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The importance of regional value creation structures in the battery industry

Tie-in and transfer potential for the battery ecosystem with regional economic structures in Germany and Europe

Publication of the accompanying research on battery cell production on behalf of the German Federal Ministry for Economic Affairs and Climate Action

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Steinplatz 1
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Authors
Mischa Bechberger
Jan-Hinrich Gieschen
Arno Spreen
Frauke Bierau-Delpont
Stefan Wolf

Editor
Sandra Gensch
Mira Maschke

Layout
VDI/VDE-IT, Anne-Sophie Piehl

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LIST OF ABBREVIATIONS

ACOD	Automotive Cluster Ostdeutschland (German: Automotive Cluster Eastern Germany)
ANEFA	Asociación Nacional de Empresarios Fabricantes de Áridos
BEPA	Batteries European Partnership Association
BEV	Battery Electric Vehicle (German: [batterie-elektrisch betriebenes] Elektrofahrzeug)
BFC	Bourgogne-Franche-Comté (region)
BMBF	Federal Ministry of Education and Research (German: Bundesministerium für Bildung und Forschung)
BMWi	Federal Ministry for Economic Affairs and Energy (German: Bundesministerium für Wirtschaft und Energie)
BMWK	Federal Ministry for Economic Affairs and Climate Action (German: Bundesministerium für Wirtschaft und Klimaschutz)
BTU	Brandenburg University of Technology (German: Brandenburgische Technische Universität)
BZF	Battery cell manufacturing (German: Batteriezellfertigung)
CI	Cluster Initiative
CMO	Cluster Management Organisation
CPC	Customized Precision Components
DBSCAN	Density-Based Spatial Clustering of Applications with Noise
DESAF	Deutsche Eisenbahn Service AG
EBA	European Battery Alliance
ECPE	European Center for Power Electronics
EEG	Renewable Energies Act (German: Erneuerbare-Energien-Gesetz)
ERDF	European Regional Development Fund
ESCA	European Secretary for Cluster Analysis
ETIP	European Technology and Innovation Platform
FFB	Fraunhofer Research Institution for Battery Cell Production FFB (German: Forschungsfertigung Batteriezelle)
GBA	Global Battery Alliance
GWh/a	Gigawatt hour per ampere
ICT	Information and Communication Technologies
IPCEI	Important Projects of Common European Interest
KfW	Reconstruction Loan Corporation (German: Kreditanstalt für Wiederaufbau)
KLiB	Kompetenznetzwerk Lithium-Ionen Batterien e.V.
Li-Ion	Lithium-Ion

LNF	Light commercial vehicles (German: Leichte Nutzfahrzeuge)
MCU	Micro Control Unit (microcontroller)
NEB	Niederbarnimer Eisenbahn
OEM	Original Equipment Manufacturer
OLEC	Oldenburger Energiecluster
OWL	OstWestfalenLippe
PV	Photovoltaics
R&D	Research and Development
RDI	Research, Development and Innovation
RIS3	Regional research and innovation strategies for smart specialisation
RWTH	RWTH Aachen University (German: Rheinisch-Westfälische Technische Hochschule)
SET Plan	Strategy plan for Energy Technology
SME	Small and Medium-sized Enterprises
SNF	Heavy commercial vehicles (German: Schwere Nutzfahrzeuge)
SPIN	Spitzencluster für industrielle Innovationen e.V.
VITO	Vlaamse Instelling voor Technologisch Onderzoek
WSK	Value chain (German: Wertschöpfungskette)

EXECUTIVE SUMMARY

A prominent success factor for the sustainable development of a new industry and its lasting incorporation in the innovation system is for its stakeholders to tie in with existing economic structures and networks, thereby gaining a foothold in the innovation landscape and realising potential synergies with its established stakeholders and organisations.

Regional proximity often proves to be a success factor for economic cooperation. Cluster initiatives in particular are examined in this report. Their potential for supporting the sustainable development of the battery industry in Germany and Europe is examined. On the one hand, clusters as regional network structures can offer good opportunities for tying in with a region's stakeholders and – due to their thematic focus – with potential relevant cooperation partners. On the other hand, clusters are key innovation stakeholders and make a decisive contribution to the intra-regional and inter-regional transfer of knowledge and technology.

This is important for the battery industry, which has existing transfer potential with numerous established industry sectors regarding the materials processed and the production facilities or processes used by them, or due to the use of the battery as an application in an industry sector. For the new, developing battery ecosystem, it turns out that the automotive sector, on its way to transforming in the direction of electromobility, constitutes the leading driving force at this time. Apart from that, an important relationship with the energy sector is ongoing, where the battery plays a growing role for energy storage.

The **objectives** of this study are to show:

- How the sustainable development of the battery industry in Germany and Europe can be realised successfully.
- What possibilities are relevant for stakeholders in the battery ecosystem to gain a foothold in the innovation system and in established economic structures in Germany and Europe.
- What industry sectors and regions offer transfer potential for the battery industry, and therefore tie-in potential for stakeholders in the battery ecosystem.

Key results of the study

… with regard to the relevance of regional anchoring for the lasting competitiveness of the battery industry:

- Strategic site planning and vertical integration of battery manufacturers along the value chain are of essential importance for the lasting success of the battery industry.
- "Classic" industry sectors, in particular the chemicals industry as well as machine building and plant construction, are important partners for the success of the battery industry.
- Additional industry sectors with technology transfer potential for the battery industry are, in particular, the packaging industry, electronics sector, software development, the plastics industry and the energy sector.
- The prospects of success for the in part politically promoted development of battery cell manufacturing in Germany and Europe can be improved by learning from other industrial policy funding initiatives to establish innovative technology sectors.

… with regard to the contribution of cluster initiatives and regional business development to the lasting incorporation of the battery industry:

- Industry-specific and technology-oriented regional cluster initiatives are key stakeholders in the innovation ecosystem, also in the context of the battery industry.
- Cluster initiatives are key innovation stakeholders and make a decisive contribution to the intra-regional and inter-regional transfer of knowledge and technology.
- Cluster initiatives are important supporters for training and continuing education, internationalisation, start-ups, spin-offs and cross-cluster cooperation.
- Regional research and innovation strategies for smart specialisation (RIS3) help with the identification of existing regional value creation structures and cluster initiatives in the field of battery cell manufacturing.
- Business development should provide more support for transformation capabilities. Focal points should include establishing resilient structures, knowledge orientation, cooperation and improving flexibility and agility.

- Linking cluster and industrial policies supports an effective response to the respective regional framework, stakeholders, development paths and speeds, and existing industry specifics.

… with regard to opportunities for the regional networking of the battery industry:

- The automobile industry is the driving force for the development of the battery ecosystem. Batteries tend to play a subordinate role in other industry sectors.
- Cluster organisations constitute an important link for the networking of the battery ecosystem. Based on the data examined in this study, memberships in cluster organisations account for more than 70% of the connections between all stakeholders in the battery ecosystem.
- Clearly defined focal regions with a high concentration of companies in the battery ecosystem are forming in Europe. A particularly dense concentration is forming in the “Blue Banana” region in Germany and Europe. A second strong concentration is forming from Brandenburg and Saxony via southern Poland to Hungary.
- The regions in Germany and Europe with agglomerations of highly networked stakeholders improve the chances of the lasting incorporation of battery cell manufacturing.

MOTIVATION AND OBJECTIVE

Energy storage plays an ever-increasing role in the course of the energy, transport and industry transformation and the associated rapid renewable energy expansion. The Federal Ministry for Economic Affairs and Climate Action (BMWK) in cooperation with the European Commission and other European member states has been funding the development of industrial battery cell manufacturing in Europe since 2019 through Important Projects of Common European Interest (IPCEI).[1] The political objective of this funding is to increase the proportion of battery cells produced in Europe in relation to worldwide production to 30 per cent by 2030. Currently the European market for battery cells is already developing rapidly and has great growth potential. The production capacities for battery cells manufactured in Europe should be 30 times greater by 2030 compared to 2020.

Reaching these goals requires the lasting incorporation of the battery cell manufacturing ecosystem, comprising all stakeholders in research, development and industry as well as the structures and partnerships connecting them,[2] in Europe's regional economic structures. This study attempts to answer the questions of how to firmly establish the battery industry in Germany and Europe and how to integrate ecosystem stakeholders in regional networks as effectively as possible, so that they grow to become an integral part of the innovation system. The ecosystem is intended to maintain its established place even after the public funding initiatives end. This study examines how sustainable development can be supported from both a political and market economy perspective, and what criteria industry decision makers should consider in the search for a suitable location to establish a site in Germany and Europe.

Thus one goal of this study is to identify opportunities for tying in battery ecosystem stakeholders with existing regional economic structures and stakeholder networks. Cluster initiatives and other battery-related industry initiatives play a major role here. Against this background, the study examines regions in Germany and Europe that already constitute focal points of the battery ecosystem's industrial development. As a rule, such regions already have numerous stakeholders, some of whom are also well networked with other relevant stakeholders, so that the potential for tying in with existing local network infrastructures is high when establishing operations in these regions. Regions that have explicitly identified the battery sector as a development goal and (proactively) support the establishment of battery industry stakeholders are highlighted as well. Emphasis is placed on examining the potential of clusters and on the question of how existing, excellent cluster initiatives can be included in strengthening the battery ecosystem and associated industry sectors. The resulting findings regarding the realisation of cluster potential primarily help political decision makers in designing their local industrial policies and funding instruments.

Industries with technology transfer potential that may represent strong partners for the battery industry are also examined in the study. The battery cell manufacturing value chain does not generally represent a field of application for such partner sectors at this time. Findings regarding transfer potential, also in fields of application that are far removed from batteries, may serve as a starting point for decision makers in the industry for the development of new business opportunities or the further development of value chains. Existing regional innovation and economic structures as well as development strategies are important indicators of potential sites for stakeholders in the battery ecosystem.

Figure 1 illustrates the study design. An overview of the industrial battery ecosystem is provided first. Its structural design, the expected market growth and the associated industry projects as well as the various funding initiatives at the federal and European level along with European and international networking are described. This is followed by a description of the cluster concept. Here the key functions of cluster initiatives for innovation and technology transfer are identified. Certain German and European regions that already have clusters with a focus relevant for the battery industry are also described as examples. Approaches for the regional incorporation of the battery industry are then explained. Conditions that favour the battery industry are discussed along with industry sectors with relevant technology transfer potential and similar examples of industrial policy support for attempts to establish innovative industry sectors.

This section is followed by an examination of the existing battery ecosystem on the basis of a data-based network analysis. Ecosystem stakeholders are identified by way of research or economic activities, geographically located, assigned to certain stages of the battery value chain and finally, their links to other stakeholders are analysed. The

1 Federal Ministry of Economic Affairs and Climate Action (BMWK): battery cell production; Federal Ministry of Economic Affairs and Climate Action (BMWK): Battery cell funding

2 Gieschen et al. (2021).

networking of stakeholders with relevant associations, initiatives and cluster initiatives is examined as well.

This report examines key questions such as:

- Where are important battery industry stakeholders located in Germany and Europe?
- Where are the (research) focal points of the battery industry?
- Are there existing regional network structures that battery cell manufacturing can tie into?
- What industry sectors harbour transfer potential for the battery industry?
- In what research topics are German stakeholders the most active?
- What groups of stakeholders are the most involved in battery cell manufacturing?
- Are there existing regional specialisations indicative of a presence of clusters?

The geographic distributions of the stakeholders in Germany and Europe are examined here, and regional ecosystem focal points are identified. Such regions either exhibit an above-average number of (well networked) stakeholders in the battery ecosystem or from industry sectors with a high transfer potential, or address battery cell manufacturing with its strategic economic development goals . Thus they offer high tie-in potential and better prospects of success for battery ecosystem stakeholders that establish themselves there. Furthermore, the study explains which stakeholders are active in the respective sections of the battery value chain, and which ones are particularly well networked already – either through membership in associations, networks, initiatives or cluster initiatives with battery relevance, or through research partnerships.

In particular, the extent to which cluster initiatives can support the development and regional incorporation of the battery ecosystem is examined. Trends in regional business development as well as possibilities for linking cluster and industrial policies for the successful regional incorporation and networking of the battery industry are described. The study concludes with recommendations for decision makers in the battery industry and politics as well as regional organisations, including business development and cluster initiatives.

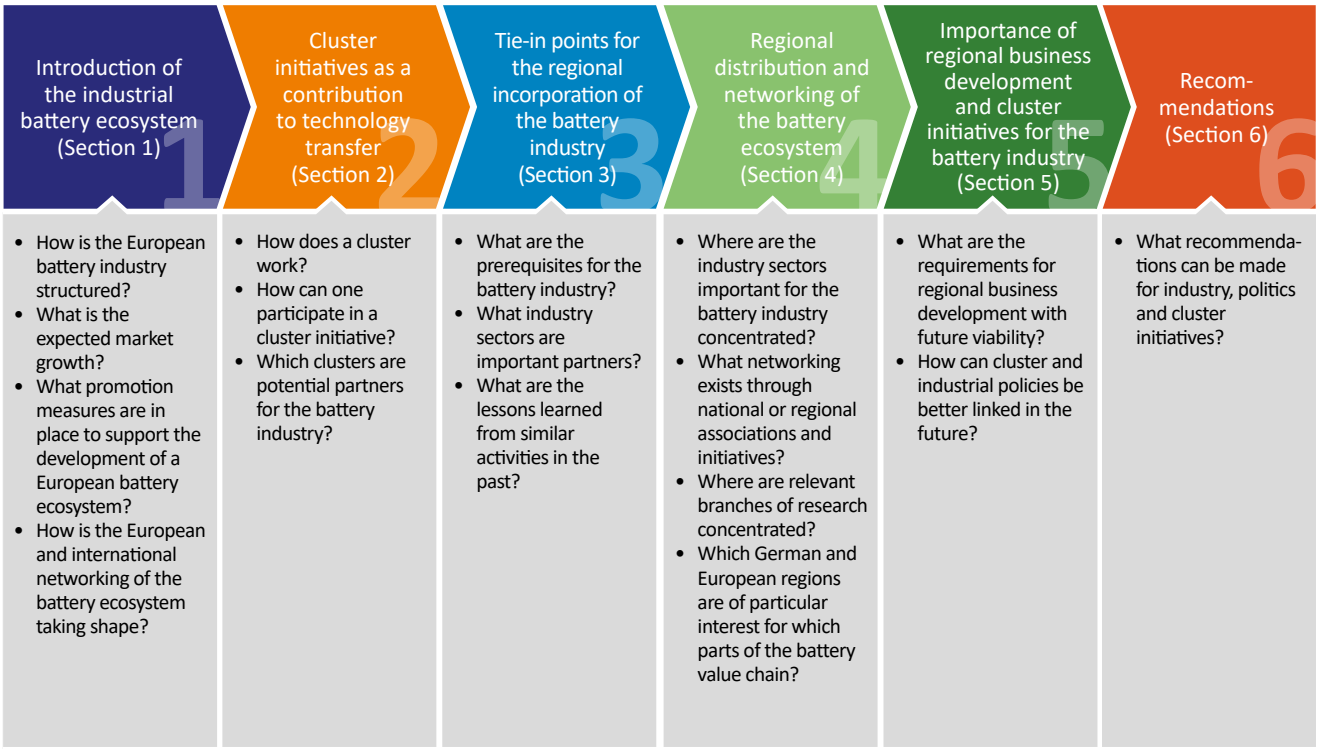


Figure 1: Design and structure of the study

1 BACKGROUND OF THE INDUSTRIAL BATTERY ECOSYSTEM

Key findings

- The European **demand** for battery cells is **growing by a factor of 15 by 2030** compared to 2020.
- To date, battery cell production is mainly in the hands of Asian manufacturers (especially in China) and only a (very) small part that does not cover the European demand currently comes from Europe.
- Thus there is a long-standing "(capital) market failure" with regard to establishing a battery industry in Europe.
- Aside from ambitious climate protection goals, developing a European battery industry is mainly stimulated through **dedicated funding initiatives**.
- This is intended to alleviate the "market failure" to date and help catch up with Asian and other competitors outside Europe.
- Two Important Projects of Common European Interest (**IPCEI**) in the area of battery cell manufacturing form the **industrial nucleus of the funding**.
- Market stimulation effects are being felt: **Production capacities in Europe** are expected **to increase by a factor of up to 30 by 2030** compared to 2020.
- The **private sector** is participating in the development and expansion of a European battery ecosystem with **own investments in excess of 67 billion euros** by 2030.
- Thus the demand for battery cells is expected to be covered by European production.
- Additional important, **accompanying funding initiatives** to solidify the industrial nucleus for the battery ecosystem exist on the part of the **BMWK and BMBF**.
- **Numerous European and international initiatives** contribute to the networking of relevant stakeholders and the development of an intact and sustainable battery value creation chain in Europe.

1.1 Development of the European battery industry

Back in 2017, the then newly-founded European Battery Alliance (EBA) set the goal that one-third of the global market demand for electric vehicle batteries would be manufactured, sold and exported by Europe by the year 2030. The EBA estimates the market potential for electric vehicle batteries manufactured in Europe at up to 250 billion euros annually by the mid-2020s (BMWK 2022; EBA)[3 4]. Investments of more than 67 billion euros (announced) are already expected today.[5] This is motivated in particular by the worldwide and, initially especially in China, rapid increase in demand for electric vehicles as well as political support, especially in the form of the ambitious EU climate targets. They result in emission reduction requirements for the European automobile industry. Not only will the demand for electric vehicles and therefore battery cells grow considerably in Europe as well, but there will be a massive development and expansion of European production capacities for Li-Ion cells as a consequence as well.

To meet the target of the new EU climate package "Fit for 55" published by the EU Commission in July 2021 to reduce the EU's total greenhouse gas emissions by at least 55% by 2030 compared to 1990, the CO_2 emission standards for passenger vehicles and light commercial vehicles are to be tightened so that the average CO_2 emissions of new vehicles are 55% lower starting in 2030 and 100% lower starting in 2035 compared to 2021. For the automobile industry, this means that emission-free vehicles must make up a large proportion of production, by 2030 and that all passenger vehicles and light commercial vehicles produced for the European Single Market have to be emission-free by 2035. Some EU member states (Sweden, Austria, Greece, Denmark and the Netherlands) and various European automobile manufacturers (including Audi, Daimler, Volvo and Renault) have set even more ambitious goals and want to prohibit the

3 European Battery Alliance (EBA).

4 Federal Ministry of Economic Affairs and Climate Action (BMWK).

5 Beermann, Vorholt (2022).

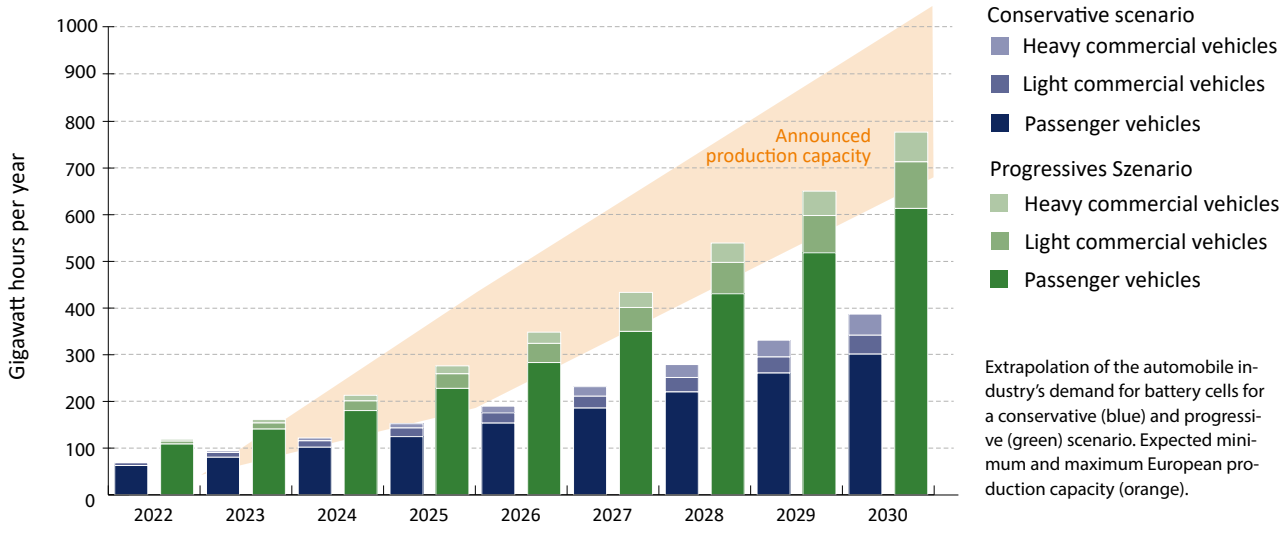
registration of passenger vehicles with combustion engines or stop their production even before 2035.[6]

Strong growth in the battery market

The European demand for battery cells for vehicles with battery electric drive systems (passenger vehicles, light commercial vehicles and heavy commercial vehicles) will increase to 387 to 777 GWh/a by 2030. That corresponds to a production capacity increase by a factor of 10 to 15 compared to 2020. The production capacities for battery cells in Europe (EU-27, UK, Norway, Serbia) will increase from around 35 GWh/a in 2020 to 693 to 1,072 GWh/a in 2030. This corresponds to an increase by a factor of up to 30. If the planned production capacities in Europe are realised, the European demand for battery cells is expected to be covered by production within Europe by 2030.[7] Overall about 27% of the projected global production volume for Li-Ion cells in the year 2030 is expected to be covered by these capacities.

For better visualisation, Figure 2 compares the expected demand of the European automobile industry for battery cells by 2030 with the production capacities announced in Europe up to that time. Furthermore, Figure 3 Politecnico di Torino illustrates the ambitious development and expansion plans of the battery industry in Europe, respectively listing the production start dates, planned capacities per year, investment volumes and jobs associated with the gigafactories. Stimulated by government funding (see Section 1.2), this is associated on the whole with significant, in particular private investments in the European battery value chain of more than 67 billion euros by 2030, of which investments in battery cell manufacturing alone account for more than 56 billion euros. More than 58,000 jobs are to be created as a result, with over 47,000 of them in battery cell manufacturing (Beermann, Vorholt, 2022).

Announced European battery cell production capacities compared to modelled battery cell demand in European until 2030



Extrapolation of the automobile industry's demand for battery cells for a conservative (blue) and progressive (green) scenario. Expected minimum and maximum European production capacity (orange).

With numerous, mostly highly ambitious announcements, uncertainties exist with regard to their implementation, especially after 2025. Therefore, the production capacities are presented in a minimum and a maximum view. Furthermore, it was assumed that all manufacturer announcements are maximum figures, and that the cell factories will obtain a utilisation of 85% and a yield of 90% in practice.

Figure 2: Announced battery production capacities in Europe by 2030. Source: Beermann, Vorholt 2022

6 Beermann, Vorholt (2021).

7 Beermann, Vorholt (2022).

1.2 Funding the industrial battery ecosystem

The strong growth in demand for battery cells in Europe and the associated, considerable development and expansion of a German and European battery industry is stimulated in particular by two closely interrelated factors. Firstly, by ambitious (EU) climate targets and the resulting emission reduction requirements (see section 1.1) and secondly, by innovation support measures in the form of corresponding industrial policy funding activities. With regard to the latter, the federal government via the BMWK is pursuing an ecosystem approach:

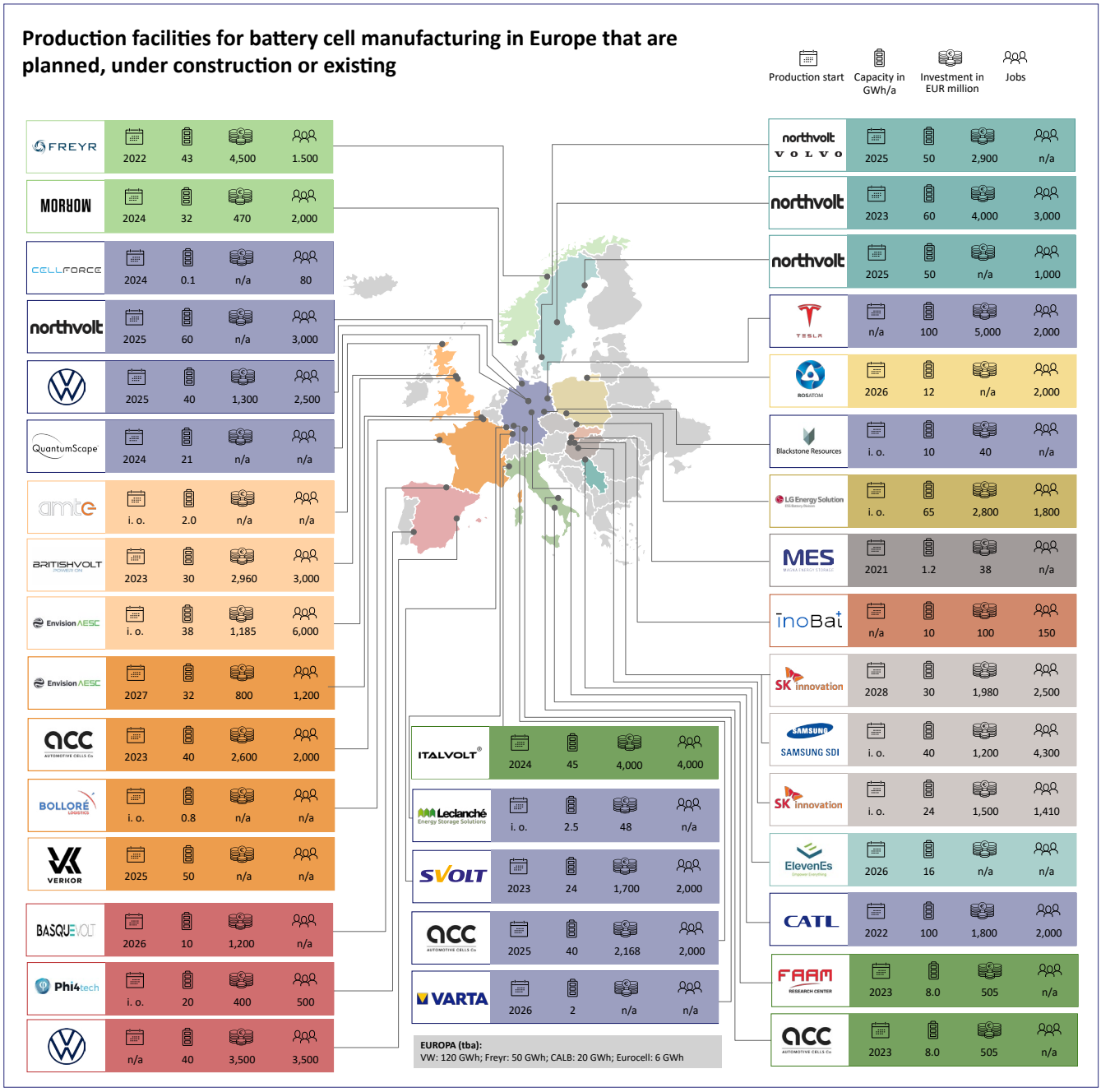


Figure 3: Battery cell manufacturing production facilities in Europe. Source: Beermann, Vorholt 2022.

Battery IPCEIs – supporting the development of a European battery industry

Two important projects of common European interest (IPCEIs) in the field of battery cell manufacturing that form the industrial nucleus of the battery value chain and the focal point of BMWK funding take centre stage in the funding initiative. Stimulating European battery cell manufacturing is the motivation behind the IPCEI funding. This is because sustainably produced batteries are a supporting pillar of the European Green Deal to make the EU climate-neutral by 2050, since they contribute to the decarbonisation of transportation and to the better usability of renewable energy sources.

The goal of being climate neutral requires technological innovations in the battery value chain, which will make Europe a world leader. While the demand for electric vehicles, including the traction batteries they require, has been growing continuously for years, the corresponding production of batteries has been largely concentrated in Asia (in particular China) to date. The IPCEI battery projects are large-scale industrialisation projects combining a total of more than 9 billion euros of private investments in considerably more than 100 GWh of battery production capacities and creating around 18,000 new jobs[8]. These projects form the critical mass of a newly emerging battery industry and serve as seed crystals, both for the landscape of the research institutions and for the suppliers and customers.

Beyond the IPCEIs – which for their part are expected to generate spillover effects and activities – it is also important to network the research and business landscape in order to best support the IPCEIs with regard to innovation, skilled workers and supplier and customer integration, but also in order to introduce as many more companies and research institutions as possible in the battery sector to industrial applications. The BMWK has also recognised this objective and launched corresponding funding initiatives to accompany the IPCEIs. This is intended to stimulate the expanded battery ecosystem in particular.

Accompanying measures: Funding the battery ecosystem

To this end, the BMWK has launched two funding initiatives to accompany the two battery IPCEIs. The first is the call for proposals "Research in battery cell manufacturing priority funding" initiated within the federal government's 7th energy research programme. With a volume of up to 180 million euros, it is intended to fund the innovation base along the battery value chain (from raw materials through all intermediate and supplier products to system integration and subsequent recycling) to support the industrial production of battery cells of the highest quality in Germany. The second is the "Guideline for the funding of qualification measures for battery cell manufacturing[9]", intended to contribute to improved networking and cooperation between the participating stakeholders in science, education, society and industry.

The goal of the funding guideline is to support efficient and innovative solutions for the planning and coordination of occupational qualification for jobs along the battery value chain, and to implement corresponding continuing education measures. This aims to cover the projected, tremendous demand for (highly specialised) skilled workers within the rapidly growing German and European battery industry in the next few years, and to offer viable future prospects for workers in the internal combustion engine value chain and related jobs. The establishment and networking of a prospering and innovative European battery ecosystem is also supported by the accompanying research commissioned by the BMWK with the three pillars of knowledge transfer (in the form of conferences, the preparation of studies, technical papers etc.), community building (including networking events, a LinkedIn group, international cooperation etc.) and stakeholder dialogue (including live talks and multidisciplinary working groups).[10] [11]

Further funding initiatives of the BMBF

Aside from the BMWK, the battery ecosystem in Germany is also supported by the federal government through the funding activities of the BMBF, especially in the area of fundamental research. This includes funding under the

8 European Commission (2021).

9 Federal Ministry of Economic Affairs and Energy (BMWi) (2021).

10 Federal Ministry of Economic Affairs and Climate Action (BMWK) (2022).

11 Federal Ministry of Economic Affairs and Climate Action (BMWK) (2021).

"Battery research institution" umbrella concept[12] with the three modules of "Materials", "Cell and processes" and "Battery cell manufacturing" – here in particular the ongoing financing of the Fraunhofer Research Institution for Battery Cell Production FFB in Münster and (financial) support for the establishment of the new battery competence clusters (Cluster of Competence for Intelligent Battery Cell Production (InZePro), Competence Cluster Recycling & Green Battery (greenBatt), Competence Cluster Battery Utilization Concepts (BattNutzung), Battery Competence Cluster Analytics / Quality Assurance (AQua), Cluster of Competence for Solid-state Batteries (FestBatt) and Cluster of Competence for Battery Materials (ExcellBattMat).[13]

The various activities that support or accompany the development and expansion of a European battery ecosystem are illustrated in Figure 4.

European and international networking

Beyond the IPCEIs described above and the accompanying national funding initiatives, numerous European and international initiatives also contribute to the networking of relevant stakeholders and to the development of intact and sustainable battery value creation in Europe. This European innovation system is differentiated among numerous institutions according to tasks. Figure 5 and the sections that follow explain the institutions and their roles in more detail.

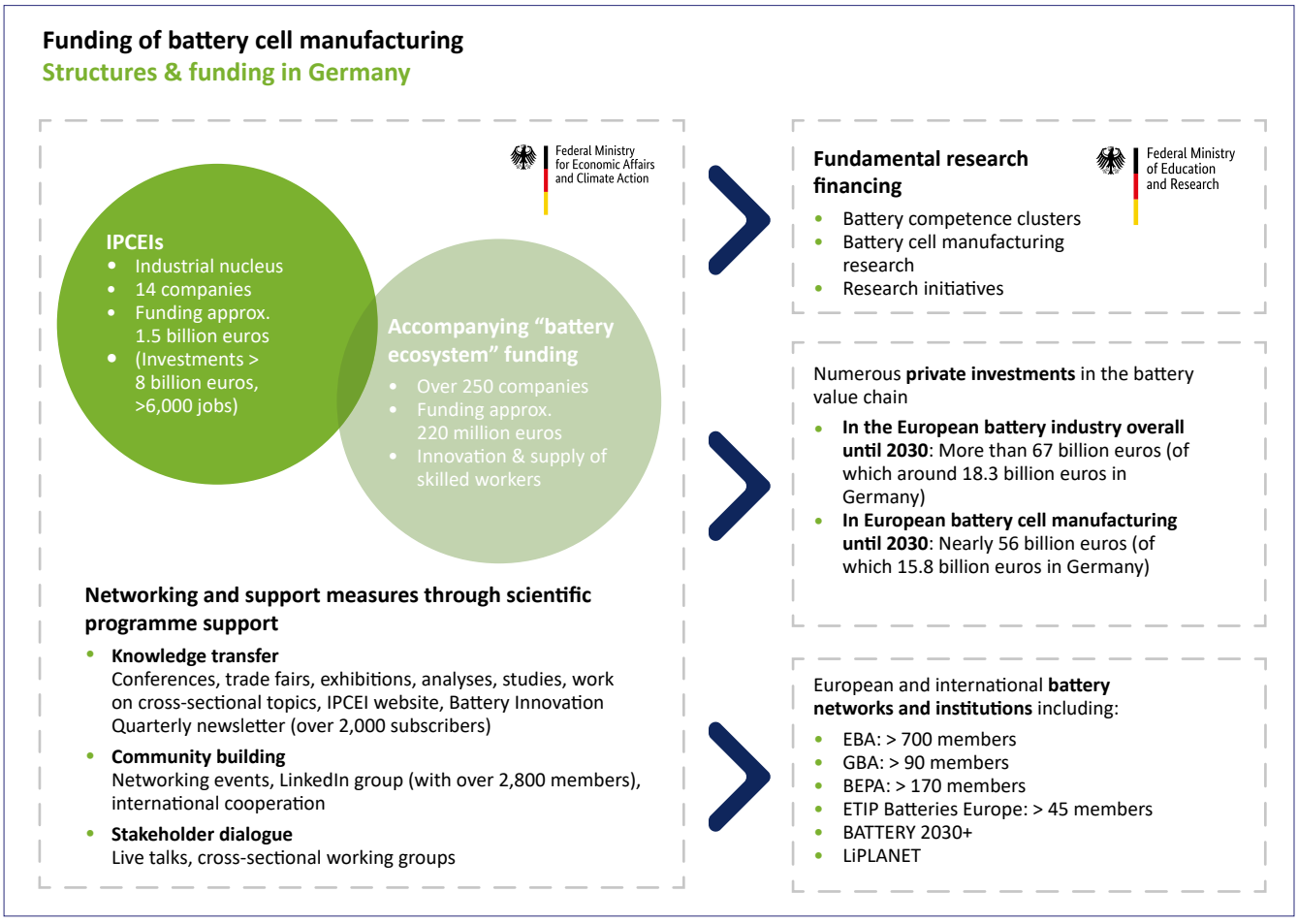


Figure 4: IPCEI accompanying measures (source: In-house representation)

12 Federal Ministry of Education and Research (BMBF).

13 Batterie-Kompetenzcluster.

The European Battery Alliance (EBA) is a central stakeholder connecting numerous stakeholders in science, industry and politics with the goal of developing and establishing a sustainable and competitive battery value chain in Europe. The EBA co-initiated many of the institutions listed in Figure 5. Most recently the EBA Academy was launched to develop and offer demand-oriented training and continuing education programmes, study programmes and teaching materials on battery topics in cooperation with numerous EBA partners.[14] The EBA also provides the Business Investment Platform to facilitate investments in European battery projects, speed up transactions between companies and investors, and reduce the investment risks for both sides.[15]

The European Technology and Innovation Platform on Batteries (ETIP Batteries Europe) is the central European think tank for battery innovations. This platform works hand in hand with an open community of European battery experts on review reports on the status quo of battery research at the European and international levels. It also conducts explorative evaluations of future research and innovation needs in working groups, thereby laying the foundation for the European battery research strategy. Batteries Europe aims to speed up the development of a globally competitive European battery industry by driving the implementation of battery-specific research and innovation measures of the Strategy Plan for Energy Technology (SET Plan) and the strategic research and innovation agenda for transportation.[16]

The coordination and support action "Battery 2030+" accompanies and networks European fundamental battery research projects. Thus it plays an important role for academic research and drives the research and development of new battery technologies from a medium to long-term perspective.[17]

The Batteries European Partnership Association (BEPA) in cooperation with ETIP Batteries Europe coordinates the preparation of the European battery research strategy. It also implements this strategy in concrete calls for research proposals for the Horizon Europe research programme

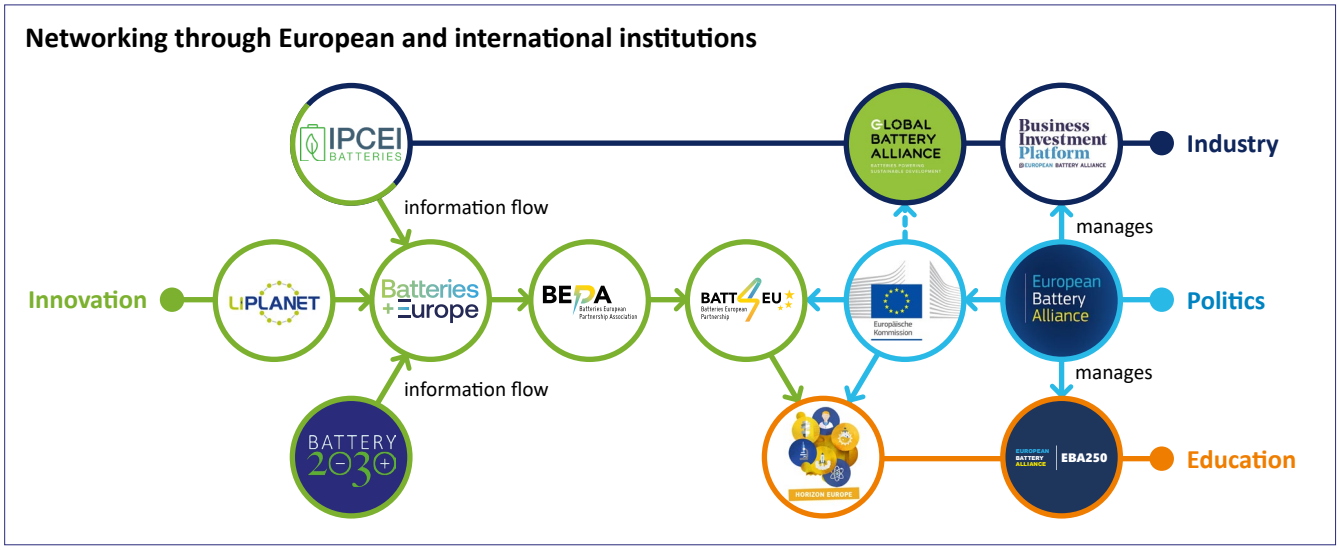


Figure 5: European and international networking within the battery ecosystem: European networks in the areas of innovation, industry, politics and education (source: In-house representation)

14 See: European Battery Alliance (EBA).

15 See: Business Investment Platform.

16 See: Batteries Europe.

17 See: Battery 2030+.

under the co-programmed partnership Batt4EU with the European Commission. The BEPA is an international non-profit organisation representing the interests of companies, research institutions and other private stakeholders in Batt4EU. Advising the European Commission in setting priorities for research and innovation activities and the definition of proposal topics for the work programmes of Horizon Europe is the BEPA's main task.[18]

The LiPLANET network of the European battery pilot lines is another important stakeholder for networking the European battery value chain. LiPLANET sees itself as a point of contact for piloting new battery and production technologies. Initially funded by the European Commission, the network has now been transferred to an association and continues to drive the networking of European pilot lines for Li-Ion cells and the leading associated institutions.[19]

The Global Battery Alliance (GBA) is a consortium of industry, NGO and government organisation representatives driving the development of the "Battery Passport". This is a type of digital twin of a battery that collects information along the entire supply chain. It is intended for the secure, non-discriminatory and transparent exchange of data between the stakeholders along the battery supply chain.[20] The GBA aims to prepare rules and standards for the measurement, collection and processing of battery indicators. Introducing a Battery Passport is part of the new EU Batteries Regulation.[21]

18 See: Batteries European Partnership Association (BEPA).

19 See: LiPLANET.

20 See: Global Battery Alliance (GBA).

21 Proposal for a Regulation of the European Parliament and of the Council (2020).

2 EUROPEAN AND GERMAN CLUSTER INITIATIVES CONTRIBUTE TO TECHNOLOGY TRANSFER

Key findings

- **Cluster initiatives** are **key innovation stakeholders** and make a decisive contribution to the intra-regional and inter-regional transfer of knowledge and technology.
- **Cluster initiatives are important supporters** for training and continuing education, internationalisation, start-ups, spin-offs and cross-cluster cooperation.
- Regional research and innovation strategies for smart specialisation (RIS3) help with the **identification of existing regional value creation structures and cluster initiatives** in the field of battery cell manufacturing.

Cluster initiatives[22] and the cluster stakeholders involved in them are essential, key innovation stakeholders, making a significant contribution to technology transfer in numerous branches of industry. Nearly all industries and industry sectors in Europe and Germany therefore have science/industry cooperation alliances called cluster initiatives. Cluster initiatives already play an important role in the battery industry as well (see Section 2.2). Two main development trends are discernible here: On the one hand, the topic of battery cell manufacturing is promoted from within existing cluster initiatives and, on the other hand, it forms the basis for new regional cluster structures.

It is a fact that the regional proximity of companies and academic/non-academic research institutions has a very positive mutual effect, increasing cooperation between them and thereby intensifying innovation and boosting competitiveness.[23] Due to the binding, long-term nature of regional partnerships with a strong bond of trust between the stakeholders, the existing competencies can be used very effectively and new topics can be implemented more quickly.

2.1 Cluster concept in brief: What's behind it

Germany and Europe have numerous regional and sectoral cluster initiatives. At the European level, the European Cluster Collaboration Platform[24] illustrates the high number of cluster initiatives. In Germany, the "Clusterplattform Deutschland"[25] as the joint information portal on cluster policy and cluster initiatives of the Federal Ministry for Economic Affairs and Climate Action (BMWK) and the Federal Ministry of Education and Research (BMBF) lists more than 430 regional cluster initiatives distributed across all federal states.

The term "cluster" in the economic sense was coined by Michael E. Porter, who defines a cluster as a "geographic concentration of companies, specialised suppliers/vendors, service providers, companies in related sectors and related institutions (e.g. universities, standardisation institutes and industry bodies), who are connected to each other in certain fields and simultaneously compete and cooperate with each other"[26]. Intensive cooperation among the stakeholders over many years leads to the emergence of what are called

22 In the literature as well as scientific and political discourse, various concepts are found in the cluster context that are in part used synonymously or only differentiated by small definition nuances. Aside from the "cluster" concept according to Michael E. Porter as an umbrella category for the geographic concentration of connected companies and institutions in related sectors, complementing each other through joint exchange relationships and activities along one or more value chains, these include "regional cluster initiatives", "regional networks" and "cluster networks" for intensive, usually institutionalised scientific/economic cooperation. In the interest of uniformity, this study uses the terms "cluster", "cluster initiative" and "cluster management organisation".

23 Künzel et al. (2019).

24 See: European Cluster Collaboration Platform.

25 See: Clusterplattform Deutschland.

26 See: Porter, Michael E. (1999).

Cluster initiatives
Cluster initiatives are regionally concentrated science/economic/cooperation alliances focusing on a shared topic. As a rule, they comprise the various stages of the value chain (vertical networking) and different sectors and disciplines (horizontal networking). Cluster initiatives are defined by intensive, goal-oriented interactions of the cluster stakeholders. Cooperation has a binding character and is aimed at sustainability and longer-term perspectives. Cluster initiatives have stable organisational structures, including participation elements such as working groups, focus groups, etc. and a management organisation. Thus they establish the framework for strategic, systematic and innovation-oriented cooperation relationships.

Cluster management organisations
Cluster management organisations are operational units with the goal of further developing the cluster initiative through strategic offers, projects etc. in addition to strengthening the competitiveness and innovativeness of regions and the established industry sectors.

Cluster stakeholders
Participants in a cluster initiative are called cluster stakeholders. As a rule, the entire value chain is covered or the stakeholders are integrated according to the quadruple innovation helix. They include academic and non-academic research institutions, companies of different sizes (number of employees) and different classifications (primary sector to quaternary sector), knowledge transfer and educational institutions, business development and regional development institutions, and clubs and associations.

regional cluster initiatives under the coordination of cluster management organisations.

A cluster-specific innovation process with various innovation stimulation measures, along with ongoing support for the cluster stakeholders with the identification of innovation topics, forms the core of cluster initiatives and constitutes a key success factor for accelerating innovation dynamics and technology transfer. This extends from initiating RDI project consortiums to implementing RDI projects to putting market-ready product, process and service innovations on the market. Participation formats geared toward the long term, such as working groups, focus groups, innovation circles etc. that focus on innovation topics and initiate joint RDI projects, are important for cooperation among and between the cluster stakeholders. Furthermore, joint RDI activities and the networking of science and industry are the central intention behind the establishment and long-term (further) development of regional cluster initiatives. [27]

2.2 Benefits for companies from participation in cluster initiatives

With the battery industry, a new industry sector is emerging in Europe. The simultaneous development of the entire value chain demands a great deal of communication, networking and regional integration. In order for this to succeed at the required speed, it is advisable for companies in the battery industry to utilise existing structures. Cluster initiatives are a good way to accomplish this. So how does a company or an academic or non-academic research institution find a suitable cluster initiative? While there is no direct route, various possibilities exist for taking action and approaching corresponding cluster initiatives:

1. Research on “Clusterplattform Deutschland” with an overview of more than 400 regional cluster initiatives in Germany.
2. Asking for recommendations from existing cooperation partners regarding regional cluster initiatives they are involved in and what the effects are.
3. Obtaining information about or getting in contact with business development institutions at the municipal, district or state level.

It is crucial for the success of a cluster that companies and research institutions get actively involved in cluster activities and openly communicate their topics and support needs. The greater the engagement, the greater the resulting benefits.

27 See: ibid page 14

Cluster initiative spheres of activity	Effects for the cluster stakeholders/cluster region
Internal networking and exchange of experiences	• Strengthening existing and initiating new contacts with business and R&D partners along the value chain • Strengthening existing and initiating new contacts with partners in administration and politics • Strengthening existing and initiating new contacts with partners in other associations and clubs (within the focus topic) • Strengthening existing and initiating new contacts with experts having other know-how • Transfer of knowledge on overarching topics, expansion of technical expertise
Innovation | Innovation-related measures	• Support throughout the innovation process • Participation in working groups and joint (further) development of topics • Identification of RDI topics, participation in project consortiums and implementation of RDI projects • Support with funding acquisition • Access to technical know-how and technical infrastructure • Participation in joint innovation hubs
Business development | Improving the entrepreneurial performance of cluster stakeholders	• Increasing turnover and profits • Increasing the number of innovative products, processes and services • Quality improvement of the product, process and service portfolio • Increasing productivity • Reducing the time-to-market • Increasing R&D spending (increasing the innovation intensity: R&D spending versus turnover) • Development of new business opportunities • Addressing new markets (with new products, processes and services)
Internationalisation	• Participation in international delegations and initial business contact trips • Support with the acquisition, initiation or implementation of international innovation projects (R&D and/or non-R&D) • Support for international market access
Training and continuing education | Qualification	• Joint development of training and continuing education measures • Participation in training and continuing education measures • Recruitment measures | Implementation of cluster-specific job portals • Participation in job fairs
Start-up support	• Consulting and coaching for potential start-ups • Support with the development of sound business models and business plans • Support with the acquisition of financing sources (risk capital, banks, public funds) • Conducting start-up competitions

Cluster initiative spheres of activity	Effects for the cluster stakeholders/cluster region
Visibility and external image improvement | Reputation	• Improving the image and reputation of the sector • Improving the image and reputation of the cluster stakeholders • Improving the image and reputation of the cluster region • Participation in joint exhibition stands at (trade) fairs

Table 1: Spheres of activity and added value of cluster initiatives; source: Institut für Innovation und Technik in der VDI/VDE Innovation + Technik GmbH (Cluster Impact Analysis)

2.3 Potential cluster partners for the battery industry

Numerous existing cluster initiatives offer tie-in potential for companies in the battery industry. This is true in particular for the electromobility and renewable energy sectors. Cluster initiatives with transfer potential regarding their production and manufacturing technologies are also relevant for the battery ecosystem.

RIS3 – tools for the identification of regional value creation structures and clusters in the area of battery cell manufacturing

Regional focal points of economic development and funding are described at the German and European level in the regional research and innovation strategies for smart specialisation (RIS3[28])[29]. The RIS3s in Germany that are most interesting for the purpose of this study are found, on the one hand, in the federal states with traditionally highly developed economic structures in the automobile industry, with a corresponding transfer potential for the battery value chain. On the other hand, these are RIS3s for regions where relevant battery cell manufacturing sites have been announced or are already being established. These are in particular the states of Baden-Württemberg, North Rhine-Westphalia, Lower Saxony and Saxony. Their RIS3s describe numerous focal points with direct and indirect links to batteries. This offers potential for the tie-in of the battery ecosystem and for synergies.

Selection of regional research and innovation strategies and clusters related to battery cell manufacturing

Baden-Württemberg's RIS3s refer in particular to the Electric Mobility South-West cluster with regard to relevant cluster initiatives in the field of battery cell manufacturing. This cluster has been coordinated since 2010 by the State Agency for New Mobility Solutions and Automotive Baden-Württemberg e-mobil BW GmbH. It currently has around 180 members from industry and research in the Baden-Württemberg region. The goal is to promote innovative mobility solutions and to strengthen Baden-Württemberg as an economic and scientific site. Currently the Electric Mobility South-West cluster is well positioned in the drive train field (electric motor, thermal management, power electronics, storage/batteries) and in testing and development. In the recycling economy field, the cluster is also driving the recycling of traction batteries, second-life applications and the design of recycling approaches.[30]

Lower Saxony's RIS3s primarily mention the Cluster Automotive Nordwest e. V,[31] 3N Kompetenzzentrum e.V.[32]

28 RIS3 = Regional innovation strategy for smart specialisation

29 All (271) European regions have developed (such) RIS3s, and they have been recently adapted to the term of the current period of the European Regional Development Fund (ERDF), (2021-2027).

30 See: Cluster Elektromobilität Süd-West.

31 See: Automotive Nordwest.

32 See: 3N Kompetenzzentrum.

and Oldenburger Energiecluster OLEC e.V.[33] regarding networks and cluster initiatives with battery relevance.[34]

With regard to relevant clusters related to battery cell manufacturing, North Rhine-Westphalia's RIS3 highlights the state cluster NanoMikroWerkstoffePhotonik.NRW. In particular, the cluster's technology fields of nanotechnology (for battery storage solutions) as well as innovative (raw) materials offer direct tie-in points for the battery ecosystem.[35] Beyond that, it's OWL – The Technology Network: Intelligent Technical Systems OstWestfalenLippe – offers areas of competence that are relevant for battery cell manufacturing, for example, with regard to the digital twin.[36]

Saxony is another federal state with a RIS3 offering numerous tie-in points for the topic of batteries in Germany. Among other things, Saxony's RIS3 emphasises the development of new value creation potential, for instance in the area of electromobility (battery and fuel cell electric).[37]

Access to the labour market and especially to the skilled workers urgently needed for the development of the battery ecosystem also plays an essential role. Supporting skilled workers through occupational qualification to acquire the necessary new skills is an important tool to ensure labour availability. With the goal of maintaining, upgrading and improving employability in the regional context, the BMWK recently issued a corresponding funding guideline.[38] To this end, battery competence networks comprised of industry-specific innovation clusters and educational and scientific institutions from various German regions have formed and applied for funding. In particular, a corresponding competence network is forming in the central Germany region (Saxony, Saxony-Anhalt and Thuringia) that, by devising and piloting appropriate qualification measures for skilled workers, can make an important contribution to intelligent specialisation and the regional incorporation of battery cell manufacturing in the region.

The clusters with the greatest relevance for battery cell manufacturing in Saxony are the Energy Saxony cluster, in particular with its Storage and Grid Services working group[39], and the Automotive Cluster Ostdeutschland (ACOD) with its competence cluster "Drive Systems/Electromobility" and, within that, especially the focus topics of linking battery development/manufacturing, cell assembly, vehicle integration, second-life applications and battery recycling.[40]

Aside from Germany's federal states, many European regions also deal with parts of the battery value chain in their current RIS3s. Within the scope of this study, regions that identify cooperation potential of existing cluster initiatives with German stakeholders of the battery value chain are of particular interest. These can, for example, be focal points on applications outside the passenger vehicle sector, potential synergies or complementary competence profiles.

Here the RIS3 of the French region Bourgogne-Franche-Comté (BFC) in middle western France stands out in particular. This French region is for instance home to PSA (now Stellantis) as an OEM with extensive experience in drive train electrification, Faurecia as a developer of battery packs and companies in the cell chemistry field (APERCAM and SOLVAY).

The most important cluster located in the BFC region in the field of battery cell manufacturing is the Véhicule du Futur cluster, with drive train electrification as one of its focal points along with topics such as mobility as a service, design, materials and recycling. It also has ties to the lithium-ion battery competence network "KLiB", the German reference cluster for Li-Ion batteries. This is reflected in particular by the organisation of the German-French forum for lithium-

33 See: Oldenburger Energiecluster (OLEC).

34 Lower Saxony Ministry for Federal and European Affairs and Regional Development (2020).

35 See: Landescluster NanoMikroWerkstoffePhotonik.NRW.

36 See: Technologienetzwerk Intelligente Technische Systeme OstWestfalenLippe – it`s OWL.

37 Saxony State Ministry for Economic Affairs, Labour and Transport (2020).

38 German Federal Gazette (2021).

39 See: Energy Saxony.

40 See: Automotive Cluster Ostdeutschland (ACOD).

ion batteries.[41] Véhicule du Futur also names the automotive clusters Automotive-bw and e-mobil bw in southern Germany as well as bayern-innovativ as German cluster partners.[42]

Similar to France, there are various federal states in Austria that mention different segments of the battery value chain as strategic competence and/or development fields in their RIS3s. The federal states of Upper Austria and Lower Austria are discussed here as examples. While Upper Austria's RIS3 focuses on the areas of lightweight construction/ sustainable materials (mainly fibre composite materials), life cycle assessment and the recycling economy with regard to topics with battery relevance,[43] the main topics of interest in Lower Austria's RIS3 are the identified strengths of additive manufacturing, big data and data security.[44] One of the most relevant clusters in reference to battery cell manufacturing in Austria is the Mechatronics Cluster, comprising the metal, mechanical engineering, electrical, electronics and ICT segments. The Mechatronics Cluster is a joint initiative of the federal states of Upper and Lower Austria, responsible among other things for Lower Austria's electromobility initiative "e-mobil in Niederösterreich".[45]

41 See: Région Bourgogne-Franche-Comté (2021).

42 See: Pôle Véhicule du futur.

43 See: Business Upper Austria (2020).

44 See: Land Niederösterreich (2021).

45 See: ecoplus (Niederösterreichs Wirtschaftsagentur GmbH).

3 RELEVANCE OF THE REGIONAL INCORPORATION OF THE BATTERY INDUSTRY FOR ITS LONG-TERM COMPETITIVENESS

Key findings

- **Strategic site planning** and **vertical integration** of battery manufacturers along the value chain are **important for the lasting success of the battery industry**.
- "Classic" industry sectors, in particular the **chemicals industry as well as machine building and plant construction**, are **important partners** for the success of the battery industry
- Additional **industry sectors with technology transfer potential** for the battery industry are, in particular, the **packaging industry, electronics sector, software development**, the **plastics industry** and the **energy sector**.
- The prospects of success for the in part politically promoted development of battery cell manufacturing in Germany and Europe can be improved by **learning from other industrial policy funding initiatives to establish innovative technology sectors.**

3.1 Conditions that favour the battery industry

A strategic innovation policy and, at the regional level, corresponding business development and innovation strategies are considered essential for the lasting incorporation of the battery industry in Germany. With the participation of regional cluster initiatives, focused RIS3s are to be developed and later also implemented, encompassing a successful tie-in of the battery ecosystem. Beyond that, strategic site planning and, where possible, vertical integration of battery manufacturers along the value chain are essential for the lasting success of the battery industry.

Strategic planning and selection of sites for the battery industry

In strategic site planning, one can differentiate between general, state and region-specific criteria that can often be assigned to the categories of market access, cost reduction and efficiency improvement, access to knowledge, competencies and technologies, and access to (scarce) resources.

With regard to the market access category, site factors such as market attractiveness, proximity to customers and proximity to or existence of leading markets play an important role. Concerning the motive of cost reduction and efficiency improvement, site factors such as personnel costs, productivity, automation and digitalisation are often in the foreground. When it comes to access to knowledge, competencies and technologies, factors such as the existence of industry-specific clusters and networks, (complete) local value chains, the availability of skilled workers and proximity to relevant research institutions are decisive. Access to resources includes access to (raw) materials and infrastructure in particular.[46]

Site factors using Tesla in Grünheide as an example

These categories can also be applied to the battery industry in Germany and Europe. By way of an example, this is explained on the basis of site selection for the first electric vehicle production facility constructed in the Berlin-Brandenburg region (Tesla's gigafactory) and battery cell manufacturing that is also planned in Grünheide, Brandenburg in the vicinity of Berlin. Here the following site factors in particular played an important role:

- Access to Germany's leading automotive industry market
- Availability of qualified workers
- High density of relevant research institutions
- Guaranteed access to an environmentally friendly energy supply thanks to Brandenburg's leading role in the use of renewable energy[47]

46 Kinkel (2019).

47 Currently most of the electricity and heat demand of Tesla's gigafactory in Grünheide is still covered by natural gas. However, the energy demand for production is to be covered by local and regional renewable energy sources to the greatest possible extent in the future. A photovoltaic system on the roof of the factory building will supply part of that. https://www.brandenburg.de/cms/detail.php/bb1.c.658136.de, last accessed on 16 June 2022.

- Infrastructure factors (motorway, (urban) railway link, proximity to the airport (BER), location at the intersection of the trans-European transport axes between Western and Eastern Europe). [48]

Note that these site factors also play an important role for the selection of other battery industry sites in Germany and Europe that are currently in the planning stage or under construction, and can insofar also be considered transferable.

It is true that Berlin, unlike classic German automobile regions such as Baden-Württemberg, Bavaria or Lower Saxony, does not have a comparable industrial core. Nonetheless, numerous companies in the automobile industry and related sectors have established themselves in and around Berlin, including production facilities of Daimler Truck and the Mercedes-Benz plant in Berlin, BMW Motorrad, Rolls-Royce aircraft engines, Stadler-Rail rail vehicle construction and Alstom (formerly Bombardier). In addition, there are

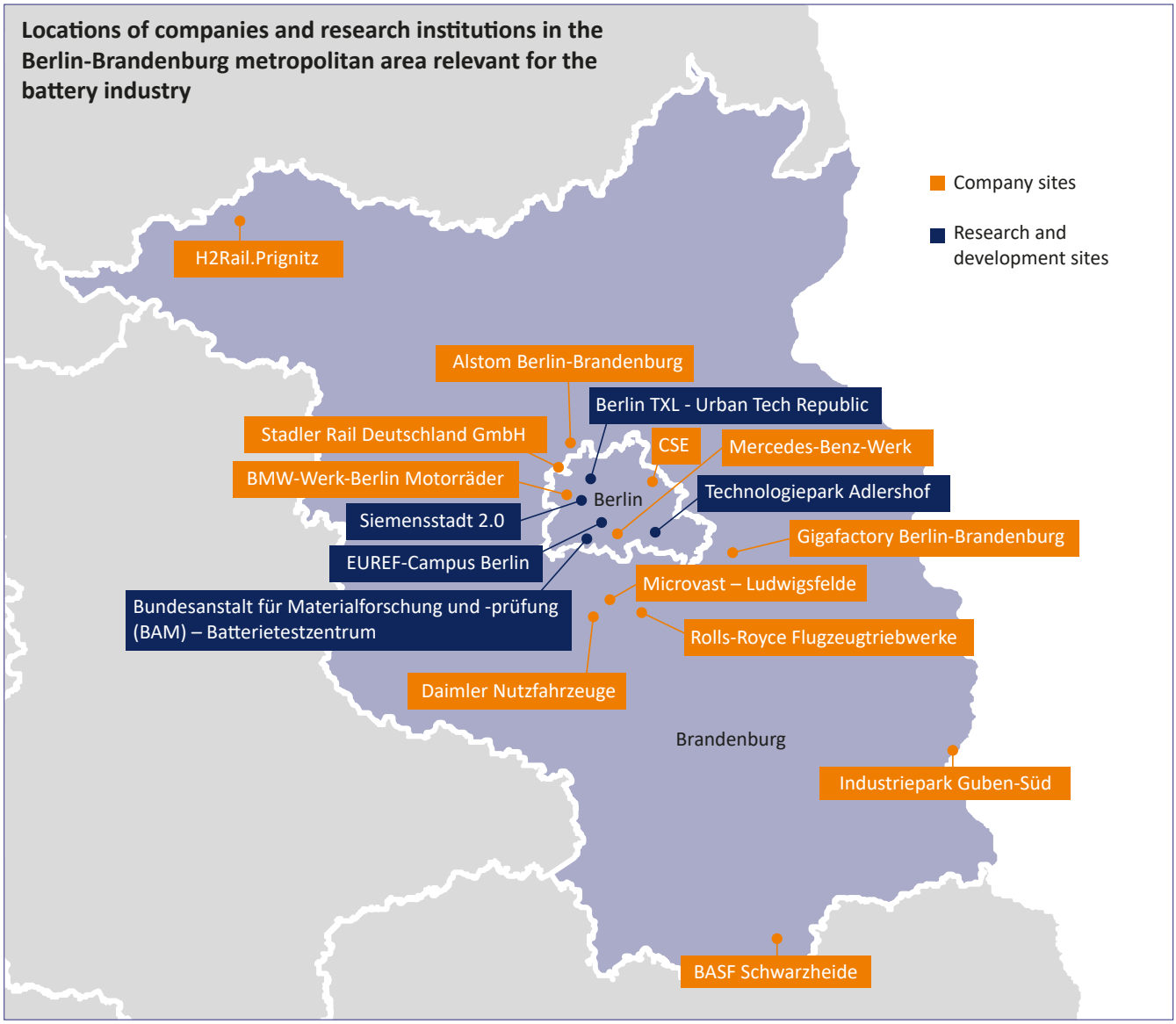


Figure 6: Locations of companies and research institutions in the Berlin-Brandenburg metropolitan area with relevance for the battery industry, source: In-house representation or Regioconsult 2019

48 Idem.

research and development sites such as Adlershof, the EUREF campus for electromobility, the Federal Institute for Materials Research and Testing (BAM) with its new battery test centre or planning around the Siemensstadt and the Urban Tech Republic. Altogether the image of a broad-based cluster for (electro)mobility emerges.[49] This also becomes readily apparent based on the following map of the Berlin-Brandenburg metropolitan area: The mentioned companies and research institutions in the automotive field and related sectors make the region attractive.

The larger regional environment may have played a role for the establishment of Tesla in Grünheide as well: Along the value chain, Tesla is one of a series of key investment projects in the electromobility sector in the region: Among these is the establishment of a production facility for battery components (cathodes) for electromobility by BASF in Schwarzheide (Oberspreewald-Lausitz). BASF has also announced the construction of pilot plant for battery recycling there. Rock Tech Lithium intends to establish lithium production in Guben (Spree-Neisse) with an investment of nearly half a billion euros. The US battery manufacturer Microvast has its new European headquarters in Ludwigsfelde (Teltow-Fläming). Lithium-ion battery systems are produced there. Rolls-Royce in cooperation with the BTU Cottbus-Senftenberg among others is researching alternative drive technologies for aviation. eRockit is producing an electric motorcycle with a speed of 90 km/h in Hennigsdorf (Oberhavel). Niederbarnimer Eisenbahn (NEB) and Deutsche Eisenbahn Service AG (DESAF) are testing hydrogen trains with the project H2Rail.Prignitz in Putlitz. DEKRA is testing autonomous driving on the Lausitzring and a digital test site for autonomous shipping is planned on the Oder-Spree waterway.[50]

Soft factors likely played a role as well: The increasingly globalised Tesla Group will have a much easier time getting its employees excited about spending time abroad in Germany when the site is located in Berlin rather than, for instance, Emden. What's more, Berlin's labour market offers access to skilled workers in the IT sector that are in high demand, but also to less qualified employees since the unemployment rate in Berlin is relatively high compared to other federal states.[51]

Vertical integration along the value chain is a success factor

Beyond strategic site planning, vertical integration also plays an increasingly decisive role for a successful regional incorporation of the battery industry. This refers to a form of enterprise integration that increases the vertical range of manufacturing along the value chain. It is achieved in particular through partnering along the value chain.

Tesla for example is much more vertically integrated than classic automobile manufacturers and controls value creation from end to end. This extends from battery and chassis production to distribution, software, in part the computer hardware and its chips, customer relations and activities in the electricity market and the Supercharger network as the company's own charging infrastructure.[52] [53]

Some of the European OEMs are responding to this competitive advantage of Tesla and pushing greater vertical integration in battery cell manufacturing. Stellantis and Daimler with their stakes in the battery cell manufacturer Automotive Cell Company (ACC) and Volkswagen's activities with regard to strategic partnerships with relevant stakeholders in various segments of the battery value chain are prominent examples of this. VW announced its cooperation with the material technology group Umicore, the battery specialist 24M Technologies and the lithium supplier Vulcan Energy Resources in December 2021. Beyond that, partnerships already exist in the battery sector with the solid-state battery specialist QuantumScape, the Swedish company Northvolt and the Chinese manufacturer Gotion High-Tech.

While all three partnerships are independent of each other according to Volkswagen, they serve the same goal, namely

49 regioconsult (2019).

50 See: State of Brandenburg (2021).

51 Kapalschinski (2019).

52 Daum (2021).

53 Voigt (2019).

the industrialisation of battery technology and the large series production of more sustainable, innovative batteries in the interest of the planned in-house development and production of a "unit cell" and the construction of six battery cell plants in Europe by 2030. According to VW, this is to be realised by expanding the battery technology know-how, improving cost management and through the vertical integration of the battery value chain. VW plans to supply Volkswagen's cell factories with cathode materials through the partnership with Umicore in the form of a joint venture in the future. The solid-state battery technology is to be established at VW over the medium term with 24M Technologies. From this, VW expects a reduction in production space by up to 40 per cent, significant investment savings, more efficient product recycling and an improvement of the CO_2 balance for battery production. With Vulcan Energy Resources, the delivery of CO_2-neutrally extracted lithium from the Oberrheingraben in Germany is to be realised in order to meet Volkswagen's demand for future in-house cell production in Germany and Europe.[54]

3.2 Industry sectors with transfer potential for the battery industry

Due to the highly dynamic market, the battery industry in Germany and Europe is comprised of a broad and steadily growing range of stakeholders, representing the entire battery value chain and also encompassing numerous other stakeholders in a broader battery ecosystem. According to the European Battery Alliance (EBA), more than 700 stakeholders covering the entire value chain are already represented in this network. Most of these are European stakeholders.[55]

Important partners for the success of the battery industry in Germany and Europe are:

- Chemicals industry (discussed in detail below)
- Machine building and plant construction (discussed in detail below)
- Packaging industry (foil materials as cell outgoing conductors, e.g. aluminium and copper foil)
- Electronics industry (battery management system components, e.g. MCUs, sensor systems, switches)
- Software development (data security in the entire development and production process; data science for quality assurance in the production process)
- Plastics industry (e.g. plastic component manufacturers as housing and battery component producers)
- Energy sector (e.g. cooperation between grid operators and manufacturers of stationary battery storage systems).[56]

Chemicals industry – most relevant cooperation partner for the battery sector

Since the activities of the chemicals industry with regard to battery cell manufacturing range from the enrichment, refining and purification of the raw materials to the actual production of the battery cell to battery recycling, this sector is classified as the most important cooperation partner of the German and European battery industry. The chemicals sector is involved in particular in the production of cathode and anode materials, battery electrolytes and separators for batteries. In the field of cathode production, for example, BASF is currently establishing two production facilities in Harjavalta, Finland and Lausitz in Schwarzheide, Germany, both of which are slated to commence operation before the end of 2022. A battery recycling plant is to be additionally established in Schwarzheide.

With regard to anodes, SGL Carbon of Germany and Imerys of France come to mind, both of which produce anode materials on the basis of synthetic graphite, respectively with sites in Germany, France and numerous other (EU) countries. The German supplier Custom Cells is an example of an electrolyte producer. It operates two such sites (in Tübingen and Itzehoe) and, aside from electrolytes, produces other electrode materials, cooperating among others with Porsche and BASF. An example in the field of separators for batteries is the speciality chemicals company Evonik, which produces

54 Werwitzke (2021).

55 See: European Battery Alliance (EBA).

56 The examples of the technology transfer potential from the packaging industry, electronics, software, the plastics industry and the energy sector to the battery value chain are based on technical contribution from P3 automotive GmbH.

metal oxides for the coating of cathodes and separator foils in Rheinfelden, Germany. [57]

Machine building and plant construction – considerable technology transfer potential for the battery industry

Machine building and plant construction also offer numerous tie-in points and considerable technology transfer potential for applications in the various (sub-)segments of the German and European battery value chain, for example, in the area of mixing various battery materials: The German company Eirich for instance is the global market leader in the field of mixing technology for lead-acid batteries, and is increasingly transferring this experience to lithium-ion battery processing.[58]

Another example of an innovative transfer of technology from machine building and plant construction in Germany comes from the coating technology field: Groz-Beckert, originally a textile technology company, has used its microtechnology know-how and metallurgy expertise from its core business to establish the new Customised Precision Components (CPC) branch of production that, among other things, develops and produces punching tools with already patented processes for the punching of extremely thin foils that are increasingly being used in the battery industry as well.[59]

Rolling is another technology with direct transfer potential for battery cell manufacturing. This applies in particular to the process step known as calendering.[60] Breyer Extrusion is

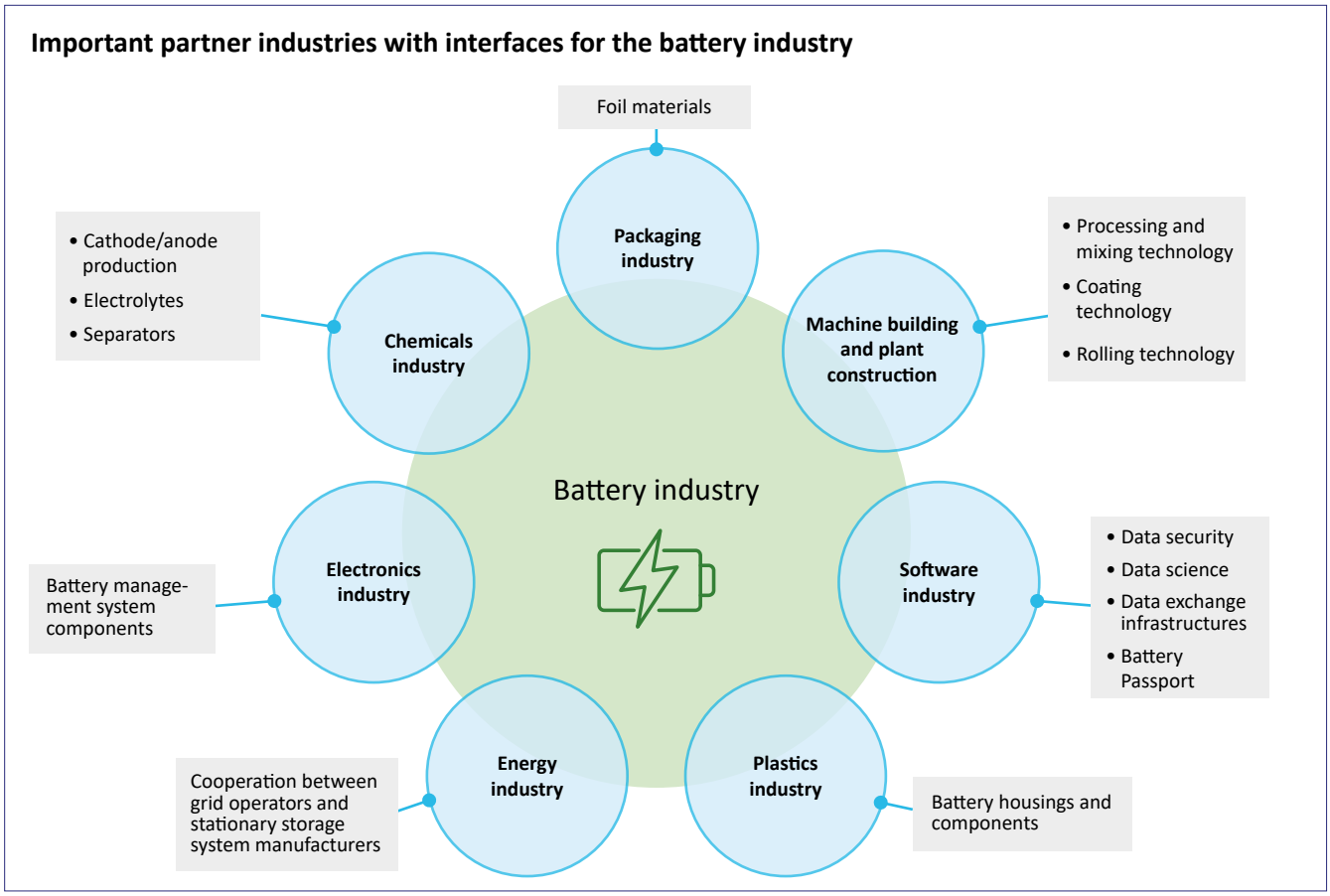


Figure 7: Interfaces between the battery industry and partner industries

57 Menzel (2021).

58 See: Eirich.

59 Groz-Beckert (2020).

60 Essential characteristics such as increasing the power density, optimised electron transport and improved contact between the particles have to be obtained during the calendering process.

a technology supplier in this field of the German machine building and plant construction sector.[61] Beverage filling is another example for the transfer potential from the machine building and plant construction sector. The systems technology used there could be used for electrolyte filling in cell production. The most important partner industries with interfaces and transfer potential for the battery industry are shown in Figure 7.

3.3 Lessons learned from the past

The chances of success for the lasting development and expansion of battery cell manufacturing in Germany and Europe can also be increased by learning from other industrial policy funded attempts to establish innovative industry sectors. Here the flourishing and decline of the photovoltaics industry in Germany and Europe serves as an example. Lessons for the future can be learned from that.

It is a fact that, starting around the year 2010, there was a considerable technology transfer of in particular German PV know-how to China as a consequence of the PV boom in Europe in the 2000s. This attracted numerous Chinese manufacturers and suppliers who wanted to participate in this prospering market with Chinese PV cells. The technology transfer resulted in the establishment of complete production facilities with a large-scale export of Chinese PV modules to Europe. It was skilfully employed by China for the further development of the technology. This enabled the mass production of Chinese PV modules, also with significant government funding. The resulting price decline in the global PV market led to the insolvency of most German PV producers such as Solar Millenium, Q-Cells and Solar World, who were no longer able to withstand the price pressure from China.[62] [63] [64]

Beyond this, the decline of Germany's PV industry can also be traced back to an abrupt weakening of PV funding policy: Both in 2011/12 and in 2014, considerable reductions, especially with regard to the PV feed-in tariffs, were established in the respective amended versions of the Renewable Energies Act (EEG), causing a massive downturn in the German PV market.[65]

To avoid a similar fate for the battery industry in Germany and Europe, numerous supporting requirements have already been established through what is called the ecosystem approach to government funding as illustrated in 1.2. This is intended to ensure the lasting success of establishing a German and European battery cell manufacturing value chain. The measures encompass the two battery IPCEIs, supporting funding initiatives and R&D funding provided by the BMBF. If the experience from the collapse of Germany's PV industry is taken seriously, the ecosystem approach could also be supplemented by additional risk minimisation tools. These could include government credit lines, e.g. through the Reconstruction Loan Corporation (KfW) (for instance in the form of low-interest loans) or declining balance depreciation options. To protect against unfair competition, the introduction of a European tool against companies from third countries that are not subsidised in accordance with the WTO rules could also be considered. The avoided internalisation of environmental damage resulting from non-sustainable production methods would have to be treated in a similar fashion. One example of this is the introduction of a Carbon Border Adjustment Mechanism (CBAM) discussed in the EU.[66] [67] [68] [69] [70]

61 See: Breyer GmbH Maschinenfabrik.

62 Sufang, Yongxiu (2013).

63 Vorholz (2012).

64 Interview with Lars Waldmann (ew-con) on 20 January 2022.

65 Vogelpohl et al. (2017).

66 See footnote 18.

67 Interview with Sarah Michaelis (VDMA) on 18 January 2022.

68 See: VDMA – German Mechanical Engineering Industry Association (2022).

69 European Commission (2021).

70 Dröge (2021).

4 REGIONAL DISTRIBUTION AND NETWORKING OF THE BATTERY ECOSYSTEM

Key findings

- Europe is well positioned in **battery research**. Research activities extend along the entire value chain.
- The **automobile industry is the driving force** for the development of the battery ecosystem. Batteries tend to play a subordinate role in other industry sectors.
- Cluster organisations constitute an important link for the networking of the battery ecosystem. Based on the data examined in this study, **memberships in cluster organisations** account for more than 70% of the connections between all stakeholders in the battery ecosystem.
- Clearly defined **focal regions** with a high concentration of companies in the battery ecosystem are forming in Europe. A particularly dense concentration is forming in the "Blue Banana" region in Germany and Europe. A second strong concentration is forming from Brandenburg and Saxony via southern Poland to Hungary.
- The regions in Germany and Europe with agglomerations of highly networked stakeholders improve the chances of the lasting **incorporation** of battery cell manufacturing.

The battery ecosystem is establishing itself in many parts of Europe and Germany. Numerous tie-in opportunities with existing regional economic structures in various industry sectors are helpful here. With regard to both research and industrial production, certain regions set themselves apart with a particularly high concentration of well networked battery ecosystem stakeholders or the existence of proven transfer potential. Outstanding regions for the battery ecosystem are identified based on their concentration of relevant or especially well networked stakeholders, or based on existing industry sites and industrial networks. Furthermore, the analysis results show how good the coverage of the battery value chain in Europe and Germany is and whether there are existing gaps.

In the following sections, the geographic distribution of the economically active stakeholders in the battery cell manufacturing ecosystem (companies) and their assignment to the segments of the battery value chain are examined (Section 4.1). Section 4.2 presents networking at the level of stakeholder engagement in associations/initiatives or cluster organisations.[71] This includes the networking of the stakeholders in Germany and Europe through joint research activities (Section 4.3). The stakeholders that stand out due to their high degree of networking and the regions for which the analysis revealed an especially high concentration of relevant stakeholders or especially well networked stakeholders are respectively highlighted.

4.1 Geographic distribution of the battery industry in Europe

The battery ecosystem is very diverse and defined by a complex value chain with many participating industry sectors.[72] The most relevant industry sectors are named in Table 2. They include raw material processing companies, the chemicals industry, machine building and plant construction, and testing and inspection centres (also see Section 3.2). It turns out that numerous different components are required in the various value-added steps of battery cell manufacturing in order to turn raw materials into a finished battery cell that, packaged in battery modules, ultimately supplies electric vehicles and other equipment with energy. Conversely these raw materials have to be recovered through recycling processes and returned to the production cycle.

An examination of the locations (headquarters) of the economic stakeholders in Europe's battery ecosystem shows that certain regions exhibit a concentration of stakeholders

71 This study differentiates between associations/initiatives dedicated to higher-level topics, such as the VDA (German Association of the Automotive Industry) or the Circular Economy Initiative, and cluster initiatives with a pronounced regional focus (see Section 2). Although the organisational forms are quite similar, they differ due to their focus on higher-level topics that, as a rule, have no pronounced regional basis or on cluster activities (see section 2). Thus this study makes an analytical distinction between these associations/initiatives and cluster initiatives. They constitute different networking levels in terms of this study. Insofar as a cluster focus is given, cluster initiatives are explicitly identified as such.

72 Gieschen et al. (2021).

Value-added step	Relevant industry sectors	Examples of companies participating in IPCEI
Raw material extraction	Mining and quarrying, processing trade	Keliber
Material production	Chemicals industry	BASF
Component production	Processing trade, chemicals industry	Nanocyl, Solvay
Battery cell and module production	Processing trade, automobile industry	Varta, ACC
Battery recycling	Waste disposal and cleanup of	
Environmental pollution, chemicals industry	Umicore, Elemental	
Cross-sectional tasks	Testing & inspection, electronics & ICT, mechanical engineering & plant construction	Manz, SEEL

Table 2: Overview of the leading industry sectors with a relevant contribution to the value-added steps of battery cell manufacturing. Industry sectors based on the 2008 classification of economic sectors (WZ 2008). (Source: Federal Statistical Office (2008))

that can be assigned to specific stages of the value chain. Figure 8 shows locations of various companies currently engaged in activities with a concrete relationship to battery cell manufacturing. While the production of battery cells and modules is distributed relatively evenly across Europe, a concentration of companies in the component manufacturing field is observed in Eastern Europe in particular (Poland and Hungary). These are mainly material producers and some of these companies are branches of Asian enterprises. New industrial regions are emerging here outside the European Union's traditional economic centre along the Rhine.

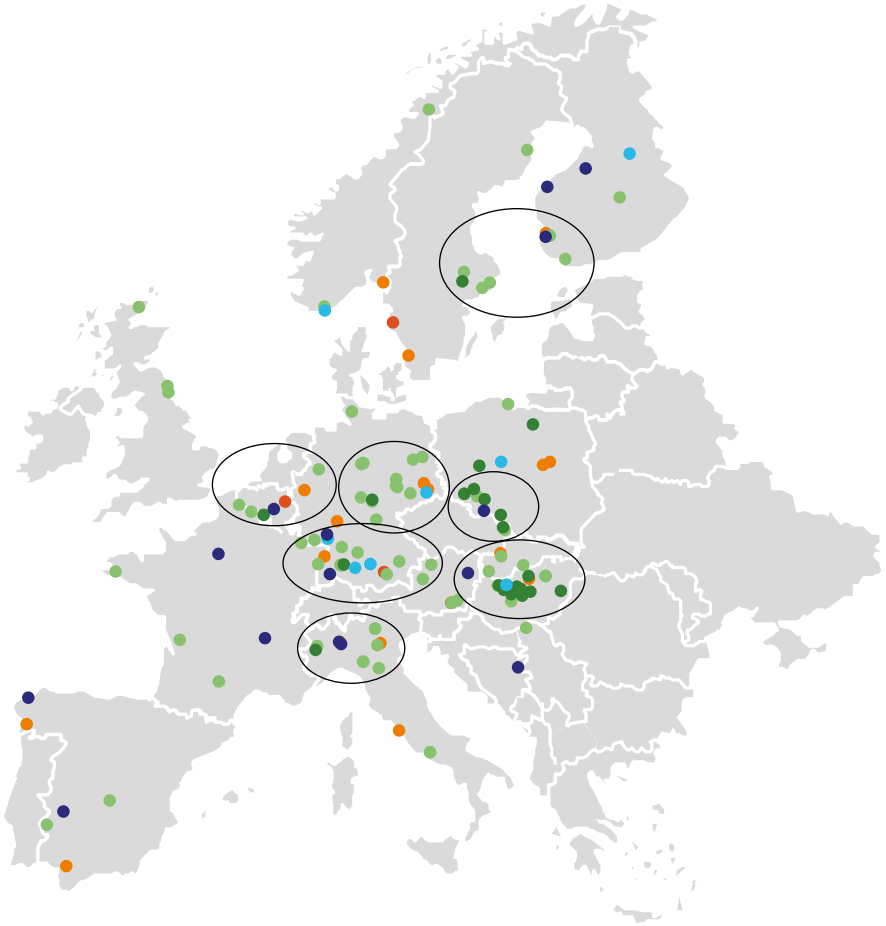
On the other hand, companies from all value-added steps are found in Germany and the border region. Here the focus is on cell and module production, primarily because of the strong automobile industry. However, battery recycling is comparatively well represented too with various companies, especially in the recycling sector but also the chemicals industry and the automobile industry. Southern and western Germany however also stand out. A high concentration of company locations is seen in eastern Germany as well, especially in the area of battery cell and module production.

4.2 Networking through national or regional associations and initiatives

Regions with a large number of stakeholders that are well networked in the battery cell manufacturing ecosystem offer better chances of gaining access to that ecosystem. Physical proximity facilitates mutual contact between companies that establish themselves in these regions. Even though online communication has become more prevalent due to the pandemic, personal contact continues to be important. The concept of cluster initiatives is based on this idea among others (see Section 2).

A data analysis of the members of select German and European associations and initiatives with battery relevance shows that well networked stakeholders are concentrated in several cluster points. Regional networking exists through their membership in associations and initiatives with battery relevance. This is remarkable insofar as the membership in associations and initiatives is not tied to regional criteria as a rule. According to the data basis used in this study, cluster initiatives account for the largest proportion of the

Geographical distribution of industrial actors of the European battery ecosystem



Value-added step

- Raw material extraction
- Material production
- Component production
- Battery cell and module production
- Battery recycling
- Cross-sectional tasks

Planned and existing sites of companies in various industry sectors in Europe with concrete participation in the battery cell manufacturing value chain.

The circles indicate various focal regions of the battery industry in Europe.

(In-house representation, data basis: Manufacturer information, last updated: December 2021)

Figure 8: Overview of the battery industry in Europe

connections (about 65 per cent for Germany, about 71 per cent for the EU), followed by network activities in interest groups or initiatives. This is because clusters or associations, as a rule, have a large number of members. Nevertheless the results of the data analysis indicate that there are only minor geographic overlaps between these two networking levels at both the German and European level at this time. Geographically defined cluster points of stakeholders therefore form, that are highly networked either through associations and initiatives or through cluster initiatives. However, the cluster points of the associations and initiatives and the cluster initiatives only overlap in rare cases Figure 9 and Figure 10).

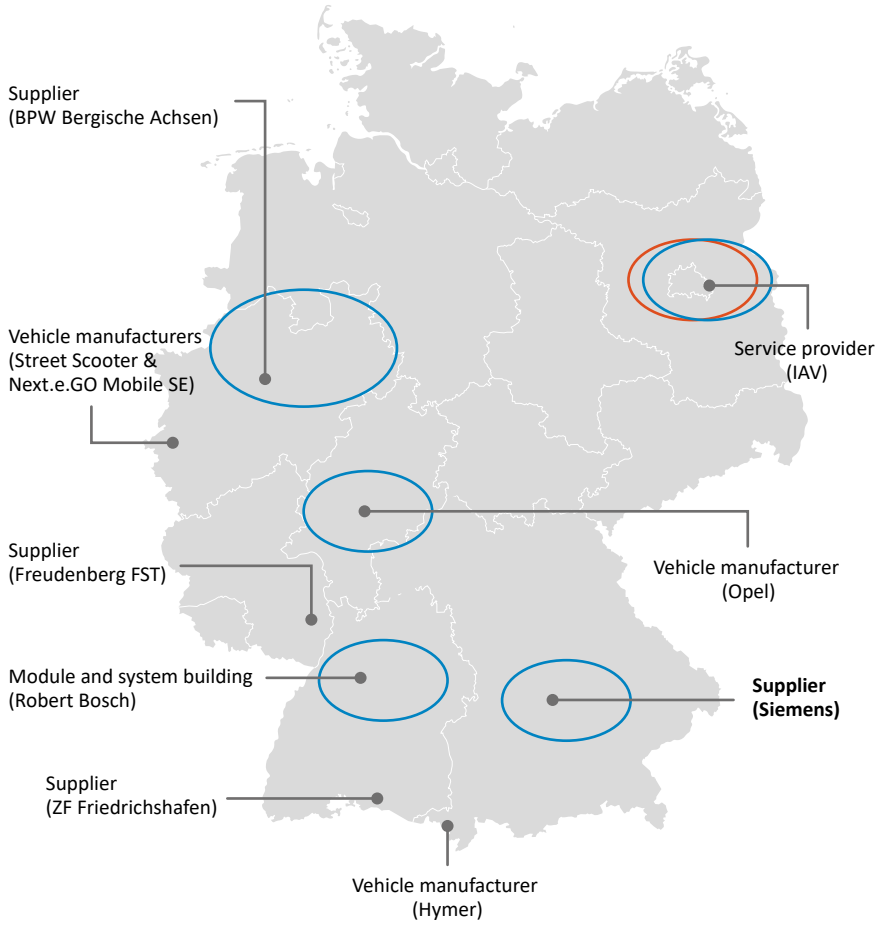
Networking at the German level

In Germany, the analysis identifies five regions with improved chances of establishing contact with the battery cell manufacturing ecosystem (Figure 9). Based on the network analysis of relevant German initiatives, networks and interest groups related to batteries, cluster points were identified in the Berlin-Brandenburg capital region, the north of Baden-Württemberg, northern Bavaria, the south of Hesse and in North Rhine-Westphalia. However, only the Berlin-Brandenburg region also offers access to the cluster initiative landscape. This means the chances for lasting contact with the battery cell manufacturing ecosystem and

other companies associated with that ecosystem are even better.[73]

Concentrations of stakeholders that are especially well networked through membership in these associations and initiatives[74] are found in the identified regions. The degree of stakeholder networking is a good indicator for the chances of gaining access to the battery ecosystem. Here the degree of networking is a measure of how many opportunities for access to other stakeholders a stakeholder can obtain through the membership in initiatives and associations.[75] Eight of the ten most highly networked stakeholders are also found in the

Minor overlaps between the networking levels of the initiatives and associations and the clusters may reduce chances of more in-depth incorporation in the ecosystem



The circles indicate regions with a higher concentration of stakeholders more highly networked in initiatives and associations (blue circles). Only in the Berlin/Brandenburg capital region is there also a geographical overlap with higher concentrations of stakeholders networked in clusters (red circle), in reference to the clusters examined in this study. This reduces the chances of more extensive networking with both stakeholder groups – and therefore more in-depth incorporation in the ecosystem.

The top ten of the most highly networked stakeholders in associations and initiatives are highlighted. Stakeholders that are highly networked in both associations/initiatives and in clusters are highlighted in bold.

(In-house representation, data basis: Publicly available membership lists of initiatives, associations and clusters)

Examined associations and initiatives in Germany

- BEM – Bundesverband eMobilität e. V.
- Bundesverband der deutschen Abfall-, Wasser- und Rohstoffwirtschaft (BDE)
- BVES – Bundesverband Energiespeicher e. V.
- Circular Economy Initiative Deutschland (CEID)
- Kompetenznetzwerk Lithium-Ionen-Batterien e. V. (KLiB)
- VDMA battery production
- German Association of the Automotive Industry (VDA)

Figure 9: Regional distribution of highly networked stakeholders (in reference to the degree of networking) through activities in Germany (associations, initiatives etc.) and interfaces to the landscape of the examined cluster initiatives.

73 Baden-Württemberg and Bavaria also have a defined cluster landscape, especially with regard to the automobile industry. However, not all of these clusters have been analyzed here for data availability reasons.

74 For an overview of the examined networks, initiatives and interest groups at the German level, see Appendix I.

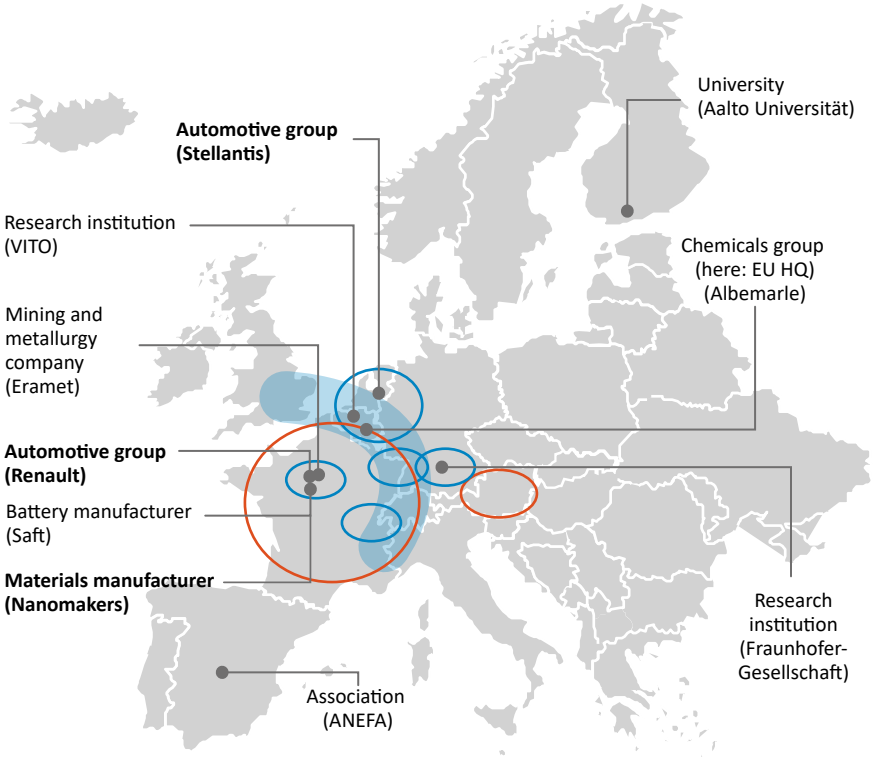
75 The degree of networking does not necessarily reflect the actually realised partnerships between the stakeholders.

well networked regions. Their locations are shown in Figure 9 (respectively in reference to headquarters).

Initially it appears conspicuous that no OEMs such as Volkswagen or BMW appear among the ten most highly networked stakeholders. However, this is explained by the fact that the examined associations and initiatives go beyond the automotive field of application, and that OEMs are not usually or only rarely members of the Energy Storage System Association (BVES), the German Waste, Water and Raw Materials Industry Association (BDE) and others. Even the eMobility Association (BEM) only has few OEM members (Opel, for instance).

The identified regions are also defined by the automobile industry[76] to various degrees, since defined supplier

Larger conglomerates of highly networked companies are found along the "Blue Banana". At the European level, a geographical overlap between the networking levels of the initiatives and associations and the cluster levels only exists in France



The circles indicate regions with a higher concentration of stakeholders more highly networked in initiatives and associations (blue circles). There is a noticeable concentration of these conglomerates along the "Blue Banana".

Only in France is there also a larger geographical overlap with higher concentrations of stakeholders networked in clusters (red circle), in reference to the clusters examined in this study. This reduces the chances of more extensive networking with both stakeholder groups – and therefore more in-depth incorporation in the ecosystem.

The top ten of the most highly networked stakeholders in associations and initiatives are highlighted. Stakeholders that are highly networked in both associations/initiatives and in clusters are highlighted in bold.

(In-house representation, data basis: Publicly available membership lists of initiatives, associations and clusters)

Examined associations and initiatives in Europe

- Advanced Rechargeable & Lithium Batteries Association (RECHARGE)
- ALISTORE European Research Institute
- EUROBAT - Association of European Automotive and Industrial Battery Manufacturers
- European Association for Automotive Suppliers (CLEPA)
- European Association of Metals (Eurometaux)
- European Automobile Manufacturers' Association (ACEA)
- European Battery Alliance (EBA)
- European Battery Recycling Association (EBRA)
- European Council for Automotive R&D (EUCAR)
- European Green Cars Initiative (EGVI)
- European Institute of Innovation and Technology (EIT InnoEnergy)
- European Institute of Innovation and Technology (EIT RawMaterials)
- European Power Tool Association (EPTA)
- European Raw Materials Alliance (ERMA)
- European Road Transport Research Advisory Council (ERTRAC)

Figure 10: Regional distribution of stakeholders that are highly networked through European networks and associations (in reference to the degree of networking).

76 Kempermann et al. (2021).

structures are found there in part in addition to various automobile manufacturers.

Furthermore, there appear to be only minor links in Germany between the association and initiative level and the level of the cluster initiatives examined in this study (see Appendix I b). Only one stakeholder is highly networked on the association and initiative level and on the level of the cluster initiatives. There are many possible reasons for this result and a clear determination is not possible based on the analysis performed here.

Possible interpretations lie, for example, in the number of members of the respective associations, networks, initiatives or cluster initiatives or in the fact that some stakeholder groups are mainly involved in association-like networks, others mainly in clusters.

Networking at the European level

At the European level, stakeholders that are highly networked through memberships in associations, initiatives or networks[77] are found distributed across Europe overall, but two greater concentrations can be identified along the "Blue Banana", i.e. the German/French border region, the BeNeLux countries, the Paris and Lyon region and southern Germany. The "Blue Banana" is a curved agglomeration band from Great Britain to the BeNeLux region to the Rhine region to northern Italy. This area is defined by comparatively high economic dynamics, wealth and transport connections. [78]Especially in these regions, there are also geographic overlaps with stakeholders that are highly networked through memberships in cluster initiatives.

Here there is a high overall chance of lasting contact with the battery ecosystem. Table 3 shows that the most highly networked stakeholders are, as a rule, members of several associations and also more broadly positioned in terms of content, and thus exhibit a greater potential for knowledge transfer and establishing value-added partnerships. Not only do they have a better chance of establishing partnerships with a larger number of other members, they also cover a wider range of topics.

This makes them interesting as gatekeepers for these networks[79] on the one hand, since topical access to these networks can be obtained through them, and these stakeholders can initiate cooperation between networks on the other hand. Potential multiplier effects can thus be realised.[80]

The European Battery Alliance and the European Raw Materials Alliance are strong links since almost all the stakeholders listed in Table 3 are members of at least one of these associations.

Incorporation of the IPCEIs in the cluster landscape

Various interfaces can be identified between the IPCEIs and the examined cluster landscape. Overall, twelve of the companies involved in at least one of the two IPCEIs (IPCEI on Batteries and EuBatIn) are also members of various clusters in Germany and in particular at the European level. At the German level, only three companies are involved in three clusters (Cluster Transport, Mobility and Logistics in Berlin-Brandenburg, Composites United e.V. and the European Center for Power Electronics e.V. (ECPE)). At the European level on the other hand, seven companies are involved in the four clusters AXELERA, CEAGA, Nextmove and the Plastics Cluster. Therefore, links to the examined cluster landscape are mainly found in the areas of mobility/ automotive engineering and new materials. German companies are not represented in the clusters examined here at the European level, but only in the clusters at the German level. However, since German companies are more likely to become members of clusters in close regional proximity as a rule, this distribution must be qualified. Nevertheless it turns out that initial tie-in points with the IPCEIs already exist with regard to the examined cluster initiatives. However, these links occur primarily at the European level whereas.

77 For an overview of the examined networks, initiatives and interest groups as well as cluster initiatives at the European level, see Appendix I.

78 See: Spektrum Akademischer Verlag (2001).

79 Gieschen et al. (2021).

80 The ANEFA constitutes an exception, being found in only one topical network. Here the association serves as a corporate stakeholder that, as a member in another association, represents the interest of its members.

Stakeholder	Category	Number of memberships in examined networks	Focus topics of the networks	Member in a European cluster
Renault	European automobile group	7	Raw materials, battery cells, vehicles, sustainability	Yes
Stellantis	European automobile group	5	Raw materials, battery cells, vehicles	Yes
Eramet	European mining and metallurgy company	5	Raw materials, battery cells	No
Albemarle	International chemicals group	5	Raw materials, battery cells, product integration	No
Saft	European battery manufacturer	5	Raw materials, battery cells, product integration	No
Vito	National research institution	4	Raw materials, battery cells, energy storage	No
Aalto University	European university	4	Raw materials, battery cells, energy storage	No
Fraunhofer	National research institution	3	Raw materials, battery cells	No
Nanomarkers	European material producer	3	Raw materials, battery cells	Yes
Anefa	National association	1	Raw materials	No

Table 3: Top ten of the most highly networked stakeholders through European networks based on the degree of networking and their potential for knowledge transfer and establishing value-added partnerships

Comparing the location of stakeholders from associations and initiatives with those of the examined clusters does show a stronger connection between the two networking levels than in Germany with regard to geographic links. That improves the chances of tying into the battery cell manufacturing ecosystem in these regions. The more stakeholders are highly networked on the level of the networks and associations and on the cluster level, the better the chances of multiplier effects in the transfer of knowledge or the formation of partnerships between levels. However, the links between these two networking levels only appear to be slightly more pronounced than in Germany to date with regard to the associations and clusters examined in this study (see Appendix I). Overall, only three of the organisations out of the top ten stakeholders most highly networked through memberships in associations and

initiatives are also represented in the examined European cluster landscape (see Table 3).

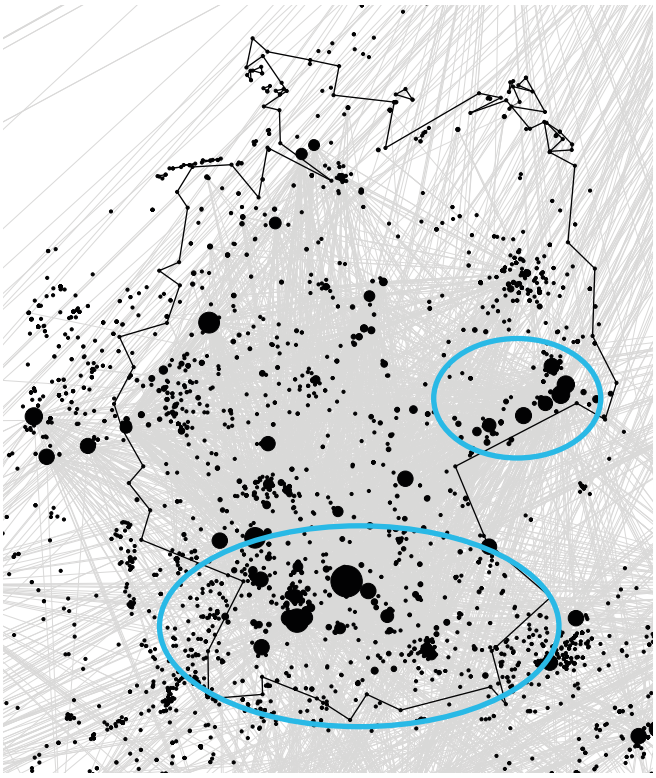
4.3 Regional and topical focal points in battery research

Research in Germany and Europe

All topics of the battery value chain are being researched in Germany and Europe. Most partnerships in Germany exist in research projects on topics at levels higher than the value chain as well as battery cells and their production. In European research on the other hand, partnerships focus on the integration of batteries in vehicles or on stationary storage applications and on materials research. In German battery research, regional focal points exist primarily in southern Germany but also in Saxony (see Figure 11).

Both the automobile industry and machine building and plant construction are strongly represented in both regions,[81] which likely favoured this focal point formation. For research at the European level, it turns out that the largest number of highly networked stakeholders is found primarily in Germany, the BeNeLux countries, France, Austria and Great Britain. While the geographic distribution within these regions is relatively even, there are some focal points. A large number of stakeholders in France is found in the Paris region

Networking through German research level



Access to stakeholders highly networked in research increases the chances of access to research stakeholders of the battery ecosystem in other German regions

Research projects related to battery cells along the value chain since 2014 are considered. The node size indicates the degree of networking[i], that is, the number of connections to other stakeholders

The graphic shows the focal regions of research in Germany based on the degree of networking of the stakeholders. Regions clearly emerge with stakeholders that are very highly networked in research. At the same time, the connecting lines show that research stakeholders are networked across regions throughout Germany. Access to stakeholders that are highly networked in research also improves the chances of access to battery ecosystem research stakeholders in other regions.

(In-house representation, data basis: Funding catalogue; stakeholders with no geographical assignment were excluded from the illustration)

i The degree of networking provides information about the number of connections a stakeholder, such as a company or research institution, maintains with other stakeholders. This information refers only to the direct relationships of a stakeholder with others. It does not say anything about the extent to which these connections are important for the overall structure of the ecosystem under consideration (measure of betweenness) or the extent to which all stakeholders of the ecosystem under consideration can be reached along the shortest route (measure of proximity). The latter refers exclusively to the structural examination of the ecosystem under consideration based on the examined connections, and not to geographical proximity. For simplicity, only the degree of networking is used in this study.

Figure 11: Networking through research projects in Germany

81 See, for Saxony and Bavaria: STMWI (2021). “Industriebericht Bayern 2021” (Industry report Bavaria 2021).

but also on the border to Germany and in the Lyon region. In Germany, concentrations of stakeholders networked through research are found in the Berlin-Brandenburg region as well as Saxony in the border region to the Czech Republic, North Rhine-Westphalia, the Stuttgart region and Munich. Geographic overlaps with German research, which is strongly represented in southern Germany as well, are therefore apparent.

The most highly cross-linked stakeholders (based on the degree of networking) on this networking level are found across Europe with headquarters in larger cities or state capitals, or in their vicinity. Exceptions include RWTH Aachen, which is however located in the border region and near the Cologne-Bonn metropolitan region, and Donostia-San Sebastian (see Table 5). This means that companies and research institutions that establish themselves in these metropolitan regions have greater chances of encountering stakeholders that are well networked in research.

Companies that are highly networked in research are particularly important as catalysts for the development of innovative solutions and further research, and therefore as key partners for tying in new stakeholders with the ecosystem. They simultaneously improve the chances for the transfer of knowledge to other parts of the ecosystem. Among the top ten stakeholders most highly networked through German funding projects, companies and research institutions are represented in about equal numbers. That companies are also among the stakeholders mostly highly networked through research further underscores the application proximity of battery research.

A somewhat different picture emerges for Europe. Here companies appear to benefit less from the networking effects in European research. All of the top ten stakeholders are research institutions. Even when this group is expanded to include the top 20, there are only three companies among them (AVL List, IDIADA AUTOMOTIVE TECHNOLOGY SA[82], Siemens AG). Two of these companies are classified as suppliers or service providers for the automobile industry

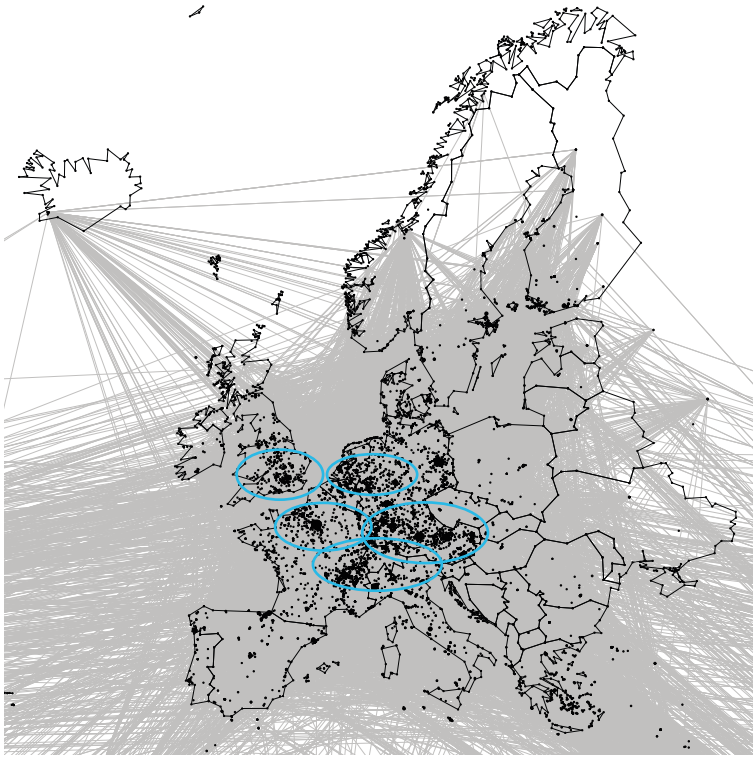
	Institution	Domicile
1	**WWU Müster**	Münster
2	**Varta**	Ellwangen
3	**Fraunhofer IISB**	Erlangen
4	**Fraunhofer ICT**	Pfinztal
5	**Justus Liebig Univerität Giessen**	Gießen
6	**Fraunhofer IKTS**	Dresden
7	**Litarion (Insolvent since 2018*)**	Kamenz
8	**DLR – Institut für Technische Thermodynamik**	Stuttgart
9	**Thyssenkrup**	Heilbronn
10	**SGL Carbon**	Wiesbaden

*Since research data since 2014 are being considered, the company is listed here regardless.
Data basis: Funding catalogue – statistical series 2014 to 2021

Table 4: Top ten of the stakeholders most highly networked through publicly funded research projects at the German level, with the respective location (For information on creating the ranking, see the section on the methodology and approach in Appendix II.)

82 IDIADA AUTOMOTIVE TECHNOLOGY SA is a Spanish development services provider for the automobile industry.

Networking through European research level



Access to stakeholders highly networked in research increases the chances of access to research stakeholders of the battery ecosystem in other European regions

Research projects related to battery cells along the value chain since 2014 are considered. The node size indicates the degree of networkingi, that is, the number of connections to other stakeholders.

The graphic shows the focal regions of research in Germany based on the degree of networking of the stakeholders. Regions clearly emerge with stakeholders that are very highly networked in research. At the same time, the connecting lines show that research stakeholders are networked across regions throughout Germany. Access to stakeholders that are highly networked in research also improves the chances of access to battery ecosystem research stakeholders in other regions.

(In-house representation, data basis: CORDIS, UK funding data; stakeholders with no geographical assignment were excluded from the illustration)

Figure 12: Networking through research projects in Europe

	Institution	Sitz
1	**cea**	Paris, Frankreich
2	**Fraunhofer**	München, Deutschland
3	**Centro Ricerche Fiat**	Turin, Italien
4	**CNRS - Centre national de la recherche scientifique**	Paris, Frankreich
5	**Vrije Universiteit Brussel**	Brüssel, Belgien
6	**Cidetec**	Donostia-San Sebastian, Spanien
7	**RWTH Aachen University**	Aachen, Deutschland
8	**TNO innovation for life**	Den Haag, Niederlande
9	**Politecnico di Torino**	Turin, Italien
10	**AIT Austrian Institute Of Technology**	Seibersdorf, Österreich

Datenbasis: CORDIS, Förderdaten UK – Datenreihe von 2014 bis 2021

Table 5: Top 10 of the most highly networked stakeholders in research at the European level, with the respective location

and one as a conglomerate. Thus fewer companies at the European level are potential catalysts for innovative new battery solutions as stakeholders highly networked in research.

This also indicates a comparatively lower application proximity of the research. However, the smaller number of companies may be due to the fact that EU funding procedures are, as a rule, relatively unattractive for small and medium-sized enterprises (SMEs). As a further restriction, note that only funding recipients (e.g. with the Fraunhofer-Gesellschaft) are named in many cases in the underlying CORDIS database. The subordinate, executing entity (division, institute or similar) is not listed in the available data, in contrast to the data of the funding catalogue, for example. Universities and research organisations that bundle numerous institutes and specialist divisions are therefore seen in the network analysis.

4.4 Regions with high potential for connecting to the battery ecosystem in Germany and Europe

Overall the examination in the previous section shows that there are various regions of importance and significance across all examined networking levels. In Germany this is primarily the southern region with the two "automotive states" of Baden-Württemberg and Bavaria. Numerous stakeholders and good network structures as well as active (state-owned) agencies for innovations and regional business development are already established there, actively driving the region's economic and topical development.

Examples include the state of Baden-Württemberg's innovation agency e-mobil BW[83] and Bayern Innovativ, the Free State of Bavaria's company for innovation and knowledge transfer. Southern Germany has several cluster organisations that, as automotive/electromobility clusters, either actively promote the topic of battery cell manufacturing already – such as Electromobility South-West and the Bavarian Automotive Cluster – or offer transfer potential as partner industries (see Section 3.2).

North Rhine-Westphalia also stands out, both with regard to the RIS3 approaches and, in the network analysis, as a region with a particularly great tie-in potential for the battery ecosystem. With its position on the "Blue Banana" and the proximity to Belgium, the Netherlands and Luxembourg (BeNeLux), the state already offers strong economic structures with tie-ins for the topic of battery cell manufacturing. This is based on the one hand on the existence of numerous, well-networked stakeholders with battery relevance and, on the other hand, the presence of industrial network structures with transfer potential, for example, to the packaging industry with the city of Lengerich in Westphalia as a hidden champion. The state of North Rhine-Westphalia's "Spitzencluster für industrielle Innovationen e.V." (SPIN)[84] also offers opportunities. It is funding six projects in the renewable energy storage field, establishing alliances between the energy sector, industry and applied research in the process . Not least, the Rhineland as a traditional lignite mining site is facing the need for structural change in the near future, and has been pursuing the transformation of the Rhine coal-mining district into a model region for energy supply and resource security with a structure development programme for quite some time.[85]

The Berlin-Brandenburg region stands out as a focal point, especially in the area of research. The proximity to research institutions and a well-developed infrastructure (transportation, water etc.) are identifiable regional advantages that are already leading to more and more battery ecosystem stakeholders establishing themselves in Berlin-Brandenburg.

The Saxony region on the border to the Czech Republic is another focal point for research sites. Its proximity to Eastern Europe where numerous factories for cell and component production already exist is a location advantage (see Figure 8 in Section 4.1). Saxony and especially Lausitz also offers great potential for developing into a regional transformation cluster. A structural transformation away from the lignite industry needs to happen here. "Leave lignite behind – embrace the battery!" is a possible innovation mission. The battery ecosystem could access industrial structures and the existing infrastructure directly. Through the shift to

83 See: e-mobil BW.

84 See: SPIN.

85 See: Zukunftsagentur Rheinisches Revier (2021).

the battery industry, the region's industrial core could be preserved or even (technologically) enhanced. The battery ecosystem would continue to offer well-paying jobs.

At the European level, the greater Paris metropolitan region, the BeNeLux countries and Austria are the main cluster points for battery stakeholders. These regions have a strong representation of the automobile industry in common. In the border region to Germany, there is increased potential for European partnerships and networking between stakeholders in Germany and France, Belgium, the Netherlands, Luxembourg and Austria.

As shown in Section 4.2, there are gaps in the geographic distribution of the battery ecosystem in Europe. These also relate in particular to tying in with existing cluster initiatives with a topical focus on one of the battery partner industries. This means that no systematic geographic overlaps between the distributions of the members of the pre-selected cluster initiatives with stakeholders of the battery ecosystem could be found when the topical focus of the clusters is outside the automotive sector.

The analysis results based on the existing data indicate that the tie-in with the battery ecosystem is currently successful primarily in the automotive/mobility clusters. Nevertheless, existing economic structures of the industries with transfer potential for battery cell manufacturing, as described in Section 3.2, should be increasingly used to also incorporate the battery ecosystem there over time. Such a development would require targeted incentives and the identification of potential synergies.

Northvolt is an example for the realisation of this transfer potential, in this case with the paper industry. The company has purchased an abandoned paper plant in Sweden and is striving to convert it into a gigafactory for electric vehicles by 2024[86]. Beyond that, Northvolt also serves as an example for the tie-in potential of the energy sector: Another battery factory is to be constructed in Heide in Schleswig-Holstein. The excess of offshore and onshore wind power is being cited as a key site factor[87]. Batteries for energy storage will become increasingly important in the energy system of the future, so that supply security can be maintained with fluctuating energy sources such as wind and solar.

Table 6 provides an overview of the regions that are of interest for the battery industry based on the analyses in the preceding sections.

86 See: ecomento.de (2022).

87 Schaal (2022).

Region	Topics	Relevant clusters in the region
Baden-Württemberg	Energy storage technologies in the context of sustainable mobility, drive train electrification, testing, development, recycling, second-life applications	• Electric Mobility South West • Cluster Initiative CARS Automotive Region Stuttgart[88] • Packaging Valley Germany e. V.
Bavaria	Automotive/electromobility; battery integration in vehicles; battery applications for stationary storage; materials research	• Cluster Automotive • Chemie-Cluster Bayern • Kompetenz-Netzwerk Mechatronik in Ostbayern • Kunststoff-Cluster
North Rhine-Westphalia	Networked mobility and logistics, environmental economics and recycling economy, energy and innovative construction, innovative materials and intelligent production	• NanoMikroWerkstoffePhotonik.NRW • it's OWL – The Technology Network: Intelligent Technical Systems OstWestfalenLippe • Automotiveland-NRW
Lower Saxony	Battery cells, electromobility charging infrastructure, alternative drive systems in the mobility context, energy technologies, materials research, resource efficiency and recycling in the context of production technologies, new materials, digitalisation	• Automotive Nordwest e.V. • 3N Kompetenzzentrum e.V. • OLEC e.V.
Saxony	Cell and module production; chemicals; battery technology, sensor technology and charging infrastructure systems in the electromobility sector; environment, raw materials, digital systems, energy; battery recycling, electrical engineering, lightweight construction; qualification of skilled workers	• Energy Saxony • Automotive Cluster Eastern Germany
Rhine-Main area (Southern Hessen, Rhineland-Palatinate)	Cell and module production, component production	• Automotive-Cluster RheinMainNeckar[89] • rhein-main-cluster chemie&pharma[90]
Bourgogne-Franche-Comté (BFC, central western France)	Innovative vehicles, drive train electrification, energy storage, vehicle architecture, mobility-as-a service, materials, recycling	• Pôle Véhicule du Futur • Plastipolis

88 See: CARS Region Stuttgart

89 See: Automotive-Cluster RheinMainNeckar

90 See: rhein-main-cluster chemie & pharma

Region	Topics	Relevant clusters in the region
Upper/Lower Austria	Lightweight construction and sustainable materials, life cycle assessment, recycling economy; metals, mechanical engineering, electrical, electronics, ICT; additive manufacturing, big data, data security	• Mechatronics Cluster with electromobility initiative “e-mobil in Niederösterreich”
Alsace-Lorraine (Germany/France border region)	Automotive/electromobility; battery integration in vehicles; battery applications for stationary storage; materials research	• autoregion e.V.[91] • automotive.saarland[92]
Paris metropolitan region (Île-de-France)	Raw materials, battery cells, vehicles	• NextMove (Mov’eo) • Elastopôle[93]
BeNeLux countries	Cell and module production, component production, extraction of raw materials	• RAI Automotive Industry NL[94] • Luxembourg Automobility Cluster[95]
Eastern Europe	Component production and materials; chemicals; plastics	• Moravian-Silesian Automotive Cluster[96] • OMNIPACK • Slovak Plastic Cluster[97] • Bydgoszcz Industrial Cluster[98] • Slovak Electric Vehicle Association (SEVA)[99] • Electric Vehicles Industrial Cluster (EVIC)[100]

Table 6: Overview of interesting regions for establishing the battery industry based on the examinations and analyses in the previous sections

91 See: autoregion e.V.

92 See: Saaris Automotive Transformation Hub

93 See: Elastopôle Pôle de Compétitivité Caoutchouc et Polymères

94 See: RAI Automotive Industry NL via European Cluster Collaboration Platform

95 See: Luxembourg Automobility Cluster via LUXINNOVATION

96 See: AUTOKLASTR Moravian-Silesian Automotive Cluster

97 See: Slovak Plastic Cluster, ESCA Silver Label

98 See: Industry Cluster Bydgoszcz, Poland

99 See: SEVA Slovak Electric Vehicle Association, Slovakia

100 See: EVIC Electric Vehicles Industrial Cluster, Bulgaria

5 IMPORTANCE OF REGIONAL BUSINESS DEVELOPMENT AND CLUSTER INITIATIVES FOR THE BATTERY INDUSTRY

Key findings

- The importance of regional **cluster initiatives** for innovation will continue to increase. This also applies to **support for the establishment of new economic sectors** such as the battery industry.
- **Business development** should **provide more support for transformation capabilities**. Focal points should include establishing resilient structures, knowledge orientation, cooperation and improving flexibility and agility.
- Linking **cluster and industrial policies supports an effective response to the respective regional framework**, stakeholders, development paths and speeds, and existing industry specifics.

The importance of regional cluster initiatives for innovation and to support the establishment of new economic sectors, such as the battery industry, will continue to increase in the future since the complexity, differentiation and performance of the economy must be functionally addressed, especially at the regional level. Cluster initiatives with high innovation potential that develop into future labs and formative stakeholders of regional transformation processes must and can contribute to accomplishing structural change in terms of ecosystems for value creation and employment. They also help generate innovations, thereby tying into existing strengths and simultaneously supporting "reinvention" in numerous industries.

Strategically oriented cluster activities at the regional level and in specific forms respond to the major upheaval of economic structures and value creation systems that will be caused by technological change, new digital business models and decarbonisation in accordance with the climate goals. Global competition is intensifying at the same time due to system competition, neo-protectionism and the battle for technology sovereignty.

A key task for cluster initiatives and cluster management organisations is to provide even more support for the cluster stakeholders – primarily small and medium-sized enterprises – to help them overcome and respond to the "grand challenges" and mega-trends such as digitalisation, connectivity, globalisation, urbanisation, sustainability etc. The automobile industry is affected by these changes in several ways. Part of the response to the resulting challenges is to develop the German and European battery industry. Since a new value chain is being created here at high speed and in parallel at numerous sites, communication and cooperation are of central importance for the success of this new industry sector. Cluster initiatives can provide support in exactly these points.

5.1 Requirements for a future-oriented regional business development

In view of the outlined, simultaneous developments and upheavals and the growing imponderables resulting from the "Great Acceleration" of the Anthropocene,[101] the complexity of the challenges that need to be mastered is increasing to the point that the acting stakeholders are often overwhelmed. Thus, instead of seeking or developing solutions sequentially for each individual challenge, a mechanism needs to be established that makes it fundamentally possible to adjust to changing requirements. The keyword "resilience" did not only emerge in the times of the COVID-19 pandemic.[102]

Creating resilient structures

Resilient structures and organisations are defined by the ability to anticipate and also proactively implement necessary new paths (in terms of "related variety")[103] or path changes. Necessary path changes, which are typical for transformations and therefore system changes, are decidedly contingent on many factors since, as a rule, they cannot be carried out on the level of a single organisation (company) but involve the stakeholders in a region as a whole. For the

101 Steffen et al. (2015)

102 Brinkmann et al. (2017).

103 Frenken et al. (2007).

transformation of the automobile industry, the currently ongoing system change is taking place throughout the entire supplier industry. Since not all operations engaged in the traditional drive train segment can be expected to find prospects in electromobility including battery cell manufacturing, the conversion potential of those suppliers that are not e-mobility ready has to be utilised and developed in addition.[104] In well-developed ecosystems, they have the opportunity to develop prospects outside their core business through interactions with other industry sectors (for example, drive systems for e-bikes instead of ventilation and fan motors;[105] also see Section 3.2).

Knowledge, flexibility and cooperation as characteristics of future-oriented regions

It is self-evident that regions are more versatile (resilient) the more pronounced their knowledge, flexibility and cooperation are. Accordingly an intact network of relationships between companies, academic and non-academic research institutions, and other institutions with a high degree of employee interaction (use of the human capital) can serve as an important indicator for a region's future viability. Integration into an ecosystem, such as that of battery cell manufacturing, can further support the strengthening of regional resilience. In view of the ability to implement new paths and, in particular, path changes – for instance from the combustion engine to electromobility – the concept of economic complexity[106] increasingly gains importance in this examination.

Here we are talking about a model or an indicator system to characterise the competitiveness of national economies or also smaller units such as regions. Economic complexity quasi describes the uniqueness of an economic area in view of its ability to produce complex products as an expression of knowledge-based competitiveness. The greater the complexity of a product, the smaller the number of competitors will naturally be. With economic complexity, the amount of useful knowledge and the ability to (re) combine this in different variations increases as well. This recombination can be opportunity-driven or induced by challenges (keyword resilience).

Supporting transformation ability through knowledge orientation, cooperation and agility

Business development today therefore has to focus on supporting transformation ability based on fundamental characteristics such as knowledge orientation, cooperation, flexibility and agility, both at the level of individual organisations (companies) and in industry sectors as well as in regional contexts. The latter in particular harbours the potential of high economic complexity and therefore transformation ability. Cross-sector and cross-cluster partnerships are an expression of such an orientation.

5.2 Cluster and industrial policy hand in hand for networking with the battery ecosystem

Due to the growing importance of regions as innovation and value creation hot spots and the far-reaching transformation processes of the economy, society and regions, the interplay of cluster and innovation policy with the regional economic and structure policy is becoming increasingly important.

With a joint ecosystem approach that correlates a variety of challenges but also potential, the respective regional frame conditions, stakeholders, development paths and speeds as well as existing industry specifics can be effectively addressed. However, the existing sector logic needs to be left behind at the same time in order to address the potential of the region as a whole. This not only applies for direct value creation but also and especially for developing the potential of skilled workers through reskilling and upskilling measures. The same applies for job transitions between different companies and from a (stagnating) industry sector to another (prospering) one. This is an important approach to overcoming job fit problems in the regional labour market.[107] An example of this is the BMWK funding initiative for occupational qualification in the battery industry (also see Section 2.3.).[108]

104 Holzschuh et al. (2020).

105 Böckmann (2021).

106 Hidalgo, Hausmann (2009).

107 Zika et al. (2021).

108 German Federal Gazette (2021).

At the European level, the trend of linking cluster policy even more closely with industrial policy measures continues in order to utilise the design potential of the cluster initiatives more effectively for the joint further development of industrial structures. Especially in a highly OEM-dominated sector such as the automobile industry, the development of shared and overarching perspectives and strategies is a central element:

Cluster initiatives as economic cooperation alliances represent a higher proportion of a region's industry stakeholders, who have already been cooperating for many years and serve as information carriers and drivers for the changing or emerging industry structures. Knowledge of these regional processes, the existing relationship network and the effectiveness of the cluster initiatives should therefore be utilised for a dialogue and interactions with other innovation and industrial policy measures.

6 RECOMMENDATIONS FOR THE UTILISATION OF TIE-IN AND TRANSFER POTENTIAL FOR THE BATTERY ECOSYSTEM WITH REGIONAL ECONOMIC STRUCTURES IN GERMANY AND EUROPE

The following recommendations result from the findings of the preceding sections. They are aimed at decision makers


Industry


Cluster initiatives


Business development


Industrial policy


Existing structures and potential should be utilised in the development of the battery ecosystem. This applies in particular to economic structures from industries with transfer potential for battery cell production. It is important in principle to tie into regional economic structures instead of starting over on a "greenfield". The existence of industry stakeholders with transfer potential is also important here (see Section 3.2). The ecosystem approach is well suited for the regional integration of the battery industry. Since the (increasing) complexity, differentiation and performance of the economy can be functionally addressed, especially at the regional level, the importance of regional cluster initiatives for innovation and as a supporter for the establishment of new economic sectors such as the battery industry will continue to increase in the future. For this reason, cluster initiatives – especially in case of new or emerging economic sectors such as the battery industry in Europe – should be understood as potential supporters for their successful establishment. Insofar, an increased involvement of battery industry stakeholders in existing regional cluster initiatives should be pursued. Therefore, promising regions are those that have existing clusters involved in electromobility, and those having industry clusters with transfer potential for battery cell manufacturing with regard to (raw) materials, plants, processes or applications (see Section 3.2). The transfer of technology and knowledge is aimed in particular at the production of battery materials and components as well as process steps and plants used in battery cell production and other industry sectors.


Strategic site planning and vertical integration of battery manufacturers along the value chain are essential for the lasting success of the battery industry. Vertical integration succeeds primarily through partnerships along the value chain. Here cooperation is recommended in particular with industry sectors that are already relevant partners for the battery industry, such as the chemicals industry or machine building and plant construction. This is complemented by industry sectors with transfer potential for the battery industry, such as the packaging and paper industry, the electronics sector, software development, the plastics industry and the energy sector.



Utilising cluster initiatives to support regional transformation processes along with targeted incentives. In the course of site selection for battery industry companies, topical links with regional economic stakeholders should be examined and worked out. A region's attractiveness can also be improved through financial resources, for instance in the form of investment subsidies. This can be sensible when existing cooperation and transfer potential can be realised as a result. In order for this to succeed, developing and maintaining a regional research and innovation strategy for smart specialisation (RIS3) is meaningful. The linking of actors in the battery ecosystem to economic structures of industries with transfer potential for the battery industry should be specifically stimulated and synergy potentials emphasized.



Utilising benefits of regional cluster structures. Good networking between the stakeholders is a crucial strength of clusters. This networking makes it possible to address new topics quickly and efficiently within a cluster. Furthermore, this coordination improves the quality of the results that can be obtained. Stakeholders who are already part of the battery ecosystem and a cluster initiative should assume a mediator role to position topics with battery relevance and to expand the network.

Boosting the transfer of knowledge between cluster initiatives and activities of the battery ecosystem. The analyses of the network structures (Section 4) show that there is some existing overlap between battery ecosystem stakeholders and various regional cluster initiatives. This is true both geographically (through proximity) and structurally (through stakeholders equally involved on both levels). That being said, the link between these two networking levels can be further developed – and therefore also the institutionalised transfer of knowledge. Selectively/strategically approaching topically relevant cluster initiatives that currently have few activities related to battery cell manufacturing is recommended in order to strengthen the transfer of knowledge and identify the potential of battery cell manufacturing. This can be realised, for example, through shared events or the integration/application eligibility of existing cluster initiatives in (new) funding programmes. Beyond that, regional transformation agencies can launch innovation missions with a focus on the battery ecosystem and development impetus. Here the ecosystem stakeholders can be involved as well. This can be included in the portfolio of the cluster management organisations and implemented directly. Conversely, battery ecosystem stakeholders that are not currently members of a cluster initiative should identify appropriate clusters and actively participate in them (see Section 2.2).

Business development should promote a region's transformation ability based on fundamental characteristics such as **creating resilient structures, knowledge orientation, cooperation, flexibility and agility**.

Linking cluster and industrial policies is recommended since this supports an **effective response to the respective regional framework, stakeholders, development paths and speeds** as well as the **existing industry specifics**.

Specifically incentivising cross-sector and cross-cluster partnerships. Experience from the "go-cluster" programme of the Federal Ministry for Economic Affairs and Climate Action (BMWK) shows that cluster stakeholders are generally very open to cross-cluster partnerships.[109] When economic prospects for participation in the emerging value chain in a region are offered by the establishment of the new battery cell manufacturing ecosystem, a clear win-win situation can be realised in the respective region. This requires cluster management organisations to initiate strategic partnerships from which cross-cluster cooperation/innovation potential is derived. As a rule, these cross-cluster partnerships are initiated at the level of cluster management organisations and can, for example, be accelerated by pending tenders/funding programmes. Cross-sector and cross-cluster partnerships can support the transfer of technology and knowledge from the partner industries to the battery industry.

109 See: Federal Ministry for Economic Affairs and Energy (BMWi) (2016).

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APPENDIX I: OVERVIEW OF THE EXAMINED NETWORKS AND VALUE CREATION LINKS

Notice: Only additions versus the ecosystem study[110] are listed below.

a) Networks and interest groups examined at the network level

Name	Origin	Member scope of examination
Circular Economy Initiative (CEID)	D	Complete
European Power Tools Association (EPTA)	EU	Complete
European Raw Materials Alliance (ERMA)	EU	Complete

b) Cluster initiatives examined

Name	Origin	Member scope of examination
Composites United e. V.	D	Complete
Cluster Transport, Mobility and Logistics in Berlin-Brandenburg	D	Complete
Commercial Vehicle Cluster - Nutzfahrzeug GmbH (CVC)	D	Complete
deENet – Kompetenznetzwerk Dezentrale Energietechnologien e. V.	D	Complete
European Center for Power Electronics e. V.	D	Complete
Competence Network Mechatronics in eastern Bavaria	D	Complete
Oldenburger Energiecluster OLEC e. V.	D	Complete
Chemie-Cluster Bayern GmbH	D	Complete
CARA European Cluster for Mobility Solutions	EU	Complete
AXELERA	EU	Complete
TENERRDIS	EU	Complete

110 Gieschen, J.-H., Bünting, A., Kruse, S., Vorholt, F., Wolf, S., & Zachäus, C. (2021). "Ökosystem der Batteriezellfertigung in Europa: Netzwerkstrukturen als Grundlage für Wissenstransfer und Wertschöpfungspartnerschaften" (Battery cell manufacturing ecosystem in Europe: Network structures as the basis for knowledge transfer and value creation partnerships). Publication of the scientific analysis of battery cell manufacturing on behalf of the Federal Ministry for Economic Affairs and Energy (BMWi) (analysis no. I / 2021). Berlin, from https://vdivde-it.de/de/publikation/oekosystem-der-batteriezellfertigung-europa, see Appendix I

Name	Origin	Member scope of examination
ViaMéca	EU	Complete
Nextmove	EU	Complete
Pôle Véhicule du Futur	EU	Complete
Green Tech Cluster	EU	Complete
CEAGA - Cluster de Empresas de Automoción de Galicia	EU	Complete
Plastics Cluster	EU	Complete
Plastipolis	EU	Complete

c) European cluster initiatives for the packaging industry

The following packaging industry clusters offer tie-in points to the packaging industry in Europe

Name	Country	Website
Packaging Cluster	Spain	https://www.packagingcluster.com
	Schweden	https://packbridge.se
Packbridge	Sweden	https://packbridge.se
	Deutschland	https://www.packaging-valley.com/de
VerpackungsCluster Südniedersachsen	Germany	http://www.verpackungscluster.de
	Slowakei	https://www.konopnydvor.sk
Packaging Valley	Germany	https://www.packaging-valley.com/de
	Schweden	https://paperprovince.com
PMAG Packaging Cluster	Georgia	http://pmag.ge/en
HEMP Cluster	Slovakia	https://www.konopnydvor.sk
Omnipack	Hungary	http://klastromnipack.cz/en/omnipack
Paper Province	Sweden	https://paperprovince.com

APPENDIX II: METHODOLOGY AND APPROACH

The results in Sections 2, 3 and 4 were obtained through own (desktop) research. Findings from interviews with experts and legwork from partner institutions were also included in the study.

For Sections 4.2 and 4.3, a network analysis of the new, steadily growing battery ecosystem was performed, with the methodology and data basis building to a great extent on groundwork from the analysis of the battery cell manufacturing ecosystem[111]. The connections between stakeholders through joint research projects, memberships in initiatives, associations, networks or cluster organisations related to battery cell manufacturing and existing economic partnerships in the form of joint ventures are examined. The data basis consists of data accessible to the public in national or European funding databases or public membership lists of associations, networks and cluster initiatives (see Appendix I).

Parts of the existing data basis were updated or supplemented for the study. Updates relate in particular to the network data for research partnerships. Research projects from the last seven years related to the topic of batteries were recorded for this purpose. The CORDIS funding databases and the German (FOEKAT) and British national funding databases serve as the data basis in this study. Other national funding databases are not included for availability reasons. In addition, data were included for members of select cluster initiatives with a gold or silver label of the European Secretary for Cluster Analysis (ESCA) in Germany and Europe.

Aside from the label, these clusters were selected based on the presumed relevance of a cluster to one or more value-added steps in battery cell manufacturing. This contribution was measured using a scoring system. The highest-rated clusters and their members were added to the data basis (see Appendix I). Compared to the original study, network data for additional interest groups and initiatives (including the Circular Economy Initiative) were added as well. The data collection period was March to June 2021. Due to the importance of regionality, the conducted analyses were location-sensitive. This means that stakeholders are differentiated between different locations (e.g. branch office, agency, research institution etc.). Geocoordinates were automatically assigned to the identified stakeholders based on the data using the Azure locations service to determine the location. This assignment was reviewed on a random sample basis and corrected as needed. Since a review could only be performed on a random sample basis, the incorrect geographic assignment of some stakeholders is possible. In the course of data cleaning, only uniquely assignable stakeholders are recognised as duplicates and combined.

When stakeholders could not be uniquely assigned based on the existing designation and geocoordinates, they are therefore considered separate stakeholders, i.e. locations. It is therefore possible that universities or research institutions with various institutions and locations, for example, do not appear in the rankings by the degree of networking (Section 4) even though they jointly exhibit a similar degree of networking as the top 10 stakeholders.

Two essential points need to be considered in the interpretation of the data: 1) Most of the connections in the data basis used here represent cluster and network initiatives in interest groups or initiatives (about 65 per cent for Germany, about 71 per cent for the EU). This is because clusters or associations have a large number of members as a rule. 2) The analysis results must be viewed as exemplary. They provide an overview of the battery ecosystem in Germany and Europe, based on the existing data basis, but not a complete view of the entire ecosystem. Limitations also exist due to the classification of the connections to the segments of the value chain, which were done by the study authors and in part automated.

111 For the methodology and data basis, see: Gieschen, J.-H., Bünting, A., Kruse, S., Vorholt, F., Wolf, S., & Zachäus, C. (2021). "Ökosystem der Batteriezellfertigung in Europa: Netzwerkstrukturen als Grundlage für Wissenstransfer und Wertschöpfungspartnerschaften" (Battery cell manufacturing ecosystem in Europe: Network structures as the basis for knowledge transfer and value creation partnerships). Publication of the scientific analysis of battery cell manufacturing on behalf of the Federal Ministry for Economic Affairs and Energy (BMWi) (analysis no. I / 2021). Berlin, from https://vdivde-it.de/de/publikation/oekosystem-der-batteriezellfertigung-europa.