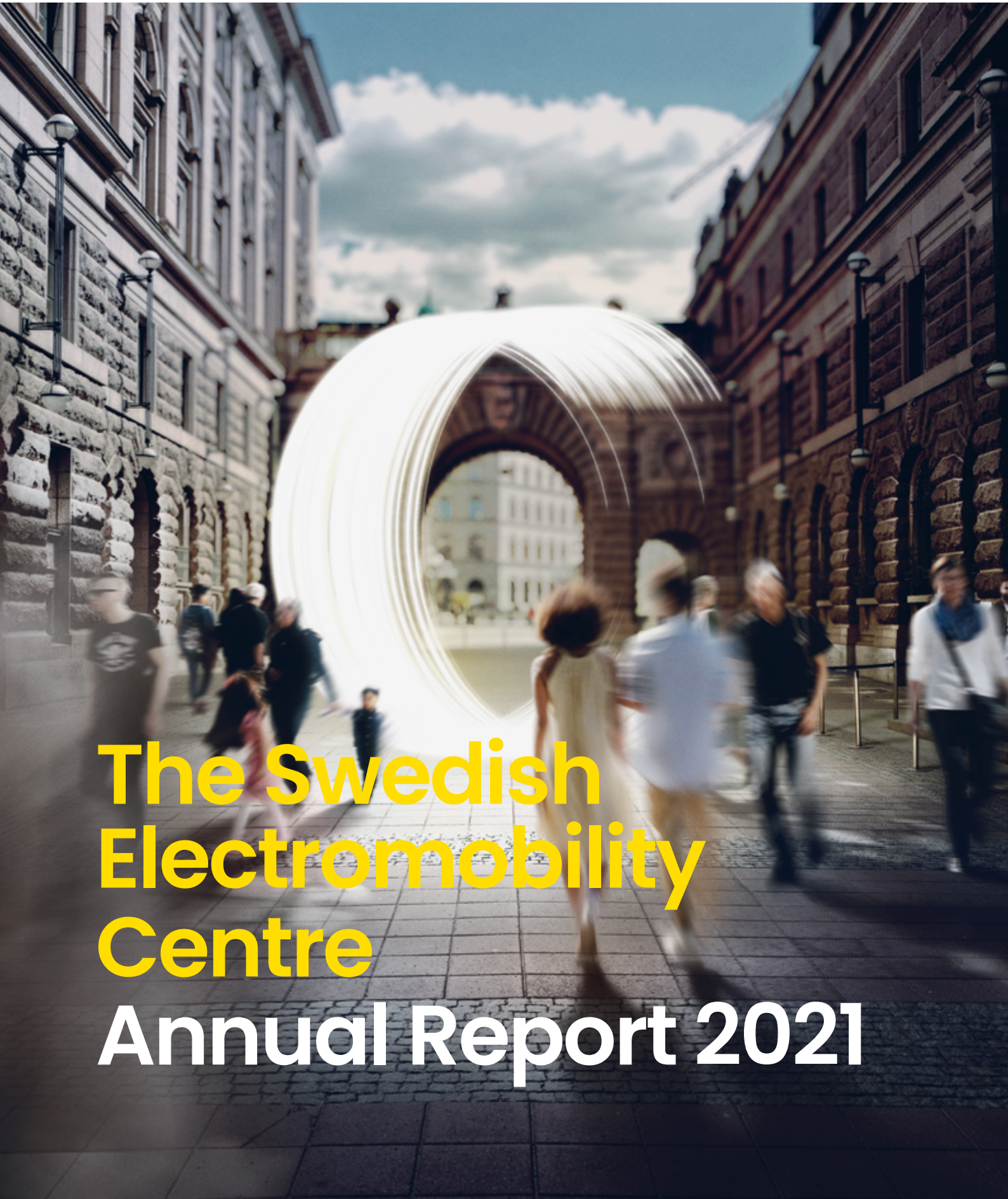
Swedish Electromobility Centre



The Swedish Electromobility Centre Annual Report 2021

Swedish Electromobility Centre, 2021 03 31

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This year with the Swedish Electromobility Centre

2021 has been a year with a lot of activities and good work. After three calls for projects, we are now funding some 40 new projects within our five theme areas. These projects are now beginning to report some very exciting results and we look forward to following their progress over the upcoming years.

The network is the heart of the centre and Swedish Electrombility Centre function as a platform for interaction for the emobility society in Sweden. During the year we have hosted almost 50 workshops/events and welcomed two new members, EON and Lindholmen Science Park, to the centre.

During the year, SEC has participated in the work of the Electrification Commission. SEC made an electrification promise for regional transport and contributed to an action plan for heavy electric transport. SEC has also taken the initiative for a gap analysis for strategic research in electric aviation. A work that will continue in 2022.

Thank you all for contributing a lot of energy and commitment to our centre!

Linda Olofsson,
Director, Swedish Electromobility Centre

> Dear all, 2021 has for many of us been characterized by hard work to ensure the future financial support of the centre from the Swedish Energy Agency. Just before Christmas we learned that our efforts paid off when funding was approved. A very good way to complete another eventful year. Congratulations to us all!

During the year we also spent a lot of effort in realizing our conference days, not knowing until the very last minute if we could meet in real life or if we would have to go digital. Luckily, a small window in the pandemic situation allowed for us to meet in Uppsala for our events Roads to the Future and Emobility Day. Both days turning out to be successful and well visited, with renowned international speakers. It was so good to meet in person after almost two years of covid.

SEC covering the full range of electromobility

The Swedish Electromobility Centre is the leading centre and collaboration hub for emobility research in Sweden. The Centre gathers the main actors within Swedish emobility research and innovation, constituting a strong network for collaboration and progress between corporations, academia, and society. The SEC model allows knowledge and competence to be shared and grow in a unique way. Competing companies work side by side to achieve the breakthroughs that are needed for Sweden to lead the electrification of the transport sector. In 2021 SEC has even more established its position as a contributor to society's development in a sustainable way, by the important work of the Swedish government's Electrification commission.

We apply both deep knowledge of components and technology as well as understanding of the system perspective to all applications for electromobility, including road, off -road, rail, air, water, and power infrastructure. It is the combination of width and depth of knowledge in our research that gives the centre its strength and provides a foundation for the development of Swedish electrification of transportation.

Together we constitute the main Swedish platform for collaboration within electromobility.

Vision

The vision of SEC is that electromobility, together with renewable electricity generation, reaches its full potential for serving as a building block of the sustainable society of the future.

Goal

Our goal is to be an internationally distinguished centre of excellence, renowned for its competence building, research, and development of sustainable technology for electrification, for all types of vehicles – on land, at sea or in the air. The long-term (>10 years) goal is to ensure electromobility being the cornerstone for transition to a sustainable society.

Mission

The mission of SEC and medium-term (5-10 years) goal is to accelerate the development and implementation of electric propulsion technologies into the transport ecosystem by maximizing their applicability, versatility, and efficiency, while minimizing their overall impacts on the environment, human health, and natural resources, and strengthen the Swedish industry's competitiveness.

Towards the fifth stage

Nils-Gunnar Vågstedt, Chairman of SEC about 2021

This year has been framed by the application for the fifth stage of the Centre. And it ended with a positive response from the Swedish Energy Agency who approved the application.

SEC was (and still is) in the fourth stage of funding from the Swedish Energy Agency in the beginning of 2021 when we got the message that we had to apply for the next step to start earlier than planned. The application became a true challenge for the centre. We had to put a high priority on it, and at the same we needed to keep up with the ongoing work in the projects which lie in the fourth stage.

We came together and reschedule for the extensive work that the new application meant. It was a really positive thing to experience when the whole centre came together and delivered a winning application. We, of course, had a very good position to start off with, being the only electromobility research centre in Sweden, but still, hadn't we managed to collaborate in a very good way, then we wouldn't get the funding.

The granted application is a good recipe proving that we are a very strong constellation and that what we do is relevant and wanted by society. In the end I see that we did this exceptionally. Our projects are delivering results and the application was approved by the energy agency, which means that cycles of stages are extended to five years instead of the earlier four years. But I must admit that it has been an intensive year for us working within the centre, and we are lagging somewhat in use of resources.

Roads to the future and Emobility Day

One energy booster in 2021 was that we managed to arrange the two live events Roads to the future and the Emobility Day in Uppsala in the autumn. A big thanks to Uppsala University for making this possible. We had international key note speakers coming to Uppsala and gathered participants from the whole Swedish electromobility sector. The centre is very well suited for distance collaboration, but to meet once in a while like this is worth very much too, it can't be neglected.

Prepared for the fifth stage

Our newest themes are now getting established and the projects that are connected to them are too. Unfortunately, not in the rate that I had hoped, and this is due to both the pandemic and the efforts the application brought. Also, an heroic effort by the administration of the centre has secured our deliverables despite the fact that much of the staff changed during the year which also is costly in terms of efficiency.

So even though the pandemic and the work with the application have slowed us down a little, we are now prepared for the fifth stage. This stage will give us the foundation to a more robust and resilient administration and organization in total.

Associated activities

I'd also like to highlight our associated activities. This is where the partners of SEC participate as one unit in collaborations with other actors, and one very good example of this is the project E-Charge where we collaborate with multiple other Swedish organizations. Working under the same SEC flag in associated collaborations is a smart and sustainable way to fund our work and also a great way to share our knowledge with other electromobility actors and society.

A growing interest from society for SEC's knowledge

The interest from society for SEC's achievements is growing, with requests from major Swedish institutions such as the Swedish government's electrification commission as well as requests for collaboration from international stakeholders.

The knowledge produced in SEC's research projects, very appreciated by the industrial partners, is a major outcome of the centre, but the direct outreach to society with knowledge is an activity for the centre that is becoming increasingly important.

"The need for knowledge is great, the competence that we have combined with the holistic approach that we have is hard to find anywhere else", SEC director Linda Olofsson says.

SEC shares knowledge with society through activities supporting the electrification of the transportation system and as electrification is identified as a key for sustainable mobility the demand for knowledge concerning implementation, systems integration, user adoption as well as sustainability of the whole value chain is growing.

Having a dialogue with the rest of society is not only part of the task of scientific outreach, but also necessary for the centre to understand how the developed technology can fit in and what the needs from society look like.

"Our main goal is to contribute to making electromobility one of the cornerstones of the sustainable society. We need to interact with actors in society to learn about the challenges to solve and then disseminate our gained results back to society to accomplish this", Linda says.

SEC's scientific dissemination activities already give unique knowledge to the Swedish government's electrification commission and in workshops for the electrification strategy, and many of the centre's researchers participate in expert groups for electrification of transport. During spring SEC issued an electrification pledge together with some 250 other actors in the Electrification Commission's action plan and applied to disseminate our centre through the Pioneer the possible initiative by Svenska institutet.

The plan is now to increase the research activities that have direct ties to society.

"We are very happy to see the huge interest for our knowledge from society. Our plan is therefore to further strengthen the research concerning system perspective and societal implementation.", says Linda Olofsson.

How SEC will achieve the goals

To lead the way towards electromobility in high speed and at the same time ensure sustainable development the centre is put together in five themes based on the challenges foreseen. The theme road maps, with identified knowledge gaps and strategic research areas, form the basis for the project calls and through the SEC funded projects, each theme contributes to fulfilling the goals of the centre.

Industry's view of SEC's role

SEC is the hub in Sweden for applied research in electrification of transport. SEC will contribute to coordination gains across academia and industry but also across SEC and with other centre formations in adjacent areas.

SEC is a recruitment base at lic / doctoral level and at senior research level.

SEC is a platform and trustful network that work for mobility between industrial and academic researchers, thus facilitating bi-directional knowledge transfer.

SEC should continue to be a catalyst that accelerates the electrification of vehicles.

SEC should continue to deliver world class research results.

SEC's task towards academy

To gather and build long-term knowledge in relevant areas for vehicle electrification and development of associated charging infrastructure.

Bring industry and university partners together, in order to develop free, strong and creative research environments.

Initiate and finance relevant research projects and themes.

Disseminate the knowledge generated within the centre by providing courses within the framework of postgraduate programs.

Create knowledge that can be used in undergraduate programs at each university and with industry partners.

Deepen knowledge exchange between automotive companies and companies in the electrification field, and universities.

Help increase the level of knowledge in relevant areas.

SUSTAINABLE DEVELOPMENT GOALS

SEC contributes to the development of a sustainable society: The activities of SEC have a strong connection to several of the Sustainable Development Goals adopted by United Nations in 2015. The 5 most direct interrelations are:

No.7 - Sustainable energy for all

Electrifying all or parts of the vehicle fleet enables the energy for these transports to come from several different sources, with low greenhouse gas emissions, in contrast to the current system and its dependence on fossil fuels.

No. 8 - Decent working conditions and economic growth

Industrial activity in the field of electromobility is increasing significantly. Many vehicle manufacturers have hybrid vehicles, rechargeable hybrid vehicles or fully electric vehicles in their model portfolio. Subcontractors to vehicle manufacturers are also affected.

No. 9 - Sustainable industry, innovations and infrastructure

Research, innovation and technological progress are the key to developing sustainable solutions for both economic and environmental challenges in the development of electromobility.

No. 11 - Sustainable cities and communities

A very important part of the pursuit of sustainable cities is high utilization of the city's surface through densification and efficient transport systems for both goods and people. Electromobility plays several roles here.

No. 13 - Fighting climate change

Climate change is a real and undeniable threat to our entire civilization. An electrification of a larger proportion of the world's vehicles, in combination with climate friendly electricity production has great potential to reduce significantly its contribution to total carbon dioxide emissions.

SEC’s objectives and KPI’s

SEC has been operating in its Stage IV throughout 2021. Six objectives, with the purpose to measure how well SEC’s projects contribute to the centre’s overall objectives, are used. To monitor performance, a set of KPIs (key performance indicators) are used. The objectives and the KPIs have been chosen in dialogue with the Swedish Energy Agency to support the overall goals of the centre in terms of the scientific excellence of the research, industrial applicability and societal impact, both in terms of results and the need for qualified workers.

Objective 1

Interdisciplinary projects

80% of all projects that last for two years or more and are funded by SEC must meet at least one of the criteria below:

• The project shall pave way for the researcher or PhD student to work for a limited time on site at one of the industrial partners. SEC also encourages industrial researchers to work at one of the academic partners for a limited time within the project.

• The project must plan and work for international exchange.

• The project must touch on and collaborate with expertise from a field other than its main field.

Objective 2

Interdisciplinary research environment

SEC must offer researchers, PhD students and those working on degree projects from industry an interdisciplinary research environment. The industrial parties must also get the opportunity to participate in SEC's planned PhD courses.

Objective 3

Scientific competitiveness

SEC's projects must be scientifically competitive internationally. SEC must, on average over the period of the phase, publish at least thirty reviewed articles in international journals and/or at conferences every year.

Objective 4

Dissemination of knowledge and research findings

The theme areas must convene theme group meetings three times a year, and SEC must arrange an activity that involves all theme areas every year.

Objective 5

Collaboration

SEC must be involved in at least two projects with other centres or research organizations or major international collaboration projects with operations that can be linked to SEC.

Objective 6

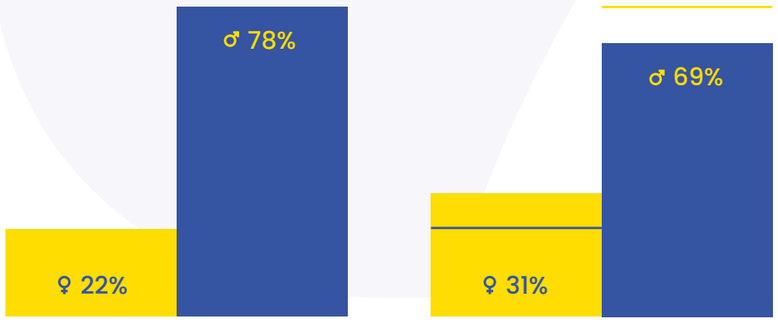
Competence supply

Half of SEC-funded research projects that last for two years or more must be PhD student projects. The PhD student should be involved in the Doctoral Student Network and SEC's planned PhD courses.

During 2021, unfortunately, many project activities have been affected by the corona pandemic, which is to some extent reflected by delayed start of the work and some projects being extended in time. Nevertheless, several SEC projects have hade good activity which is reflected by several articles and conference contributions produced during the year.

The project portfolio includes 19 PhD projects spread over all 5 thematic areas, and 17 other projects divided between 6 pre-studies and 11 thematic or postdoc projects, which is well composed for SEC to deliver the expected KPIs (see projects in Appendix A).

In addition, the gender equality has gone from 22/78 (% female vs male) in 2020, to 31/69 in 2021 which is a great improvement towards SEC's goal of 40/60.



Gender equality 2020 vs 2021

Stage IV during 2021

33 journal & conference papers

26 master thesis

16 theme workshops

3 PhD and licentiate
*associated projects only

21 international collaborators

2 Center conferences
Emobility Day, Roads to the Future

Stage IV total (since 2019)

80 journal & conference papers

43 master thesis

31 theme workshops

11 PhD and licentiate
whereof 3 associated projects only

24 international collaborators

4 Center conferences
Emobility Day 2021 & 2020, Roads to the Future 2021, and STAGE IV kick-off 2019

Roads to the future and Emobility Day are SEC's annual events for the Swedish electromobility community and oru partners. Photo: Mats Tiborn

Roads to the future and Emobility Day 2021

Roads to the future and the Emobility day are two conferences arranged by SEC. The first is open for anyone and gathers industry, society and academia for a day of lectures by the forefront of electromobility from all over the world.

The conference brings together researchers, students, and professionals from all over the world to promote an enthusiastic and collaborative approach, and to share knowledge across borders and fields of interest within the scientific community as well as the electromobility industry. The 2021 conference highlighted topics on the theme "Charging from all perspectives".

Albeit in the middle of the pandemic, SEC managed to arrange the event live at the conference centre in Uppsala. The restrictions allowed for most to participate at site, but a few of the speakers had to do the presentation online, due to their national restrictions.

At the 2021 event keynote speakers were Dr. Keith Hardy of Argonne National Laboratory, USA, Dr Giorgio Rizzoni, Ohio State University, Dr Rachid Yazami, KVI, and Dr. Anna Teyssot, Verkor.

SEC research behind Volvo Cars Technology Award

The car suggests where you should charge based on the individual conditions. Photo: Volvo Cars

Get a road map planned for charging tailored from your electric vehicle's unique capabilities. Volvo is first car manufacturer to add a Google Maps connected service in their cars. Viktor Larsson, a former SEC-PhD, led the team which is now awarded for the technology.

In 2021 Viktor Larsson, Volvo employee and former PhD-student at Chalmers in an SEC-funded project, led the team that received the Volvo Cars Technology Award for a charge planner, that was developed together with Google. The technology lets you put in your destination data into Google Maps, which will suggest a plan for where you should stop to charge based on the individual condition of your car.

The work is a collaboration between Volvo and Google where Volvo sends Google the data of the individual car for the calculation and Google sends back the route data through Google Maps.

"You just tell Google maps where you want to go and it will give you a route for where you should stop and charge, where we have considered your car's capabilities, like how much energy is in the battery, how heavy is it, how much energy the car uses in different speeds", says Viktor Larsson.

The technology is now to be found in both Polestar cars and Volvo's XC 40 electric cars and led to the Volvo Technology Award.

The work derives from work done years earlier when Viktor Larsson was a PhD-student at Chalmers, funded by SEC. He was working on an optimized control of hybrid vehicles that helps the driver plan the mix between the combustion engine and the electric motor. By putting the route into the car's navigation system, the car calculates the best energy economic balance between the two drivelines. The results for this study have since become integrated in Volvo's plug-in hybrid cars and is now also the foundation for the charge route technology awarded with the Volvo Technology Award.

SEC contributing to E-Charge and REEL2

The Swedish government and the Swedish industry are making an important and substantial investment in electrification of heavy transportation through the projects E-Charge and REEL. SEC is one of the participants and has been an important collaboration partner to match the researchers for projects.

SEC was involved in the application work for the two projects. It proved to be a good decision since the centre provided the right competences for a successful consortia.

“The way SEC is constructed makes it the perfect network to find and match the perfect set of researchers and also other actors of the network. Through SEC the project now has the right kind of research competence”, says Nils-Gunnar Vågstedt, SEC’s Chairman of the board.

The government and industry are together investing SEK 400 million through the program FFI to support E-Charge and REEL2.

REEL2 is focusing on regional transportation with 40 battery electric trucks that will be utilized in multiple transport services. The project is a sequel to the REEL-project and has a focus on up scaling.

E-Charge is a new project which is following the same structure as REEL, with the ambition to reach higher levels of technology readiness in coming projects.

E-Charge’s focus is on long-distance heavy transports, with a range over 500 km. The vehicles will be tested in logistic systems between Sweden’s major cities, and are charged with high-effect charging when the drivers have their rest.

Both projects are starting immediately and will end by 2024, where the ambition is to continue with the next steps.

“These two projects are very important for the future of sustainable electrified transportation in Sweden. Together the two projects will lay out the transport eco system of Sweden’s electrified regional and long-distance heavy transports, says Nils-Gunnar Vågstedt.

Adding quenchers, substances that prevent chemicals to react with each other, to the car's batteries, reduces the risk for fire. Photo: Matt Hearne, Unsplash.

Safe from battery fires

As electric vehicles are rapidly increasing in numbers on the roads, fires in damaged batteries are becoming a new safety issue for the rescue service. In an SEC funded project, researcher Elna Heimdal Nilsson is looking to prevent the fires through so called quenchers.

The batteries of electric vehicles contain a number of chemicals that you don't want to slip out. And even though it is extremely uncommon with fires in the batteries, due to outer force, heating or even defects from the factory, they do occur. Many of the gases produced in battery fires are extremely toxic and the rescue service's equipment isn't adapted for filtering it out, making them reluctant to putting out fires where electric vehicles are involved.

"Some of the gases that are produced in battery fires, such as hydrogen fluoride, are lethal and the rescue service isn't prepared for working in those conditions, which makes car accidents with electric vehicles potentially a big problem the more common they become", says Senior Lecturer Elna Heimdal Nilsson, at Lund University, who leads the project.

In the SEC funded project "Chemical quenchers for inhibition of battery fires", Elna Heimdal Nilsson and her group aim to gain a better understanding of the gases that are released in a battery fire, create chemical models for simulations of battery fires and identify and test chemicals that may mitigate fires, so called quenchers.

Toxic gases

Inside the battery, the chemicals are liquid or in a solid state, but heated up and mixed with the surrounding oxygen, multiple toxic gases are produced. Exactly how this happens on a chemical level is still not fully mapped. In the two-year project Elna Heimdal Nilsson, her colleague at Combustion Physics at Lund University Christian Brackmann, and her post doc Intu Sharma will increase the knowledge of which toxic gases that are released and systematize this knowledge, creating models to foresee what will happen when different batteries burn.

Quenchers

The quenchers, that the project aims to detect, are substances with a characteristic that decreases the reaction and stops reactive chemicals, such as hydroxyl radicals, from react with other chemicals that may cause toxic gas emissions.

"It is important that the reaction is stopped immediately. The more substances the reaction is exposed to the more it is propagated and the wilder the reaction becomes. We want to mitigate the reaction by letting it react with quenchers as soon as possible", says Elna Heimdal Nilsson.

Volvo Cars as a partner

Volvo Cars is an important collaboration partner in the project. The group will work with their batteries and do some tests in Volvo Cars' site in Gothenburg.

"I am very excited to work with Volvo Cars in this project. Safety is a very important part of what Volvo Cars stands for and so of course they are very skilled in this kind of work", says Elna Heimdal Nilsson.

Elna Heimdal Nilsson. Photo: Mats Tiborn

Fl: Valeria Castellucci, Magnus Blinge, Göran Lindbergh, Lars Eriksson, Linda Olofsson, Anders Nordelöf, Francisco Márquez Fernández, Daniel Brandell. Photo: Mikael Wallerstedt

Our theme areas

The Swedish Electromobility Centre brings together the Swedish automotive industry and technical universities with a range of different research disciplines. It is the combination of width and depth of knowledge in our research that gives the centre its strength and provides a foundation for the development of Swedish electrification of transportation.

To cover the full landscape of the growing fields related to electromobility, the centre hosts five theme areas. The theme areas are the activity groups where researchers from all partner universities collaborate, the core of SEC. Each area is led by two theme leaders, from different universities. Here are their reports on what happened within the areas in 2021.

Theme 1

Intelligent Vehicles & Systems

System studies and methods develops methods and algorithms for model-based systems engineering, which are adopted and utilized in electrified vehicles. The core question for our theme area is how to manage the vehicle's onboard energy in an optimal manner, so that it satisfies the customer's need.

To address this requires knowledge of the customer, the vehicle, its subsystems and its surroundings. This is done by utilizing tools, like mathematical modelling, dynamic simulation, performance analysis, control design and optimization on vehicle system level or fleet level, i.e., design and control of system of systems. The focus for these methods and techniques is to reduce development time and effort, while striving for system optimality.

Research advancements within 2021

The projects have revolved around understanding and characterization of the customers, the vehicle, its subsystems and its surroundings in order to address the core question. During 2021 the theme researchers have addressed the topics of modelling and control of electrified vehicles for complete powertrain performance improvement, including thermal systems for heating and cooling of powertrain components. The theme area also started up a project to develop an open-source simulation platform for analysis and design of fuel cell vehicles.

During 2021, the theme area also got a theme researcher focusing on electric range estimation for battery electric vehicles. Other achievements have been on characterization of external factors, like wind and road resistance, as well as analysis of electric all-wheel drive concepts.

As the year has been special, due to the corona pandemic, most activities have been held online. Researchers from the theme have been active in providing material for students and supporting active engineers in their life-long learning in the area of model-based systems engineering and electromobility.

National and international attention

Project members have attended different conferences spreading information and presenting interesting research results. Among these conferences are the SAE WCXTM, US, and IEEE Intelligent Transportation System Conference, US.

Viktor Larsson, Volvo Car Corporation, a former PhD student in the centre and the theme, received the Volvo Cars Technology Award together with his colleagues for the work they did on range estimation for battery electric vehicles. The ideas were also presented at the Roads to the Future 2021.

SEC and the theme have also been part of the setup of the Vinnova financed 215 million SEK project E-Charge, which has been promoted by the organizations and received attention in the media.

Challenges and possibilities

"Zero emissions" is the challenge most vehicle manufacturers are addressing. And as electrification is a possibility to achieve "zero-emissions", onboard complete vehicle energy management is the main challenge in the area. It is not limited to just energy used for propulsion of the vehicle, it also includes energy use in vehicle subsystems, like cooling of batteries or electric machines, and driver and passenger comfort, like HVAC systems. This means that methods and tools needed to address the main challenge cannot be by studying the individual sub-systems in the vehicle, but needs to address the system as a whole, i.e., system of systems. A central part of the research utilizes dynamic models, computational methods and simulation techniques to study system properties and optimize the vehicle designs in system and mission settings, so we get energy efficient electromobility solutions.

Connected vehicles, where information about the vehicle and the outside world, provide system knowledge of how the vehicle is used, where it will go and how the traffic situation is ahead of the vehicle gives new opportunities, and a lot of functions that are using this knowledge are being developed right now. Vehicle manufacturers already have information sharing systems in the vehicles on the market. This gives an excellent plat- form for developing new system functionality, such as route management planning, range estimation, traffic flow control etc. This area is sometimes called Vehicle-to-X (V2X) and is an enabling technology on which our theme area is building functionality.

Business intelligence

Electrification, automation, and digitalization are the mega trends in the area. Research is done in basic research on development of methods and tools for addressing the design of system of systems, like numerical optimization, deep learning from data, dynamic simulation, and control design. To ensure the usefulness of these methods and tools to all parties within the Swedish Electromobility Centre, the theme's projects adapt and use such general methods on hybrid and electric vehicles. To cope with the multi-disciplinary challenges, the combination of knowledge on general methods and application know-how is the core, which is the foundation that the theme area relies on.

Theme 1

Project spotlight:

A sandbox for emobility research

Lars Eriksson, Photo: Mikael Wallerstedt.

Great innovation, but does it work with the rest of the system? Professor Lars Eriksson at Linköping University is leading the development of a model where all components of the electric vehicle can be tested in a full system, whether it is a car, a truck or even a plane.

In this SEC project a sandbox for testing innovations in a systems context is being developed. The name of the project is A Model and Simulation Platform for Electric Vehicle Systems with Motors, Power Electronics, Batteries and Fuel Cells and their Heating and Cooling Needs and it gathers researchers and industry from the whole centre, led by Lars Eriksson, Linköping University and theme leader of Theme 1, System studies and methods.

The aim is to develop a tool for collaboration and communication between all partners by providing a model where anyone can put their specific research in a systems perspective and make tests in simulated situations such as on high altitude, under high pressure, cold, heat or just regular "home conditions".

"It is like a start-up kit of Lego, where you can build whatever you want to make it work for you. The model is supposed to increase the speed of innovations in the centre. This will make it easier to test and evaluate how your domain specific research work fits into the bigger picture work along with other components in the vehicle", says Lars Eriksson.

The model is built as open source in Matlab Simulink, which has widespread use in universities and industry, thereby making it possible for anyone at the center partners to test, use, and modify. Similar models do exist within many companies already, but according to Lars Eriksson, they are so full of IP that it is very hard share them with researchers and use in collaborations. Two of the partners that have shown the most interest in the project are Scania and Volvo Trucks, and since they also have contributed with data, the model is well fitted to be used in their systems.

The hardest part is to get the different interfaces to connect, according to Lars Eriksson. "How do we make a battery exchange info with both an electric machine and a cooling system for instance? There are so many applications that need to work together, but we are on the right track and by the summer 2022, we will have a model that Volvo Trucks and Scania can start to use", Lars Eriksson says.

Theme 2

Electric Drives & Charging

The research activities in the theme span over a broad area and use various methodological tools. Theoretical/numerical modeling and simulation of components is based on analytical equations, dynamic models, finite-element numerical analysis, computational fluid dynamics, and more. The component integration into a dynamic system model exploits Matlab/Simulink or similar software platforms. Prototyping and laboratory testing are essential for the activities, using real-life conditions testing when relevant.

Research advancements within 2021

2021 has been a difficult year due to the restrictions imposed by the COVID-19 pandemic. Virtually all projects granted in the project calls during 2020 had a delayed start due to the difficulties in the recruiting process related to travel restrictions. Nonetheless, all projects have been finally manned and have started with the first workpackages, consisting mostly of literature review, data gathering and model development.

The delays in the start of SEC financed projects also influence the number of publications, since the initial stages of research projects are not particularly productive in terms of results. Moreover, travel restrictions have severely affected scientific conferences, most of them moved to the virtual ground, making them less attractive. Among our associated projects, a total of 7 papers and 11 Master theses have been published in 2021. Moreover, a paper based on the results of the project IDEAS (from SEC Phase III) that was submitted in 2020 was published finally in 2021 in IEEE Trans. on Transportation Electrification – this serves as an illustration that publications often come in the end of a project, or even well after that.

National and international attention

2021 has been for the most part as tough as 2020 in terms of limited opportunities for social gathering and travelling restrictions. Many of the programmed events have been carried out virtually with the exception of our international conference Roads to the Future and the Electromobility Day celebrated in Uppsala in October.

Also in October, Fran Márquez (theme 2 co-leader) presented for a wide audience at a seminar arranged by the Swedish Vehicular Engineering Association (SVEA) in collaboration with SEC on Infrastructure for the charging of Electrical Vehicles.

Nationally, Theme 2 has been involved in the discussions with the Electrification Commission together with the rest of the themes, and former Theme Leader Mats Alaküla has been part of the Electric Roads investigation commanded by the government.

Challenges and possibilities

Despite a brief hopeful return to normal activities in autumn 2021, the ongoing pandemic has had a dominating impact on the activities throughout the year. Industrial partners stay put, keep going on while maintaining the SEC collaborations within the theme. Personal mobility and in-person idea exchanges are not at the pre-pandemic level yet, but – fueled by the temporary absence of long-term project SEC calls due to the transition between phase IV and phase V – the theme looked at the future perspective of the center. The recurring digital theme meetings provided an opportunity to shape an updated roadmap and a radar chart on the most relevant topics deserving a focus. Theme 2 is now ready for the SEC phase V challenge.

Business intelligence

Despite economic instability due to the pandemics, the electric transportation trend is observing no slowdown. Beyond road transport, even marine and aerospace applications are significantly trending upwards. Some of the most significant trends in our area are:

- Vehicle manufacturers are making big strides towards the mass-production of electric machinery designed with the most modern available technologies. Their efforts could be even considered a threat to other companies operating in more conservative markets in industry.
- Fuel cells as on-board energy storage solutions are receiving more attention than in the past, particularly for marine transportation.
- Electric aviation is continuously reaching very higher and higher drivetrain power density values and breaking the world speed records of electrically-powered aircrafts.

The results of the project will in the long run give a tool to find the perfect match between energy efficiency, torque ripple and lifetime of the stator. Photo Mats Tiborn.

Theme 2

Project spotlight:

Improving accuracy in modelling electric machines

Adding 3D in the system modelling of electric drives has for long been neglected due to the increase of computation time it would take. Now this SEC funded project builds models for an energy saving wholistic approach.

In this newly started project, Chalmers researchers Sonja Lundmark, Torbjörn Thiringer and Emma Grunditz take a wholistic approach to modelling the stator core and windings in electric machines, hoping to improve performance and reduce the energy loss.

In electric motors and generators, torque is created in the magnetic fields between the rotating part, the rotor, and the stationary part, the stator. The stator consists of a stack of thin plates (a laminated core) and electromagnetic coils (windings). The project aims to create models that will give an overview of the efficiency and performance of the machine, including 3D-effects such as leakage magnetic fields. In the long run this can give manufacturers a tool to find the perfect match between energy efficiency, torque ripple and lifetime of the stator.

Normally the stator and the coils are analyzed in 2D to save time and computational power.

“There have been 3D studies before on parts of the stator. The unique in this project is that we will create a model for analyzing the whole stator, to combine the 3D models with existing 2D models, and this could give our partners an improved tool for energy efficiency” says Associate Professor Sonja Lundmark, who studied 3D modelling of electric machines already as a PhD student.

The models could also enable, in a more precise way than before, to find the right composition of the stator to control amount of torque ripple and energy loss and weigh it against other constructional issues like cost and environmental friendly design.

“The electric engine is 130 years old, and it hasn’t changed much since the beginning. Perhaps no ground-breaking changes are possible, but just increasing the energy efficiency a tenth of a percent can become many megawatt hours in the energy consumption looking at an entire electrified transportation system”, says Professor Torbjörn Thiringer.

Volvo Cars is the main partner of the project and the researchers think there is a good chance the car manufacturer will be able to use the project’s results.

“We are grateful that we get time to test this and the interest from industry is large looking at the many industrial participants in the reference group. Input from industry is important for us. They can give us that know-how that isn’t to be found in literature”, says Torbjörn Thiringer and Sonja Lundmark.

Theme 3

Energy Storage

Within the Energy storage theme, the focus is to understand the energy storage units of different forms of batteries and fuel cells when used in electric vehicles. This range from the materials and the components of the electrochemical cells, to its integration with the vehicle and monitoring during use. By this knowledge, ageing can be mitigated, energy losses kept at a minimum, safety be assured, and health maintained, which warrants long driving range and optimal charging conditions. At the same time, novel cost-effective and benign energy storage solutions can be explored.

Research advancement within 2021

The SEC projects running and initiated during 2021 have revolved around the thematic focus areas testing procedures and protocols, electrochemical modelling, system safety and diagnostics, and fuel cells. Two PhD student projects within the area are now up to speed: one focused on fuel cell performance prediction, and one on gas evolution in Li-ion battery cells. Moreover, two thematic researcher projects have been launched during 2021: on solid-state batteries and on intermediate temperature fuel cells. New research projects have comprised quenchers for battery fires, bridging the gap between lab scale cells and commercial cells, tomographic techniques for battery diagnosis, and the use of phase-field modelling techniques.

Theme 3 has also organized a number of online events during 2021, to highlight research within the area and stimulate research interactions. A battery ageing modelling workshop was held in March with a focus on empirical models, a workshop on recycling of vehicle batteries was co-organized with Batteries Sweden and held in April, and a workshop on fuel cells was organized in December. Theme 3 also contributed to the PhD autumn school, to Electromobility Days and Roads to the Future, where Professor Rachid Yazami was invited to discuss non-linear voltammetry for battery diagnosis.

National and international attention

Batteries as energy storage solutions for electric vehicles have most likely never received as much media attention as in 2021. There has also been a larger public interest in energy storage solutions for other types of vehicles, such as heavy-duty transport, trains, ships and electric flights. The very rapid electrification of the vehicle park has launched a gigantic push for battery fabrication, also outside of the traditional battery producing countries in East Asia. So called 'gigafactories' are being built in very many countries in Europe, with Sweden as a prime example. Recently, novel sites for battery production in Sweden have been announced, with SEC partners involved (Volvo Cars). Considering the amount of financial resources and human capital being channelled to the battery sectors, there has been no shortage of media attention, and theme leaders and profiled researchers associated with SEC appearing both locally, nationally (SVT, SR, DN, SvD, Ny Teknik, Dagens Industri, Kemisk Tidskrift, etc.) and internationally in media as experts on this development. Moreover, has raw materials for batteries and battery recycling emerged as critical issues, which has sparked further media attention. Internationally, SEC partners in the energy storage area has been very active and visible in several European research projects, not least Battery 2030+.

In parallel with batteries, interest for hydrogen has also flourished. In the hydrogen strategy for a climate-neutral Europe communicated by the European Commission, hydrogen has been identified as a key contributor in the mitigation of climate change. The European ambition is that at least 6 GW of renewable hydrogen electrolysers should be installed in the EU by 2024 and 40 GW by 2030. The strategy is to make green hydrogen along with electricity the main energy vectors that enables a zero-emission Europe. It then becomes important to obtain synergetic intersectoral effects by integration of hydrogen into the existing systems for energy and transport. Thus, it is quite evident that hydrogen based on renewable electricity will be available at a competitive cost also for transportation purposes and a natural consequence of this is that the interest in electrification of the transport sector with the help of hydrogen-powered fuel cells has increased dramatically during the past year.

Swedish research and SEC researchers within energy storage are highly competitive by all international comparisons.

Challenges and possibilities

The different levels of maturity for different energy storage solutions, i.e. batteries and fuel cells, means that the challenges and possibilities to some extent are different. For batteries, the very high volume of batteries being produced puts an extra focus on critical raw materials, materials processing, cell production and recycling to close the loop and provide cost-effective and sustainable solutions.

The maturity of the technique and its large-scale implementation also means that safety issues become more critical. Nevertheless, the complexity of the battery cell chemistry and its inherent materials renders it necessary to continue to perform research and diagnosis, and also incremental improvements can generate exceptionally large impacts on the overall energy system. Challenges regarding life-time, diagnosis and predictions still remain, and depend intrinsically on the battery cell chemistry. Fuel cell-powered vehicles are in an earlier phase of commercialization than battery-powered vehicles, and important issues revolve around system integration, costs and the design of auxiliary systems. As with batteries, life-time and predictability are important, and linked to the continued development of improved catalysts and membranes. It is also important to remember that most fuel cell vehicles also use batteries, and that the balance between the two ways of storing energy is part of the optimisation of the propulsion system.

Business intelligence

With the Li-ion battery truly pushing the production limits, there are novel aspects which become critical in terms of supply chains and closed-loop systems. Novel Li-ion battery cell chemistries are targeting both higher electrochemical performance and more sustainable materials (Si/C composite anodes, Ni-rich and/or Co-free cathodes), which also applies for other vehicle-related future battery chemistry (solid-state, Na-ion systems). A major challenge for fuel cells to become more important in the field of transport is linked to the availability of a hydrogen infrastructure. The importance of infrastructure issues will therefore grow, in the same way that charging, and electricity grids are already key issues for battery vehicles. Already today we can see how regions are investing in leading this development. It is also evident that there is a large need for educational efforts, not least re-education of labour in the current vehicle industry, to supply the emerging industry with competences.

Erik Berg and Casimir Misiewicz. Photo Mats Tiborn.

Theme 3

Project spotlight:

What makes the battery age?

The lifetime of EVs are highly depending on the wellbeing of the battery, and much can be done to make them last longer. The aging process of batteries are investigated in this SEC, led by professor Erik Berg and with PhD-student Casimir Misiewicz, both Uppsala University.

Even though it is now many years since lithium-ion batteries have become a main technology for most of the rechargeable devices we use, it is not until now, when EVs are changing the vehicle market, that increasing the lifetime of the battery has become a main concern for the battery manufacturers.

"The expected life-time of li-ion batteries in electric vehicles is today around 10 years. This makes people hesitant to invest. If we increase the lifetime, then we also speed up the electrification of vehicles. Knowing what makes the batteries age is crucial for electromobility", says professor Erik Berg, who is leading the project.

One result of the ageing process is gas development inside the batteries. In this project the researchers at Uppsala University collaborate with Scania and Volvo Trucks. The companies supply the team with batteries that are pre-tested and with basic information about the capacity from the start. The researchers then investigate what kind of gas and how much is being developed under different circumstances. They are now running tests to learn what causes the formation of different gases.

"We have learned a lot from these experiments. We have seen that gas has been released from the battery, and it might not even be from any usage of the battery, but just from sitting unused on a shelf, so there might be a number of different reasons why gas is developed in the batteries", says PhD student Casimir Misiewicz.

Since the battery consists of chemical cells, there are chemical reactions inside it. It is when these reactions go wrong that gasses are produced, essentially using up the battery's fuel and in so doing, aging it. In the project the researchers are backtracking all the reactions that lead to the formation of the gases. Step by step they can then get back to the initial event that started the unwanted reactions.

"We hope that the project will provide an important methodology for the electric vehicle industry to develop strategies that prevent the battery from aging" says Erik Berg.

A possible follow-up project would be to use the learnings from the project in collaboration with producers of battery cells and upgrade their chemistry to prevent gas evolution and thereby prolong the lifetime of the cells.

Theme 4

Environment & Society

Electromobility in Society investigates electromobility from a societal and environmental perspective and focus on understanding the socio-technical systems and how they interact. The aim of all activities is to guide development and policy work towards sustainable electromobility.

The development in the area is very fast and new technology increases the need for Understanding user adoption and transport services. This first strategic area focusses on the interplay between technology and the different actors, both in the passenger- as well as freight transportation system and also the mechanisms that govern the interaction that influence the development of electromobility.

The second area, Measures for resource availability and circular economy, implies research that investigates vehicle and societal system design strategies for securing important raw materials by promoting circular material flows. In the third area, Assessment of environmental impact and resource use, the focus is on developing tools and models for assessing relevant technologies.

Research advancements within 2021

Thirteen projects, whereof four funded by the center and nine associated, have been running within the theme area during this year. Another eight projects are linked to the theme but are coordinated within another theme area – three funded Ph.D. projects (in theme areas 2, 3 and 5) and five other associated projects. Theme 4 is the main theme area for two SEC funded Ph.D. projects. One assesses lithium-ion battery production and its role in the overall life cycle of lithium-ion batteries, and the other explores plug-in hybrid electric car adoption and real household consumer behavior in terms of drive patterns and preferences for the charging infrastructure. Associated projects include environmental assessments, innovation system studies and transport system analysis.

Although still struggling with consequences from the COVID-19 pandemic, two theme researcher projects started in 2021. One focusing on electrification of freight transport system from an actor's perspective and the other on environmental assessment of charging systems. Both projects were presented at Emobility day in October. Also, several associated master- and candidate theses were conducted.

Other activities have been four theme specific open seminars, and one large cross-thematic webinar about recycling of vehicle batteries in collaboration with theme area 3 and Batteries Sweden. The remaining four had the following titles: "Understanding of different application areas for electrified freight transports"; "Thesis presentation bonanza"; "Electric Cargo Bikes"; and "Electrified regional and long-range heavy road transport". The theme group has had reoccurring meetings during 2021 to share reflections, listen to theme related seminars and research presentations, and to discuss project proposals and updates of the road map.

National and international attention

During the spring, theme leader Anders Nordelöf's research portfolio entitled "Life cycle assessment and circularity for electric vehicles" was selected by IVA – the Royal Swedish Academy of Engineering Sciences – to be one of the 100 most important ongoing research activities in Sweden, as regards the potential to create industrial and societal impact. In November, Anders Nordelöf and PhD student Mudit Chordia were interviewed together about research results by Ny Teknik, the largest technology magazine in Sweden in an article entitled "Batteritillverkning i gigafabriker – då får elbilen lägre utsläpp". Project leader and Chalmers theme representative Frances Sprei was interviewed twice, in October and November, on Swedish national radio P1, in the program "Nordegren och Epstein", about EV use and ownership. The second time, theme leader Anders Nordelöf joined to talk about social issues and environmental aspects of batteries and EV use.

Challenges and possibilities

The EV technology and adoption is evolving faster every year. This implies new challenges for the society and a need for fundamental knowledge and assessment methods. Clear gaps remain in terms of understand all environmental impact on a system level, and how the technology can be implemented to co-evolve with formative industrial business models. During this fast transition, theme 4 must remain excellent in our research and relevant in our topics to create understanding for our partners on the keys to

societal acceptance and continued difficult but necessary strive for enhanced sustainability, especially when related to resource extraction and resource availability. Important questions in the coming year can be found connected to the deployment of infrastructure for charging, and how the transport system set demands on increased electricity supply.

Business intelligence

Electrification is clearly seen as a major opportunity to create a sustainable transport system. Governments and industry show increasing ambitions to take action to mitigate ongoing global warming. A big challenge is to keep a high pace in all necessary areas, e.g., vehicles, batteries, production of renewable energy, infrastructure, and societal acceptance. We need to understand how a sustainable transport system can be implemented, what actor needs to do what and when? How can a circular economy be designed and how will technologies and solutions affect the environment from a systems perspective? Technology driven development of connectivity and eventually autonomous vehicles will affect the possibilities to improve system efficiency.

Frances Sprei. Photo: Anna-Lena Lundqvist

Theme 4

Project spotlight:

Charging behavior of plug-in vehicle users

No matter how much you minimize the environmental impact of a plug-in vehicle, in the end the user is the key factor.

Plug-in vehicles are subsidized for their potential to reduce CO2-emissions. But just a few misses in your charging routine increases the emissions rapidly. In this SEC-funded project Frances Sprei, studies charging behavior from swedes using Volvo cars and from American users in California together with UC Davis and Volvo. This far into the study only American data has been available.

"We see that in our case car in the USA, looking at a span over 10 days, it shows that if you skip charging the car just once the effect is increased CO2-emissions with 43 grammes per kilometer which is in fact pretty much considering that 50 grammes per kilometer is one of the limits that have been used to control emissions", says Frances Sprei.

Another lesson learned from the project is that the range of plug-in vehicle is a key factor for its environmental impact. A car with a range up to 80 kilometers is more likely to be driven on electricity in its everyday activities than one with a shorter range.

The project has just received data from European users through their collaboration partner Volvo. With this data the researchers will be able to learn in more detail about the situation for user behavior for plug-in vehicles in Sweden.

The results from the project will give important information to policy makers of the impact of plug-ins in reality. In the Swedish bonus-malus system where you get a bonus for buying a car with less emissions and a fee for buying one with high environmental impact, real data on charging behavior could make the system more efficient.

"The behavior differs between countries. One study shows that users using company owned plug-ins in Germany and the Netherlands prefer fossil-fuel before electricity, probably because the fossil-fuel is paid for by the employer, but the electricity is paid for by the employee", says Frances Sprei.

The work in theme 4, Electromobility in society, often results in knowledge useful for citizens and policy makers. As a way for dissemination Frances Sprei and her colleagues frequently appears in media writing debate articles and participating in interviews. In 2021 she could be heard in the Swedish Radio show Epstein och Nordegren, talking about plug-ins, and she is also Chair in Region Västra Götaland's research council for the climate transition.

"Of course, I bring the knowledge I get from projects like this when I'm working with outreach. Knowledge about human behavior is important to understand how the climate transition shall succeed", she says.

Theme 5

Vehicle–Grid Interaction

The number of electric vehicles is rapidly increasing in society and so does the present and future need for electric energy and power. This will have a significant impact on the operation of the electrical power system, considering that the electrification of other sectors - such as the industry and the built environment - is also expected.

The main task of Theme 5 is to conduct research in key areas related to this topic, to promote collaborations and knowledge sharing. The research within Theme 5 is divided into four strategic research areas: Charging at lower power levels, Charging at higher power levels, Charging infrastructure from a system perspective and, finally, Need and use of energy storage in the power system.

During the year, the Theme group have arranged and participated to several different activities for Theme members but also to a broader audience. There have been four workshops/seminars covering topics such as battery swapping, charging of heavy-duty vehicles from a manufacturer perspective and the role of electric grid operators in the future electrification. In addition to these events, the theme group meets approximately twice a month to discuss ongoing or potential research projects as well as other activities related to the Theme.

Research advancements within 2021

During 2021, two new research projects were initiated within the Theme: One PhD project focusing on High Power Charging and one Theme researcher project focusing on data exchange between the vehicles and the power system. There are also several projects associated to SEC and Theme 5. Two examples of such associated projects are REEL and E-charge. Both projects focus on the electrification of heavy-duty trucks and researchers as well as industrial partners from Theme 5 participate in both of them. Another associated project is the, so-called, Mobility house of tomorrow, which focuses on charging infrastructures and electromobility in smart cities. This project brought a new PhD student to the SEC doctoral network.

National and international attention

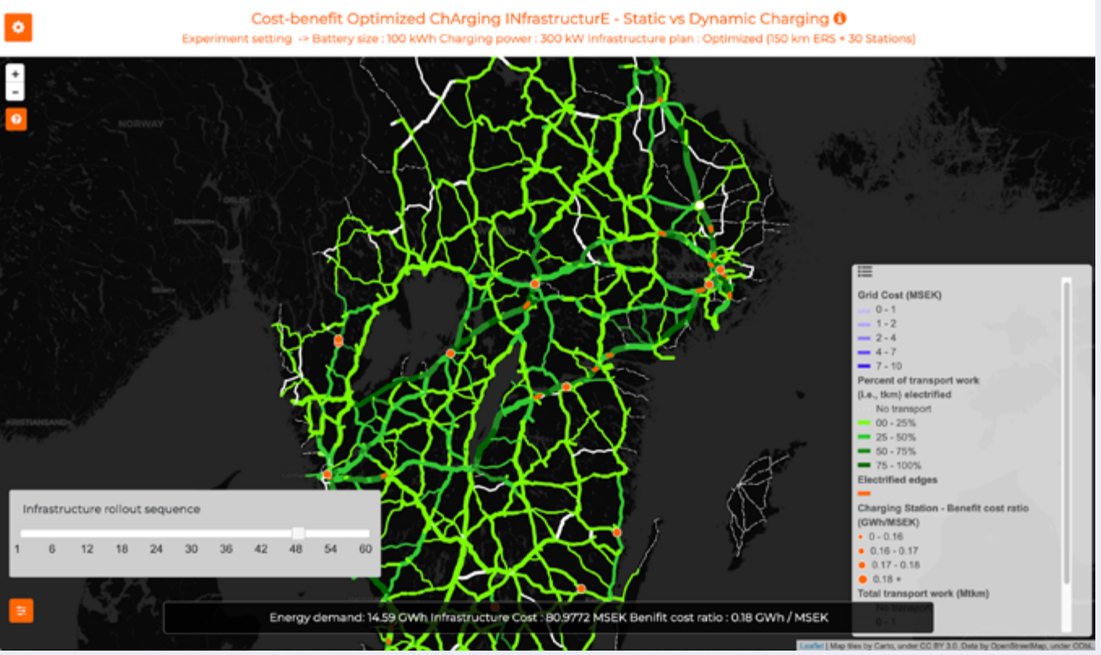
Theme 5 participated to the international conference Roads to the Future, which was held in Sweden in October 2021. The conference shines a light on the latest research and cutting-edge technology within the field of electromobility including the vehicle-grid interaction. The Theme contributed by co-organizing the conference, presenting the research going on within Theme 5, and inviting international speakers.

Challenges and possibilities

The activities within this field have increased drastically during the recent years and there is a lot of ongoing research and development in different sectors at the same time. This continuous evolution is compelling as well as challenging when doing research in the field since so many factors can change. Another challenge is that the development is going fast - within five year we expect to have a large proportion of EVs on our roads – and new solutions are required in the near future. At the same time as the electric vehicle fleet is growing, other sectors such as the industry sector is also expected to increase the demand of electricity. Thus, the power system needs to be upgraded and expanded to handle the need for more electric energy. Normally, it takes time to make substantial reinforcements of the grid. For many projects, the time frame is several years. Therefore, it will be important to look at charging solutions that the power system can handle in a short as well as medium time window, and also to investigate if any additional infrastructure will be needed. The electrification of the transportation sector also brings a lot of opportunities. First of all, it contributes to a more sustainable transportation system, but it may also enable a more sustainable power system. Our power generation will be more and more dependent on non-dispatchable power sources with the consequence that we also need to consider how we consume our electricity. If we have flexible loads, as EV charging, and we can plan when to turn them on and off, we can meet the power generation in a better way. Further on, if we can use the energy stored in the EV batteries for supporting the grid and other systems, e.g., V2G, the EVs can be an even more important part for the energy transition.

Business intelligence

Nowadays, there is a lot going on within the field of Interaction between vehicles and grid and there are a lot of innovative solutions on how to meet a future power demand for EVs. The public and private sectors are engaged to carry on research and invest in this area. The capacity of the power grid is getting more attention than ever before. As electrification of the transport system - as well as society as a whole – takes off, big cities face considerable problems with the capacity of the electric grid. At the same time more and more distribution grid owners realize that they must create flexibility in the system in order to avoid huge investments in the present grid. They also realize that the transport sector might not only be a burden on the grid but actually also an asset.



The interactive web map explores the return on investments of an optimized charging infrastructure roll-out plan for 150 lane-kms of electric roads and 30 charging stations.

Theme 5

Project spotlight:

Maximizing the ROI of charging infrastructures

To reach climate goals, a well-planned charging infrastructure is paramount for a rapid, efficient, and smooth transport electrification transition. To this end, in the SEC-funded project LOLA, researchers are building a model and method to plan cost-effective charging infrastructures.

A well-planned charging infrastructure that can meet the charging demand of commercial, electric heavy-freight vehicles is necessary to accelerate transport electrification. But the required infrastructure investments are high and risky, so stakeholders need accurate decision support to estimate the return on investments, ROI, for different charging infrastructure plans. But the number of possible plans is endless. One can install electric roads, charging stations, or a mix of these. One can place these different types of charging infrastructure components forming a network in virtually an infinite amount of possible ways on the road network. Also, one can dimension the charging capacity of each of these components.

The LOLA project looks into how to incorporate charging stations as an electrification option and how to effectively model the charging infrastructures costs, including the cost of grid connections that is required to supply the charging demand, in the cost-benefit optimization of charging infrastructure plans.

An interactive map allows the user the explore the ROI of an optimized charging infrastructure roll-out plan. Add target transport routes to be electrified, some predefined scenario setups, such as vehicle battery sizes, maximum charging power per vehicle, and charging time limits at stations, and electrification budget in terms of a lane-kms of electric roads and number of charging stations, and the map suggests the most efficient plan.

Vehicles with batteries already fully charged have limited use of an electric road segment and thus locations should be electrified from the premise of the vehicles' need of charging and not from where there is a lot of vehicle traffic. Prior research has shown that the charging needs of vehicles and the charging utility of locations is primarily influenced by the vehicle's routes, not the traffic counts.

"Electric road network plans that are optimized based on the vehicle routes can electrify up to three times the transport work and hence can yield up to three times as much revenues compared to traffic count-based corridor plans", says LOLA's project leader, Gyözö Gidofalvi, Associate Professor in Geoinformatics, ITRL, KTH.

Stationary charging at stations takes a relatively long time hence will be most attractive at locations where the driver can use the time during charging for other activities. These locations will most likely be at the start and end of the route and around five hours into the route when loading, unloading and mandatory rest stops usually take place. Thus, as with electric roads, the charging needs and the charging utilities along the route should primarily depend on routes and not the traffic counts.

To maximize ROI, the model also estimates the grid cost and the charging equipment cost that is required to satisfy the estimated charging need for both electric roads and charging stations. The model then develops an optimized roll-out plan, combining these conclusions.

"Preliminary results show that the optimized charging stations may have a larger ROI than the optimized electric roads. However, for the large-scale electrification scenarios, the charging demand on charging stations is well into the double-digit MW ranges, something that requires large charging infrastructure and grid reinforcement investments, says Gyözö Gidofalvi.

To ensure that the right type of infrastructure development happens at the optimal locations and thereby avoid huge losses in investments in long-term infrastructure, Distribution Service Operators (DSOs) and Charging Point Operators (CPOs) need accurate evidence-based decision support. The maps and statistics produced in the LOLA project are just a start and some indications. The DSOs and CPOs will need to do sensitivity analysis of the scenarios, grid enforcement optimizations and cost estimations in the grid.

"Also, charging stations appear to be a better infrastructure investment option than electric roads now, but the opposite might be true in an autonomous transport future when stopped vehicles are considered "waste" from an operational efficiency perspective" says Gyözö Gidofalvi.

Collaborations 2021

SEC is a major host for collaboration within electromobility research in Sweden. Collaboration lies at the core of the centre, providing a link between major universities together with each other and industry involved in electromobility in the country. Together, this covers a large part of all research activities within hybrid and electric vehicles in Sweden.

The centre mainly focuses on collaboration with organizations that complement its knowledge, and strengthen its role in Sweden. But the collaboration doesn't stop there. SEC is growing in many ways, in members, in project funding, but also in collaboration with other centres and with associated projects. Here are some of the organisations and projects the centre collaborated with in 2020.

EVS-application

SEC collaborated in a consortia lead by Business Region Gothenburg to get to host one of the world's largest conferences within electromobility. Director Linda Olofsson participated in an event together with other representatives for Swedish electromobility, where she presented SEC and the Swedish electromobility research landscape for the delegation from AVERE, the European association for electromobility. The consortia did a good job, resulting in getting the EVS38 to Gothenburg in 2025.

SVEA

SEC and Swedish Vehicular Engineering Association, SVEA, jointly arranged a seminar that covered Infrastructure for the charging of electrical vehicles in Sweden.

The seminar highlighted challenges related to the infrastructure for the charging of the rapidly growing volumes of electrical vehicles that require charging in Sweden and present possible scenarios for the infrastructure for the charging of electrical vehicles, including charging when driving and high-power charging.

Safer

The directors of SEC and Safer. Linda Olofsson and Magnus Granström are supporting each other in the development of the centres and possible collaborations. Linda Olofsson also participates in one of SAFER's groups with a focus on battery safety.

Base

BASE stands for Batteries Sweden and is a competence Centre funded by VINNOVA. The strongest connection between the centres is through SEC Theme 3, both in terms of the participating universities (Uppsala, KTH, Chalmers), industries, and key people. While BASE cover the value chain of batteries and has a focus on the materials within the cell and has battery industry as partners, SEC in turn focus in this respect on battery application within electromobility. Nevertheless, there are interesting interfaces between these scientific and technological areas, and many of the issues regarding battery behavior in vehicles have a clear background in the applied cell chemistry. Joint activities between the centra have therefore taking place, such as a workshop on recycling of vehicle batteries in April 2021.

Battery 2030+

BATTERY 2030+ is a large scale, long-term European research initiative with the vision of inventing the sustainable batteries of the future.

SEC is a supporting organisation to Battery2030+. It actively gave support in designing the vision, aims and goals of the BATTERY 2030+ initiative and roadmap. SEC also gives input to the activities in the initiative as a part of the European battery eco-system that can ensure the uptake of new knowledge and technologies.

SICEC

The SEC project (prestudy) Fuel Cells in Vehicle Systems aimed at identifying research needs associated with integration of fuel cells in vehicle systems. The project involved a number of researchers from various SEC Theme groups as well as industry partners and was carried out as a series of workshops. Workshop participants were also invited from three other competence centers. As these centers focused on combustion engine research, they could provide competence related to various aspects of fuel cell systems research, mainly air and fuel handling. These centers are KCFP (LTH), CERC (Chalmers), and CCGEx (KTH).

Tunga fordon

In southern Sweden, the Association of Heavy Vehicles (Tunga fordon) is a membership organisation with world-leading manufacturers of heavy vehicles such as dumper trucks, wheel loaders, forestry machinery, compacting and paving equipment as well as heavy forklifts. SEC director Linda Olofsson held a lecture on SEC's research at the association's general meeting in 2021.

SEEL

The Swedish Electric Transport Laboratory (SEEL) is a test center for research and development in the field of electromobility, and is owned and run by Chalmers and RISE as a joint venture. Collaborations with SEEL will be initiated in 2022. SEC has contributed at a workshop on potential research areas of the test centre.

PhD network

The Swedish Electromobility Centre's (SEC's) Doctoral student network is open for all PhD students in Sweden who study aspects of electrification and hybridization of vehicles. The network is an arena for collaboration and networking between PhD students and stimulates their interaction with the Swedish automotive industry.

The Doctoral student network offers access to SEC's activities and network, knowledge building through seminars and PhD courses, contact and networking activities with other PhD students from different fields within electromobility, and preparation for future work and research challenges.

The PhD students in the network comes form all partner universities, and includes both academic and industrial PhD students. The network has been hosted by SEC coordinators (Frida Barret, Lena Holmberg, Linnea Qvirist) and administrators (Rebecka Andersson and Anna Abelius) during 2021.

SEC summer school – autumn edition

Due to the pandemic situation, the summer school was postponed from 2020, and finally took place the 22nd – 26th of November at Söderköping Brunn. This is a course that is given annually by SEC and is aimed for PhD students that want to deepen their knowledge in electromobility. The school covered topics from all five theme areas of SEC, where theme leaders or project managers associated to each theme held lectures and practical exercises during the course. In addition, there was also time for networking activities and group work, which will be presented during part 2 of the course in February 2022. A total of 20 PhD students participated in the course this year.

Autumn school

The PhD network met in Söderköping for this year's autumn school.

20 PhD students from SEC's all participating universities took part of lectures and practical exercises related to the five themes in SEC. This year the focus was on components and system studies for electromobility, with emphasis on electric battery and fuel cell vehicles.

Anar Ibrayeva, PhD student at Uppsala University

"The autumn school is a perfect place for networking and exchange of knowledge between experts in different fields. It was not only engaging but also fun!", says Anar Ibrayeva, PhD student at Uppsala University.

Lecturers were Jonas Fredriksson, Chalmers and and Lars Eriksson, theme 1, with assistance from many of the other theme leaders online, and also Mats Leksell, KTH.

Collaboration and networking is a central part of SEC and the PhDs got to collaborate between university borders in the group exercises.

PhD courses during 2021

The major part of the course Electromobility Systems Design Project, led by Anders Grauers took place in the first two months of 2021. A total of 16 students fulfilled and graduated from the course.

In March 2021, the course Hybrid Electric Powertrains, Modeling, Control and Optimization took place, led by Lars Eriksson. A total of 27 students followed the course.

Lunch Seminars 2021

SEC hosted eight digital lunch seminars during 2021, with presentations from Power Cell, Swedish Electric Transport Laboratory (SEEL), Swedish Energy Agency, Linköping University, Swedish Transport Administration, Northvolt and Saab.

Other networking activities

Tappa competition

Due to the pandemic situation physical networking meetings were not possible and instead we arranged a digital 'Tappa competition'. Interested SEC-students were divided into teams. They competed who could walk around Sweden the fastest (digitally). The students registered steps/activity time from walks, runs or other physical activities and were urged to talk to each other digitally as well as meeting up for outside activities if possible. They got to see more of Sweden (digitally) the longer they walked, or the more they exercised. Some teams also met up for 'online fikas' to get to know each other better. Students enjoyed the activities and the acquired good habits so much that some continued with them also after the competition had ended.

There were also some digital networking meeting during the competition, where everybody met online.

Networking in connection to the lunch seminars

As the networking for the PhD students can be challenging during the pandemic situation, SEC held small "meet and talk" session in direct connection to the lunch seminars. This was a way to allow the PhD students to meet, talk and network on a monthly basis, when already connected to the lunch seminar digital meeting room.

Outreach and communication

The centre's communication and outreach efforts are there to bind together all extraordinary work that is being done within the network of the centre. The efforts get even more important as SEC is a virtual centre organisation with activities spread over Sweden. The efforts are meant to glue together the different activities and increase the knowledge of what is going on in all of the five themes, in all participating Universities and industries. The outreach activities are also strengthening the brand and in the long-run contributes to the impact of electromobility in society.

Newsletter

Every month subscribers of the SEC newsletter get an update on what is going on in the centre, what events have happened and are about to happen, and the latest news from the collaboration that is going on within the centre and that the centre does in external collaborations. Anyone can sign up for the newsletter at the SEC webpage. In 2021 the subscribers increased from 2500 to 3300 subscribers.

Events

The centre has themes workshops arranged by the theme groups, lunch webinars for the PhD-students, workshops in collaboration with external partners. The most significant events in 2021 were the live events in Uppsala in October. The centre hosted the open event Roads to the future, with international keynote speakers. The second day was the internal SEC event Emobility Day where the themes presented their projects and results. It was a well visited two days with around 200 participants the first day and 100 the second.

Director Linda Olofsson has been invited as a speaker at major emobility related events in Sweden. She presented the work of the Swedish government's Electrification commission, which she is part of, at the eCarExpo in Gothenburg, represented SEC at the Scania Innovation Day, presented the centre research to the European insurance industry at EURAPCO, presented SEC at the Taiwan-Sweden JBC, presented SEC research to the association Tunga fordon and was also one of the speakers that supported Gothenburg's application to host a very large international electric vehicle conference.

Global watch

The omEV newsletter is a global watch service run through SEC. Magnus Karlström is the editor-in-chief and up to three times a week they give the subscribers a quick overview of what is happening in the§ world. They gather, analyse and package information about what is happening in the world of emobility and that may influence Swedish mobility development.

Selected Media Coverage

Därför saknar elbilar och hybrider manuell låda

Ett batteribälte växer fram i norr – batteriforskaren: ”Är högintressant” | SVT Nyheter

Batteriforskaren: ”Onödigt att köra runt på ett ton metall”

Här skapas framtidens bilbatterier | SVT Nyheter

Europe seeks to compete with Asia in electric vehicles

Kan vem som helst äga en elbil? 25 oktober 2021 - Nordegren & Epstein i P1 | Sveriges Radio

Batteritillverkning i gigafabriker – då får elbilen lägre utsläpp

The omEV newsletter

Magnus Karlström
Editor-in-chief of omEV

omEV is a daily and free of charge newsletter, funded by the Swedish Energy Agency, about the development of electrified vehicles. An independent editorial staff carries out the analysis, writes newsletters, and produces a podcast.

Our summary of the year 2021 must start with the severe problems for the automotive sector, including pandemic-driven lows and disrupted supply chains, significantly influencing the supply of semiconductors. For example, registrations of new passenger cars in the EU were only 9,7 million vehicles, the lowest numbers since 1990.

Despite the problematic situation, 2021 saw a greater plug-in vehicle (PEV) adoption. The PEV market almost reached 6.5 million globally. For comparison, 2020 ended with 3,1 million cars registered. In Sweden, the share of PEV of the total new registrations was 45.0 per cent in 2021, compared with 32.2 per cent in 2020. The rapidly increased market share of PEV is one trend showing the strength of the transformation of the transport sector to electrification. Another one is the increased stock value of companies focusing upon electric vehicles and batteries. Tesla is valued more than all other car manufacturers. Another electric vehicle company called Rivian raised a total of $13.8 billion in an of the hottest IPO (initial public offering) in 2021.

Several factors contribute to the increased market share. First, many governments extended their incentives to support electric car purchases during the pandemic. Another factor was the availability of more price-competitive PEV models. One major factor influencing the price of PEV is the price of batteries. Even though the price of several materials used to produce batteries raised during 2021, the price of batteries fell during 2021.

Batteries continue to be the most critical technology to follow to analyse the electrification of road transport. This year, we saw even more plans for building battery plants in the world. For example, in Sweden, Northvolt produced the first battery cell in a Swedish Gigafactory, and Northvolt and Volvo cars decided to make a battery plant in a joint venture. Another battery trend was the increased focus upon using and planning to use LFP(Lithium Iron Phosphate) batteries. For example, both Tesla and VW want to use LFP batteries long-term. LFP have some pros and cons, but one advantage is they contain neither nickel nor cobalt.

Cobalt and nickel are both elements needed for a clean energy transition. During 2021 policy initiatives, business activities and debate increased about the need for more mining and increased recycling, selection of battery types, and second life uses of batteries to manage the supply of critical material to achieve a clean energy transition.

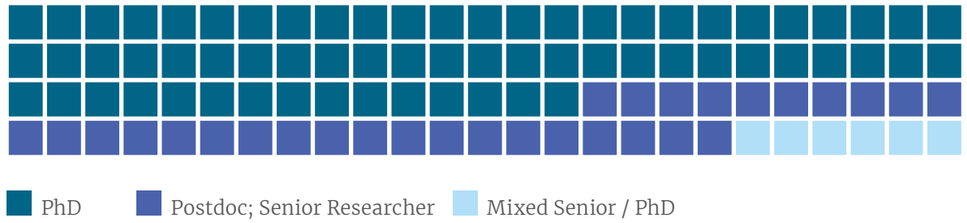
Not only private cars are getting electrified. Electric heavy-duty trucks have merged onto the fast lane to full-scale adoption. Although, the market share is still relatively low. In Sweden, around 1% of new registered heavy-duty vehicles were battery electric vehicles in 2021. But according to the Swedish automotive industry, up to 50 per cent of sales of new heavy trucks by 2030 may consist of electric trucks. The debate about how to charge heavy-duty trucks cost-effective and without productivity losses has started. One of the most exciting events was the signing of a joint venture between the TRATON GROUP, Daimler Truck, and Volvo Group to create an agreement for a European high-performance charging network. The plan is to install and operate at least 1,700 high-performance green energy charging points on and close to highways and at logistic and destination points within five years of the establishment of the JV.

Hydrogen is also more discussed as a fuel for heavy-duty trucks. One major event during 2021 was the signing between The Volvo Group and Daimler Truck AG for a joint venture to develop, produce and commercialise fuel-cell systems for use in heavy-duty trucks.

Centre finance

Project types

One of the centre's objectives is that half of SEC-funded research projects that last for two years or more should have PhD students involved. Of the projects approved and started during 2021, 41 percent are PhD student projects.

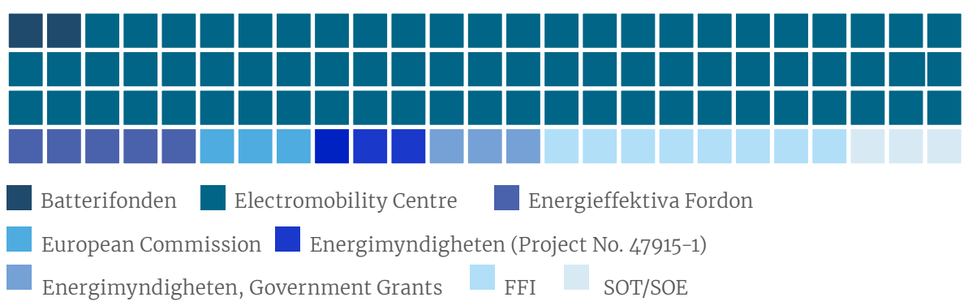


Funding in each theme (projects financed by SEC)

In 2021 the amount of projects connected to the themes have been more evenly distributed than in 2020. This shows that the newer theme 5 is gaining momentum and increased the amount of projects.

Cash funding

71 percent of the projects connected to Swedish Electromobility are SEC-funded projects. In addition, 29 percent are associated projects from various programs/centres.



Events

Theme events

Date	Event name	Event type	Participants
29/1	Electrification of off-road applications	Workshop	Approx. 35 participants
2/3	Electric roads and other charging solutions from the Scania perspective	Workshop	Approx. 20 participants
8/3	Electric roads and other charging solutions from the Volvo perspective	Workshop	Approx. 20 participants
9/3	Battery ageing modelling	Workshop	Approx. 30 participants
24/3	Understanding of different application areas for electrified freight transports	Web-seminar	66 participants
27/4	Recycling of vehicle batteries	Workshop w BASE	Approx. 130 participants
19/5	The role of electricity network companies in the future electrification	Seminar	31 participants
28/5	Electrical machines for electromobility	Workshop	Approx. 45 participants
2/6	Battery-swapping for electric vehicles in China	Seminar	21 participants
8/6	Workshop on Reinforcement learning and data driven methods for electromobility	Online	35 participants
18/6	Thesis presentation bonanza, master thesis presentations	Web-seminar	38 participants
17/9	Electric Cargo Bikes	Web-seminar	19 participants
7/10	Reliability and condition monitoring workshop	Workshop	Approx. 60 participants
12/11	Electrified regional and long-range heavy road transport	Web-seminar	23 participants
9/12	Fuel cells	Workshop	Approx. 20 participants
16/12	Dissemination of results from ongoing projects	Hybrid at Volvo Cars	12 participants

PhD-student lunch seminars

Date	Event name	Event type	Lecturer
3/2	On Energy Management in Aeronautics – trend and needs related to SEC	Digital lunch seminar	Magnus Eek, Saab AB, Business Area Aeronautics
3/3	The world's greenest battery	Digital lunch seminar	Emma Nehrenheim, Northvolt
1/1	Electrification underground	Digital lunch seminar	Erik Svedlund, Epiroc Electrification
7/4	Calculation models	Digital lunch seminar	Björn Hasselgren & Elin Nässtrom, Trafikverket
5/5	Electrification of freight distributions system	Digital lunch seminar	Henrik Johansson, Linköping university
6/10	The Swedish Energy Agency	Digital lunch seminar	Peter Engdahl, Energy Agency
3/11	Swedish Electric Transport Laboratory – SEEL	Digital lunch seminar	Martin G. H. Gustavsson, SEEL
2/12	High Power Fuel Cells: Driving the technology shift in the maritime industry	Digital lunch seminar	Thomas Tingelöf, Powercell

PhD-network courses

Date	Event name	Event type	Examiner
1/3	Hybrid Electric Powertrains – Modeling, Control and Optimization	Course	Lars Eriksson, Linköping University
Ended 5/3	Charging infrastructure	Course	Anders Grauers, Chalmers
22-26/11	SEC Autumn School	Course	Reps. from all themes

SEC main events

26/10	Roads to the Future	Live-seminar
27/10	Emobility Day 2021	Live-seminar

Projects

Project	Project manager	Main thematic area	Main university partner	Other university partners	Company partners in SEC
ACTUAL grid and road simulation for emobility	Francisco Marquez-Fernandez	5	LTH	KTH	CEVT, Scania, Vattenfall, Volvo Cars, E.ON
Combining physical and data-based modelling to understand material failures in recharge-able lithium ion batteries	Peter Broqvist	3	UU		Scania, Volvo Cars
Design of rare earth element free motors for electromobility	Sandra Eriksson	2	UU		Scania
Diagnostics and supervision of dynamically configurable battery systems (DiConBatt)	Mattias Krysander	1	LiU		Scania
Electric vehicle charging strat-egies and grid management – interaction with the electric grid	Maria Taljegård	5	Chalmers		CEVT
E-machine design for enhanced recyclability and minimized environmental impact	Torbjörn Thiringer	2	Chalmers		ABB, CEVT
High Power Charging when, where and how?	Karin Thomas	5	UU		CEVT, Scania, Vattenfall, Volvo AB
Life Cycle Assessment of Large-Scale Lithium-Ion Battery Production and Recycling	Anders Nordelöf	4	Chalmers		CEVT, Scania, Volvo AB, Volvo Cars
On-line health diagnostics of inverters for commercial vehicle drive systems	Staffan Norrga	2	KTH		Scania
Real-time observation of side-reactions: Understanding and predicting the lifetime characteristics of Li-ion cells	Erik Berg	3	UU	KTH	ABB, Volvo AB, Volvo Cars
Testing, Analysis and Design of Axial Flux Motors	Sonja Lundmark	2	Chalmers	KTH	ABB, Volvo AB, Volvo Cars
Thermal modelling and fault prognosis for Li-ion battery systems	Changfu Zou	3	Chalmers		Scania, Volvo AB
Modeling, System Analysis, and Control of Hybrid Electric Vehicles with Aftertreatment Systems	Lars Eriksson	1	LiU	Chalmers	Scania, Volvo AB
PETECI Predictive Energy and Thermal management	Nikolce Murgovski	1	Chalmers		Volvo Cars
Prerequisites for electrification of freight transports	Henrik Johansson	4	LiU		BorgWarner, CEVT, Scania, TitanX, Vattenfall, Volvo Cars
Road resistance estimation for improved range estimation	Mikael Askerdal	1	Chalmers		CEVT, Volvo AB, Volvo Cars
Charging behaviour and infra-structure, Stage IV	Frances Sprei	4	Chalmers		Volvo Cars
Chemical quenchers for inhibi-tion of battery fires	Elna Heimdal Nilsson	3	LTH	UU	Volvo Cars
A Model and Simulation Platform for Electric Vehicle Systems with Motors, Power Electronics, Batteries and Fuel Cells and their Heating and Cooling Needs	Lars Eriksson	1	LiU	LTH	Scania, TitanX, Volvo AB, Volvo Cars
Modelling and control of com-plex AWD BEV architecture	Fredrik Von Corswant	1	Chalmers		BorgWarner, CEVT, Volvo Cars
Environmental Assessment of Electromobility Charging systems	Anders Nordelöf	4	Chalmers		CEVT, Scania, Volvo AB, Volvo Cars
Investigation of winding config-uration and leakage inductance	Sonja Lundmark	2	Chalmers		ABB, Scania, Volvo AB, Volvo Cars
Measurements and modelling of thermal and electrical behavior of labscale/industry prototype Li-Ion cells	Torbjörn Thiringer	3	Chalmers		CEVT, Powercell, Scania, Volvo AB, Volvo Cars
XRD tomography of electrodes from Ni-rich Li-batteries	Anti Liivat	3	UU	LTH	Scania
Planning Support for Electric Vehicles based on Optimal Control	Lars Eriksson	1	LiU		Scania, Volvo AB, SAAB
NVH Analysis and Mitigation in Electrical machineS - NAMES	Francisco Marquez-Fernandez	2	LTH		ABB, CEVT, Volvo AB, Volvo Cars
Data exchange between vehicle and power system for optimal charging	Jennifer Leijon	5	UU		CEVT, Vattenfall, Volvo AB, Volvo Cars
Evaluation and optimization of materials for IT-PEMFC	Björn Eriksson	3	KTH		ABB, Powercell, Scania, Volvo AB
Fuel Cell Performance Prediction	Rakel Wreland Lindström	3	KTH		ABB, Powercell, Volvo AB
Performance and ageing of Li-based solid-state batteries	Mario Valvo	3	UU		Scania, Volvo Cars

Associated Projects

Project	Project manager	Main thematic area	Main university partner
Optimal energy management of construction equipment including battery wear		3	LiU
Emission Aware Energy Management of Hybrid Vehicles	Jonathan Lock	1	
Innovation system for electric distribution trucks	Ksenia Onufrey		KTH
Anticipating Metal Scarcity challenges in mobility	Björn Sandén	4	
Life Cycle Assessment of All-Electric Aircrafts	Selma Brynolf	4	
Blood Batteries, Social Life Cycle Impacts of Lithium Ion batteries	Rickard Arvidsson	4	
Battvolt		1	LiU
LINK_SIC		1	
Multifysiksimulering av kylsystemet och dess komponenter	Torbjörn Thiringer	2	
Evolution Road	Per Löfberg	2	
EPOS - Electric Powertrain OptimiSation for Vehicles and Fleet		2	
Diagnostics and Open Loop Lifetime Estimation for Electrical Traction Machines (DILEMA)		2	
Integrated electric Generator and motor (InGe)		2	
Transition to a fossil free European transport	Maria Taljegård	5	Chalmers
The role of stationary batteries and electric vehicles for balancing the grid in a 100% renewable energy system	Maria Taljegård	5	Chalmers
Low carbon transport solutions	Maria Taljegård	5	Chalmers
Compact, modular, integrated electric machines	Oskar Wallmark	2	
Optimering av elektriska maskiner baserat på nya standardiserade körcykler.	Sandra Eriksson		
Integrated Electric Long-Haul Truck & Charger	Gunnar Ohlin	4	
Life cycle assessment of future battery chemist	Rickard Arvidsson	4	
Energy efficient propulsion system			Chalmers
Sustainability transitions in urban goods distribution	Thomas Magnusson	4	
REEL2		5	LTH
High performing circular battery flows	Patricia van Loon	4	
System Effects of Automation, Electrification and Digitalization on Freight Transport	Anna Pernestål	4	
A Ageing of Lithium-ion Batteries with Nickel-Rich Cathodes for Electromobility (ALINE)	Matilda Klett	3	KTH
TVS Modelling		2	
Electromobility in smart cities	Rafael Waters	5	UU
Operational Network Energy Management for Electrified Buses	Balázs Adam Kulcsár	1	
Ti3C2Tx MXene in Li- and Na-ion batteries		3	LiU, UU
The mobility house of tomorrow		5	
STORM - Smart freight TranspOrt and logistics Research Methodologies	Yancho Todorov	4	

Gender Equality

Project name	Project leader	Participants (f/m)	Funding (%f/%m)
A Model and Simulation Platform for Electric Vehic	Lars Eriksson	0/2	0/100
Diagnostics and supervision of dynamically configurable battery systems (DiConBatt)	Mattias Krysander	1/2	75/75
Evaluation of an electro-mechanical linear actuator in heavy-duty applications	Kristoffer Ekberg (Lars)	0/1	0/100
Fuel Cells in Vehicle Systems	Öivind Andersson	0/6	0/100
Modeling, System Analysis, and Control of Hybrid Electric Vehicles with Aftertreatment Systems	Lars Eriksson	0/3	0/100
Modelling and control of complex AWD BEV architect	Fredrik Von Corswant	0/3	0/100
PETECI Predictive Energy and Thermal management	Nikolce Murgovski	0/3	0/100
Planning Support for Electric Vehicles based on Optimal Control	Lars Eriksson	0/2	0/100
Road resistance estimation for improved range estimation	Mikael Askerdal	0/2	0/100
Design of rare earth element free motors for electromobility	Sandra Eriksson	2/1	0/100
E-machine design for enhanced recyclability and minimized environmental impact	Torbjörn Thiringer	5/4	95/5
Investigation of winding configuration and leakage	Sonja Lundmark	3/6	0,65/0,35
NVH Analysis and Mitigation in Electrical machineS - NAMES	Francisco Marquez-Fernandez	1/0	100/0
On-line health diagnostics of inverters for commercial vehicle drive systems	Staffan Norrga	0/1	0/100
Switchable pole phase drive systems for electromobility	Luca Peretti	0/2	0/100
Testing, Analysis and Design of Axial Flux Motors for Vehicle Applications	Sonja Lundmark	4/6	93,3/6,7
Chemical quenchers for inhibition of battery fires	Elna Heimdal Nilsson	2/2	90/10
Data exchange between vehicle and power system for optimal charging	Jennifer Leijon	1/0	100/0
Fuel Cell Performance Prediction	Rakel Wreland Lindström	2/4	0/100

Project name	Project leader	Participants (f/m)	Funding (%f/%m)
Measurements and modelling of thermal and electrical behavior of labscale/industry prototype Li-Ion cells	Torbjörn Thiringer	5/6	40/60
Performance and ageing of Li-based solid-state batteries	Mario Valvo	0/1	0/100
Real-time observation of side-reactions: Understanding and predicting the lifetime characteristics of Li-ion cells	Erik Berg	0/1	0/100
Thermal modelling and fault prognosis for Li-ion battery systems	Changfu Zou	1/3	0/100
XRD tomography of electrodes from Ni-rich Li-batteries	Anti Liivat	1/3	0/100
Charging behaviour and infrastructure, Stage IV	Frances Sprei	1/1	0/100
Environmental Assessment of Electromobility Charging systems	Anders Nordelöf	0/2	0/100
Life Cycle Assessment of Large-Scale Lithium-Ion Battery Production and Recycling Current lithium-ion batteries	Anders Nordelöf	0/3	0/100
Prerequisites for electrification of freight transports	Henrik Johansson (Gillström?)	0/1	0/100
ACTUAL grid and road simulation for emobility	Francisco Marquez-Fernandez	1/2	100/0
Cost-benefit Optimized ChArging INfrastructurE	Gyözö Gidofalvi	0/1	50/50
Electric vehicle charging strategies and grid management – interaction with the electric grid	Maria Taljegård	2/2	75/25
High Power Charging when, where and how?	Karin Thomas	2/1	0/100
Power systems integration of electric vehicles for balancing power support through all-dc systems	Massimo Bongiorno	0/3	0/100
Fuel cell durability prestudy	Anneli Jedenmalm	3/4	43/57
Evaluation and optimization of materials for IT-PEMFC	Björn Eriksson	0/1	0/100
Combining physical and data-based modelling to understand material failures in rechargeable lithium ion batteries	Peter Broqvist	2/3	100/0

International collaborations

Project	Project leader & PhD	Theme	Collaboration within the project
Modeling, System Analysis, and Control of Hybrid Electric Vehicles with Aftertreatment Systems	Lars Eriksson, PhD student Olov Holmér	1	IFPEN in France and with TNO Automotive in The Netherlands.
A Model and Simulation Platform for Electric Vehicle Systems with Motors, Power Electronics, Batteries and Fuel Cells and their Heating and Cooling Needs	Lars Eriksson	1	University of Michigan, Ann Arbor
PETECI - Predictive Energy and Thermal management of Electric vehicles with Connectivity to Infrastructure	Nikolce Murgovski	1	Currently, our research group at Chalmers is hosting 3 guest PhD students from China, all enrolled at different universities: School of Electrical Engineering, Southwest Jiaotong University School of Mechanical Engineering, Xi'an Jiaotong University School of Mechanical Engineering, Nanjing University of Science and Technology. The guest students are working on problems involving energy management, thermal management, and eco-driving within the transport sector. Their topic is well connected to the topic of this SEC project and the involved PhD students collaborates closely with the guest PhD students from China.
Design of rare earth free motors for electromobility	Sandra Eriksson	2	The project manager is involved in an EU-consortium working on improving ferrite magnets.
Switchable pole phase drive systems for electromobility	Luca Peretti	2	The pre-study indirectly contributes to an active collaboration at the international level with the University of Bologna, Italy. A Ph.D. student from Bologna and the KTH Ph.D. student Yixuan Wu (partly funded by this pre-study) is actively developing a fault-tolerant control solution for switchable pole/phase induction machines.

Project	Project leader & PhD	Theme	Collaboration within the project
Thermal modelling and fault prognosis for Li-ion battery systems	Changfu	3	Through a Vinnova-funded research project (led by Prof Torsten Wik), we collaborate with Beijing Institute of Technology and Geely Automobile in China.
Combining physical and data-based modelling to understand material failures in rechargeable lithium ion batteries	Peter Broqvist	3	We are collaborating with the BIG-MAP project (https://www.big-map.eu/), where especially WP3 deals with similar questions as dealt with in this project.
Real-time observation of side-reactions: Understanding and predicting the lifetime characteristics of Li-ion commercial cells	Erik J Berg	3	With the BMW group – Munich, Germany.
Charging behaviour and infrastructure need for plug-in electric vehicles	Frances Sprei	4	International EV Policy Council, UC Davis, California, USA and Fraunhofer ISI, Germany
Life Cycle Assessment of Large-Scale Lithium-Ion Battery Production and Recycling	Anders Nordelöf	4	Institute of Transport Economics, Oslo, Norway
Associated project: Life Cycle Assessment of All-Electric Aircrafts	Rickard Arvidsson, CTH	4	Pipistrel d.o.o Ajdovščina, Slovenia
Power systems integration of electric vehicles for balancing power support through all-dc systems	Massimo Bongiorno	5	Technical University of Catalonia, University of Padova, Aalborg University, University of Lille

Councils and Management

Program Council 2021

2021-03-09	2021-05-12
2021-03-11	2021-09-21
2021-03-23	2021-12-14
2021-05-05	

General Assembly 2021

April 22	September 1

Permanent Members

Nils-Gunnar Vågstedt (Chairman)	Scania
Johan Hellsing	CEVT
Robert Eriksson	Volvo Cars
Elna Holmberg	Volvo AB
Fernanda Marzano	Scania
Erik Svahn	Energimynd.
Maria Abrahamsson	Chalmers
Lina Bertling Tjernberg	KTH
Öivind Andersson	LTH
Peter Värbrand	LiU
Eva Pålsgård	UU

Co-opted Members

Linda Olofsson (director)	SEC
Lena Holmberg/ Linnéa Qvirist	SEC
Jonas Fredriksson	Chalmers
Lars Eriksson	LiU
Francisco M-Fernández	LU
Luca Peretti	KTH
Daniel Brandell	UU
Göran Lindbergh	KTH
Magnus Blinge	LiU
Anders Nordelöf	Chalmers
Mikael Lantz	LU
Valeria Castellucci	Uppsala University
Anders Grauers	Chalmers
Magnus Karlström	SEC
Magnus Lindgren	Trafikverket
Arne Nåbo	VTI
Dmitry Svechkarenko	ABB
Arnaud Contet	TitanX
Thomas Tingelöf	PowerCell
Katarina Öquist	Epiroc
Christian Guffman	Vattenfall
Gabriel Domingues	BorgWarner
Boel Ekergård	Högskolan Väst
Magnus Eek	SAAB
Magnus Forsén	Alstom
Elin Eriksson	IVL
Pär-Ola Andersson	E.ON
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Heiner Linke	Lund University
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Jan Palmér	Scania
Stefan Christiernin	Volvo Cars
Leif Axelsson	CEVT
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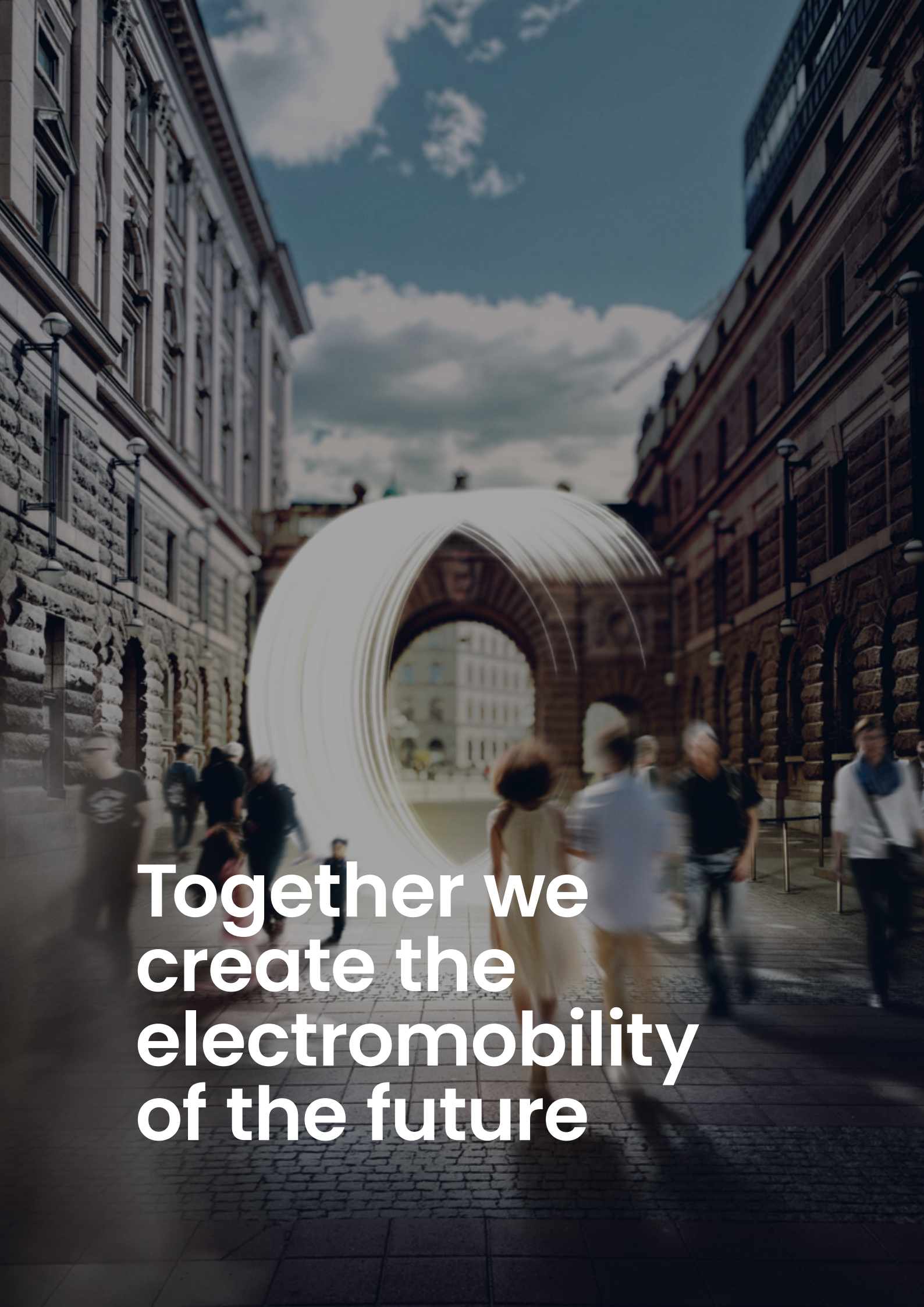
Arne Nåbo	VTI
Magnus Eek	SAAB
Magnus Forsén	Alstom
Elin Eriksson	IVL
Peter Thelin	E.ON
Peter Öhman	LSP
Anders Hedqvist	Epiroc
David Hellstedt	Volvo AB
Thomas Tingelöf	PowerCell
Boel Ekergård	University West
Gabriel Domingues	BorgWarner
Arnaud Contet	TitanX

Co-opted Members 2021

Linda Rinaldo/ Erik Svahn	The Swedish Energy Agency
Christofer Sundström	Linköping University
Peter Öhman	Lindholmen science park
Lena Holmberg	SEC
Linda Olofsson	SEC



Together we create the electromobility of the future