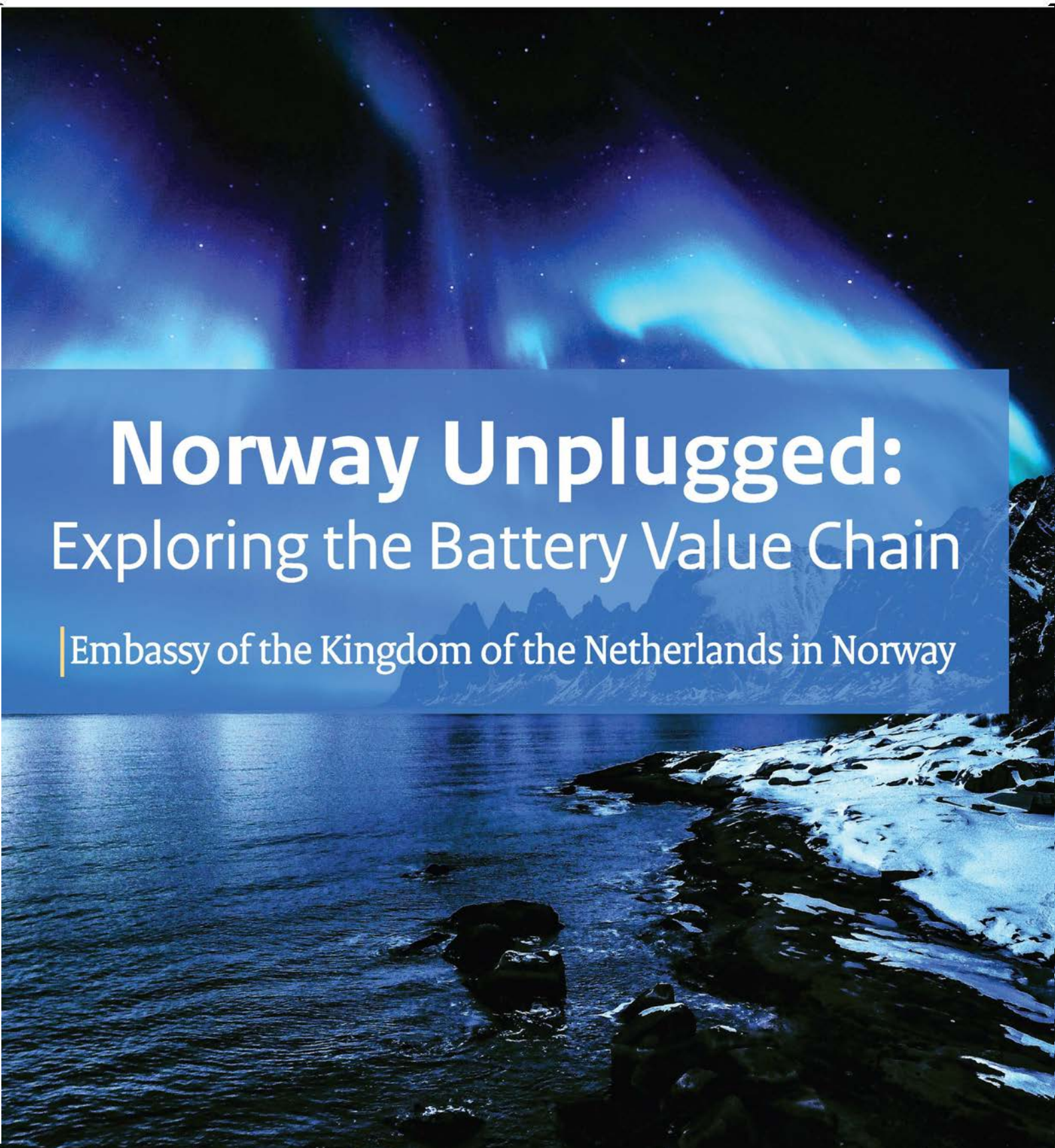
Ministry of Foreign Affairs



Norway Unplugged:
Exploring the Battery Value Chain

Embassy of the Kingdom of the Netherlands in Norway

Executive summary

This report provides an overview of the Norwegian battery industry, including government policy and relevant documents. It analyzes the strengths, weaknesses, opportunities, and threats (SWOT) of the Norwegian battery value chain and identifies opportunities for Dutch actors in the Norwegian battery industry. The opportunities identified in this report align with the 'moonshots' outlined in the 'Actieagenda batterijsystemen' by Holland High Tech. These moonshots include research and development of material and cell design, delivery of manufacturing equipment to battery-producing factories in the EU, production of batteries for heavy-duty transport, production of batteries for grid support, testing of every aspect in the value chain, and reuse, second life, and recycling.

Regarding the moonshots of research and development of material and cell design and delivery of manufacturing equipment, there currently seem to be no short-term opportunities for Dutch companies due to the established technology and existing manufacturing equipment partnerships. However, medium to long-term opportunities may arise as future battery chemistries, technology advancements, and capacity expansion require additional research, development, and manufacturing equipment.

In terms of the production of batteries for grid support, there are significant opportunities for Dutch players. Norway's grid system, divided into zones, allows for power exchange, and employing stationary storage batteries can help balance price differentials between zones. As Norway faces an electricity deficit, Dutch batteries could contribute to stabilizing the grid, especially with the expansion of offshore wind capacity. Dutch manufacturers with expertise in grid support batteries, such as redox-flow, hydrogen, and salt batteries, can capitalize on these opportunities.

The production of batteries for heavy-duty transport presents a growing market, particularly in the electrification of construction machinery and buses. Norwegian initiatives for zero-emission construction sites and the goal of zero-emission city buses by 2025 create avenues for Dutch actors to contribute. Additionally, Dutch shipping can benefit from Norwegian companies offering fully electric solutions for the maritime sector, especially in inland shipping.

The opportunity for testing every aspect in the value chain is less pronounced, but Dutch players should establish contact and engage with Norwegian stakeholders. While there may not be an immediate demand for extensive testing capacity in Norway, Dutch expertise can be valuable in the future as Norwegian companies may require comprehensive testing services.

Regarding reuse, second life, and recycling, Norway is more advanced in battery reuse and repurposing, while the Netherlands excels in circular practices such as reconditioning, repair, and refurbishing. Dutch small businesses can find opportunities in circular practices in Norway, where such services are less emphasized. In terms of recycling, Dutch actors can potentially export battery materials and residual materials to Norway for further recycling, and collaboration with Norwegian companies like Hydrovolt can be beneficial.

Overall, Dutch companies may face competition from Norway in battery reuse and repurposing but can find opportunities in circular practices, collaboration in recycling, and contribute to the production of batteries for heavy-duty transport and grid support.

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Cover design: Robert-Jan Duit
Cover picture: Noorderlicht
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Embassy of the Kingdom of the Netherlands in Norway

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Disclaimer

This report provides general guidance and information purposes only, based on data gathered between February and May 2023. Readers should exercise caution as the rapidly evolving Norwegian battery industry may render some information outdated in the near future. The report offers information on a non-exhaustive selection of organizations in the battery value chain, sourced mainly from public information and supplemented by personal consultation. The recommendations in the final chapter represent the author's personal opinion and readers are encouraged to exercise their own judgment when interpreting the contents of this report.

Reading guide

- The volatility of the Norwegian Krone and inflation of the past two years makes it difficult to employ a standard conversion rate from NOK to EURO in this report. In April of 2022 1 EURO = +- 9.5NOK while currently, as of May 2023, 1 EURO = +- 11.8 NOK. For the sake of simplicity, a conversion rate of 1 EURO = 10 NOK will be employed.[1]
- For desktop/mobile readers the blue highlighted organization names can be clicked to be redirected to their website.

[1] European Central Bank (europa.eu)

Introduction

"We are currently going through the biggest restructuring the Norwegian economy has seen in recent times," declared Norwegian Prime Minister Jonas Gahr Støre on June 23, 2022, as he unveiled the Green Industrial Initiative. With this ambitious initiative, Norway aims to transform itself into a leading 'green industrial and energy giant,' capitalizing on Norway's natural resources, knowledge environments, industrial expertise, and historical advantages. Prime Minister Støre emphasized the collective effort required to achieve this vision, stating, 'Together we will create more profitable jobs, increase investment on the mainland, increase exports, and contribute to emission reductions.' Recognizing the immense potential for the future, the Norwegian government has actively stimulated the growth of the battery value chain, aligning with the goal of a climate neutral economy, and contributing to Norway's energy transition. By fostering the development of the battery value chain, Norway is strategically positioning itself to seize future opportunities and play a significant role in shaping a sustainable and prosperous economy.

Within a week of the Green Industrial Initiative's announcement, Jan Christian Vestre, the Minister of Trade, Industry, and Fisheries presented Norway's Battery Strategy, underscoring the nation's high aspirations for the battery value chain. Recognizing Norway's potentially pivotal role for the industry, the government aims to capitalize on its historical and geographical advances. Entrepreneurs and academia in Norway have eagerly awaited the government's support in leveraging the nation's advantages along the value chain. The Netherlands, too, acknowledges the opportunities presented by the value chain and is preparing to participate actively. Both governments are actively stimulating investments in the industry.

In Norway, universities, companies, and research institutes across the country are actively contributing to battery research, development, assembly, production, and recycling. Notably, Norway exhibits significant potential in innovation and new technologies such as silicon applications, performance improvements, recycling techniques, and second-life applications. Conversely, the Netherlands showcases impressive levels of research and development, particularly in testing and material science.

The primary objective of this report is to provide information on the emerging and rapidly developing Norwegian battery value chain. Additionally, the report aims to offer an overview of legislations, organizational structures, opportunities, and knowledge to Dutch stakeholders in the sector. By examining the Norwegian battery industry, this report facilitates knowledge exchange, and fosters mutually beneficial partnerships between Norway and the Netherlands.

Chapter 1: Norway and batteries

1.1 Introduction

In 2022 McKinsey published the report 'Norway Tomorrow' on future opportunities for Norway. McKinsey ranked ten opportunities from the energy transformation, digital transformation, and from the sustainable transformation to determine in what areas Norway should invest. McKinsey posits that in the period 2020-2030 the battery industry could result in a GDP increase of 4 billion EURO and result in an additional 33.000 FTE (Full Time Equivalent). According to McKinsey there are three opportunities for Norway: for Norway to become one of Europe's largest battery cell manufactures, for Norway to become the European leader in Anode production for up to 50% of European demand, and lastly, become Europe's leading raw material refiner in combination with raw material extractor and recycler. The report concludes that Norway could become Europe's 'most sustainable and competitive battery value chain.'

In response, the Ministry of Trade, Industry, and Fisheries published the roadmap for the Green Industrial Initiative. The goal voiced in this initiative 'is to make Norway a green industrial and energy giant based on our natural resources, knowledge environments, industrial expertise and historical advantages.' In this roadmap the government provides details on six other priority areas alongside batteries being offshore wind, hydrogen, CO2 management, the process industry, maritime industry, and the bioeconomy.

Alongside the Green Industrial Initiative, the Norwegian Ministry of Trade, Industry, and Fisheries published 'Norway's Battery Strategy.' This report discusses the advantages of Norway for the battery industry, its challenges, and how to overcome these challenges. The report covers the vision of the Norwegian government, the Norwegian value chain, initiatives and opportunities, the EU, Nordic collaboration, and ten 'actions for sustainable industrialization.' The Ministry of Trade, Industry, and Fisheries intends to develop the complete battery value chain in Norway covering mineral extraction, refining, material and cell development, pack assembly and the eventual recycling of the battery.

Figure 1: Norway Tomorrow, the Green Industrial Initiative & Norway's Battery Strategy.

	Action
1	Leadership in sustainability along the entire battery value chain
2	Promote Norway as an attractive host country for green investments
3	Enter into industrial partnerships with key countries
4	Provide capital, loans, and guarantees that mobilize private capital action
5	Improve access to relevant expertise
6	Pave the way for greater access to renewable power
7	Contribute to provision of suitable sites and other central infrastructure
8	Ensure predictable, efficient, and coordinated public processes
9	Support pilot municipalities during the growth phase
10	Become a leader in tomorrow's battery solutions and leveraging the opportunities afforded by digital technologies

Figure 2: ten actions for sustainable industrialization.[2]

1.2 Norway in a nutshell

To facilitate better comprehension and comparison of the Netherlands and Norway in this report, some basic facts on both countries will be provided in this section.

	Norway	Netherlands
Population	5.505.000	17.900.000
Land area	385.207 km²	41.850 km²
Population density	14 per km²	428 per km²
GDP per capita	€85.734[3]	€53.200

Figure 3: key figures on Norway in comparison to the Netherlands.

1.2.1 Geography

Norway and the Netherlands are completely different geographically. Of course, Norway's total land area is nearly ten times the size of the Netherlands. Despite this fact, the country has less than a third of the population of the Netherlands. Norway has a coastline of more than 100.000 km, and the inland terrain is varied with abundant hills, mountains, rivers, lakes, and plains. These geographical features often make construction of infrastructure difficult and expensive.

Color	Region
Green	Northern Norway
Blue	Trøndelag
Yellow	Western Norway
Cyan	Eastern Norway
Pink	Southern Norway

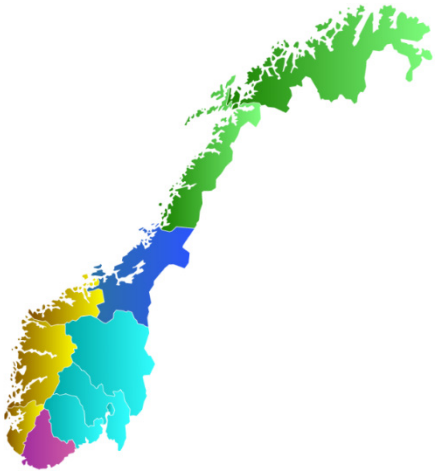

Figure 4: map of Norway.

[2] Norway's battery strategy - regjeringen.no

[3] GDP per capita is extremely volatile as of the writing of this report. For this figure, the actual conversion rate as of 31 May 2023 has been used.

1.2.2 Economy

Norway has a mixed economy which is highly developed. The economic prowess of Norway is based on the historical finding of oil and natural gas in the North Sea. Through the exploration of their oil fields, the country has stimulated its growth in the second half of the 20th century. To prevent 'Dutch disease' by overstimulation of the domestic economy, the Norwegian government saves a significant portion of the natural resource income in the so-called 'Oljefondet,' the Government Pension Fund Global. The oil fund is the greatest sovereign wealth fund globally and invests primarily abroad. Norway's history in oil and gas has resulted in an experienced workforce in the energy sphere. Norway took the seventh place in the world in GDP per capita in 2021. In comparison, the Netherlands took the nineteenth place in 2021.[4]

1.2.3 Subsidies

Providing financial incentives to promising players in the battery value chain through public financing mechanisms is one of the Norwegian government's tools to help businesses. Organizations such as Innovation Norway, Enova, and Eksfin distribute subsidies, loans, and grants to companies and projects in Norway. These subsidies are aimed at Norwegian companies, but Norwegian companies collaborating with foreign companies, or working on a project in another country are also mostly eligible to receive subsidies. All subsidies, loans and guarantees granted by Innovation Norway, Enova and Eksfin are in line with the EU's state aid regulations, which Norway is a part of through the EEA agreement. The EFTA (European Free Trade Association of Iceland, Liechtenstein, Switzerland, and Norway) Surveillance Authority monitors compliance with the EEA rules in its member states.

1.2.4 Organizations

In Norway, the majority of subsidies granted in the battery value chain are distributed by the three previously mentioned organizations.

Enova

Owned by the Ministry of Climate and Environment, Enova promotes a shift towards more environmentally friendly energy consumption and production, while also driving advancements of energy and climate technology. Enova provides substantial annual funding of several hundred million euros to support various projects. Enova supports the battery value chain, through project-based funding and direct funding. For example, in the past, Freyr and Vianode received significant investments of 14.2 million EUR and 1 million EUR, respectively.[5][6] Enova's website has an overview of subsidies granted.

Innovation Norway

Innovation Norway is the Norwegian Government's most important instrument for innovation and development of Norwegian enterprises and industry. Its Dutch counterpart is the Dutch Enterprise Agency (RVO), which shares a similar role in promoting innovation and supporting the growth of Dutch businesses. In addition to their supporting role in business development, Innovation Norway manages the granting of loans and subsidies to Norwegian companies. Actors in the Norwegian battery value chain make a significant part of the recipients of these loans and subsidies.[7] Innovation Norway offers Green Growth Loans (Grønt vekstlån) targeting climate-friendly investments in Norwegian companies. The purpose is to adhere to the goals of the Paris Agreement and reduce greenhouse gas emissions by 55% in

[4] GDP per capita (current US$) | Data (worldbank.org)
[5] FREYR Receives Government Low-Emission Grant from ENOVA to Support Development of Initial Clean Battery Cell Production Facility - FREYR (cision.com)
[6] Latest news | Vianode
[7] Hvem har fått tilbud om finansiering fra oss? (innovasjonnorge.no)

2030.[8] The website of Innovation Norway has a complete overview of all financial aid granted by Innovation Norway. Figure 4 displays examples of aid provided by Innovation Norway.

Company	Grant in EUR	Loan in EUR
Morrow	11.390.000	15.000.000
Beyonder	6.412.150	15.330.000
Freyr	5.390.000	-
Norsk Hydro	650.000	-
Vianode	550.000	-
BatteriRetur	50.000	-

Figure 5: examples of funding by Innovation Norway to actors in the battery value chain.

Eksfin – Export Finance Norway

Export Finance Norway is a governmental financial enterprise, under supervision of the Norwegian Ministry of Trade, Industry and Fisheries, and a merger between the Norwegian Export Credit Guarantee Agency (GIEK) and Export Credit Norway. Eksfin offers government loans and guarantees in close cooperation with commercial banks to ensure Norwegian export is financially competitive abroad. In the battery value chain so far, only Corvus Energy has secured investments from Eksfin totaling to around 8 million EURO in the period 2020-2022.[9] Eksfin has ongoing dialogue with major battery cell producers in Norway. However, no projects have thus far secured a financial solution and no guarantees have been issued by Eksfin. Securing funding from Eksfin and its partnering commercial banks is difficult for battery companies until the reach mass-scale production. Eksfin foresees a key role for itself in the future as the domestic Norwegian market for batteries is small and the Norwegian battery companies produce for export. The Eksfin website offers a complete overview of issued loans and guarantees.

1.3 Norwegian goals

In addition to supporting business through legislation and financial incentives, the Norwegian government has several goals for the future of the country which impact the battery value chain. These goals prove valuable in the assessment of opportunities for Dutch actors in Norway.

Year	Goal
2025	All newly purchased passenger cars and light vans shall be zero-emission vehicles
2025	New city buses shall use zero-emission technology or biogas
2026	Ban on greenhouse gas emitting vessels in World Heritage fjords
2030	75% of new long-distance coaches shall be zero-emission vehicles
2030	50% of new lorries shall utilize zero-emission technology
2030	All newly purchased heavy duty vehicles shall be zero-emission vehicles
2030	All newly purchased heavy vans shall be zero-emission vehicles

Figure 6: goals for vehicles in Norway from National Transport Plan 2022-2033.

To facilitate the achievement of these developments, the government is making significant investments in the charging network. This includes the addition of chargers for both passenger vehicles and heavy-duty charging. Charging infrastructure for heavy vehicles requires larger areas and increased capacity in the electricity grid compared to that of light vehicles. Initially, the provision of charging facilities for heavy vehicles will rely on public subsidies from Enova. Additionally, the charging services for light and semi-heavy vehicles will be separate from the charging service dedicated to heavy-duty vehicles to prevent long waiting times at charging stations. As an additional measure to reduce carbon emissions, the Norwegian

[8] Grønt vekstlån (innovasjonnorge.no)
[9] Governing documents and reports | Public procurement (eksfin.no)

government has implemented a ban on non-climate neutral shipping in certain fjords starting from 2026. Specifically, this ban affects the World Heritage fjords, Geirangerfjord, and Nærøyfjord, thereby granting access to these fjords exclusively to zero-emission ships.[10]

1.4 EU Legislation

Since December 2020, the EU's stance on the significance of batteries is changing. The Union previously had directives in place governing batteries and their waste. Since the advent of the European Green Deal, the EU has repealed these directives or is in the process of replacing them. These European developments have implications for the Norwegian battery market, as Norway mostly adheres with European policies, including those related to the battery value chain.

1.4.1 Subsidies

At the European level, Norwegian actors in the battery value chain had ambitions to participate in EUBatin 2, the second battery IPCEI (Important Project of Common European Interest). However, due to discontinued German participation, EUBatin 2 was cancelled. Consequently, Innovation Norway is exploring alternative European aid avenues for these companies. Options include the Temporary Crisis and Transition Framework (TCTF) or the amended General Block Exemption Regulation (GBER).

The TCTF amends and prolongs the Temporary Crisis Framework enacted to support the European economy following the Russian aggression against Ukraine. The TCTF aims to speed up investment and financing for clean tech production in Europe. The framework extends the possibility for member states to support measures which speed up the transition to a net-zero industry. The TCTF makes it easier for member states to grant state-aid to companies. The TCTF also attempts to counter the Inflation Reduction Act (IRA) by allowing support for companies on the same level they would receive if they relocated, the so-called matching aid. Additionally, the TCTF allows Member States to provide the amount needed for a company to locate in the EEA, the so-called funding gap.

The amended GBER simplifies granting necessary support for key sectors in line with the Green Deal Industrial Plan by Member States. The amendment will help speed up investment and financing for clean tech production in Europe. Previously, the EU commission had to approve all state aid prior to granting. The amended GBER allows Member States to grand aid directly and inform the commission only ex-post.[11]

For a more in-depth overview of European legislation and discussion of subsidies, check out the report '[Battery Subsidies in the EU, Norway, and the US]' by [Menon Economics].

1.4.2 Recycling

The Green Deal contains rules and regulations pertaining to the life cycle of the battery. The EU calls this the cradle-to-grave regulatory framework. This framework is still in development, but detailed rules and regulations will be released in 2024 and become fully operational in 2028.

A significant aspect of the Green Deal will be the battery passport. The battery passport will contain information on the source of minerals and materials, production location, production process, assembly location, and installation of every individual battery. The battery passport will be stored in a central, European database accessible through an ID number, QR code and a barcode.[12] The objective of the

[10] Green cruising: Norway's World Heritage fjords are becoming emission-free (businessnorway.com)
[11] State aid: Commission amends General Block Exemption rules (europa.eu)
[12] Battery Passport Pilot (globalbattery.org)

battery passport is to extend battery lifecycle, enable full recycling of the battery, and provide consumers the means to responsibly purchase products containing batteries.

1.4.3 Resources and minerals

Another important aspect of the Green Deal is the collection of rare earth minerals and other materials like copper, cobalt, lithium, nickel, and lead. Even though China does most material processing, the EU aims to expand domestic recycling and refining capacity. Additionally, Norway is currently assessing the viability of deep-sea mining on their continental shelf. More on this in chapter 3.

1.4.4 Norway in the Green Deal

Norway and Norwegian companies will participate with the European battery passport to facilitate export of Norwegian battery cells and packs. The Green deal includes Norway for participation in European battery investments and as previously stated, Norwegian actors are looking to participate and receive EU funding.

1.5 What is a battery?

Batteries are energy storage devices that convert chemical energy into electrical energy through electrochemical reactions. They typically consist of one or more electrochemical cells, each containing positive (cathode) and negative (anode) electrodes separated by an electrolyte. When a battery is connected to a circuit, a chemical reaction occurs at the electrodes, causing the flow of electrons from the negative electrode (anode) to the positive electrode (cathode) through the external circuit. This electron flow creates an electrical current that can be used to power devices.

Different types of batteries utilize various chemical reactions and materials to store and release energy. Different cathode and anode materials impact a battery's performance characteristics, such as energy density (the amount of energy a battery can store), power density (how quickly a battery discharges its energy), cycle life, and safety. The most common type of battery is usually a variation of the lithium-ion battery. In this report the following battery chemistries are (briefly) discussed:

Type	Explanation
Lithium-ion	Li-ion batteries are rechargeable batteries that use lithium ions to store and release energy.
NMC	NMC batteries, or lithium nickel manganese cobalt oxide batteries, are a type of Li-ion battery that offers a balance between energy density, power density, and cost-effectiveness.
LNMO	LMNO batteries, or lithium manganese nickel oxide batteries, are another variant of Li-ion batteries known for their high energy density and thermal stability.
Redox flow	Redox flow batteries are a type of rechargeable battery that store energy in liquid electrolyte solutions, enabling flexible scalability and long cycle life.
Salt battery	Salt batteries, also known as sodium-ion batteries, utilize sodium ions instead of lithium ions for energy storage, offering a potential alternative to Li-ion batteries.
LFP	LFP batteries, or lithium iron phosphate batteries, are a type of Li-ion battery known for their enhanced safety, long cycle life, and stable performance under high temperatures.
Hydrogen battery	Hydrogen batteries, also known as hydrogen fuel cells, generate electricity through a chemical reaction between hydrogen and oxygen, offering a clean and efficient power source.

Figure 7: battery chemistries in this report.

Chapter 2: The Value Chain in Norway

The Norwegian government invests in business and academia across the value chain. Many actors operate in several parts of the value chain. For this report, the Norwegian value chain is divided in the following eleven sections:

1. Platforms
2. Mining
3. Refining
4. Battery materials
5. Battery packs
6. Cell production
7. 2nd life and reuse
8. Testing
9. Collection
10. Recycling
11. Events

With the support from the Norwegian government for the entire battery value chain in mind, expertise throughout the value chain is often shared in platforms and collaboration agreements are common. This chapter will present a selection of companies from every section of the value chain.

2.1 Platforms

In Norway, several platforms were established in the last couple of years which foster cooperation and contact between actors in the battery value chain. Cooperation proliferates between members of these platforms.

2.1.1 The EYDE Cluster

The EYDE Cluster (Norwegian Centre of Expertise for Sustainable Process Industry) aims to further the transition towards a sustainable future. The Cluster currently has 88 member organizations. Its members are from different industries like resource and material suppliers, research organizations, and educational institutes. Most members are in the South of Norway and are part of the Norwegian battery value chain. The Cluster promotes collaboration between its members through working groups, and coordinates collaboration on research and innovation.

2.1.2 Battery Norway

Battery Norway (Norwegian Battery Platform) is a national industrial collaboration platform focused on sustainable innovation in the battery value chain. Battery Norway aims to reach this goal by expanding the Norwegian value chain, build industrial competence and infrastructure, explore synergies within the Norwegian/Nordic battery ecosystems, connect Norwegian companies internationally, and promote Norway as a battery nation.

2.1.3 Maritime Battery Forum

The Maritime Battery Forum, which started in Norway, brings together stakeholders related to maritime batteries. The organization has grown to encapsulate shipowners, battery producers, offshore companies, mineral companies, and more, from all over the world, but has a high concentration of players from Nordic countries.

2.1.4 The Battery Coast

The University of Agder (UiA) has started a five-year project, the Battery Coast, in 2021 in collaboration with business and industry to build up expertise in the field of battery technology. While players in the battery value chain are located throughout the country, the majority is situated along the 'Battery Coast' in southern Norway.

Figure 8: the Battery Coast.

On the Battery Coast the UiA cooperates with companies on six aspects of the battery lifecycle:

1. Material characterization and electrochemical analyses in laboratory scale battery cells
2. Commercial cell format investigations and use-case specific design optimization
3. Strengthening the predictive power of battery simulations
4. Battery management and control in applied systems and 2nd life use
5. Automated battery disassembly for recycling
6. Analysis of sustainable business models and regulative restrictions for the battery industry

2.2 Mining

In Norway, the mining industry for minerals and raw materials crucial to the value chain is currently limited. For battery materials in Norway there are known deposits of 11.600 tons of cobalt, but there is currently no active cobalt mine. Due to Norway's limited access to domestic minerals and raw materials, the country is dependent on imports to satisfy the needs of the battery value chain. However, there are potential opportunities on the horizon. The Norwegian government is actively exploring the potential of mining the seabed of their continental shelf and assessing the economic feasibility of deep-sea mining.

2.2.1 Skaland Graphite

Skaland Graphite, owned by Mineral Commodities Ltd, is a major producer of graphite with a carbon content ranging from 85% to 99%. The Skaland mine, located southwest of Tromsø, produces 12.000 tons of graphite annually. The company offers its graphite in powder form, flake form, and special grade.[13] The amount mined in Norway currently is enough to satisfy 5% of European graphite demand.[14]

2.3 Refining

While Norway does not host significant mining operations for battery materials, the domestic refining industry is significant. In McKinsey's report on the opportunities for Norway, the consultancy firm sees a huge opportunity for Norway in this regard.

2.3.1 Hydro

Hydro operates internationally and is one of the largest aluminum companies worldwide. Aside from its aluminum operations, Hydro develops business opportunities in the battery value chain, renewable energy solutions, and the development of green hydrogen production. In Norway Hydro operates forty power plants closing in on 10% of total production in Norway. Consequently, its aluminum production in Norway operates on 100% renewable energy. On the other hand, globally around 70% of Hydro's aluminum production operates on renewables.[15] The company has a 'Batteries business unit' which actively invests in the battery value chain. Current investments in Norway include Hydrovolt, Vianode, and Corvus. In the Netherlands, Hydro has invested 5 million EURO in E-magy, a Dutch developer of silicon anode materials.[16]

2.3.2 Nikkelverk

Nikkelverk is located centrally in Kristiansand and is the biggest nickel refinery in the western world. Nikkelverk exports 100% of their production. In addition to nickel refining, the company also refines nickel, copper, cobalt, and sulfuric acid.[17] Nikkelverk is wholly owned by Glencore, one of the biggest global companies with businesses in over 35 countries all dealing in natural resources.[18]

Material	Production capacity in Megatons
Nickel	92.000
Cobalt	5.000
Copper	39.000
Sulfuric acid	115.000

Figure 9: Nikkelverk production capacity.

[13] Skaland Graphite AS – Europe's major producer of Crystalline Flake Graphite
[14] 2023-03-BZF_Studie_Lieferketten-ENG.pdf (ipcei-batteries.eu) 31
[15] Hydro.com
[16] Hydro invests in emerging battery technology company E-magy
[17] At a glance (nikkelverk.no)
[18] At a glance (glencore.com)

2.4 Battery materials

In Norway, the battery material production ecosystem has many players. The country is a relevant exporter of materials like nickel, aluminum, and graphite, but also cobalt, copper, and silicon.

2.4.1 Elkem

Elkem produces silicon-based materials for a wide range of industries like healthcare mobility & transportation, energy & power, etc. For battery applications, Elkem produces graphite and silicone solutions for battery packs/modules and other applications in electric vehicles.[19]

2.4.2 Vianode

Vianode is a company owned by Elkem, Hydro and Altor Equity Partners.[20] Vianode produces synthetic graphite for the anode in batteries which far outperforms the use of natural graphite.[21] The production process makes use of renewable energy, a cleaner production technology reducing CO_2 emissions, and recycling.[22] Vianode will finalize is full-scale production lines in 2024 at Herøya, approximately between Oslo and Kristiansand, and start operations with 2,000 tons per year ramping up to 50,000 tons annually in 2026 and 150,000+ in 2030.[23]

2.4.3 Borregaard

Borregaard makes use of Norway Spruce, a variety of tree abundant in Norway, to create a range of materials. For lead batteries, Borregaard makes an organic expander improving performance, battery life, capacity, static and dynamic charge acceptance, water retention, cold temperature performance and high-temperature life.[24] For lithium-ion batteries, Borregaard makes sustainable additives also based on Norway spruce to improve the capacity, cycle life and safety while reducing the environmental burden of production.[25]

2.4.4 Cenate

Cenate recently opened its pilot plant in Tomter, south of Oslo. The company produces anodes containing silicon aimed to increase cycle life, energy density, safety, and lower production costs. Multiple tests have shown the efficiency of Cenate's technology. As a result, the company has been awarded research grants and has secured financing by multiple companies. The company offers two variants of their silicon anode, one containing graphite and one without.[26]

2.4.5 Cealtech

Cealtech produces graphene for electrolytes. The company has received funding from a myriad of sources such as Graphene Flagship, Enova, Innovation Norway, the Research Council of Norway, and the EU horizon 2020 program.[27]

[19] Battery solutions | Research projects | Innovation | About Elkem | Elkem.com
[20] About us | Vianode
[21] Anode Materials | Vianode
[22] Sustainability | Vianode
[23] Sparebank 1 Energy Markets Conference
[24] Vanisperse: organic expanders for lead batteries - Borregaard
[25] Lithium-ion battery systems – Innovations from Borregaard - Borregaard
[26] Cenate Centrifugal nanotechnology
[27] ENERGY STORAGE - CealTech AS

2.4.6 Tiotech

Tiotech is a producer of titanium dioxide nanomaterials and technologies. One of these technologies is a carbon-free anode incorporating titanium dioxide.[28] The company has recently announced a collaboration with Morrow sharing that Tiotech's anode pairs well with Morrow's cathode.[29]

2.5 Battery packs

The Norwegian battery pack ecosystem focuses on sustainable energy solutions for maritime and offshore applications. Batteries can be used as primary power source or in a hybrid power system providing clean and efficient energy for propulsion. Larger batteries can also be used for peak shaving and load leveling to manage peak power demands and ensure a stable power supply during high-demand periods. By storing excess energy during low-demand periods and releasing it during peak times, batteries help balance the load and optimize the operation of onboard systems. Another application is the use of battery systems in aquaculture operations like fish farms.

2.5.1 Corvus Energy

Corvus Energy develops zero-emission battery systems for use in shipping, offshore wind, oil and gas, fisheries and aquaculture, and subsea.[30] Energy storage systems by Corvus have accrued more than 4.000.000 operating hours, showing their operational experience. This company has deployed energy storage systems with a total capacity of 400 MWh (megawatt-hour) in more than 600 projects globally. The 400 MWh capacity indicates the combined energy storage potential of all the deployed systems, allowing them to provide sustained power to ships for extended periods of time. Corvus offers a complete overview of all vessels that run on their battery systems. This overview includes extensive information on vessel type, Corvus product used, liters of diesel saved per year, CO_2 emission reduction per year, and much more. In 2016 Corvus delivered an early battery system to TESO for use in the Dutch ship 'Texelstroom' which sails between Den Helder and the island of Texel. Corvus makes use of cloud-based technology to foster extension of battery life cycle and increase recycling possibility. Their systems are scalable and offer the opportunity to make all short-distance trips zero emission. Currently, Corvus collaborates with Toyota to develop a hybrid fuel cell system which will be available in 2024. The cornerstone of this technology is hydrogen which the fuel cell converts into electrical energy allowing for zero-emission shipping. Corvus promotes combining the fuel cell and their batteries to form a hybrid power system harnessing 'the strengths of each component, while limiting exposure to weaknesses.' The company has recently opened a new factory in Bellingham, Washington State in the US.

2.5.2 Siemens Energy

Similarly, Siemens Energy has also contributed to make the Norwegian shipping industry zero-emission.[31] Siemens Energy opened an automated pack-production facility in Trondheim, Norway in 2019 to primarily supply the maritime cluster.[32]

2.5.3 ZEM Energy

ZEM has developed a fully scalable battery system for maritime use with components from different foreign companies. Their battery systems are used for a variety of applications like ferries, fishing boats, lifeboats, and offshore supply ships. In addition, the company offers a large power bank ideal for peak

[28] TioTech AS | Titania materials for Li-ion battery anodes
[29] Om de lykkes, kan vi få billige batterier med høy ytelse - Tu.no
[30] Corvus Energy - Powering a clean future
[31] Electrifying the sea | 2022 | Siemens Energy Global (siemens-energy.com)
[32] PowerPoint Presentation (eba250.com)

shaving and fast charging applications like aquaculture feed barges and construction sites.[33] The German lithium-ion battery cell manufacturer Akasol, now part of BorgWarner, delivers the cells for ZEM Energy.

2.6 Cell production

In Norway, battery cell production has not yet entered the industrial production phase. However, starting from 2024, the industry is set to take off with companies gearing up for large-scale production of battery cells in gigafactories. A 'gigafactory' is the term used for advanced manufacturing facilities that produce significant quantities of, in this case, batteries to meet the rising demand for clean energy solutions.

2.6.1 Freyr

Freyr, clean battery solutions, is a major future player in the Norwegian battery production industry. The company is currently building a gigafactory in Mo i Rana Industrial Park, Nordland, scheduled to start production in 2024. The company aims to achieve an impressive 81% reduction in CO_2e (carbon dioxide equivalent) emissions across the entire supply chain compared to other producers in the industry. This is possible by leveraging the region's abundant hydropower supply and favorable local climate. Additionally, Freyr is investigating how to minimize emissions from construction activities and lower the carbon footprint in the supply chain.[34]

The company has recently announced their plans to expand abroad and purchased a plot of land in Georgia to build their US gigafactory.[35] This move by Freyr clearly demonstrates the competitiveness and the alure of the US since the implementation of the Inflation Reduction Act (IRA). To facilitate sustainable production in the US, the gigafactory will most likely run on purpose-built solar power. In addition, Freyr recently started cooperation with Finland Minerals Group and together planned to build a gigafactory in Finland.[36] Sadly, this plan is currently on hold as the prospect of doing business in the US is too great to establish a gigafactory in Finland.

Freyr is set to produce semi-solid lithium-ion batteries utilizing 24M technology. This technology facilitates stronger recycling opportunities, lowers CO_2e emissions, reduces operational costs and the use of rare minerals. The first production of Freyr will focus on batteries using LFP (lithium iron phosphate) chemistry for ESS (electronic stationary storage) applications. In the future, Freyr will produce batteries for ESS, electric cars and larger applications like buses, trucks, and marine vessels.[37]

2.6.2 Beyonder

Beyonder is planning to build a gigafactory at Haugaland Næringspark near Stavanger, Rogaland. Production will start in 2026. Beyonder utilizes sawdust to produce active carbon. This active carbon is then employed in cathode production, resulting in a cobalt-free cathode. Moreover, Beyonder combines the capacitive cathode of a supercapacitor with the battery-type anode of a lithium-ion battery, creating a unique lithium-ion capacitor. This combination results in a faster charge time, greater durability, and higher power density opposed to regular lithium-ion batteries. Beyonder will produce batteries for a variety of applications like power backup, transmission network, marine and transport applications.[38]

Recently, the company signed an MoU with ReNew Power and Tata Consultancy Services for multiple projects in India in addition to a partnership agreement with Midwest Energy.[39] This partnership with

[33] Batterisystemer og elektrisk drivlinje til skip | ZEM | Norway (zemenergy.com)
[34] FREYR Battery Norway | Technology and Product Management
[35] Sparebank 1 Energy Markets Conference 6-3-2023
[36] FREYR Battery Norway | Giga Factory Finland
[37] FREYR Battery Norway | Decarbonizing transportation and energy...
[38] Beyonder
[39] Sparebank 1 Energy markets conference 6-3-2023

Midwest Energy revolves around the planning of gigascale battery production in India with the technology developed by Beyonder.[40]

2.6.3 Morrow

Morrow is constructing a factory at EYDE Material Park in Arendal, Agder, with significant investments from the Norwegian government. The factory will be fully operational in 2028.[41] In terms of technology, Morrow is the most advanced in Norway. In their second generation of batteries, Morrow will make use of LNMC (Lithium nickel manganese oxides) chemistry for their cathode material, completely removing the need for cobalt.

Morrow will focus on two applications, ESS and mobility. For ESS, the company will first focus on the production of LFP cells in 2024, upgrading to LNMO-X in 2025. This upgrade combines a LNMO cathode material with the anode material XNO. This will cater to improvements in cycle life, and reduced nickel content. For the automotive industry, Morrow will start production of traditional NMC (Nickel Manganese Cobalt) cells in 2025. In 2026, Morrow will start producing LNMO-C significantly lowering costs. LNMO-C combines the cathode material LNMO with graphite. The LFP and NMC cells will allow fast access to the market, while their new chemistries bring an innovative product to the market.

2.6.4 Elinor Batteries

Elinor, launched in January 2023, plants to construct a gigafactory in Orkland, Trøndelag, near Trondheim. Elinor signed a MoU with research institute SINTEF on strategic cooperation and to cooperate on the establishment of their gigafactory. In 2026, the factory plans to introduce its initial production of batteries that are free from nickel and cobalt, exclusively relying on LFP technology. Intended uses for its batteries will be stationary storage for buildings and industry in addition to charging stations for electric transportation.[42]

2.6.5 Hreinn

Hreinn is set to establish its gigafactory in Viken Park, Fredrikstad, although the official location announcement is still pending. The factory is scheduled to start production in 2026, with a strong emphasis on battery cell manufacturing using the latest LFP commercial cell technology.

2.7 Battery testing

Norway's battery testing capacity primarily resides in research institutes and universities, while many battery cell and pack manufacturers have their own dedicated in-house testing capabilities.

2.7.1 Sintef

Sintef is a large independent research organization which operates in numerous industries like materials, transport and mobility, climate and environment, etc. Sintef shares a battery lab with the NTNU, Norwegian University of Science and Technology, and has testing capacity both for battery cells and for battery materials.

[40] Beyonder signs agreement with Midwest Energy for giga battery factory in India — Beyonder
[41] Home - Eyde Material Park
[42] Elinor (elinorbatteries.com)

2.7.2 IFE Institute for Energy Technology

The Institute for Energy Technology works in a broad series of industries. Across the battery value chain IFE participates in national and European research projects conducting research on different subjects like silicon alloys, silicon anodes, graphite, raw material demand, other battery materials, and battery safety. IFE conducts research in its Battery Materials Lab, Battery Development Lab, and Battery Testing and Characterization Labs. In its Battery Testing and Characterization Labs IFE can assess small-scale cells and larger, commercial cells.[43]

2.8 2nd life and reuse

The 2nd life and reuse industry in Norway is advanced. Most companies offer scalable battery storage systems using repurposed batteries for a variety of applications while simultaneously extending the lifespan of batteries.

2.8.1 ECO STOR

ECO STOR promotes a circular economy in the battery industry both in Norway and Germany. ECO STOR has an office in Oslo and a subsidiary, ECO STOR GmbH, in Munich, Germany. The company reuses batteries to create battery storage systems on all scales, from solutions for private use to power grid stabilization. ECO STOR determines the energy needs of the client, builds fully scalable energy storage systems, and monitors the systems throughout their lifetime. ECO STOR's systems have a variety of applications like spot price optimization, energy management, solar power utilization, frequency services, and as virtual power plant. The company also offers first life solutions using batteries that are brand new.[44] ECO STOR has partnered with Canadian Li-Cycle, and Morrow Batteries to open a lithium-ion battery recycling facility in Norway.[45] In both first and second life solutions, the company reuses and recycles the remaining battery materials.

2.8.2 Evyon

Like ECO STOR, Evyon offers scalable battery systems using repurposed car batteries. Evyon, located in Oslo, uses battery modules from German car manufacturer, Mercedes, reducing the carbon footprint up 95% compared to new battery systems. Evyon also makes use of overstock from Mercedes to produce their first battery systems. Additionally, using repurposed batteries lowers the price of the battery system. Evyon offers its customers a 'Battery Cloud' which collects data from, monitors and updates the battery improving its safety and performance. Also offers API's allowing for integration with third-party applications.[46] Evyon delivered its first next-generation pilot industrial battery system in February of 2023.[47]

2.8.3 Hagal

Hagal, owned by Entheos Network, produces battery energy storage systems (BESS) and is part of the EYDE Cluster. For their storage systems, Hagal uses second life EV batteries extending their lifespan. Hagal has a 'Battery LifeCycle Hub' in Hokksund, west of Oslo, where the company produces new batteries and tests, analyzes, and repurposes used batteries. Hagal has a range of products like Hagal Flow, a cloud-based energy management system, indoor energy storage and outdoor BESS on utility-scale.[48] Hagal has

[43] Ife.no
[44] ECO STOR | An Ecosystem For Batteries (eco-stor.com)
[45] Introducing: Lithium-ion Battery Recycling Facility in Norway (eco-stor.com)
[46] Home page (evyon.com)
[47] Evyon delivers its next-generation battery system.
[48] Hagal | Maximising battery life for a cleaner tomorrow

a subsidiary, Hagal Ocean, focusing on green maritime battery solutions utilizing LFP chemistry. Hagal Ocean's batteries are suitable for workboats, fish farming and aquaculture, and ferries and shipping.[49]

2.9 Collection

Battery collection services have an extensive network in Norway.

2.9.1 BatteriRetur

Most of the battery collection throughout Norway is done by BatteriRetur. The company collects batteries transporting the majority to Hydrovolt. BatteriRetur operates EU-wide and cooperates with other actors across Europe importing materials from abroad for recycling at Hydrovolt. The company is looking to expand and source batteries from the Baltic states.

2.9.2 Norsirk

Norsirk operates nationwide and collects electrical and electronic products, batteries, and packaging. Norsirk provides certificates to their customers, companies, showing they recycle and take care of producer responsibility. The company also offers data collection and recycling quantities of different battery chemistries.

2.10 Recycling

Norwegian recycling capacity is significant and expanding. The industry has enough capacity the service their Norway's own recycling needs multiple times over. To make use of this overcapacity, Norwegian companies are looking abroad.

2.10.1 Hydrovolt

Hydrovolt is a collaboration between Northvolt and Hydro. Northvolt is a Swedish battery manufacturer with keen interest in a circular battery ecosystem. Hydro is a Norwegian aluminum and energy company but invests in a wider range of business areas.[50] These companies have partnered up to form Hydrovolt and opened Europe's largest electric vehicle battery recycling plant in May 2022.[51] The plant is situated in Fredrikstad in the south of Norway. The company has the capacity to recycle around 12,000 tons of battery packs annually. Hydrovolt will expand recycling capacity to 70,000 tons in 2025 and 300,000 tons in 2030. Consequently, Hydrovolt will facilitate the recycling of the Norwegian end-of-life battery market multiple times over.[52] Hydrovolt currently faces two challenges: small pieces of Nickel and cobalt embedded in plastic and chemicals in the electrolyte. The latter is difficult to recycle while Hydrovolt currently burns the former. Currently, Hydrovolt recycles around 85% of the collected batteries. The company will recycle more than 90% in 2025 with the eventual goal of 95%.

2.10.2 ReSiTec

ReSiTec, owned by Agder Energi Venture, produces silicon powder, and recycles silicon materials. The company operates factories in Norway, China, and Singapore. Its headquarters and R&D center are in Kristiansand, with a processing plant twenty kilometers from Kristiansand. In 2021 the company signed an MoU with Morrow Batteries for the development and supply of silicon-based anode materials.[53] ReSiTec is part of the EYDE Cluster and partners in different projects in Norway and beyond.

[49] Hagal Ocean – Powering a green maritime sector
[50] Hydro.com
[51] Europe's largest electric vehicle battery recycling plant begins operations - Hydrovolt
[52] Europe's largest electric vehicle battery recycling plant begins operations - Hydrovolt
[53] Morrow and ReSiTec signs MoU for development of battery materials from recycled silicon - ReSiTec

In early 2023 ReSiTec announced its participation in EMINENT (Energy MINerals for the Netzero Transition) and, together with Future Materials, will be responsible for processing and technical solutions related to beneficiation of the ores.[54] In the European sphere, ReSiTec collaborates with other European companies in the project EIT RawMaterials to develop a process for the production of new solar wafers from recycled silicon kerf. Several Dutch players are also part of this project such as TU Delft, Tata Steel, Admatec, and more. ReSiTec is also part of the COBRA (CObalt-free Batteries for FutuRe Automotive Applications) consortium also funded by the Horizon 2020 program. In COBRA ReSiTec aids the development of Cobalt-free Li-ion batteries for electric vehicles.[55] ReSiTec was also part of the EU project CABRISS approved by the Horizon 2020 program. CABRISS pioneers the circular economy and promotes the recycling of photovoltaic waste while benefiting the electronics, metallurgy, and glass industries.[56]

2.11 Events

2.11.1 Oslo Battery Days

The first edition of the Oslo Battery Days (OBD) conference took place in 2016 and is organized for the fifth time in 2023 at the Grand Hotel in the center of Oslo. The OBD brings together both national and international stakeholders for a two day conference on 21+22 August. The program includes an exhibition and several speakers from companies, academia, and government.

2.11.2 Nor-Shipping

The first edition of Nor-Shipping took place in 1965 and is organized biannually ever since. Currently, the event is hosted in Lillestrøm, near Oslo. Nor-Shipping is a leading international shipping conference attracting exhibitors and visitors globally. The conference concerns everything maritime related and had more than 800 exhibitors from 41 different countries in the 2023 edition. The conference also attracts players from the global battery value chain such as manufacturers, charging infrastructure, battery equipment manufacturers, and more. Of course, for this event the participants from the battery value chain provide solutions for maritime applications. The Netherlands has a stand at every edition of Nor-Shipping. Please contact the embassy for more information on the Dutch presence at Nor-Shipping.

2.11.3 Nordic EV Summit

In 2024 the fifth edition of the Nordic EV summit (NEVS) will take place in Lillestrøm, near Oslo. The NEVS is the largest electric mobility conference in the Nordics. The two-day conference gathers stakeholders and companies from government, car production, battery technology, charging infrastructure, and more. At the 2023 edition, few players from the Norwegian battery value chain were present. The Netherlands has a stand at every edition of the Nordic EV Summit. Please contact the embassy for more information on the Dutch presence at the Nordic EV Summit.

[54] Future Materials and Resitec engaged in Deep Sea Minerals - ReSiTec
[55] COBRA | CObalt-free Batteries for FutuRe Automotive Applications (projectcobra.eu)
[56] Networks and clusters - ReSiTec

Chapter 3: Opportunities for Dutch-Norwegian cooperation

3.1 Introduction

This chapter present opportunities for Dutch-Norwegian cooperation in the battery value chain. First, this chapter discusses the strengths/weaknesses of- and threats to the Norwegian battery value chain followed by a brief discussion. Second, this chapter briefly describes Dutch goals for the battery value chain. Third, this chapter connects these goals with opportunities in the Norwegian battery value chain.

3.2 SWOT analysis

Strengths	Weaknesses
• Country has experienced workforce in energy as result of history with oil/gas. • Hydropower makes up 92% of generated electricity resulting in low energy prices. • Plans for battery value chain formulated in National Battery Strategy. • Highest share of EV's globally. Generous incentives for EV's. • Eligible for investments from the EU. • Norway has significant refining capacity for minerals vital to battery production. • Norwegian government invests heavily in offshore wind power.	• High import dependence due to small domestic mining industry. • Geographical features result in high costs for construction of infrastructure. • High labor costs.
Opportunities	**Threats**
• In Early 2023 the National Petroleum Directorate (NPD) announced the estimated amount of potential mineable minerals on the Norwegian continental shelf. Will still take a long time before the start of mining operations. • Government invests heavily in the battery value chain through loans and grants. • Cooperation with domestic and foreign companies is high.	• Statnett market analysis predicts an electricity deficiency from 2026/2027. Norwegian investments in high-energy industries and electrification leads to increased demand. • Inflation Reduction Act decreased Norwegian comparative advantage.

Figure 10: SWOT analysis of Norway.

Advantages of Norway for the battery value chain include its favorable business climate, supported by an experienced workforce with a strong background in the oil and gas industry. The country's government offers incentives for EV's and actively invests in the battery value chain through loans and grants, in addition to Norwegian eligibility for investments from the EU. Norway's national battery strategy provides clear direction and predictability for the industry, promoting growth and development. The strategy also clearly signals to foreign companies and investors that the Norwegian battery industry has a bright future.

Geographically, Norway benefits from access to cheap hydropower, ongoing investments in offshore wind power expansion, and significant refining capacity. Norway also has huge potential future mining opportunities on the Norwegian continental shelf. The NPD has examined the continental shelf and found significant amounts of precious metal, some indispensable for the battery industry. Figure 11 shows the estimates of available minerals on the seabed of the Norwegian continental shelf. These factors contribute to the country's competitive advantage in the battery value chain.

Metal	Metal volume (tons)
Manganese	185.000.000
Zinc	45.000.000
Copper	38.100.000
Magnesium	24.100.000
Titanium	8.400.000
Cobalt	4.058.100
Vanadium	1.918.900
Cerium	1.681.200
Neodymium	420.300
Lanthanum	368.800
Yttrium	300.900
Lithium	229.300
Praseodymium	102.500
Gadolinium	99.900
Dysprosium	85.400
Silver	85.200
Tungsten	80.300
Niobium	73.000
Scandium	55.800
Europium	23.200
Gallium	19.200
Terbium	15.200
Hafnium	14.700
Gold	2.317

Figure 11: materials present on the Norwegian continental shelf.[57]

However, the Norwegian battery value chain does face some challenges. The country's high labor costs can impact the overall competitiveness of the industry. Norway is highly dependent on imports for minerals and goods required in the battery value chain, which introduces potential vulnerabilities in the supply chain and increases the risk of price fluctuations and disruptions. Additionally, Norway, like all European countries, faces immense competition from the US with the introduction of the Inflation Reduction Act. The advent of the Net Zero Industry Act, to counter the influence of the IRA, has clearly not done enough as companies like Freyr and Corvus Energy have recently paused the construction of their new Norwegian facilities. How Norway and the EU will deal efficiently with this competition is still unclear. Furthermore, geographical features, such as harsh terrain and remote locations, lead to high costs for infrastructure construction and transport. Lastly, a report by Stattnet, the Norwegian TSO (Transmission System Operator), has shown that the country will face an electricity deficit in 2026 or 2027. Investments in emerging energy-intensive industries, such as the battery industry, along with extensive electrification efforts, contribute to a significant rise in electricity demand in Norway. Currently, Norway is already

[57] Seabed minerals: Substantial resources on the Norwegian shelf - The Norwegian Petroleum Directorate (npd.no)

experiencing issues with high demand for new grid connections. Of course, Norway is investing in the expansion of electricity production through offshore wind. However, the research, tender, licensing, and construction processes involved in the offshore wind industry often result in significant time delays. Recently, the government decided against the construction of an interconnector from the wind farms to the European mainland, reducing the economic viability of these projects. How the country will solve and handle this electricity deficit is unclear.

3.3 The Netherlands

In December 2021, strategy&, part of the PWC network, commissioned by the Dutch Ministry of Economic Affairs and Climate policy, and the Dutch Ministry of Infrastructure and Water Management, published The business position and opportunities in the battery value chain for the Netherlands. A study conducted in the span of 12 weeks on the Dutch battery value chain including significant amounts of data, recommendations, and an overview of the Dutch battery ecosystem.

In the Netherlands 236 organizations with 13.250 FTE are active in the battery value chain.[58] In September 2022 Holland High Tech released the 'Actieagenda Batterijsystemen' describing opportunities for the Netherlands in the battery value chain. The moonshots in the 'Actiegenda' envision a leading role for the Netherlands in:

1. Research and development of material and cell design
2. The delivery of manufacturing equipment to battery producing factories in the EU
3. The production of batteries for heavy duty transport
4. The production of batteries for grid support
5. The testing of every aspect in the value chain
6. Reuse, second life, and recycling

The following paragraphs will employ these moonshots to identify potential opportunities for Dutch players within the Norwegian battery value chain.

3.4 Moonshots

3.4.1 Research and development of material and cell design

The Norwegian battery value chain invests extensively in research and development. Major cell producing companies like Morrow, Beyonder and Elinor have internal R&D departments and cooperate with Norwegian actors across the value chain. This is evident from initiatives and collaborations, such as the Norwegian battery coast, the EYDE Cluster, Battery Norway and signed MoU's.

The Norwegian battery value chain has several notable collaborations. Some examples: Vianode and Morrow have partnered to develop specialized anode materials for lithium-ion cells, with the goal of securing a long-term supply agreement. TioTech and Morrow are jointly exploring the use of titanium dioxide as an alternative anode material, aiming to enhance performance, charging speed, lifespan, and cold temperature operation. Additionally, Elinor Batteries and SINTEF have teamed up to establish a sustainable and competitive gigafactory, focusing on research, development, and technological advancements. These partnerships highlight the collaborative efforts within the Norwegian battery industry, fostering innovation and progress.

This does not mean Norwegian companies do not cooperate with players outside of Norway. Freyr utilizes American M24 battery technology to produce their first line of batteries and sources important battery materials like Lithium Hydroxide from AMG Lithium. Morrow partners with German IBU-tec advanced

[58] Actieagenda batterijsystemen (hollandhightech.nl)

materials for the supply of cathode material. These are just some examples of cooperation inside and outside Norway. The list of Norwegian actors with international collaborations is extensive.

When comparing Dutch and Norwegian companies, it is clear both sides are researching similar technologies. Several actors in the Netherlands are researching the battery material silicon, like Norwegian companies Cenate, Elkem, and Vianode. Also, Dutch company E-magy, which does research on silicon as anode material, has already received a grant from Norwegian aluminum concern Hydro of five million Euros. Signifying once more the Norwegian interest in the new innovative technologies.

The abundance of signed MoU's between Norwegian companies and international players illustrates the Norwegian value chain's search for innovative technologies and avenues for cooperation. It is advisable for Dutch actors to explore the possibility of establishing contact and collaborating with Norwegian players. While the technology for the upcoming cell production by major battery companies appears solidified, extensive research and development is still required for future battery chemistries and improvements in existing technology. Dutch players may discover opportunities in this area.

3.4.2 The delivery of manufacturing equipment to battery producing factories in the EU

In the report The business position and opportunities in the battery value chain for the Netherlands, the consultancy firm PWC Strategy& sees a significant opportunity for Dutch players in the construction of manufacturing equipment for the future. PWC states there is no opportunity in the short term as the demand for production equipment for current in-use li-ion cells is already satisfied by the Asian market. In the Norwegian context, this report reaches the same conclusion, but with a notable distinction: the manufacturing equipment in Norway is sourced from other European companies.

In Norway, several gigafactories are set to start production in the run-up to 2030.

Company	Location	Start production	projected Capacity in GWh
Freyr	Mo i rana	2024	29
Beyonder	Haugaland Næringspark	2026	-
Elinor	Trondheim	2026	40
Hreinn	Fredrikstad	2026	-
Morrow	EYDE Material Park	2028	43

Figure 12: battery cell manufacturers in Norway.

Freyr has finalized the design of its gigafactory in Mo i Rana and aims to start production in 2024. For the manufacturing process at the Mo i Rana facility, Freyr partnered with the UK-based company Mpac Group to provide the necessary manufacturing equipment. The agreement between Freyr and Mpac Group spans three years, until September 2025, with the potential for extension. Currently, there may not be immediate opportunities available with Freyr. However, it is noteworthy that Freyr has intentions to expand internationally, as evident from their recent land acquisition in the USA. Moreover, they are collaborating with the Finnish Minerals Group within Europe and actively planning the establishment of a gigafactory in Finland. Due to the competitive advantage for battery producers in the US through the effects of the IRA, the plans for Finland are paused.

Currently, there is no available data regarding the manufacturing equipment employed by Beyonder. However, considering that the company is scheduled to commence production in 2026, there might be a potential opportunity in this regard. The same is the case for Hreinn.

Morrow has established its own research and development center located on the campus of the University in Agder. In addition to serving Morrow's needs, this center will also provide a facility for other manufacturers to conduct battery testing specifically for the European automotive industry. While Morrow plans to reach its maximum production capacity in 2028, it will initially produce on a smaller scale

in 2024. Prior to this timeline, Morrow will produce cells in South Korea utilizing its Customer Qualification Line (QCL). The plant in Arendal will function like the QCL. Consequently, it does not seem there is an immediate opportunity available here.

Elinor will produce LFP cells, eliminating the use of nickel and cobalt in their production process. In 2023, Elinor signed an MoU with Sintef. As part of this collaboration, Sintef will provide Elinor with production technology, infrastructure, management expertise, economic insights, and considerations of societal impact. This partnership with Sintef aims to support and enhance Elinor's production capabilities and ensure a sustainable and efficient manufacturing process for their LFP cells.

While it may not appear that Dutch companies have immediate opportunities with major battery-producing companies in Norway, it is important to recognize that these companies will continue to innovate and potentially transition to new technologies or enhance their existing ones in the coming years. Such developments may necessitate additional manufacturing equipment, presenting a potential avenue for Dutch players to contribute in the medium to long term.

3.4.3 The production of batteries for heavy duty transport

Dutch producers of heavy duty batteries can find a market in Norway. The country is a frontrunner in the electrification of passenger vehicles but is also headed in the right direction in construction vehicles and heavy duty vehicles like busses. In the maritime sector Norway is host to global leading companies for shipping which might provide an opportunity for Dutch shipping to become more economical and sustainable. In this paragraph the liberty is taken to look beyond just heavy duty transport. Instead, heavy duty vehicles in a broad sense are discussed.

Construction

Oslo earned the title of European Green Capital of 2019 which can be attributed to its ambitious and sustainable policies. One noteworthy outcome of their dedication and commitment has been the establishment of a market for zero-emission construction machinery. This presents a significant opportunity for Dutch players to contribute to this emerging sector.

The world's first emission-free construction site opened in Oslo in 2019 operated by Bymiljøetaten, the Agency for Urban Development. As a result, the Grønn Byggallianse, Norwegian Green Building Council, cooperated with Oslo's businesses development company, Oslo Business Region, to increase demand for fossil free and emission free construction sites. The City of Oslo has also cooperated internationally to promote clean construction. The city sends a clear signal to the industry demanding that all municipal construction sites are zero-emission by 2025.[59] This demand resulted in Norwegian property developers like Veidekke and NCC acquiring heavy-duty, electric construction equipment, facilitating emission-free construction zones. In addition, suppliers such as NASTA and Heidelberg Materials started 'to develop all-electric excavators, all-electric mixer drums for concrete mixer trucks, and more'.[60] NASTA uses lithium-ion batteries produced by Akasol, now BorgWarner, for their electric machinery.

Heavy duty vehicle like busses

Dutch actors need to move fast to make use of the expected demand in Norway. The country has the goal that all new city buses shall use zero-emission technology or biogas in 2025.[61] In 2022, in Norway about

[59] Oslo European Green Capital 2019 - Oslo kommune
[60] Norway is greening the construction industry (businessnorway.com)
[61] National Transport Plan 2022–2033 - regjeringen.no

half of all new busses were electric.[62] Oslo's bus fleet will be fully-electric by the end of 2023.[63] In Bergen a similar development is taking place where the city's bus fleet includes more than 600 electric busses.[64] However, this is not the case for all Norwegian cities. Trondheim, the third largest city in Norway, currently has 38 electric busses and according to ATB, one of the bus operators in Trondheim, the preferred future for zero-emission buses in Trondheim is electric. Stavanger, Norway's fourth largest city, currently has 13 electric buses and, according to Kolumbus, one of the bus operators in Stavanger, there are no plans to increase their electric bus fleet. However, Norway is committed to the goal of having all new buses be zero-emission by 2025. The municipality must adhere to this rule, so despite not having plans currently, the city will have to invest in zero-emission buses in the future. Whether this will be electric is uncertain.

Maritime

In Norway, from 2026, the government will ban all vessels in the World Heritage fjords, Geirangerfjord, and Nærøyfjord, that are not zero-emission. Clearly signaling the country's direction to zero-emission shipping. Several companies produce battery packs for maritime uses like Zem, Siemens Energy, and Corvus Energy. Of which Corvus Energy is the biggest player with an impressive track record and more than 400 MW installed capacity in shipping. They offer fully electric solutions for shipping but also provide the option to add electric capacity in addition to a regular diesel engine. As a result, shipping can become more economical through decreased diesel usage and more sustainable through decreased CO_2 production. Corvus Energy has already provided electric capacity to the Dutch ship 'Texelstroom'. Also, electrifying ferries can be an additional way to decrease CO_2 production. Norwegian examples are the fully electric ferries, Oslofjord I-V, used by the Oslo public transport service, Ruter, which are fully electrified by Corvus Energy. Another example is the sightseeing ferry 'Vision of the Fjords', electrified by Zem. The Dutch 'binnenvaart' (inland shipping) sector holds a promising opportunity in this context. While the Netherlands already hosts several fully electric operational ships, there is significant room for capacity expansion. Recently, Shell acquired a portion of Corvus Energy. The company has since opened a sales department in Amsterdam, showing the willingness of Norwegian companies to expand internationally.

3.4.4 The testing of every aspect in the value chain

In Norway, several players are in battery testing. Institutes such as IFE and Sintef possess dedicated testing facilities, while battery producers like Morrow and Freyr employ a mix between internal and consumer testing. The Institute for Energy Technology (IFE) offers an extensive equipment portfolio for battery and material testing. IFE offers:

Equipment portfolio
More than 100 test channels (0-5 V, 0 – 50 A)
Channels can be paralleled up to 500 A
Temperature chambers from -40 °C to 80 °C
Emulation of drive-cycles
Constant current, power, voltage, and resistance cycling
Characterization of cell degradation with different techniques

Figure 13: IFE testing capability for larger, commercial cells.[65]

[62] Trends in electric heavy-duty vehicles – Global EV Outlook 2023 – Analysis - IEA
[63] E-bus deal puts Oslo on track for zero-emissions public transport goal | Reuters
[64] More than 600 buses in Bergen now run on electricity or renewable energy! - Meetings (visitbergen.com)
[65] Battery Testing - IFE

Another significant player is Sintef. Sintef is an independent research organization and operates in different industries. The institute has a battery lab in Trondheim. The Sintef Battery Lab offers the following testing portfolio:

Equipment portfolio
64 channels (0-6 V, 0-60 A)
80 channels (0-5 V, 0-50 A) (currently 20 channels, but expansion of 60
16 channels (0-5 V, 0-15 A, high precision)
64 channels (0-5 V, 0-6 A, with temperature and pressure control for formation)

Figure 14: Sintef testing capability for larger, commercial cells.

In the Dutch battery testing landscape, various players are involved. One notable example is TNO, which possesses an array of testing capabilities making them a significant player in the field.

Equipment portfolio
Independent test channels to 100 A
Channels can be paralleled up to 1200 A
Temperature chambers
Electrochemical Impedance Spectroscopy
Battery pack testing up to 750 V and 400 A

Figure 15: TNO testing capability.

Based on analysis of testing capacity, Dutch players are currently ahead of the discussed Norwegian examples. To progress in this area, it is crucial to establish contact and proactively engage with key stakeholders in the Norwegian value chain, emphasizing the importance of comprehensive testing for all battery-related components. Dutch actors should proactively engage with Norwegian players and make their presence known, highlighting the need for their advanced testing facilities. It is possible that in Norway there is currently no demand for high voltages and amperes. However, Norway will become a hub for diverse battery production. Consequently, Norwegian companies might require the expansive Dutch testing capacity in the future.

3.4.5 Reuse, second life, and recycling

In comparison to Norway, the Netherlands is an earlier stage of the development of its battery reuse and repurposing industry. In Norway, it is common to see actors actively engaged in reusing batteries and extending their lifespan on a large scale. Notably, companies like Evyon and ECO STOR have already made successful sales of battery systems utilizing used batteries. Evyon currently has a partnership with Mercedes for the delivery of old batteries and overproduction. A clear sign this company is far ahead of Dutch initiatives. Consequently, instead of finding opportunities for collaboration, Dutch companies may encounter competition from Norway in this field.

What is more advanced in the Netherlands compared to Norway are circular practices like reconditioning, overhaul, repair, refurbishing, and remanufacturing of batteries. Dutch circular battery services are abundant. In Norway, there seems to be less focus on these services, and this might prove an invaluable opportunity for Dutch small business. In Norway, people are used to purchasing new products instead of making use of second-hand or refurbished products. The Dutch circular business models might therefore find a market in Norway.

In the field of recycling, Norway is also ahead of the Netherlands. In Norway Hydrovolt, as discussed in chapter 2, opened its EV battery recycling plant in May 2022. With current capacity to recycle approximately 12,000 tons of battery packs annually, the company has ambitious plans for expansion. By 2025, they aim to increase their recycling capacity to 70,000 tons, followed by a target of 300,000 tons in

2030.[66] A similar venture in the Netherlands exists in the Port of Rotterdam. TES, a company from Singapore, is building a battery recycling facility. Unfortunately, current information on the operations of TES in Rotterdam is not publicly available. Different modes of recycling exist for batteries like mechanical, metallurgical, thermic, and chemical, of which the latter three are barely employed in the Netherlands. The former takes place in the Netherlands which results in increased efficiency in the latter three processes. As Hydrovolt and its partner, BatteriRetur, operate on a European level, Dutch actors can export their battery materials, battery packs, and residual materials (after mechanical recycling) to Norway for further recycling. Nonetheless, the transportation of substantial quantities of batteries for recycling poses a challenge due to the associated CO_2 emissions. However, Hydrovolt's extensive future capacity enables them to achieve economies of scale, potentially offsetting the carbon footprint. Ultimately, the recycling industry does not appear to offer significant opportunities for Dutch players. Still, Dutch actors may find Norwegian expertise in this field valuable and are encouraged to establish communication.

3.4.6 The production of batteries for grid support

Norwegian grid

The country's grid is divided into five price areas. Each area produces power but will exchange power when demand is higher in another area. Supply and demand balance the price in the different areas which usually does not result in large price differences between Northern Norway and Eastern Norway. Norway also exports power to Finland, Sweden, Germany, the Netherlands, Denmark, and the UK. Due to the energy crisis in Europe with exceptionally high power prices, the southern parts of Norway experienced higher prices than the northern parts. Employing stationary storage batteries might be an effective way for Norway to balance this price differential. For more information on the price areas and live data from the power system visit the website of Stattnet.

Figure 16: five price areas in Norway.

[66] Europe's largest electric vehicle battery recycling plant begins operations - Hydrovolt

Even though Norway is a net exporter of electricity currently, Stattnet predicts in their report 'Kortsiktig Markedsanalyse 2022-27' an electricity deficit in Norway. Many energy-intensive industries are scheduled to grow in Norway which will put pressure on the Norwegian grid and electricity supply. Statnett is working with Swedish TSO, Svenska kraftnät, to improve overall north-south transmission capacity which will decrease price differences and decrease the likelihood of electricity deficits in specific areas.[67]

Employing grid support through large Dutch batteries might be a way for Norway to stabilize their grid. Dutch companies should move swiftly and contact Norwegian TSO Statnett. Norwegian battery manufacturer Beyonder will also produce batteries for grid support and might be preferred to Dutch companies.

Offshore wind

The necessity for storing electricity will grow significantly in the future. The government is investing to expand their production of sustainable energy. One of their methods is the expansion of offshore wind capacity in the North Sea. Norway has one wind farm, Hywind Tampen, with a production capacity of 60 MW. In early 2023 the licensing process for two additional offshore wind projects, Sørlige Nordsjø II and Utsira Nord started. Sørlige Nordsjø II will be a bottom-fixed wind farm with a production capacity of 3 GW, while Utsira Nord will be a floating wind farm with a capacity of 1,5 GW.[68] The Norwegian government has the ambition to produce 30 GW through offshore wind by 2040. A directorate group led by the Norwegian Water Resources and Energy Directorate (NVE), consisting of the Norwegian Directorate of Fisheries, the Norwegian Environment Agency, the Norwegian Coastal Administration, the Norwegian Petroleum Directorate and the Danish Defense Building, investigated 19 areas for the production of offshore wind parks. The findings can be found here in Norwegian. The next licensing round for offshore wind will be in 2025 with a new licensing round every two years.[69] Norwegian Offshore Wind, the wind cluster of Norway, predicts that the majority of Norwegian offshore wind capacity will be made up of floating wind turbines. The cluster showed in their report on possible new areas for offshore wind, that Norway could host significantly more offshore wind energy than the current ambitions of the government. Furthermore, Norwegian politicians are debating the construction of an interconnector between the future wind farms and the European mainland. While such an interconnector would make Norwegian wind farms economically viable, it would also lead to higher electricity prices for Norwegian consumers. Due to the unpopularity of such a policy, the Norwegian government is in a political stalemate. Instead, the government has chosen to increase the subsidy package for wind farms.

The expansion of offshore wind in Norway will have extensive effects on the Norwegian power system. The development of offshore wind will require large grid investments to get power from the windfarm to land, and grid investments to manage the additional power.[70] Here lies an opportunity for Dutch manufactures of grid support batteries. Since most batteries scheduled for production in Norway utilize lithium-ion technology, Dutch expertise in the fields of redox-flow, hydrogen and salt batteries might prove more effective.

Charging

Norway's passenger car vehicle fleet is currently 20% electric.[71] Additionally, in 2022 more than 80 percent of car sales were electric.[72] The high percentage of EV's in Norway requires expansive charging

[67] A seamless grid for the future | Statnett
[68] Creating offshore winners - Capgemini Norway
[69] Norway announces big new offshore wind targets | WindEurope
[70] Sammendrag - Del 1 (nve.no) Sammendrag - Del 2 (nve.no)
[71] National charging strategy - regjeringen.no
[72] Statistikk elbil - Norsk elbilforening

infrastructure. To facilitate this infrastructure, the Norwegian government has published the National Charging Strategy in early 2023. This strategy includes initiatives to facilitate appropriate areas and sufficient capacity to deploy rapid chargers. Currently, grid companies and energy authorities are experiencing great demand for new connections to the electricity grid. As a result, the capacity of the grid is not always sufficient. To resolve this issue, several measures were proposed in a report by the Electricity Grid Commission titled 'Future development of the electricity grid in Norway', like reducing implementation time of grid expansion and connections, decrease licensing time, increase efficiency of licensing process, employing Enova to support financing of infrastructure which lack commercial viability, and more. Employing grid support through large Dutch batteries might be an interim solution.

3.5 Opportunities

This report analyzed the 6 moonshots as presented in the Actieagenda Batterijsystemen by Holland High Tech to determine where Dutch companies might find an opportunity in Norway. This report clearly sees a larger opportunity for Dutch companies in Norway in some of these moonshots. The ranking of these moonshots can be found in the figure below.

Rank	Moonshot
Clear opportunity	The production of batteries for heavy duty transport
	The production of batteries for grid support
Moderate opportunity	Reuse, second life, and recycling
	Research and development of material and cell design
	The delivery of manufacturing equipment to battery producing factories in the EU
Limited opportunity	The testing of every aspect in the value chain

Figure 17: ranking of opportunities.

Conclusion

Norway's commitment to the battery industry serves as a clear indicator of the sector's prosperous outlook and its potential for driving economic growth. Actors in the value chain already received subsidies and regulations in the past, but since the release of the National Battery Strategy the government has renewed their support for the battery industry by amending regulations, providing financial incentives, and by attending opening ceremonies of companies. The Norwegian battery industry has a large share in employment, and predictions for the future are that employment in this industry will only grow.

Extensive cooperation exists within Norway, with companies actively pursuing collaborations in R&D and production. Additionally, Norwegian companies extend their reach beyond the country's borders. The collaborations between Norwegian and international actors is abundant, presenting opportunities for Dutch actors to contribute to Norway's battery industry or facilitate Norwegian companies' involvement in the Netherlands.

For Dutch actors there is a clear opportunity in the production of batteries for heavy duty vehicles. Norway has its sight set at the electrification of nearly all segments of transport. With the clear goals the government has set, and municipalities with clear plans and actions to achieve these goals, electrification of construction and of buses is in full sway so the demand for batteries of this format is high. For Dutch shipping, the Norwegian expertise in this field could aid Dutch actors in the electrification of the fleet. Norwegian actors clearly have plenty experience in this regard and could supply battery packs for maritime purposes.

For the production of batteries for grid support there is also a clear opportunity in Norway. The price areas in Norway, in combination with the expected increase in electricity demand through energy intensive industries and electrification, and the arrival and expansion of offshore wind capacity and charging stations, hold opportunities for Dutch producers of grid support batteries. The Norwegian grid will likely need support, and grid support batteries might be a great interim solution to support the Norwegian grid.

In the delivery of manufacturing equipment and R&D of material and cell design there is a moderate opportunity for Dutch actors. In the short term, the Norwegian landscape seems crystallized. Factories are under construction and the companies' full-capacity production is scheduled in one to five years. Therefore, for Dutch actors, the opportunities lie in the medium to long term. Norwegian companies may expand their factory, or establish a completely new facility, which requires manufacturing equipment. Likewise, their technology will require updates in the future, or if the cell producing companies transition to innovative technologies, Dutch knowledge and expertise will be necessary and wanted.

For the moonshot reuse, second life, and recycling there is also a moderate opportunity for Dutch actors. Norwegian actors are very much ahead of Dutch second life and reuse companies. Norwegian companies have made their first sales and expansion of their capacity is likely. Dutch players are likely to find competition from Norway in this regard. Where the Netherlands seems ahead of Norway is in circular practices such as reconditioning, repair, and refurbishing of batteries, which presents an opportunity for Dutch small businesses in Norway where such services are less emphasized. In the field of recycling Norway is also very much ahead of the Netherlands. To make an impact in this area, Dutch actors need to use the extensive knowledge of material science of Dutch academia. Collaboration in research and development appears to be the primary avenue for potential cooperation.

The last moonshot, the testing of every aspect in the value chain, seems to hold limited opportunities for Dutch companies. Despite the enormous capacity of the Netherlands, the Norwegian ecosystem currently has its own testing capacity. However, when the production of Norwegian cells ramps up, these companies might look for greater testing capabilities. Therefore, Dutch actors are still encouraged to establish contact with Norwegian parties to ensure visibility in the future.