Knowledge base

– Basis for Norway's battery strategy

Table of contents

Introduction 4

Why a battery strategy? 5

The battery markets 8

Horizon scan 15

Collaboration and competition: the strategic powerplay between China, the EU and the USA 15

The EU's extensive strategic approach to realising a European battery industry 16
- Development of the EU's battery policy 16
- Europe's cluster approach to realising the battery industry 17
- Financial support for the building of European battery production 17
- New Batteries Regulation 18
- Research and development 18
- Access to raw materials 19
- Enhanced facilitation of battery production in the EU towards 2030 20

Strategy and battery initiatives in the UK 20

The Nordic battery value chain 21

The Swedish battery strategy 23

Finland's battery strategy 24

Previous input and measures by Norwegian stakeholders 26

The battery value chain and Norwegian stakeholders 29

Minerals 29
- Norway's access to minerals and battery-critical raw materials 31

Raw materials (nickel, cobalt, manganese, aluminium, silicon and synthetic graphite) 32

Precursors and cathode active materials 32

Production of anode materials 33

Cell production 34

Maritime applications 36

Batteries in tomorrow's energy systems 37

Recycling 38

Norwegian stakeholders 39

Norwegian stakeholders in a growing ecosystem 40

Piloting, demonstration and associated needs for capital 42
- Barriers to capital 44

Development of new battery technology 45

Sustainability challenges for battery production and how to address them 46

Energy needs **49**

Industrial sites and co-location **51**

Expertise **53**

Host attractiveness **56**

SWOT (strengths, weaknesses, opportunities and threats)... 57

Appendix **59**

The EU Batteries Regulation.. 59

Battery IPCEI – Important Projects of Common European Interest... 60

Example of equipment for pilot production of pouch battery packs 61

Introduction

The Norwegian Government is in the process of developing a national battery strategy. The basis for this work is a strong increase in the demand for more sustainable batteries for various purposes, both globally and in Europe, and the fact that Norway is considered to be in a good position to take market share in several parts of the battery value chain. The battery value chain has the potential to become a major new, profitable industry in Norway, giving us a chance to contribute to emission reduction, create green jobs and aid the transition from fossil to renewable energy in Norway and abroad.

The battery strategy forms part of the Government's Green Industrial Initiative, and the value chain for batteries is one of seven pillars in this initiative. The others are the value chains for offshore wind, hydrogen, carbon capture and storage (CCS), the process industry and the forest and wood industry. Other areas as well, such as green shipping, are of relevance to this work. The purpose of the initiative is to create new green jobs, increase mainland investments, increase non-oil and gas exports and cut greenhouse gas (GHG) emissions. The Government is in the process of specifying the ambitions for each of the pillars and has drawn up a roadmap that will be used to set the course for an overall coordination of the Green Industrial Initiative.

Various stakeholders in and outside Norway have developed a broad knowledge base for the development of the battery value chain. To continue building on this basis, the Government represented by the Ministry of Trade, Industry and Fisheries appointed a working group in December 2021 that was tasked with preparing a comprehensive foundation for the Government's action-oriented national battery strategy. The working group has consisted of the secretary of Prosess21 and key individuals from InvestIN[1] and SIVA, representing the governing bodies of these enterprises. The working group has engaged in dialogue with the Ministry of Trade, Industry and Fisheries and has used EIT InnoEnergy and the European Battery Alliance as sparring partners in its work. A reference group consisting of more than 50 stakeholders either in or affiliated to the battery value chain has provided written input on the working group's draft of the knowledge base. One-to-one meetings with key stakeholders in or affiliated to the battery value chain have taken place in parallel. An input meeting on the battery strategy was held on 18 February, chaired by the Minister of Trade and Industry. An executive meeting on batteries was held on 22 April chaired by the Prime Minister. Representatives of the working group attended these meetings.

The present document is the result of this preparatory work, and the working group is responsible for its content.

June 2021

[1] InvestIN is part of Innovation Norway

Why a battery strategy?

One-fifth of all global GHG emissions come from transport, and for many people, the move from internal combustion engine (ICE) cars to electric vehicles (EVs) will be one of the most visible results of the climate transition. Thirty countries and six of the world's largest carmakers have signed the COP26 declaration[2] and committed to working towards 100% zero emission cars and vans by 2035 in leading markets, and by 2040 globally. Ford, Volvo and Mercedes-Benz are among the signatories. An increasing proportion of automotive producers have pledged to work towards reaching 100% zero emission vehicle production and use. By 2030, countries such as Denmark, the Netherlands, Scotland and Sweden will ban the sale of light-duty ICE vehicles. Norway has played a leading role in the electrification of the car fleet over many years and is a pioneering country in terms of banning the sale of new ICE passenger cars (from 2025), in addition to having the highest percentage of new EV sales.

The electrification of the car fleet is the key driver behind the massive increase in the world's battery production. The EV market is expected to grow exponentially over the next decade. A large increase in demand for products often leads to strong competition and reduced prices, which we have seen examples of in onshore wind and solar. The price of batteries is expected to drop, thereby helping to open up new markets. We have seen this happen with bicycles, power tools and gardening tools. The market for stationary energy storage systems is also under development, with several pilot projects under way, and the market is expected to grow significantly in combination with an increase in renewable, variable power production. Solutions for heavy onshore and maritime transport will also represent an increasing market for batteries. In this area, Norway is far ahead through the electrification of its ferries.

Electrification in general and battery technology in particular represent great business opportunities. Norway has been a driving force for changing the market by providing incentives for the purchase and use of EVs, facilitating charging infrastructure and promoting electric ferries in connection with public tenders. At the same time, the Norwegian authorities have to a lesser extent taken direct steps to enable Norwegian business and industry to share in the global business opportunities that arise from the market development, despite the fact that Norway produces many of the materials currently used in batteries (e.g. aluminium, nickel, copper, graphite and silicon). This is partly because batteries have been developed and produced by Asian manufacturers, and that Europe has been a relatively small market. In 2017, however, the EU launched a large-scale initiative through the Strategic Action Plan on Batteries and the establishment of the European Battery Alliance, with the ambition of being largely self-sufficient and stimulating climate-friendly production throughout the battery value chain. Norwegian authorities and businesses have taken little part in this activity. As a country that produces raw materials equivalent to those used in batteries and with almost 100% renewable power production, Norway is capable of hosting battery production facilities with Europe's lowest GHG emissions and efficient use of material resources.

The Government's political platform, known as the Hurdal Platform,[3] sets out clear goals for industrial policy: We will pursue a green industrial agenda to create jobs in Norway, safeguard the future welfare system and help to cut emissions in Norway and globally. Norwegian exports excluding oil and gas shall increase by at least 50 per cent by 2030. Steps shall be taken to facilitate large-scale battery cell production in Norway by introducing more internationally competitive framework conditions in the industry. The platform also dictates investments in industrial activity in a complete battery value chain, including raw materials, components, applications, collection and recycling. To achieve the goals outlined in the Green Industrial Initiative, the central government will assume a more prominent role by means of a powerful toolbox and ensure good, predictable and stable framework conditions that mobilise private investments and continued growth. Access to land, infrastructure, expertise and competitively priced renewable energy is emphasised in particular.

Several official studies have emphasised the market opportunities the Norwegian battery value chain represents, and the preconditions that need to be in place to unlock this potential. Many actors have also expressed a wish to become part of the battery value chain. The NHO project "Green Electric Value Chains"[4] estimates the potential annual turnover in the Norwegian battery chain to be around NOK 90 billion in 2030 and NOK 180 billion in 2050. The figure estimated for 2030 is expected to exceed that of offshore wind and hydrogen combined, among other things because the technology and markets will provide for a considerable scaling-up of the battery value chain in Europe and worldwide over the next few years. According to the report, Norway is well positioned to succeed in

[2] COP26 declaration: zero emission cars and vans – GOV.UK (www.gov.uk)
[3] hurdalsplattformen.pdf (regjeringen.no) – in Norwegian only
[4] gronne-elektriske-verdikjeder.pdf (nho.no) – in Norwegian only

several parts of the battery value chain, contingent on swift, significant investment. If not, the report predicts that market shares will be taken by other countries. McKinsey gives the following advice: *Companies and governments must move quickly to gain a foothold in the fast-growing battery market for electric vehicles.*[5] It is a matter of urgency, and Norwegian operators need to become part of the best consortia if and when the industry consolidates. McKinsey recently published the report "Norway tomorrow",[6] which proposes an ambition of 200 GWh of battery cell production in Norway, which will generate a GDP increase of NOK 40 billion and employ 33,000 people in 2030. Menon recently published a report that estimates the employment effects of battery cell production in Norway in a base case, low-growth and high-growth scenario.[7] The base case estimate is 8,100 employees and does not include ripple effects. By comparison, only three Norwegian industries have grown at the same rate over an eight-year period since the financial crisis in 2008, and they were all existing, established industries, which makes the expected employment rate in the battery industry even more remarkable.

Up until now, developments in the battery industry have primarily been driven by countries in Asia. Only a small proportion of lithium batteries are currently manufactured in Europe. In 2017, the EU established the European Battery Alliance[8] for the purpose of establishing competitive battery value chains in Europe, boost the competitiveness of the European automotive industry and reduce dependence on battery cells produced in China. Among other things, the alliance has emphasised the Nordic countries as essential contributors to the "European battery project", due to their industrial expertise, critical raw materials, renewable energy and experience of specialised markets such as passenger cars and maritime applications, supported by a renewable energy system. The market for lithium batteries is expected to expand by 14–20 times by 2030, and the EU is expected to produce around 30 per cent of these batteries.

Many countries in and outside Europe have launched ambitious, binding strategic initiatives targeting the battery value chain. In the Nordic region, both Sweden[9] and Finland[10] have launched their own battery strategies, and a Nordic collaboration[11] in the field was initiated in autumn 2021.

Norway has competitive advantages in the form of e.g. access to renewable energy, critical raw materials, available land, ports and industrial expertise. Our expertise is especially related to large-scale industrialisation in the process industry, including in battery materials, the maritime industry and know-how relating to the utilisation of digital technology.[12] Norway is many years ahead of other countries when it comes to EV diffusion, and is at the forefront in terms of batteries for the maritime industry. With a renewable energy supply close to 100%, Norway is in a unique position to produce battery materials and battery cells with a lower carbon footprint than any other European country.

A critical success factor for high-volume manufacturing such as battery cells is high yield across the whole production line, with the highest possible production volume, minimum downtime and the right quality. Norway has world-leading industrial centres, for example at Raufoss and Kongsberg, despite not being known as a manufacturing country.

A comprehensive knowledge base has already been established based on Prosess21,[13] Energi21,[14] NHO/LO,[15] the Federation of Norwegian Industries, the Nordic Council of Ministers[16] and others.

The Hurdal Platform describes the following objectives: *A goal has been set to facilitate the establishment of forward-looking industry in Norway. To achieve this, we need to introduce better framework conditions and ensure that Norwegian natural resources, including low cost renewable energy, remain a competitive advantage for Norwegian industry. The government must increasingly help businesses to develop and scale up industrial*

---

[5] Electric vehicle battery value chain opportunity | McKinsey
[6] Norway tomorrow | McKinsey
[7] 2022-72-Sysselsettingseffekter-fra-norsk-batteriproduksjon.pdf (menon.no) – in Norwegian only
[8] Building a European battery industry – European Battery Alliance (eba250.com)
[9] Strategi-for-en-hallbar-batterivardekedja.pdf (fossilfrittsverige.se) – in Swedish only
[10] National Battery Strategy 2025 (valtioneuvosto.fi)
[11] NORDIC BATTERY THURSDAYS – Home (b2match.io)
[12] lar-av-de-beste_sammendrag.pdf (norskindustri.no) – in Norwegian only
[13] prosess21_rapport_hovedrapport_web_oppdatert_060821.pdf – in Norwegian only
[14] energi21-strategi2022-horingsversjon.pdf – in Norwegian only
[15] anbefalinger-for-en-industriell-satsing-pa-batterier-i-norge.pdf (nho.no) – in Norwegian only
[16] Mapping of lithium-ion batteries for vehicles (diva-portal.org)

technology in Norway. Industrial enterprises must be subject to stringent emission reduction requirements, but they may also receive assistance to implement the cuts where needed.

Furthermore:

- Facilitate large-scale **battery cell production** in Norway by introducing more internationally competitive framework conditions in the industry.
- Invest in industrial activity in a complete **battery value chain**, including raw materials, components, applications, collection and recycling.
- Use Statkraft to spearhead the development of renewable energy through active, predictable ownership. We will also help Statkraft to become an industrial developer in the context of green hydrogen and **battery projects** and to help Norwegian suppliers gain a foothold abroad.
- Make long-term capital available where it may play a decisive role in establishing **new industrial initiatives** in Norway, for example in the healthcare, hydrogen and mineral industries.
- Present a national strategy for developing green **industrial areas and parks** with international competitive advantages. The strategy will ensure access to land, energy supply, infrastructure and expertise for future industrial development.

The EU's battery initiative must be seen in conjunction with the EU's focus on increased strategic autonomy, based on a desire to be self-sufficient in technology areas that are critical to overcoming the climate challenges and maintaining employment and production. The Hurdal Platform underlines the need for green industrial initiatives, but Norway has a small, open economy that requires extensive collaboration with partners. This underlines the importance of a stronger industrial partnership with the EU, including that Norway, for example in the battery area, can help to achieve common European goals and reduce Europe's vulnerability in relation to security of supply, among other things.

The battery markets

Batteries are considered a core technology in the transition to renewable energy, particularly in the transport sector. Batteries are undoubtedly relevant for other purposes than transport, however, such as power grid stabilisation, energy supply and energy storage. The global battery industry is growing rapidly. Most of the lithium batteries currently used in Europe are manufactured in Asia, but the situation will change significantly over the next decades. By 2030, battery production in Europe is expected to account for about 30 per cent of the global production. The rapid development of the European battery industry is now driven by the goal of strategic autonomy, and the EU has set a clear ambition of bringing battery production closer to the European automotive makers. This will make the European automotive industry less dependent on battery import, realise a new large-scale industrial initiative and compensate for reduced employment in the European automotive industry. Furthermore, considerable efforts are being put into making the European battery industry sustainable, with minimum GHG emissions and high resource utilisation.

The electrification of transport is also about maritime applications, however, and about aviation in the long term. Not least, batteries for energy storage will form an important part of future energy systems. The energy crisis that has gripped Norway and Europe in 2021/2022 has the potential to raise awareness of the role of batteries in these contexts. A number of initiatives are therefore already devoted to building large-scale battery cell factories in Europe. There are currently six factories in operation, and a considerable number of "gigafactories" are expected to become reality by 2030. Growth in demand for batteries represents a rare opportunity for Norwegian industry as well.

Norwegian industrial enterprises already produce input factors, products and services that make up part of the complex battery value chain. Over several decades, knowledge of materials has been developed in closer collaboration between the process industry and academia. This, in turn, has spawned expert groups that utilise this knowledge in the development of sophisticated battery materials. Well-established materials knowledge from the process industry is also relevant to the establishment of a sustainable battery value chain. This expertise will be key to achieving the battery cell manufacturers' goal of the lowest possible carbon footprint and the highest possible degree of reuse and recycling of raw materials. The Norwegian battery value chain also includes expertise in advanced systems integration and assembly of battery modules, in symbiosis with users representing e.g. the maritime industry. The electrification of shipping has been made possible by battery technology development and innovative procurement for the purpose of testing technology on different ferries and ships. Batteries will be used in several maritime applications because they optimise operations and reduce the engine load, and are often also a precondition for the development of most modern energy solutions.[17]

There are currently three actors with industrial ambitions to build battery cell factories in Norway, two of which will be producing battery cells (Freyr and Morrow) and Lithium-Ion capacitors (Beyonder). Freyr has ambitions to build a pilot plant by the end of 2022. The exact employment effect that will result from the planned factories is difficult to ascertain, but an estimate of up to 7,000 direct employees is realistic once they are up and running at full capacity. In addition come the social ripple effects for the entire battery value chain.

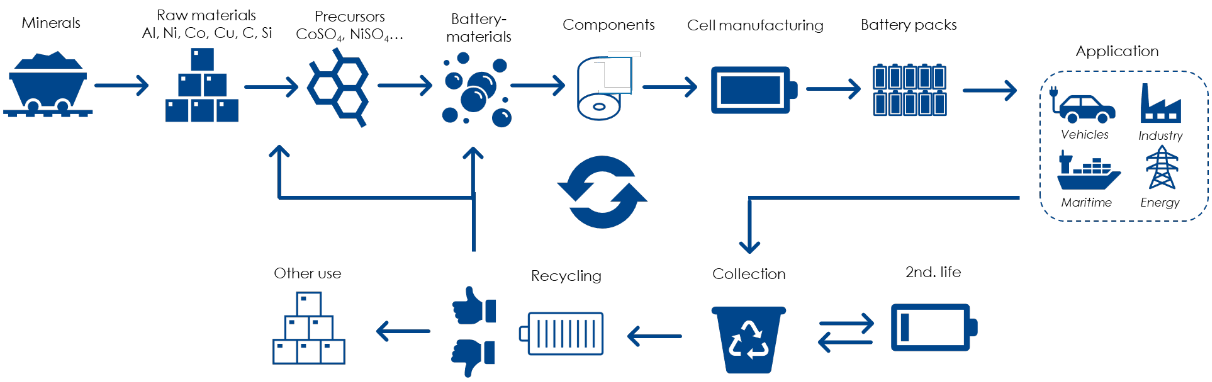

Figure 1 – Value chain for lithium-ion batteries

[17] maritim21_v02-5.pdf (regjeringen.no) – in Norwegian only

There is no time to lose if Norway is to succeed in developing a large-scale battery industry, however. The project BattKOMP,[18] which addresses the skills gap in the battery value chain, launched the term "battery time crunch". Competition in Europe is intense, the time window is short, and industrialisation is already under way.

The total market for lithium-ion batteries (LIB) consists of minerals, refined active materials, battery cells, battery packs and recycling. A relatively extensive value chain is involved in making the battery cells and packs used in the products that surround us. Like other physical products, it all starts with mineral extraction through mining. In simplified terms, metals (for example Al, Ni, Co, Cu etc.) are refined from minerals, from which precursors are developed that are used in battery materials. These, in turn, make up the raw materials for battery cell manufacturers. We will describe the different links in the value chain and the role of Norwegian stakeholders in more detail later.

Turnover throughout the value chain is difficult to estimate, as one upstream manufacturer is the supplier of another downstream enterprise. Turnover is usually measured as the sale of battery cells. The production of battery packs (i.e. a pack of battery cells) varies depending on their area of application. EV OEMs (Original Equipment Manufacturer) are increasingly taking responsibility for "packing" the cells themselves, and install battery packs in their vehicles that are adapted to the different platforms/series/models. In the maritime sector, there are enterprises specialising as systems suppliers, including suppliers of battery packs. A systems supplier in the maritime industry supplies battery packs and control systems. Such systems are integrated with steering of a combination of electric motors and internal combustion engines. Norway is well positioned in maritime activities where battery systems are combined with hydrogen/ammonia fuel. These green hybrid systems represent an area where Norway has the potential to become a market leader. Stationary storage as a supplement to variable sources of power is also a high-growth market.

Precursors, battery materials and components are largely custom-made for use in different types of battery cells (which in turn make up battery packs). When battery cells are specified, the use of components, battery materials and precursors is largely defined. In order words, the value chain consists of interdependent stakeholders.

The most common way of defining the market is in terms of the energy content of the batteries produced per year, measured in gigawatt hours (GWh). The most important drivers of this market are electric vehicles (EV), battery energy storage systems (BESS), other mobility (marine applications) and power tools etc. For many years, consumer electronics were the driver of the energy market, until vehicle batteries took over with the electrification of the transport fleet.

The need for batteries is estimated based on the need for the products mentioned above, and there are various approaches to estimating the markets. So far, all estimates have proven to be too conservative, and the expected market size in 2030 is ever growing.[19]

- Future EV sales can be estimated based on the regulations of different countries. In 2025, Norway will become the first nation to introduce a ban on the sale of light-duty ICE vehicles. In 2030, other countries such as Denmark, Iceland, Ireland, Israel, the Netherlands, Scotland, Singapore and Sweden will follow suit.[20]
- The automotive manufacturers' own ambitions to phase out ordinary ICE cars contribute to credible market estimates. The biggest manufacturers have undertaken to increase EV sales considerably over the next few years, or have announced phaseout dates for the sale of ICE vehicles. According to McKinsey,[21] ICE phaseout targets will affect almost 50 per cent of global car sales by 2050.
- The announced capacities of different battery manufacturing companies provide a third estimate of the need for battery cells. There are many battery cell initiatives, and more than 50 plans for manufacturing have been announced in Europe alone (including three in Norway by Beyonder, Freyr and Morrow).
- The campaign group Transport & Environment[22] points to the danger of EV sales in the EU levelling out based on how the current regulatory requirements of CO_2 emission performance standards per automotive maker are designed. There is a risk of the announced capacities of battery cell manufacturing exceeding demand based on lack of requirements for the carmakers' annual emissions. The EU Commission has announced measures[23] that compensate for this through the "Fit for 55" package. The European Battery

[18] BattKOMP Norsk Industri – in Norwegian only
[19] From the presentation of EIT InnoEnergy / EBA at a meeting on 22 April 2021
[20] Global EV Outlook 2021 (windows.net)
[21] Unlocking growth in battery cell manufacturing for electric vehicles | McKinsey
[22] Battery brief (transportenvironment.org)
[23] CO_2 emission performance standards for cars and vans (europa.eu)

Alliance and selected manufacturers also point to the need for rapid implementation of the EU Batteries Regulation.[24]

- There are few market figures available for other applications, as the dominating driver is EV batteries. It is assumed that the second biggest market will be energy storage (for power grids and industry). The global consultancy firm Rystad Energy[25] has looked at the need for stationary storage in order to meet the climate targets, and estimated the subsequent need for energy storage in GWh.

Different methodological approaches lead to considerable variation in the estimated market for batteries in 2030. Market figures from McKinsey, the Global Battery Alliance (GBA) / World Economic Forum (WEF),[26] Mineral Intelligence and IEA vary as a result of different approaches and the time of estimation. However, all the analyses confirm that the global demand for batteries, measured in GWh, is strongly increasing. Estimates range from 3,600 GWh to more than 6,000 GWh, the latter based on brand new estimates. The estimates have increased significantly in the past year.[27]

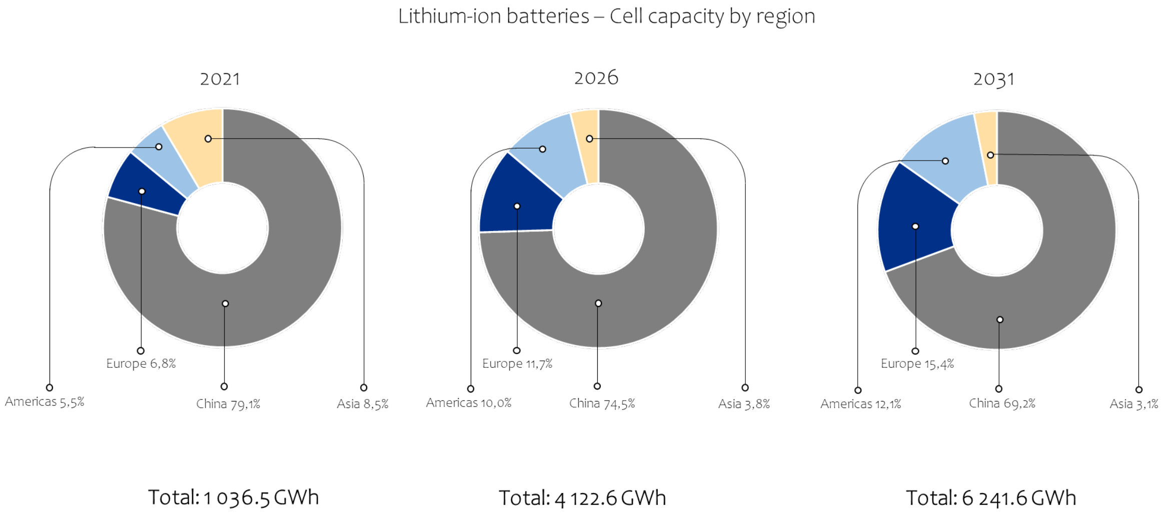

Figure 2 – Estimates for the market development of lithium battery cell capacity. Source: Benchmark Minerals Intelligence / European Battery Alliance

Rystad Energy has estimated the battery storage needed in order to meet the UN IPCC's 1.6˚C scenario to 9,000 GWh, of which 2,600 GWh is stationary energy storage. The European need is estimated to around 1,000 GWh in 2030, dominated by electrification of the transport sector. The European Battery Alliance recently presented an updated prognosis for Europe in connection with the Battery Innovation Days.[28] Freyr[29] uses slightly higher global market figures (5,150 GWh) in its investor presentation, which is based on its own study conducted through a global consultancy firm. Freyr recently signed its first two contracts on deliveries of batteries for energy storage purposes, of 31 GWh[30] and 19 GWh[31] respectively.

An increasing share of variable renewable energy will drive demand for what are known as energy balancing solutions, which increasingly enable renewable energy to be available on demand. Batteries are ideal short-term energy buffers and can be used on a large scale ("front-of-meter") and close to the energy consumer ("back-of-meter"). According to GBA/WEF, demand for storage batteries increased by 60–70% per year during the period 2015–2018.

Battery energy storage systems (BESS) have the potential to make up a significant market. Various market reports have shown that it may account for 35–45% of the total market for battery cells (the remainder is primarily

[24] Open Letter – Battery Regulation (industry) (transportenvironment.org)
[25] Rystad Energy – Your Energy Knowledge House
[26] WEF_A_Vision_for_a_Sustainable_Battery_Value_Chain_in_2030_Report.pdf (weforum.org)
[27] Benchmark Mineral Intelligence / European Battery Alliance
[28] Battery Innovation Days – YouTube
[29] Microsoft PowerPoint – FREYR Investor Presentation_1.28.21_FINAL (freyrbattery.com)
[30] FREYR Battery Norway | FREYR Battery Awarded 31 GWh Inaugural Offtake…
[31] FREYR Battery Norway | Honeywell and FREYR collaborate to deploy…

vehicles).[32] This is also confirmed by Rystad Energy's analyses, which point to the considerable increase in projects initiated in this market area in 2021. These systems can create considerable added value and will be used for e.g. balancing/stabilisation of wind turbines, hydrogen, solar cell systems etc. for both power generation and in commercial and residential buildings. Other relevant areas of use are uninterrupted power supplies (UPS) for data centres, hospitals etc., peak shaving / grid redundancy, process industry, aquaculture industry, heavy vehicles such as trains, mining and construction plant, as well as ships and vessels, both hybrid and electric.

Asia has dominated the development of battery technology, and Chinese companies currently dominate the production side of the value chain (from minerals to battery cells). Chinese companies have secured access to raw materials outside China through the large-scale acquisition and development of companies.[33] In some cases, the position of these companies is further strengthened through Chinese state investments in local industrial production.[34] In 2017, the EU established the European Battery Alliance for the purpose of establishing competitive battery value chains in Europe, boosting the competitiveness of the European automotive industry and reducing dependence on battery cells produced in China. As a result, Europe is now the fastest growing market for the whole battery value chain. The figure below shows the global market development and is based on the announced capacities of battery cell manufacturers:

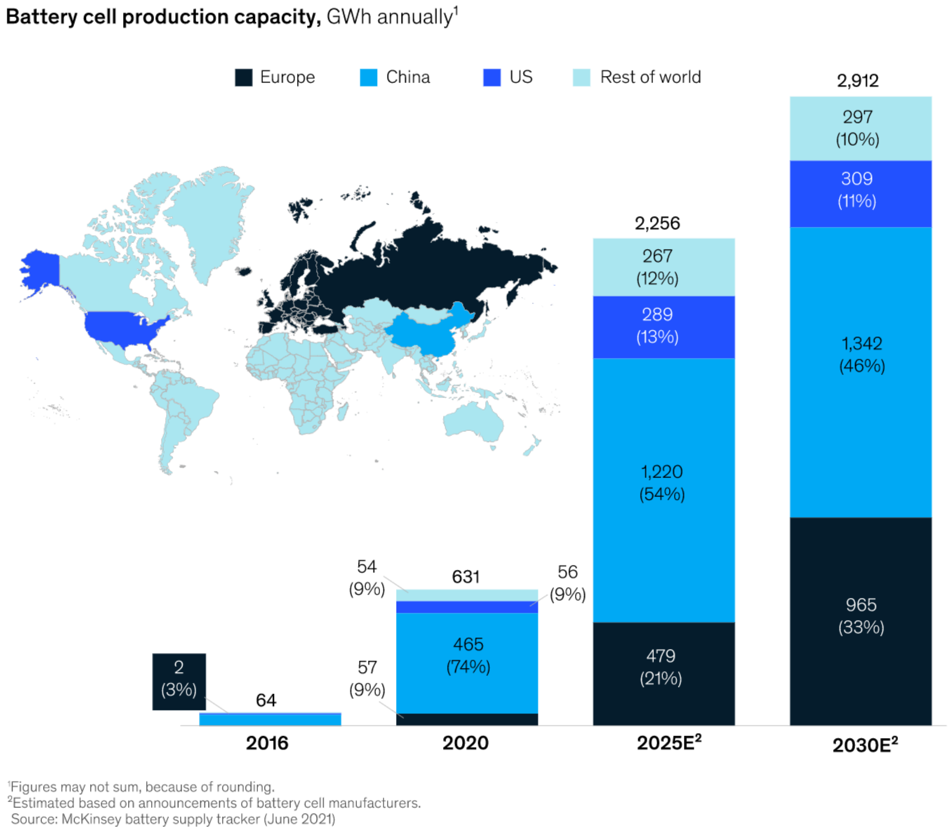

Figure 3 – Global battery cell production capacity based on announced battery cell production per year in GWh. Source: McKinsey

A significant build-up of capacity for battery cells is expected, especially in China and Europe. The work initiated by the EU under the concept of strategic autonomy has been followed up through financial support schemes and more stringent regulation. An updated list of battery cell initiatives (as of August 2021) compiled by the European Battery Alliance ("EBA250 Observatory monitoring of public announcements on Li-Ion cell production capacity") is presented in the table below:

[32] Input from H Devold, ABB, 14 February 2022 (email)
[33] "Battery arms race": how China has monopolised the electric vehicle industry | Electric, hybrid and low-emission cars | The Guardian
[34] Anunciarán inversiones chinas en baterías de litio y en autos eléctricos (ambito.com)

Table 1 – Overview of announced battery cell initiatives in Europe (August 2021). Source: EiT InnoEnergy

			GwH capacity 2025	GwH capacity 2030		
Germany	ACC (TOTAL/Stellantis)	Kaiserslautern	8	24	Probable	
	BLACKSTONE	Döbeln	0,5	0,5	In operation	
	BMW	Parsdorf near Munich			Announced	Pilot
	CATL	Erfurt	35	80	Probable	
	Cellforce Group (Customcells/Porsche)	Tübingen	TBA	TBA	Announced	
	FARASIS	Bitterfeld-Wolfen	6	10	Probable	
	Leclanché- Eneris	Willstätt	1	1	In operation	
	QuantumScape	Salzgitter	1	21	Possible	
	SVOLT	Überherrn, Saarland	18	24	Announced	
	TESLA	Grünheide, Berlin	55	100	Under construction	
	Varta	Tübingen	5	5	Announced	
	Volkswagen	Salzgitter	7	24	Under construction	
France	ACC (TOTAL/Stellantis)	Douvrin	8	24	Probable	
	ENVISION AESC/Renault	Douai	9	24	Announced	
	VERKOR	Southern France	16	50	Probable	
Hungary	SAMSUNG SDI	Göd	30	30	In operation	
	SK Innovation	Komárom	7,5	7,5	In operation	
	SK Innovation	Komárom 2	7,8	7,8	Under construction	
	SK Innovation	Iváncsa	6	21	Possible	
Sweden	NORTHVOLT LABS	Västerås	0,5	0,5	In operation	Pilot
	NORTHVOLT ETT	Skellefteå	43	60	Under construction	
	NORTHVOLT-VOLVO	TBD		32	Announced	
Poland	LG Energy Solutions	Wroclaw	67	67	In operation	
UK	AMTE Power	Thurso, Scotland		2	Announced	
	BRITISHVOLT	Blyth, Northumberland	0	20	Possible	
	ENVISION AESC	Sunderland	1,9	1,9	In operation	
	ENVISION AESC/Nissan	Sunderland	9	25	Announced	
Norway	BEYONDER	Rogaland	TBA	TBA	Announced	
	FREYR	Mo-i-Rana	0	2	Announced	
	FREYR	Mo-i-Rana	0	14	Announced	
	HYDROVOLT (Panasonic/Equinor/Hydro)	TBD			Announced	
	MORROW	Agder	8	32	Possible	
Spain	BASQUEVOLT (BATTCHAIN)	Basqueregion	2	10	Announced	
	CTAG/ Zona Franca de Vigo	Vigo	TBA	TBA	Unclear	Might not produce cells
	Phi4Tech	Badajoz	6	20	Announced	
	Volkswagen	Spain		10	Possible	
Italy	ACC (TOTAL/Stellantis)	Termoli	8	16	Possible	
	FAAM (FIB)	Teverola	2	10	Probable	
	ITALVOLT	Scarmagno	6	45	Announced	
Slovakia	InoBat Auto	Košice	10	10	Under construction	
Czech Republic	MES (He3Da)	Horní Suchá	8,4	15	Under construction	
Finland	FREYR	Vaasa			Announced	
Serbia	ElevenEs	Subotica	4	16	Announced	focus on LFP
Russia	ROSATOM	not disclosed	1	2	Announced	
TBD	BYD	not disclosed	TBA	TBA	Unclear	
TBD	CALB (China Aviation Lithium Battery Technology)	not disclosed	TBA	TBA	Unclear	
Eastern Europe	Volkswagen	not disclosed		7	Announced	

The overview shows battery cell production initiatives that are under construction, announced and wholly or partially financed, as well as potential and uncertain battery cell production announcements. Several countries are potential host countries for start-ups, and a vast array of owners are behind the respective initiatives, ranging from established battery manufacturers such as Tesla, Samsung, CATL and BYD to new European operators in the start-up phase, for example Northvolt/Volkswagen. Other announced large-scale plans involve European owners, for example ACC. There are also smaller companies already at the production stage, including Envision (China) and SK Innovation (South Korea). In addition, a number of cell initiatives have been announced without certain delivery agreements with customers or financing in place. It is expected that several of these initiatives will have received sufficient financing in the next 12–24 months.

GBA/WEF have estimated the total turnover broken down by actors in the value chain. The estimate is from 2018 and amounts to a total of USD 300 billion, based on an accumulated battery cell production of 2,600 GWh. The breakdown of turnover is shown in the figure below and reflects that the highest turnover is expected in battery cell production, refining of raw materials and battery pack production. This highlights the importance of cell manufacturing and why different countries are competing to host this activity. Battery cell manufacturing contributes to the highest contribution to employment.

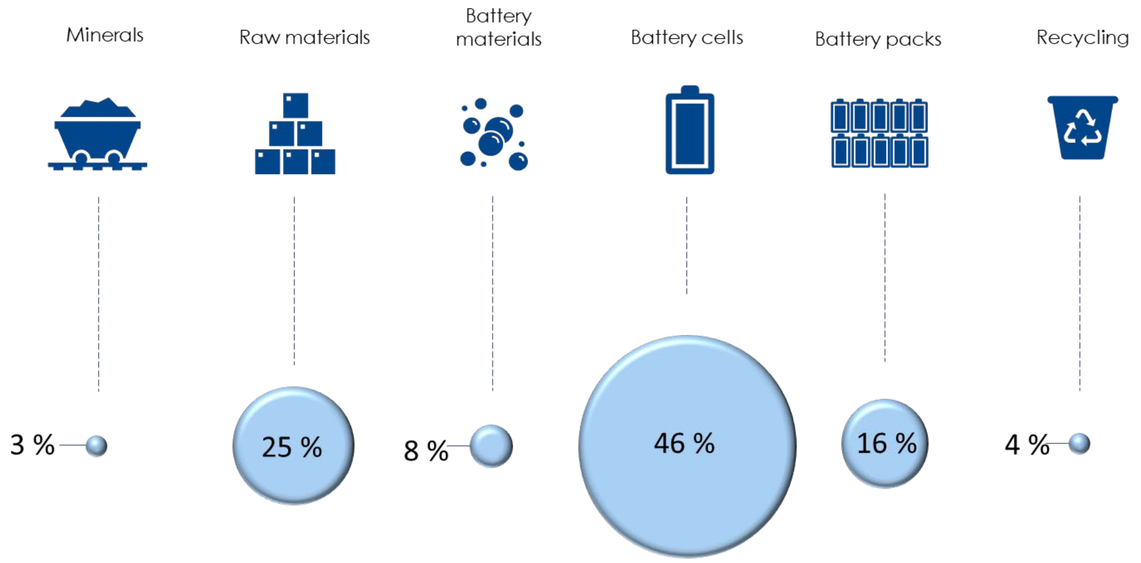

Figure 4 – Estimate of turnover in different parts of the value chain. Source: Green Battery Alliance & World Economic Forum Insight report

The EBA has conducted a study of announced industrial initiatives in a European battery value chain. Based on announced upstream capacities (i.e. for raw materials and active materials), we see that there is a scarcity in relation to meeting the announced capacities for battery cell production.[35] This is particularly the case for upstream capacities in the value chain for graphite, cobalt, nickel and anodes. It is natural that some of this capacity will be built outside Europe, but it also highlights the significant market potential for raw materials and battery materials in the EU. As a result, it is important to highlight how Norway maximises its positions (as a manufacturer/supplier of raw materials/battery material) in relation to global stakeholders.

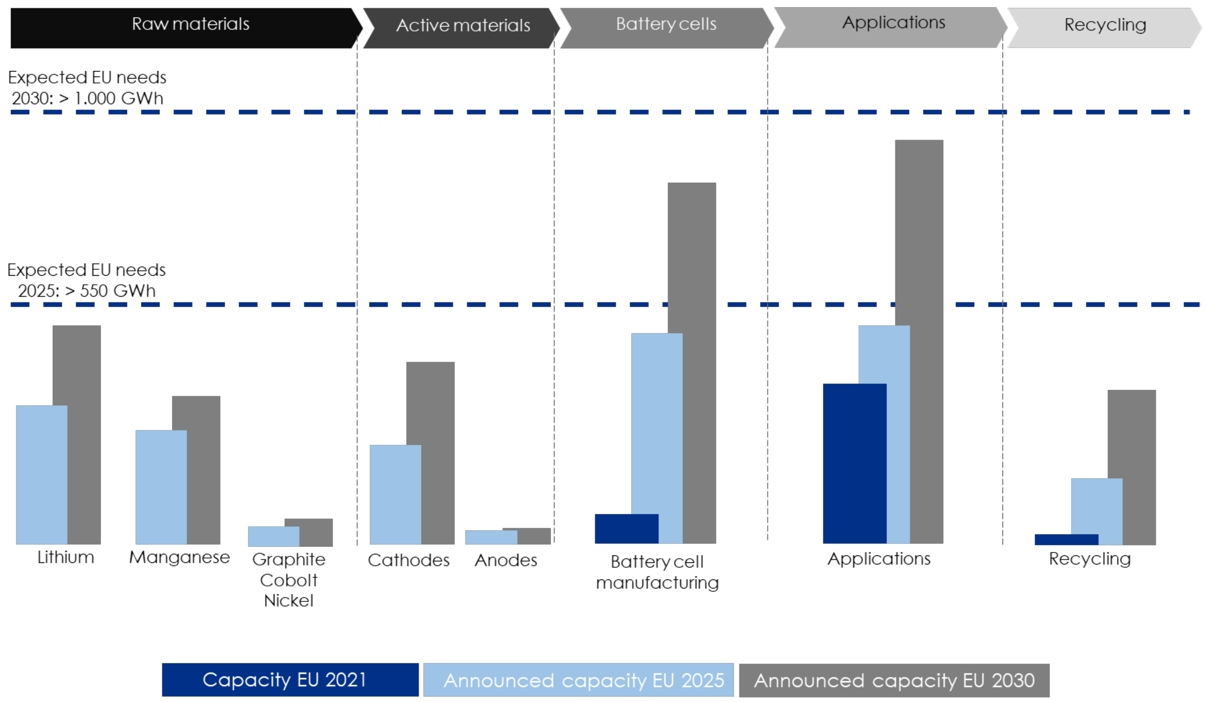

Figure 5 – Announced capacities in the EU for the parts of the battery value chain. Illustration recreated from EiT InnoEnergy

Norwegian battery value chain initiatives are currently aimed at raw materials, battery materials, battery cell manufacturing, battery application for specific markets, and recycling (see more detailed description later). Capacity

[35] PowerPoint Presentation (energimyndigheten.se) – in Swedish only

is defined based on the energy content of the batteries produced per year, which makes battery cell manufacturers Beyonder and Morrow particularly relevant. Freyr[36] and Morrow[37] have expressed ambitions to build 43 GWh-capacity factories in Norway. Beyonder has its eyes on the market for capacitor lithium-ion batteries and has not expressed any capacity ambitions at present, but an expansion plan is expected in the near future.

The price of battery cells amounted to around USD 100 per KWh in 2021.[38] In the years ahead, further price reduction is expected as the volume of mass production increases and technology is able to generate more cost-effective solutions. The price development will largely be affected by the availability of raw materials. If the availability is good, the prices must be expected to drop below USD 70/KWh before 2030. With a volume of 43 GWh and a price of USD 70/KWh, the turnover of such a factory could realistically be around NOK 27 billion, which would put Freyr and Morrow among the 20 biggest companies in Norway (compared with the turnover of companies in 2020). Including battery materials, components, systems integrators and recycling, the turnover of these companies could amount to around NOK 90 billion, with almost the same in export value. The estimate produced by Green Electric Value Chains is around that level. Compared with the total export of physical goods in 2019 (last normal year) of NOK 915 billion,[39] there is a potential for this industry to account for around 10% of the value of Norwegian exports.

In a few years, the price of battery energy storage systems (BESS) will typically be between USD 150/kWh and USD 250/kWh (currently USD 300–500/kWh), which means that if 25% of the Norwegian battery cell production went to BESS for domestic/export purposes, it would generate added value of NOK 60–70 billion. Companies such as ABB, Corvus and Siemens are already building these systems (in Skien, Bergen and Trondheim) and also have contracts that have not yet been announced.[40]

[36] FREYR Battery Norway | Decarbonizing transportation and energy…
[37] Morrow Batteries
[38] BloombergNEF: Average battery pack prices to drop below US$100/kWh by 2024 despite near-term spikes – Energy Storage News (energy-storage.news)
[39] 08801: External trade in goods, by imports/exports, contents and country. Statistikkbanken (ssb.no)
[40] Input from H Devold, ABB, 14 February 2022 (email)

Horizon scan

Norway is a small, open economy, and international trends such as increasing demand for low-emission technology will therefore significantly impact the potential of the Norwegian battery value chain. Norwegian operators cannot base their business on demand in the Norwegian market alone. More specifically, European and other international battery initiatives will form an important framework for Norway's national battery strategy. The EU, selected EU member states, the UK and China see it as a key strategic objective to develop their own battery industry, especially battery cell production. This chapter looks at these strategic initiatives, with particular emphasis on developments in the EU.

In simplified terms, the current industrial policy situation is as follows: Since 2011, China has actively been building a Chinese automotive battery industry with the help of favourable aid schemes.[41] In 2018, 97 per cent of all EV batteries were manufactured by three countries: China, Japan and South Korea. In the course of the 2020s, global production will rise sharply, and both Europe and the USA are making active efforts to ensure that a greater share of global production takes place in their domestic markets. To achieve this, the EU in particular has adopted an offensive industry policy centred around regulation and large-scale financial support. In the USA, the recently adopted Bipartisan Infrastructure Law (Infrastructure Investment and Jobs Act), which includes USD 1.2 trillion in spending, will also provide for the possibility of state aid to develop an EV industry and electrify the car fleet in this market.

Collaboration and competition: the strategic powerplay between China, the EU and the USA

Building a European battery industry has become a strategic objective for the EU for two reasons in particular: New battery technology and large-scale battery manufacturing are crucial to the successful transition to a greener economy and to achieving the ambitions of the European Green Deal. Equally important is the automotive industry and jobs. The European automotive industry accounts for seven per cent of the countries' GDP and employs more than 13 billion people. The industry also has an important effect on the steel, chemical, textile and information technology sectors.[42] Battery innovation capacity and creating links between battery and vehicle design are expected to become key competitive advantages in the global automotive industry going forward. Batteries are, and will likely remain, one of the most expensive and important components of a car. European politicians and business leaders fear that failure to link European automotive factories both geographically and organisationally to battery cell producers will jeopardise the entire European automotive industry, and they therefore call for a dedicated European battery value chain.

This market competition can also be placed in a greater political context. In a recent article,[43] Stina Torjesen points out that the global battery industry reflects the political tension between the USA and China, and in part also the EU and China.[44] President Joe Biden has largely taken the same harsh line as former President Donald Trump and has made competition with China a key element of US domestic and foreign policy.[45] European leaders are more cautious in their rhetoric, but recognise that China in many areas is a "rival" rather than a partner.[46] China's new role in international politics is based on its economic power, and development in key industrial sectors, for example the automotive industry, has gained greater political importance. The EU, USA and China's respective strategies in this area can be described as "strategic capitalism" or "geoeconomics".

The EU also explicitly mentions that the development of a European battery industry will strengthen the overarching goal of open strategic autonomy. The EU would like Europe to become more self-sufficient and with a greater ability to act independently of both China and the USA. This applies to a number of fields, including trade, climate action, defence policy and conflict resolution, but also in the industrial context, including in connection with critical breakthrough technologies such as batteries and their associated value chain. Improved European access to raw

[41] How China's CATL Became the Top Electric Car Battery Maker – The New York Times (nytimes.com)
[42] Automotive industry (europa.eu)
[43] Stina Torjesen, The age of strategic capitalism: What can we learn from the global EV battery race? Article submitted for publication (2022)
[44] Innlegg: Mission-økonomi i Europa | DN – in Norwegian only
[45] Subscribe to read | Financial Times (ft.com)
[46] What Joe Biden Said About China in His First Speech to Joint Session of Congress – Bloomberg, EU President Says 'China Is a Systemic Rival' – YouTube

materials and, in turn, the development of European battery cell production is directly linked to the open strategic autonomy agenda. There will still be arrangements in place to ensure trade and mutual investments between the EU and China, but these activities will be monitored and controlled to a greater extent so as to achieve the long-term goal of building a European battery industry.

The EU's extensive strategic approach to realising a European battery industry

Development of the EU's battery policy

Vice-President and Commissioner for Interinstitutional Relations and Foresight at the European Commission, Maroš Šefčovič, put batteries high on the EU's political agenda in 2017. Up until then, batteries had been a marginal topic in the EU's industrial and environmental policy. Šefčovič's initiative was supported by French and German political leaders, with developments in German politics and business forming a particularly important backdrop. German political leaders went from supporting the German automotive industry's focus on petrol and diesel engines to advocating a changeover in the industry.[47] One of the triggers of this shift may have been a draft Chinese bill in 2016 stipulating that new cars in the Chinese market should be electric and that batteries should be produced in China by Chinese companies.[48] This had the potential to reduce market shares in one of Germany's leading export markets. In order words, a significant shift in attitudes took place in German politics and business in 2016, and electrification of the car fleet was put on the political agenda as a current objective. Extensive efforts were also made to implement good support schemes at the federal level in Germany and at the European level, with a view to establishing a new battery industry. Former Federal Minister for Economic Affairs and Energy, Peter Altmaier, was one of several architects behind this work. The figure below shows the timeline for the EU's initiatives from 2017 up until the end of 2021.

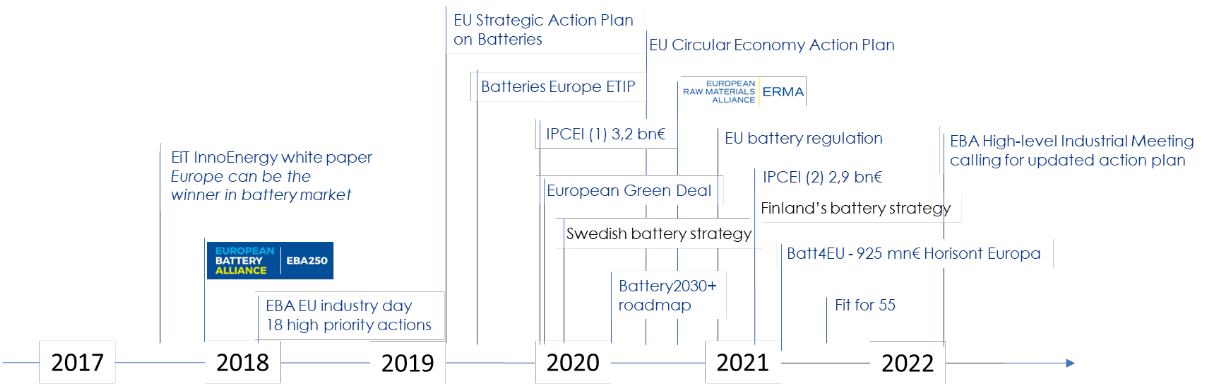

Figure 6 – Timeline showing the EU's activities towards the realisation of a battery industry. The launch of the Swedish and Finnish battery strategies is also indicated

One of the first initiatives launched by the EU was the European Battery Alliance (EBA)[49] in 2017. The EBA was tasked with facilitating collaboration between key industry stakeholders and strengthening dialogue and consultation with the European Commission. The EU also published a Strategic Action Plan for Batteries in 2019.[50] It contained six focus areas, including securing access to raw materials, building a full battery value chain in Europe, becoming a global leader in battery research and development, introducing stringent sustainability requirements, and defining the political framework in (and outside) the EU.

Battery cell manufacturers in China have operated under favourable conditions, and European decision-makers were most likely highly aware of this situation when they devised Europe's battery strategy. In 2016, electric cars in the Chinese market, with batteries made in China, qualified for considerable state subsidies from the Chinese authorities in the Chinese market. Public procurement has also driven sales in certain categories, particularly public

[47] Running On Empty: Germany Lags Behind Asia in E-Car Battery Race – DER SPIEGEL
[48] German Government at Odds with Industry over Electric Cars – DER SPIEGEL
[49] Building a European battery industry – European Battery Alliance (eba250.com)
[50] REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE, THE COMMITTEE OF THE REGIONS AND THE EUROPEAN INVESTMENT BANK on the Implementation of the Strategic Action Plan on Batteries: Building a Strategic Battery Value Chain in Europe – Publications Office of the EU (europa.eu)

buses. China's measures have facilitated the unrestricted growth of battery cell companies such as Contemporary Amperex Technology (CATL) until they became robust enough to tackle the global market competition.[51] In 2021, CATL was worth more than General Motors and Ford combined, with a market value of USD 240 billion and secure long-term access to large quantities of battery raw materials.

The EU's battery initiative is described in the European Green Deal[52] and the EU's circular economy strategy.[53] The European Green Deal points out that: *"Promoting new forms of collaboration with industry and investments in strategic value chains are essential. The Commission will continue to implement the Strategic Action Plan on Batteries and support the European Battery Alliance (EBA). It will propose legislation in 2020 to ensure a safe, circular and sustainable battery value chain for all batteries, including to supply the growing market of electric vehicles".* In the "Fit for 55" package, the European Commission proposes to phase out the production of internal combustion engines in 2035.[54]

In March 2021, Vice-President Maroš Šefčovič stated that, "*despite the pandemic, Europe continues to be a battery hotspot, closing the investment gap to our major Asian competitors, and in moving fast towards its open strategic autonomy in this critical sector*".[55] He was particularly pleased with the fact that Europe had seen the greatest share of new battery cell production investments globally in 2020, which he attributed to the increased attention to EV batteries by the European Commission and key EU member states in recent years.

Europe's cluster approach to realising the battery industry

The development and industrialisation of lithium-ion batteries has been ongoing for several decades, based on the need for batteries in the electronics industry. Production facilities for home electronics and the pertaining value chain are largely located in Asia, and mainly in China. The above-mentioned legislative amendment in China in 2016 dictated that new cars in the Chinese market should be electric, and that batteries should be manufactured in China by Chinese companies. As a result, the production rate of EV batteries increased considerably. Asia, and China in particular, thereby has a head start in battery production compared with the EU.

When the EU sees the need to establish its own battery production, a great deal of technology, expertise and market know-how must be moved from Asia to Europe. As the EU wishes to be independent of Asian companies located in the EU, activities must be established based on European companies. This requires a great deal of coordination and collaboration between the 27 member states. To enable Europe, with its different countries and cultures, to compete with China, a concerted European effort is needed to ensure targeted, coordinated and effective development.

The EU's approach must therefore been seen as a cluster in which the members, through collaborative efforts and a division of roles, complement each other and act as a driver for realising the growth ambitions. In this context, it is important that different stakeholders play different roles, and that gaps are identified at an early stage to remove bottlenecks in the development. The European Battery Alliance plays the role of coordinator in this European battery cluster. Consequently, it is important that Norwegian initiatives are aligned with the joint European initiative.

Financial support for the building of European battery production

In 2019[56] and 2021[57] the European Commission launched the Important Projects of Common European Interest (IPCEI) instrument, with total available funding of EUR 6.2 billion. IPCEI is intended to support innovative projects in selected areas that require coordinated cross-border effort. It is an important arena for the harmonisation and coordination of European projects. IPCEI projects receive national funding, but are subject to dedicated state aid rules. The IPCEI regulations are a separate set of guidelines under the state aid rules that provide for the possibility of a higher aid intensity and support for industrial start-ups, as long as the European benefit of the project outweighs the potential market distortion. The European Commission explains that the initiatives are of strategic value to Europe as a whole, that they contribute to extensive innovation and will foster growth, competitiveness and employment. The two battery IPCEIs will also trigger EUR 14 billion in private investments. The funds are distributed

[51] How China's CATL Became the Top Electric Car Battery Maker – The New York Times (nytimes.com)
[52] https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf
[53] https://ec.europa.eu/environment/circular-economy/pdf/new_circular_economy_action_plan.pdf
[54] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0550&from=EN
[55] "Europe to be world's biggest lithium-ion battery cell maker after China by 2025" – Energy Storage News (energy-storage.news)
[56] State aid: €3.2 billion public support battery value chain (europa.eu)
[57] State aid: Commission approves aid in battery value chain (europa.eu)

across the battery value chain and will be spent on improving raw materials extraction, promoting battery cell manufacturing, developing battery systems and supporting recycling and sustainability The German Federal Ministry of Economic Affairs and Energy and the French Ministry of Economics and Finance played decisive roles in initiating and mobilising funds for the IPCEIs.[58] On behalf of the Confederation of Norwegian Enterprise (NHO), KREAB[59] has compiled an overview of funding instruments for Sweden, Finland and Germany. The description includes IPCEI as well as other funding instruments.

New Batteries Regulation

In December 2020, the European Commission presented a proposal for a new Batteries Regulation[60] to be applicable throughout the single market from 2023. The proposal has been described as highly progressive and addresses sustainability from an overall perspective.[61] The Regulation will define levels of recycled materials in the production of new batteries and set absolute limits for the total level of carbon emissions in battery production, including the minerals extraction phase. It also stipulates explicit environmental and social requirements relating to the acquisition of minerals and provides guidelines on the possibility of a "second life" for EV batteries. European manufacturers point to the need for rapid implementation of the Batteries Regulation and ask for the 2023 deadline to be complied with (see separate appendix for a more detailed description).

Research and development

A coordinated R&D initiative is one of the measures intended to give the EU a leading position in a future battery value chain. This activity is based on the European Strategic Energy Technology Plan (SET plan),[62] which has fostered collaboration between member states, industry and research institutes for the purpose of coordinating and realising efforts to achieve the EU's climate and energy targets and strengthening the EU's industrial competitiveness. The SET Plan Action for batteries is implemented by Batteries Europe,[63] the technology platform of the European Battery Alliance, which has received support from the European Commission since 2019. Batteries Europe brings together national representatives of industry and research along the whole battery value chain in a network consisting of more than 550 experts. The expert group is helping to devise a technology roadmap and the Strategic Research Agenda (SRA) for European battery research. In addition, Batteries Europe supports the Battery 2030+[64] initiative, which focuses on long-term battery research. The relationship between the European Battery Alliance, Battery 2030+, Batteries Europe and Horizon Europe is visualised below. Norway participates in Horizon Europe as part of the EEA Agreement. Norwegian operators can apply for funding on equal footing with enterprises, public sector bodies and research institutions in EU member states.

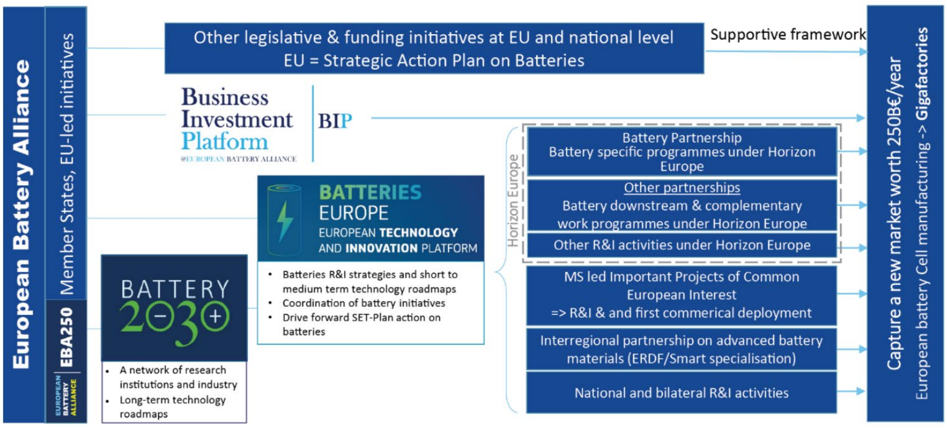

Figure 7 – The EU ecosystem and policy instruments for realising battery industry

---

58 franco-german-manifesto-for-a-european-industrial-policy.pdf?__blob=publicationFile&v=2 (bmwi.de)
59 Plugged in for a full charge – Unleashing the full potential of the Norwegian battery value chain, KREAB April 2021
60 New EU regulatory framework for batteries (europa.eu)
61 Global implications of the EU battery regulation (science.org)
62 SET Plan progress report 2021 (europa.eu)
63 Batteries Europe (europa.eu)
64 Battery2030+ – Battery 2030+

Batteries Europe's governance structure includes thematic working groups, whose members represent industry, research and public sector organisations, tasked with devising research roadmaps covering the different parts of the battery value chain. They also work on cross-cutting topics such as education/skills, sustainability, security and the role of digitalisation in battery technology.

An independent, but closely linked national and regional coordinator group (NRCG) composed of member states (and representatives of affiliated countries like Norway) has been established to ensure a mutual exchange of information between countries and facilitate joint action by the member states. The members of NRCG receive updates from the European Commission and Batteries Europe on policy and funding programmes, including Horizon Europe. Even closer collaboration takes place through the governance structures of the two IPCEIs, in which selected businesses and member states participate. Most of the work that takes place under the IPCEIs is at a high level of maturity according to the Technology Readiness Level (TRL) scale.

In 2020, Batteries Europe revised its battery implementation plan,[65] including its goals and R&D activities, through the launch of the Strategic Research Agenda (SRA). Batteries Europe also contributed to the development of Horizon Europe's R&D&I programmes for 2021–2022, a task that has now been taken over by the newly formed BATT4EU[66] partnership.

Battery 2030+ is a research initiative of the CSA type (Coordination and Support Action), and its vision is to help establish projects that can develop the sustainable batteries of the future and enable Europe to achieve the goals outlined in the European Green Deal. SINTEF is the Norwegian research partner in Battery 2030+, and the Institute for Energy Technology (IFE) is what is known as a Supporting Organisation. Lithium-ion batteries play an important role in the roadmap devised by Battery 2030+, but much focus is also devoted to long-term research with a chemistry neutral approach. The ideas launched through Battery 2030+ give Europe an opportunity to meet and perhaps even exceed the ambitious battery performance targets proposed in the SET plans. At the same time, they can give the industry a competitive advantage in future sustainable battery technologies. Battery 2030+ has now started Phase 2, in which attention is devoted to establishing technology neutral tools that can help to change the way batteries are developed and designed in Europa.

Access to raw materials

The expected increase in battery demand and production creates challenges in terms of access to the minerals used in batteries, including lithium, cobalt, nickel, graphite and manganese. In the long term, technological innovation will probably help to overcome any limitations and identify replacements. In the short term, however, we are likely to experience periods with a shortage of certain raw materials, especially during the period 2025–2030.[67]

China plays a crucial role in minerals extraction and processing. In addition, many Asian companies own shares in African, Latin American and Australian mining companies. Europe's vulnerability is illustrated by the structure of the lithium market. The global production of lithium is highly concentrated, both geographically and through ownership of individual enterprises. About 85% of the world's production comes from Chile, Argentina and Australia.[68]

Asian countries also play a key role in raw materials processing. A report from the EU Commission noted that "when it comes to processed materials and components, Asia delivers 84% while the EU.…only has a relatively small share (8–9%)".[69] Furthermore, the Commission predicts that OEMs (i.e. vehicle manufacturers), battery cell manufacturers and suppliers will likely compete globally with each other to secure their battery supply chains and to secure access".[70]

The global competition for access to raw materials has resulted in increased attention by the EU to ensuring international access and increasing self-sufficiency. As early as in 2011, the EU identified critical raw materials of great importance to the European economy.[71] The EU has defined and recently included additional sectors particularly exposed to "strategic dependence". An updated list published in 2020 included lithium as a critical raw

[65] batteries_europe_strategic_research_agenda_december_2020__1.pdf (europa.eu)
[66] BATT4EU (bepassociation.eu)
[67] Rystad Energy, "Rystad talks energy", webinar, 24 June 2021
[68] Lithium Supply – Orocobre Limited
[69] strategic-dependencies-capacities.pdf (europa.eu) – page 70
[70] strategic-dependencies-capacities.pdf (europa.eu) – page 20
[71] Methodology for establishing the EU list of critical raw materials – Publications Office of the EU (europa.eu)

material (cobalt and magnesium were already on the list).[72] It is also being discussed whether to include nickel the next time the list is updated.

The EU also established the European Raw Material Alliance (ERMA) in 2020, which was tasked with improving Europe's ability to extract, design, produce and recycle materials.[73] The EU financed the activities and secretariat of the alliance, which consists of more than 150 members representing industry, non-profit organisations and research institutions. One of its key tasks is to facilitate investments, among other things by offering investment matchmaking, market information and help to clarify regulations and procedures that may pose a barrier to investments. The establishment of ERMA was also seen as an instrument for generating and managing public funding from the EU and its member states to the raw materials sector. Maroš Šefčovič recently talked about the need to "*increase domestic sourcing, support innovation for alternatives, and mainstream circularity*".[74]

The EU is also attempting to change consumption and production from a linear to a circular model through its circular economy strategy, which stimulates growth in secondary raw materials markets through a new regulatory framework and improved disclosure on product content. The new Batteries Regulation proposes making it mandatory to include recycled content in the production of new battery cells. The Circular Economy Action Plan is also attempting to prevent valuable waste from being exported to non-EU countries, and this was reinforced by the proposed Waste Shipment Directive adopted in November 2021.[75]

Enhanced facilitation of battery production in the EU towards 2030

The European Battery Alliance (EBA) recently held a High Level Industrial Meeting in Brussels that brought together key stakeholders along the battery value chain and representatives of the European Commission. The representatives confirmed their commitment to building a robust, sustainable and competitive battery value chain in Europe and called for an accelerated action plan to fill remaining gaps up until 2030.[76]

The summary of the meeting confirms the need for enhanced efforts in the upstream segment of the value chain, with a greater focus on access to raw materials and establishing its battery materials capacity. Furthermore, there is a gap in the downstream segment in terms of recycling and end-of-life solutions, and a considerable need for building skills. This underlines the EU's limitations relating to control of the access to raw materials, which may make it vulnerable to price fluctuations and shortages. It is also worth noting that Asian and US stakeholders play a significant role in building the new European industry: Investments, expertise and ownership are partly supplied through non-European companies. This ensures rapid development, but contributes to a lesser extent to the EU's underlying goal of increased autonomy.

The recently held EBA meeting therefore underlined the need for rapid implementation of the EU Batteries Regulation to ensure that competition for customers is based on attributes such as climate and environmental footprint, and not just on cost. The need for swift adoption of relevant legislative provisions in the "fit-for-55" package is also underlined in order to boost demand for decarbonisation of the transport sector and accelerate the need for energy storage systems. Furthermore, it is agreed that an upgraded toolbox is needed to support and de-risk investments in raw and processed battery materials, including a set of measures for projects of strategic importance to Europe, especially a joint approach to licensing processes for minerals extraction and reducing the risk of private investments.

The EBA also considers it necessary to update the European Strategic Action Plan on Batteries, which was published in 2018. The EBA believes the updated action plan should contain updated targets for the different parts of the value chain, and underlines the need to build strategic alliances and partnerships with non-EU stakeholders to enhance the competitiveness of the EU battery industry. Norway is mentioned as a potential alliance with a view to securing material resources and partnerships to build the European battery value chain.

Strategy and battery initiatives in the UK

The British Government has allocated GBP 2.8 billion to building a thriving battery industry in the UK. The UK's industrial strategy identifies future mobility, including EVs, as one of four main challenges to be addressed. The

[72] EUR-Lex - 52020DC0474 - EN - EUR-Lex (europa.eu)
[73] https://erma.eu
[74] Speech by Vice-President Šefčovič at the European Conference (europa.eu)
[75] Proposal for a new regulation on waste shipments (europa.eu)
[76] Joint Statement EBA HL Industrial Meeting 23 March 2022-Final1.pdf (hubspotusercontent-na1.net)

Faraday Battery Challenge[77] and the Faraday Institution[78] are key players in this context. The Brexit negotiations and the final EU-UK Trade and Cooperation Agreement[79] also included material provisions on cars and batteries. The Brexit agreement requires EV batteries to be of UK or EU origin by 2027 in order to avoid an additional 10 per cent import duty on the vehicle.

The Rules of Origin part of the agreement dictates that batteries may contain up to 70% content from non-EU/non-UK sources and still meet the origin requirement in 2023, while EVs may contain 60% such material. Between 2024 and 2026, batteries may contain up to 50% non-EU/non-UK content, and EVs up to 55%. From 2027, the standard product-specific requirement of 90% applies.

It is likely that an intended consequence of the agreement was to afford additional protection to the building of the UK and continental battery industry. It helps to prevent Asian batteries form entering the single market through the "back door" via the UK market and UK manufacturers. The clauses on EVs in the EU-UK Trade and Cooperation Agreement are remarkably detailed and comprehensive. As such, they provide further indication of the strategic importance European and UK decision-makers attach to batteries.

The British Government recently announced financial support for the company Britishvolt.[80] This will be provided through the Automotive Transformation Fund by a direct investment of GBP 100 million from the Government alongside two capital management companies, to finance the huge building that will house the battery gigafactory.[81] The Automotive Transformation Fund was established to realise the transition in the transport sector. The recently allocated GBP 350 million takes the fund up to a total of GBP 850 million. Britishvolt's plant will be built in Blyth in Northumberland, which is also where the 720-km-long North Sea Link[82] power cable from Suldal in Rogaland makes landfall. Britishvolt has previously stated that "*the 95-hectare site in Blyth would use renewable energy, possibly hydro-electric power generated in Norway and transmitted via a link under the North Sea"*.[83]

It was recently announced[84] that Britishvolt negotiated a two-year deal worth several million pounds with the UK Battery Industrialization Centre (UKBIC)[85] to develop and compile next-generation battery cells for mass production and commercialisation. The UKBIC is a government-funded facility formed to help the British automotive industry bring new battery technologies to market.

The Nordic battery value chain

The Swedish Energy Agency and Business Sweden are working to boost Sweden's competitiveness in the energy sector, among other things by promoting a sustainable battery value chain in the country. Enhanced collaboration between the Nordic countries represents an opportunity to strengthen the Nordic battery value chain in the international context. The first step in finding out how such collaboration can be designed is described in the report[86] *The Nordic Battery Value Chain – Nøkkelaktører langs den nordiske verdikjeden og overordnede kriterier for utenlandske investorer* ("Key stakeholders along the Nordic value chain and overriding criteria for foreign investors" – in Swedish). The report shows that there are many relevant stakeholders in the battery value chain, especially in Finland, Sweden and Norway.

In April 2021, Innovation Norway, Business Finland and Business Sweden signed a letter of intention on Nordic collaboration on trade promotion efforts including in the area of battery production. The ambition is to work closely with carefully selected initiatives and to nurture the value of acting as a unified force.

---

[77] Faraday Battery Challenge – UKRI
[78] The Faraday Institution – Powering Britain's Battery Revolution
[79] EU-UK Trade and Cooperation Agreement: Rules of Origin | Novedades | DLA Piper Global Law Firm
[80] Government backs Britishvolt plans for Blyth gigafactory to build electric vehicle batteries – GOV.UK (www.gov.uk)
[81] Britishvolt gets £100m boost to build UK's first large-scale 'gigafactory' | Electric, hybrid and low-emission cars | The Guardian
[82] Nå er strømkabelen til England ferdigbygd | Statnett – in Norwegian only
[83] Electric car battery plant for Blyth power station site – BBC News
[84] Britishvolt signs agreement to develop high-nickel EV batteries | Reuters
[85] UK BATTERY INDUSTRIALISATION CENTRE – UKBIC
[86] Den nordiska batterivärdekedjan (energimyndigheten.se) – in Swedish only

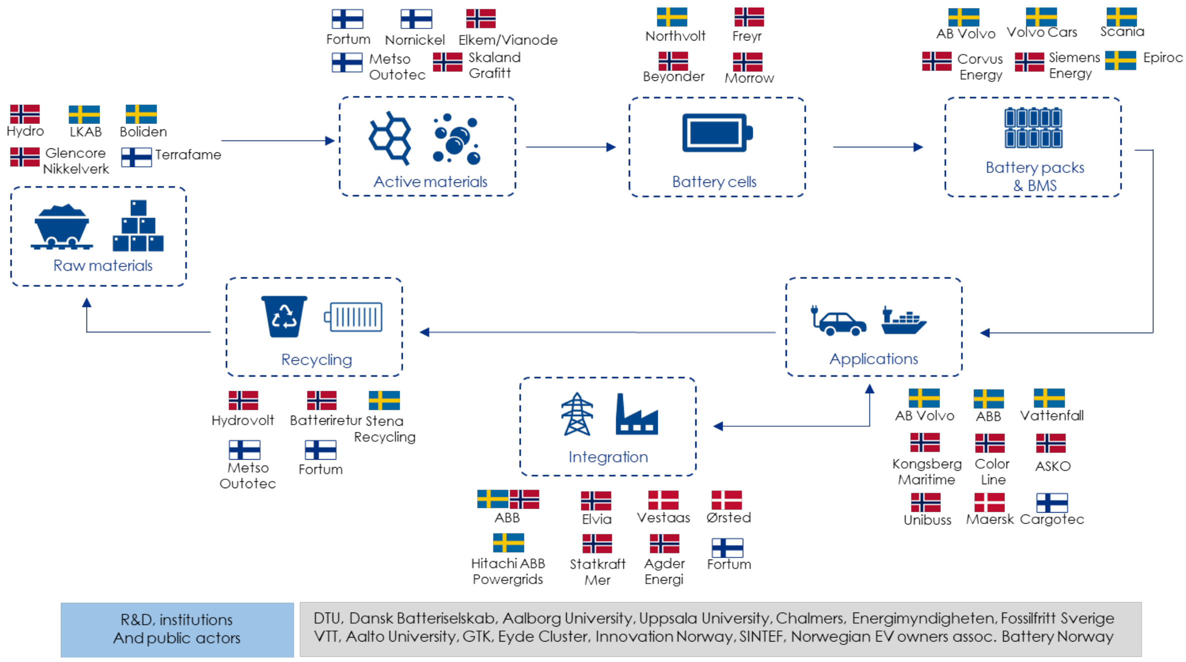

Figure 8 – Overview of important stakeholders in the Nordic battery value chain. Illustration recreated from The Nordic Battery Value Chain, Business Sweden.

The work continued in the form of a feasibility study,[87] also conducted by the Swedish Energy Agency and Business Sweden, the goal of which was to identify gaps that must be addressed to achieve a complete Nordic battery value chain, and the scope of possibilities for a Nordic value proposition that can help attract foreign investments.

The study points out that the Nordic region seen as a whole enjoys a favourable position in the growing European battery value chain, but that the time window is becoming smaller. Europe is mobilising considerable resources to build a competitive battery value chain, and it is expected that many of the stakeholders have become established already in three to four years. The Nordic countries have a favourable momentum, with stakeholders in all parts of the value chain and a potential inflow of foreign investors. The report shows that Finland, Sweden and Norway also have complementary comparative and industrial strengths that, taken together, make the region a good host. The EU Batteries Regulation is favourable for the Nordic countries and will serve as a framework for activities in the value chain.

Feedback from industrial stakeholders in the Nordic region emphasises the importance of implementing the EU Batteries Regulation, reducing the investment risk during the initial phases and attracting foreign investments. The report concludes that a joint Nordic value proposition would be highly favourable and may attract the interest of more foreign investors in these countries. The figure below shows the Nordic countries' attractiveness to foreign investors, seen in light of their operational activities and operating conditions.

Through InvestIN, Innovation Norway has received an increasing number of enquiries as a result of announced battery cell manufacturers like Freyr, Beyonder and Morrow. This underlines that battery cell production will be a mobilising factor for other relevant stakeholders and suppliers. The need for a sound, efficient system to receive business enquiries and start-ups that ranges from the national to the municipal level in the host municipalities is also underlined. Nordic collaboration is important, but the use of resources must be balanced between external marketing and the facilitation of specific enquiries.

[87] PowerPoint Presentation (energimyndigheten.se)

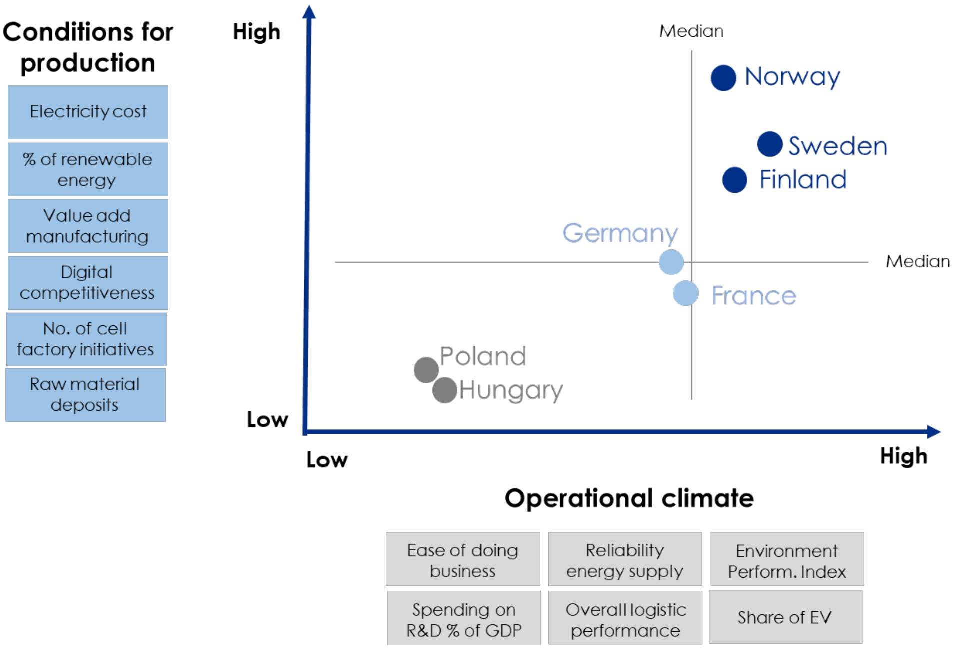

Figure 9 – the Nordic region consists of attractive host countries for battery production based on operational climate and conditions for production. Illustration recreated from The Nordic Battery Value Chain, Business Sweden.

The Swedish battery strategy

In Sweden, the national initiative "Fossil Free Sweden"[88] has published Sweden's battery strategy[89] in partnership with EiT InnoEnergy (EiT – the European Institute of Innovation and Technology). Discussions with EiT InnoEnergy underline the need for national strategies to complement the EU's strategies, with necessary ownership in a national reference group. The recommendations outlined in the Swedish strategy are adapted to five perspective that are also used in the EU's Strategic Action Plan for Batteries: i) stimulate the need for sustainable batteries, ii) develop framework conditions in order to develop stakeholders in the value chain, iii) develop framework conditions for the development of minerals and recycling, iv) invest in R&D&I and build necessary expertise, and v) follow up the measures through a broad private-public partnership. In August 2020, the Swedish Energy Agency, the Swedish Environmental Protection Agency and the Geological Survey of Sweden (SGU) were tasked with developing a public partnership to support businesses in Sweden that may make up part of a sustainable European battery value chain.[90] The final report is scheduled to be submitted to the Government Offices in October 2022.[91] The assignment letter describes Sweden's extensive engagement in this area.

Work on the Swedish battery strategy was completed before the initiative to define a joint Nordic battery value proposition, but the strategy recommends Nordic collaboration to attract more investments to the region as a whole. The strategy otherwise contains recommendations on policy development and recommendations for the industry. As an EU member state, Sweden has an opportunity to influence relevant political processes at an early stage. Sweden is also part of the European Battery Alliance, Battery 2030+, Batteries Sweden (BASE)[92] , Batteries Europe, and a participant in the EU's two battery IPCEIs.

Below, we list some of the recommendations of relevance to the work that takes place in Norway (not in order of priority):

- Allocate around **EUR 500 million** a year across ten years as a large-scale national investment in battery expertise: material science, refining, electrical systems and installations, monitoring and control systems,

[88] Start – Fossil Free Sweden
[89] Strategy_for_sustainable_batter_value_chain.pdf (fossilfrittsverige.se)
[90] Uppdrag att utveckla myndighetssamverkan för Sveriges delar av en hållbar europeisk värdekedja för batterier – Regeringen.se – in Swedish only
[91] Utveckla samverkan för Sveriges delar av en hållbar batterivärdekedja i EU (naturvardsverket.se) – in Swedish only
[92] Center for Swedish Batteries – An Alliance for Ultrahigh Performance Batteries (BASE) | Vinnova

structure and design of battery packs, battery safety and digitalisation, and train 1,000 persons per year in battery skills from the level of upper secondary school to higher education and research.

- Reduce the risk associated with the import/purchasing of large quantities of raw materials by introducing raw materials guarantees. These guarantees are proposed within the framework of **EUR 50 billion** in government credit guarantees via the Swedish Export Credit Agency (EKN). The government may also furnish guarantees when battery companies (under financing) are to negotiate long-term agreements on the purchase of raw materials.
- Sweden's primary possibility of competing and winning market shares is a well-functioning public-private partnership in which the public helps to minimise the risk associated with projects and thereby increases the possibility of sourcing private capital for investments. Sweden has systems for public funding and risk-sharing with industrial enterprises, but basic financing remains a challenge, especially for the biggest and most innovative projects.
- Commission the Geological Survey of Sweden (SGU) to prepare support documentation for the minerals strategy in cooperation with relevant agencies and stakeholders, with a view to developing efficient, transparent licensing processes for the extraction of primary and secondary innovation-critical metals and minerals, and continue to give consideration to Sweden's environmental legislation.
- The government should review the need for a centre for battery production technology and the need for competence investments to develop production processes for battery cells and battery systems.
- Exploit the existing ecosystem and ongoing initiatives to strengthen expert environments and Centres of Excellence that cover different parts of the value chain (the Swedish Electric Transport Laboratory, the Swedish Electromobility Centre, Northvolt Labs, Batteries Sweden and the Arctic Centre of Energy Technology).
- Active and coordinated participation in shaping EU legislation and a clear stance on increased sustainability, transparency and the circular economy in the battery industry. Sweden should assume a clear position in order to raise the goals for collection and efficient recycling processes.
- A stronger Nordic partnership to promote sustainably produced batteries will provide increased opportunities to exert influence at EU level.

Finland's battery strategy

Finland's national battery strategy[93] was launched by the Finnish Government as a collaborative project between four different ministries, and was published by the Ministry for Economic Affairs and Employment (which has now been split into two different ministries). In June 2020, Minister of Economic Affairs Mika Lintilä appointed a working group supported by a secretariat comprising representatives of Business Finland, the Geological Survey of Finland and research institute VTT. The group was tasked with devising a battery strategy for Finland for the purpose of strengthening the battery industry's innovative ecosystem, accelerating sustainable and carbon-efficient economic growth in Finland, and supporting attainment of the climate goals set for the transport sector.

The battery strategy is intended to show the measures Finland needs to implement to become an internationally recognised stakeholder in the battery industry and electrification. Among other things, the strategy concludes that the goal is attainable, but the overarching understanding of the strategy process supports the perception that there is no time to lose.

Finland's approach is based on comparative strengths in the upstream segment of the battery value chain, i.e. raw materials, metals processing and battery materials. Reference is made to the European Commission's expressed need to reduce dependence on imported critical raw materials. Finland has considerable mineral reserves and a long-standing tradition in mining and refining of such raw materials, in addition to its huge potential in batteries and electrification in general. A sound plan and swift implementation are needed to exploit this opportunity. Finland's battery strategy sets out a vision, clear goals and well-defined actions to succeed in the global battery race. Through the strategy, the Finnish Government and the most important stakeholders in the battery and electrification sectors seek to send a clear, strong message.

93 National Battery Strategy 2025 (valtioneuvosto.fi)

The Finnish working group proposed seven objectives for the 2021–2025 strategy period: growth and renewal of the battery and electrification cluster, growth of investments, promotion of competitiveness, increased international awareness of the strategy, responsibility, definition of key roles in the sector's new value chains, and promotion of circular economy and digital solutions.

The working group proposes the following strategic actions to achieve these objectives:

- *Enhancing national cooperation*: Encourage and foster efficient, productive and relevant cooperation by creating a national body that rounds up the various stakeholders in the national battery and electrification sector.
- *Scaling up the skills of the battery and electrification cluster*: In order to ensure the competitiveness of our battery and electrification sector, we need to develop excellent skills in this field. Furthermore, we need to develop an in-depth understanding of the international battery business landscape.
- *Expanding EU and international cooperation*: Getting advocates of the Finnish battery and electrification cluster into the right forums (e.g. EU working groups and Horizon Europe) requires cooperation on a national level.
- *Establishing an operating environment that attracts investments to Finland*: We need to make sure that the operating environment is more favourable than in competing countries, by nominating "battery ambassadors", enhance the collaboration between authorities and further develop licensing processes etc.
- *Making Finland a forerunner in sustainable and responsible battery production*: To develop digital tools based on Life Cycle Assessment (LCA) and enhance legislation to support a sustainability battery industry.
- *Developing the brand of the Finnish battery and electrification cluster*: In order to attract the best talent, the Finnish battery sector needs to build a brand through communication, conferences and forums.
- *Developing bigger and more agile funding*: The battery industry needs funding for large, high-risk and long-term investment projects. The public sector must support this development by sharing the risk in major investment projects.

In the revised budget for 2021, the Finnish Government proposed allocating EUR 450 million through the Finnish Minerals Group as an investment in the battery value chain.[94]

[94] Supplementary budget includes a large investment in the battery industry: Building a responsible battery industry will create jobs and tax revenue (valtioneuvosto.fi)

Previous input and measures by Norwegian stakeholders

The research centre FME MoZEES was established in 2017 to contribute to developing new battery and hydrogen materials, battery components and battery systems for current and future application in the transport sector (road, rail and sea). The Institute for Energy Technology (IFE) hosts the MoZEES centre.

As a result of increased activity in the EU and pertaining R&D grants, SINTEF established the BEACON initiative with support from the Research Council of Norway for the purpose of mobilising the industry to participate in national and EU-level projects, as well as strategic European work on batteries. SINTEF in particular, but also IFE is well positioned in relevant forums relating to the EU's battery technology research activities. The figure below shows documented input from and activities by Norwegian stakeholders.

Innovation Norway (InvestIN), the Eyde Cluster and the BATMAN project consortium worked together through 2019 to bring together Norwegian stakeholders in the battery value chain. An event[95] that included workshops brought together Norwegian stakeholders in the value chain and invited international stakeholders such as Northvolt, Nickel Institute, the British Geological Survey etc. This was followed by a series of webinars organised by Innovation Norway under the heading "Nordic Battery Scene",[96] which included an introductory talk by former Prime Minister Erna Solberg. The Eyde Cluster and the Norwegian Board of Technology also organised a batteries webinar[97] attended by the EU Ambassador to Norway, Thierry Béchets.

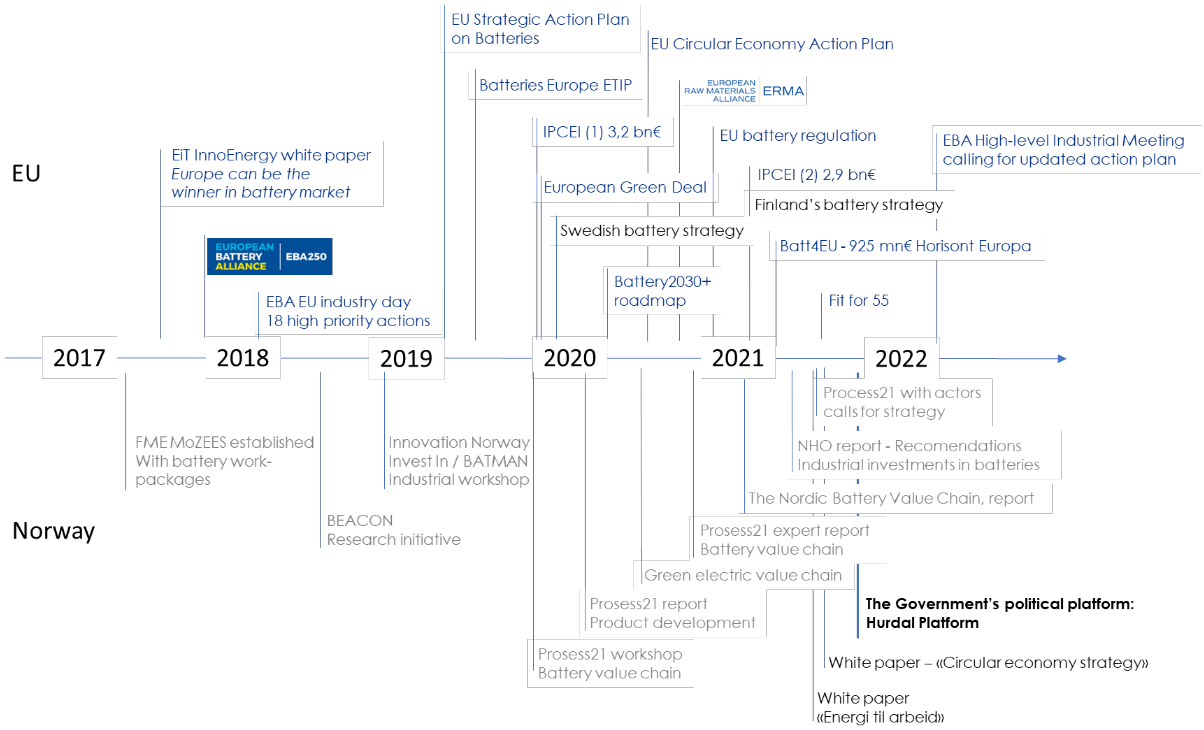

Figure 10 – Timeline including relevant Norwegian activities

A mere few days after the EU published the Batteries Regulation proposal, the Mission of Norway to the European Union, NORCORE, the Eyde Cluster and the University of Agder invited key representatives of the European Commission to a webinar to discuss implications for the battery value chain. Various Norwegian stakeholders have provided input for the Batteries Regulation, which appears to be largely positive with a view to production in Norway.

In February 2020, the Prosess21 forum pointed to the battery market as an opportunity to specialise products and increase value creation in the process industry. This is referred to in a report from the expert group for product development.[98] A workshop was held with key stakeholders as a basis for this report, which focused on a SWOT

95 Eyde-cluster – Fullt hus på BATMAN (eydecluster.com) – in Norwegian only
96 The Nordic Battery Scene – YouTube
97 Eyde-cluster – Batteriwebinar: - Vi deler samme virkelighetsforståelse (eydecluster.com) – in Norwegian only
98 Produktutvikling i prosessindustrien (prosess21.no) – in Norwegian only

analysis.[99] Based on raised ambitions among certain enterprises in the process industry (especially Hydro, Elkem and Glencore Nikkelverk), Prosess21 chose to bring together different battery technology stakeholders in Norway and compiled a broad-based expert group report[100] on the battery value chain. Prosess21 has also drawn up a document that explains lithium-ion battery technology and development trends in simple terms.[101]

The report on the project Green Electric Value Chains has been important in highlighting the potential for a battery value chain in Norway. The project was driven by industry stakeholders and was established for the purpose of identifying business areas that may become important in a situation where Norway is among the OECD member states that most quickly loses shares in international export markets. The need for new value chains is illustrated by the fall in export value from oil and gas activities, which will accelerate up until 2050. The analysis indicates a turnover potential for Norwegian operators in the prioritised business areas of at least EUR 32 billion per year in 2030 and at least EUR 76 billion per year in 2050. The estimate relies on the assumption that Norwegian operators invest in these six main areas and that the Norwegian government actively facilitates these investments, allowing them to take market share in growing markets.

Batteries are identified as one of six industries that will be important to Norwegian exports going forward. The report describes the industries' potential in the form of turnover. The turnover potential for the Norwegian battery value chain has been set to NOK 90 billion per year in 2030 (with the help of McKinsey). The report describes attractive business areas resulting from Norwegian competitive advantages. The objectives can be achieved by developing a broad value chain that includes battery cell manufacturing. In step with such development, Norwegian operators can establish both upstream production and downstream assembly, as well as batteries recycling. The turnover potential exceeds that of offshore wind and hydrogen combined in 2030.

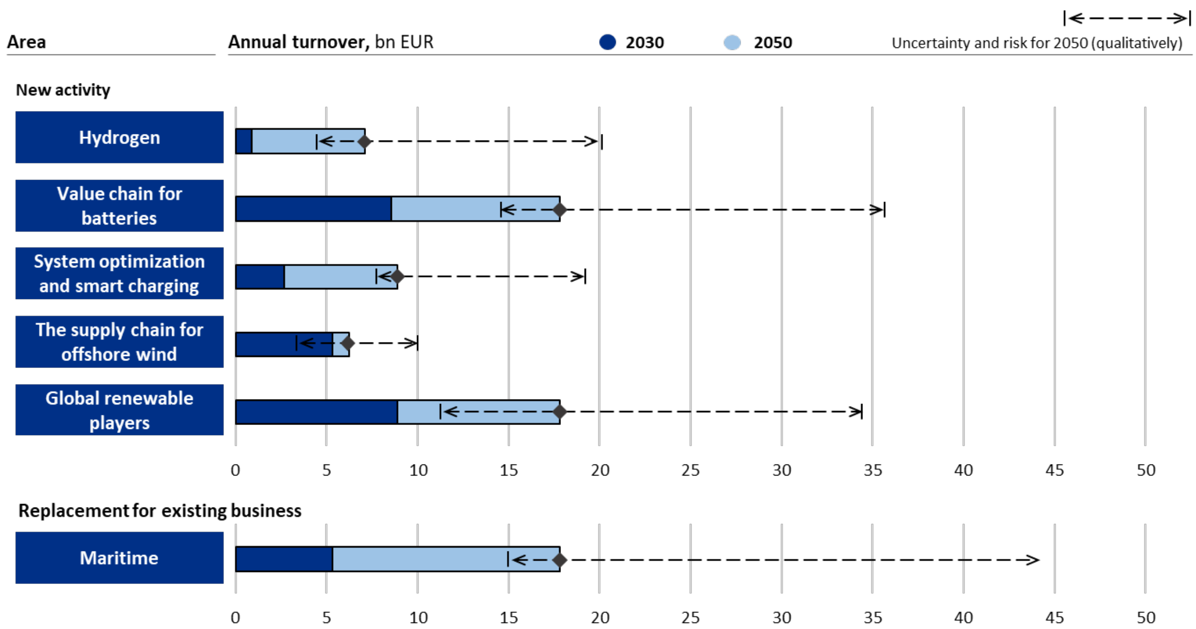

Figure 11 – Turnover potential for new Norwegian business activity. Source: Green Electric Value Chains

In May 2021, the Confederation of Norwegian Enterprise (NHO) brought together various businesses, R&D institutes and universities to identify the measures needed to unlock the potential for a considerable increase in activity in the Norwegian battery value chain. NHO, the Norwegian Confederation of Trade Unions (LO), the Federation of Norwegian Industries, Energy Norway, Equinor, Hydro, Elkem, Freyr, Morrow Batteries, Beyonder, Corvus Energy, Hydrovolt, Siemens Energy, the Norwegian University of Science and Technology (NTNU), SINTEF, the University of Oslo (UiO), the Institute for Energy Technology (IFE), Bellona, Battery Norway and the Norwegian Electric Vehicle Association are behind this report. The report[102] on recommendations for industrial investment in batteries in Norway (*Anbefalinger for industriell satsing på batterier i Norge* – in Norwegian only) was

99 191121-executive-summary-battery-materials-workshop-kristiansand_final.pdf (eydecluster.com)
100 prosess21_ekspertnotat_batteriverdikjeden_211220.pdf – in Norwegian only
101 prosess21_lithium_batteri_kartleggingsrapport_221021.pdf – in Norwegian only
102 anbefalinger-for-en-industriell-satsing-pa-batterier-i-norge.pdf (nho.no) – in Norwegian only

presented and handed over to then Minister of Trade and Industry Iselin Nybø (Liberal Party). The report calls for goals and ambitions to be set out in a Norwegian strategy and lists a number of brief recommendations relating to i) goals and strategy, ii) infrastructure, licenses and permits, iii) support schemes and access to capital, and iv) expertise, research and education.

Prosess21 submitted input[103] for the Ministry of Petroleum and Energy in connection with their work on the white paper on long-term value creation from Norway's energy sources. In its submission, Process21 referred to the need for increased value creation for each produced MWh and for building land-based value chains with reference to the report on Green Electric Value Chains. The white paper (Meld. St. 36 (2020–2021) *Energi til arbeid – langsiktig verdiskaping fra norske energiressurser* – in Norwegian only) was presented in June 2021. Because the report made little mention of the battery value chain, Prosess21 decided, together with battery cell initiatives Beyonder, Freyr and Morrow, to call for[104] the development of a Norwegian battery strategy.

In the white paper, the Solberg Government expressed a wish to establish five hydrogen hubs for maritime transport, one to two industry projects for production and five to ten pilot projects by 2025. It was also proposed to establish a dedicated research centre (FME) for hydrogen and ammonia. The same Government had previously, through the third crisis package (Prop. 127 S (2019–2020)) allocated NOK 120 million to the Research Council of Norway[105] for innovation projects for the industrial sector, of which projects focusing on hydrogen were to be given priority. The national budget for 2021 (Prop. 1 S (2020–2021)) included an appropriation of NOK 100 million to follow up the Government's hydrogen strategy. Furthermore, Enova was assigned responsibility for following up the IPCEI initiative for hydrogen, which has resulted in more than NOK 1 billion being allocated to three projects[106] by Tizir, Yara and Horisont Energi. The Research Council recently announced that it would be awarding a total of NOK 310 million to two hydrogen research centres (FME).[107]

Seen in relation to the expected value creation from batteries (ref. Green Electric Value Chains), public investment in batteries has been relatively low when compared with hydrogen, with no earmarked funds or underlying strategies. Through open calls for proposals, the Research Council of Norway has awarded a total of NOK 550 million to battery projects during the period 2016–2021.[108] Innovation Norway has awarded approximately NOK 600 million in grants and loans[109] during the period 2016–2021 based on applications from individual enterprises representing the breadth of the battery value chain. Through the Green Platform Initiative (Research Council, Innovation Norway and SIVA), a total of NOK 150 million was awarded to two battery projects, "Norwegian Battery Packing Network" and "Sustainable Materials for the Battery Value Chain" (discussed later) in 2021–2022. No awards were made based on earmarked funds.

In June, the Solberg Government also presented a national strategy for developing a green, circular economy.[110] The strategy discusses the EU Batteries Regulation and how it can promote Norway's green competitiveness. The Solberg Government supported the Batteries Regulation proposal and wanted to work to ensure that it fostered important Norwegian interests. The strategy is relevant in this context because it sets out *to "look into the possibility of and consider whether it would be useful to become affiliated to existing IPCEI battery projects"*.

[103] 201210-Prosess21-innspill-energimelding.pdf – in Norwegian only
[104] 210614-Prosess21---onske-om-a-etablere-norsk-batteristrategi.pdf – in Norwegian only
[105] Regjeringens hydrogenstrategi og øremerking av midler til hydrogen (forskningsradet.no) – in Norwegian only
[106] Milliardstøtte til hydrogenprosjekter – regjeringen.no – in Norwegian only
[107] Oppretter to nye forskningssentre på hydrogen – regjeringen.no – in Norwegian only
[108] Information from the Research Council of Norway (2022)
[109] Information from Innovation Norway (2022)
[110] Nasjonal strategi for ein grøn, sirkulær økonomi (regjeringen.no) – in Norwegian only

The battery value chain and Norwegian stakeholders

The total market for lithium-ion batteries consists of minerals from mines and quarries, refined raw materials such as nickel, cobalt and manganese, refined precursors and active materials, battery cells, battery packs and recycling. In other words, an extensive value chain is behind the production of battery cells and battery packs that are used in the products in our everyday life (see Figure 1 – Value chain for lithium-ion batteries). The location of industrial activity in the different parts of the value chain is dependent on access to minerals and materials, and their respective needs and input factors such as competencies, electrical power, water, transport etc. It is therefore expedient to describe different parts of the value chain in more detail, and to describe processes and resource use. The figure below provides a more detailed overview of the process flow from minerals extraction to battery cell production. The figure shows the current situation. Changes in technology are discussed later.

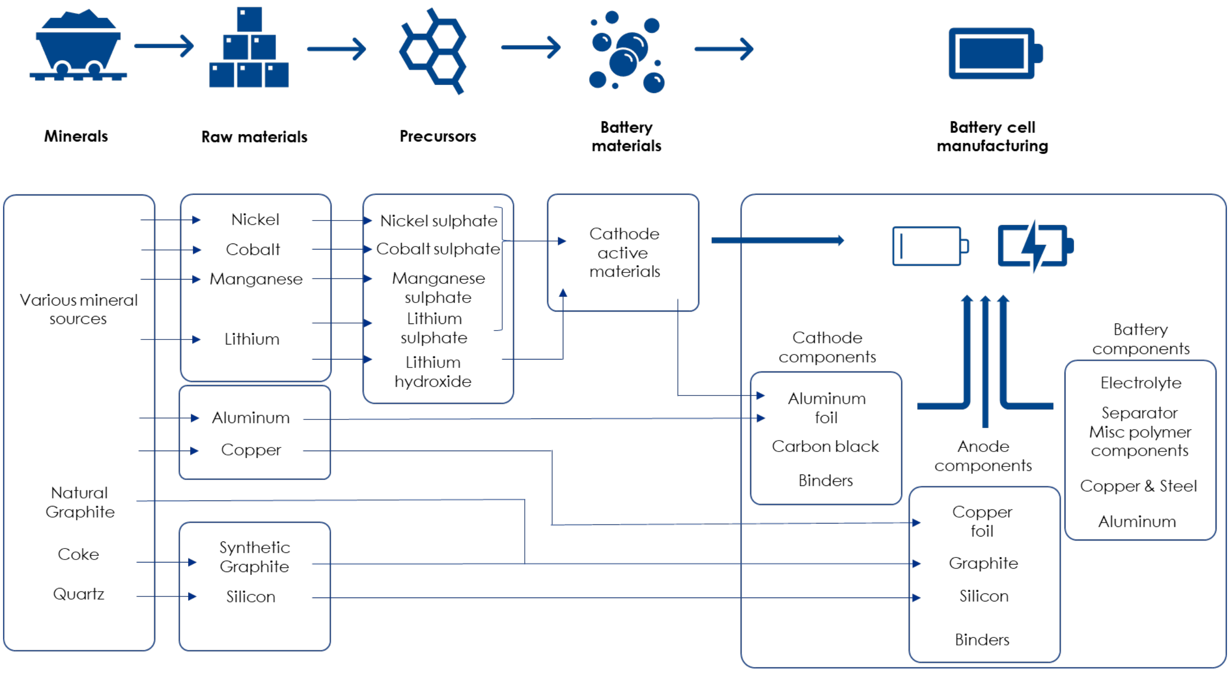

Figure 12 – Flow of materials and resource use in the battery value chain based on today's battery cell chemistries

To ensure long-term competitive advantages in the battery value chain, it must be possible to trace and document the environmental footprint throughout the value chain. Batteries with a documentable climate and environmental benefit will be the winners, provided that regulations require sustainability documentation and that the requirements are adhered to. The EU Batteries Regulation provides for this through a "battery passport" and requirements relating to information about components, carbon footprint throughout the value chain and recycled content requirements. There is also reason to believe that consumers who buy electric vehicles and other battery-based products will increasingly ask for climate and environmental documentation. It will be necessary for all producers (from all countries) to maintain the necessary focus. Based on this framework, Norway will be in a favourable position to develop competitive stakeholders in the value chain by ensuring minimal or negative GHG and maximum environmental benefit through the use of materials throughout the value chain.

Minerals

Minerals have been the foundation of almost everything in our society and will continue to be so in the years ahead, when transitioning to a climate-neutral society. Many minerals come from countries such as Australia, Brazil, China, Indonesia and several African countries. A circular economy will be essential to exploit the resources already in the cycle, but in a growth phase, the need for materials to make the transition to a greener economy will increase strongly. McKinsey[111] describes the enormous quantities of minerals required to start using the new zero-emission technologies, such as the electrification of transport via hydrogen and battery solutions.

[111] The raw-materials challenge: How the metals and mining sector will be at the core of enabling the energy transition | McKinsey

In the overview below, McKinsey shows the materials intensity of zero-emission vehicles compared with traditional fossil vehicles.

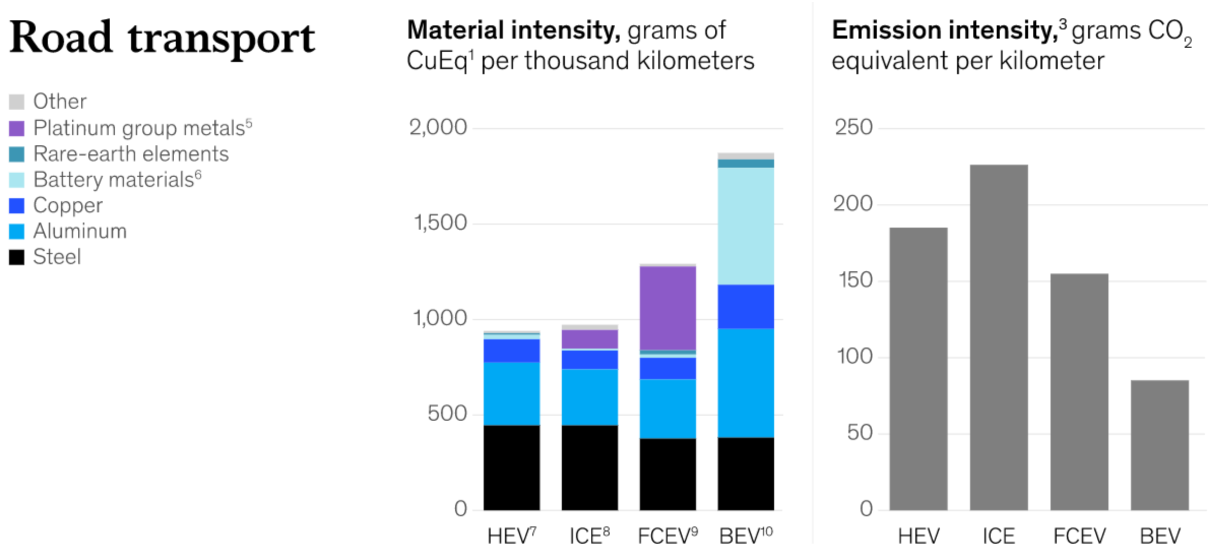

Figure 13 – Materials and emission intensity for traditional and zero-emission vehicles. The carbon intensity of electric power that forms the basis for the calculations is not known. HEV: hybrid-electric vehicle, ICE: internal combustion engine vehicle, FCEV: fuel-cell electric vehicle, BEV: battery-electric vehicle. Source: McKinsey

The minerals industry is capital intensive, and it can often take seven to ten years (or longer) from when a deposit has been found to be commercially viable until a mine has been developed. Furthermore, mining projects entail encroachments on nature, and in some cases have detrimental effects on other business activities (incl. reindeer husbandry) and consequently a conflict of interests[112] that may be entirely justified. In many countries, the discussion relating to minerals extraction is also characterised by a reluctance to have such activities in one's neighbourhood, known as "*NIMBY – not in my back yard*". Going forward, metal and minerals extraction will be subject to more stringent requirements to minimise waste and ensure handling of tailings. Uncontrolled pollution and human rights violations in connection with mining operations are of great significance to the sustainability of the battery value chain, and considerable challenges still exist, especially in countries with weak political governance and a lack of control bodies. Pressure from human rights organisations and, increasingly, conscious consumers has led to increased attention from manufacturers and the establishment of organisations such as Responsible Business Alliance.[113] More and more international enterprises are relying on UN Global Compact[114] and increasingly disclose information in accordance with international standards such as the Global Reporting Initiative (GRI).[115]

The energy transition will entail a great need for various minerals, which in turn may lead to shortages and rising prices. This, in turn, may lead to considerable innovation and a technology shift. We have seen this happen in connection with using cobalt in batteries, where the challenges are also combined with ethical dilemmas in DR Congo. Battery manufacturers (including Norwegian ones) are currently attempting to reduce or eliminate the use of cobalt in batteries. The Institute for Energy Technology is participating in the EU project CoFBAT,[116] which focuses on longer service life, reduced costs, enhanced safety and cobalt-free recyclable batteries. We have also seen the emergence of other battery chemistries, where enterprises are willing to compromise energy storage capacity for more easily available, cheaper materials.

The EU Raw Materials Initiative[117] from 2008 aimed to increase European domestic production to secure supply and sustainable European production, and served as a model for all other minerals strategies in Europe. The EU's list of critical minerals is in many ways a list of the raw materials that should be in focus. In the same way as the

---

[112] Developing countries pay environmental cost of electric car batteries | UNCTAD
[113] Responsible Business Alliance
[114] Bli med – UN Global Compact Norway
[115] GRI – Home (globalreporting.org)
[116] CoFBAT | Cobalt-Free Batteries | Belgium
[117] Policy and strategy for raw materials (europa.eu)

Raw Materials Initiative, the national minerals strategies aim to facilitate local value creation by stimulating increased exploration and sustainable production. The Ministry of Trade, Industry and Fisheries is leading the work on the Government's minerals strategy, which is expected in autumn 2022.[118] It is natural to see the battery strategy in conjunction with the minerals strategy.

Many of the minerals required in renewable energy production, energy storage and mobile technology are wholly or partly extracted as by-products from other mineral and metal production. This is true for many special metals such as indium, tellurium, germanium and gallium, but also for cobalt. Nearly all cobalt that is produced today is a by-product of nickel or copper mines. Glencore Nikkelverk's refining facility in Kristiansand is a good example of such extraction, where imported nickel matte from Canada is refined into nickel, copper, cobalt and metals in the platinum group.

Little minerals extraction of relevance to battery production takes place in Norway. An important exception is Skaland Graphite[119] in Senja, which is one of Europe's largest and purest sources of natural graphite. The company was acquired by the Australian company Mineral Commodities Ltd in 2019. Its ambition is to extract and refine battery-grade graphite. Elkem also has mines for the extraction of pure quarts, which is used in its silicon production. Silicon is expected to be used in anode materials in battery cells together with graphite, but so far in relatively small quantities.

Norway's access to minerals and battery-critical raw materials

The following section describes potential mineral deposits, based on the need for NMC batteries (today's dominant technology), which contain nickel, manganese and cobalt. Other battery chemistries require e.g. phosphate (LFP batteries) and vanadium (redox flow batteries). The latter is also on the EU's list of critical raw materials. Norway has produced both vanadium (Raudsand) and phosphate (several places), and active exploration projects for these raw materials are currently ongoing, for example Norge Mining's project at Bjerkreim[120] to identify deposits of phosphate, titanium and vanadium.

The Geological Survey of Norway (NGU) has registered about 8,000 mineral deposits divided between 6,000 ore deposits and 2,000 industrial mineral deposits. Under Norwegian law, mineral deposits are divided into two groups: i) the State's minerals, which are metals with a density of 5 g/cm^3 or higher, and ii) property owners' minerals, which are all other mineral deposits, with a few exceptions. Knowledge about the individual deposits varies.

Extensive metal production takes place in Finland and Sweden, while Norwegian production is dominated by industrial minerals such as graphite, quartz, carbonate and olivine. Norway's metal production includes iron ore (Rana Gruber) and Europe's largest production of the titanium mineral ilmenite (Titania). There are mature projects expected to start up in a few years for copper (Nussir) and the titanium mineral rutile (Engebø). A reopening of the iron mines near Kirkenes (Sydvaranger) is also possible.

On assignment for the Nordic Council of Ministers, the Geological Survey of Norway submitted a report in 2021 on the potential for critical mineral resources in the Nordic region.[121] The report shows that the potential for additional production of critical minerals in Norway and the other Nordic countries is high, and that the region must be considered one of the most prospective areas in Europe. The last Norwegian nickel mine closed down in 2002 (Bruvann), but Norway is still prospective for nickel. At the same time, the cobalt content of Norwegian nickel deposits varies, which can be produced as a by-metal from nickel production. Several of the Norwegian copper-zinc deposits, of the type found at Løkken and Sulitjelma, have a documented content of cobalt that can be produced in connection with a possible copper operation. Active, commercial efforts are being made to find both nickel and copper-zinc deposits in Norway. The report underlines the need for enhanced mapping and a better official data basis to increase both exploration activity and the discovery frequency.

So far, no significant deposits of lithium have been documented in Norway. The biggest European potential for lithium is found in Spain and Portugal, with some smaller deposits in France (Massif Central), Germany (Ertzgebierge), Ukraine, Sweden and Finland. None of the active lithium producers in the EU currently produce lithium for batteries, but this issue has now started to gain attention.

[118] Prop. 1 S (2021–2022) – regjeringen.no – in Norwegian only
[119] Skaland Graphite AS – Europe's major producer of Crystalline Flake Graphite
[120] Norge Mining Bjerkreim prosjekt anslått til 70 milliarder tonn – Norge Mining – in Norwegian only
[121] The Nordic supply potential of critical metals and minerals for a Green Energy Transition (diva-portal.org)

There are three areas with graphite deposits in Norway: Senja, Lofoten-Vesterålen and Holandsfjorden. There have been mines in production in all these areas, but only Trælen in Senja is currently in operation. None of the graphite producers in Europe currently produce spherical graphite for use in batteries. Graphite from Skaland could be processed into spherical graphite if appropriate plants are established. For almost ten years, the Geological Survey of Norway has given priority to surveys of Norway's graphite potential. Overviews have recently been published of the resource potential for the graphite deposits in Senja, Vesterålen and Holandsfjorden (Gautneb et al., 2020b).[122] In these areas, 28 deposits have been described with an average graphite content of 11.6% and total tonnage of 241.6 million tonnes, which corresponds to 21.51 million tonnes of pure graphite.

It is important to point out that Norway's mining and minerals processing industry is currently integrated with European countries in the same way as corresponding industry located in current EU member states, which has been the situation since before the EU was established. In many cases, the industry is also integrated in a global value chain, from primary production to the end product. The resource potential and production of batteries and battery raw materials cannot be seen from a Norwegian perspective only, but must be considered at the European level as a minimum.

Side streams (especially graphite-based) from existing industrial activity represent an interesting opportunity if they can be upgraded to battery-grade quality. The potential of this area is currently being looked into, but it is associated with too much uncertainty to be able to define possible business opportunities. Initial tests need to be carried out, and the opportunities must be mapped. As regards the extraction of battery metals such as nickel, lithium and cobalt from side streams and by-products of the minerals and processing industry, there are probably few opportunities, according to Bergfald.[123]

Raw materials (nickel, cobalt, manganese, aluminium, silicon and synthetic graphite)

Norway is a major producer of metals and currently among Europe's most important producers of aluminium (Al), zinc (Zn), nickel (Ni), manganese (Mn), cobalt (Co) and platinum group metals (PGM). The production is based on the import of minerals or semi-finished materials such as alumina and nickel matte. Ores are processed in Norway because of access to renewable, competitively priced electric power. This industry is described in more detail in the Prosess21 report.[124] It also describes how the traditional process industry has the potential to grow by tailoring its products to the growing battery market. Prosess21 has set an ambition to double exports from the process industry by 2030, and a fundamental part of the solution is to expand the product range and build capacity in a greater part of the value chains. Examples include to establish production (and offer to host production) of active battery materials, battery cells and battery packs. The specialisation strategy is described in the report from the expert group for production development and in the expert report on batteries.[125]

Precursors and cathode active materials

In order to produce precursors, the raw materials (typically nickel, cobalt and manganese in metal form) undergo a chemical process in which the metal is dissolved in acid, which results in metal sulphates/metal nitrates called salts. A precipitation reaction can then be induced through different methods to form a solid product with the desired composition of materials. The process will often be governed by an ion concentration so that the salts (sulphates or nitrates) come together to form fine particles. High-purity nickel and cobalt sulphates are typically used in the battery industry as the basis for the production of cathode active materials. Such particles are used in the production of the active electrode mass that in turn is used in lithium-ion cell production. An intermediate product can also be a mixture of the chosen materials included in the final battery electrode chemistry, for example a mixture of nickel, manganese and cobalt salts in a given ratio, e.g. 6:2:2.

This intermediate product must be further refined into a cathode active material before it can be used in battery cell production. Lithium for lithium-ion batteries is typically introduced to the cathode precursor material, where lithium carbonate or lithium hydroxide is introduced into the cathode structure. This product is further refined through heat treatment, which often takes place at high temperatures and in a process known as calcination. The purpose of this

[122] Minerals | Free Full-Text | The Graphite Occurrences of Northern Norway, a Review of Geology, Geophysics, and Resources (mdpi.com)
[123] Mindre-deponering-av-farlig-avfall_1.9_web.pdf (bergfald.no) – in Norwegian only
[124] prosess21_rapport_hovedrapport_web_oppdatert_060821.pdf – in Norwegian only
[125] The reports can be downloaded from www.prosess21.no

process is to burn off undesired compounds that still exist in materials and to form the structure of the materials matrix.

Cathode active materials can be purchased from recognised materials producers such as BASF[126] or Johnson Mattey.[127] The production requires high-purity materials and is subject to stringent requirements of input raw materials, and chemical process control. The development and production of cathode active materials are associated with a range of intellectual property rights (IP), and different battery cell manufacturers define their own "prescription" based on agreements with end users.

Some battery cell manufacturers choose to include the production of cathode active materials in their own processing. This allows for a greater backflow of reused materials from used battery cells. The "used" cathode material comes back in the form of what is known as "black mass", which consists of a matrix of materials (e.g. nickel, manganese, cobalt and lithium) that must undergo a new chemical precipitation process. Northvolt AB has chosen to include such a process in its battery cell concept under the term "Revolt".[128] HydroVolt[129] in Fredrikstad was established to recycle used batteries and supply Hydro with aluminium and Northvolt with black mass. Aluminium recovered from used batteries can be recycled and reused by Hydro. Glencore Nikkelverk in Kristiansand currently uses recycled materials that stem from batteries as a raw material resource, and is also in a good position to take receipt of increased quantities of materials for recycling. As Norway was among the first to phase in electric cars, we will be the first to deal with the batteries at the end of their life cycle. This creates a basis for new industrial activities.

Access to raw materials and renewable energy, in addition to our expertise in process technology, makes it expedient to facilitate the relatively energy-intensive production of precursors and cathode active materials in Norway. The production of such materials requires insight into the application area and integration with battery cell manufacturers. It also requires a great deal of electrical power, because calcination and hydro-metallurgical processes require large amounts of energy. Norway can therefore be a good host country for this type of processing. With the increased focus on a lower carbon footprint in battery production through the EU Batteries Regulation, Norway will have a geographical advantage as long as renewable energy is available at competitive prices.

Production of anode materials

Graphite is the main component of lithium-ion battery anodes used in electromobility, with an admixture of silicon (5–10%) as part of the last generation of NMC 8:1:1 batteries, known as state-of-the-art technology. Lithium-ion batteries that only contain graphite and silicon-graphite composite anodes will play a key role in achieving a large-scale EV revolution in Europe up towards 2030. It is therefore important that Europe develops safe, sustainable supplies of i) anode graphite and ii) silicon-graphite composites. At present, Norway is a major producer of primary silicon with a record-low carbon intensity.

Norway produces both natural (Skaland Graphite) and synthetic graphite (Vianode), but so far in small volumes. Elkem, the previous owner of the new company Vianode,[130] has completed a pilot line in Kristiansand and is preparing to build a factory in Herøya Industripark. In April 2022, Elkem, Hydro and Altor announced a partnership for the further development of Vianode.[131] The final investment decision is expected in spring 2022.[132] Vianode has developed a dedicated process that reduces GHG emissions significantly compared with traditional graphite production. The combination of renewable energy and process development will help to reduce the carbon footprint by 90 per cent compared with the current product.

Today, most of these types of graphite are made in China, where the production has a carbon footprint of between 4 and 14 kg of CO_2 per kg of graphite. The use of graphite extracted and produced in this way can lead to the emission of 900,000 extra tonnes of CO_2 from production alone (i.e. not including transport to Europe) of the anode graphite for 250 GWh lithium-ion batteries. Improving efficiency and materials performance, combined with reduced energy consumption and a smaller carbon footprint from graphite, will be key factors in sustainable European

[126] BASF-Battery_Booklet_as-of-Dec-3-2021.pdf
[127] Battery materials | Johnson Matthey
[128] Revolt | Northvolt
[129] Hydrovolt
[130] Synthetic Graphite Manufacturers | Vianode
[131] Article | Nyheter | Elkem.com
[132] Latest news | Vianode

production of anode materials. In addition, the development of silicon-graphite composite production will not only enhance battery performance, but also reduce the total carbon footprint of anode materials.

Cenate[133] is among the world's leading companies in the development and production of brand new, unique nano materials based on silicon, to be used in the next generation of lithium batteries. These materials will make the batteries cheaper and smaller, thereby significantly increasing the range of electric vehicles and heavy-duty equipment. The company is working with several of the world's battery manufacturers.

Cell production

Battery cell production is the activity where different components and materials from earlier processes are connected and assembled to form a battery cell. As mentioned in the introduction, the capacity of a battery cell factory is measured by the energy content of the batteries produced, measured in gigawatt hours (GWh). A "gigafactory" would be able to deliver batteries for 6–700,000 cars a year at full capacity (e.g. a 40 GWh factory). This corresponds to millions of batteries in production (Tesla, for example, has 4,000–7,000 cylindrical cells in each car, depending on the battery pack). The production can consist of different configurations of battery packs such as cylindrical, prismatic or pouch, as shown below.

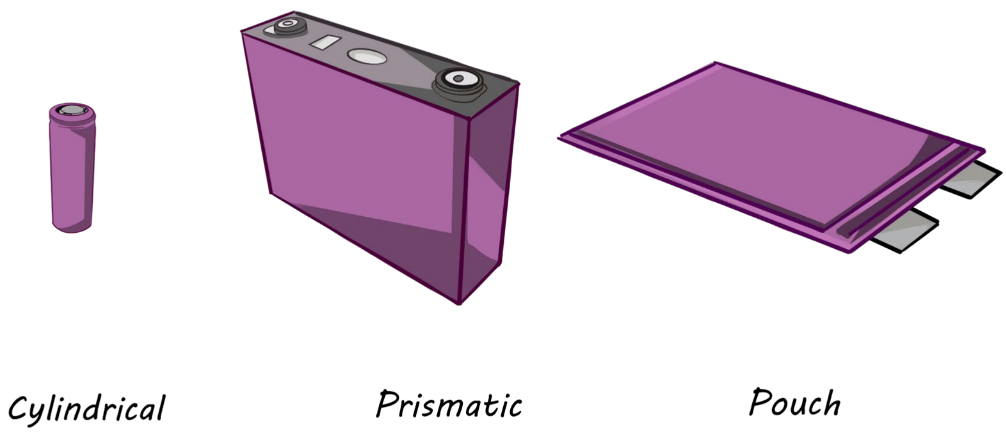

Figure 14 – Battery cells with different configurations (cylindrical, prismatic or pouch)

The production of battery cells is high-volume mass production, and examples of the process elements that make up the production line for pouches are shown in the figure below. The figure provides an overarching description of the process stages of the production line and their purposes. It can be useful to see videos of these processes, for example Volkswagen's pilot line at Salzgitter.[134]

[133] Cenate Centrifugal nanotechnology
[134] CAR FACTORY: Lithium-ion Battery Cells Production at VOLKSWAGEN Salzgitter Plant – YouTube

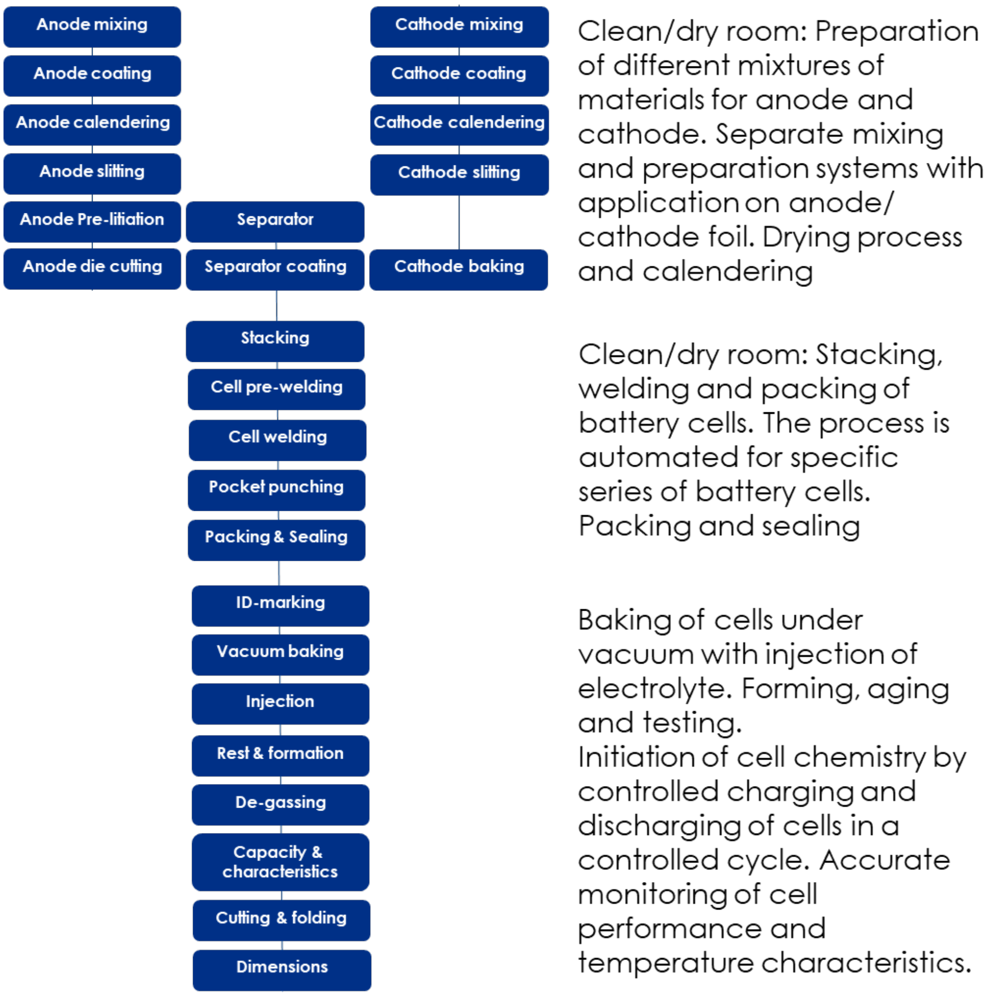

Figure 15 – Process flow of battery cell production – example of pouch cell production

For a complete description of the process in a cell factory, see Figure 12 – Flow of materials and resource use in the battery value chain and Figure 15 – Process flow of battery cell production – example of pouch cell production. The cathode active material is a powder that is mixed with a binder, solvent and carbon, often in the form of carbon black, before this liquid mixture is applied to a thin sheet of aluminium foil. The foil with the moist cathode material is passed through a roller press that ensures the right density/porosity of the cathode coating (calendering), before being cut into the right dimensions. The dimensions are defined by the battery size. Correspondingly, the anode material (graphite and often a small quantity of silicon) is mixed with a binder and applied to thin sheets of copper foil, which are pressed and cut.

Cathode and anode are stacked alternatively with a separator, often made of a polymer material (polyethylene or polypropylene). The electrodes are then welded together, and the alternate layers of anode/cathode/separator are baked in a packing foil under vacuum, before the “can” or "envelope" that now makes up the battery is filled with electrolyte. The battery then needs to be conditioned, which means charging it in a controlled environment and “activating” the chemical reaction, i.e. moving the lithium ions from the cathode to the anode. This is followed by a final, extensive quality control of the battery characteristics.

Beyonder will be producing high-performance batteries. Their solution is based on a combination of lithium-ion and capacitor technology, which produces cells with a higher efficiency than normal lithium-ion batteries, making them suitable for applications in the power system, renewable energy, transport and offshore energy infrastructure markets. Beyonder’s battery technology is based on a patented process they have developed themselves, where cathodes are produced from sawdust. The batteries are non-flammable and can be fully charged in two minutes and recharged up to 100,000 times, thus reducing the need for frequent replacement of batteries. Beyonder’s patented battery technology is an alternative to the use of conventional lithium-ion batteries and resolves challenges not addressed in today’s batteries in high-performance applications. The market for such products is expected to increase significantly in the next few years.[135] Hybrid solutions such as lithium-ion capacitors are capable of taking market share where fast, high-power solutions are required. The production process has many similarities with the process for traditional battery cells, but differs in the composition and use of materials.

Battery cell production is characterised by the high number of elements included in the cost model. The cost of the materials used in the battery, in the form of cathode active material and anode material, is considerable. Electric power and payroll expenses for employees are among the other elements impacting costs. The cell factory uses electric power in an extensive drying line to remove all moisture and burn off residues of organic components, maintain a clean/dry environment and to conduct the formation and conditioning processes that activate the chemical reaction. The total power consumption will depend on how much of the raw materials are processed in the cell factory rather than purchased, and the possibility of recycling. It is assumed that the Northvolt facility in Skellefteå, which includes battery cell production, preparation of cathode active materials and recycling, will consume 2.5% of Sweden's power production, or approximately 4 TWh.[136]

The development of flexible industrial production lines that produce batteries of high, consistent quality is decisive to Norway's ability to establish competitive, lasting and profitable battery cell production. In order to succeed, it is essential that all equipment throughout the value chain runs without disruption, with the highest possible production volume and minimum downtime e.g. maximum yield. It is also very important, of course, to verify that all produced batteries checked at the final inspection stage meet the narrow tolerance limits set. Producing batteries that do not meet the requirements and cannot be used for their intended purposes entails a considerable loss of capacity and resources. For this reason, all links in the production chain must be continuously monitored with built-in sensors, including 3D vision systems. The manufacturers that best succeed in applying and optimising production with Industry 4.0 technologies will build international competitiveness.

Technologies that will be important to battery cell and pack production include automatic/autonomous production technology with steering/digitalisation, robots, unmanned aerial vehicles (UAV) and pertaining tracking systems. As mentioned, battery cell production could result in 7,000[137] direct jobs. However, the goal should be considerably lower in low-staffed, highly automated facilities. The building and application of battery energy storage systems (BESS) may lead to more jobs if Norway succeeds in taking a significant position. This is a type of mass production Norway has limited experience of, and it may generate useful spin-off effects in other industries.

To enable Norway to develop a competitive battery cell and pack production over time, it will be decisive to draw on the experience-based expertise of leading Industry 4.0 environments, including at Raufoss and Kongsberg. The next-generation battery solutions will also require new production technology. By developing digital pilots for industrial enterprises, Norway can ensure that it is one step ahead of next-generation battery production.

There is also an independent need for testing and certifying finished battery products, i.e. after the R&D phase, which is a precondition for the products entering the markets, both in the EU and worldwide. These activities will largely have to be carried out by independent, accredited laboratories, for example Nemko.[138] The manufacturers' self-declarations will often not be sufficient. In practice, several product properties will have to be verified by independent laboratories, and new requirements are likely to follow, including for i) customer specifications, ii) explosion protection during transport and iii) sustainability requirements under the EU Batteries Regulation.

Maritime applications

Norway has a long-standing maritime tradition and has been a significant shipping nation with global presence for more than 150 years. Norway currently produces battery packs and hybrid systems for maritime applications. Leading companies in this field are Corvus, Siemens Energi and Kongsberg. Green shipping and the development of specialised battery solutions appear to represent considerable business opportunities.

The Norwegian maritime industry plays an internationally leading role in the development of low and zero-emission solutions and electrification of maritime transport. The companies in the Norwegian maritime cluster engage in extensive R&D activities and have established close partnerships with maritime customers in oil and gas, ferries and passenger transport, and shipping. The market is largely domestic. The development of battery solutions is key

[135] IDTechEx: Market Research, Scouting and Events on Emerging Technologies
[136] Inside Northvolt – Scandinavia's 'Gigafactory' | FULLY CHARGED – YouTube
[137] From the report on industrial investment in batteries ("Anbefalinger for industriell satsing på batterier i Norge", NHO, 2021)
[138] https://www.nemko.com/no/

to the development of zero-emission and hybrid solutions. New battery solutions and green shipping are at the early stages of development, where considerable R&D efforts are made. It is important for the Norwegian maritime cluster to ensure further development and access to battery solutions and components for maritime applications.

Stringent requirements apply to maritime battery solutions with regard to e.g. fire, explosion hazard and corrosion. Maritime regulations and classification requirements make the maritime battery industry a niche market seen in relation to the global production volume. The degree of specialisation and requirements of application expertise are high. This means there is a basis for establishing a stronger marine battery value chain and a world-leading, robust value chain for maritime battery solutions that will contribute to further electrification of global shipping.

The annual volume of maritime battery solutions amounted to around USD 0.37 billion in 2021 and is expected to increase to USD 1.99 billion in 2030 (0.9% of annual production).[139] Although the volume is considerable, it is overshadowed by the need for land-based applications. As such, access to specialised batteries for the maritime industry will be under further pressure in the years ahead, as the biggest international battery suppliers are expected to focus their development and deliveries on land transport.

Batteries in tomorrow's energy systems[140]

Increasing electrification in various sectors and an increasing share of variable renewable energy in the power system put additional strain on the energy distribution network. The use of energy storage systems such as BESS, combined with flexible use and production of energy, has been presented as a less costly alternative to upgrading the grid. In this way, BESS has the potential to become an important technology in the planning of tomorrow's energy solutions. Rystad Energy has estimated the battery storage needed in order to meet the UN IPCC's 1.6˚C scenario and arrived at 2,600 GWh. According to the analysis, this makes up slightly less than 30% of the total market for batteries.

Battery systems can be used in connection with physical installations for the production, transmission, distribution and consumption of electric power, which may replace or reduce the need for a costly power grid upgrade. In many cases, batteries can be a more reasonable solution than upgrading the grid, within a given horizon. This is especially the case when batteries are used to overcome bottlenecks. Another aspect is that high output will lead to increased ageing. Peak load shifting can reduce the maximum energy load on equipment during high-demand periods, typically transformers, and thereby potentially contribute to a longer service life and postpone the need for investment.

The frequency of voltage quality problems is expected to increase in step with more use of demanding electrical equipment and increasing variations in load and production. Grid connection of distributed power generation systems and EV charging, especially in poorly developed distribution grids, may give rise to voltage quality challenges. A battery system has the potential to overcome many of these problems, where battery systems linked to ferries are a well-known example of voltage quality support.

A battery system can be used to shift or reduce peak demand in the grid in connection with short peak loads, known as peak shaving. The highest peaks can be reduced by letting the battery supply active power at peak load. Customers subject to restrictions in the power or voltage that can be fed to the grid can thereby sometimes produce more electricity than they supply, by using internal storage and then supplying the surplus electricity at a later date. Customers who occasionally produce more than the grid is capable of receiving can use such a battery system rather than having to pay an investment contribution to upgrade the grid.

Battery systems will also be used to ensure a continuous (uninterruptable) power supply. Brief power outages may damage sensitive equipment, disrupt ongoing processes or cost time because equipment and production needs to be restarted. An uninterruptable power supply (UPS) is used to avoid disrupting production or processes. This is typically combined with e.g. filters to improve the voltage quality.

The use of modern battery systems will enable better power quality and reliability of supply, higher voltage quality, fewer interruptions and disruption.

---

[139] www.alliedmarketresearch.com (2022)

[140] The text is taken from Battery Norway's input to the supplementary white paper (Meld. St. 11 (2021–2022)) relating to the previous government's white paper on energy policy and long-term value creation from Norwegian energy resources (Meld. St. 36 (2020–2021) *Energi til arbeid*)

Recycling

In the future, all batteries will have to be recycled due to limitations in the availability of primary metals combined with the need for raw materials for new batteries. At present, reuse mainly takes place in China, since the country has had a considerable amount of batteries to recycle. Since China produces a large volume of batteries and battery precursors, they are familiar with using recycled metals from batteries as input for new production.

Batteries degrade with time and age, and their lifetime depends on the chemistry involved and usage pattern. The consultancy firm Circular Energy Storage[141] has found that a battery in normal use should retain 80% of its capacity after 14 years. Future battery technology will probably mean that batteries will have a service life equal to that of the electric vehicle, and probably even longer for stationary storage systems.

Through the BATMAN project,[142] the Institute of Transport Economics (TØI) has estimated the number of electric vehicles that will reach end of life by 2030.[143] It is primarily electric (passenger) cars that will contribute to considerable volumes of lithium-ion batteries for recycling in Norway and the rest of Europe. It is estimated that the total battery capacity installed in new electric vehicles in Norway, across lithium-ion battery types, will be 2.4 GWh in 2018, and rising to ~8.5 GWh in 2030. The net amount of batteries that will be available for reuse or recycling per year in Norway was estimated to approximately 0.6 GWh in 2025, and approximately 2.2 GWh in 2030. These batteries may potentially be reused for different areas of application, for example energy storage in houses, but it may be more profitable to recycle them.

The recycling of a battery must take account of different sizes, shapes and chemistries, and facilitate safe and correct handling of hazardous battery components. There is currently a large gap between the production and recycling capacity for lithium-ion batteries. This is partly because not enough batteries are returned for recycling purposes, and partly because recycling companies are looking for the elements that generate the highest value, such as cobalt, copper, iron and aluminium. The low recycling rate is also due to inefficient collection systems, lack of regulatory compliance in some countries, and lack of established recycling technology.

Large-scale recycling of lithium-ion batteries primarily takes place in China, although some recycling companies are based in Europe, the USA and a few other countries. One of the reasons for Europe's low recycling rate is that most of the companies outside China lack a direct connection to the battery materials market in the EU (because it is at the development stage). The batteries are therefore exported or sold for reuse in Asia. The good news, however, is that companies such as HydroVolt could become an important stakeholder going forward, in both Norway and Europe.

Automotive companies worldwide are looking to Norway and describe our handling of EV batteries as best practice.[144] Over the last decade, we have developed and acquired expertise in high-energy batteries as a result of an ambitious electrification initiative. Pending the implementation of the EU Batteries Regulation, the challenge lies in the fact that the handling of returned batteries is currently governed by the Waste Regulations. There is a lack of regulations describing producer responsibility and clear requirements of reuse, tracing and reporting. The recycling company Batteriretur has launched an initiative in partnership with Autoretur, the Norwegian Automobile Importers' Association and the Norwegian Association of Motor Car Dealers and Service Organisations vis-à-vis the Directorate for Civil Protection and Emergency Planning (DSB) to boost batteries expertise among car dismantlers. The regulations currently in force are not adapted to the situation today and allow for uncontrolled sale of high-energy batteries with no quality control. A considerable boost in expertise is needed through autorepair shops and return and recycling companies to assure that the qualities of batteries sold are safe for reuse. This will require close dialogue with e.g. the Norwegian Environment Agency and DSB and their superior ministries, as the regulations currently in force cut across these bodies.

The recycling of batteries and battery materials represents a unique opportunity for Norway, and huge capacity will be needed as EVs start to be phased out of the car fleet. Today's restrictions in the transport of batteries and materials must be harmonised to ensure a well-functioning European market and prevent the material from being exported to Asia. Norway's advantages are based on access to renewable energy, as the hydrometallurgical and

[141] The+lithium-ion+battery+life+cycle+report+sample.pdf (squarespace.com)
[142] https://prosjektbanken.forskningsradet.no/#/project/NFR/299334
[143] Estimating stocks and flows of electric passenger vehicle batteries in the Norwegian fleet from 2011 to 2030 – Thorne – 2021 – Journal of Industrial Ecology – Wiley Online Library
[144] Input from Batteriretur, Fredrik Andresen, February 2022

pyrotechnical processes involved in recycling can be energy-intensive. Furthermore, we have an existing process industry with experience of many of these processes. When the quality of recycled battery materials is degraded, the process industry may therefore find opportunities in other markets.

Norwegian stakeholders

Norway is a major producer of refined metals and can use its academic and industrial expertise to develop more specialised/recycled products for use in the batteries market. Norwegian companies currently supply 21% of the aluminium, 13% of the nickel and 8% of the cobalt raw materials needed in the EU.[145] Other companies develop specialised products and operations to supply battery materials such as natural and synthetic graphite (**Skaland Grafitt AS** and **Vianode**). The figure below shows Norwegian actors in different parts of the value chain.

Figure 16 – Norwegian stakeholders in different parts of the battery value chain

There are currently three battery cell production initiatives in Norway. **Freyr** has applied to build a 43 GWh lithium-ion battery production facility in Mo i Rana, and has been granted support from InnoEnergy[146] with planned production start-up in 2023. **Beyonder** in Sandnes will produce high-performance batteries and has decided to build the production unit in Haugaland industrial park in Tysvær municipality. Beyonder's solution is based on a combination of lithium-ion battery capacitor technology that produces cells with a much higher performance than normal batteries. **Morrow Batteries** has applied to build a lithium-ion battery production facility in Arendal, with new technological solutions and battery technology material compositions. They are also working on further developing lithium-sulphur batteries (further development of today's technology). A fourth initiative involving a partnership between Hydro, Equinor and Panasonic to look into the possibility of building large-scale production facilities in Norway has now been shelved.[147] In addition to these initiatives, Eidsiva Energi has carried out a feasibility study[148] and Narvik Batteri[149] was recently acquired by Aker Horizons.[150]

Norway enjoys an internationally leading position in transport electrification and the production of battery systems for maritime applications. **ZEM Energy, Corvus Energy** and **Siemens** engage in large-scale battery pack production in Norway with the help of imported battery cells. **Schive AS**, based in Asker, makes customised batteries for various industry, defence, subsea and offshore applications. On a smaller scale, companies such as **Evoy AS** and **Greenwaves AS** are developing fully electric products for the leisure boat market.

[145] Metals_for_a_Climate_Neutral_Europe_0.pdf (ies.be)
[146] FREYR secures €7.25 million investment from EIT InnoEnergy to build a 32 GWh battery cell production facility in Norway – FREYR (cision.com)
[147] Equinor, Hydro and Panasonic conclude Joint Battery Initiative
[148] Batteriproduksjon i Innlandet – Bellona.no – in Norwegian only
[149] Nytt selskap vil bygge batterifabrikk i Narvik – Tu.no – in Norwegian only
[150] AKER satser 200 millioner på industriarealer i Narvik. I tillegg satser de på batteriproduksjon. – NRK Nordland – in Norwegian only

Several start-ups/small companies such as **ECO Stor, Evyon, Alternativ Energi** and **Marna Energi** have entered the market for battery-based household energy storage systems, often in combination with solar and wind production. Other companies such as **Hagal** specialise in developing technology that enables efficient use of second-hand batteries, which considerably reduces costs and safety risk.

Reuse of batteries represents opportunities for value creation in Norway due to the early introduction and high market share of EVs. As the volume of batteries from second-hand EVs increases over the next five years, Norway could assume an important role in reuse and recycling. The country also has a sophisticated collection system that may represent a competitive advantage. The company **Batteriretur AS** specialises in the collection and handling of batteries from the transport sector. Recycling company **Hydrovolt AS,** a joint venture between **Hydro AS** and **Northvolt AB**, will recycle batteries from Norway's EV fleet.

Norwegian stakeholders in a growing ecosystem

InvestIN maps investment opportunities for international companies on behalf of Innovation Norway. InvestIN is developing the potential for "Norway as a battery nation", and has mapped the whole ecosystem to showcase and exploit Norway's full potential in this industry. Meetings with international stakeholders are being held continuously. It is essential in this context that there is good cooperation with expertise communities to ensure that subject matter experts are involved in dialogue with clients.

In 2020/2021, Innovation Norway, the Eyde Cluster, Hydro, the Confederation of Norwegian Enterprise (NHO), SINTEF and Northvolt organised a series of webinars on the Nordic battery ecosystem. Industry experts were well represented on the participant lists, and the participation of EU Vice President Maroš Šefčovič was testimony of the great interest in Norway as an attractive partner. In April 2021, Innovation Norway, Business Finland and Business Sweden signed a letter of intention on Nordic collaboration on trade promotion efforts, including in the area of battery production. The ambition is to work closely with carefully selected initiatives and to nurture the value of acting as a unified force. In autumn 2021, these organisations therefore organised a series of webinars in cooperation with the European Battery Alliance / EiT InnoEnergy. In February 2022, the partners gave the green light to continuing and intensifying their collaboration.

MoZEES[151] (Mobility Zero Emission Energy Systems) is a Centre for Environment-friendly Energy Research (FME) that will contribute to developing new battery and hydrogen materials, battery components and battery systems for current and future application in the transport sector (road, rail and sea). The research centre contributes to designing and developing safe, reliable and cost-effective zero-emission solutions for transport. The centre is a collaboration between 4 research institutions, 3 universities, 7 public sector partners, 3 private non-profit organisations and 22 trade and industry partners, including suppliers of materials, key components, technology and battery and hydrogen systems. The Institute for Energy Technology (IFE) hosts the MoZEES centre.

BEACON[152] is a new initiative by SINTEF and the Research Council of Norway that aims to give a voice to the Norwegian and European battery ecosystem, provide information about the status and future development in Europe, provide access to knowledge and information about technological development and create an arena for establishing strong partnerships and cooperation with other stakeholders. BEACON also brings its participants together in dialogue with the Norwegian and European authorities and funding bodies.

The **BATMAN[153]** project, led by the Eyde Cluster, is working to develop a dynamic strategic tool based on material flow analysis (MFA) that will enable Norwegian companies to take a leading role in the battery value chain (lithium-ion batteries). Partner businesses can identify their value creation opportunities in i) re-manufacturing, ii) secondary use, iii) recycling and iv) new energy systems and models. This will enable them to make strategic decisions and improve their understanding when it comes to investing in product development and/or facilities. Among other things, the project looks at policy and the design of framework conditions and regulations in the EU.

151 FME MoZEES
152 Battery ecosystem accelerator of Norway, SINTEF
153 Eyde Cluster – BATMAN (eydecluster.com)

Battery Norway[154] is a national industrial collaboration platform focused on innovation and market opportunities that comprises the whole battery value chain. Battery Norway is also an industrial forum that enables national and international collaboration across the value chain. At the time of application, it had 15 participants, but all ecosystem representatives will be invited to join. Battery Norway provides motivation for and contributes to the sharing of knowledge and experience to the benefit of all participants. It is organised as a project with funding from Innovation Norway. It has been identified that the project must prioritise work on i) skills, ii) piloting/infrastructure and iii) internationalisation. The participants at start-up in 2022 were Morrow, Beyonder, Freyr, Vianode/Elkem, Glencore Nikkelverk, Batteriretur, the Norwegian University of Science and Technology (NTNU), the University of Agder (UiA), SINTEF, IFE, Future Materials Norwegian Catapult Centre, Mechatronics Innovation Lab, the Kongsberg Cluster/Kongsberg Innovation, the Federation of Norwegian Industries (Norsk Industri) and InvestIN Norway. The Eyde Cluster is the secretariat for Battery Norway.[155]

NorGiBAtF[156] (The Norwegian Giga Battery Factories) is a project led by NTNU with 6 PhD/post-doc students looking at knowledge-building and education in the segment as the basis for implementing battery gigafactories in Norway. The project includes most industry stakeholders in Norway (Freyr, Beyonder, Hydro, Equinor, Nordic Mining, IFE and SINTEF). It is working to develop skills and expertise relating to value chains up to battery cell production, and analysing how battery gigafactories work and should be developed. According to an estimate from a working group associated with the project, 400 new student places at master's and bachelor's level should be established in Norway in addition to developing further education for 200 engineers each year.

BattKOMP has its primary focus on the need for competence building in the Norwegian battery sector. The project is based on interaction and involvement, and the participants have endorsed an initiative that seeks to highlight Norway's skills needs. Employee representatives from the Federation of Norwegian Industries, Prosess21 and the Norwegian Confederation of Trade Unions (LO), as well as a broad resource group comprising stakeholders from business and industry and the education sector will be involved in the project through the project board. BattKOMP is made up of three sub-projects with working groups comprising employees from the Federation of Norwegian Industries, LO and clusters (see separate description under skills).

NABLA (Norwegian Advanced Battery Laboratory Infrastructure) is a battery research infrastructure supported by the Research Council of Norway, with a proposed budget of NOK 168 million. It was granted funding at the end of 2021. The applicant consortium received NOK 80 million from the Research Council as a basis for negotiation. This means that the investment project will be significantly smaller than the amount applied for. NABLA's primary goal is to provide national infrastructure dedicated to battery research and development for Norwegian research and industry organisations. NABLA covers research needs and interests in the battery field and is built on the expertise of six leading Norwegian research institutions in battery research: The Institute for Energy Technology (IFE), the Norwegian Defence Research Establishment (FFI), NTNU, SINTEF, UiA and the University of Oslo (UiO). NABLA will be coordinated by IFE.

The **Norwegian Battery Packing Network**[157] (a Green Platform project) was developed by Kongsberg Innovation alongside ZEM, Nordic Batteries and other key consortium partners. The project seeks to position the Norwegian technology industry in the global battery value chain, with the emphasis on battery packs for a number of different sectors. The first step is to focus on the aquaculture industry's requirements and the market for high-speed catamarans, and cooperation with Freyr and Beyonder ensures that the project will involve the whole battery value chain. Cooperation with Manufacturing Technology Norwegian Catapult Centre, Siemens Digital and Intek Engineering means that Kongsberg will be part of a national test and competence centre where Norwegian operators can test and develop battery technology based on fully digitalised product development and production.

SUMBAT[158] (a Green Platform project) brings together important stakeholders from across the battery value chain representing industry (Morrow, Freyr, Hydro, Elkem, Corvus), research institutes (IFE, SINTEF) and academia (UiA, NTNU). The aim is to build a strong Norwegian battery alliance that secures skills development and creates cost and technology synergies between industry and academia. The project will establish new innovation-driven

154 (3) Battery Norway: Company Page Admin | LinkedIn
155 Eyde-cluster - Eyde-klyngen blir det nasjonale batteri-sekretariatet (eydecluster.com) – in Norwegian only
156 Nor Norwegian Giga Battery Factories – Project bank (forskningsradet.no)
157 Kongsberg Klyngen AS tildeles 52 millioner kroner – Kongsberg Innovasjon AS – in Norwegian only
158 Sustainable Materials for the Battery Value Chain (SUMBAT) A Norwegian RDI Flagship Program – Pre-project – Project bank (forskningsradet.no)

activities for Norwegian industry and research institutes, ranging from sustainable procurement and development of battery materials and technology to battery recycling and reuse.

SIVA has conducted a survey of available equipment of relevance to battery technology in Norway. This will be discussed later. It includes the catapult centre **Future Materials**[159], **RISE**[160], **FFI**[161] and universities and R&D institutes.

Piloting, demonstration and associated needs for capital[162]

The need to pilot technological solutions ranges from testing new materials in laboratories to industrial production of the same type of equipment that will be used to produce the final batteries (potentially for use in new car models with a service life from 2026 to 2034). Work on technology development and qualification of production processes based on the developed technology takes place between these two extremes. Since the production technology for battery cells (composition) is often known, most of the development concerns the material composition and/or the combination of technology changes at different stages of the production line.

The different stakeholders in the battery value chain have different piloting needs depending on whether they are going to qualify a product (battery) and/or materials (potentially also recycled variants of these). Generally, all stakeholders will need the product or material to be verified in a "small-scale" series of produced batteries. The magnitude of the series depends on what needs to be qualified (material or complete cells) and where in the qualification/verification process they are (early development or qualification). The need for piloting is described in the following section with the help of the illustration below. The need for battery cell piloting is described first, followed by piloting needs in materials production.

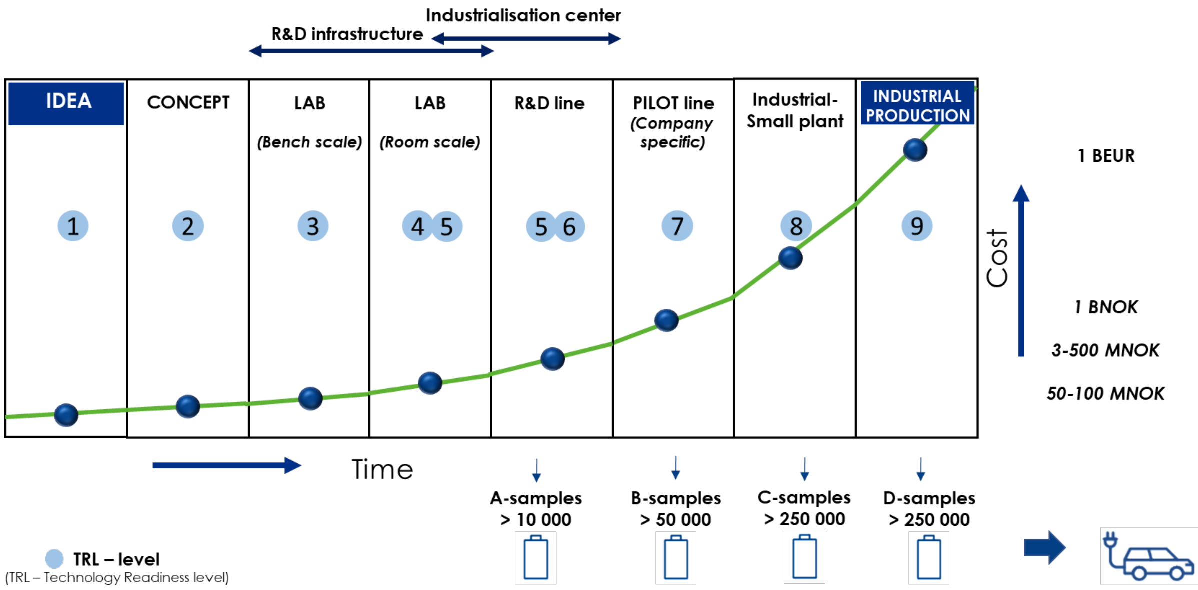

Figure 17 – Piloting solutions for battery development depending on technology readiness level (TRL)

The size, scope and need for piloting/infrastructure for battery cells depends entirely on what stage of the development process you are at. R&D projects will typically be at the early technology readiness level (TRL), e.g. TRL levels 1–5, while verification of a developed product (e.g. a battery solution) will be at TRL levels 8–9, where the product must be verified in an almost identical industrial environment to that of the forthcoming manufacturing process.

159 Futurematerials
160 Batteri – RISE Fire Research (risefr.no)
161 Batterisikkerhet (ffi.no) – in Norwegian only
162 The text is an extract from a memo by Battery Norway (translation from Norwegian): Maltby, Lars Petter – Piloting needs for qualifying materials and products in the battery value chain – Industrialisation centre

As regards the qualification of products for the automotive industry, there are rigid qualification systems that follow a time plan for launch of the model/type/solution. The duration of this process is normally three to four years from prototype development to completing certification of the off-the-shelf product. Qualification is initiated upon development of a prototype to prove that the solution is feasible for production. This is followed by a series of qualification stages defined through what are known as A, B, C and D tests, and then verification of industrial production. The original equipment manufacturer (OEM) will nominate the supplier based on the final qualification of the B test. From that point, changes are minimal and there is limited possibility of introducing new technology relating to the solution. The time frame from the qualified B test to assumed start-up of industrial mass production is around two years.

To qualify B tests, it is necessary to develop a separate production line that enables the production of components without any further negative scale-up effects. This can resemble a company-specific pilot (shown at TRL 7). This will be a continuous automated production line for the production of battery cells, typically with 50,000 or more cells in a campaign. After qualification at this level, the next step is a full-scale production line (shown at TRL 8) that can be duplicated repeatedly to form what is known as a "gigafactory". This enables the production of C tests. Here, the qualification requirement is over 250,000 cells, which in practice requires fully automated production at the facility. All battery manufacturers in Norway are developing, or intend to develop, such battery-specific pilots. Freyr[163] and Morrow[164] will be developing theirs throughout 2022 and 2023, while Beyonder completed its pilot plant in 2020.[165] The equipment included in these pilots is mainly imported from abroad, but with the assistance of technology suppliers like ABB[166] and Siemens[167] as well as local[168] or national[169] suppliers.

The requirement for qualifying battery cells for an automotive maker is to initially produce 10,000 battery cells (A-tests). This can be done through an independent pilot for cell production (pouch, cylindrical or prismatic cells). This is shown at TRL 5–6 in the figure above. A-tests do not have to be produced in a supplier-specific pilot line, which enables the development of common infrastructure. UK BIC[170] addresses this piloting level.

The need to develop a company-specific pilot will lapse if an operator with established technology wishes to expand its capacity based on this technology. This is on the condition that the product and the process technology are identical. The qualification requirement defines that 250,000 cells must be produced with the same material combination and production equipment as in later industrial production. However, it is expedient for these stakeholders to also have the support of an industrial development environment for further development of the product and process technology.

A material manufacturer that develops a new process or product to be used in a battery cell first needs to demonstrate their own process and then demonstrate the new product/material's properties. The manufacturer must therefore, through their own pilot (plant), demonstrate the production of new materials before using the materials to demonstrate the battery cells' functionality. The qualification requirement for material manufacturers varies somewhat, but they are expected to demonstrate product properties at a volume corresponding to A samples, i.e. 10,000 battery cells. This illustrates that qualifying as a "second supplier" is challenging and that a significantly improved product is required.

Piloting needs for companies in the battery value chain are at a different level to the needs defined by R&D activities. R&D infrastructure for TRL 1–4 is useful since it can be used by several stakeholders in different projects. Companies must have sole ownership of company-specific pilots for TRL >6, since it will be an essential tool for i) starting production and ii) qualifying the new future products they innovate. In the phases between this, TRL 5 and 6, there is a need for industry-oriented infrastructure to serve as a multi-purpose centre for different stakeholders (e.g. industrialisation centres such as catapult centres). These centres must also contain necessary laboratories and characterisation equipment that can ensure product and process optimisation.

163 FREYR Issues Invitations to Tender for the Purchase of Battery Cell Production Equipment for Pilot Plant – FREYR (cision.com)
164 Morrow signs agreement to start the construction of its Pilot Factory (morrowbatteries.com)
165 We want to meet the global need for eco-friendly energy storage solutions for industrial use — Beyonder
166 Morrow Batteries and ABB collaborate on manufacturing technology and comprehensive battery solutions
167 Beyonder får Siemens med på laget – Beyonder – in Norwegian only
168 Freyr Battery, Momek Group AS | FREYR Battery har inngått kontrakt med Haaland, Momek og Bryn Byggklima for byggearbeidet på Pilotlinjen i Mo i Rana (ranablad.no) – in Norwegian only
169 Morrow signs agreement to start the construction of its Pilot Factory (morrowbatteries.com)
170 Virtual Tour – UKBIC

Battery cell manufacturers and material manufacturers alike need to be able to assemble battery cells to qualify their products. Characterisation needs will be the same for the different manufacturers. The UK and Germany have invested in large battery industrialisation centres that cover large parts of the battery value chain with an emphasis on battery cell production. Planned activities in the Norwegian battery value chain indicate that there will be a great need for testing and for a large-scale industrialisation centre. This activity currently takes place in environments abroad. The current situation is three cell manufacturers and suppliers of graphite, silicon, nickel and cobalt.

It is important that an industrialisation centre can cover IP-related activities. Pilot plants can be co-localised with R&D environments, but it is essential that the activities are linked to the qualification of products and supplementary R&D (not the other way around). The objective of Norwegian catapult centres is to develop this kind of infrastructure particularly targeting the SME segment. In the industrial production of battery cells and battery materials, it is presumed that this will be done by operators that wish to evolve into large-scale enterprises with significant industrial complexity. Today, Norwegian catapult centres are limited by public financial support of EUR 7.5 million per centre. An attempt to extend this limit is currently subject to the EFTA Surveillance Authority’s approval. The Mechatronics Innovation Lab (MIL) was financed directly through the national budget under the Ministry of Trade, Industry and Fisheries. Private financing was guaranteed by the industry.

Barriers to capital

Constructing factories for battery materials and cells is highly capital intensive and requires investments with a long time horizon. The investment also involves a technical risk associated with establishing new production on a new continent (moving production and development from Asia to Europe), and also developing increasingly efficient batteries at a lower cost.

In the EU, the state aid rules and private capital (loan capital and equity) have not proven to be sufficient to meet the huge need for capital. The exception is automotive-producing countries, where the large carmakers receive state aid. Some cell manufacturers have also received funding from multinational financial institutions, such as the Swedish Northvolt in connection with constructing a lithium-ion battery cell production facility with a capacity of 16 GWh in Skellefteå. Announced investments currently amount to EUR 1,522 million.

The two IPCEIs relating to batteries launched by the European Commission were initiated because of the strategic importance of European battery production for Europe’s growth opportunities, with ripple effects such as increased competitiveness, expertise and employment. These two IPCEIs, which are worth a total of EUR 6.2 billion, are expected to trigger EUR 14 billion in private investments. Available documentation about IPCEI EuBatIn emphasises capital market failure as the biggest challenge.

European stakeholders have a broad need for capital, loans and guarantees to mitigate the private capital exit risk. European countries are investing in different ways to realise the first factories. The British government has pledged to invest GBP 100 million through the Automotive Transformation Fund along with two capital management companies to finance buildings and infrastructure. The Automotive Cell Company (ACC), a Franco-German initiative that comprises PSA, Opel and Saft, has received risk mitigation funding[171] from the German government (BMVi) and the state of Rhineland-Palatinate to develop a battery cell factory in Germany as part of the EU’s first battery IPCEI. The federal and central government authorities are providing a total of EUR 436.8 million in project funding. ACC will produce batteries at the Opel factory in Kaiserslautern. The Finnish government granted EUR 450 million to the Finnish Minerals Group[172] to enable them to invest in the battery value chain.

The above-mentioned examples of state mitigation of exit risk are related to the green transition of the economy to achieve the necessary climate ambitions. The nation states follow up with funding to realise common European ambitions. To trigger necessary private capital, the government is taking a leading role. Private capital has already been invested in profitable activities, and the state contribution aims to mitigate risk for the purpose of shifting this private capital towards the desired green growth areas that are gradually emerging.

The next step for battery cell manufacturers is to secure funding for facilities for small-scale production of prototypes. This is necessary to be able to qualify for clients and achieve delivery contracts. Financing of gigafactories is also a relevant challenge. The challenges for businesses is that banks require delivery contracts to provide funding, which requires production facilities, which they are applying to the banks to finance. This challenge is considered a

[171] ACC granted funding to make batteries in Germany – electrive.com
[172] Home – Finnish Minerals Group

natural task for funding agencies, which create a “bridge” over to the next stage of development of the battery value chain.

Investment of state capital is initially intended to help businesses during the qualification phase and until the development of industrial pilots. State ownership is also relevant by the government taking a larger ownership position at an early stage of industrial development. This can ensure Norwegian ownership and provide opportunities to maintain technology development in relevant sectors of Norwegian industry and pertaining academic groups.

Development of new battery technology

The Battery 2030+ roadmap describes the state of the art of today’s battery technology and outlines the need for future development. The description also encompasses batteries that are likely to see cautious growth, such as traditional lead batteries and redox flow batteries, the latter of which are suitable for stationary energy storage.

Since the first commercial lithium-ion batteries were launched on the market in the 1990s, the energy density has more than doubled, while costs have dropped by a factor of 15. There is considerable activity internationally to further increase performance and reduce costs by developing suitable material combinations, improving electrolytes, changing design parameters and developing more cost-effective and optimised production. The figure below summarises the energy performance of different commercially available batteries and possible future battery chemistries.

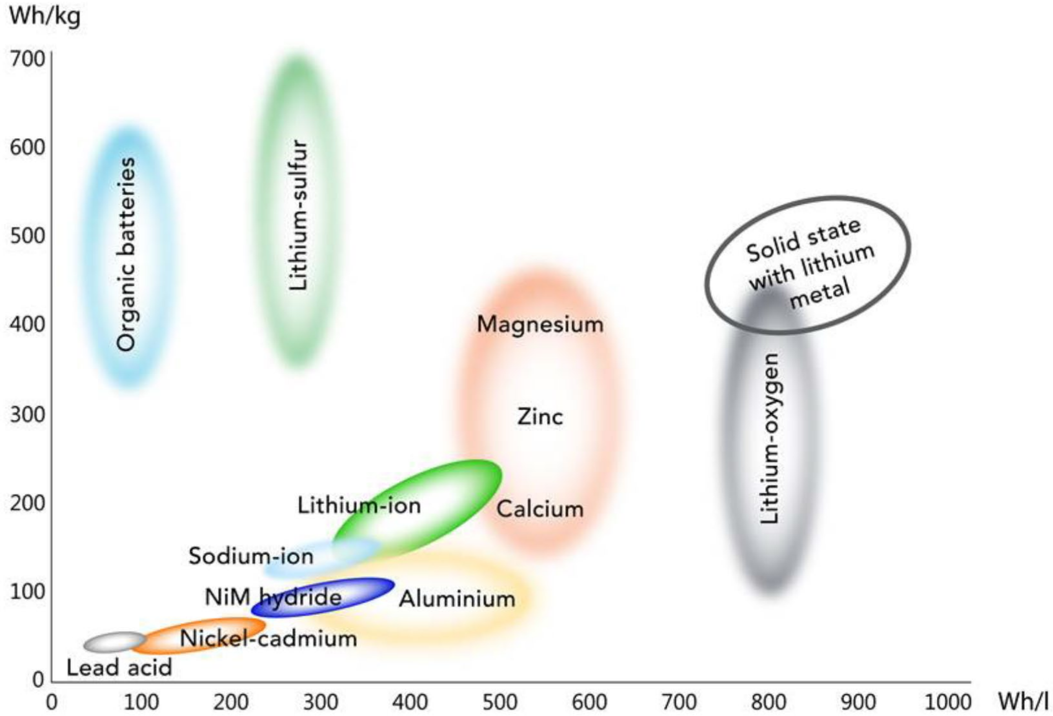

Figure 18 – Current commercial batteries and targeted performance of future possible chemistries. Source: Battery 2030+

The power output of lithium-ion batteries is expected to level off in the years ahead, since there have been incremental advances in characteristics within the current material chemistries. It will be difficult or even impossible to satisfy future requirements of energy storage simply by optimising current battery solutions. New solutions must address safety, costs, lifetime, power output and charging time. It is not surprising that the spotlight is particularly on solutions that can satisfy future mobility and stationary storage requirements. It is important that we develop solutions that provide the flexibility necessary for heavy transport and storage of power from variable energy production.

The EU’s Battery 2030+ initiative is a common European approach to developing future solutions. China, the USA and Japan have a similar focus defined through roadmaps.

In Norway, it will also be important to develop national expertise and IP in parallel with industrial development to ensure long-term, sustainable value creation. Our competitive advantage in the form of renewable energy will gradually be reduced as power production in Europe shifts to comprise a higher percentage of renewable sources. Batteries constitute a dynamic and quickly changing subject area, which makes it difficult to take a sequential approach, i.e. 1) importing licences and expertise, 2) establishing battery industry, and d) developing expertise and IP. Step 3 should take place in parallel with steps 1 and 2. Developments at the research frontier take place quickly, and failure to make investments in parallel with industrial development means we will fall behind the international stakeholders. This would result in the industry and research environments losing out in the long run.

The EU is making arrangements to construct its own battery industry instead of depending on global supply lines. The IPCEI on batteries and the UK's Faraday Challenge will give our neighbours an advantage through highly favourable conditions for knowledge production that can quickly go all the way to the industrial scale. The UK's Faraday Institution is centred around electrochemical research and brings together scientists and industry partners in projects along the whole value chain and on different components. Norway is a frontier at this type of collaborative approach. We can further develop our expertise and use it to develop our own technologies, thereby reducing our dependence on foreign licences.

Norway's research sector should be strengthened to support the industry's need to create its own IP and prevent outsourcing of this competence-building process as well. One of the recommended action points from the NHO report "Recommendations for industrial investment in batteries in Norway" was to "build strong, world-class education, research and expert environments in Norway of the right dimension and at the forefront of industrial initiatives".

Norwegian research institutes and universities own and further develop their research infrastructure for the development, production and testing of battery cells, modules and systems, partly financed by the Research Council of Norway. These form an important foundation for improving the knowledge base and the associated production of graduates. It is also important to maintain and strengthen cooperation with both Nordic and European stakeholders through collaborative projects. To create a level playing field, it is therefore important that Norway participates in all relevant EU arenas and that Norwegian industry and research institutions have access to the same instruments as our European partners and competitors.

Sustainability challenges for battery production and how to address them

A comprehensive survey of the sustainability challenges related to battery production is described by the Nordic Council of Ministers.[173] Sustainability challenges relating to battery production have also been described by the Global Battery Alliance and the World Economic Forum (GBA/WEF).[174] As regards batteries, it is important to consider all aspects of sustainability, i.e. environmental, social and economic sustainability.

Battery technology is a key technology in the transition towards a fossil-free society by replacing products, appliances and means of transport that require fossil fuels. There are significant social and environmental consequences associated with the extraction of several of the raw materials used in lithium-ion batteries, especially in the case of minerals sourced from politically unstable areas where there is a risk of human rights violations, corruption and money laundering. Cobalt is the most problematic raw material in the battery value chain. More than 50 per cent of the global production of cobalt takes place in the Democratic Republic of Congo (DRC). Traceability in the value chain will be critical for future manufacturers and customers across the battery value chain, and stakeholders have started to announce collaboration agreements[175] and partnerships to enable a high degree of recycled materials in new battery production.[176] The development of new battery technology focuses on eliminating/minimising the use of elements such as cobalt and developing batteries based on more widely available low-cost materials.

Both advantages and disadvantages must be considered in connection with increased demand for different types of batteries. The amount of greenhouse gases emitted from producing batteries today is about the same as that

[173] Batteries in the Nordics – Changing for circularity, Nordic Council of Ministers, 2022 (draft report)
[174] WEF_A_Vision_for_a_Sustainable_Battery_Value_Chain_in_2030_Report.pdf (weforum.org)
[175] FREYR og Glencore inngår MoU for mulige leveranser av sporbare batterimaterialer – FREYR (cision.com) – in Norwegian only
[176] Morrow Batteries, Li-Cycle and ECO STOR forms a JV to build a lithium-ion battery recycling facility

from producing the car itself. Throughout their service life, electric vehicles emit considerably less CO_2, and the total amount also depends on mileage. The accumulated CO_2 emissions from an electric car will be lower than from an ICE car after a certain number of kilometres driven. This depends on the carbon intensity of the electrical power consumed through production and use of the electric car. Carbon emissions from battery cell production are largely linked to the energy mix used throughout the value chain and the production/refining of raw materials.

In Figure 13 – Materials and emission intensity for traditional and zero-emission vehicles, McKinsey shows the material and emission intensity for traditional and zero-emission vehicles, respectively. As the overview clearly shows, an electric car is not climate neutral, but the emission accounts vis-à-vis fossil cars show significant improvement with increased mileage. The carbon footprint is also affected by whether or not the car is charged with renewable energy. This signals that it is important that the cars have a high frequency of use (car sharing) and that the batteries have a long useful life and can be recycled. The need for materials generated from linear material flows is significantly higher than what can be recovered through circular material flows as long as there is a significant increase in demand for batteries. Over time, this will balance out, but it will take many years.

Several parts of the battery value chain are demanding in terms of the land needed for production. Mines and quarries involve substantial encroachments on nature and the need for safe disposal of tailings. Raw materials/ores to be imported require large areas for port storage and, where relevant, associated land transport. Battery cell production (based on the gigafactory concept) is characterised by the need for large factory areas with pertaining degradation of nature. This poses potential challenges relating to loss of biodiversity and possibly cultivated land, which must be resolved through land-use planning in accordance with the Norwegian Planning and Building Act. It is difficult to find available areas for larger projects in the battery value chain in existing industrial parks. The exception is Mo Industrial Park, which is adapting the site to host Freyr. It would be beneficial, to the degree possible, to concentrate production in the whole value chain in one large area. That would ensure the greatest possible degree of industrial symbiosis, with optimum utilisation of heat, energy, water and materials. InvestIN and host municipalities are seeing a significant increase in requests from suppliers looking to establish business in the immediate vicinity of the battery cell factories.

The Norwegian Environment Agency has established a mitigation hierarchy[177] that applies to development in natural environments. The highest priority is to avoid significant negative impacts by e.g. changing/adapting the localisation of the activity (Priority 1). If that is not possible, the activity must be minimised in order to reduce significant negative impacts that cannot be avoided (Priority 2). The next level is to look at the possibility of reversing or restoring significant negative impacts that cannot be avoided. For the negative impacts that cannot be avoided, minimised or restored, solutions must be found to compensate for these. Arendal municipality[178] has addressed such challenges under the guidance of WWF, Sabima, and Nature and Youth.

Large global businesses in all industries are focusing on ESG (environmental, social and corporate governance) in their overall strategies, and report on their progress and goal attainment to owners and the financial market. To meet the goals of the Paris Agreement, the production of batteries and the rest of the car must be climate neutral. This is further reinforced through the EU Sustainable Finance Action Plan and the introduction of the EU taxonomy. The taxonomy will also mean, among other things, that industrial sites that have a negative impact on valuable natural ecosystems cannot be classified as sustainable. The taxonomy is therefore also important for land-use planning. It is expected that only transport by electric vehicles will be classified as a sustainable economic activity.[179] These considerations can further increase the focus on Norway as a suitable production location, as the green energy supply helps companies to meet the SDGs and increases their market value.

To ensure a long-term competitive advantage in the battery value chain, we must ensure that sustainability becomes a lasting advantage. This can be done by ensuring traceability and thereby enabling documentation of high climate and environmental standards, which can make us winners on the condition that the regulations stipulate requirements for this. The EU Batteries Regulation provides for this through a “battery passport” and requirements relating to information about components, carbon footprint reporting throughout the value chain and recycled content requirements. Based on this framework, Norway will be in a favourable position to develop competitive stakeholders in the value chain by ensuring minimal or negative GHG emissions and maximum environmental benefit through the use of materials throughout the value chain. All Norwegian manufacturers in the battery value

[177] Forebygge skadevirkninger for miljø og samfunn – Miljødirektoratet (miljodirektoratet.no) – in Norwegian only
[178] Hvordan etablere grønn industri og samtidig bevare natur? Memo from workshop 5 April 2022 – in Norwegian only
[179] LEAK: Only zero-emission cars will win EU green investment label – EURACTIV.com

chain highlight the advantage of being able to produce the most sustainable batteries. They describe sustainability as a pillar of their own strategies, with the possibility of producing batteries with a minimal environmental footprint based on renewable energy.

On assignment for the Ministry of Climate and Environment, the Norwegian Environment Agency[180] has drawn up requirements and case processing rules under the Pollution Control Act and other relevant environmental regulations that will apply to the industry, including import and export regulations. They also describe how to best facilitate the effective processing of applications for emission permits, taking into account the needs of the industry for rapid clarification, while also keeping in mind climate and environmental considerations. The Norwegian Environment Agency has also assessed the necessary prerequisites for a sustainable value chain, in particular issues that will be important for safeguarding climate and environmental considerations in the development of the Norwegian battery value chain.

The Agency also describes elements that affect effective case processing, where the industry's need for rapid clarification and climate and environmental considerations are addressed. Ensuring adequate knowledge at an early stage is important both for safeguarding the environment in the planning of new industry and for efficient case processing. Already when a developer makes a decision about location, the environmental impact, including on recipient conditions, should be taken into account. This requires the developer to start work on the necessary assessments at an early stage. To achieve this, they must employ personnel with the necessary expertise and experience. This includes expertise in Norwegian public administration processes, including knowledge of EU climate and environmental regulations and local conditions. Participation processes and consultation rounds are a central part of the public administration's case processing. It will therefore be crucial that the developer gives priority to informing and aligning the project with relevant stakeholders. Local resistance and unrest can delay case processing considerably.

[180] Response to assignment to devise a battery strategy knowledge base, the Norwegian Environment Agency, 21 March 2022

Energy needs

The energy needed for battery production in Norway is uncertain despite the fact that production capacity is normally measured by the energy content (GWh) of the battery cells produced. We must look at which parts of the value chain are to be developed and how many stages of the value chain are involved (see Figures 1 and 11). The CEO of Northvolt mentions in an interview that the total power required is equivalent to 80–100 times the amount of battery capacity produced. Northvolt will handle most of the activity in the value chain with the exception of mining, metallurgical processing and the production of anode materials. The company estimates a consumption of around 80 KWh per KWh of battery capacity. Recent studies[181] of Tesla Gigafactory and Northvolt Labs indicate a power requirement of 50–65 KWh per KWh of battery capacity, but these figures do not include the production of anode and cathode materials. Tesla is indeed planning to construct this gigafactory for future battery development.[182] We can therefore assume that the power consumption of a gigafactory with a battery production capacity of 30 GWh will be approximately 1.5 TWh (just over of 1% of Norwegian renewable energy production). Consumption must be expected to be stable around the clock, indicating a power requirement of 170 MW. Expansion is likely to occur in increments, in modules of 8–10 GWh each, resulting in a 400–500 GWh incremental increase in demand. If battery factories produce cathode materials on the company's premises, consumption will be around 80–100 KWh per KWh of capacity. If three factories produce 80 GWh of battery cells, this means an increased total power requirement of 4–7 TWh.

The production of precursors and materials used to produce battery materials (nickel, manganese, cobalt, aluminium, synthetic graphite and silicon) is also power intensive. However, these products are already part of today's process industry. For example[183] Glencore Nikkelverk requires about 550 GWh (nickel, copper and cobalt), Hydro Sunndal 6.0 TWh (aluminium) and Elkem Bremanger 720 GWh (silicon).

In other words, power supply is one of the most important inputs for the battery value chain. Industrial companies that would like to base their activities in Norway are often concerned with having predictable access to renewable power at competitive prices. Power costs do not represent a large proportion of battery cell manufacturers' total costs compared with traditional power-intensive industry, but the consumption is still significant and power therefore constitutes an important cost element. The carbon footprint of power consumption is essential to meeting future requirements of the carbon intensity of batteries. Locally produced power that is as good as 100% renewable is therefore a competitive advantage for Norway until other countries have developed their energy mix in a renewable direction. Price and the environmental footprint are essential factors in future investment decisions.

We have seen that battery cell companies choose to locate major industrial activities at or in the immediate vicinity of the transmission grid. If they wish to be part of the competition, there is simply no time to wait for the process of making the necessary power available far from the major transmission lines. A power grid committee[184] has been appointed to propose measures that can reduce the time it takes to license new network installations. The conclusions and implementation of the committee's recommendations will be too late for operators that are scheduled to make deliveries to the battery value chain from 2023/2024. The work is nonetheless relevant to future development.

A discussion has emerged over the past year about Norway being at risk of quickly developing a power deficit, most recently discussed in Statnett's short-term analysis.[185] Access to renewable power is quickly becoming a prerequisite for maintaining existing industry, and for attracting new green industrial activity. Menon and Afry have recently submitted a report[186] for Nordland county on the ripple effects of new power-intensive industries. The report serves as a knowledge base for the work on using renewable energy for value creation and new jobs in the Nordland region, and to reduce greenhouse gas emissions. Analyses show that the employment effects relative to power consumption are by far the highest in battery production. We find a similar effect for value creation. The table below shows the employment effect and value creation of four different power-intensive, forward-looking industries:

[181] Energy use for GWh-scale lithium-ion battery production – IOPscience
[182] Tesla Battery Day – YouTube
[183] Norske utslipp – Utslipp til luft og vann og generert avfall – in Norwegian only
[184] Strømnettutvalget – regjeringen.no – in Norwegian only
[185] Statnetts Kortsiktige Markedsanalyse 2021–2026 | Statnett – in Norwegian only
[186] 2021-37-Ringvirkninger-av-Nye-Kraftintensive-Industrier-i-Nordland.pdf (menon.no) – in Norwegian only

Table 2 – Overview of ripple effects per GWh with energy consumption for the four power-intensive industries. Source: Menon

Activity	Employment effect by annual GWh	Value creation effect by annual GWh (mNOK)
Traditional energy intensive industry	0,9	0,9
Battery cell production	5,3	7,5
Hydrogen production	0,04	0,2
Data center	0,2	1,8

Norway is competing with other countries in the impending industrialisation of climate technologies, or products that contribute to reducing greenhouse gas emissions (e.g. batteries, hydrogen and ammonia). This means that funding and policy instruments should be arranged so as to support the green transition of industry. In the EU, this is done through various instruments, the strongest being IPCEI, the EU Innovation Fund and the European Investment Bank.

Industrial sites and co-location

Available industrial land with facilitated infrastructure is necessary to ensure start-ups. New processing plants may need available land of around 10–100 hectares, as well as a power supply of up to several hundred megawatts. To position Norway for the industry of the future, national, regional and local authorities, together with existing industrial parks, should actively contribute to developing strategic industrial sites and parks with the necessary space, energy solutions and competitive common functions.

In June 2021, the major Norwegian power companies, Hydro, Elkem, Energy Norway and the Federation of Norwegian Industries proposed to strengthen Norway as a host nation for green industry by developing industrial sites with access to power.[187] This approach is also described in NHO and LO's Common Energy and Industrial Policy Platform.[188] The background is that Norway has not succeeded in attracting new industry to the same extent as our neighbouring countries, nor in achieving a large-scale expansion of existing industry.

The proposal is to create a new government policy instrument to accelerate the development of industrial sites and trigger major private investments. The instrument aims to ensure shorter lead times for the establishment of industry and avoid increasing the network tariffs of other customer groups. The proposal means that SIVA can make the necessary up-front investments in network capacity and other infrastructure. The operators that then set up business on the industrial sites will then reimburse their share of the advanced investment costs. The instrument will not require significant changes to existing regulations. The investment costs are self-financing, while the government bears the risk associated with preparing the industrial sites. It is nevertheless important to base such activity on partnerships with existing private initiatives and professional stakeholders in order to maintain the necessary rate of development. It is important that such proposals include and support existing private initiatives. Cooperation between the companies, county governor, county authority, municipality and landowner is essential in battery cell production.

The McKinsey report "Norway Tomorrow" refers to the need for an ecosystem approach through favourable co-locations. Battery clusters will be crucial to the international competitiveness of Norwegian industry. This is also beneficial because long distances entail high transport costs, which in turn could increase the overall cost level. More co-location of battery factories and necessary subcontractors has been recommended to enable the stakeholders to benefit from common energy and transport infrastructure. Finland, for example, has managed to establish a strong battery cluster in the GigaVaasa industrial zone.[189]

On establishment, it does not take long before businesses/municipalities and landowners receive requests from relevant subcontractors that wish to set up business in the immediate vicinity. Below is a specific example concerning Morrow and Arendal municipality,[190] but it could easily represent other similar establishments. Current stakeholders are subcontractors with a need for power access, port access and coolant solutions. These industrial enterprises demand plots from 5 to 30 hectares, and expect to employ 50–900 people. These are typically companies currently located in Asia that are looking to establish "bridgeheads" in Europe, where factors such as renewable energy and proximity to battery factories are important. Arendal municipality is therefore planning to make available an additional 250 hectares of land for these companies (in addition to Morrow's current plot of 94 hectares).

In its dialogue with the county governor, the municipality requests that the following issues be addressed:

- *There is a need, through zoning plans, to further accommodate specific industrial and commercial activities relevant to the green transition, and specifically the battery factory value chain.*
- *The adaptation of industrial sites for battery factories and related subcontractors often requires expansion into agricultural, nature and recreational areas (known as LNF areas). The conflict of objectives between global carbon emission reduction and consumption of natural environments is a dilemma that requires good land-use planning processes and good environmental impact assessments to minimise negative effects. Habitat mapping must be included as a central element. The municipality will need assistance from the county governor/ Norwegian Environment Agency to ensure that this is carried out with a sufficiently high and verifiable quality.*
- *As a follow-up to the report from the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), there is a desire to adopt land accounting and land neutrality at the national, regional and local level. Municipalities that become hosts to battery factories will have great difficulty achieving land neutrality. Arendal*

[187] 2021-06-14-forslag-for-a-styrke-norge-som-vertskapsnasjon-for-gronn-industri.pdf (norskindustri.no) – in Norwegian only

[188] rapport-felles-energi--og-industripolitisk-plattform-.pdf (lo.no) – in Norwegian only

[189] Gigavaasa

[190] Home – Eyde Material Park

municipality has therefore launched the idea of looking at land neutrality in the regional context of Agder. However, more knowledge of relevant methodology and strategic approaches is needed for this work.

The above example is not exhaustive for the many tasks that need to be solved in connection with planning and developing industrial sites for activities related to the battery value chain. When such industry is to be realised quickly, it can challenge established bureaucratic processes. It may be necessary for various public bodies to act quickly and give priority to these projects in their case processing. The Planning and Building Act and associated requirements for environmental impact assessments have not been adapted to accommodate the rapid development of industrial sites. The appointment of case officers and associated studies and assessments by institutions such as the Norwegian Water Resources and Energy Directorate (NVE) and Statnett follow well-established procedures, and the county governor and Norwegian Environment Agency use similar procedures when processing land use and emission permit applications, respectively. If Norway is to join the competition to establish a battery industry, time is an important factor, and potentially a barrier.

Expertise

Expertise is and will remain one of the key success factors for developing a battery value chain. Most European countries face similar challenges in that there is not enough in-depth expertise or a large enough volume of candidates to meet the forthcoming need.

To ensure that the Norwegian battery industry is sustainable, it is important to invest in long-term expertise in the form of research and education (both module-based continuing and further education and entire courses of education from craft certificates to PhD). This will involve universities, partly also university colleges, and not least vocational technical colleges. Education in Norway is largely driven by demand, which means that the number of applicants largely affects the number of student places. It is therefore important that young people are aware of the opportunities available in this industry and of the programmes that provide the relevant skills. The fact that there will be good access to jobs and that the industry is part of the green transition will be important considerations for young people choosing an education.

The battery companies Freyr, Morrow and Beyonder have taken the initiative to collaborate on a recruitment campaign for the battery industry in connection with admissions under the Norwegian Universities and Colleges Admission Service. The campaign will be carried out in the weeks leading up to the application deadline of 20 April, and is aimed at young people who are deciding on their future studies, in the form of short video clips disseminated through social media. The campaign will direct them to an information page on the Federation of Norwegian Industries' website about where to apply for study programmes focusing on batteries.[191]

Importing experts is also essential because it provides both quick access to expertise and an opportunity to transfer important experience-based skills and knowledge to the enterprise. Furthermore, importing highly skilled labour provides rapid access to research-based expertise. It is therefore important to stimulate the transfer of expertise from foreign experts in the companies. and attract foreign experts to Norwegian academia. Close interaction between academia and industry is attractive to foreign researchers. NOKUT is the agency responsible for the recognition of foreign higher education in Norway.

Tertiary vocational colleges work closely with employers and the business community through the National Council for Tertiary Vocational Education, various national academic councils, and local academic councils at the individual vocational colleges. This means that higher vocational education provides good opportunities for retraining. The pilot project "Battery vocational college"[192] in Viken county, in cooperation with tertiary vocational colleges all over the country, is currently gaining important experience of this.

The project, named BattKOMP, builds on interaction and involvement across the battery value chain. Stakeholders have a common interest in jointly endorsing an initiative to highlight the national skills needs. The Federation of Norwegian Industries has led the project in collaboration with LO and Process21. The work has involved extensive cooperation with representatives from industry, clusters and the education sector. The project is divided into three phases (phases 1 and 2 have been completed):

In **BattKOMP PART 1**[193] skills needs have been mapped throughout the battery value chain. In Phase 1, a survey was conducted and complemented by in-depth interviews with key stakeholders in battery materials, cell production and cell composition. This provided in-depth insight into the various technologies needed in the different companies. The report recommends:

- In the short term, importing foreign expertise with experience from the battery industry to Norway must be made "agile".
- In the medium term, the greatest possible number of people with transferable skills who are available in the labour market must take continuing/further education.
- In the longer term, we need to train many people in the various disciplines needed in the battery value chain. We must also create attractive research and professional environments in the field of batteries in Norway (and the Nordic region and Europe).

As part of this work, "the ten battery competence commandments" have been developed to highlight, for example, the need to build national competence, develop battery modules through the relevant industry programme, establish

[191] Batteristudier Norsk Industri – in Norwegian only
[192] Etablerer landets første batterifagskole (norskindustri.no) – in Norwegian only
[193] BattKOMP (norskindustri.no)

tailor-made study programmes in battery production that include the possibility of selecting modules from different educational institutions, while at the same time increasing the capacity of existing programmes in process chemistry, electrochemistry, materials technology and automation, particularly related to large-scale manufacturing with a high degree of Industry 4.0 technology. The need for investment in research and test infrastructure for batteries is also emphasised.

The overview also highlights the need to establish effective processes for recruiting battery specialists from abroad, systematic development of an internationally competitive battery expert community based on close cooperation between industry and academia, and strengthening Nordic collaboration on battery expertise.

BattKOMP PART 2[194] presents results from an analysis of the gap between the battery value chain's defined skills needs in Norway and the study programmes and qualifications the educational institutions currently offer. The report is based on a series of workshops held in autumn 2021. All relevant educational institutions were invited and represented, and the representatives were subsequently interviewed.

The analysis is limited to the higher education sector, defined as tertiary vocational education (vocational colleges), universities and university colleges. The project has drawn up an overview of which skills currently exist and where there are shortcomings in the various higher education sectors. Due to the large skills gap and short time window, the report has emphasised continuing and further education programmes as well as shorter modules that can be used to develop specialist expertise relevant to the battery value chain.

Overall, the report shows that the higher education sector to a great extent is capable of providing the programmes and skills required by the battery value chain for continuing and further education. The gap becomes apparent when the scope of the education is to be dimensioned. The capacity is not sufficient to train enough people – quickly enough – to meet the industry's expressed needs. The express goal is to immediately increase the number of student places and continuing and further education programmes and scale up the offer in step with the industry's needs. Schemes and funding models supporting cooperation between educational institutions should be arranged to enable competence-raising measures of an appropriate scope to be developed and offered quickly enough.

The report shows a different picture when it comes to tertiary vocational education. Through the workshop and interviews, it became clear that there is a large knowledge gap in vocational colleges. This represents a major challenge for industrial establishment as the vast majority of recruitees to the battery value chain going forward will need to build on their skills at a vocational college. This challenge related to tertiary vocational education is not only relevant to "battery subjects". In reality, there are also major skills challenges when it comes to satisfying the needs of existing industry.

The gap analysis provides a good indication of what needs to be done for Norway to develop a national battery team and take a position in the new industrial adventure. Several participants said that they felt the workshop was "historic" in that the industry's skills needs were discussed directly with the educational institutions jointly. The project demonstrates the potential for a more significant skills boost through stronger cooperation in the sector, including cooperation between vocational colleges and the university and university college sector. It also indicates that the current funding system partly counteracts such a model of cooperation and that this matter should be looked into by the committee tasked with looking at the financing of universities and university colleges.[195]

BattKOMP PART 3 had not yet been implemented at the time of writing this report, but is scheduled for completion in spring 2022. The plan is to compile recommendations on the establishment of robust, long-term courses of education for the battery industry. The sub-project also discusses other needs relating to recruitment for a rapidly growing industry, taking the "Norwegian model" as its point of departure. The work will build on the knowledge base from parts 1 and 2.

A further analysis of study programmes from a longer-term perspective should look at possible new approaches that will ensure the necessary knowledge boost in academia for the future battery industry. An important element from sub-report 1 is that the industry, at this stage of the development, brings in experts from abroad with experience of both research and industry. Prioritising collaboration with industry in order to increase and transfer expertise to academia will therefore be essential going forward. Recruitment of foreign battery experts to adjunct professor positions and investment in state-of-the-art laboratory facilities will be important elements in this context.

---

194 Internt notat (norskindustri.no) – in Norwegian only
195 Utvalg om finansieringen av universiteter og høyskoler – regjeringen.no – in Norwegian only

On completion of BattKOMP Part 3, we will have established a comprehensive strategy to build the necessary capacity, with an appropriate depth of the study programmes relevant to the battery industry. This also includes upper secondary schools with vocational subjects, including apprenticeship schemes. That will require a prioritisation of resources in the education sector, as well as cooperation between industry and educational institutions, between the various educational institutions and, not least, the involvement of the public authorities.

Host attractiveness

The mandate of Process21's expert group on host attractiveness[196] was to explore opportunities to strengthen Norway's ability to attract new investments, start-ups and new jobs in the process industry and associated value chains, and to present measures that can make Norway attractive to the global processing industry of the future. The recommendations from this report are relevant to attracting stakeholders from across the battery value chain.

In a 2050 perspective, we must expect owners and companies in all Norwegian processing industries to go through many strategy cycles, and the decision on whether a plant should be further developed or closed down will be based on more than just local conditions. Global trends in markets, technologies and competitive conditions will influence the assessments that are made. The government and business sector must work together to make Norway an attractive host for the process industry of the future.

Based on interviews, workshops and meetings with industry stakeholders, the Process21 expert group recommended the following actions:

- Ensuring a renewable power supply at competitive prices with predictable, minimum grid costs.
- Adopting a national strategy for the preparation of industrial sites and parks with international competitive advantages, large areas, energy supply, infrastructure and access to expertise.
- A strong international system to promote opportunities for establishing an enterprise in Norway and deal with business enquires.
- Close cooperation with the EU on policy instruments and framework conditions in areas where Norway has particular advantages and value creation opportunities (such as the value chain for non-ferrous production, batteries, hydrogen and CCUS).
- Adjusting Norway's implementation of the guarantees of origin scheme to eliminate any doubt that Norwegian power consumption is emission-free, regardless of how guarantees of origin are traded.
- Further development and communication of Norway's advantages related to the tripartite cooperation, the expertise of Norwegian skilled workers and expert environments, industrial parks, clusters and R&D environments.
- The public authorities must improve their policy instruments for potential new industry and introduce a binding and increased share of green public procurement.

All proposals are relevant to stakeholders in the battery value chain, and conditions relating to power and land use will be elaborated later. The process industry and the battery value chain are, by their nature, global industries in which raw materials and finished goods circulate around the world. What is unique about the battery value chain is that the EU is taking steps to ensure strategic autonomy (as described earlier).

Proximity to research, development and expert environments (R&D) and clusters is considered an important criterion for the choice of location, and according to Norwegian industrial enterprises, Norwegian environments score high in this respect. Norway's host attractiveness is further strengthened by Norwegian skilled workers, characterised by a high level of expertise, independence and a sense of responsibility, in addition to flat corporate structures with a short distance between management, engineers and skilled workers, and a widespread culture of cooperation both within the companies and with the authorities. It is important to retain and further develop such unique cultural and societal competitive advantages.

The authorities play an essential role in host attractiveness. Framework conditions such as tax policies, government loans, grants and guarantees that promote a competitive business environment are the responsibility of the government. It is also necessary to have a professional system in place to deal with enquires from international enterprises and help them to evaluate opportunities to set up business in Norway. The Process21 expert group proposes further developing InvestIN to strengthen this role.

The following main recommendations from Process21 are highlighted: *A national strategy should be established for industrial sites with international competitive advantages, energy supply, infrastructure and access to expertise. The government, funding agencies and businesses must work together to make Norway an attractive host for the industry of the future.*

[196] 200827-prosess21-vertskapsattraktivitet-endelig.pdf – in Norwegian only

SWOT (strengths, weaknesses, opportunities and threats)

Stakeholders in the Norwegian battery value chain have taken part in various workshops and seminars to define Norway's position in order to realise the establishment of industrial activity in the battery value chain. Seminars have been organised by Process21, NHO, Battery Norway and Energi21. The first seminars took place more than two years ago, and the most recent one was organised by Process21 and Energy21 jointly in autumn 2021. Various workshops have focused on developing a SWOT analysis broken down by positions in the different parts of the value chain, such as raw materials, cell production and recycling. The figure below combines the various sub-parts into a joint SWOT analysis that forms the basis for Norway's position. **The SWOT analysis is defined by stakeholders in the Norwegian battery value chain.**

Strengths

- Renewable, emission-free power at a competitive price
- Competence in process/material/energy-intensive industry with good resource/material utilization
- Norway leads the electrification of the car fleet → Unique age and composition of the Norwegian electric car fleet / Norway as pilot arena
- Stable political governance
- Skilled workers, flat structures, cooperation between parties, frontline subjects
- Positive collaborative environment between industrial actors
- Strong R&D environments that are internationally oriented
- Private public cooperation
- EEA membership
- Green reputation

Weaknesses

- Lack of expertise (in volume, depth and reskilling)
- Reactive attitude towards the EU (example IPCEI)
- Few companies supply to OEMs
- Little experience in high-volume product manufacturing
- Lack of industry-oriented business policy
- Scarce resources linked to hosting foreign investment activity
- Time-consuming permitting processes (power/emissions/regulation)
- Capital environment without experience with capital-intensive industrial processes (except Oil/Gas)
- Expected shortage of skilled workers
- No production of active cathode material

Opportunities

- Increased and more diversified exports that balance Oil/Gas dependence
- Strategic partnership with the EU (complementary)
- Higher value creation and employment for each MWh
- Specialized expertise-intensive products in an extended value chain
- Maritime domestic market
- Energy storage in a fully electrified power system in collaboration with power grid owners
- Recycling of batteries
- Historically lower employee turnover
- Major investments
- Nordic cooperation in the industry
- The EU's battery regulation favors Nordic countries

Treaths

- Tax as a third country on EU/UK trade from 2027
- Time - the race is on
- Lack of relevant raw materials (especially cathode)
- Work with the EU remains reactive
- A demanding competitive industry
- Master new technology based on imported expertise
- Lack of capacity build up on electrical Power
- Inflexible and locked-in tools at policy actors
- Not daring to bet big enough - conservative capital environment
- Export of used subsidized electric cars
- Mining - NIMBY
- Remain a raw material supplier of «commodities»
- Chinese manufacturers are better
- Brown reputation

Figure 19 – Combined SWOT analysis for industrial activity in the battery value chain in Norway. The SWOT analysis is defined by stakeholders in the Norwegian battery value chain.

Several points in the SWOT analysis are not specific to Norway, and individual elements may be a weakness in many European countries, such as a lack of expert expertise in battery technology. Likewise, many countries have stable policy frameworks or are reliant on importing various raw materials. If we look at **where Norway stands out**, this can be summarised as follows:

Strengths – Norway produces renewable, emission-free energy at a competitive price and, in recent years, we have been a net exporter with competitive prices. We have considerable experience of and expertise in process/material/energy-intensive industry. We were the first to start using electric ferries and have a strong position in maritime battery and hybrid solutions. Furthermore, Norway is the leading country in the electrification of the car fleet (including charging infrastructure), and is used as a pilot arena by several automotive OEMs. The latter also provides a unique opportunity to take advantage of "end-of-life" batteries.

Weaknesses – Norway is not a member of the EU and is therefore only included to a limited extent when the European agenda is set and strategies discussed. Norway can therefore become reactive. Because the oil and gas industry has been dominant, we have developed a great deal of offshore and maritime technology. However, we have paid significantly less attention to land-based industrial policy, which means that we have few businesses in high-volume goods manufacturing. This also means that we have a capital environment with limited experience of such capital-intensive industry. Norway's resource pool for attracting foreign business start-ups is relatively small (with the exception of some areas).

Opportunities – Sweden, Finland and Norway are complementary in their industrial composition and will be able to offer the EU batteries with the lowest possible carbon and material intensity, and with certain raw materials originating in the Nordic region. The battery value chain can be used as one (of several) levers to achieving a closer strategic partnership with the EU based on national strengths, as described above. Since Norway is already "fully electrified", we could also serve as a pilot arena for energy storage (should be mapped out in more detail) and maritime solutions. Norway possesses the "oldest" batteries and will be able to build recycling capacity.

Threats – The Brexit agreement has led to Norway being seen as a third country, and from 2027, a 10 per cent import duty will be levied on electric vehicles with batteries produced in Norway. This is an obvious barrier where Norway should maintain "pressure", balanced by offering Norwegian products, such as gas/non-ferrous metals and carbon storage. A reactive approach to forthcoming EU strategies and regulations could have a negative impact on Norway's export opportunities. Norway has little tradition of carrying out major industrial investments (with the exception of oil/gas), and our policy instrument system is currently not sufficient to provide impetus to scaled projects that could contribute to lasting industrialisation.

The SWOT analysis also outlines other points where Norway's challenges are similar to those of other countries. A strategy should therefore also consider where we have coinciding challenges with other countries and how we work together to address them. Examples with respect to the Nordic countries could be:

- A common Nordic mechanism to attract investments
- A common Nordic approach to ensure adequate expertise in both depth and volume
- The Nordic countries largely have a joint power system that can make the Nordic region a pilot arena for stationary energy storage and charging infrastructure.
- Taking joint positions, establishing a Nordic "shadow group" relating to changes in framework conditions and financial support schemes (including R&D)
- Closer cooperation between host municipalities in the Nordic countries
- …

The SWOT analysis is a logical presentation that summarises "internal" and "external" conditions that apply to the future of the Norwegian battery value chain. This forms the basis for the overall choices to be made in the strategy work that lies ahead.

Appendix

The EU Batteries Regulation

On 10 December 2020, the European Commission launched a proposal for a new regulatory framework for batteries (the EU Batteries Regulation). This is the first major revision since the 2006 Batteries Directive. The underlying vision behind the new Regulation is fundamentally different from the original directive. Batteries were previously considered to be primarily an environmental waste problem that needed to be addressed. The way the new Regulation is worded, it actively facilitates the development of a circular and green European battery industry capable of asserting itself in competition with the current market leaders in China.

The proposed Regulation includes requirements for the documentation of carbon emissions throughout the production process. A classification system will then be introduced in 2026 where batteries are ranked in relation to the size of their carbon footprint. From 2027, the European Commission will also set absolute limits on the permitted carbon footprint of batteries. Specific requirements on recycling and recovery of the minerals contained in batteries have also been proposed. The EU envisages a significant development in recycling and recovery rates from the current level. Starting from 2027, battery manufacturers must report on the share of recovered minerals that have been used to make new batteries. From 2030, it is then proposed that producers will be required to use recovered minerals in production. Initially, new batteries containing the given minerals must include recycled quantities of at least 12% cobalt, 85% lead, 4% lithium and 4% nickel. These requirements will become even more stringent from 2035. At the same time, the European Commission would like to see a functioning market for reused (second-life) batteries, where used car batteries can more easily be used directly in other areas. The proposal for the new regulatory framework sets out simpler and clearer rules for such use. The Batteries Regulation will also contribute to extensive access to and disclosure of information about each battery through digital solutions such as QR codes and a "battery passport". This will show information about the origin of the battery's raw materials, including ethical considerations.

The Batteries Regulation was presented as an EU Commission proposal on 10 December 2020. The proposed Regulation was under consideration by both the European Council and the European Parliament in 2021 and early 2022. The final decision by both bodies is expected towards the end of 2022. If it is adopted, the Regulation will enter into force from 2023. European industry, including the automotive industry, is largely in favour of the proposal, although some member states want a greater degree of freedom in its implementation. There is also considerable debate about how strict the requirements for recycled material should be. The Regulation is very comprehensive, and further guidance in more detailed delegated acts will be implemented in the years after 2023. Consideration of the proposed Regulation was given high priority during the German Presidency of the European Council in 2021 and is expected to remain so during the French Presidency from March 2022. France is expected to play a driving role, thereby increasing the chances of the Regulation being adopted by the end of 2022.

After the Council and Parliament have made their decision, it will be sent to the EFTA bodies, which will then decide whether the Regulation should apply in the EFTA countries.

Battery IPCEI – Important Projects of Common European Interest

The European Green Deal provides an important backdrop for the IPCEIs and explicitly highlights the mechanism as crucial for the emergence of new green industry. The IPCEI arrangement is intended to support innovative projects in selected areas that require coordinated cross-border effort. It is an important arena for the harmonisation and coordination of European projects. IPCEI projects receive national funding, but are subject to dedicated state aid rules. The IPCEI regulations are a separate set of guidelines under the state aid rules that provide for the possibility of a higher aid intensity and support for industrial start-ups, provided that the European benefit of the project outweighs the potential market distortion. The European Commission explains that the initiatives are of strategic value to Europe as a whole, that they contribute to extensive innovation and will foster growth, competitiveness and employment. Participating companies and institutions gain access to significant funding, but should the IPCEIs become more profitable than stipulated, some of the profits will be returned (claw-back mechanism) to the public contributors.

Two IPCEIs have received state aid (EUR 6.2 million) and have been implemented to promote battery production in Europe, contribute to growth and employment, and increase the competitiveness of EU industry. **IPCEI Batteries** has 17 participants from 7 member states and **IPCEI European Battery Innovation (EuBatIn)** has more than 40 participants from 12 member states. In sum, these will trigger investments of up to EUR 14 billion in research and initial industrial scale-up. The two IPCEIs share the objective of developing a competitive, innovative and sustainable battery value chain in the EU. Both projects have been constituted and officially launched with a focus on detailing plans for the partnership. External communication is important and is based on the IPCEI website.[197] Both IPCEI projects are co-organisers of the Battery Innovation Days in November 2021[198] and other upcoming events.

The EU's prioritisation through IPCEI is described in the *Report of the Strategic Forum for Important Projects of Common European Interest: Strengthening Strategic Value Chains for a future-ready EU Industry*, which includes detailed descriptions of barriers and proposed solutions in *Annex II: Key Strategic Value Chains – detailed recommendations.*[199]

Work on the first **IPCEI Batteries** has been led by France. Seven member states are participating (France, Belgium, Finland, Germany, Italy, Poland and Sweden) together with 17 enterprises and a further 70 other partners. The IPCEI triggers EUR 3.2 billion in support to the participants, while also mobilising at least EUR 5 billion from the private sector. The initiative is aimed at the development of new battery technologies that generate more environmentally friendly batteries with significantly better performance. All production must be circular and sustainable. The work of this IPCEI is organised in four packages: raw materials; cells and modules; battery systems; and reuse and recycling. **IPCEI Batteries** was the second application and succeeded the first initiative on microelectronics.

The lessons learned are summarised by DG Competition[200] and underline the need for political governance and strategy, transparency of all stakeholders and intense cooperation between the member states / stakeholders. It also emphasises that the process of establishing an IPCEI may be different in each case.

IPCEI European Battery Innovation (EuBatIn) is coordinated by the German Federal Ministry for Economic Affairs and Energy (BMWi) with the support of VDI/VDE-IT. The European Commission approved the initiative in early 2021. Twelve member states and more than 40 companies have been brought together under the European umbrella. In addition, 200 companies and other stakeholders are indirectly involved. This IPCEI has four workflows: raw and advanced materials; battery cells; battery systems; and recycling/sustainability.

A more detailed descriptions of what Germany, Sweden and Finland are implementing can be found in the KREAB report *"Plugged in for a full charge: unleashing the full potential of the Norwegian battery value chain*".

[197] IPCEI Batteries: IPCEI Batteries (ipcei-batteries.eu)
[198] Battery Innovation Days – YouTube
[199] DocsRoom – European Commission (europa.eu)
[200] Lessons_learned_IPCEI_Batteris_EU.pdf (ipcei-batteries.eu)

Example of equipment for pilot production of pouch battery packs

Sub-processes	Equipment	Purpose
Cathode mixing	Storage tanks, binder tanks, mixers	Preparing cathode material for foil coating
Anode mixing	Storage tanks, binder tanks, mixers	Preparing anode material for foil coating
Coating	Coating systems for anode and cathode, respectively	Coating foil with anode and cathode mixes
Calendering	Calendering system with roller press calender and cold/hot pressure and cooling system for anode and cathode, respectively	Ensuring homogeneous coating of foil with the defined porosity by means of compaction
Electrode slitter	Cutting equipment with subsequent brushing and dusting for anode and cathode, respectively	Splitting electrode rolls into defined widths, including a cleaning system to avoid contamination
Notching/cutting	Sizing of electrode length. Cleaning and inspection of anode and cathode, respectively	Final sizing of electrodes
Electrode baking	Temperature-controlled furnaces for baking electrodes followed by cooling	Ensuring degassing of binders
Stacking	Automated positioning and stacking of anodes and cathodes	Stacking anodes and cathodes to form battery cells
Cell assembly/welding	Compaction and welding equipment for assembling electrodes	Equipment that, based on an automated method, assembles electrode tabs into positive and negative terminals
Cell assembly/pocketing	Packaging machine with sealing and quality control	Packaging the battery in a protective pouch
Cell assembly/baking	Vacuum drying process of packed batteries	Ensuring that all moisture in the battery has been removed
Cell assembly/electrolyte filling	Electrolyte filling machine to fill the battery pouch	Filling of electrolyte fluid
Degassing	Storage device for stabilising the battery, capacity and characteristics	Battery stabilisation and activation of battery chemistry, including measurement of this
Cutting, folding, heating and taping	Folding machine, battery packing	Cutting, folding, heating and taping

Inspection/sorting	**Automated sorting of battery cells by characteristics**	**Removing battery cells that do not meet the necessary quality criteria**