Strategy for fossil free competitiveness

SUSTAINABLE BATTERY VALUE CHAIN

Fossil Free Sweden

A strategy by
Fossil Free Sweden

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Foreword

Within the framework of Fossil Free Sweden different industry and transport sectors have developed 22 roadmaps for increased competitiveness. Together they cover more than 70 per cent of Sweden's greenhouse gas emissions. But for the roadmaps to become a reality, policies must be in place to remove the obstacles that will arise when all the roadmaps are to be implemented.

Fossil Free Sweden is now drawing up a number of strategies for fossil-free competitiveness to get the pieces of the roadmap puzzle to fall into place and form an integrated narrative about how Sweden can become fossil-free.

You are holding the first strategy in your hand – a strategy for a sustainable battery value chain. Electrification of various sectors runs as a common thread through many roadmaps. But replacing oil with electricity also requires batteries. The shortage of sustainable batteries is one of the largest bottlenecks, now that traffic in a wide sense is to be electrified at a rapid rate. Batteries are also needed in the industry and to store electricity and balance peak loads in the electricity grid. At the same time, the production and use of batteries must become more sustainable, and this applies throughout the value chain.

Sweden has the potential to develop this new green industrial value chain and show how each link on the way can be made sustainable: from recycling and mining via the battery factory to use in the transport sector, electricity grid and in industries, and then via recycling and round again. This fits well with Sweden's vision of being a permanent world exhibition for new climate-smart technology that can both inspire other countries and lead to Sweden being able to export sustainable solutions.

Our strategy shows that Sweden has a unique role in this transformation of the EU and the whole world. But the strategy also shows that this opportunity can only be realised through extensive research investments and concentrated efforts to train engineers at different levels. The supply of raw materials is also a challenge that requires the development of more sustainable mines and a dramatically increased degree of recovery of battery metals.

Now there is a strategy on the table that has large and broad support from major parts of the value chain that have also been part of the strategy's reference group. At the same time, three agencies have already been given the responsibility for continued work on the basis of the proposals presented here, so there is nothing to wait for. The pace of climate efforts must increase throughout the world and a key success factor is an increased rate of production of sustainable batteries. There is much to gain from Sweden taking the lead in this work.

Svante Axelsson
National Coordinator, Fossil Free Sweden

Working methods:

The work was led by Fossil Free Sweden and carried out in collaboration with EIT InnoEnergy and a reference group with representatives from the entire battery value chain. EIT InnoEnergy has provided reference data and texts, implemented workshops, and contributed experience from working in Europe with the European Battery Alliance.

Reference group:

The reference group was composed to represent all parts of the battery value chain and the group contributed to the preparation of the report through workshops and working groups, as well as input to the action plan.

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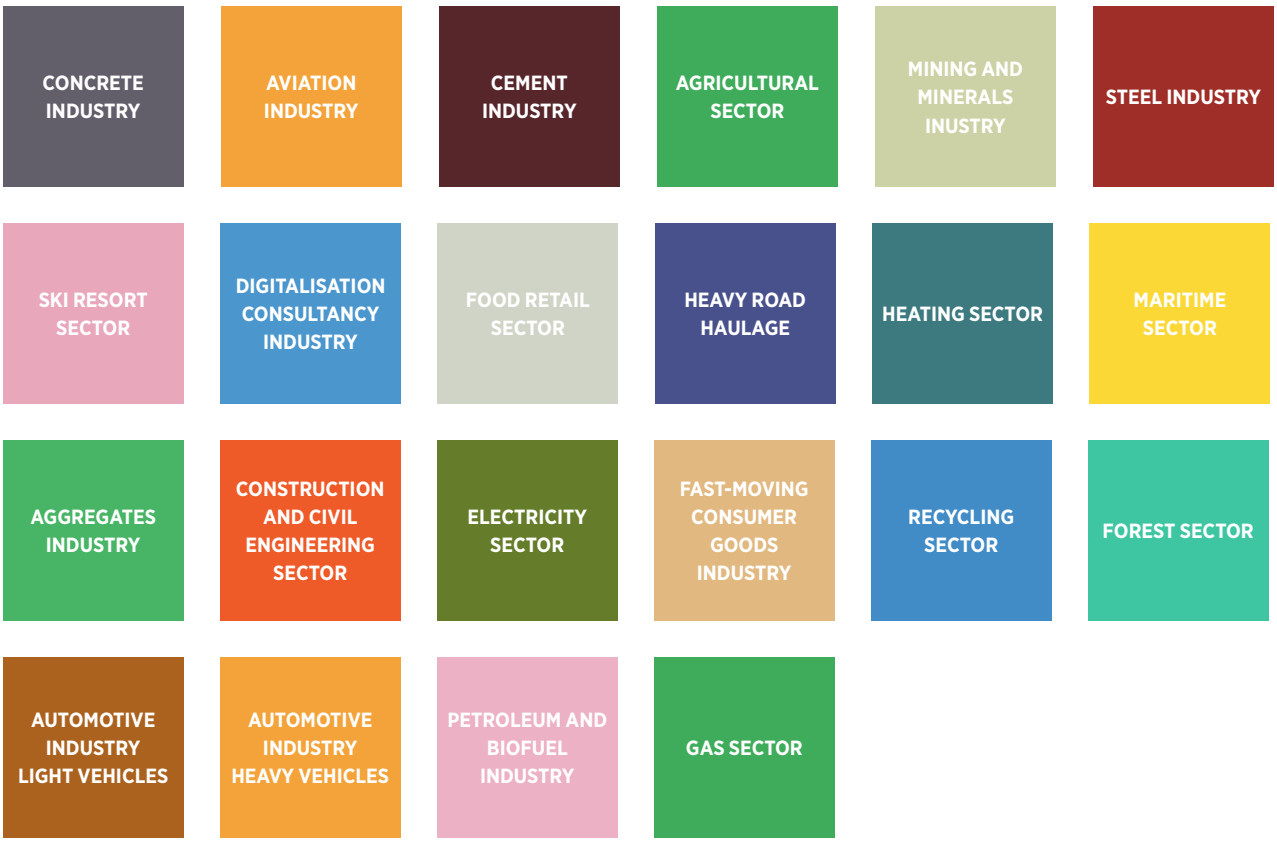
22 roadmaps for fossil free competitiveness

In the roadmaps for fossil free competitiveness 22 sectors describe how they can contribute to the Swedish climate target of climate neutrality by 2045. Together they also show in what key areas decisive action needs to be taken in order to succeed with the transition in a way that strengthens competitiveness. Because of that, Fossil Free Sweden has developed horisontal strategies together with the actors in the the different value chains to pave the way and show the road ahead.



Summary

Sweden is to be one of the first fossil-free welfare countries in the world and electrification is an important method to achieve this objective. Sustainable batteries will be a key technology, especially for a fossil-free energy and transport system. The development of sustainable battery production is not only important for achieving climate goals, but also enables the emergence of a competitive industry that creates growth and jobs throughout the battery value chain. Sweden has a strong position, with access to raw materials, cheap and fossil-free electricity, expertise and policy instruments that promote continued electrification with high environmental requirements. In addition, Sweden has strong actors along the entire value chain, from recycling and mining to the manufacture of active materials, complete battery cells and battery packs, to applications in the automotive industry as well as in the power system. The most crucial thing is to develop and secure the supply of raw materials and to ensure that the necessary skills exist to meet the needs of industry. Development will not take place by itself but will require well-thought-out investment from both industry and politics.

Figure 1: The circular and sustainable battery value chain.

A global industrial race is underway in the wake of the accelerating electrification of the vehicle fleet. High-performance, rechargeable lithium-ion batteries that are sustainably produced are central to the development of the entire transport and energy system and are needed in much greater volumes than can be produced today. To meet European demand, at least about 20-30 new large-scale plants for the production of battery cells are necessary. This requires investments in the order of EUR 100 billion in the EU over the next decade.

The European Battery Alliance, launched by the European Commission, has developed a cohesive European strategy for the entire value chain that includes measures to develop an innovative, sustainable and competitive battery eco-system in Europe. The objective is that the EU, and above all the European automotive industry, should not become dependent on the import of batteries, raw materials and technology, but instead create investments and jobs in a market that is estimated to have a turnover of EUR 250 billion per year from 2025.

The strategy presented here is based on Swedish goals and conditions and shows how potential in the Swedish value chain can contribute to fulfilling the European action plan. The strategy shows how several different industries can become fossil-free with the help of a sustainable and fossil-free battery value chain. By being a pioneer in this area, Sweden can also strengthen its position in the European battery eco-system.

Powerful and coordinated efforts are now required for Sweden to retain and develop its position and include more companies in the ongoing electrification of society. Incentives are needed for increased use of sustainable batteries on a general level to drive the market, not least as regards charging infrastructure for electric vehicles. Politicians and agencies also need to draw up clear regulations and transparent calculation models that ensure that environmental considerations are included throughout the value chain so that the batteries really are green and sustainable.

European actors have good prospects of growth in all

parts of the value chain. Sweden's main opportunity to compete and gain market share is increased cooperation within the value chain. But cooperation must also increase between central government and the business sector so that the economic risk for companies is minimised, for example by central government issuing various forms of credit guarantees. Central government and industry also need to work together to increase the pace of permit processes and new regulations. Central government should promote trial activities to test new regulation at the same time as new technologies and actors in the value chain should form consortia for relevant trials. Central government also needs to investigate the conditions for infrastructure and energy supply for new establishments in the battery value chain.

Electrification of industries and transportation in connection with the increase in renewable energy sources will continue to require access to minerals and metals. Reuse and recycling of raw materials is a crucial factor in achieving a sustainable battery value chain, as well as investments in minimising as far as possible the environmental and climate impact of primary production. Conditions need to be created to enable the mining industry to contribute to a more sustainable battery industry, for example through shorter permit processes. But it is also important that the mining projects themselves become more sustainable by becoming fossil-free and developing innovative concepts that link to the ongoing applied research to develop the "sustainable mine".

The transition to a fossil-free society with a focus on electrification needs new skills along the entire battery value chain and at all levels – from new upper secondary and higher education programmes to world-class research. Access to a skilled workforce is identified as a key area where central government and industry need to cooperate. For example, the Government should make a major national investment in more skills in the battery area and educate more than 1,000 people per year in battery skills in upper secondary school, university and at the research level.

To ensure continued positive and efficient development of a sustainable battery value chain in Sweden, central government and industry need to follow up on the proposals in the battery strategy, but also market Swedish strengths. This needs to be done in continued dialogue between all stakeholders, i.e. industry, research, decision-makers and civil society. The Swedish Energy Agency, the Swedish Environmental Protection Agency and the Geological Survey of Sweden (SGU) have been commissioned to develop inter-agency cooperation for Sweden's part in a sustainable European value chain for batteries. The remit includes analysing the proposals from this battery strategy and highlighting in relevant aspects the socio-economic consequences, which means that there is already a process in place for managing the strategy.

Below are prioritised recommendations highlighted in the strategy for a sustainable battery value chain and they are examined in more detail in Chapter 5.

1. **Sustainable batteries for a fossil-free energy and transport system: Stimulate demand for and use of sustainable batteries**
   - Accelerate the transition of the transport system through continued expansion of charging infrastructure for passenger cars, buses and freight services as well as for aviation, shipping, working machinery and industrial battery solutions
   - Stimulate battery storage in households and electricity grids
2. **Sustainable battery production, a new sustainable industry for Sweden: Create conditions for the development of a sustainable battery value chain in Sweden**
   - Develop financing models for larger, sustainable companies through green financing and risk sharing
   - Support trials of both technical and business innovations as well as new regulations
   - Contribute to attracting investments to Sweden and the Nordic region
3. **Recovery and extraction of materials for a sustainable and circular battery industry: Create conditions to enable the mining industry**

and the recycling industry to contribute with sustainably produced raw materials

- Create conditions to enable the mining industry to contribute to a more sustainable battery industry
- Stimulate extraction and recovery of secondary raw materials for increased circular material flows
- Create criteria for sustainable and traceable batteries through advocacy and collaboration in the development of sustainability criteria for batteries

4. **Skills development for a charged future: Invest in research, innovation and education for skills development**
    - Investments in increased skills and skills reorientation
    - Attract and retain international cutting-edge expertise in Sweden
    - Develop skills and training clusters close to the battery industry to create synergies

5. **Collaboration and dialogue for growth and export: Implement and follow up the action proposals through broad collaboration throughout the battery value chain**
    - Marketing of batteries as a sustainable industry in Sweden to attract investment and increase export

1. Introduction

1.1. Strategies to enable the roadmaps for fossil free competitiveness

Within the framework of Fossil Free Sweden, 22 industries have drawn up roadmaps for fossil free competitiveness. The roadmaps show how each industry will reach net-zero greenhouse gas emissions by 2045 with increased competitiveness and the policies required to achieve the targets. The roadmaps were drawn up by the industries themselves and together they form a puzzle that shows how Sweden can become one of the first fossil-free welfare countries in the world.

However, for the pieces of the puzzle to fall into place, deeper analyses of common challenges, conflicting objectives and synergies of the different roadmaps are required. This is the setting in which Fossil Free Sweden develops strategies in prioritised areas.

Electrification is an important enabler for several of the roadmaps. A strong and expanded power grid will be an important cog, but the roadmaps are also dependent on the availability of the latest generation of high-performance rechargeable batteries produced with little climate and environmental impact. Batteries are already needed in working machinery, passenger cars and power grids, and in the near future demand from shipping and aviation will also increase rapidly. In addition, Sweden has unique potential for delivering sustainable and circular batteries, which in itself will be a new export industry.

One of the goals in the roadmap of the mining and minerals industry is for the first fossil free mine to be operating in Sweden by 2035. This will require a high degree of digitalisation, efficiency and electrification, largely with the help of battery-powered working machinery. Together with reduced emissions in the refinement process as well, the industry will be able to supply metals and minerals with a very low carbon footprint for battery and other production.

The Swedish electricity industry is largely fossil-free already and is therefore a key actor for other industries to reach their climate goals. A robust and flexible grid will be needed, and batteries are highlighted in the electricity roadmap as one of several enablers for various electrical system services that can help to provide existing and new industries with good power quality.

Several roadmaps on the user side raise the need for batteries for electrification. The automotive industry's target in its roadmap for passenger cars is that electric cars will represent 80 per cent of the new car market by 2030. The target for heavy vehicles is 50 per cent the same year. The aviation industry also has progressive plans for electrification. There is great potential for electric flights on shorter routes, and the goal is that Swedish manufacturers will be able to produce a fully battery-powered aircraft as early as 2025. The shipping industry sees a similar development for ferry traffic on shorter routes and already today a battery-powered ferry runs between Helsingborg and Helsingör. Battery operation, together with biofuels and renewable gases in working machines, will also contribute to fossil-free operation at, for example, construction sites, in the rock materials industry and in the forest industry.

1.2. Why a battery strategy for Sweden?

Investments in new technology lay the foundation for a country's future economic growth and competitiveness. Investments create a dynamic in companies and in the labour market and lay the foundation for new resources and capabilities at both central and regional levels.[1]

Skilful industrial policy gives domestic industry a head start in global competition.[2] This is not due to any market failure, but the ability of central government to facilitate the utilisation of new opportunities. A head start for a country within a certain technology can affect the development of technology to suit the country's comparative advantages and continued ability to produce at

[1] Nilsson, L. J. (Red.), Johansson, B. (Red.), Ericsson, K., Hildingsson, R., Khan, J., Kronsell, A., Andersson, F. N. G., Svensson, O., Hansen, T., Coenen, L., & Ahman, M. (2017). Nollutslapp i basindustrin - forutsattningar for en ny industripolitik. (101 uppl.) (IMES/EESS report). Miljo- och energisystem, LTH, Lunds universitet.

[2] Rodrik, D. (2014). Green industrial policy. Oxford Review of Economic Policy 30(3): 469-491.

lower relative cost and with higher product quality. The connection is illustrated by the establishment of one or more battery plants in Sweden that create opportunities for further investments in other parts of the battery value chain. In addition to significant deposits of graphite and various metals, which in some cases are used for the production of lithium-ion batteries, Sweden has complementary industries for further processing, system suppliers of process technology, such as Atlas Copco, Sandvik and ABB. At the same time, there are large and competent customers for batteries such as Epiroc, Husqvarna Group, Volvo AB, Volvo Cars and Scania. Sweden also has several leading companies in recovery of minerals and battery metals with ambitious goals. Boliden, Ragnsells and Stena Recycling already have on-going recovery of metals and in Västerås Northvolt is setting up its demo plant for recycling lithium-ion batteries with the aim of producing batteries containing 50 percent recycled raw material by 2030. Sweden thus has good prospects of becoming a global leader when it comes to producing, using and recycling sustainable batteries with the least possible environmental impact if it can be ensured that all parts of the value chain are working towards this common objective. In support of this, there is already an established and internationally renowned Swedish research environment at the different higher education institutions.

Coordinated initiatives throughout the battery value chain, from raw material supply, battery production and various areas of use to their recycling, are facilitated by a common vision and a strategy with central government support. This strategy can thus generate significant positive effects on the Swedish economy.

According to international rankings, Sweden holds good initial position given a number of initiatives in recent years and is also expected to strengthen this position. But the development in Sweden depends on how well government, parliament and industry can collaborate to rapidly develop institutions, business models and regulations to remove obstacles to new technological opportunities. Long-term success also requires that this be combined with high sustainability requirements. Development may depend on whether individual parts function or not.

It is also a matter of individual competence. Regulations only work if there are competent officials at the agencies that can apply them. Profitable technical opportunities need business models and financial actors who understand how they work. Local and global environmental impacts need to be balanced in permit processes.

Sweden has been a driving force in designing the European battery strategy and major investments, not least in research and development, are ongoing in Sweden. However, so far there has been no coherent strategy that identifies all the ideas developed in the preparation of the European strategy and that adapts the recommendations to Swedish conditions. Advances in battery technology will require changes for important industries in Sweden. With a well-thought out strategy, Sweden can benefit from these industrial investments throughout the battery value chain.

Cheaper and better performing batteries will accelerate the electrification that replaces fossil energy in the transport sector. The fast-growing demand for electric cars, trucks and busses is driving up production volumes and reducing costs. The greatly reduced cost makes batteries a realistic and cost-effective way to deliver many of the system services required in the electricity system, such as frequency maintenance and voltage stability. The power system will have access to an entirely new component that can be installed quickly and flexibly, which is especially important when the production system changes, and the share of non-synchronous generation increases.

The ability to manufacture and use batteries with good environmental performance will determine Sweden's ability to achieve climate targets. For the automotive industry, rapid development of the battery industry is crucial to competitiveness over the next decade.

Sweden and the Nordic countries play an important role in European development because we have natural resources in the form of clean cheap energy and important raw materials for the manufacture of battery cells with good environmental performance.

With a strategy to coordinate decisions in Swedish political assemblies and industries with European policy, there are good prospects of attracting major investments that create employment and economic growth in Sweden. This has already led to the establishment of Northvolt's battery production in Västerås and Skellef-


northvolt

teå, as well as extensive cooperation agreements with European vehicle manufacturers.

Natural resources are not the only factor. In Sweden there is also an industrial tradition, process know-how and knowledge of large-scale industrial establishments. The leadership of the European research initiative Battery 2030+[3] is a confirmation of Sweden's prominent role in research on the sustainable batteries of the future. Several strong actors on the user side have developed and driven the industrial development of battery applications, which gives Sweden favourable conditions.

If the Swedish Government, agencies and industry actors remain active, Sweden will not only achieve its own climate policy goals, but through export will contribute to Europe and the world reducing fossil use.

[3] Battery 2030+: https://battery2030.eu/ [2020-11-05]

2. Conditions for the development of a sustainable battery value chain in Sweden

2.1. Conditions for the battery industry in Sweden – strengths and areas for development

Sweden can become a leader in developing, producing and recycling the world's most sustainable batteries. It is important that central government and industry build on the areas of strength identified, but this also applies to the areas where the conditions are good, but which are as yet relatively undeveloped. One example is in raw material supply, where Sweden has geological potential

Figure 2: Overview of the Swedish battery eco-system.

and a world-leading industrial cluster in the mining sector, but the extraction is hampered by complex permit processes, among other things.

Compared to other European countries, Sweden commands a large share of the value chain. This is not least due to the world-leading automotive industry, both in terms of passenger cars, heavy trucks, busses and industrial applications. The strong automotive industry has successfully acted as requirement setter for the growing battery industry and there is a tradition of raw material extraction, refinement and recycling. As regards the raw material supply stage, the Swedish mining cluster is a leader in productivity, automation and the development towards fossil-free mining. This knowledge can be used to extract battery minerals in the future, even if this is not done at present in Sweden. Research on batteries is also an area where Sweden maintains a high international standard, for example with the research team at the Ångström Laboratory at Uppsala University and as leader of the EU's collaborative project on the battery technology of the future, Battery 2030+.

Sweden's access to clean and cheap electrical energy is a requirement for being able to produce batteries with a low carbon footprint at competitive prices. Sweden has a good position here compared to other European countries. By ensuring good environmental performance from a lifecycle perspective, batteries become part of a climate-friendly transport and energy system. In that way a sustainable and competitive battery value chain supports Sweden's ambitions to become the first fossil-free welfare country in the world.

The image provides an overview of identified strength areas and development needs along the value chain identified during the work on the battery strategy. The parts of the value chain where Sweden has strengths are in raw materials, production of battery cells, use, and recycling.

There are several overarching strengths and development needs. Skills development is required in the transition to an electrified society with production and use of batteries in more and more applications. This requires a long-term perspective in research and education initiatives to meet the lack of knowledge at all levels of education. There is also potential in active materials and packs, although the volumes are not yet very large.

Swedish companies have great opportunities to take advantage of Sweden's status as an IT nation to increase the value added of batteries by adding important features for traceability, lifetime optimisation and planning of charging and heating. In the next few years, software engineers with a focus on batteries will be in short supply in the world economy. Sweden should be able to quickly offer advanced IT services in the battery sector. The focus on electronics, cloud services and system development gives Sweden a place among world leaders that suits battery applications, despite its small population. In the event of a growing global demand for batteries, Sweden is well placed to take market shares and gain a prominent position as a producer of sustainable batteries in the European market. Well-coordinated national and international co-operation, with a focus on the Nordic countries, and strong connections with the European battery industry support the competitiveness of the Swedish battery ecosystem.

2.2. The importance of batteries for industry and employment with a focus on the transport sector

Electrification will play a major role in the transition to a

fossil-free vehicle fleet. Batteries and electric motors will replace fuel tanks, traditional internal combustion engines and gearboxes. This will have major consequences for vehicle manufacturers and their subcontractors and thus also employment. This is especially true in Sweden, where the automotive industry is relatively larger than in most European countries. Access to batteries and knowledge of their production will be crucial for the automotive industry in the 2000s. Important parts of the battery value chain still exist outside Europe, which makes Swedish actors dependent on imports, both in terms of supply of materials to produce batteries and the skills needed for the production and use of batteries.

The automotive industry is of great importance to Europe. More than 14.6 million Europeans work directly or indirectly in the automotive industry, representing 6.7 per cent of total employment in the EU. There are 2.7 million people working directly or indirectly in vehicle manufacturing.

Sweden is one of the countries in Europe that is most dependent on its automotive industry. Only Slovakia and Romania have more people employed in the automotive industry in relation to the industry's total employment.

Europe has been good at all parts of the automotive industry's traditional value chain, but that will change quickly if production and expertise in battery manufacturing are not built up. The electric powertrain accounts for 30-40 per cent of the value of an electric car and up to 70 per cent in an electric truck and is crucial to the car's performance. Internal combustion engines and their components account for only about 26 per cent of the value added of a vehicle. These components are largely manufactured by vehicle manufacturers in Europe who, with their current business models, risk losing their employment opportunities in the transition to the production of electric vehicles. The extent to which the European industry can benefit from the future transition depends on where in the future value chain for electric vehicles it wants to be positioned, which is largely determined by where the production of battery cells and complete batteries takes place.

Initiatives in the form of training will be required if EU Member States do not want to lose jobs when the focus shifts from mechanics to electronics and digitalisation. Several reports indicate that new jobs will be created during electrification, provided that the entire vehicle, including batteries, is manufactured in Europe.[4, 5]

Overall, however, the transition to electric power is fundamentally positive for Sweden, as there is a relatively strong automotive and electrical industry as well as access to raw materials for battery production. This provides a good framework for Sweden to take market share in the vigorously growing European battery industry if politicians, government agencies and the business sector act fast and coordinate their efforts.

[4] Harrison, P. (2017). Low-carbon cars in Germany: A summary of socio-economic impacts. Cambridge Econometrics.
[5] Transport & Environment (2017). How will electric vehicle transition impact EU jobs?

SHARE OF DIRECT AUTOMOTIVE EMPLOYMENT IN TOTAL MANUFACTURING
BY COUNTRY / 2018

Source: Eurostat

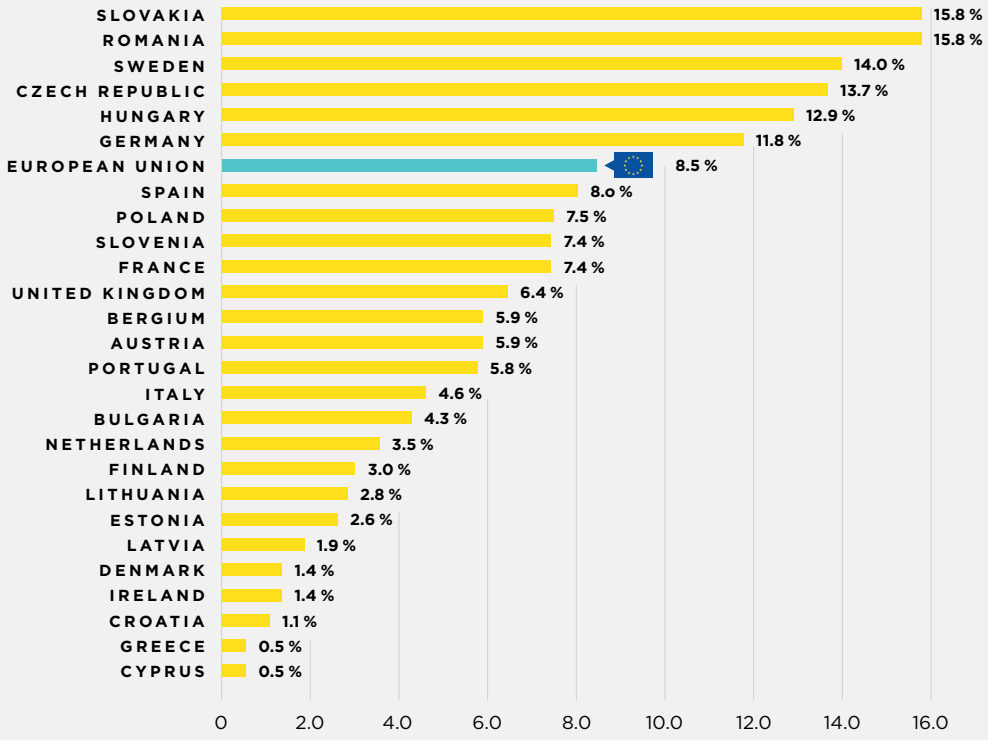


Figure 3: The figure shows Sweden's great dependence on a viable automotive industry when comparing the percentage of people employed in the automotive industry in relation to total employment in industry.

VEHICLE MANUFACTURING JOB PROJECTIONS FOR 2030

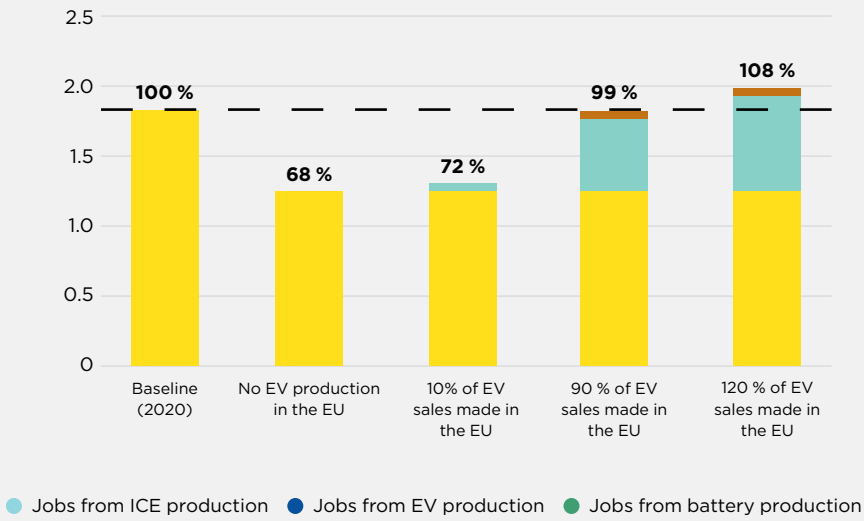


Figure 4: Domestic vehicle manufacturing combined with battery production is decisive for avoiding significant workplace losses. Source: Transport & Environment (2017).

3. Advances in technology and innovation

3.1. Sustainable batteries as a condition for the green transition

Electrification has an important role to play in Sweden's achievement of climate goals and emergence as the first fossil-free welfare country in the world. Sustainable batteries manufactured in Europe support the transition of the energy and transport system by reducing greenhouse emissions considerably and contribute to several UN Sustainable Development Goals.

The superior environmental performance of electric vehicles from a lifecycle perspective has been confirmed in several new studies, but the manufacturing process of battery cells and the raw material for the batteries are energy-intensive.[6,7] The battery's carbon footprint will thus determine the total climate impact of the electric vehicle and battery production must take place with as little environmental impact as possible and under strict environmental protection regulations. An electricity and energy system with as low a climate footprint as possible across the entire EU will thus be important for all parts of the battery value chain.

Although environmental and climate impacts are perhaps the most obvious sustainability aspect in the production of sustainable batteries, there is also a need to take into account the other sustainability dimensions that address economic aspects (such as reliable supply of raw materials, development of new circular business models, etc.) and social aspects (such as human rights, education opportunities, etc.) to make the entire battery value chain truly sustainable.

Since the establishment of a battery industry in Europe began to be discussed around 2016, sustainability has been important. The issue has been pursued by the European Commission with the support of several of the major German vehicle manufacturers. A new regulatory framework for batteries that specifies requirements for environmental performance will be presented by the Commission in November 2020. In addition to regulations, there are currently also strong commercial reasons to focus on sustainability in supply chains. The vehicle industry cannot afford another "dieselgate". How companies are perceived in relation to the environment is crucial for customers' choice of car.

Europe is also well-equipped to produce batteries with good sustainability performance. The major European vehicle manufacturers have made many commitments to produce "zero-emission" cars and commercial vehicles that also include manufacture. Through its uniquely low CO2 emissions in electricity production Sweden has a direct advantage. Sweden can, through large-scale production, combine very low emissions with low cost and retain its environmental advantage.

But the environmental advantage can be further improved by extracting raw materials in fully electrified mines and through efficient recycling. Both these aspects are discussed later on in the strategy.

In Sweden, it is possible to impose high requirements on the entire supply chain if this new industry is built up with sustainability as a guiding principle while stimulating demand for sustainably produced batteries.

3.2. Overview of available battery technologies

Energy storage technologies are often described in the form of diagrams that contain output and energy or storage time. Different technologies are best suited to different areas for output and energy.

[6] Knobloch, F., Hanssen, S., Lam, A. et al. (2020). Net emission reductions from electric cars and heat pumps in 59 world regions over time. Nat Sustain 3, 437–447. https://doi.org/10.1038/s41893-020-0488-7

[7] LVI (2019) Lithium-Ion Vehicle Battery Production.

Figure 5 shows where the different technologies have the greatest areas of use. As long as it is a matter of moderate output, up to ten megawatts and times of less than six hours then batteries are often the best option. The other technologies that are close in application, such as flywheels, have not been able to keep up with the heavy price reduction of lithium-ion batteries. Since most applications have so far been in this area, lithium-ion batteries have taken a large market share. But when the need to store larger amounts of energy over a longer period of time increases, heat layers or chemical layers of various kinds, such as hydrogen, become more attractive options. There are more dimensions that do not fit into a diagram. One is the number of cycles and here electrostatic super capacitors have an advantage. They can handle a very large number of cycles and thus have a given role in applications that require many cycles, high output but small amounts of energy.

Lithium-ion batteries of various compositions are currently the battery technology used for all major applications; in cars, buses, trucks, bicycles and power tools, and increasingly in industrial applications. Given the dramatic cost reduction due to manufacturing volumes over the past decade, lithium-ion batteries have also taken over the market for stationary batteries.

Looking ahead, the greatest development and technological advances are also expected to take place in the lithium-ion battery family. Energy density has almost tripled in 10 years and development is expected to continue for at least another 10 years.

Thus, the next technology generation is very likely to be found in batteries with lithium-based chemistries. Those mentioned most in this context at the moment are dry “solid state” and lithium-sulphur batteries that could be in production in 3-5 years, and then ready for commercial mass production at low cost. However, the constant aim is to develop more resource-efficient batteries with fewer hazardous substances. The batteries of the future will be produced with more recycled materi-

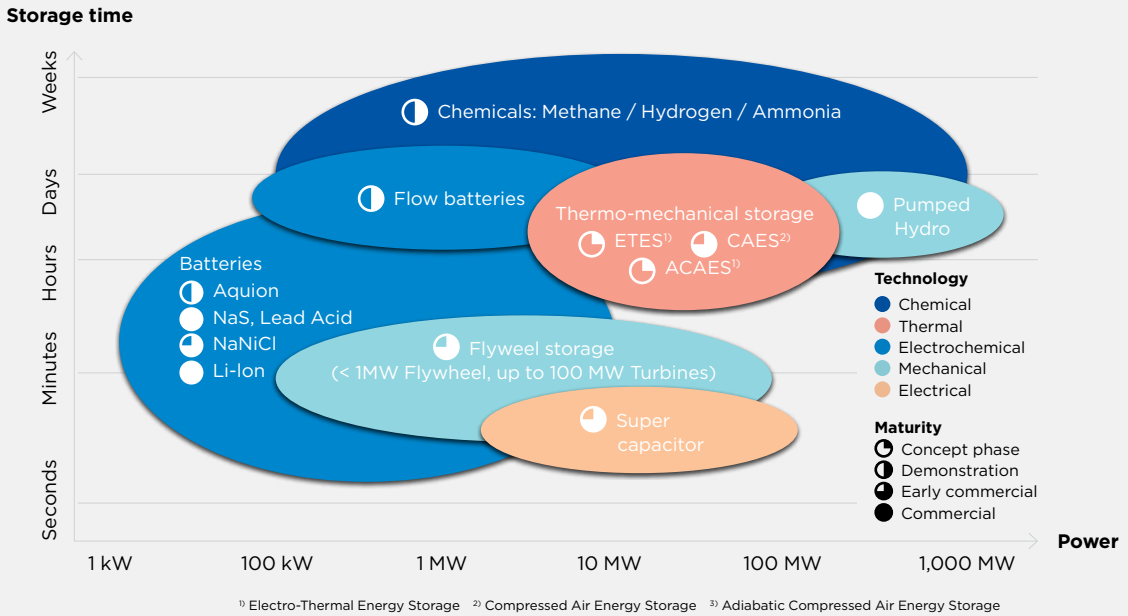


Figure 5: A typical diagram of this type reports a range of technologies to visualise different areas of use based on output and energy.[8]

[8] Siemens (2017) Green Ammonia. 1st NH3 European event: https://www.ammoniaenergy.org/wp-content/uploads/2019/12/NH3-Energy-2017-Ian-Wilkinson.pdf

als, while reducing the use of hazardous substances as manufacturers replace them with other materials. More and more technologies are being developed within the lithium-ion battery family, and one example is the most energy-dense batteries used in vehicles. Here, the cobalt content of car batteries has gradually decreased from about 12 per cent to today's 4 per cent (NMC811). In addition, there are completely cobalt-free technologies (LFP or LiFePO4) that are achieving ever higher energy density and thus becoming a realistic alternative even in passenger cars.

The increase in the energy density of the batteries and more efficient control systems also provide increased resource efficiency as a smaller amount of metal is needed with retained functionality.

It takes a long time from being able to manufacture a new type of battery to being able to mass-produce it at low cost. But Tesla very recently announced that it intends to speed up the development of technology and costs and has set very aggressive targets, such as increasing the energy density of the batteries and thus the range of electric cars by 54 per cent while reducing battery costs by 56 per cent. All this within about 3 years. See illustration 6:

The development not only relates to battery cells, but the entire system, including packaging batteries with control systems and integrated with the vehicle. Similar work is also underway at other manufacturers and it is likely that these targets can be achieved within five years in mass production. In addition, new cells utilising solid

LITHIUM-ION BATTERY PRICES KEEP FALLING

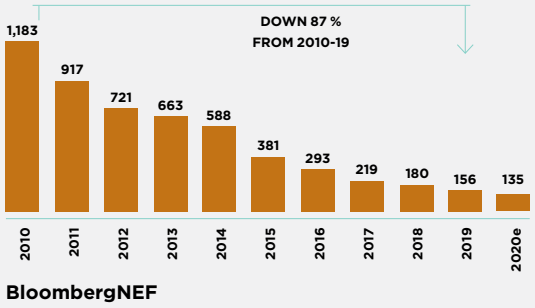
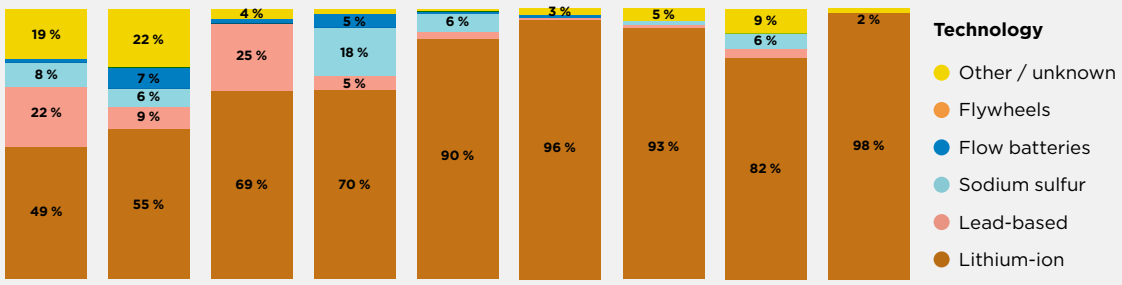


Figure 6: Falling prices for lithium-ion batteries. Source: BNEF 2019 lithium-ion battery price survey

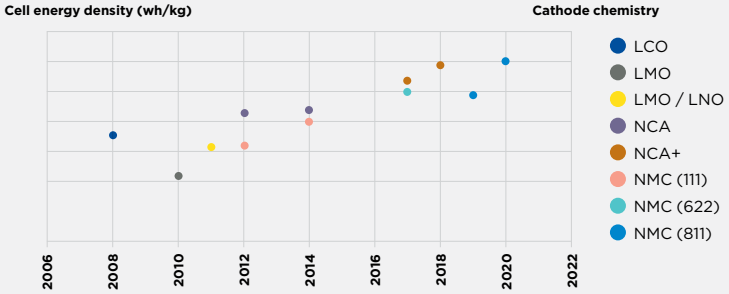
TECHNOLOGY MIX OF COMMISSIONED UTILITY-SCALE ENERGY STORAGE PROJECTS BASED ON POWER OUTPUT



Source: BloombergNEF. Note: Excludes pumped hydro and compressed air energy storage projects. If multiple technologies are selected, the capacity is divided equally amongst them.

Figure 7: The comparison shows the great predominance of lithium batteries.

BATTERY-CELL ENERGY DENSITIES HAVE ALMOST TRIPLED SINCE 2010



Source: BNEF, company reports

BloombergNEF

DEVELOPMENT OF THE LITHIUM-ION TECHNOLOGY

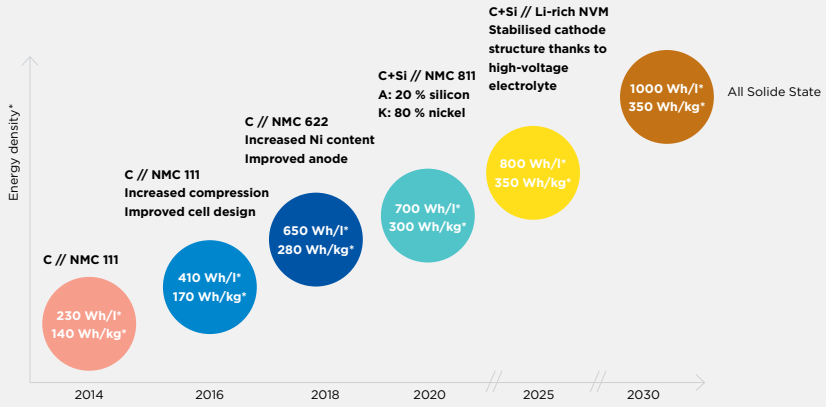


Figure 8: Development of lithium-ion batteries towards higher energy density. Source BNEF and Volkswagen.

state, lithium sulphur and similar technologies are being developed that deliver even higher energy density and potentially further cost reductions. This is worth keeping in mind when assessing the competitiveness of other technical options.

3.3. Development in the recovery of battery metals

The technical potential for recycling is high. Within the frameworks of the strategic energy plan, the SET Plan and the technology and innovation platform ETIP Batteries Europe the EU sets targets for the recycling potential of various battery metals from lithium-ion batteries, such as lithium: 35 per cent in 2020 to 70 per cent in 2030 and 95 per cent for cobalt in 2030. The upcoming regulation for batteries will also set entirely new targets for the collection of batteries and recovery efficiency in recycling processes.[9]

The extensive electrification in society combined with more developed batteries means that a new battery is used for between 6-15 years in a vehicle application, for example, and can then be used for 6-10 years in an

[9] EU Commission, New regulatory framework for Batteries and Waste Batteries, that among other things will replace the so-called Battery Directive. Scheduled Dec 2020.

LITHIUM DEMAND VS FINANCED AND UNIFINANCED SUPPLY (MT LCE)

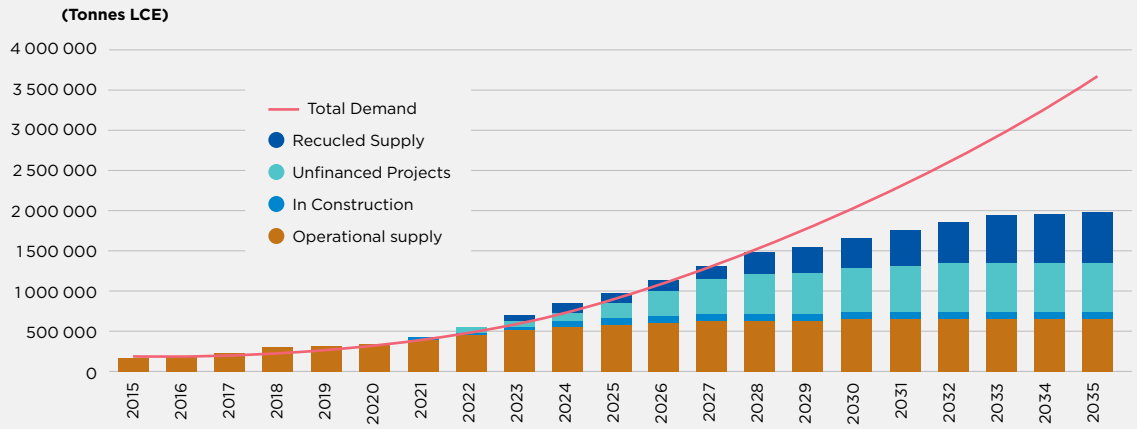


Figure 9: The drastically increasing demand in combination with the challenge of financing new projects will lead to a shortage of raw materials for batteries. As can be seen, the shortage will not either be possible to make up entirely by recycling in the foreseeable future.[10]

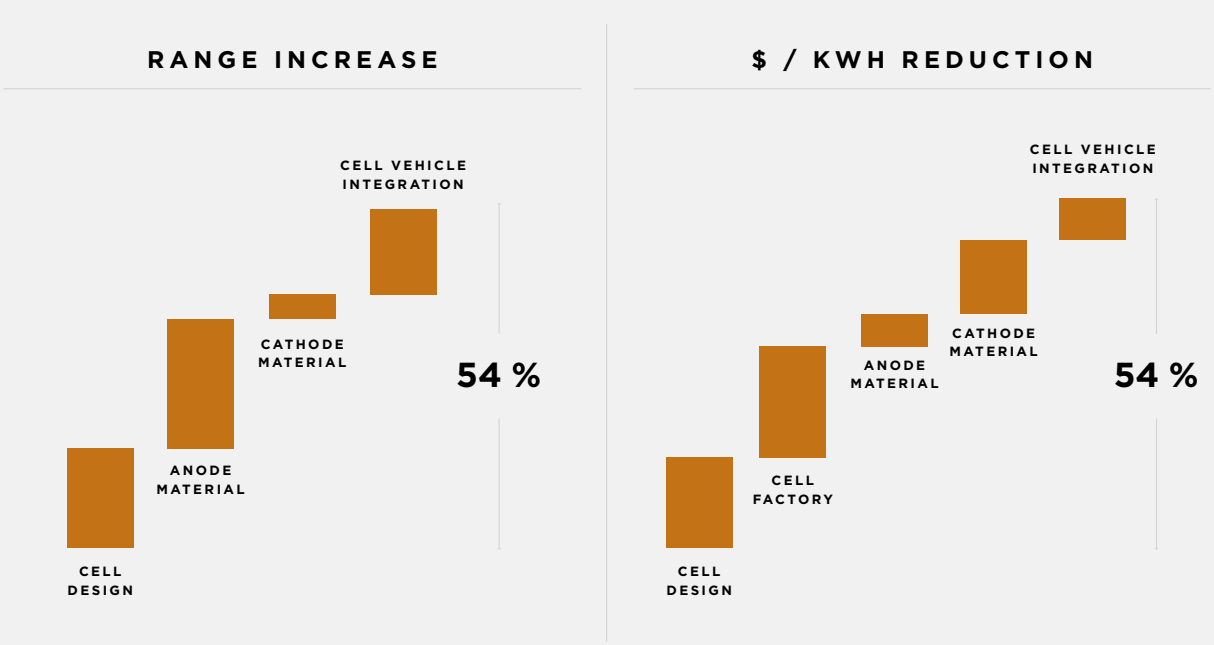


Figure 10: Tesla's plans for increased range and reduced battery costs with increased energy density. Source: Tesla.

[10] Source: Benchmark Minerals, 2020

application with less demanding conditions, such as an electrical system application. In practice, this means that a battery manufacturer who wants to be able to recover battery metals may have to wait 12-25 years to get the battery back before it can return as raw material in production.

However, the recycling industry needs to prepare already for the large-scale recycling that will be required when today's and tomorrow's batteries are worn out and available. Scaling up recycling plants is thus an industrial challenge when profitability and volume are not yet available, but it also provides an opportunity to really create circular material flows in Europe.

At the same time, the metals in batteries are undergoing development. The increase in the energy density of the batteries and more efficient control systems also provide increased resource efficiency, as a smaller amount of metals is needed for retained functionality.

Overall, this picture of the development and approach corresponds largely with the Swedish Society for Nature Conservation's "mineral hierarchy" with its starting point in using mineral resources more effectively, reusing and repairing to then recycle materials already mined. The last step of the hierarchy is about sustainable extraction of primary minerals.

The challenges faced by the recycling industry are largely about the collection of batteries. The few car batteries that are at the end of their lives now are often left in the system in one way or another, but with the greatly increased production capacity and sales volume, the collection systems will become increasingly important. Since the collection needs to take place after the third or fourth battery owner, it is difficult to get an overview of the batteries' location and how the best incentives can be designed. One possible development when the shortage of critical metals increases is for battery producers to retain ownership of the batteries throughout their lifecycle and for the batteries to be only leased by the vehicle owner.

Norway has an industry initiative "Batteri Retur" that collects and dismantles vehicle batteries and builds them into new modules. Sweden's equivalent to this is "El-kretsen", which offers a collection solution for the new generation of industrial and electric car batteries, but car manufacturers and those who collect batteries from electric cars can also conclude agreements directly with recyclers.

4. Development in the EU in the wake of the pandemic

4.1. Emergence of the European Battery Alliance

Batteries are at the heart of one of the largest industrial transformations in Europe of the post-war period. It is about the survival of the automotive industry as well as a battery market of EUR 250 billion and more than 1 million jobs. This was established by EU Commissioner Maroš Šefčovic, who launched the European Battery Alliance in 2017 with the aim of building a sustainable battery value chain in Europe. Within the Alliance, actions were developed together with stakeholders, including industry and Member States. These then formed the basis for the EU›s strategic action plan for batteries, which was published in the spring of 2018. In 2018, the Alliance launched a Strategic Battery Action Plan, which has been developed in consultation with stakeholders, including industry and Member States The plan includes goals in six areas spanning the entire battery value chain. It is about securing access to raw materials, training, support for research and development, as well as financial support instruments, such as the Important Projects of Common European Interest (IPCEI). The latter enables support from Member States to projects where Member States are able to cover a higher share of project costs than normal in the application of state aid rules as well as supporting industrial use.

The European Commission has repeatedly highlighted the ambition of sustainability in all stages of the battery value chain and the central role of batteries in the transition to a fossil-free society, including the European Green Deal, the circular economy action plan and the EU's new industrial strategy.

The Swedish battery strategy is based on the EU's strategic action plan and the Green Deal that stakes out the direction for a European battery industry – but is based on Swedish areas of strength and adapts the proposals to national conditions and development areas.

Just as for the European action plan, cooperation and a holistic approach are important. This applies not only along the Swedish battery value chain but is also a matter of seeing the potential for co-operation with other countries, especially in the Nordic region.

4.2. Possible impact of COVID-19 on the battery value chain

The vulnerability of global value chains has been made clear during the pandemic of 2020, which has disrupted the global social system. Although the final effects are still not known, some conclusions can start to be drawn that are relevant to the Swedish battery strategy. Some of the more obvious consequences are dealt with here. By far the largest market for lithium-ion batteries is the transport sector and in this sector passenger cars largely predominate. It is therefore of particular interest to study how this market is affected by the pandemic. The research company BloombergNEF (BNEF) recently conducted a global study in its annual report Electric Vehicle Outlook[14] and the result is that:

- The forecast shows that the passenger car market in total will not recover until 2025 and also that the market will peak in 2036, after which it will decline.
- Sales of rechargeable vehicles have continued to increase even during the pandemic, despite the decline in the total vehicle market, and the long-

[11] EU Commission, European Battery Alliance, https://ec.europa.eu/growth/industry/policy/european-battery-alliance_en [2020-11-05]
[12] EBA250, https://www.eba250.com/ [2020-11-05]
[13] EU Commission, COM(2018) 293 final ANNEX 2 (2018), Strategic Action Plan on Batteries.
[14] BloombergNEF (2020). Electric Vehicle Outlook. BloombergNEF. Executive Summary.

term sales forecast remains unchanged. One of the reasons the overall market will decline in the longer term is the impact of car sharing and autonomous taxis.

The increase in sales of rechargeable cars began before the pandemic. Several important countries have launched new incentives for rechargeable vehicles during the pandemic, which means that these are currently the cheapest option in all classes. BNEF's analysis states that it is the purchase price that will limit sales of rechargeable cars until 2030. After 2030, the lack of charging infrastructure is instead identified as the greatest obstacle to electrification of the vehicle fleet. Political policy instruments, such as support for the expansion of infrastructure, will therefore be important.

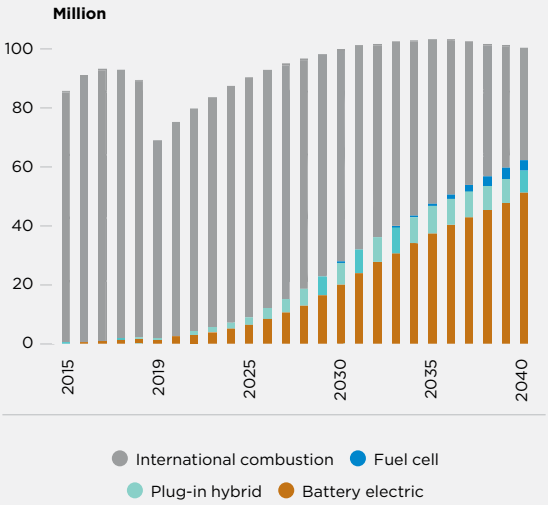


Figure 11: The effect of Covid-19 on sales of cars. Source: BNEF.

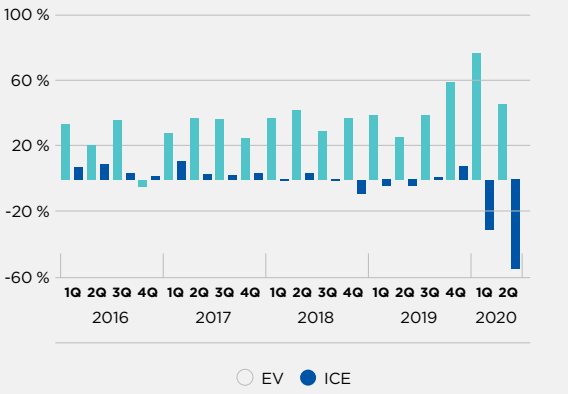


Figure 12: Change in sales of electric vehicles (EV) and internal combustion engine driven vehicles (ICE). Source: BNEF.

EV SHARE OF NEW PASSENGER VEHICLE SALES BY REGION

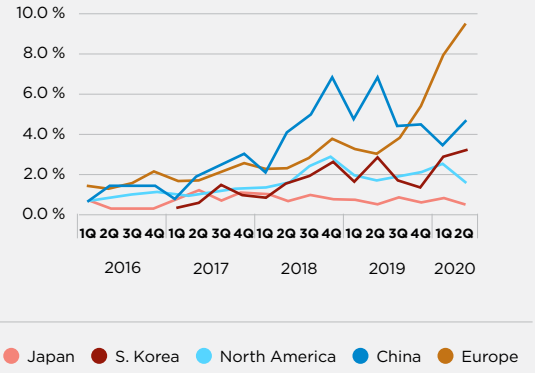


Figure 13: EV share of new passenger vehicle sales by region. Source: Automotorsport and BNEF.

Electrification in other parts of the transport sector is also evident. The market share of fully electric three-wheelers and two-wheelers is already large today, with 30 per cent of all new three- and two-wheelers. According to forecasts from BNEF, the market share is expected to rise to 77 per cent by 2040.

Also in public transport, electrification is gaining market share and electric buses will dominate sales of buses and in 2040 will account for 67 per cent of the entire bus fleet globally. The same is expected for the heavy vehicle sector.

For stationary batteries, the largest market is directly linked to an increased breakthrough of solar and wind power. Stationary batteries are expected to increase substantially but nevertheless still account for less than 10 per cent of the transport sector market.

In its new strategy, the European Commission has raised the ambitions for emission reductions in 2030 from 40 per cent to 60 per cent. The initial analyses indicate that emissions from passenger cars must be reduced by 50 per cent from 2021 to 2030 compared to 37.5 per cent previously. This will greatly drive the transition speed for the power industry and the transport sector, thereby also increasing demand for batteries.

In a recently published report, the Climate Institute anticipates a total ban on the sale of fossil-powered vehicles already in 2028 to reach the targets.[15] The year is debatable, but the stricter emissions targets mean that earlier forecasts regarding the growth of electric vehicles must be revised to a faster impact and faster growth of the battery market. Several countries have already announced bans on new sales of fossil-powered cars.

4.3. EU financing of the Green Deal and temporary support packages and response to COVID-19

In autumn 2019 the European Commission launched its new growth strategy, the Green Deal. It aims to make the economy sustainable and covers all sectors, including the transport and energy sector as well as various industries and is therefore relevant to the battery value chain.

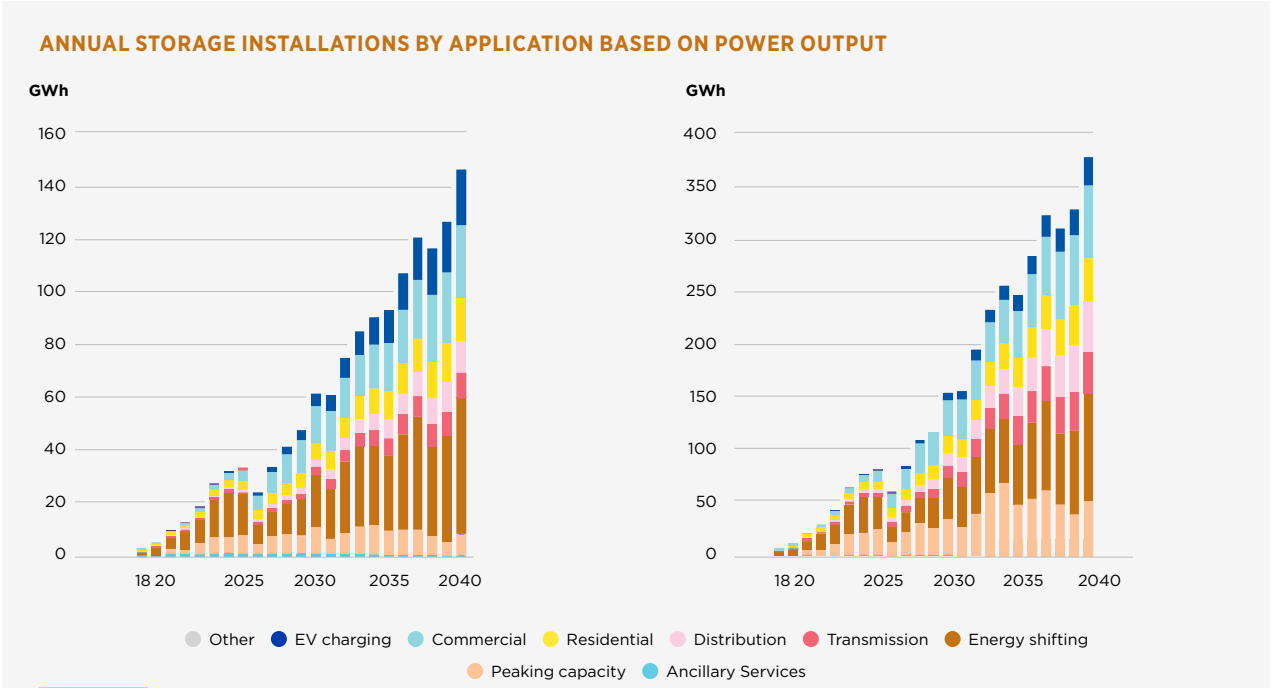


Figure 14: Annual storage installations by application based on power output. Source: BNEF

[15] New Climate Institute (2020): A radical transformation of mobility in Europe: Exploring the decarbonisation of the transport sector by 2040 Explorative scenario and related policy packages.

The Green Deal covers efficient use of resources by moving to a clean, circular economy, but also describes what investments are needed and what financing tools are available.

The European Green Deal Investment Plan (EGDIP), also known as the Sustainable Europe Investment Plan (SEIP) will mobilise at least EUR 1,000 billion in sustainable investments in the coming decade. Part of the plan, the Just Transition Mechanism, will be directed towards a fair and green transition. In the period 2021-2027 at least EUR 100 billion will be directed towards supporting workers and citizens of the regions most affected by the transition to a fossil-free society.

The European Investment Plan for the Green Deal has three main objectives:

1. **Increase funding for the transition and mobilise at least EUR 1 trillion to support sustainable investments in the coming decade through the EU's budget and associated instruments, especially InvestEU.**
2. **Create a framework for private investors and the public sector that supports sustainable investments.**
3. **Provide support to public administrations and project managers to identify, structure and implement sustainable projects.**

In response to the economic impact of the pandemic, the European Commission proposed further financial support measures under the collective name NextGenerationEU. Together with the EU's next long-term budget for 2021-2027 (Multi-Annual Framework MFF 2021-2027), the total financial support channelled through the EU budget would thus amount to over EUR 1.8 trillion.

The European Council has agreed on an appropriation of 672.5 billion to the "Recovery and Resilience Facility". The Recovery and Resilience Facility is central to Next Generation EU, whose appropriations are to be allocated in the form of both loans and direct grants to Member States for implementing investments and reforms. Sweden is expected to receive SEK 40 billion.

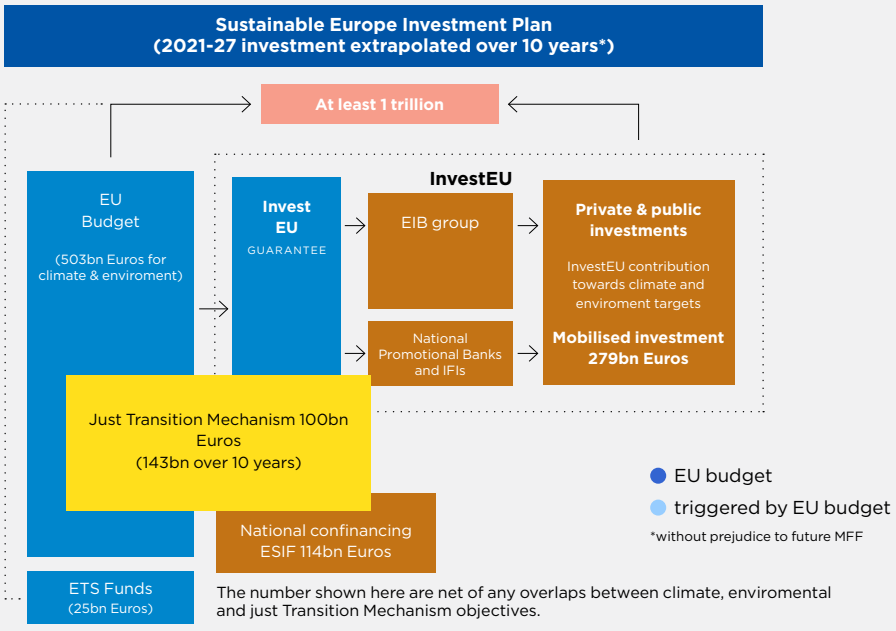


Figure 15: Illustration of various financing components totalling at least EUR 1 trillion during the period 2021–2030 according to the European Investment Plan for the Green Deal. Source: European Commission.

In order to benefit from these funds, Member States need to compile a recovery and resilience plan.[16] Several points mentioned by the Commission have a bearing on the measures in this strategy for a sustainable battery value chain, such as:

- Investments in smart and sustainable mobility projects for the entire battery value chain (from materials to recycling).
- Reduce industrial greenhouse gas emissions, investments in energy efficiency in the industrial sector and SMEs, support for innovation, competitiveness in their value chains and reform programmes.
- Development of renewable energy capacity (including infrastructure) and other fossil-free energy technologies, promotion of energy efficiency and industry carbon neutrality, smart grid and storage infrastructure.
- Investments in smart and sustainable mobility, such as promotion of smart, safe and fossil-free public transport.
- Investments in charging infrastructure and other elements to reduce transport-related emissions, to the extent they are cost effective or of strategic importance.
- Financing of projects for traceable materials and associated databases (such as a product passport) to facilitate circular material flows.

Several countries have already announced national recovery and resilience plans, several of which contain funding to accelerate the green transition. Support for boosting charging infrastructure, and bonuses for the purchase of electric cars are available in Germany, France and Austria.

The European Commission has therefore presented measures aimed at making Europe's raw material supply more secure and more sustainable by improving resource efficiency and circularity. These measures will help reduce Europe's dependence on imports of raw materials from individual countries, diversifying the supply of both primary and secondary sources, while promoting responsible procurement worldwide. In order to reduce the environmental impact of raw material extraction and raw material processing, sustainable financing criteria for direct investments will be developed to be published at the end of 2021.

In order to better utilise the resources of the different Member States, the Commission will cooperate with Member States to identify the mining and processing projects in the EU that may be in operation by 2025.

[16] Commission Staff Working Document, Guidance to Member States – Recovery and Resilience Plans

5. Action plan for actors and policy makers

The action plan contains measures that are to enable the use of sustainable battery technology and contribute to Sweden becoming the first fossil-free welfare country in the world. The proposals presented are based on five perspectives that are also used in the European Action Plan for Batteries, but which have been adapted to better suit Swedish conditions. The five perspectives view different parts of the battery value chain, but focus on the overall functioning of a Swedish battery ecosystem that will become a leader in Europe, and contribute to strengthening European industry in global competition.

Figure 16: Overview of the Swedish battery eco-system.

5.1. Sustainable batteries for a fossil-free energy and transport system: Stimulate demand for and use of sustainable batteries

Batteries are needed for the transition to an electrified society at all levels, from industrial applications to private users.

Batteries in electricity grids can help to meet the challenges that the growing share of distributed and flexible production of renewable energy sources and rechargeable vehicles gives rise to. Batteries thereby increase the potential use of renewable energy sources, thus supporting development of a more decentralised and resilient energy system. Batteries may also make it possible to replace or postpone investments in the electricity grid.

However, increased use of batteries needs to go hand in hand with high environmental considerations, and clear regulations and transparent calculation models are needed to ensure the use of “green and sustainable batteries”.

Sweden is to be a leader in the use of sustainably produced batteries with the least possible environmental impact and low carbon footprint. But how must society and infrastructure be equipped to enable and support electrification at all levels and what concrete obstacles need to be eliminated?

Greater incentives for increased use of sustainable batteries on a general level are needed to drive the market. One strength for Sweden is that there is strong domestic demand from manufacturers of heavy vehicles, to industrial applications, stationary storage as well as from passenger car manufacturers.

To increase market share for sustainably produced batteries, robust sustainability criteria need to be deve-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loped, on which to base for example public sector procurement requirements concerning the use of batteries with a low carbon footprint.

The priority proposals aim to stimulate demand and create incentives for increased use of sustainable batteries at all levels.

Accelerate the transition of the transport system through continued expansion of charging infrastructure for passenger cars, buses and freight services as well as for aviation, shipping, working machinery and industrial battery solutions

Policies: In order to secure the infrastructure for heavy vehicles, the central government, via the Swedish Energy Agency, should ensure that there are charging points at loading and unloading areas, in depots for charging overnight and in the form of public fast charging along major roads.

Actors in the value chain: The industry will continue vigorous expansion of charging stations for light vehicles.

Actors in the value chain: Develop technology that combines charging infrastructure with energy storage for increased balance and stability in the electricity grids.

Stimulate battery storage in households and electricity grids

Policies: Introduce requirements for power distribution companies and Svenska Kraftnät (Swedish transmission system operator) to always evaluate alternatives to conventional grid investments, for example battery storage, when grid planning and making investment decisions, in the Electricity Act and electricity grid regulation.

Policies: Introduce a tax allowance for green investments for private individuals, where deductions are applied for separately for each product category.

Actors in the value chain: Increase knowledge about why sustainably produced batteries are needed and how Swedish companies can contribute to building a sustainable battery value chain in Europe.

5.2. Sustainable battery production, a new sustainable industry for Sweden: Create conditions for the development of a sustainable battery value chain in Sweden

Climate change adaptation, and the transition to renewable energy, will require extensive investments for almost all industrial and transport segments. However, the battery value chain is still as yet dominated by non-European actors, which makes it vulnerable. There are good growth prospects for European actors in all parts of the value chain.

Sweden has a unique role in the European landscape through its access to clean and competitive energy and proximity to metal and mineral resources and expertise. It is important to take advantage of Sweden's areas of strength. For example, the Swedish mining cluster has a lot of expertise that is also relevant to recycling, and when Northvolt builds up an entirely new large-scale industrial business, it places many demands on various societal functions. Here, there is a chance for Sweden to attract establishments and subcontractors to the battery industry to localise in Sweden, which helps to diversify industry, build a stable industrial landscape and create new jobs. It is also important to retain existing jobs in the user industry and create new jobs.

Sweden's main opportunity to compete and win market share in this transition is to combine the power of business and society, where society can contribute by minimising project risks and thus increasing the prospects of localising private capital for investments. This cooperation is already taking place in Asia, and in European export nations such as Finland and Germany.
Sweden already has a couple of systems for public support and risk sharing for industrial establishments, but they usually operate on a small scale and are therefore not relevant for larger establishments. Despite the interest in green industry, basic funding remains a challenge, especially for the largest and most innovative projects, which both make the most impact and require the greatest investment. Sustainability and climate innovations

are still seen as something new and risky rather than fundamental and natural, not least for banks and credit institutions that are accustomed to counting on returns in traditional industries – but not in carbon dioxide reductions. To increase the pace of investment, companies should make greater use of the opportunities available in the EU and Sweden, such as the EIB, the Recovery and Resilience Fund, the Innovation Fund, the Green Industry Leap and the Climate Leap. In the Budget Bill for 2021, the Swedish Government and the parties cooperating with it have proposed both green credit guarantees and broader mandate for the governmental investment program Industriklivet (The Industry Leap). Both of these could contribute to supporting new establishments in Sweden and it is therefore important that they are implemented promptly.

By reviewing and developing the existing system, the public sector and the business sector could cooperate and share the risks, thus creating conditions for new investments and establishments that will be a decisive force in climate change adaptation. Development of the EU's new taxonomy for sustainable activities is a step in the right direction here. It is a tool that gives the financial sector clear, common guidelines on whether an investment is green or not. The taxonomy is a regulation that should be implemented by the Member States by 31 December 2021.

Concrete proposals for building a new large-scale industry are important here – efforts are needed now as the time factor is important, more is needed than just "showcases" and demonstrations if Sweden is to remain attractive for the establishment of new, green and energy-intensive industries. After the corona crisis, there will be opportunities here to take a fresh approach to new initiatives.

The priority proposals aim to create conditions for sustainable and large-scale battery production and to support the establishment of companies along the entire value chain that produce sustainable raw materials and batteries with a low carbon footprint.

Develop financing models for larger, sustainable companies through green financing and risk sharing

Policies: Reduce the risk when importing/purchasing large quantities of raw materials by introducing raw material guarantees. These guarantees can be accommodated within the framework of EUR 50 billion in government credit guarantees via the Swedish Export Credits Guarantee Board (EKN).

Actors in the value chain: Impose sustainability requirements when purchasing large amounts of raw materials.

Support trials of both technical and business innovations as well as new regulations

Policies: Central government should draw up a strategy and action plan to promote trial activities. The strategy should include work on identifying and implementing some concrete trials, where gradual development of permit processes and regulations can take place at the same time as new technology is tested. This is in line with the proposals of the Committee for Technological Innovation and Ethics (Komet).

Actors in the value chain: Form relevant consortia and value chains to generate trial activities, for example in sustainable mines, electric aircraft, heavy vehicles or electrification in sustainable cities.

Contribute to attracting investments to Sweden and the Nordic region

Policies: Investigate the conditions for infrastructure and energy supply so that new establishments within the battery value chain can take place in the vicinity of, for example, the automotive industry and areas with electrification expertise.

Actors in the value chain: Industry should boost the establishment of relevant start-up environments and attract investors and private funds to develop strong green technology projects with high requirements concerning reduction targets and carbon dioxide savings.

5.3. Recovery and extraction of materials for a sustainable and circular battery industry: Create conditions to enable the mining industry and the recycling industry to contribute with sustainably produced raw materials

Electrification of industries and transportation in connection with the increase in renewable energy sources will continue to require minerals and metals. The work to meet climate change, population growth and to lift countries from poverty gives rise to a growing need for metals for, among other things, batteries. This means that new methods to manage raw materials supply need to be developed.

The foundation of this is society's supply of pure metals which can then be further refined into various forms of active components. Increased circular material flows are a cornerstone in this.

The technical potential for recovering metals is very high, among some metals as much as 95 per cent. It therefore goes without saying that investments need to be made in order for this to be realised on a larger scale. Consequently, new targets and policy instruments are needed to create the commercial and systemic conditions that enable metal recovery to grow faster. Research and development initiatives are also needed here. Today's recovered materials are more complex than before, and complexity is expected to increase in the future. The use of recovered material as the raw material for new products thus becomes problematic and methods and techniques for mechanical and chemical separation of the components of recovered materials must be developed.

In the foreseeable future, however, recovery alone will not be sufficient to manage the supply of raw materials. The increased need for batteries is estimated by the JRC or IEA to be somewhere between 2500-3000 GWh by 2030. BNEF estimates that a total of 350 GWh used batteries will have reached their lifespan by then, based on a lifespan of 10 years for batteries in electric vehicles, 7 years in electric buses, 10 years for stationary batteries and 4 years for consumer electronics. This corresponds to less than 10 percent of the total demand for batteries. The World Bank[17] estimates that by 2050 about 60 per cent of the world's aluminium demand will be met by recovered material, given a hundred percent recovery rate. The Bank also states that the need for graphite, lithium and cobalt will increase by between 450 and 500 per cent as of production in 2018. Regarding EU´s expected demand for cobalt and lithium when the transport sector is being electrified, the EU Commission estimates in its report ‹Critical raw materials for strategic technologies and sectors in the EU› that cobalt and lithium will increase by a factor of 4 and 10 by 2030 respectively, by a factor of 10 and 40, respectively, by 2050. Consequently, primary mining of ore for production of metals will be necessary for a long time.

The EU's raw materials action plan launched in September 2020 "Critical Raw Materials Resilience: Charting a path towards greater Security and Sustainability" states that supply of critical raw materials is a strategic matter of security for the EU in its ambition to realise the Green Deal. The majority of the raw materials needed for battery production are currently mined outside Europe, despite the fact that some of these raw materials are found in the European bedrock (not least in Sweden, Norway and Finland). For example, cobalt is mainly mined as a by-product in copper and nickel mines where the Democratic Republic of Congo dominates with over 60 per cent of world production. Most of it then goes on to smelting plants in China. In the EU there is only one cobalt smelting plant in Finland. China is a large, global actor also for other battery metals.

Without its own production of important metals, the EU is very sensitive to disruptions in global trade, which could jeopardise the transition to a fossil-free society, as the current pandemic situation has made clear, even though it was other supply chains that were primarily affected.

A much higher degree of recovery, as well as the extraction and refinement of raw materials from Europe will thus help the EU reduce import dependence, not least for geopolitical reasons. This could, among other things, reduce the need to transport materials needed in battery production and improve the possibilities of checking that extraction takes place under better conditions with regard to the environment and the work environment, although further steps towards increased sustainability

[17] Hund et al.: Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition; World Bank Group 2020

must of course be taken here as well. The new innovations in recycling and extraction that are being developed in Sweden are also important export products and can thus facilitate climate change in the rest of the world.

Some important activities to ensure a sustainable supply of metals and metal compounds for battery production include strengthening the Swedish mining industry so that it retains its leading role as one of the world's most sustainable and enable it to develop in Sweden, including through simplified and more predictable permit processes. The Swedish Government has taken a few steps in this direction, including a new committee of inquiry on modern and efficient environmental assessment[18] and by proposing in the 2021 Budget Bill increased resources to the County Administrative Boards, the Swedish Environmental Protection Agency and the Swedish Energy Markets Inspectorate to shorten the processing times for permit applications.

It should be ensured that the refinement stages (smelting, steelworks) take advantage of all potential reuse and recovery of raw materials. This means that Sweden will continue to be and develop as a leader in circular raw material flows. It should also be done through conscious efforts, at all stages of supply chains, to further improve resource efficiency in the primary supply stages, and to increase use of by-products and previously deposited materials (sometimes referred to as "secondary materials"), as well as to increase use of recovered materials. A concentrated effort in the mining and metal industries also means that Sweden can develop its leading role in resource efficiency and materials recovery and develop the parts of the circular economy that are not yet in place.

Initiatives that support the development of resource-efficient extraction of primary raw materials as well as increased use of by-products and deposited materials are thus needed. It is also important that the batteries are designed from the start so that they can be recycled. At the same time, initiatives for increased reuse, increased repair of simple faults, adaptation of existing goods (re-manufacturing) and recycling of all forms of goods in order to achieve increasingly circular material flows[19] must be encouraged and supported economically, politically and legislatively. One of the challenges concerns collection of used batteries. The car batteries that are at the end of their lives now (mainly lead batteries) are now to a great extent recycled, but with the substantially increasing production capacity and sales volume, the collection systems will become increasingly important. Robust sustainability criteria and calculation models for the climate footprint of products also need to be developed. Here Sweden has good opportunities to participate in and influence the development of international standards and perspectives in the global value chain. Reuse and recycling of raw materials is a crucial starting point in the strategy for a sustainable battery value chain, but as pointed out above, so are investments in minimising as far as possible the environmental and climate impact of primary production.

Create conditions to enable the mining industry to contribute to a more sustainable battery industry

Policies: Create broad political legitimacy for a sustainable mining industry

Policies: Sweden should actively contribute to the implementation of the EU action plan for critical raw materials, such as the development of criteria for sustainable financing for the mining, extraction and processing sectors in the delegated acts on taxonomy by the end of 2021.

Policies: Instruct the Geological Survey of Sweden (SGU) to prepare supporting documentation for the mineral strategy in collaboration with relevant agencies and actors to develop effective and transparent permit processes for extraction of primary and secondary innovation-critical metals and minerals, continuing to take Sweden's environmental legislation into consideration.

Policies: The government should give instructions to concerned authorities to map and collect information on the potential of battery metals both in the Swedish bedrock, in the mining waste, and in the form of previously broken metals that already exist in the technosphere.

[18] På engelska anges detta ofta som fem (5) R: Reduce, reuse, repair, remanufacture, recycle.
[19] Regeringskansliet (2020). Direktiv 2020:86 En modern och effektiv miljöprövning. https://www.regeringen.se/4a4bbe/contentassets/ea3a4b77147140b8b853761f61f42d1c/en-modern-och-effektiv-miljoprovning-dir.-202086

Actors in the value chain: Develop the ongoing projects with fossil-free and innovative mines and link this to the applied research to develop a "sustainable mine" with the aim of establishing a mine for the extraction of innovation-critical metals/minerals needed in the battery industry and with the ability to demonstrate the following: sustainable management of groundwater in mining, dry deposits, sustainable finishing, reduced emissions of carbon dioxide, and other substances, etc.

Stimulate extraction and recovery of secondary raw materials for increased circular material flows

Policies: Create incentives for companies that want to extract innovation-critical raw materials and utilise previous mining waste or extract more metals as by-products by opening the Industry Leap and other financial incentive systems for this type of activity.

Policies: Investigate how Sweden can approach a vision for 100 percent circularity for batteries and battery materials that covers collection, transport and recycling systems. The work should be done in consultation with stakeholders from other relevant value chains and provide predictability for all stakeholders.

Policies: Sweden has successful research in battery recycling, but the potential for streamlining and improving processes is great and increased investments will therefore also be needed in the future. For example, Sweden should invest in increased resources in applied research to continuously increase the efficiency of metallurgical processes in the extraction of the metals in end-of-life batteries.

Policies: Sweden should develop a model that guarantees the collection of batteries in a cost-effective way.

Actors in the value chain: Promote recycling design by creating dialogue and joint industry-related research between cell and battery manufacturers, battery users and recyclers to understand how manufacturing can facilitate recycling.

Create criteria for sustainable and traceable batteries through advocacy and collaboration in the development of sustainability criteria for batteries

Policies: Participate actively and in a coordinated way in EU legislative work and pursue a clear line for increased sustainability, transparency and circularity in the battery industry. Sweden should take a clear stand to raise ambitions for collection and efficient recycling processes. Stronger Nordic co-operation to promote sustainably produced batteries increases opportunities to exert influence at EU level. Monitor, influence and support development of international standards for carbon footprints (for example UNECE) and environmental labelling to guide the end user. Moreover, central government should express interest internationally in leading the standardisation work of developing sustainability criteria linked to battery production and life cycle perspectives. A budget should be set aside to enable the work to be done.

Actors in the value chain: To increase the traceability of the material used in battery manufacture, work on the traceability of raw materials for batteries continues. Industry actively contributes to developing sustainability criteria for batteries; globally, at Nordic and EU level, for example by contributing expertise in the development of calculation models for the climate footprint of batteries and active involvement in standardisation work.

5.4. Skills development for a charged future: Invest in research, innovation and education for skills development

The transition to a fossil-free society with a focus on electrification needs new skills along the entire battery value chain and at all levels – from new upper secondary and higher education programmes to world-class research. Access to skilled labour is already a bottleneck for the entire battery value chain. The transition to electrified vehicles and industrial applications also requires new skills. Substantial expansion of both basic education and the possibility of job transition in working life are needed to meet the high demand for labour.

The transition to an electrified society also requires skills

development provision to teachers in schools for young people and vocational training. They need to be stimulated with new knowledge, not only about batteries but about artificial intelligence, production methods, control engineering, recycling issues and environmental thinking, the transition to an electrified society, legislative issues, etc. with shorter courses at different levels and that can be combined into a whole package. Chemistry teachers need in-depth knowledge of electrochemistry, technology teachers need more knowledge of the electrical engineering side, etc. Sweden could benefit from the inventory of the education and training landscape for the entire battery value chain currently being conducted at EU level and could translate it to Swedish conditions. It includes upper secondary school, vocational education, higher education and EU initiatives.

The priority proposals aim to quickly meet the needs for broader skills, attract and retain cutting-edge expertise and build on opportunities for industry-related research relevant to all parts of the battery value chain.

Investments in increased skills and skills reorientation

Policies: Central government should guarantee resources for the vocational transition of people already in work to cope with technology shifts and increase flexibility in the creation of new vocational education and training by establishing more upper secondary and vocational programmes specialising in electrification and battery and process industries. Increased support is needed for the Swedish National Agency for Higher Vocational Education to develop new vocational programmes. Targeted support for municipalities to be able to adjust and gear up industrial programmes at upper secondary school and training programmes for adults is expected to be at the same level. The flexibility in the creation of new vocational training programmes (for example the requirement for more industrial actors who can provide work experience places) could be solved through more flexible setups with shorter programmes that can be combined in different ways for different employers.

Actors in the value chain: Industry provides support so that training and jobs are synchronised.

Attract and retain international cutting-edge expertise in Sweden

Policies: Create attractive conditions to attract foreign experts with valuable expertise from the battery industry.

Actors in the value chain: International recruitment in the areas of expertise with the greatest needs and creation of training and skills transfer platforms.

Develop skills and training clusters close to the battery industry to create synergies

Policies: The Government should allocate about EUR 500 million per year over 10 years to make a major national investment in battery expertise: materials science, enrichment/refining, electrical systems and installations, monitoring and control systems, battery pack structure and design, battery safety and digitalisation. To train 1,000 people per year in battery skills from upper secondary school, higher education and research.

Policies: Utilise existing establishments and ongoing initiatives to augment skills and “clusters of excellence” covering different parts of the value chain. Examples include the Swedish Electric Transport Laboratory, the Swedish Electromobility Centre, Northvolt Labs and Batteries Sweden and the Arctic Center of Energy Technology.

Policies: Central government should investigate the need for a centre for battery production technology and the need for expertise to develop production processes for battery cells and battery systems.

Actors in the value chain: Investments in research centres are co-financed by industry.

5.5. Collaboration and dialogue for growth and export: Implement and follow up the action proposals through broad collaboration throughout the battery value chain

To ensure continued positive and efficient development

of a sustainable battery value chain in Sweden, central government and industry not only need to market Swedish strengths but also above all to follow up on the proposals in the battery strategy. This needs to be done in continued dialogue between all stakeholders, i.e. industry, research, decision-makers and civil society. Therefore, one should look at all political and industrial measures as a whole.

In August 2020 the Swedish Energy Agency, the Swedish Environmental Protection Agency and the Geological Survey of Sweden (SGU) were commissioned to develop inter-agency cooperation for Sweden's part in a sustainable European value chain for batteries.[20] The remit includes analysing the proposals from this battery strategy and highlighting in relevant aspects the socio-economic consequences, which means that there is already a process in place for managing the strategy.

The priority proposals aim to follow up the proposals in the battery strategy and are continuously updated – both through coordination at agency level and also through continued dialogue with the industry.

Marketing of batteries as a sustainable industry in Sweden to attract investment and increase export

Policies: Task Business Sweden with marketing the sustainable battery value chain (from recycling and extraction, battery manufacturing, automotive industry and electrical systems) as a green and competitive key industry in Sweden and the Nordic region to attract foreign investors and thereby promote increased production and future exports.

Actors in the value chain: Contribute by attracting investors and private funds to develop strong green technology projects with high requirements concerning reduction targets and carbon dioxide savings.

Actors in the value chain: A long-term promotion programme should be created through Business Sweden, with the aim of giving Sweden a leading position in the global battery industry. The programme can focus on i) ensuring that key actors in the battery value chain establish manufacturing, research and development in Sweden, ii) giving Swedish small and medium-sized enterprises the opportunity to develop and commercialise their solutions in an international context, and iii) supporting leading Swedish companies in winning major international business and thereby contributing to electrification globally.

[20] https://www.regeringen.se/4a3d05/contentassets/7e462a39d26f4c09b8f5a36ccbc9ff21/uppdrag-om-myndighetssamverkan-for-batterier-till-energimyndigheten

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