Fraunhofer IPT

Accelerating Deep Tech Innovations

A case study approach for characterizing actors along the national technology transfer process

Authors

Prof. Dr.-Ing. Dipl.-Wirt.-Ing. Günther Schuh
Chair of Production Engineering at RWTH Aachen University and member of the Board of Directors of the Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University and the Fraunhofer Institute for Production Technology IPT in Aachen

Tim Latz, M. Sc.
Research Assistant in Strategic Technology Management, Fraunhofer Institute for Production Technology IPT

Moritz Hedemann, B. Sc.
Student Research Assistant in Strategic Technology Management, Fraunhofer Institute for Production Technology IPT

Till Felix Reufsteck, B. Sc.
Student Research Assistant in Strategic Technology Management, Fraunhofer Institute for Production Technology IPT

Contents

Management summary

Systemic innovation success in Europe lags behind its expectations as Europe spends most funding in basic research and development (R&D) while commercialization takes place in other regions such as the US or China. Therefore, this whitepaper aims to enhance the technology transfer for Deep Tech innovations in Europe through developing a framework for actors in Deep Tech ecosystems based on a case study analysis. For this, 25 actors from science and industry in three Deep Tech areas are analyzed – lithium-ion battery cells, semiconductors and electrolyzers. Based on a cross-industrial synthesis, recommendations for actions are derived building on the individual actors' strengths and weaknesses.

As Deep Tech is considered a disruptive technology with a high degree of uncertainty regarding its actual feasibility, investments in such technologies are associated with high risks but great economic and societal opportunities. To benefit from such high-risk investments, it is mandatory that sufficient support is provided from research all the way to commercialization. This technology transfer includes both public funding of fundamental research and private funding for scaling and commercializing innovations. In addition to insufficient risk capital in basic research, however, a lack of consistent funding on the path from research to commercialization can be observed in Europe. This gap phenomenon between public and private funding is often referred to as the Valley of Death [1] (see Fig. 1).

To foster the technology transfer for Deep Tech innovations, three needs for action are derived from the analyzed case studies: First, collaboration between actors should be strengthened to deliver Deep Tech innovations more effectively. Furthermore, a sufficient environment needs to be created in which the individual actors' strengths complement each other optimally. Finally, protection spaces for intellectual property must be created to avoid legal disputes from the outset. By following these recommendations and taking the individual profiles of actors into account, the Valley of Death can be minimized.

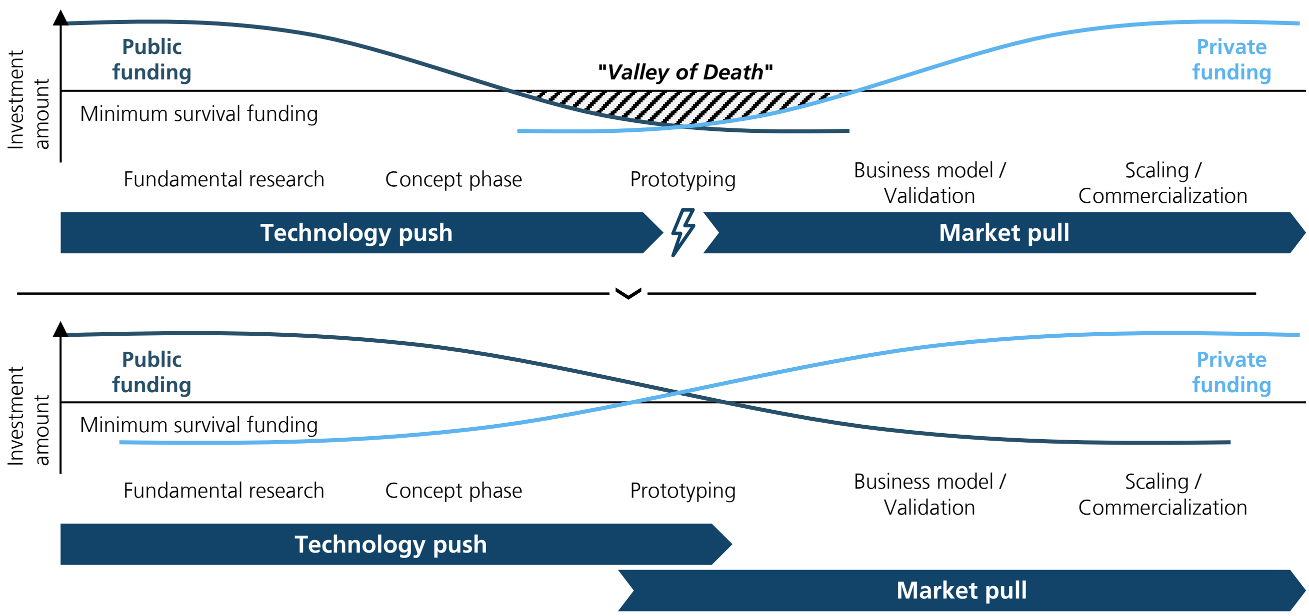


Fig. 1: Closing the "Valley of Death" for Deep Tech innovations based on a sufficient innovation system understanding

Deep Tech, innovation systems and their value chains

In recent years, it has become increasingly obvious that Germany is dependent on other nations within many technological areas with high relevance for regional value creation and production (e.g., chemical products, electrical equipment, etc.) [2]. Consequently, its technological sovereignty has been eroding in these areas. In order to understand the reasons for this phenomenon and to analyze how this technological sovereignty can be regained, three crucial areas of Deep Tech innovation systems (Deep Tech, technological innovation systems and value chains) are investigated in the scope of this whitepaper (see Fig. 2).

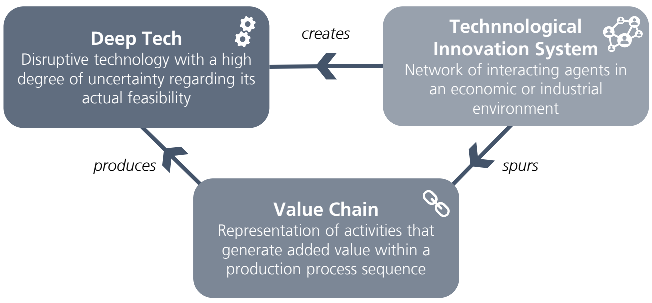


Fig. 2: Dependencies between the relevant elements within Deep Tech innovation systems

As Deep Tech is commonly referred to these days without a unified understanding, its concept and characteristics are presented in the following. Further, the generic set-up of a technological innovation system for Deep Tech innovations is presented and problems that arise while scaling and exploiting successful basic research, particularly in Germany, are analyzed. Finally, the increasing regional and procedural complexity of value chains is investigated as these have and will have additional influence on the decline of Europe's technological sovereignty.

What exactly is Deep Tech?

Technology means the application of scientific knowledge for practical purposes, especially in an industrial context [3]. Deep Tech (DT) are a specific kind and refer to technologies that are characterized by a (I) high degree of uncertainty about their actual technological feasibility at the start of development. As a result, there is a (II) high level of specific R&D efforts until successful exploitation, which is fed by scientific research. In the early stages of technological developments, there is also a (III) major market risk, as the products associated with the technology are highly novel and it is often not clear how system integrators and end customers will react to these adaptations. Furthermore, so-called (IV) spill-over effects in the area of DT, i.e., the impact on many industries and areas, are very high. All these characteristics add up to (V) enormously high financing demand over (VI) very long development periods. [4-5]

To gain a better understanding about the theoretic DT characteristics, they can be illustrated by investigating the all-solid-state-battery cell (ASSB) as an example, which is considered to become an essential enabler for the realization of high performance electromobility in the near future (see Fig. 3) [6]. Due to the requirements for safety, sustainability and energy density, research has been conducted on the further development of conventional lithium-ion battery cells (LIB) into battery cells with solid-state electrolytes for more than ten years [7]. In addition to prestigious research institutes funded by public institutions (e.g., Fraunhofer, Helmholtz, Massachusetts Institute of Technology [8]), various market players have emerged, supported by high volumes of private-sector funding (e.g., Quantumscape by Volkswagen with over €300 million [9]). Since 2020, the ASSB became more present, with OEMs such as VW, BMW and further specialists such as Solid Power, Licap or Printed Energy concretizing and substantiating their ASSB projects [10-11]. However, high market uncertainties such as the future demand for different powertrain technologies and the uncertain industrialization success create skepticism among experts and managers as there are significant changes along the entire value chain compared to the classic lithium-ion battery [12-13]. In addition to new materials, especially for the electrolyte, new challenges arise in production at the solid-solid interfaces between the active material and the oxide material [14]. Subsequently, mass production processes for the ASSB are currently still under development. Depending on whether the battery is an oxide ASSB, a sulfide ASSB or a polymer ASSB, there are fundamental differences in the component production and assembly. In particular, the extrusion process for the lithium-foil of the anode represents a major challenge with a fundamentally different process compared to typical wet coating [14]. E.g., the automotive company Fisker stopped its solid-state battery projects at the beginning of 2021 due to the result of an assessment which identified that solid-state technology is still far away from mass production as well as much more difficult and different to produce than expected [15]. In addition to mobility, other sectors, such as consumer electronics and energy storage, are suited for exploiting the new possibilities of this battery technology showing enormous spill-over potentials. All in all, research on the solid-state technology has been going on for more than a decade with high funding, whereas a serious estimate of a market penetration for the automotive mass market is still not possible yet. The mapping of these ASSB findings to the theoretic DT characteristics described above is highlighted in Fig. 3.

#	Generic characteristic	ASSB-specific characteristic
I	High degree of **uncertainty** about **technological feasibility**	Uncertainty about manufacturability and battery lifetime of ASSB-cells
II	High level of specific **R&D-efforts**	Very high research efforts (e.g., Quantumscape with €1.8 billion invested capital)
III	Major **market risk**	Future demand of different powertrain technologies is uncertain
IV	**Spill-over** effects	„Game changer" in electromobility and further energy storage industries
V	High **financing requirements**	High research expenditures and long time periods lead to high financing requirements
VI	**Long development** periods	Long-term development due to safety restrictions and problems in industrialization

Fig. 3: The Deep Tech characteristics exemplified by the ASSB

As shown by the exemplary ASSB case, DT has a strong disruptive character for existing value chains and infrastructures. At the same time, DT is often characterized by complex production processes and the production is heavily dependent on raw materials as well as perfectly organized machinery and production systems. As a result, competence development along the entire DT value chain is essential for a successful adoption in an economy.

A look at exemplary DT areas (e.g., semiconductor industry, battery technology) shows that in recent years Germany and Europe often fail in exploiting innovations and R&D in the form of products and market access [16]. Although research and funding in the semiconductor industry have been strongly promoted in Germany for many years through various initiatives, the companies with the largest global market share are invariably based in America and Asia. [17] Similarly, the market for battery cells is dominated by Asian market players, although large sums have already been invested in basic research in Germany over the past decades (see Fig. 4) [18].

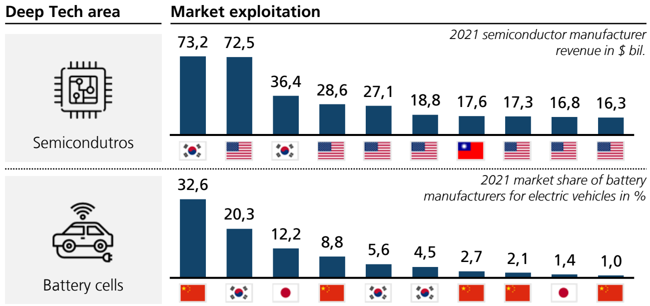


Fig. 4: Market exploitation of the top 10 competitors for exemplary Deep Tech areas

Latest since the intensified debate on climate neutrality and increasing industrial protectionism, Germany must become a technologically independent player on global scale with competitive companies in existing and upcoming DT. Otherwise, the high expenditures for research and development cannot be refinanced and Germany will lose its top position as a technology leader in other fields as well. To understand the complex innovation systems from which such technologies arise, these will be conceptualized and analyzed in the following regarding challenges and opportunities in Germany.

What are the ups and downs of the German Deep Tech innovation system?

For many decades, the German innovation system has been characterized by outstanding basic research by international standards [19]. This highly correlates with the unique research landscape in Germany covering all relevant research types through e.g., Fraunhofer, Max-Planck and Helmholtz institutions as well as a high number of universities. The outstanding research is also reflected in the proportion of world-class patents created in Germany. Germany is above average in this respect [20]. However, the necessary processes for industrializing and monetizing these through technology transfer from conceptual results into targeted applications and exploitations, are only weakly developed in Germany. These thoughts and findings can be illustrated with examples:

Nine out of ten late-stage financing rounds in Germany with a valuation of more than €50 million are led by non-German investors. Prior to these financing rounds, public money was put into these developments and startups: e.g., Celonis, the

Munich-based startup in the field of process mining, became the first German decacorn (a startup valued above $10 billion) in 2021. Therefore, the company raised $1 billion in capital in a Series D funding round. However, it is noticeable that no German investor was involved. Celonis states that the international Series D investors bring tremendous expertise in building successful technology companies, matching their long-term global strategy [21]. As an effect, significant shares of the company are held abroad. This is underlined by the fact, that all of Celonis' eight major investors have their headquarters in the US or UK (see Fig. 5). In addition, partners of foreign lead investors 83North and Accel Partners are on the Celonis management board, carrying the risk of a push for an IPO abroad - which speculation suggests could happen soon [22]. In case of a successful IPO, massive amounts of capital would re-flow into these foreign innovation systems as reward for their investment, while Germany's funding of basic research would remain unrewarded. [23]

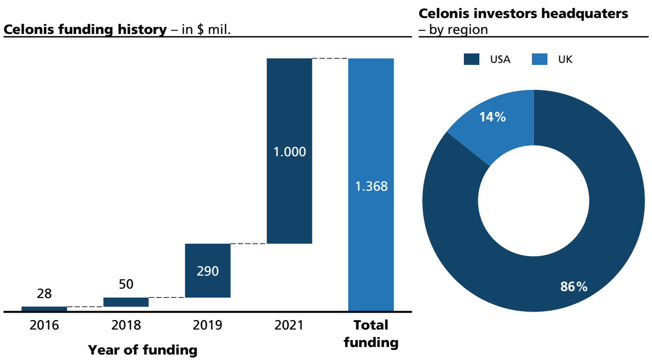


Fig. 5: Overview on Celonis' funding and investors

The growing push of foreign investors into the German startup ecosystem can also be seen in an overall increase in merger and acquisition (M&A) activity. Between 2020 and 2021, the number of M&As in which startups were involved increased by 90 percent. In 2021, foreign investors were engaged in 68 percent of the 171 M&As involving startups [24].

Additionally, one in five German companies which has conducted an IPO within the past ten years has done so at a foreign stock market [25]. One example is Lilium, a German startup within the mobility industry, which went public in 2021 through a merger with a SPAC (special purpose acquisition company) on the American technology stock exchange NASDAQ in order to save time and money [26]. For this type of public offering, capital is initially raised from investors in order to take over an unlisted company and bring it to the stock market [27]. At the time of Lilium's first considerations of going public via a SPAC, this type of IPO was rather uncommon in Germany meaning the necessary financing instrument for their next evaluation step was not available. [27-28]

Both startups, Celonis and Lilium, were created within German research ecosystems and initially supported with public funding. But what exactly is the reason for successful startups with prototypes and patents scaling in the US instead of Europe? This effect can be traced back to the so-called Valley of Death coined by Auerswald and Branscomb which describes a market failure in pre-competitive applied manufacturing research and development [1] (see Fig. 6).

In this phase of technology development – between fundamental research and the scaling and commercialization phases – a lack of suitable funding or support mechanisms exists. Bridging the technological and financial risk and to enable new technologies is required to enter the validation and commercialization phases.

It is at this stage that governments need to guide and support DT development and address market failures to ensure successful national scaling and deployment.

For such a governmental support to generate an impact and have success, relevant actors within the innovation system must be supported in a targeted and DT-specific manner. As a first step, it is therefore necessary to understand which actors participate in the development, transfer and exploitation phases of DT.

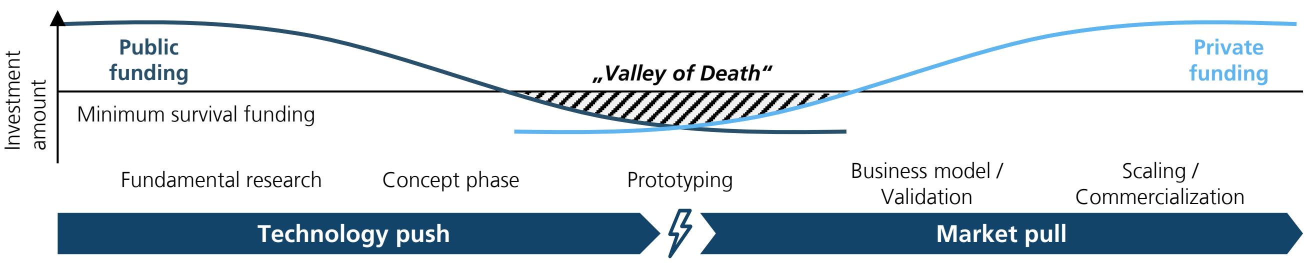


Fig. 6: Market failure in pre-competitive applied manufacturing research and development

Which actors form the ecosystem for Deep Tech value chains?

During globalization, value chains for almost all products have increased in complexity [29]. In the area of DT, these complex interlinkages are particularly pronounced and relevant. Raw materials and their extraction have a high strategic importance in the value creation process, which is why their producers and their locations are considered as important actor in the overall ecosystem. Furthermore, the complex manufacturing chains, which are characterized in particular by challenges within production and process technologies, are divided among various actors: One important influence is exerted by machinery suppliers, who are the enablers of highly scaled and efficient production lines and have focused know-how in various areas of the process chains. Furthermore, there are the actual producers, who bundle know-how as well as the resources of various suppliers and produce the core products exploiting the DT innovations. These in turn are developed and designed in close cooperation with the ultimate product integrators or users. Finally, a holistic view of production and life cycle phases is relevant in the context of an increasing aspiration towards circular economy, which is why recycling and upcycling processes and corresponding actors are highly important for DT innovations. [30]

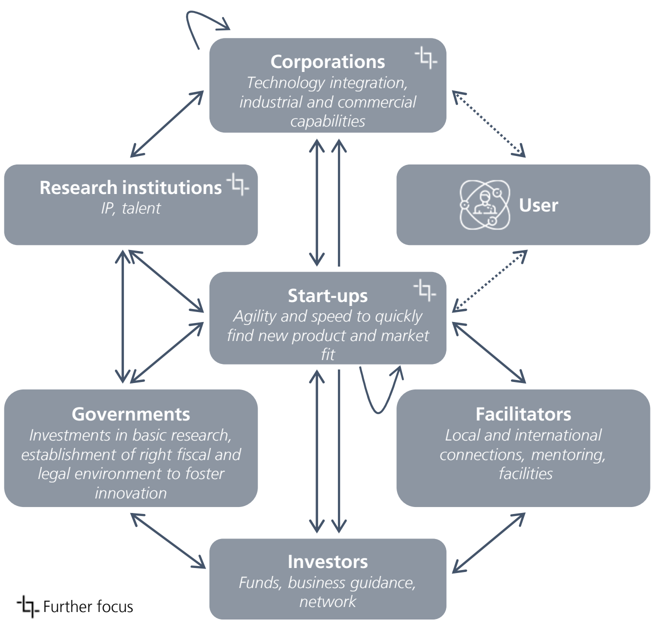


Fig. 7: Actors within the DT innovation system and their contributions [31]

Due to the strong scientific character of DT (see Fig. 3), the technology and knowledge transfer of new findings to industry is highly relevant. Therefore, transfer-institutions are positioning themselves in addition to pure universities to act as intermediaries and facilitators between industrial and scientific actors. Additionally, governments have a strong interest in helping shape new eco and innovation systems due to their responsibility for the national economy. At the same time, investors are interested in supporting startups to create business opportunities within DT ecosystems due to their high long-term potentials. Summarized, DT innovation systems consist of different actors whose characteristics and specialties need to be considered when designing structures for innovation (see Fig. 7). As the following case studies will show, generic actor descriptions cannot be applied universally to all technology fields but must be adapted to the specific DT in consideration.

Based on the outlined characteristics of DT and the German innovation system as well as the complex value chains associated, various actions for research can be derived. In order to create innovation-friendly structures for DT on a national level, transparency about the mechanisms within different industries needs to be created with respect to the individual challenges and demands. To create this understanding, the following case studies will be used to generate a conceptual understanding of relevant actors in exemplary DT areas and to discuss their competencies and interests. For this purpose, the exemplary DT areas of LIB, microchips and electrolyzers are analyzed. The findings are then synthesized to draw generic actors' descriptions for the technology transfer of DT.

Diving into selected Deep Tech ecosystems

Based on three case studies, the sectors of lithium-ion battery cells, microchips and electrolyzers are now considered and discussed in detail. For this purpose, market sizes and trends, importance for national economies as well as current industry challenges are analyzed. Afterwards selected actors of the technology-specific ecosystems are introduced. The identified actors are then classified according to their expressions within defined traits set up for this analysis (financials, assets, personell, target, operating focus, industrialization competence, unfair advantage, market access and agility, cf. annex). Exemplary, the evaluation is illustrated in detail for three selected actors per technology (cf. annex).

Subsequently a cross-technological synthesis of the individual profiles generated is provided. To this end, all actors are aggregated according to their role within the DT ecosystem. Finally, suitable conclusions are drawn on the basis of the synthesis to derive needs for action to improve the Deep Tech innovation system.

"Through spillover effects, entire regions can benefit from the successful development of Deep Tech innovations, which is why they are of great importance to the national economy."

KfW Research

Case study on the lithium-ion battery cell industry

As a reaction to climate change and its consequences, the European Commission has paved the way for the so-called Green Deal. It focusses on the transformation towards a modern, resource-efficient and globally competitive economy and on strengthening the previous insufficient decarbonization efforts. In this context, the EU member states made a commitment to reduce net greenhouse gas emissions to zero by 2050 and to become a climate-neutral society. As an intermediate step, a 55 percent reduction in CO_2 emissions by 2030 compared to 1990 is planned by the European Commission [32]. A key element in achieving this goal are electrochemical storage systems in the form of LIBs. The global annual demand for LIB is predicted to exceed 3,100 GWh by 2030 (see Fig. 8). The main factor behind this trend is the electrification of the automotive market with 74 percent market share in 2030 (including commercial vehicles and passenger transportation).

Various obstacles need to be overcome to enable the upscaling of LIB production capacities since improvements in battery technology are essential for achieving the necessary economies of scale for cost degression. Only then achieving broad social acceptance of electric vehicles. The next major product generation is expected to be the ASSB, which will enable faster charging times and higher energy densities and thus satisfy market demands better than existing battery technologies. Furthermore, the entire battery value chain must be implemented in an efficient and climate-neutral manner so that electrification can make the greatest possible contribution to achieving the climate targets outlined.

Against these potentials, four risk areas are currently prevalent in the battery market: Geopolitical risks occur in the concentration of the required raw materials and their processing in certain countries - some of which are politically unstable or unreliable trade partners. Risks related to environmental, social and governance (ESG) aspects may include problems caused, for example, by high water consumption in lithium extraction or by human rights violations at mining sites. Fluctuations and high uncertainties in the raw material prices for battery materials, as well as the capital-intensive battery production, lead to price risks which need to be managed and streamlined. Besides high prices, the availability of raw materials, especially cathode active materials, also factors into this risk. While the supply of nickel and cobalt will be tight but achievable, there is a great risk of insufficient availability of lithium. Additional challenges are posed by the long ramp-up processes for the set-up of new mines from exploration to construction (three years for lithium, six years for nickel). Fig. 9 summarizes the outlined challenges for battery cell innovations.

Along with the challenges, however, technological change also opens up major opportunities for German and European companies along the entire value chain of battery production (see Fig. 10). In addition to established production steps (i.e., material preprocessing, cell manufacturing, module and pack assembly as well as vehicle integration), the importance of sustainable value creation via recycling, refurbishment and second use continues to grow.

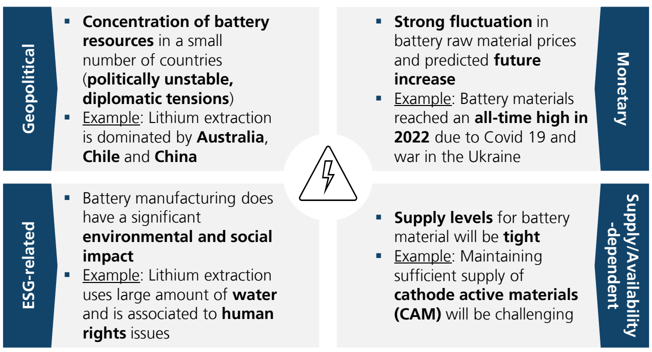


Fig. 9: Excerpt of supply chain risks for lithium-ion battery cells

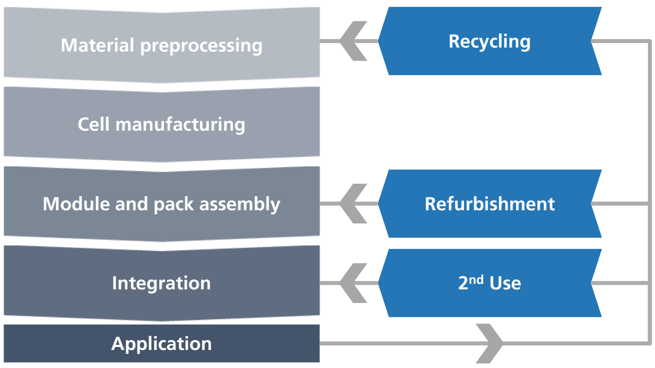


Fig. 10: Overarching value chain of battery production

Hence, to receive an overarching understanding and to enable target-oriented support measures for driving Deep Tech innovations in the battery cell industry, it is necessary to take a closer look at the various actors involved in the value chain processes of LIB:

Major actors in the battery market are large battery producers (e.g., CATL) and OEMs (e.g., VW, BMW, Tesla). The main suppliers are companies from the chemical industry for raw material processing and recycling (e.g., BASF) and mechanical and plant engineering for the supply of production equipment (e.g., Manz, Eirich). According to estimates, the global automotive industry will invest €437 billion in the electrification of its vehicles by 2030 [33]. With a share of over 40 percent of the value chain, battery production is essential for the automotive industry to maintain its own depth of value add and thus secure jobs [34]. Parts of this investment in electromobility will be spent on battery production equipment. Demand for battery production equipment alone is forecasted to reach €30 billion by 2030, opening up great potential for mechanical and plant engineering [35].

The dynamic of the battery market and the relevance of technological leadership require the integration of scientific institutions and innovative startups into the analysis. The startup Quantumscape for example promises to increase the range of electrified vehicles by 50 to 80 percent with its technology [36]. With regard to scientific institutions, Germany in particular – with its strong expertise in basic research – has good prerequisites for transferring new scientific knowledge to industrial implementation. Beyond the production process, the challenges and potentials of establishing a circular economy must further be taken into account on the product and process level [37]. These include vehicle integration, remanufacturing and recycling (e.g., Duesenfeld or Redwood).

Based on the industry structure presented, ten relevant actors of the LIB are analyzed along the traits defined. As an example, this is conducted in detail for the companies Volkswagen AG and Manz AG as well as the Fraunhofer Research Institution for Battery Cell Production FFB (cf. annex). All comprehensive results of the analysis are listed in Fig. 11.

The derived actor characterizations of the battery market lead to a morphology of traits summing up the overall findings. Significant differences can be observed between the actors in the ecosystem regarding the dimensions of financials, personnel and market access. In general, large system and product integrators such as Volkswagen AG have high resources of all kinds and have a strong unfair advantage as well as market access. On the other hand, they have low flexibility and agility, which can be a disadvantage, especially in dynamically growing environments such as the battery ecosystem. Machinery and plant manufacturer like Manz AG have lower resources but are more flexible with respect to new products and market requirements. Special research institutions such as the FFB should be integrated into the value chain as much as possible: Due to the high financial support and bundled traits within the entity, every other actor from the value chain can potentially benefit from a cooperation and the structuring competencies of research institutions. Conversely, however, research institutions such as the FFB must also actively seek cooperation with industry to understand and optimize industrialization processes on the research side and to reduce their disadvantages of low market access and personnel.

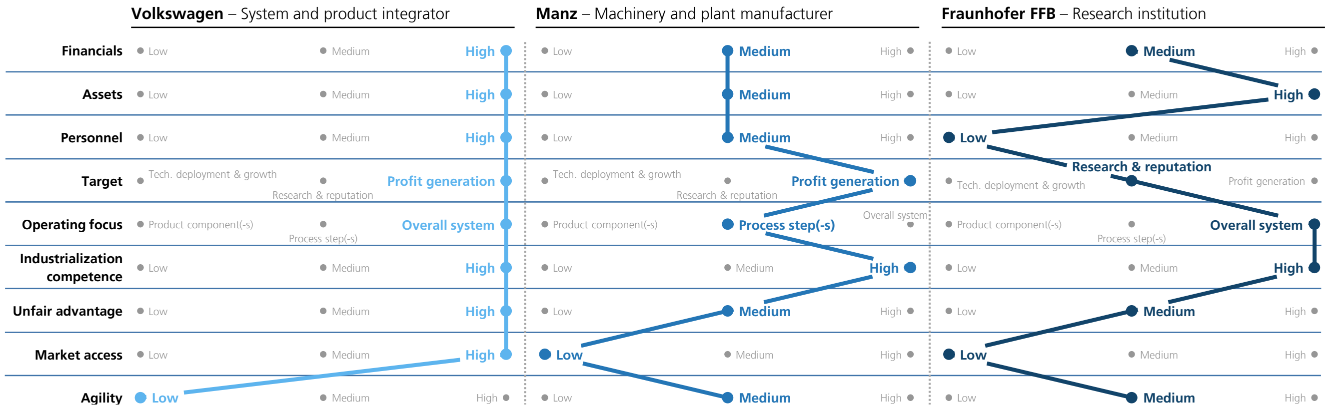
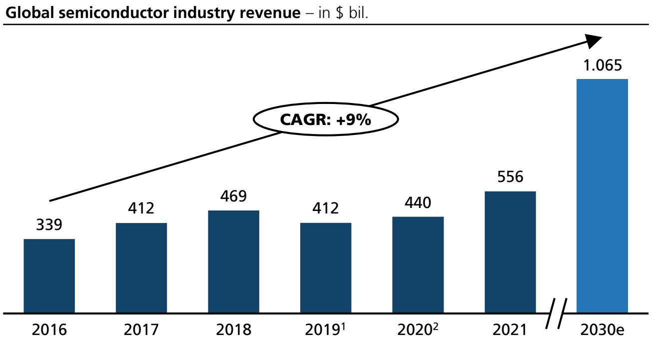


Fig. 11: Morphology of traits amongst selected participants in the lithium-ion battery cell industry

Case study on the semiconductor industry

Rapid technological progress and constantly proceeding global digitalization have led to a booming semiconductor industry throughout the last decade (see Fig. 12). Emerging trends such as Industry 4.0, Internet of Things, Machine Learning, remote work, and autonomous driving are leading to a continuous increase in demand for semiconductors required for such applications [38]. Experts anticipate a market volume of more than $1 trillion by 2030, which would correspond to an approximate doubling of the market value within just one decade [39].



1 Decline is mainly the result of oversupply in the DRAM market (semiconductor submarket) and the trade war between the United States and China
2 Bottlenecks as a result of the COVID-19 pandemic

Fig. 12: Development and forecast of the global semiconductor industry revenue [40] [41]

While the strongest market growth is expected for automotive electronics, the highest market volume is predicted for the application areas computing and data storage as well as wireless communication with an approximate total of $630 billion by 2030 (see Fig. 13).

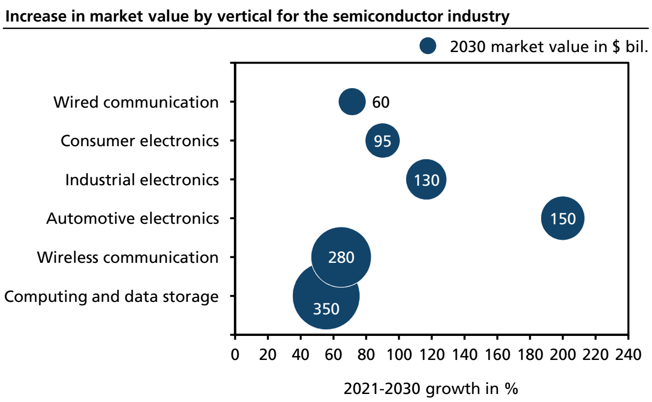


Fig. 13: Forecast of the global market value for the semiconductor industry by vertical [39]

To meet the rising demand in chips, the highly complex and globally interlinked supply and value chain must be of high resilience. However, the outbreak of the COVID-19 pandemic in 2020 has shown that the current supply chain is vulnerable, as global disruptions led to a worldwide shortage in chips which is still ongoing and expected to continue into 2023 [42]. To strengthen the supply chain resilience and to overcome the current chip shortage, companies and governments take significant measures. For instance, manufacturers plan to invest a total of $446 billion into the build-up of new plants and additional production lines, which corresponds to the 2020 total revenue of the global semiconductor market [43]. Furthermore, governments are creating incentives for chip companies to produce locally in order to mitigate globalization and sovereignty risks. For instance, the EU Chips Act aims to foster Europe's competitiveness and resilience within the semiconductor industry by investing €43 billion by 2030. With a current global market share of 10 percent Europe is positioned rather weakly [44].

Global chip manufacturers are particularly affected by these developments. Overall, three main strategies for chip manufactures can be distinguished (see Fig. 14). Companies that take over both the chip design and the more capital-intensive manufacturing process (e. g. Intel) are called Integrated Device Manufacturers (IDMs). Companies that only design chips and outsource the manufacturing (e. g. Apple) are referred to as Fabless. Contract manufacturers who produce designs for various customers (e. g. TSMC) are known as Foundries.

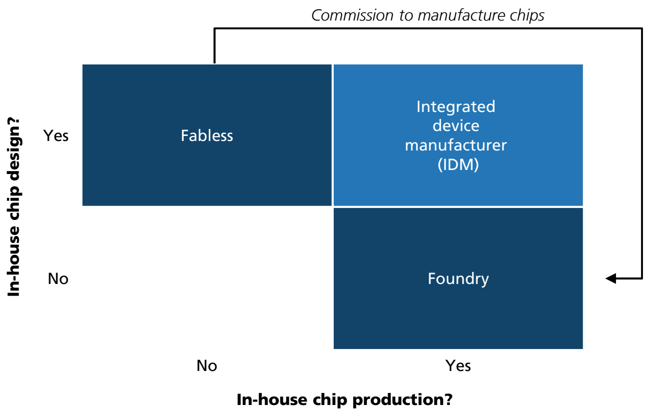


Fig. 14: Archetypes of semiconductor manufacturers

But it is not only the chip manufacturers who are affected by the market development. The exorbitantly high investments in the expansion of production facilities result in a flood of orders for machinery and plant manufacturers. For example, ASML, the leading manufacturer of lithography systems for chip production, saw an increase in net sales of around 33 percent to $18.6 billion in 2021 [45]. According to the company's management board, ASML could even sell 40 to 50 percent more in machinery if only the group had the necessary personnel and production capacity [46]. The growing chip market does also have a positive impact on the feedstock suppliers. For instance, the feedstock in semiconductor production are so-called wafers. These are thin silicon discs produced by specialized chemical companies (e.g., Shin-Etsu) from quartz sand as a raw material [38].

Furthermore, an increasing number of startups are seeking access to the lucrative business with semiconductors. Between the years of 2010 and 2020, the number of smaller companies within the semiconductor market (sales below $1 billion) grew by around 80 percent from 71 to 129 [47]. One promising startup is the Ferroelectric Memory Company (FMC). As a spin-off from the German University TU Dresden, FMC is pursuing the commercialization of the Ferroelectric Field-Effect-Transistor (FeFET). This technology allows for chips with lower power consumption while maintaining a high data throughput and fast data processing. In addition to private companies, research organizations and institutes play a central role in research and technological development. A prime example for this is the Research Fab Microelectronics Germany (FMD), a cooperation of eleven institutes within the Fraunhofer Group for Microelectronics (FVM) and two Leibniz institutes.

Based on the defined traits (cf. annex), seven actors within the semiconductor industry are analyzed subsequently. Exemplary, the evaluation is presented based on the companies Intel, ASML as well as the Fraunhofer Group for Microelectronics in fig. 15. The evaluation of the actors is shown in the appendix.

Analogous to the LIB-case, distinctive differences between the individual actor-types can be observed: While large system and product integrators have access to a wide range of resources (financials, personnel and assets) their agility is considerably limited. This deficiency is usually due to a high number of committees as well as long communication channels resulting from the hierarchical organizational structure. Large system and product integrators like Intel therefore require a defined strategic orientation with long-term vision to secure and further expand their market position. It is not only due to the smaller enterprise size, the machinery and plant manufacturer ASML is considerably more agile than Intel. While Intel focuses on serial production and economies of scale, ASML manufactures individual plants in small batches. Customizations can be made according to the client's specific needs. As already mentioned in the context of the LIB-case, research institutions such as the FMD should be much more involved in the overall value chain. Especially in the transition from publicly funded research to commercialization, the lack of cooperation and financial support within the German ecosystem becomes noticeable.

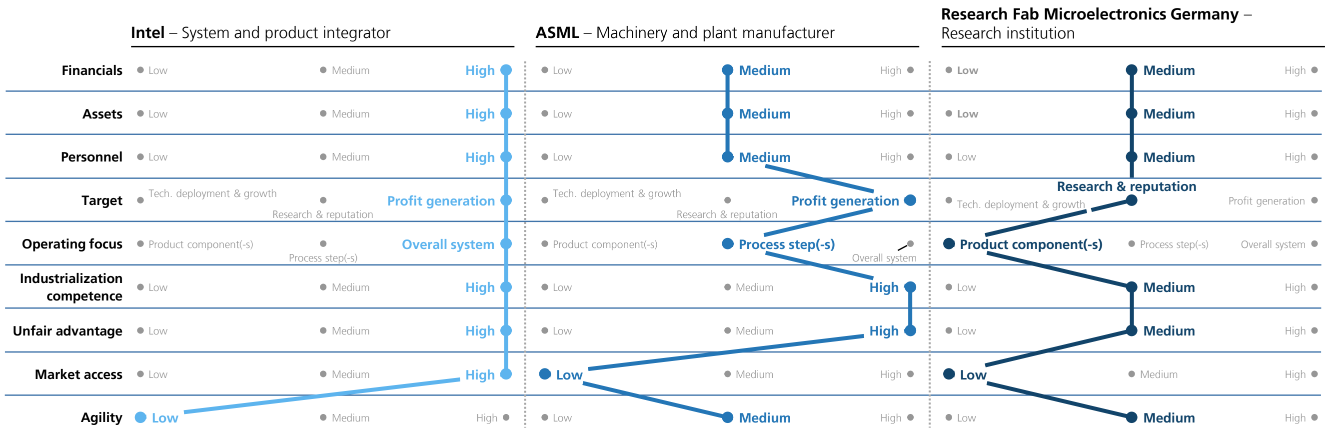


Fig. 15: Morphology of traits amongst selected participants in the semiconductor industry

Case study on the electrolyzer industry

As previously mentioned, many countries are increasing their ambitions to become climate neutral and achieve net-zero in response to the 26th UN Climate Change Conference of the parties (COP26). In addition to battery storage systems, many countries and companies see great potential in hydrogen as an energy source and storage to reduce CO_2 emissions of the hard-to-abate sectors (e.g., buses, lorries). The huge influence of hydrogen within decarbonization is shown in Fig. 16. According to a sustainable scenario, the projected hydrogen demand up to the year 2070 is predicted to reach approximately 519 millions of metric tons [48].

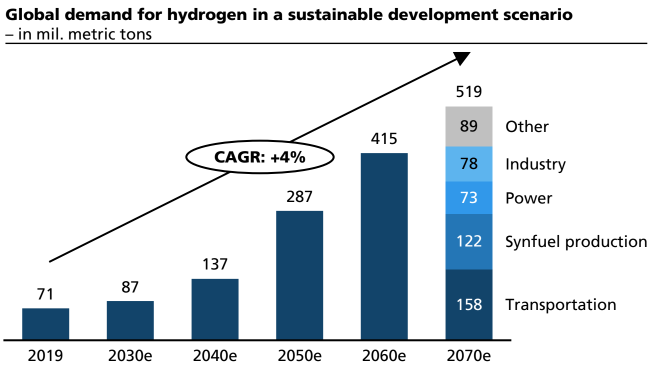


Fig. 16: Forecast of the global demand for hydrogen in a sustainable development scenario [48]

To avoid the specific problems of renewable energies (weather dependency, difficulties with transport and storage) and to achieve circularity in the energy market, green hydrogen from renewable energies produced in the so-called power-to-gas (P2G) process by elecytrolyzers must be used as a storage medium. Approximate value for the required installed electrolysis capacity in Germany alone is expected at 50 to 80 gigawatts by 2050 which corresponds to a produced volume of 1,000 to 1,600 tons of hydrogen per hour [49]. This results in a market potential for German manufacturers of electrolyzers and fuel cells of €10 billion in 2030 to €32 billion in 2050. In addition, it is necessary to reduce the production costs for electrolyzers to below €500 per kilowatt. Since mass production for electrolyzers has not yet been established, the greatest potential for cost reduction lies in the automation of production, particularly in the automation of the stacking process [50]. Research tasks on the product side aim at increasing the energy efficiency over a wide operating range and increase the operational life through a better understanding of the degradation processes. [51]

The most popular electrolysis processes are the Proton exchange membrane electrolysis (PEM), the alkaline electrolysis (AEL) as well as the solid oxide electrolysis (SOE). They differ mostly in the electrolyte used, the operating temperature and the design of the respective cells. For the production of a PEM electrolyzer, for example, the individual cell components must first be prefabricated before stacking. Thereby, the main components comprise the membrane electrode assembly, consisting of catalyst-coated-membrane and gas diffusion layer, and the bipolar plate. For economic and sustainable reasons, the relevance of recycling is also increasing in the electrolyzer value chain (see Fig. 17).

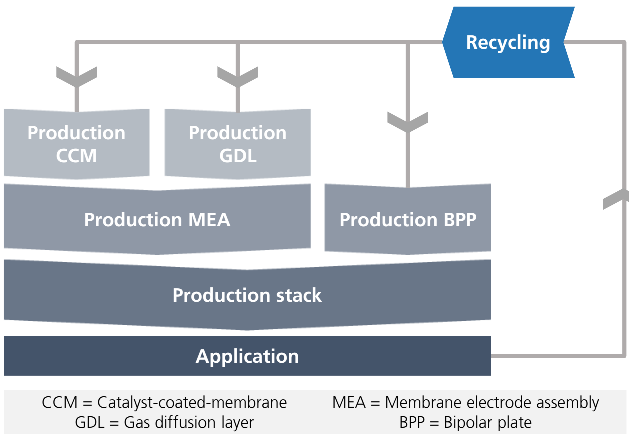


Fig. 17: Value chain of the electrolyzer production

It becomes obvious that the production process of an electrolyzer is highly complex and various actors along the value and development chain need to be involved. To gain a better understanding of their challenges and traits, again, the analysis of three of the eight actors considered is presented in detail in Fig. 18. The respective explanations can be found in the annex.

A similar ratio of resource strength and agility as in the LIB- and semiconductor-cases can be observed for the system and product integrators (high resource capacities and low agility) as well as the machinery and plant manufacturer (medium resource capacities and medium agility). However, a significant contrast to the characteristics of large system and product integrators is provided by the company Sunfire. As a startup, the company is characterized by a small number of resources and high agility. In the overall ecosystem, the more capital-intensive larger companies and investors are the growth and commercialization drivers of startups. As foreign investors increasingly acquire stakes in European startups, appropriate measures must be taken to better integrate these startups into the European ecosystem.

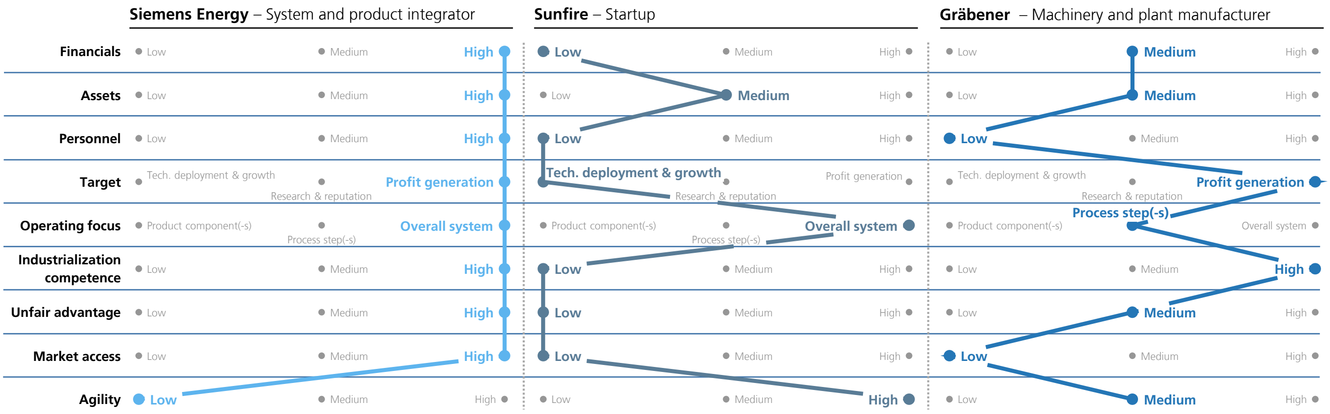


Fig. 18: Morphology of traits amongst selected participants in the electrolyzer industry

Synthesis and findings

Based on the extensive characterization of technology-specific actors within the innovation ecosystems, the analyses are synthesized in the following. As presented earlier, a generic DT ecosystem consists of various actors. The case studies, with 25 actors analyzed, help to create generally applicable trait-profiles for the different actors of DT innovation systems. Based on the quantity of actors analyzed, the frequency of the single expression identified within the areas is presented in Fig. 19. In most cases, clear trait profiles for the single actor groups of innovation system emerge.

System and product integrators are strong within almost all the traits assessed and are therefore extremely important for the development of Deep Tech innovations. However, their focus on profit generation and on holistic production systems, coupled with low agility and flexibility, inhibits their ability to focus solely on innovation and DT. In this context, research institutions as well as startups act as enablers for focused R&D and a cooperation between the types of actors is required. At the same time, system and product integrators lack know-how to transform new production concepts into holistic, economical machines and plants. This again requires the expertise of machine and plant manufacturers who have a certain agility and a strong industrialization competence within their focus of expertise. Furthermore, focus on industrialization and production is not the only success factor for DT innovations: Raw materials and components gain a strong strategic importance for upcoming products and supply chains. Therefore, feedstock suppliers must be strongly integrated into R&D processes and the set-up of value chains.

All in all, it becomes obvious how different the individual actors can be classified within the traits. Each of them has highly important traits required for successful DT innovations. At the same time, in particular research institutions show a heterogeneous picture within the fields of the operating focus and industrialization competence. Therefore, trait profiles and particular strengths need to be assessed in detail when it comes to cooperation and innovation between different actors in this field. Since cooperation between institutions and companies can have a lot of pitfalls, the cooperation process needs to be moderated and accompanied in a structed and target-oriented manner. By taking the derived traits into account when setting up innovation ecosystems, governmental decision makers can generate substantial impact within this field. Explicit measures and mechanisms need to be set up to ensure participation of all actors required by creating individual incentives. Overall, the derived traits function very well to describe differences within innovation systems and to derive target-oriented support needs for governments. Based on the case studies, concrete needs for action emerge:

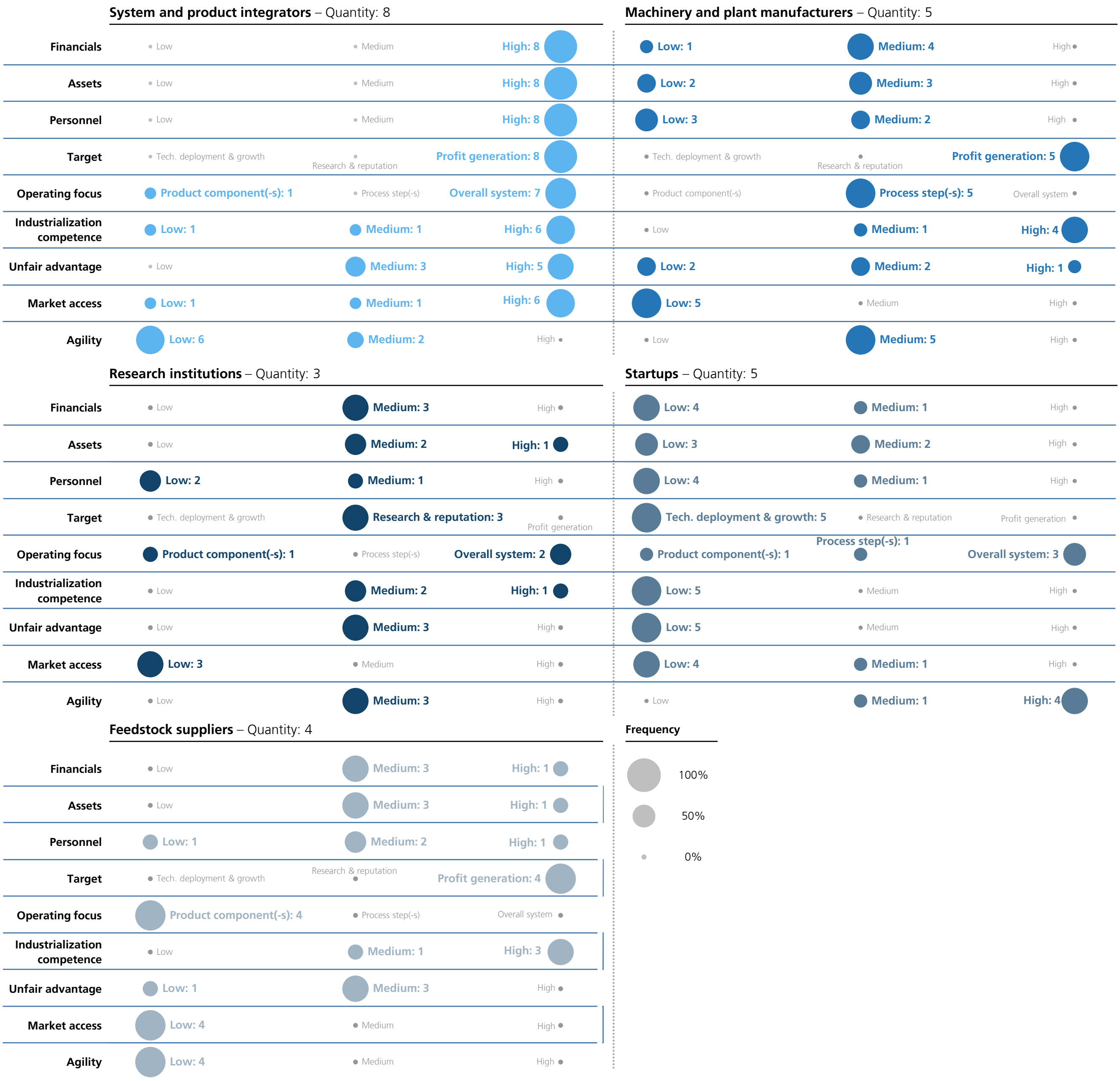


Fig. 19: Synthesis of traits by actor type within the innovation system for the participants analyzed

Collaboration is key
In order to enable and foster the innovation of Deep Tech, the actors involved must collaborate closely with each other. Only sufficient transparency enables research and development as well as the commercialization of uncertain, disruptive innovations. The different strengths and weaknesses identified in the underlying case studies need to be taken into account when designing collaboration.

Establish a constructive environment
Building a constructive ecosystem enables the strengths of individual actors to complement each other effectively. The identified traits in the case study form a basis for the elaboration of a constructive environment. Shaping this environment to best benefit all actors is essential.

Create shelters for intellectual property
For constructive collaboration to take place, protective spaces for intellectual property are mandatory to avoid cost- and time-critical legal disputes from the outset. It is of highest interest for economies to minimize the migration of knowledge abroad due to bureaucracy.

Wrap-up and outlook

This white paper addresses the innovation performance of European countries within the field of society-changing technologies, called Deep Tech, which needs to be further improved in the near future. In this context, the current situation and developments within exemplary Deep Tech ecosystems were analyzed in order to derive needs for action. These mainly concern the area of technology transfer, which covers the transition of technological concepts and findings from basic research to industrialization.

To understand the requirements for success of innovations systems and therefore how Deep Tech innovations can be accelerated, the relevant actors were defined and described along derived trait categories. For this, case studies in the fields of lithium-ion battery, semiconductor and electolyzer industries were elaborated. A total of 25 actors of the innovation systems were analyzed and led to generally applicable profiles of these actors in terms of competencies and opportunities.

Based on the needs for action outlined, collaboration environments need to be designed taking the trait-profiles identified into account. Furthermore, these profiles need to be used to identify opportunities for governmental institutions to provide targeted support to actors in various innovation systems. Following this approach, the greatest possible impact of financial or organizational investments might be achieved. Overall, these contributions will generate impactful benefits for European societies by bridging science and industries, closing the Valley of Death and enable technological growth and independency. On the long run, Europe can derive sustainable economic benefits from investments in basic research within the technologically relevant fields of the future.

Annex

Trait clusters as case study baseline

Table 1: Overview of the traits relevant for classification within case study

Analysis of explicit actors within the Deep Tech innovation systems

Exemplary, the evaluation is illustrated by means of three selected actors per Deep Tech in the following.

Battery cell industry

Volkswagen AG - System and product integrator
With a revenue of €250.2 billion, an operating profit of €19.3 billion and R&D expenditures of €15.6 billion (2021), Volkswagen AG (VW) is one of the financially strongest industrial players in the automotive industry and thus has the financial resources to actively invest in the battery business (Financials: High). As one of the world's largest vehicle manufacturers, VW owns buildings, laboratories, R&D centers and small-scale production machines - a relevant share of which can be used for the in-house development of a battery infrastructure (Assets: High). In line with the high revenue, VW AG employed an average of 667,647 people as of 2021. This allows the company to build up large capacities in new segments at short notice with access to a large pool of skilled labor (Personnel: High). Due to the public listing on stock exchanges and the associated dependence on institutional investors, the corporate targets are mostly defined in the form of profit orientation (Target: Profit generation). Current deficits in the field of battery expertise could be drastically reduced through personnel recruitment and cooperation, with the result that the scope of consideration covers the entire electrified powertrain, in particular the traction battery (Operating Focus: Overall System). The many years of experience in the efficiency-driven automotive industry are reflected in a high level of know-how in industrialization and rationalization, i.e., efficiency, quality, series production, lean management, etc. (Industrialization competence: High). Volkswagen has a high unfair advantage due to the company size, network, and global lobbying, which also has a significant impact on market structures in the context of electrification compared to (small) competitors (Unfair Advantage: High). With 8.88 million vehicle deliveries in 2021, a global passenger car market share of 11.7 percent and fully developed sales and distribution structures, Volkswagen AG is very well positioned in the intersection between the production and the customer (Market Access: High). Agility and flexibility, however, are limited by the structures that have grown organically and the size of the company - product roadmaps, e.g., cannot be adapted at short notice in case of break-through technological developments (Agility/Flexibility: Low). [52]

All in all, the system integrators of the LIB, exemplified by Volkswagen AG, represent an important actor in the systemic change of individual mobility. The system integrators and large battery cell manufacturers are important partners in the build-up of production capacities and in the development as well as implementation of new battery generations. For this reason, it is necessary that they are considered for strategic and operational orientation by all actors across the entire value chain.

Manz AG - Machinery supplier
Manz AG is a manufacturer of integrated production solutions with efficient machinery and systems for different growth industries. Revenues of €227.1 million and R&D expenditures of €16 million are divided among various industries ranging from medical technology to the automotive industry. The company's battery solutions are allocated to the energy storage segment, which at €77.2 million accounts for 34.2 percent of revenue in 2021. While the cross-divisional EBIT of Manz shows a negative value of €16.1 million in 2021, the EBIT for the Energy Storage segment is positive with €1.7 million. Compared to other actors along the presented value chain, Manz therefore has a medium financial strength within the battery ecosystem (Financials: Medium). As an established manufacturer of special machinery, Manz can use resources for the development of production and processes for batteries but lacks large production lines that could be relevant for battery cell production processes (Assets: Medium). With a workforce of 1,384 employees in 2021, the company can only provide a moderate number of employees to build up new capacities and business streams (Personnel: Medium). Having grown for over 30 years, Manz has a responsibility towards shareholders and employees (Target: Profit-orientated). The company focuses on optimizing production technologies and processes (Operating Focus: Process Steps) and includes machine and equipment types for the production of various battery recipes and cell formats for efficient and industrialized production from the laboratory to the series line (Industrialization expertise: High). Core competencies include laser processes and roll-to-roll (R2R) processes. These skills are to be transferred to cell production through cooperation and research projects such as the "Lithium Battery Factory of the Future", thus creating the basic building block for the development of European battery production. Manz was therefore able to position itself as a relevant implementation partner for individual production steps in battery cell production. Worldwide networks, first-mover activities and lobby

representatives in mechanical and plant engineering make it comparably easy for Manz to continue growing in the battery market alongside initial implemented projects and a certain market presence (Unfair Advantage: Medium). Since Manz can only demonstrate very few competencies in the battery cell product so far, direct access to the end customer market in form of its own battery cell production is not available (Market access: Low). The company can realise small to medium-sized modifications in machine configurations flexibly and thus react to changing market requirements. In contrast, new production technologies require years of research and validation within their scope of action (Agility/Flexibility: Medium). [53]

In summary, Manz can be characterized as an innovative company in the mechanical and plant engineering industry. As an innovator for future markets, Manz' strength lies in the transfer and further development of existing production technologies to individual process steps in battery cell production. In contrast to VW as a system producer and integrator Manz' financial and personnel resources are limited. In addition, Manz cannot draw on such a large economic and political network. However, cooperation and joint projects with other market participants can lead to a win-win situation and enable Manz - as exemplary machinery manufacturer within this case study - to exploit new opportunities in the billion-dollar battery ecosystem.

Fraunhofer Research Institution for Battery Cell Production FFB - Research institution
The Fraunhofer Research Institution for Battery Cell Production FFB in northwest Germany aims to become the research and development centre for modern and scalable battery production in Germany and Europe. The German Federal Ministry of Education and Research (BMBF) and the state of North Rhine-Westphalia support the set-up of the research factory with a funding of €680 million. Since it remains a scientific institution without large cash flows and margins, its financial opportunities are limited. Nevertheless, large amount of funding will be used to accelerate and transfer process innovations into the industry (Financials: Medium / Assets: High). The targeted amount of personnel is approx. 150 employees (Personnel: Low). The objective is to close existing gaps for the industrialized production of battery cells in Europe, such as production costs at too high level and too high raw material dependencies on individual countries, and to generate cross-product and cross process knowledge (Target: Research and Reputation). After its full build-up in 2027, flexible and integrated production lines for research on round cells, pouch cells and prismatic cells with a targeted capacity of 6.8 GWh will be available to support companies from different areas of the value chain in their scaling (Operating Focus: Overall System / Industrialization competence: High). The Fraunhofer network and reputation as a research institution in Germany provide advantages in exploiting opportunities and network effects (Unfair advantage: Medium). [54]

Like other research institutions, Fraunhofer FFB is a strong partner that provides companies with scientific support and can contribute expertise from 14 different Fraunhofer Institutes. The potential can be generated by connecting the actors of the various stages of the value chain and generate synergy effects. As a flagship project of German industrial research, Fraunhofer FFB nevertheless stands out from "normal" research institutions. In addition to a significantly higher financial volume, the equipment and the political back-up are special characteristics. Furthermore, the focus on the entire value chain is unique.

Semiconductor industry

Intel Corporation - System and product integrator
With a revenue of $79 billion and an operating income of $19.5 billion in 2021 Intel Corporation is among the 50 largest companies in the United States [55]. In 2021 they announced to invest $20 billion to build two new production sites in the US. Further multi-billion-dollar investments are planned to expand the production in Germany and Europe in the near term. In total, Intel had R&D expenses of $15.2 billion in 2021 which corresponds to roughly 20 percent of their revenue (Financials: High) [56]. Although this share sounds high at first glance, it is no outlier, as semiconductor has always been a R&D intensive industry. In fact, US semiconductor companies invested over 18 percent of revenue in R&D in 2015 and 2016, enabling them to maintain a rapid pace in technological advancement [57]. Of its total assets of $168.4 billion, 37.6 percent is accounted for by property, plant, and equipment, underlining the capital-intensive production facilities and machinery, which enable the company to quickly adapt to technological progress and shorten the time to market (Assets: High). By the end of year 2021, Intel had a total of 121,100 employees worldwide [55], allowing them to quickly build up new capacities (Personnel: High). As a publicly traded company, Intel is committed to its shareholders and is therefore profit-driven (Target: Profit generation). Due to its strategic positioning as IDM, the group has the expertise and capacity to design and manufacture a holistic chip system and to serve the entire ecosystem (Operating focus: Overall system / Industrialization competence: High). In total, an IDM generates a value-added share of approx. 68 percent, while of the total value-added 38 percent is accounted for by manufacturing and 30 percent is accounted for by chip design [58]. For many years, Intel was the chip manufacturer with the largest market share before they were replaced by Samsung in 2021. In a highly heterogeneous semiconductor market with many

vendors, Intel nevertheless has a high market share of 12.5 percent in 2021 (Market access: High) [59]. The high market accessibility is also reflected in their partnerships with major customers (e.g., Dell, Lenovo, US Department of Defense) strengthening Intel's global network. Furthermore, the political influence through lobbying of a company of such economic importance is enormous. For instance, the US government's interest in encouraging companies to produce locally supports Intel's position in negotiations (Unfair advantage: High). A company this size requires a high level of coordination – clear responsibilities and control instances are mandatory. In addition, there are product specific manufacturing lines, which generally require long lead times for major adjustments (Agility: Low).

In conclusion, there is a high level of competitive pressure on Intel. While an increasing share of chips manufactured worldwide comes from partnerships between fabless companies and foundries that take advantage of economies of scale and lower-cost labor, Intel maintains its strategic position as an integrated device manufacturer (IDM) [60]. The government's incentives for local production tend to raise costs even higher (e. g. labor, property, construction).

ASML Holding N.V. - Machinery supplier
With a market share of 62 percent in lithography systems, ASML Holding N.V. is the world's leading vendor for a technology essential to semiconductor manufacturing [61]. The European machine and plant manufacturer has a monopoly for lithography systems that use extreme ultraviolet (EUV) light, which is a critical technology to produce the worlds most advanced chips. With an annually growing revenue of €18.6 billion and an EBIT-margin of 36 percent in 2021 as well as an exceptional order backlog, the company looks forward to a bright future. R&D costs totaled €2.5 billion in 2021, which corresponds to 13.4 percent of the company's revenue (Financials: Medium). [45] With 9.6 percent of ASML's total assets of €30.2 billion, especially compared to Intel, only a small share is accounted for by property, plant, and equipment (Assets: Medium). This is also underlined by the management board stating that ASML cannot process all orders due to lack of personnel and production facilities [46]. Yet, they had 32,016 employees in 2021 (Personnel: Medium). As a publicly traded company, ASML is committed to its shareholders and is therefore profit-driven (Target: Profit generation). Being a market leading manufacturer of special machinery for the semiconductor industry, ASML is indirectly involved in adding value to the final product. Focus and expertise are on one specific process step (Operating focus: Process steps), where a holistic and highly complex manufacturing system is offered to the customer (Industrialization competence: High). Through cooperation with major manufacturers (e.g. Intel, Samsung, TSMC), ASML has an excellent network, which has already announced multi-billion-dollar investments to expand production. For instance, in 2021 TSMC announced to invest $100 billion dollars in the expansion of its production and the development of new technologies [62]. As Europe's most valuable company for the semiconductor industry, ASML also benefits from a special status, which leads to a good negotiating position in the context of lobbying activities (Unfair advantage: High). As a B2B company offering customized plants, ASML only contributes indirectly to value creation and is not independently able to supply the end customer with a holistic chip system (Market access: Low). Therefore, the company is not tied to specially designed manufacturing lines for mass production, resulting in a higher agility. However, there is a lower degree of flexibility regarding the orders, as building such highly complex machines is extremely time-intensive and binding (Agility: Medium). [45]

In conclusion, ASML faces a bright future, provided the company can maintain its near-monopoly position. This requires high spending on R&D in order to remain the technological leader, as well as an expansion of personnel and production facilities to meet the high demand.

Research Fab Microelectronics Germany - Research institution
In an association of 11 member institutes and 5 guest members of the Fraunhofer-Gesellschaft, the Fraunhofer Group for Microelectronics (FMD) coordinates research activities in the fields of microelectronics and microintegration. Since April 2017, the members of the FMD have been collaborating with two Leibniz institutes forming the Research Fab Microelectronics Germany (FMD). [63] FMD's research volume of €349.9 million is funded by the German Federal Ministry of Education and Research, of which €280 million are allocated to the Fraunhofer institutes involved and €70 million are allocated to the two participating Leibniz institutes. The amount was invested primarily in the initial equipment of the research fab and thus in property, plant and equipment, over the period from 2017 to 2020 [64] (Financials: Medium / Assets: Medium). With around 2000 researchers, the factory has a significant number of highly qualified employees mainly in the field of R&D [65] (Personnel: Medium), strengthening the German and European industry with their research in microelectronics. Among the most important research associations in Germany, Fraunhofer and Leibniz are driving innovation in view of future challenges (Target: Research and Reputation) and further strengthen Europe's position in terms of intellectual property. Although research is a central aspect in chip advancement, the underlying depth of value creation for the final product is low. In FMD, research is conducted on individual product components and their fundamentals (Operating focus: Product

components). The research character is also reflected in the underlying competence in manufacturing. As the factory is set up to be research-oriented, it can be concluded that no complex and coherent production process can be realized. However, SMEs and startups are provided with extensive and fast access to high technologies, as well as asset and technology pools for testing new products (Industrialization competence: Medium). As stated earlier, the research association's network among each other and into the industry provides an advantage in exploiting opportunities (Unfair advantage: Medium). Due to its research nature, the FMD is far away from large-scale manufacturing processes and thus from the final product and customer (Market access: Low). Furthermore, research contracts represent a key aspect of FMD funding, often tying researchers for several years to respective research programs. Additionally, time-consuming research proposals and projects have the effect that short-term changes in the market can only be addressed with delays. However, research is innovation-driven and future-oriented meaning that it's based on the most up-to-date knowledge (Agility: Medium).

In conclusion, the Research Fab Microelectronics Germany is an essential player in strengthening Europe's competitive position on the global semiconductor market. Future-oriented research forms the basis for initiatives such as the EU Chips Act, which aims to increase the importance of Europe for the international chip industry.

Electrolyzer industry

Siemens Energy AG - System and product integrator
Siemens Energy AG is a listed electrical and power engineering manufacturer that was formed as a spin-off of Siemens AG. With sales of €28.5 billion and R&D expenditures of €1.2 billion in 2021, Siemens Energy is a big player in the energy market (Financials: High). To achieve its corporate goals, the company has total assets of €44.1 billion, of which €5.1 billion allocated to property, plant, and equipment (Assets: High) and 92,000 employees worldwide (Personnel: High). In addition to self-proclaimed soft targets such as the purpose to energize society with a focus on ESG, innovation and society, Siemens Energy has to fulfill revenue and profit targets due to its listing on the public stock market (Target: Profit-oriented). In the area of electrolyzers, Siemens Energy is underlining its ambitions to achieve a high level of vertical value-added integration by setting up the first series production facility for the manufacture of in-house developed PEM electrolyzers (Operating target: Overall System). As a result of the spin-off from Siemens and the associated competencies in automation and digitization, Siemens Energy has a high level of expertise in series production (Industrialization competence: High). Siemens Energy's advantages lie on the one hand in its coverage of the entire energy value chain. On the other hand, in its ability to assert its interests through lobbyists, for example in the EU Parliament (Unfair advantage: High / Market access: High) [66]. The company has acknowledged its own deficits with regard to agile action within the company and has set itself the goal of increasing agility (Agility/Flexibility: Low) [67]. Siemens Energy aims to play an active role in shaping the energy transition and is underlining this by locating a hydrogen electrolyzer production facility in Berlin. The capacities in terms of financial resources, personnel and industrialization expertise enable the company to participate in the future market of hydrogen. Challenges are, besides the technology development, the financial pressure on results and the uncertainty of the hydrogen market. [68]

Sunfire GmbH - Startup
Founded in 2010, the german startup Sunfire GmbH, a vendor for industrial electrolyzers, pursues the vision of replacing fossil raw materials with renewables in all sectors [69]. In addition to the proven technology of alkaline electrolyzers, the company offers a highly efficient way of producing hydrogen with innovative high-temperature electrolyzers (SOEC) [70]. In order to expand further, the company raised €86 million in additional capital in a Series D2 funding in 2022, only shortly after receiving €109 million in a Series D funding in 2021 (Financials: Low/ Medium). [69] In addition to its headquarters in Dresden, Sunfire has obtained production sites in Germany and Switzerland through the acquisition of two companies in 2020 and 2021. To expand the German production site in the city of Solingen into a so-called Giga Factory, Sunfire plans to invest €100 million (Assets: Low/ Medium) [70-71]. The company currently employs around 370 people at its three sites. [69] By 2023 and the completion of the Giga Factory, the number of employees is set to reach around 400 (Personnel: Low). [70] The startup character of the company indicates that the focus is on further growth. This is also underlined by Sunfire's recent high-volume fundings and acquisitions as well as the planned expansion of production (Target: Technology deployment and growth). With the two technologies SOEC and alkaline, Sunfire offers a suitable solution of electrolysis for every hydrogen project and thus covers the overall system [72] (Operating Focus: Overall System). At current capacity, Sunfire's alkaline electrolyzers can produce 40 megawatts per year (Industrialization competence: Low). However, with the completion of the factory by 2023, this value is set to increase to 500 megawatts per year, [70] which would significantly increase the company's industrialization competence and make Sunfire a leading German vendor [71]. In addition to investors, strategic partnerships (e.g., SMS Group) strengthen Sunfire's network giving them advantages compared to other startups (Unfair advantage: Low/Medium). [69] In a B2B environment, Sunfire provides plants for electrolysis, which are a key part of the hydrogen value chain based on renewables, thus only

indirectly contributing to value creation (Market access: Low). The startup character as well as the small number of employees speak for a fundamental agility of the company (Agility/ Flexibility: High). [73]

However, the expansion of production and especially the Giga Factory leads to a stronger commitment, which will result in less agility in the medium term. This is mainly due to high investments and the aim to achieve economies of scale. In conclusion, Sunfire can be categorized as a company in transition, with the intention of securing market share in the medium term. For this purpose, production is expanded, and companies are acquired.

Gräbener - Machinery supplier
Gräbener Maschinentechnik GmbH & Co. KG is a mechanical engineering specialist focused on special machines with over 100 years of experience in the development of customized solutions. For more than 20 years, the business for bipolar plate manufacturing equipment has been continuously expanded. As a medium-sized company with a sales volume of €12 million (2021), Gräbener can realize projects in the field of bipolar plates from individual stand-alone systems to scalable production lines (Financials: Low). Among other things, an application laboratory is available for this purpose, which is suitable for verifying the manufacturability of bipolar plate designs before the industrialization phase (Assets: Medium). Furthermore, Gräbener employed 80 people in 2021 (Personnel: Low). As characteristic for a medium-sized company, the management has a responsibility towards company results and employees (Target: Profit-oriented). The focus in the fuel cell / electrolysis business area lies on production equipment for the process steps hydroforming, cutting and welding (Operating Focus: Process steps). The modular design of the production lines and patented innovation processes, for example, combination of sandwich mold and hydroforming press for forming several panels with one stroke, are intended to provide customers with a competitive advantage (Industrialization competence: High). Gräbener is involved in a variety of industrial and research projects, such as the Ekolyser project, in which competencies for forming and cutting new economical and sustainable materials for PEM electrolysis are developed (Unfair advantage: Medium). Despite the high level of expertise in the area of bipolar plates, the company's own entire electrolyzer production would exceed both its own expertise and its own market access, as the necessary expertise in other components and key technologies is not available to a sufficient extent (Market access: low). The company's public appearance (e.g., website, press, references) suggests a company that tries to remain agile within its own capabilities. Customer wishes are met individually by offering additional services such as demand analysis, design analysis and prototyping (Agility/Flexibility: Medium). Summed up, Gräbener can be characterized as a typical German "hidden champion" [74]. The Bipolar Plate Technologies division specializes in plant engineering and the production steps for manufacturing bipolar plates. In over 20 years, more than 100,000 bipolar plates with more than 85 different designs have been manufactured in this division. The goal is to exploit the potential of this key technology and to participate in the future markets. To achieve this, Gräbener must maintain its technological leadership and find suitable (industrial) partners for the expansion of the business area. [75]

Bibliography

[1] P. E. Auerswald and L. M. Branscomb, “Valleys of Death and Darwinian Seas: Financing the Invention to Innovation Transition in the United States,” The Journal of Technology Transfer, no. 3-4: Symposium on The State of The Science and Practice of Technology Transfer, pp. 227–239, 2003, doi: 10.1023/A:1024980525678.

[2] A. Baur and L. Flach, “Deutsch-chinesische Handelsbeziehungen: Wie abhängig ist Deutschland vom Reich der Mitte?,” ifo Schnelldienst, vol. 75, no. 4, pp. 56–65, 2022. Accessed Nov. 16, 2022. [Online]. Available: https://www.ifo.de/DocDL/sd-2022-04-baur-flach-deutsch-chinesische-handelsbeziehungen_0.pdf

[3] V. A. Binder and J. Kantowsky, Technologiepotentiale: Neuausrichtung der Gestaltungsfelder des Strategischen Technologiemanagements. Wiesbaden: Springer, 1996.

[4] T. Iwamoto, “Management of Deep Technology Startups in Japan,” in PICMET ’18. Portland International Conference on Management of Engineering and Technology: Proceedings. Managing Technological Entrepreneurship: The Engine for Economic Growth, Portland, D. F. Kocaoglu, T. R. Anderson, D. C. Kozanoglu, K. Niwa, H.-J. Steenhuis, and G. Perman, Eds., 2018, doi: 10.23919/PICMET.2018.8481863.

[5] A. Nedayvoda, P. Mockel, and L. Graf. “Deep Tech Solutions for Emerging Markets.” Fresh Ideas about Business in Emerging Markets. https://www.ifc.org/wps/wcm/connect/40de3e02-cf98-4581-b3bb-c1233364e753/EMCompass_Note_94-web.pdf?MOD=AJPERES&CVID=nnDXBtD (accessed Nov. 16, 2022).

[6] I. Bardenhagen and F. Langer. “Solid-state batteries for electric mobility: Safe and powerful solid-state batteries based on polymers and sulfides for electric cars, air taxis, mobile robots and co.” https://www.ifam.fraunhofer.de/en/magazine/solid-state-batteries-for-electric-mobility.html (accessed Nov. 16, 2022).

[7] QuantumScape Corporation. “Building the Best Battery.” https://www.quantumscape.com/ (accessed Nov. 16, 2022).

[8] D. L. Chandler. “Toward batteries that pack twice as much energy per pound: A method for stabilizing the interfaces in solid-state lithium-ion batteries opens new possibilities.” https://news.mit.edu/2022/solid-state-batteries-interface-stability-0308 (accessed Nov. 16, 2022).

[9] Volkswagen. “Volkswagen erhöht Anteil an QuantumScape.” https://www.volkswagen-newsroom.com/de/pressemitteilungen/volkswagen-erhoeht-anteil-an-quantumscape-6136 (accessed Nov. 16, 2022).

[10] StartUs Insights. “Discover 5 Top Energy Startups developing Solid-State Batteries.” https://www.startus-insights.com/innovators-guide/discover-5-top-energy-startups-developing-solid-state-batteries/ (accessed Nov. 16, 2022).

[11] M. Geilen. “Gehört der Festkörperbatterie die Zukunft?” https://battery-news.de/index.php/2021/06/18/zukunft-der-batterie-die-festkoerperbatterie/ (accessed Nov. 16, 2022).

[12] C. Hüls, Strategische Planung der Transformation von Antriebsportfolios in der Automobilindustrie. Wiesbaden: Springer Gabler, 2022.

[13] H. A. Tvete and D. Hill. “Are solid-state batteries the holy grail for 2030?” https://www.dnv.com/to2030/technology/are-solid-state-batteries-the-holy-grail-for-2030.html (accessed Nov. 16, 2022).

[14] T. Schmaltz, T. Wicke, L. Weymann, P. Voß, C. Neef, and A. Thielmann. “Solid-State Battery Roadmap 2035+: April 2022.” (Version Sept. 2022). https://www.isi.fraunhofer.de/content/dam/isi/dokumente/cct/2022/SSB_Roadmap.pdf (accessed Nov. 16, 2022).

[15] F. Lambert. “Fisker gives up on solid-state batteries after announcing ‘breakthrough’ with ‘500 miles range & 1-min charging’.” https://electrek.co/2021/03/01/fisker-gives-up-on-solid-state-batteries-after-announcing-breakthrough/ (accessed Nov. 16, 2022).

[16] K. Dörner and M. Flötotto, “Gründungen – „scaled from Europe“: Handlungsfeld 3,” in Kreative Erneuerung: Deutschland 2030, 2021, pp. 29–34. Accessed: Nov. 16, 2022. [Online]. Available: https://www.mckinsey.de/~/media/mckinsey/locations/europe%20and%20middle%20east/deutschland/publikationen/2021-06-23%20deutschland%202030%20artikel/mckinsey_report_deutschland_2030_kreative_erneuerung_2021.pdf

[17] Statista Research Department. “Weltweiter Umsatz der führenden Hersteller von Halbleiterprodukten in den Jahren 2009 bis 2021: (in Milliarden US-Dollar).” https://de.statista.com/statistik/daten/studie/168332/umfrage/weltweiter-umsatz-mit-halbleitern-nach-hersteller-seit-2009/ (accessed Nov. 16, 2022).

[18] S. Schaal. “CATL ist größter EV-Batteriehersteller der Welt.” https://www.electrive.net/2022/02/08/catl-ist-groesster-ev-batteriehersteller-der-welt/#:~:text=-CATL%20war%202021%20laut%20Zahlen,Hersteller%20von%20Batterien%20f%C3%BCr%20Elektroautos. (accessed Nov. 16, 2022).

[19] I. Ostojic and G. Richter, "Investitionen in Technologieführerschaft: Handlungsfeld 4," in Kreative Erneuerung: Deutschland 2030, 2021, pp. 36–41. Accessed: Nov. 16, 2022. [Online]. Available: https://www.mckinsey.de/~/media/mckinsey/locations/europe%20and%20middle%20east/deutschland/publikationen/2021-06-23%20deutschland%202030%20artikel/mckinsey_report_deutschland_2030_kreative_erneuerung_2021.pdf

[20] J. C. Breitinger, B. Dierks, and T. Rausch. "Weltklassepatente in Zukunftstechnologien: Die Innovationskraft Ostasiens, Nordamerikas und Europas." https://www.bertelsmann-stiftung.de/fileadmin/files/user_upload/BST_Weltklassepatente_2020_DT.pdf (accessed Nov. 16, 2022).

[21] A. Laukat. "'Wir haben eine langfristige Ambition': Celonis-Gründer im Interview." https://www.n-tv.de/wirtschaft/wirtschaft_startup/Wir-haben-eine-langfristige-Ambition-article22591278.html (accessed Nov. 16, 2022).

[22] L. Holzki. "Bewertung übersteigt zehn Milliarden Dollar: Münchener Start-up Celonis ist erstes deutsches Decacorn." https://www.handelsblatt.com/technik/it-internet/mega-finanzierungsrunde-bewertung-uebersteigt-zehn-milliarden-dollar-muenchener-start-up-celonis-ist-erstes-deutsches-decacorn/27247478.html (accessed Nov. 16, 2022).

[23] R. Laguna de la Vera and T. Ramge, Sprunginnovation: Wie wir die Welt mit Wissenschaft und Technik wieder in Balance bekommen. Berlin: Ullstein, 2021.

[24] vg. "Immer mehr ausländische Investoren kaufen deutsche Start-ups." https://www.markenartikel-magazin.de/_rubric/detail.php?rubric=marke-marketing&nr=47436&PHPSESSID=mob41ur5duatlhln95a5374tp0 (accessed Nov. 16, 2022).

[25] A. Schwander and I. Trojette. "IPOs in Germany: What Potential Shareholders Should Know: Professional Perspective." https://www.kirkland.com/-/media/publications/article/2019/10/ipos-in-germany_what-potential-shareholders-should/bloomberg-law-ipos-in-germanyschwandertrojette-oct.pdf (accessed Nov. 16, 2022).

[26] A. Dörner, F. Holtermann, L. Holzki, and S. Matthes. "Flugtaxi-Start-up Lilium sammelt weniger Geld ein als erhofft." https://www.handelsblatt.com/finanzen/anlagestrategie/trends/ipo-flugtaxi-start-up-lilium-sammelt-weniger-geld-ein-als-erhofft/27605752.html (accessed Nov. 16, 2022).

[27] C. Moore, S. Melilli, B. Sprong, and C. Cimino. "The reality of SPAC mergers." Privately Speaking Series: Insights on private company growth. https://www.kpmg.us/content/dam/global/pdfs/2021/ps82-reality-spac-mergers.pdf (accessed Nov. 16, 2022).

[28] L. Holzki. "Spac-Boom erreicht Deutschland: Gründer werden mit Angeboten überhäuft." https://www.handelsblatt.com/technik/it-internet/schnelle-boersengaenge-spac-boom-erreicht-deutschland-gruender-werden-mit-angeboten-ueberhaeuft/27259524.html (accessed Nov. 16, 2022).

[29] BDI e.V. "Globale Wertschöpfungsketten unter Druck." https://bdi.eu/artikel/news/globale-wertschoepfungsketten-unter-druck/ (accessed Nov. 16, 2022).

[30] B. Carlsson and R. Stankiewicz, "On the nature, function and composition of technological systems," Journal of Evolutionary Economics, vol. 1, no. 2, pp. 93–118, 1991, doi: 10.1007/BF01224915.

[31] A. de la Tour et al. "The Dawn of the Deep Tech Ecosystem." https://media-publications.bcg.com/BCG-The-Dawn-of-the-Deep-Tech-Ecosystem-Mar-2019.pdf (accessed Nov. 16, 2022).

[32] Europäische Kommission. "Europäischer Grüner Deal: Erster klimaneutraler Kontinent werden." https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_de (accessed Nov. 16, 2022).

[33] Reuters. "Autohersteller planen Investitionen von 515 Milliarden Dollar für E-Fahrzeuge und Batterien." https://ecomento.de/2021/11/15/autohersteller-investitionen-von-515-milliarden-dollar-fuer-e-fahrzeuge-und-batterien/ (accessed Nov. 16, 2022).

[34] Bundesministerium für Wirtschaft und Klimaschutz. "Batterien für die Mobilität von morgen." https://www.bmwk.de/Redaktion/DE/Artikel/Industrie/batteriezellfertigung.html#:~:text=Das%20Herzst%C3%BCck%20jeder%20Batterie%20ist,dies%20bis%20zu%2040%20Prozent. (accessed Nov. 16, 2022).

[35] W. Bernhart et al., "Rising opportunities for battery equipment manufacturers: Boom in electric cars and Li-Ion batteries shifts manufacturing equipment into overdrive," Roland Berger GmbH, München, 2020.

[36] QuantumScape Corporation. "Delivering on the promise of solid-state technology." https://www.quantumscape.com/technology/ (accessed Nov. 16, 2022).

[37] M. T. Lotz, R. Barkhausen, A. Herbst, M. Pfaff, A. Durand, and M. Rehfeldt, "Potentials and Prerequisites on the Way to a Circular Economy: A Value Chain Perspective on Batteries and Buildings," Sustainability, vol. 14, no. 2, 2022, Art. no. 956, doi: 10.3390/su14020956.

[38] M. Henß. "Die Halbleiterindustrie in der Branchenanalyse - ein Markt mit vielfältigen Investmentchancen!" https://aktien-mag.de/blog/die-halbleiterindustrie-in-der-branchenanalyse-ein-markt-mit-vielfaltigen-investmentchancen/p-65768 (accessed Nov. 16, 2022).

[39] O. Burkacky, J. Dragon, and N. Lehmann. "The semiconductor decade: A trillion-dollar industry." https://www.mckinsey.com/industries/semiconductors/our-insights/the-semiconductor-decade-a-trillion-dollar-industry?cid=other-eml-alt-mip-mck&hdpid=abb30383-c33b-4184-bf8b-da6bf2b59c0c&hctky=12965240&hlkid=087f77cc76d0421d905070b2495c61e6 (accessed Nov. 16, 2022).

[40] Statista Research Department. "Prognose zum Umsatz der Halbleiterindustrie weltweit in den Jahren 2006 bis 2023: (in Milliarden US-Dollar)." https://de.statista.com/statistik/daten/studie/150902/umfrage/prognostiziert-er-umsatz-in-der-halbleiterindustrie/#:~:text=Die%20 Statistik%20zeigt%20den%20Umsatz,%2C4%20Milliarden%20US%2DDollar (accessed Nov. 16, 2022).
[41] M. Rimol and L. Goasduff. "Gartner Says Worldwide Semiconductor Revenue Declined 12% in 2019: Intel Reclaimed Top Spot in Global Semiconductor Market; Samsung Moved to No. 2." https://www.gartner.com/en/newsroom/press-releases/2020-04-15-gartner-says-worldwide-semiconductor-revenue-declined-12-percent-in-2019#:~:-text=Worldwide%20semiconductor%20revenue%20-totaled%20%24419.1,memory%20market%20down%20 32.7%25%202019 (accessed Nov. 16, 2022).
[42] G. O'Donnell. "The Global Chip Shortage Won't Ease Soon." https://www.forrester.com/blogs/the-global-chip-shortage-wont-ease-soon/?utm_source=pr_pitch&utm_medium=pr&utm_campaign=tech_futurefit (accessed Nov. 16, 2022).
[43] J. Hofer and O. Scheer. "446 Milliarden Dollar gegen den Chipmangel – die Halbleiterbranche expandiert wie nie." https://www.handelsblatt.com/technik/it-internet/lieferengpaesse-446-milliarden-dollar-gegen-den-chipmangel-die-halbleiterbranche-expandiert-wie-nie/28239092.html (accessed Nov. 16, 2022).
[44] Europäische Kommission. "Europäisches Chip-Gesetz." https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/european-chips-act_de (accessed Nov. 16, 2022).
[45] ASML. "2021 Annual Report." https://www.asml.com/en/investors/annual-report/2021 (accessed Nov. 16, 2022).
[46] J. Hofer. "Chipausrüster ASML: Europas wertvollster Tech-Konzern kämpft mit der Auftragsflut." https://www.handelsblatt.com/technik/halbleiterindustrie-chipausruester-asml-europas-wertvollster-tech-konzern-kaempft-mit-der-auftragsflut/27988080.html (accessed Nov. 16, 2022).
[47] S. Alam and G. Albert. "We keep trending: consolidations and expansions." https://www.accenture.com/us-en/blogs/high-tech/semiconductor-consolidation-expansion (accessed Nov. 16, 2022).
[48] World Energy Council, EPRI, PwC. "Hydrogen on the Horizon: Ready, Almost Set, Go?" https://www.worldenergy.org/assets/downloads/Innovation_Insights_Briefing_-_Hydrogen_on_the_Horizon_-_Ready%2C_Almost_Set%2C_Go_-_July_2021.pdf (accessed Nov. 16, 2022).
[49] C. Hebling et al. "Eine Wasserstoff-Roadmap für Deutschland." https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/2019-10_Fraunhofer_Wasserstoff-Roadmap_fuer_Deutschland.pdf (accessed Nov. 16, 2022).
[50] M. Kruse and J. Wedemeier, "Potenzial grüner Wasserstoff: langer Weg der Entwicklung, kurze Zeit bis zur Umsetzung," Wirtschaftsdienst, vol. 101, no. 1, pp. 26–32, 2021, doi: 10.1007/s10273-021-2821-9.
[51] Hydrogen and Fuel Cell Technologies Office. "Hydrogen Production: Electrolysis." https://www.energy.gov/eere/fuelcells/hydrogen-production-electrolysis (accessed Nov. 16, 2022).
[52] Volkswagen AG. "New Auto: Annual Report 2021." https://www.volkswagenag.com/presence/investorrelation/publications/annual-reports/2022/volkswagen/Y_2021_e.pdf (accessed Nov. 16, 2022).
[53] Manz AG. "Growth Industries in Focus: 2021 Annual Report." https://www.manz.com/ecomaXL/files/Manz-AG_GB-2021_EN.pdf?download=1 (accessed Nov. 16, 2022).
[54] Fraunhofer Research Institution for Battery Cell Production FFB. "Fraunhofer Research Institution for Battery Cell Production FFB." https://www.forschungsfertigung-batteriezelle.fraunhofer.de/en.html (accessed Nov. 16, 2022).
[55] Intel Corporation. "Intel Reports Fourth-Quarter and Full-Year 2021 Financial Results: Delivers Record Quarterly and Full-Year Revenue." https://d1io3yog0oux5.cloudfront.net/_9f6708e241b68c1f660053b2f738a196/intel/news/2022-01-26_Intel_Reports_Fourth_Quarter_and_Full_Year_2021_1522.pdf (accessed Nov. 16, 2022).
[56] A. Demling and J. Hofer. "Intel will 20 Milliarden Dollar in Chip-Produktion investieren." https://www.handelsblatt.com/technik/it-internet/halbleiterhersteller-intel-will-20-milliarden-dollar-in-chip-produktion-investieren/27034724.html (accessed Nov. 16, 2022).
[57] S. Jones and A. Ghosh. "Evolving the D&A of semiconductor R&D: Leveraging data and analytics to create next generation R&D." https://assets.kpmg/content/dam/kpmg/us/pdf/2017/12/semiconductor-da-brochure.pdf (accessed Nov. 16, 2022).
[58] S. M. Khan, A. Mann, and D. Peterson. "The Semiconductor Supply Chain: Assessing National Competitiveness: CSET Issue Brief." https://cset.georgetown.edu/wp-content/uploads/The-Semiconductor-Supply-Chain-Issue-Brief.pdf (accessed Nov. 16, 2022).
[59] T. Alsop. "Semiconductor companies market share worldwide 2008-2021." https://www.statista.com/statistics/266143/global-market-share-of-leading-semiconductor-vendors/ (accessed Nov. 16, 2022).
[60] O. Burkacky, S. Lingemann, and K. Pototzky. "Coping with the auto-semiconductor shortage: Strategies for success." https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/coping-with-the-auto-semiconductor-shortage-strategies-for-success (accessed Nov. 16, 2022).

[61] J. Hofer. “ASML ist Europas größter Trumpf im globalen Kampf um die Chips.” https://www.handelsblatt.com/meinung/kommentare/kommentar-asml-ist-europas-groesster-trumpf-im-globalen-kampf-um-die-chips/27117054.html (accessed Nov. 16, 2022).
[62] Handelsblatt. “Chip-Hersteller TSMC investiert 100 Milliarden Dollar in Ausbau von Fertigung.” https://www.handelsblatt.com/technik/it-internet/taiwan-chip-hersteller-tsmc-investiert-100-milliarden-dollar-in-ausbau-von-fertigung/27061158.html (accessed Nov. 16, 2022).
[63] Fraunhofer-Verbund Mikroelektronik. “Fraunhofer-Verbund Mikroelektronik.” https://www.mikroelektronik.fraunhofer.de/ (accessed Nov. 16, 2022).
[64] M. Thum et al. “Für eine sichere Zukunft: Resilienz durch Innovation: Jahresbericht 2020.” https://www.fraunhofer.de/content/dam/zv/de/publikationen/Jahresbericht/jahresbericht-2020/Fraunhofer-Jahresbericht-2020.pdf (accessed Nov. 16, 2022).
[65] Bundesministerium für Bildung und Forschung. “Forschungsfabrik Mikroelektronik Deutschland (FMD): Forschungsfabrik Mikroelektronik Deutschland (FMD) – Fraunhofer-Verbund Mikroelektronik in Kooperation mit den Leibniz-Instituten FBH und IHP.” https://www.elektronikforschung.de/projekte/forschungsfabrik-mikroelektronik-deutschland-fmd (accessed Nov. 16, 2022).
[66] Corporate Europe Observatory, LobbyControl. “Welcome to LobbyFacts - exposing lobbying in the European institutions.” https://lobbyfacts.eu/representative/50ae0b097f1e462f943f190a6aa089e3 (accessed Nov. 16, 2022).
[67] A. Höpner. “Siemens-Chef Busch schwört Führungskräfte ein: „Wir müssen noch agiler und schneller werden“.” https://www.handelsblatt.com/unternehmen/industrie/technologiekonzern-siemens-chef-busch-schwoert-fuehrungskraefte-ein-wir-muessen-noch-agiler-und-schneller-werden/27716046.html (accessed Nov. 16, 2022).
[68] A. Benzinger and C. Nehring. “Siemens Energy siedelt Fertigung für Wasserstoff-Elektrolyseure in Berlin an.” Siemens Energy siedelt Fertigung für Wasserstoff-Elektrolyseure in Berlin an (accessed Nov. 16, 2022).
[69] Sunfire GmbH. “Über Sunfire: Renewables Everywhere.” https://www.sunfire.de/de/unternehmen (accessed Nov. 16, 2022).
[70] dpa/sn. “Wasserstoff-Firma Sunfire plant neues Werk.” https://www.sueddeutsche.de/wirtschaft/energie-dresden-wasserstoff-firma-sunfire-plant-neues-werk-dpa.urn-newsml-dpa-com-20090101-211007-99-508676 (accessed Nov. 16, 2022).
[71] K. Witsch. “Wasserstoff-Start-up Sunfire bringt Giga-Fabrik auf den Weg – nur die Aufträge fehlen noch.” https://www.handelsblatt.com/unternehmen/energie/power-to-x-wasserstoff-start-up-sunfire-bringt-giga-fabrik-auf-den-weg-nur-die-auftraege-fehlen-noch/27969314.html (accessed Nov. 16, 2022).
[72] Sunfire GmbH. “Sunfire übernimmt Schweizer Alkali-Elektrolyse-Unternehmen IHT.” https://www.sunfire.de/de/news/detail/sunfire-uebernimmt-schweizer-alkali-elektrolyse-unternehmen-iht (accessed Nov. 16, 2022).
[73] NEUMAN & ESSER GROUP. “Get H2 Ready!” https://www.neuman-esser.de/fileadmin/user_upload/Broschueren/COMPRESSORS/Bro_Get_H2_ready_6-seitig_EN.pdf (accessed Nov. 16, 2022).
[74] J. Block, A. Moritz, L. Benz, and M. Johann. “Hidden Champions in Nordrhein-Westfalen: Studie im Auftrag des Ministeriums für Wirtschaft, Innovation, Digitalisierung und Energie des Landes Nordrhein-Westfalen.” https://www.uni-trier.de/fileadmin/fb4/forschung/fzms/Update_Studienbericht_zu_Hidden_Champions_in_Nordrhein-Westfalen.pdf (accessed Nov. 16, 2022).
[75] Gräbener Maschinentechnik GmbH & Co. KG. “Für Ideen, deren Zukunft im Detail steckt, sind wir der richtige Ansprechpartner.” https://www.graebener.com/de/unternehmen (accessed Nov. 16, 2022).

Contact

Dr.-Ing. Marc Patzwald
Technology Management
Phone +49 241 8904-159
marc.patzwald@ipt.fraunhofer.de

Fraunhofer Institute for
Production Technology IPT
Steinbachstrasse 17
52074 Aachen
Germany
www.ipt.fraunhofer.de

DOI: 10.24406/publica-468