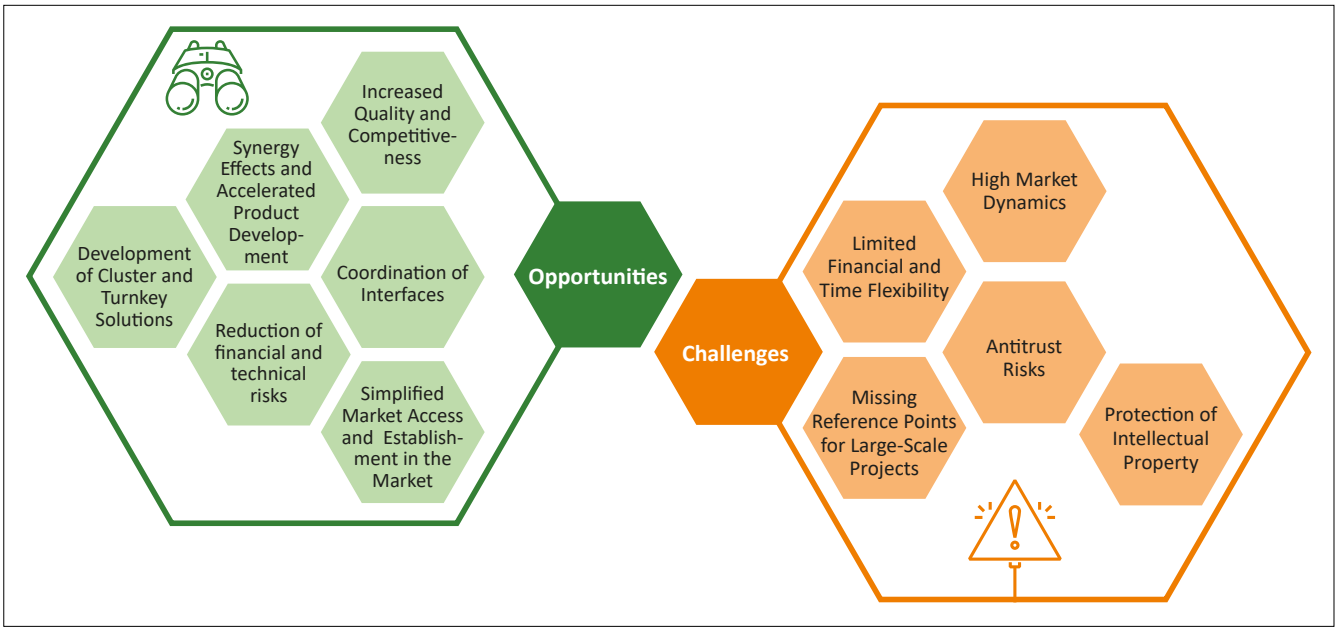


Figure 1: Opportunities and challenges of cooperations in mechanical and plant engineering (own depiction)

2 INITIAL SITUATION

Asian battery cell manufactures dominate the global market. In 2022, all of the top 10 electric vehicle battery manufacturers were Chinese, Japanese and South Korean companies. China has the largest production capacity by far with a volume of around 1,500 GWh/a. As of the end of 2023, Europe is operating production facilities with a nominal capacity of about 175 GWh/a. Production capacities continue to be expanded to meet the rising demand. Europe's production capacity could exceed 1,000 GWh/a by 2030. This expansion in turn means the demand for machinery and production facilities is high.

A strong mechanical and plant engineering sector has developed in China, South Korea and Japan, specialised to meet battery industry requirements and with a track record of constructing facilities on a gigawatt hour scale. This development was and is driven by the dominance of cell manufacturers in these countries.

Asian equipment manufacturers are not only equipping sites in Asia but also in Europe. SK On and Samsung SDI, for example, primarily engaged South Korean equipment suppliers for their cell production in Hungary. Also new European cell manufacturers are relying on the expertise of Asian mechanical and plant engineering. The Norwegian battery cell manufacturer Morrow procures most of its equipment from Asia. 97% of the machinery for new cell production in Norway comes from South Korea.

2.1 Lithium-ion battery production process

For new cell manufacturers the Asian mechanical and plant engineering is not only interesting due to its long-standing expertise, but also because of the offered turnkey or cluster solutions. These turnkey or cluster solutions integrate multiple process steps into a single system procured from one source, built by a general contractor. Turnkey or cluster solutions thus reduce the level of complexity for new cell manufacturers with little process experience, and therefore the risks associated with setting up a continuous production line.

Figure 2 shows a prototypical production process of a lithium-ion battery cell. The process steps of cell production are clustered into three stages – electrode manufacturing, cell assembly, and formation and ageing.

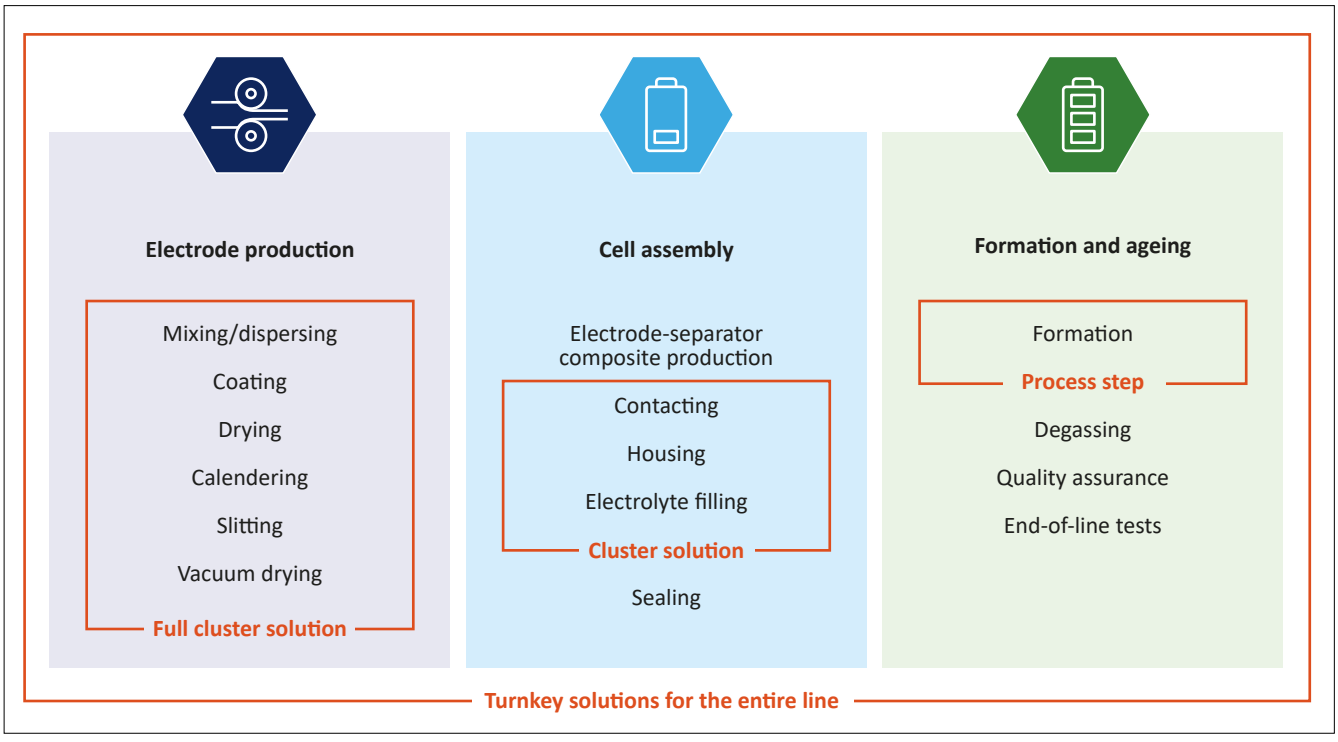


Figure 2: Definition of (full) cluster and turnkey solutions based on the production steps in battery cell manufacturing (own depiction according to VDMA)

This publication uses the following definitions for the description of plant engineering:

- **Turnkey solution:** Comprises all cell manufacturing process steps
- **Full cluster solution:** Comprises the combination of all process steps for one of the three stages
- **Cluster solution:** Corresponds to the combination of at least two process steps within a cluster.

German/European machinery and plant manufacturers need to expand their process knowledge along the lithium-ion battery production chain to meet the demand for turnkey or cluster solutions. Cooperation between production equipment manufacturers represent a way in which competencies can be quickly expanded.

2.2 Types and forms of cooperation

Definition of cooperation
Cooperation defines a partnership between at least two legally and economically independent companies with the objective of making both cooperation partners more competitive.

Cooperation is classified here as vertical, horizontal or diagonal, in reference to a publication on forms of cooperation.

Vertical Cooperation

Companies in different stages of the value chain cooperate with each other, often entering into a supplier-customer relationship. Cooperation between a cell manufacturer and a machinery and plant manufacturer would be an example of this in the battery industry. Cellforce and Dürr, for example, are engaged in this type of cooperation.

Horizontal Cooperation

Companies in the same stage of the value chain work together. The products and services of the cooperating companies are based on similar or identical technologies and production processes. For the field under consideration, this would mean cooperation between machine builders such as the cooperation between Manz, Dürr and GROB.

Diagonal Cooperation

Companies in different sectors cooperate in order to create new products and services. New technologies and market areas are developed as a result, and different value chains are linked to each other. An example of this in mechanical and plant engineering would be cooperation between a technology supplier (such as a laser technology manufacturer) and a system integrator that uses the technology in a machine to carry out a certain production step.

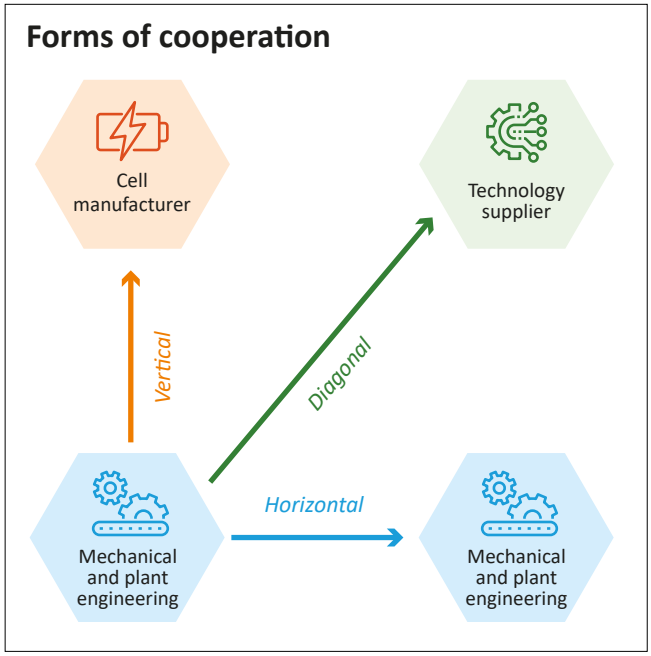


Figure 3: Forms of cooperation examined in this publication (own depiction according to Schumann)

Cooperation can be limited in time as well as formalised in various ways, for example, with legally binding contracts or through verbal agreements. Cooperation can be multidisciplinary or limited to specific areas such as procurement, production or distribution.

Cooperation can be established in various ways, including:

- Cooperation agreements
- Strategic alliances
- Working groups
- Enterprise networks
- Joint ventures

3 STUDY FINDINGS

An examination of the initial situation shows that the German/European battery ecosystem is under tremendous pressure to become internationally competitive. Aside from the discussion of government measures aimed at the development of the German/European battery ecosystem, the possibility of cooperation between stakeholders within the system is being considered as a promising step (Stronger competitive position of mechanical engineering in Germany). Since cooperation in mechanical and plant engineering requires the initiative and action of its stakeholders, one needs to clarify whether cooperation is even sensible from the perspective of users and whether this is being actively implemented already.

Interviews were conducted to this end over a period of three months with representatives of German machinery and plant manufacturers as well as some battery cell manufacturers, including Automotive Cells Co. Deutschland GmbH, Cellforce, GROB, Laserline and Manz. The object of these interviews was to confirm the initially described situation as well as the hypotheses that follow. In addition, this study aims to clarify the standpoint of German machinery and plant manufacturers with regard to cooperation, and to identify obstacles, limitations and the potential of cooperation.

Main hypothesis
Cooperation, in particular horizontal cooperation, is essential for mechanical and plant engineering in Germany in order to compensate for the existing disadvantages compared to Asian competitors.

Sub hypothesis
The cooperation objectives are to establish a marketable portfolio of cluster/turnkey solutions, to bundle know-how and to develop systems and technologies more quickly.

Framing of the initial situation by the respondents
The respondents generally confirmed the described initial situation. Numerous German machinery and plant manufacturers are developing and offering systems engineered for battery cell manufacturing. In addition, there is extensive experience and comprehensive knowledge about the own technology and plant engineering. Nevertheless, battery cell manufacturers are mainly buying from Asian manufacturers. The reasons for this are as follows:

Firstly, Asian machinery and plant manufacturers have extensive expertise in battery cell manufacturing and have grown into large, established enterprises. Even though German companies are not necessarily new to the construction of battery cell manufacturing systems, they lack experience and references in large-scale production for electromobility. Then there is the technological maturity of systems engineering, which does not yet consistently meet the requirements of annual production on a gigawatt hour scale.

Secondly, there are currently few European manufacturers in the market offering cluster or turnkey solutions that comprise several or all battery cell manufacturing process steps. Such solutions are however particularly attractive for new German/European cell manufacturers since they reduce complexity and are therefore less expensive to purchase and commission.

Finally, established Asian manufacturers are able to implement capital-intensive, large-scale projects quickly, among other things due to their size. This can be challenging for the German mechanical engineering sector, which is characterized by medium-sized businesses. Possible disadvantages of the standard Asian production lines, such as limited on-site technical service, language barriers and low efficiency factors, are initially accepted for this. As a result, system integrators in particular find themselves in a difficult competitive position.

3.1 Key findings from the interviews

Five key findings regarding the hypotheses emerge from the interviews and are discussed in more detail below.

1. Cooperation offers clear advantages and is already being practised by German machinery and plant manufacturers to compensate for competitive disadvantages.

All of the companies interviewed cooperate in one form or another. In most cases, they are engaged in vertical and diagonal cooperation for certain process steps, which means they work together with or as suppliers (vertical) or as the technology supplier and system integrator (diagonal). An example is the engineering of a plant for slitting, in cooperation between an equipment manufacturer and a laser manufacturer.

2. Horizontal cooperation with adjacent production steps is increasingly being pursued.

A variety of objectives are pursued by closer horizontal cooperation. A frequently cited objective is to accumulate know-how through joint research and development. Exchanging ideas and technologies can lead to synergy effects that speed up product development.

Cooperation can also help to minimise risks. These can be financial risks, either by distributing them or by larger companies supporting smaller ones. Furthermore, technical risks can be reduced by sharing knowledge and experience, but also by applying the principle of dual or triple control to avoid errors.

Cooperation can be particularly useful in the construction of new facilities. When interfaces are coordinated in advance, linking components or systems becomes faster and easier.

Another important cooperation objective is to facilitate market access or overcome entry barriers more easily and to ensure long-term success on the market. For example, access can be facilitated by a cooperation partner with existing references for potential customers. Note that cooperation is not only being considered at the German or European level, but also with North American or Asian manufacturers since German machinery and plant manufacturers operate internationally.

The perception of cooperation is mainly positive. Concerns about cooperation are rarely expressed. However, not all companies consider all forms of cooperation to be suitable in principle. Limitations are also placed on the scope, type and area of cooperation. Thus, some companies only consider short-term or vertical cooperation to be sensible for them, or they can only conceive of cooperating in research and development, but not at an operational level.

Cooperation can be both short-term or long-term. Often a cooperation agreement is concluded, or a written record of cooperation is prepared in another form, such as a joint development agreement or a nondisclosure agreement.

3. Successful cooperation is based on essential, core requirements such as the clear division of work, mutual trust, and active participation.

Companies already engaged in successful cooperation identify the same success factors.

The aspiration and willingness of all parties to work together and to pursue shared goals and visions forms the basis of cooperation. Appropriate basic conditions need to be established on that basis, including a structure for working together. This includes the clear division of work, defined roles, and effective coordination as well as ongoing evaluation of the partnership.

Mutual trust must be established between the cooperation partners, facilitating flexibility and a willingness to compromise as well as open communication. Shared or similar values are perceived as helpful for cooperation. Geographical proximity and efficient communication make coordination easier and are frequently accompanied by similar values as well as mutual trust in long-term relationships. Another advantage is that partners can respond more quickly in case of problems since they are present on site. Trust and shared values can also be developed and strengthened over time in long-term cooperation. Companies involved in cooperation stress that a timely, low-threshold meeting with potential partners to work out initial concrete ideas and get actively involved is constructive. Customer acceptance of cooperation is another basic requirement.

Antitrust law compliance is a fundamental requirement for horizontal cooperation.

Companies that cooperate are bound by certain legal constraints. Competition law provisions play a central role here, in particular the provisions of Article 101 of the Treaty on the Functioning of the European Union (TFEU). It imposes a general ban on agreements that restrict competition and on coordinated behaviour between companies (cartel ban). It also covers horizontal cooperation when this may affect trade within the EU and has as its object or effect the prevention, restriction or distortion of competition. Thus, cooperation is only problematic if it appreciably hampers competition.
An appreciable effect is lacking if the influence on the relevant market is negligible due to the low position of the participants in the market. Therefore, the competition law assessment of horizontal cooperation depends, among other things, on whether this cooperation (e.g. between SMEs) has appreciable effects on the target market. Such forms of cooperation can however be legitimised by Art. 101(3) TFEU in specific cases even when competition is appreciably hampered. This provision limits the general cartel ban in case of agreements where the economic benefits outweigh the negative effects on competition. The exemption can be exercised when certain requirements are met. Firstly, the cooperation in question must contribute to the improvement the production or distribution of goods. In case of battery cells, for example, this can be achieved through joint research and development of

new technologies. Consumers also have to benefit from this cooperation, for example, through lower prices or improved product quality. In addition, it is important for the restraints on competition caused by this cooperation to be limited to the essential minimum. Finally, the cooperation must not result in the elimination of competition in respect of a substantial part of the products in question. Cooperation based on this exemption is subject to increased risk since a violation of Art. 101 TFEU voids the cooperation agreement and may be punishable under civil as well as administrative law. Enacting special regulations and guidelines for this area is a competition law tool to address this uncertainty and simultaneously enable certain forms of cooperation. The corresponding authorisation is granted by Art. 103 TFEU. Defining the cartel law provisions of Art. 101 TFEU in concrete terms for specific sectors could establish greater legal certainty for the companies concerned.

4. The dynamic battery cell production market impedes cooperation.

Ongoing technology developments and innovations in battery cell manufacturing, the development of new process technology and the further development of process steps create a dynamic market that makes cooperation more difficult. Customers may (be forced to) alter their requirements to keep pace with developments, and mechanical and plant engineering needs to respond to that. This may put existing cooperation at risk and makes finding cooperation partners more difficult.

The shifting market situation and high pressure also promote competitiveness that, in excess, hampers cooperation. Dissimilar company cultures and, in particular, the protection of intellectual property and own innovations are additional concerns regarding cooperation.

Market dynamics also put a great deal of time and cost pressure on machinery and plant manufacturers as well as battery cell manufacturers, which can interfere with cooperation.

5. Cooperation and quality assurance strengthen competitiveness against Asian manufacturers.

German machinery and plant manufacturers must act in order to be competitive in battery cell manufacturing. Cooperation and the establishment of quality standards create opportunities in this regard.

New horizontal cooperation agreements, such as the strategic partnership between GROB, Manz and Dürr, are currently attracting a lot of interest. Other examples also exist, such as the Jagenberg Group which already has established, long-term, successful internal cooperation that is beneficial. Beyond that, the interviews showed that cooperation is viewed by some companies as the main or even the only option for competing with Asian manufacturers at this time.

German machinery and plant manufacturers must contribute their strengths to battery cell manufacturing in parallel with cooperation. Generally German mechanical and plant engineering operates very systematically, so that potentially significantly fewer iteration steps are required in the introduction of machines and lack of experience can be partially compensated.

German/European customers are also used to receive customized plant technology that meets very high safety and quality standards. Asian suppliers generally offer less customised systems, resulting in a unique selling proposition for German machinery and plant manufacturers. Entry opportunities are also offered by new technologies in battery cell manufacturing (e.g., silicon-based electrodes), for which there are no established manufacturing processes yet. The consideration and development of innovative technologies is a strength of German mechanical and plant engineering, allowing them to bring more efficient, specially configured systems to the market and to blaze new trails.

The ability to produce energy-efficient systems is another advantage of German machine builders. This is an especially important factor in Europe due to high energy costs.

Finally, German machinery and plant manufacturers have an established service network that can provide rapid support in case of problems and minimise downtime. Overall, German machinery and plant manufacturers should be able to compete with Asian competitors under consideration of the total cost of ownership (TCO), including both procurement and operation.

3.2 Overall picture

With regard to the hypotheses, the suitability of cooperation in German mechanical and plant engineering was confirmed to help compensate for competitive disadvantages against Asian competitors.

Such cooperation pursues a variety of objectives, comprising among other things a marketable portfolio of cluster or turnkey solutions, the bundling of know-how and the faster development of systems and technologies.

However, cooperations are not a one-size-fits-all solution and are not suitable for every company. They require a number of prerequisites, bring challenges, and are not necessarily successful.

Alternatives
The takeover or acquisition of companies is an alternative to cooperation. Competencies and know-how can be acquired in this way while avoiding obstacles such as the protection of intellectual property. However, a takeover requires corresponding financial resources so that this approach is generally only viable for larger enterprises.

The actions of some companies show that various approaches to cooperation are possible.

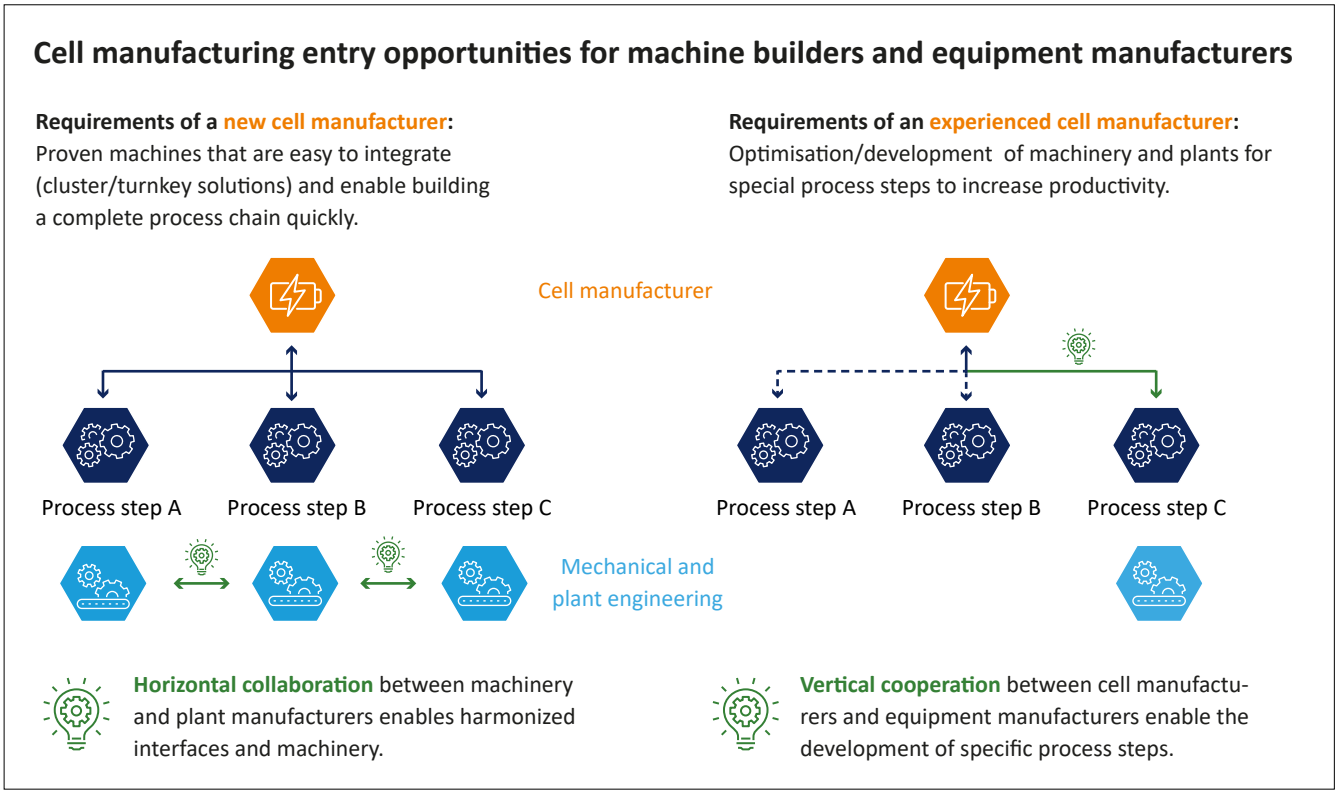
For instance, short-term strategies aim to directly offer plant technology on a gigawatt hour scale. Here the goal is to become established in the market quickly, which would make the German market more independent. This is however a major challenge and may not be successful since corresponding references are lacking.

On the other hand, more enduring strategies involve research and development collaborations that invent innovative production solutions for technologically superior battery cells.

For example, the battery cell manufacturer Cellforce is introducing smaller lines for the testing and production of special cell chemicals. Cellforce is counting on close cooperation with European machinery and plant manufacturers, who are thereby establishing references. The benefits of joint development and geographical proximity are specifically utilised here.

Cooperation is a proven tool for developing and offering turnkey solutions. However, note that turnkey solutions are of interest for inexperienced cell manufacturers in particular. As their process understanding grows, cell manufacturers may transition to systematically optimising specific production steps and requesting individual machines for this purpose. Building the process chain out of individual machines could also reduce costs, since machines for single process steps might be less costly than complete solutions.

The systematic optimisation/development of specific production steps can also serve as an entry point to cell manufacturing on a gigawatt hour scale for European



Cell manufacturing entry opportunities for machine builders and equipment manufacturers

Requirements of a new cell manufacturer:
Proven machines that are easy to integrate (cluster/turnkey solutions) and enable building a complete process chain quickly.

Requirements of an experienced cell manufacturer:
Optimisation/development of machinery and plants for special process steps to increase productivity.

Horizontal collaboration between machinery and plant manufacturers enables harmonized interfaces and machinery.

Vertical cooperation between cell manufacturers and equipment manufacturers enable the development of specific process steps.

Figure 4: Possible cell manufacturer requirement profiles depending on their production experience. The figure shows examples of how cooperation can facilitate market entry in the battery industry (own depiction).

machinery and plant manufacturers. Bühler (mechanical engineering, Switzerland) and Lishen (cell manufacturer, China), for example, developed a continuous mixing process for the production of electrode pastes and qualified it for series production through vertical cooperation. The Volkswagen subsidiary PowerCo and Koenig & Bauer took a similar approach and are currently working together on the development of a dry coating process. As a rule, vertical cooperation for the development of new processes is very time and resource intensive. It can take several years before the process is developed and qualified for series production. Development of the process can even fail in the worst case.

Complementing all measures, the strategic direction of the German market also needs to be considered. The political framework and systematic funding are decisive factors here. Supporting measures for cooperation, a legal framework to facilitate collaboration in the battery ecosystem, tax incentives for research and degressive depreciation can help to minimise investment risks. Furthermore, the promotion of research and development projects as well as guarantees or public sector loans can protect against financial risks and thus support cooperation in this field.