Da CES
Danish Center for Energy Storage

POLICY BRIEF

BATTERIES PROVIDE MORE GREEN POWER

CONTENT

DANISH CENTER FOR ENERGY STORAGE (DACES)

Denmark should become a pioneer in research, development, application and integration of energy storage technologies that are competitive in a global market and contribute to reducing the global climate footprint.

DaCES is a neutral and independent forum that works to set the direction for research, education, and innovation within energy storage. We are a network-based and action-oriented organisation that brings together actors in an equal, professionally minded community of interests, encompassing various energy storage technologies and fields of expertise, to create collaborations and networks across research environments and businesses. Our goal is that by strategic and cross-disciplinary education and research, energy storage will become a Danish position of strength, for the benefit of climate, industry and society.

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POLICY BRIEF ON BATTERIES

DaCES' working group on batteries has prepared this policy brief with project manager Niels Dyreborg Nielsen, who is chief technical consultant in DaCES. The Chairman of the Battery Group is R&D Director of Advanced Materials, Søren Dahl, from Topsoe, and Professor of Materials Chemistry, Dorthe Ravnsbæk, from Aarhus University, is Deputy Chairman.

FOREWORD

Batteries play an important role in the green transition. In Denmark, batteries are essential to make the highly polluting transport sector greener through electrification. The future climate neutral energy system is primarily based on volatile renewable energy production. This creates imbalances between electricity consumption and generation and can lead to loss of wind and solar energy. Here, batteries can reduce local short-term imbalances in the electricity grid as well as short-term storage of excess renewable electricity for later demand.

Danish companies and knowledge institutions have developed strong competencies within battery technologies such as cobalt-free batteries, flow batteries as well as intelligent battery management and integration. Through close collaboration across industry and research, the battery sector has created an innovative and dynamic sector. But there is a need to further develop and scale up positions of strength to make a real difference and create green growth.

Stable self-sufficiency and sustainable access to critical battery raw materials, battery production, recycling and reuse are also high on the EU agenda. As early as in 2017, the European Commission launched a European battery alliance between industry and research, which has continuously been supplemented by new political and strategic initiatives. The importance of these initiatives has been further accentuated with Russia's invasion of Ukraine, energy, climate and supply crises, as well as the need for Europe to create its own independent supply chains.

The Danish battery sector has great potential to develop into a new green growth engine and contribute to a sustainable European battery industry, which is able to support global climate goals. However, this requires that Danish politicians bring batteries and the sector's potential on the political agenda and give equal status to batteries and other storage technologies. The outside world has already put turbo on developing their battery sectors.

In March 2023, the Danish Center for Energy Storage (DaCES) hosted the Danish Battery Summit 2023 in Sønderborg together with the University of Southern Denmark and the Danish Battery Society The event attracted almost 100 participants and clearly showed a significant potential in a growing Danish battery sector.

Together with leading Danish stakeholders from research and business, DaCES has prepared this policy brief on batteries and their crucial role in achieving a green and sustainable transition. Our mapping of the Danish battery sector and a number of company cases clearly demonstrate that Denmark has the potential to play an important role in the development of a sustainable and secure battery industry in Europe.

On the following pages, we present three recommendations to strengthen Denmark's role as a green pioneer, also in this area. We are ready to work with decision makers, authorities, grantors, and other businesses to realise the potential of the Danish battery sector.

Danish Center for Energy Storage has three recommendations

1 **Develop a long-term national battery strategy with prioritised areas of strength and measurable initiatives**

The strategy must stimulate research, growth, and investments in the Danish battery sector. This will strengthen Denmark's competitiveness in a market where our neighboring countries have developed comprehensive strategies and plans. The battery strategy aims to demonstrate how Denmark, by strengthening our core competencies, can increase our efforts in the European battery collaboration.

2 **Energy storage, including batteries, must be prioritised as an independent strategic theme in grants from Danish public and private stakeholders**

By developing a national battery strategy, we can support and further develop already established Danish strength positions such as next generation ion batteries, new recyclable battery types and digital optimisation tools. Other applications include intelligent management, integration, and automation of battery systems. In particular, it is targeted at cars, trucks, buses, ferries and charging infrastructure, as well as local energy balancing, which reduces bottlenecks in the electricity grid and provides system services.

3 **Create supporting framework conditions for the use of self-generated renewable electricity in energy communities**

Energy communities can consist of citizens, municipalities, associations, institutions, and industry. Energy communities can reduce local, cost-intensive electricity grid expansion and encourage local green initiatives and CO_2 reductions. The tools are local production as well as flexible sharing, consumption, and storage of self-generated energy, especially electricity. The economy of energy communities is challenged due to electricity charges and tariffs for both charging and discharging from a common battery.

We propose to modify inappropriate regulations and requirements to achieve both local and societal benefits.

Rechargeable batteries are indispensable for the green transition

Rechargeable batteries are essential in a future green energy system, which will consist of a diverse range of technological solutions for energy production, consumption, infrastructure, storage, and conversion.

Realising Denmark's climate ambitions requires that increasing amounts of renewable energy (RE) are integrated into the electricity grid and phase out of fossil-based transport. The development challenges the capacity, frequency and voltage of the power grid, as well as existing battery technologies and production.

Batteries can support the development through efficient electrification of the transport sector including passenger cars, trucks, buses, ferries, etc. and through balancing the frequency and voltage of the electricity grid. This reduces the climate footprint, improves the utilisation of energy resources and ensures stability in the electricity grid despite a high share of renewable energy. The realisation requires the development of sustainable batteries and efficient upscaling of battery production that is already in full swing globally.

Batteries can be included in many applications,
of which the most important in a Danish context are listed below:

1. Energy storage for electric transport such as passenger cars, buses, trucks, ferries, etc., which potentially are intelligently connected to the power grid (Vehicle-to-Grid)

2. System services by balancing the power grid voltage and frequency at a second to hourly basis

3. Backup power supply for power outages instead of fossil-powered facilities

4. Local storage of excess electricity generation from renewable energy to periods of increased electricity demand in order to promote system integration solutions and to reduce cost-intensive power grid expansion and local bottlenecks

5. Strengthen the economy of energy communities by maximising self-generation and consumption of renewable energy, as well as applications behind the electricity meter such as virtual power plant in the industry

Projections clearly demonstrate that the battery demand for mobile propulsion accounts for the vast majority of future battery needs (around 90%), followed by energy storage and finally consumer electronics [1]. Batteries have a wide range of applications. It is clear, that when it comes to global investments in green technologies, energy storage represents the largest share (26%), of which batteries account for more than half (56%) of the investments [2].

The European battery production capacity is expected to be twenty times higher by 2030 compared to 2020, as there is also a huge increase in the need for batteries, cf. Figure 1. The battery demand entails a large growth potential in the form of a doubling of turnover from 2020 to 2030 cf. Figure 2, as well as high job creation in the EU sector, cf. Figure 3.

European capacity for battery production

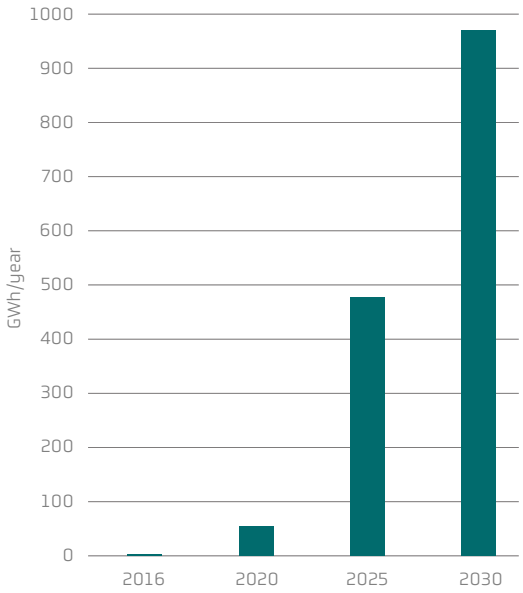


Figure 1: Projection of the capacity for battery production in the 27 countries of the EU [3]

Turnover of the European battery sector

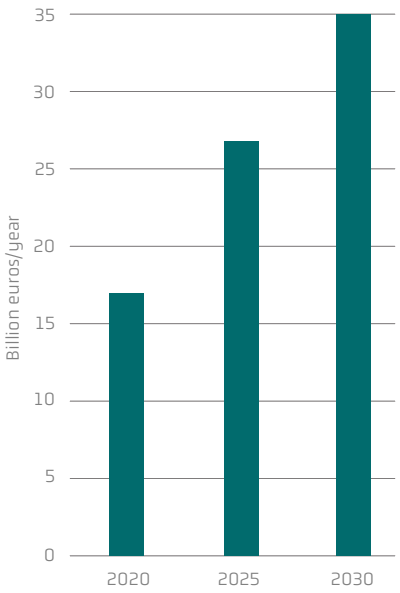
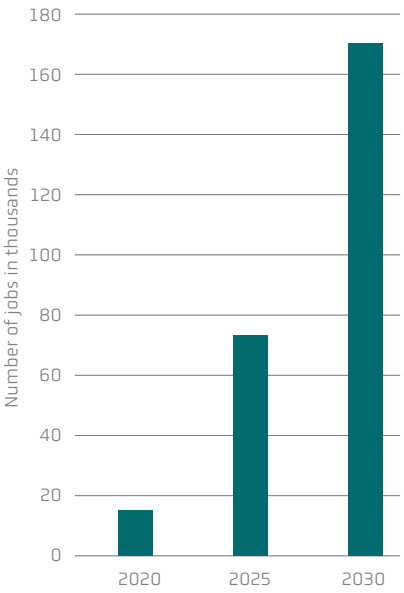


Figure 2: Projection of the turnover of the battery sector in the EU, UK, Iceland, Liechtenstein, Norway and Switzerland [4]

Job creation across the value chain in the EU



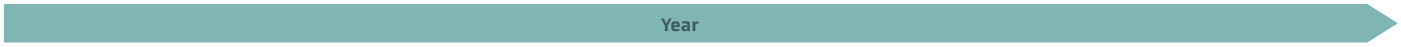


Figure 3: Projection of job creation across the total battery value chain for the 27 countries of the EU [5]

Denmark must not miss the opportunity to capitalise on a highly skilled workforce, technological strengths and strong, interdisciplinary collaborative skills in order to develop and build a national, sustainable battery sector.

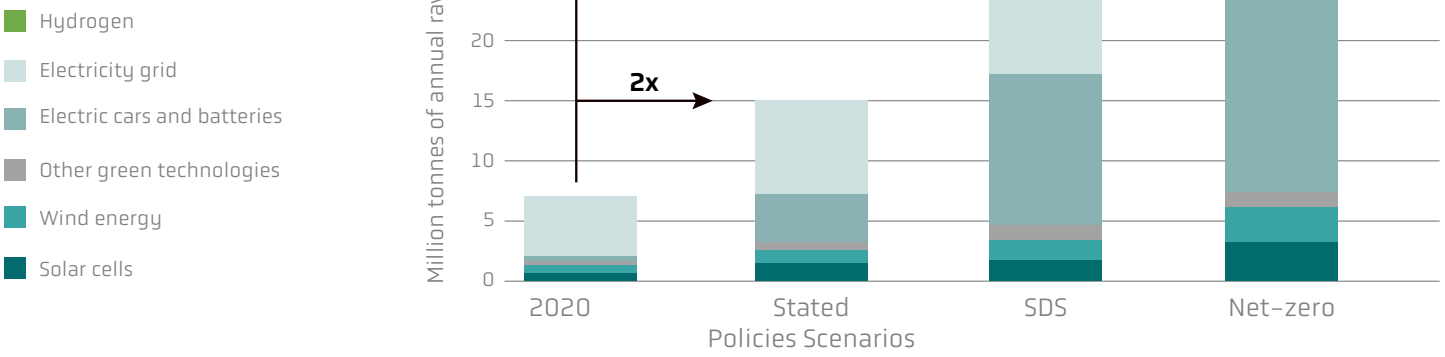
Raw material shortage is a bottleneck for the green transition

Electrification of the transport sector is the main driver of the expected increase in battery demand, which challenges all links in the battery value chain with a risk of supply shortages and global bottlenecks, cf. Figure 4. In this context, the Danish Energy Agency expects 660,000 electric cars in 2030, equivalent to 20% of Danish passenger cars [6]. A demand of this size calls for massive scale-up of raw material extraction and, in particular, recycling and the development of easily accessible and environmentally friendly battery materials. Without these initiatives, there is a high risk of delaying and raising the cost of the green transition, as well as unnecessarily damaging the environment and climate.

EU member states are particularly vulnerable, as the EU produces only about 2% of battery raw materials in the world, while China accounts for almost 40% and dominates the rest of the battery value chain with a share of around 70%, cf. Figure 5. Europe's green transition and security of supply are under threat due to both import dependency on battery raw materials from very few countries and green transport goals. The targets mean that the need for lithium batteries will increase by a factor of 12 in 2030 and a factor of 20 by 2050 compared to today [8].

(see Figures 4 and 5 overleaf)

Figure 4: Estimated annual raw material consumption in million tonnes for green technologies in 2020 and three different 2040 scenarios compared to 2020 by sector. The "Stated Policies Scenario" indicates the development of raw materials consumption by existing political agreements. "SDS" (Sustainable Development Scenario) indicates developments that follow the Paris Agreement. The "Net zero" scenario indicates the need for 2040 to achieve net global net zero CO_2 emissions by 2050 [7].



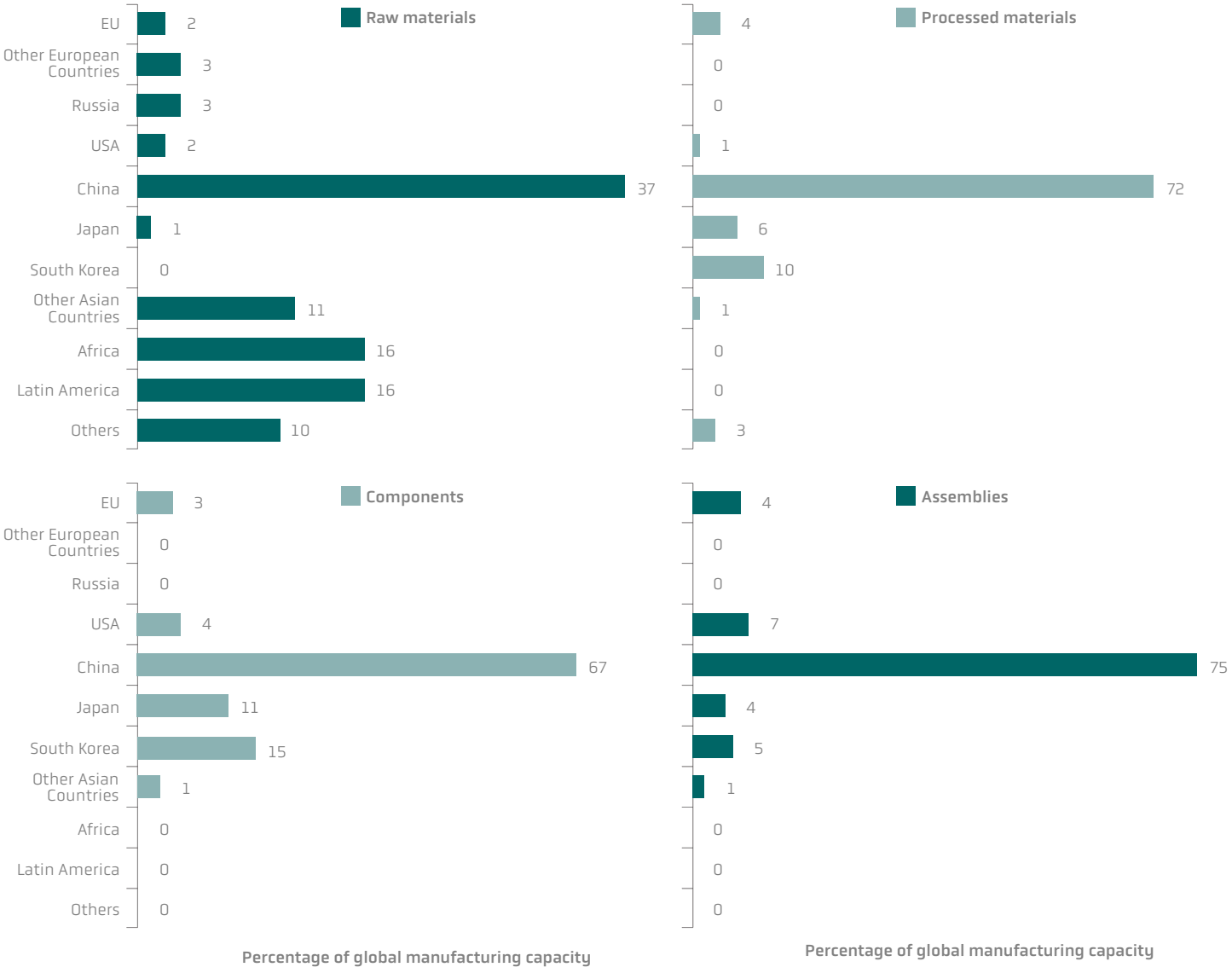


Figure 5: Overview of countries and regions' shares in the global manufacturing capacity of four stages of the supply chain for lithium-ion batteries [9]. Rounding means that the numbers do not add to 100%.

The EU sees batteries as a strategic key technology to achieve climate goals

The EU has a strong focus on energy storage, including batteries, which are considered to be one of eight key strategic technologies to achieve European climate goals [10]. In 2017, the European Commission launched the European Battery Alliance, EBA250. It was later followed by policy initiatives such as the strategic roadmap for battery research (Battery 2030+) and support for both transnational battery projects (IPCEI) and battery research, development, and innovation (BATT4EU) [11], [12].

The latest proposal from the European Commission is the Net Zero Industry Act, where nearly 90% of the annual battery demand of Member States is to be met by battery manufacturers in the EU [13]. Finally, EBA250 expects EU battery production to increase by seven times to 1,000 GWh/year by 2030 [14]. Implementation is to be achieved through a new legislative initiative to promote European production of sustainable, circular, and safe batteries and an ambitious proposal on critical raw materials presented by the Commission in March 2023 [15].

The Commission has identified the battery raw materials cobalt, lithium, manganese, natural graphite and nickel as strategic and critical raw materials. Projects in the field of the extraction, processing and recycling of critical raw materials can benefit from financial support and benefit from simplified permit procedures [16]. However, the proposal must first be examined by the EU Member States in the European Parliament and the Council of Ministers and is expected to be adopted by 2024 at the earliest.

Mining in the EU is limited despite high battery consumption. Analysis of mineral deposits shows that the EU's self-sufficiency can be significantly increased, but this requires creating infrastructure for mining and processing raw materials. These initiatives will contribute to strengthening the EU's security of supply and ensuring sustainable batteries for the green transition.

Although there are good opportunities for more mining in Europe, it is unlikely that the region will become completely self-sufficient in critical raw materials. The EU wants to form strategic partnerships with third countries to secure and diversify the supply of raw materials. Greenland has significant potential for critical raw materials, including for battery raw materials such as graphite, nickel, cobalt and lithium [17]. So far, there has been little mining in Greenland, but in these years mineral exploration is underway with the purpose of extracting critical raw materials. Several world-class deposits have already been identified where quarrying can significantly contribute to global production if mining starts. Since the Self-Government Agreement in 2009, Greenland has managed its own raw materials and issues exploration, and extraction permits and has a well-regulated and transparent licensing legislation.

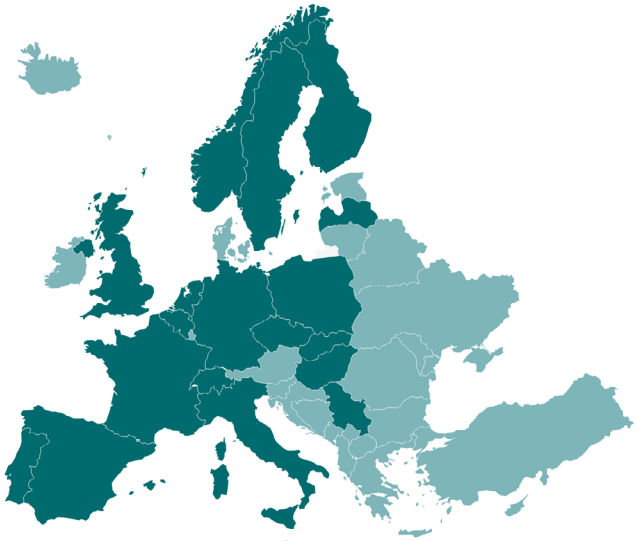


Figure 6: Map of European battery cell production capacity, which by the end of 2022 was 124 GWh/year in dark green countries [19]. Countries without production in 2022 are marked with light green. The largest notified capacity by 2030 is in Germany (545 GWh/year), Hungary (215 GWh/year), France (170 GWh/year) and Spain (140 GWh/year), updated in June 2023 [20].

The European Commission's high ambitions for the European battery industry are in stark contrast to the lack of Danish political prioritising supporting initiatives that can develop the sector. Denmark is a white spot on the European battery map with a lack of large-scale activity across the entire battery value chain compared to the rest of Europe, cf. Figure 6 [18]. The absence of a political battery strategy and support for the strength positions of Danish actors clearly shows that the area has not been a political priority.

As a green pioneer, we must and can change this by contributing to the development of a sustainable European battery sector for the sake of energy, climate, and security policies. The contribution will strengthen Danish battery stakeholders, support job creation and green growth.

The Danish battery value chain

Denmark is often overlooked in many international analyses of the European battery map, as mappings of the European battery sector often focus on a specific type of manufacturers that are not represented on the Danish market, cf. Figure 6.

We need to change that. We must promote Denmark's leading battery companies, which together cover large parts of the classic battery value chain. Examples of leading battery companies with activities in the Danish Commonwealth are shown in Figure 7 and include start-up raw material extraction, development of the inner components of the batteries (functional materials in Figure 7) and construction of total battery solutions (battery cell and package in Figure 7), which may interact with small and large RE installations (application in Figure 7). The 'integration' category in Figure 7 shows companies in associated technologies, such as the development and production of charging stations and software for controlling and monitoring battery packs.

The Danish battery sector also includes established researchers from the Technical University of Denmark, Aalborg University, Aarhus University, the University of Southern Denmark and specialists from the Danish Technological Institute. The specialist experts carry out groundbreaking activities in materials development, testing of battery performance, lifetime, and safety, as well as intelligent integration of, e.g., batteries with the power grid, self-consumption, and production. In addition, Danish consultants assist in design, optimisation, and realisation of battery projects.

Recycling of battery raw materials and the reuse of whole battery packs (second life) is crucial to achieving a sustainable battery industry, which the EU supports with a new battery law from 2022 [10]. Here, as a pioneer in the circular economy, Denmark should make a significant contribution to the EU's recycling targets. The Danish industry already includes dedicated stakeholders, who work to fulfill the great economic growth potential and ensure Denmark's access to essential recycling technology. Stena Recycling is one of the leaders in the recycling of batteries. They investigate and invest in a combination of thermal and mechanical treatment.

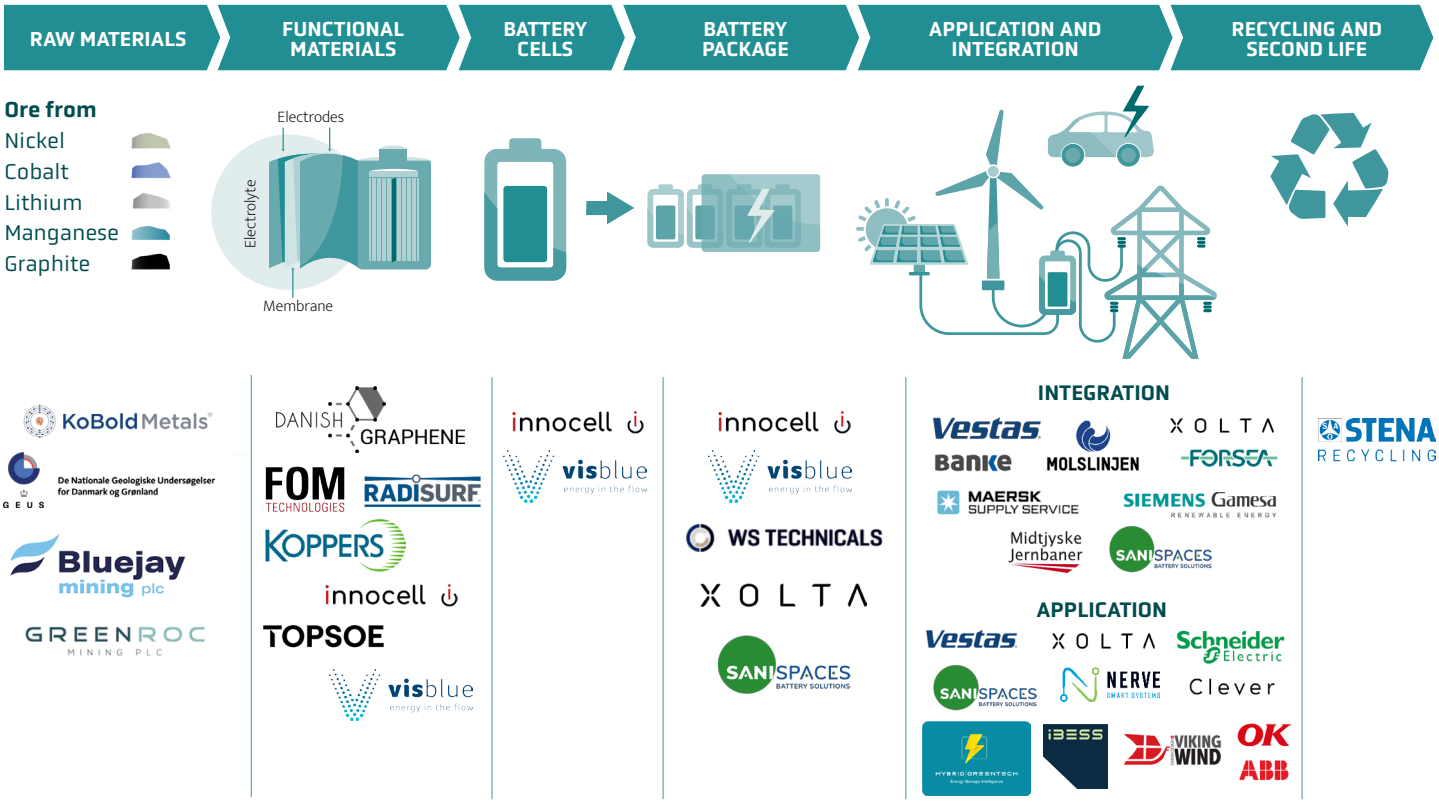


Figure 7: Examples of leading battery companies in the Danish Commonwealth and their location in the battery value chain. In addition, the Danish battery sector consists of highly specialised research environments (DTU, AAU, AU, SDU, TI, GEUS) and skilled consultancy firms that strengthen the competitiveness of the companies.

Strength positions in the Danish battery sector

Denmark is in fierce international competition for development of the battery market. We need to prioritise resources wisely and strategically if we are to be among the leaders. Several leading Danish battery players have identified niche areas and are competitive in the following areas:

1. Development of new cobalt-free battery materials and electrolytes for lithium and sodium ion batteries (Topsoe, AU, DTU)

2. Production of functional carbon nanomaterials and organic materials for innovative design and coating of active battery materials (Danish Graphene, FOM, Koppers, AU)

3. Development of new, safe, and green battery types such as flow and solid-state batteries (VisBlue, AU, DTU, SDU) as well as energy-dense, water-based supercapacitors (Innocell, SDU)

4. Integration, control, and automation of battery packs with RE-systems as virtual power plants (Vestas, XOLTA, Sanispaces, AAU) or with refrigerated trailers (Bitzer)

5. Direct and complete electrification of light-duty trucks (Banke)

6. Intelligent energy management, digitalisation, and automation to optimise customer's energy consumption (Schneider Electric, AAU)

7. Consulting and testing facilities for characterisation, safety evaluation and development of battery-powered solutions from low power Internet of Things (IOT) devices to high performing batteries in grid-connected energy storages or electrical mobility (Department of Technology, AAU, DTU)

8. Technology neutral tools such as multiscale computer models, machine learning, autonomous laboratories and test facilities that accelerate the discovery and design of new batteries (DTU, SDU, AAU)

All areas are important for developing sustainable, efficient, and competitive batteries for a variety of applications. We have selected a number of cases that show how small, medium-sized and large Danish companies develop and sell unique battery solutions, both nationally and globally.

The examples clearly show that, despite a lack of political prioritisation and clear framework conditions, Denmark can act as a focal point for the development of battery companies that are also competitive. With clear framework conditions and a strategic prioritisation of the area from political level, Danish battery players have a real opportunity to realise a promising potential and take on a market-leading role also on a global stage.

DaCES supports efforts to realise the sector's great potential through our strong professional network among business and research environments. Our members have practical experiences, innovative ideas, and specific solutions that we look forward to share and discuss with authorities, decision-makers, and grantors with the aim of turning the Danish battery sector into a green driver of growth.

Case 1

VisBlue produces sustainable battery solutions for storing green power

VISBLUE

The company is based on a collaboration between the universities in Aarhus and Porto in 2014 and has received support from both Danish and European funding programmes. Today, VisBlue has more than 20 employees and is a global partner in energy storage solutions with more than 150 installed battery systems in Denmark, Portugal, Germany and the Czech Republic.

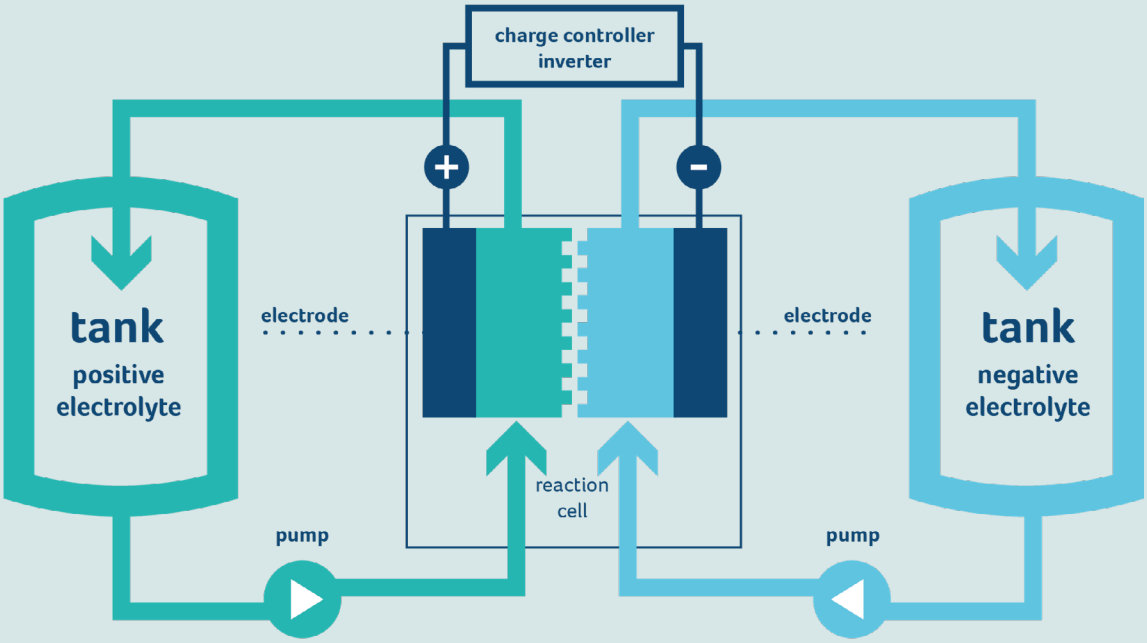


Figure 8: Concept figure of VisBlue's flow batteries. When charged and discharged, electrons are added and released between electrolyte fluids and electrodes. The pumps ensure fresh electrolyte fluid to the reaction cell for efficient storage and release of electrons in the tanks.

CHALLENGE

If we are to ensure maximum value creation of Denmark's massive expansion of wind and solar energy, we need batteries for, among other things, municipalities, industry, housing associations and self-governing institutions. The batteries must be sustainable both economically and climate-wise.

SOLUTION

VisBlue uses proven vanadium redox flow technology to store electricity in a water-based solution characterised by its non-degradable, non-flammable and low-risk benefits. With a recycling rate of 99% and a lifetime of more than 20 years (20,000 discharges), VisBlue's scalable 40 and 250 kWh flow batteries are a sustainable, safe and long-lasting alternative to standard battery types on the market.

POTENTIAL

With VisBlue's flow batteries, customers can efficiently store electricity generated from renewable sources, such as solar and wind, for calm and cloudy days. The solution is attractive to municipalities, housing associations, self-governing institutions and industrial companies that use flow battery solutions for balancing their power consumption in a sustainable direction, both economically and climate-wise.

Case 2

Topsoe develops cobalt-free cathodes with high lithium utilisation

TOPSOE

The company's ambition is to accelerate the green transition by contributing with its in-depth experience on catalytic processes, materials, and the development of green fuels. One of the areas that Topsoe has been working on over several years is to develop and scale up production of next generation battery materials for lithium-ion and sodium-ion batteries.

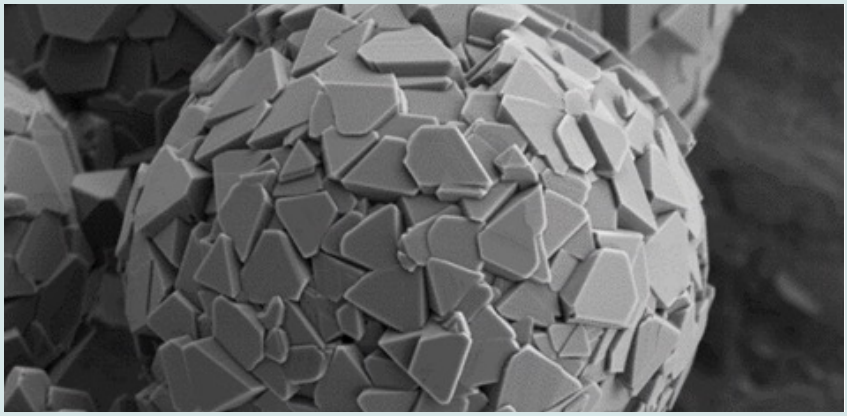


Figure 9: Visualisation of LMNO particles using scanning electron microscopy. The dense round particles have been developed to achieve high energy density in the LNMO batteries.

CHALLENGE

Exponentially increasing demand for batteries especially for electric cars is already creating problems with shortages and rising prices of critical metals for lithium-ion batteries. These include among others cobalt and lithium [21].

SOLUTION

Topsoe's lithium-nickel-manganese oxide (LNMO) material for lithium-ion batteries is cobalt-free with a relatively low nickel content and additionally utilises lithium very efficiently.

This makes LNMO a highly competitive and sustainable alternative to conventional battery materials currently used in lithium-ion batteries. The production of LMNO batteries from the battery material is also more sustainable because solvents that are difficult to process can be replaced with water.

Topsoe's LMNO battery enjoys great interest due to a sustained effort towards improving and promoting. In Frederikssund, a pilot plant under construction will have a capacity of more than 100 tons LMNO per year with expected production start in 2023. The plant provides the possibility to supply material for demonstration batteries and production mature technologies to build production on an industrial scale. It is expected that the plant on an industrial scale will be located in Northern Europe and produce 50,000 tons per year when fully developed.

POTENTIAL

LMNO batteries will be able to be designed for use in various applications. This applies to electric cars, where competitive price and high energy density are crucial. In addition, there are obvious uses for e.g. ferries and trains in need of very fast charging.

Case 3

Danish Graphene develops carbon nanomaterials (graphene) for the design of innovative battery materials

DANISH GRAPHENE

The company is a Danish startup, which in 2020 originated from research at Aarhus University and develops a special type of carbon materials called graphene. Graphene is a 2-dimensional material consisting of only a single layer of carbon atoms. The material has extremely high strength, electrical and thermal conductivity and is chemically very robust. Danish Graphene produces functionalised graphene, where chemical groups are introduced to the carbon material to target properties to specific applications. The company has extensive experience in the production and development of these nanomaterials as well as in-depth understanding of production methods for the use/implementation of graphene in e.g., electrode mixtures for battery production. Development activities are focused on graphene's ability to modify electrode materials and control the structural composition with a focus on improving new types of battery materials.

Figure 10:
Graphene dispersion for direct use in electrode formulations included in batteries.

CHALLENGE

Graphene materials have a large potential to improve a wide range of products. The challenge for broad application lies in the production of functionalised graphene, which today is very harmful to the climate, and in the implementation of graphene in other products.

SOLUTION

Danish Graphene develops and produces functional green graphene, where graphite is "split" into graphene using low-temperature electrochemistry without the use of harmful or hazardous chemical substances. In this way, only green electricity and water are used for production. The functionalised graphene can be distributed (dispersed) in aqueous solutions and easily implemented in a wide range of products.

POTENTIAL

Functional graphene is widely used in batteries, solar cells, coatings, composite materials, building materials, etc. Danish Graphene sells green graphene to researchers and companies on a small scale. The company is working to demonstrate how the functionalised green graphene can be implemented on an industrial scale and for a wider range of applications that include adding graphene additives to battery electrodes. The company has demonstrated that it is possible to encapsulate/coat the active particles in cathode materials with graphene to potentially achieve better stability and better electrical conductivity. This can lead to longer lifespan as well as faster charging of batteries in the future.

Case 4

Vestas uses batteries to optimise wind turbines and solar cells to limit the load on the electricity grid

VESTAS

The company's vision is to become a global leader in sustainable energy solutions that include energy production and energy storage systems such as batteries. Vestas has been actively working with energy storage solutions since 2010.

Figure 11: Vestas' proprietary battery storage, which can store 2 MWh of electricity and discharge with 2 MW in front of Vestas' headquarters at Hedeager 42 in Aarhus.

CHALLENGE

The load on the electricity grid increases with more electricity from wind and solar and with strong growth of the number of electric cars.

Electrification of the national and international societies significantly increases electricity consumption, but the expansion of the electricity grid does not follow at the same rate, which creates risks of imbalances between consumption and production as well as instability. This calls for flexible energy-generating solutions of renewable energy that can support the grid to an even greater extent.

SOLUTION

Vestas develops commercial systems for controlling power plants and managing energy, which at different time scales makes it possible to integrate battery storage systems with wind turbines. Storage makes it possible to transport power from wind turbines to the grid when the load of the grid is low and demand is high, which supports the grid and increases the utilisation rate of the grid.

POTENTIAL

Vestas actively participates in the integration of systems in Kennedy Energy Park (Australia), which for the first time integrates 43 MW Vestas wind turbines with 15 MW solar panels and 2 MW/4 MWh batteries in a hybrid system that supports Australian grid requirements.

Vestas has proprietary demonstrators of battery storage systems for various demonstration purposes including Denmark's currently largest battery, shown in Figure 11. The battery is synchronised with energy production from Vestas' test mills on the west coast of Denmark. The discharge is done to electric cars that charge in Vestas' parking lot whereby the cars are charged with "green" energy.

Case 5

XOLTA enables companies and private individuals to optimise RE facilities with intelligent management

XOLTA

XOLTA is a Danish-owned company specialising in battery systems for storing energy. The batteries are controlled by a cloud-based intelligent software that optimises the use of the battery for both individuals, businesses, and the common electricity grid. XOLTA has installed more than 15 MWh of battery capacity across more than 1300 plants for both companies and individuals.

Figure 12: Haarup's machinery factory at Silkeborg has installed 12 XOLTA batteries that store electricity from the factory's solar cells and make the factory self-sufficient with electricity from March to November [22].

CHALLENGE

The growing electricity consumption creates the need for more companies, private individuals and housing associations etc. to establish renewable and efficient energy systems. To limit the load on the electricity grid, it is important that more people become self-sufficient with renewable energy.

SOLUTION

The optimum use of renewable energy systems requires that the battery solution can control when batteries charge and discharge from the power grid. All XOLTA batteries are connected to a sophisticated energy management system (EMS). The system's computer-controlled optimisation tools are cloud-based and are connected to each battery. The cloud-based optimisation algorithm automatically keeps the battery's function under control whereby it performs optimally at all times taking into account weather conditions, electricity prices and expected future consumption.

POTENTIAL

XOLTA batteries make it possible to optimise energy storage and thus optimise self-produced renewable energy while at the same time helping to keep the grid in balance and delaying the use of the grid to periods of low load. This provides an economic benefit for the individual company as well as the private homeowner and reduces the load on the electricity grid. At the same time, it makes the integration of renewable energy in the electricity grid simpler and cheaper, which supports Denmark's goal of a cost-efficient and green transition.

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