Roadmap Theme 4 – Environment & Society

Introduction

The electrification of the transport sector has evolved rapidly the past few years, driven by urgency to tackle a large-scale transition from the use of liquid fossil fuels and to achieve significant climate change mitigation. Even as widespread application and adoption is now taking place in society, the electrification of the transport sector is continually evolving, with some subsectors being ahead of others, and some still in the early phases of introduction. The shift to electrification is not only motivated by mitigating climate change but also from issues concerning public health and air quality at local level and at a national level from considerations to energy security and energy independence.

Scope and boundaries

The main objective of thematic area *Environment & Society*, theme 4 is to help steer the development of electromobility towards long term sustainability hand in hand with meeting societal needs for transport, now and in the future. The research aims to identify environmental and socio-technical barriers of electrification technologies and support measures to overcome, work around or avoid these barriers, to enable a rapid large-scale transition of the transportation sector. One of the most important measures to meet the climate goals will be the electrification of the transportation sector and the transition must be fast. To find solutions where we can enable a substantial scale-up of electric vehicles and vessels, with the smallest environmental impacts and the most efficient resource use, will be important to enable the introduction of the new technology in a sustainable way.

The research activities covered by this theme are expected to partly overlap or intersect the technology content of the other thematic areas within SEC but will investigate it on a different system level. Theme 4 aims at analyzing the environmental and societal aspects of the different subsystems represented in the other themes and on an overall system level. Analysis on an overall system level of environmental, economic and social aspects avoids sub-optimizations and promotes overall efficiency. In Figure 1 the main interactions with the other themes are illustrated. The relations between the different themes are based on identified key areas for theme 4 which are further elaborated in *current trends and needs*. The key areas reflect the strategic research areas of theme 4.

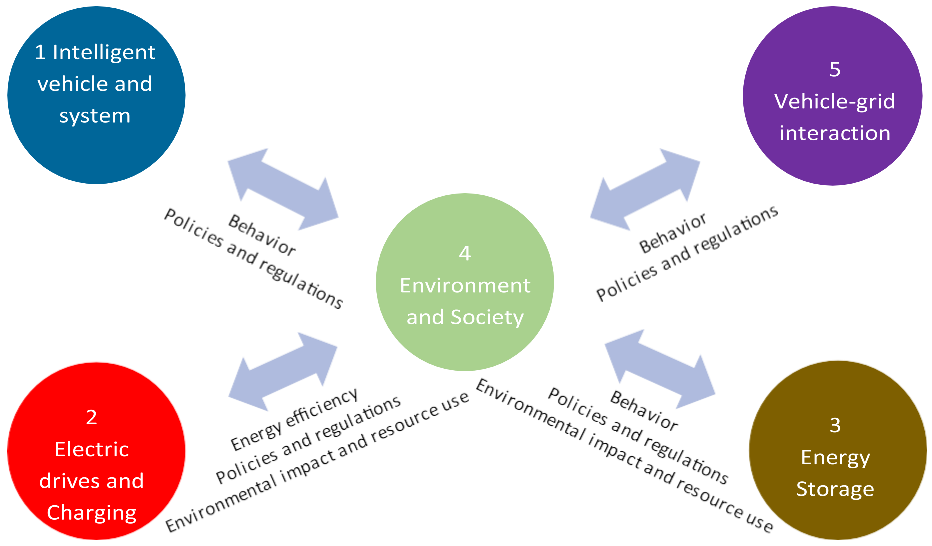

Figure 1. Theme 4 interaction and role in relation to the other themes.

Current trends and needs

The rapid implementation of electromobility in society involves a complex combination of new challenges with technical, behavioral, commercial, and governmental aspects, requiring that a systems perspective is added to the state-of-the-art knowledge. Electrification, increasing levels of vehicle automation, logistics as a service as well as carpooling and shared mobility (ride sharing services) are prevalent trends that have emerged simultaneously in the transport sector the last few years. While technical advancements in the field are enabling these parallel transitions, they are also based on innovative business models and governed by policy directives. In addition, several powerful information technology tools are rapidly being developed. These enable data collection and processing in very large quantities using AI and sensor technologies, e.g., for route optimization, and blockchains are promoted for providing traceability upstream in the life cycles of components, linking to responsible sourcing of key raw materials.

Environmental impact and resource use

The growing concerns regarding resource availability and environmental impact implies the need to design and adapt vehicles as well as the supporting infrastructure, for circular material flows and circular value chains, thereby reducing waste and increasing material efficiency. Equally important is to avoid unintentional shifting of environmental burden from one geographical site to another, or from one point in time to another, with no net benefits. For this reason, it is important to continuously monitor the effects of technical design changes and technology developments by assessing a broad spectrum of environmental impacts such that new problems can be addressed before they become major hurdles. Addressing these societal challenges will impact the pace and efficiency of the transition, and on the acceptance of electromobility by the society in general.
Battery electric vehicles are entering the market with increasingly larger battery size and longer range. This

implies an increased resource use for battery production, and possibly that higher power levels will be requested for charging, shifting the requirements set on the charging equipment (in or outside the vehicle) as well as the grid to supply sufficient power and energy. Battery manufacturers and other automotive suppliers talk about upstream “vertical integration” and modularity as a means to secure resource availability, enhance material efficiency, and reduce costs.

Second-hand EV-batteries are now beginning to enter stationary (for example battery parks for grid balancing) and semi-stationary (for example electricity backup on ships) applications. Improvements in the battery management systems lead to more uniform degradation and better predictions for the state of health of batteries on cell level, supporting the case for second-use.

There is also a discussion of business models based on leasing, which will incorporate future take-back of components for re-leasing to other applications, and eventually achieve effective steering of waste flows into material recycling to increase recycling rates.

The larger and heavier batteries also influencing the wear and tear of the roads and tires which in turn might have an impact on emitted particles and noise emissions. There might be several solutions on how to reduce the need for battery size by sufficient charging infrastructure, battery swapping, flexibility in battery size etc.

Behavior and society

It is possible to identify several societal challenges that the development of electromobility will be facing in the coming years. Many are generic and similar for any emerging technology, for example lack of industry-wide standardization, unavailability of supporting regulations and infrastructure for charging, which is a key for societal adoption. For electric cars, there is a need to know more about the users’ behavior and their willingness to depart from the known flexibility and functionality provided by existing combustion-based propulsion to the new and somewhat different electrified versions, with other types of flexibilities. For heavy-duty vehicles, there is a need to understand the impact of electromobility on transport efficiency and related systemic trade-offs, logistics planning, and charging. Addressing these knowledge gaps involves holistic analysis of electromobility, not just as technical challenges in the vehicles, or at the infrastructural level, but understanding all actors in the transport system, and assessing how the technology needs to evolve to match current and future expectations and needs.

Intelligent systems that advise the user on the most optimized charging options based on their driving preferences are under development. This could be further “gamified” by encouraging the user to alter driving behavior which would accrue “green points.”

Range anxiety has now shifted to queue anxiety, especially for the heavy vehicles where queueing may pose a huge anxiety for the freight industry where time is crucial. For the personal transportation the discussions on access to electromobility and fair distribution of charging infrastructure regarding geographical areas, gender and income has increased. Where app-based car sharing services and carpools are growing in popularity in the larger urban areas, such services has not yet reached smaller cities and rural areas.

Business models

Shared mobility is another trend that is evolving. “Mobility as a service” is gaining attention, i.e., the integration of, e.g., rental cars and taxis with various forms of public transportation by means of new platforms for bookings and tickets.

Range anxiety and risk of delays due to queues at charging stations may push transport companies to demand solutions that minimize the risks e.g., battery swapping, e-roads and batteries on trailers. For transportation of goods, routes and transport flows are optimized together with specifically designed electrical vehicles and a dedicated charging infrastructure.

Higher investment cost in battery electric vehicles and lower operating cost for using them will challenge the present business models for both OEMs and transport operators. New business models based on Vehicle/Transport as a service will emerge. Research is needed on how this can enable new forms of co-operations in terms of data sharing and also co-sharing of vehicles and joint fleet optimization.

The high focus on increasing energy efficiency and lowering manufacturing costs increases the integration of different powertrain components. Higher integration increases the challenges of cost- efficient disassembly, remanufacturing and eventually material recycling of all materials.

Technical trends

Different choices of materials and technology have different environmental impact, infrastructure requirements and resource use. Different solutions are tried out and developed, including fuel cells, LIB (Lithium-ion batteries), SIB (Sodium-ion batteries), battery swapping, structural batteries etc. The interest in fuel cells is also increasing for the heavy duty, shipping and aviation sectors.

Data collection and processing in very large quantities using AI and sensor technologies e.g., for route optimization is often requested but may also be a challenge, especially when it comes to regulations such as the GDPR regulation. With the coming AI-act further regulations may pose challenges on the availability of data and willingness to share it.

To be able to share data in a secure and trusted way data networks might be needed as well as the use of blockchains or other similar technologies to provide traceability upstream in the life cycles of components, linking responsible sourcing of key raw materials.

Policies and regulations

There are several new policies and regulations under discussion that will have effect on various parts of the electromobility sector such as the vehicle, the charging infrastructure, various types of fuels as well as various transportation modes such as maritime shipping and aviation. It is however impossible to mention all policies and regulations in a roadmap, as new are always underway. Here are a few upcoming policies and regulations trends that will affect the electromobility sector.

A new battery regulation is taking form, as part of "European green deal", which will require traceability, declared CO_2-footprint and incremental increase of recycled content in the batteries.
New legislation will put a cap on CO_2 emissions for about 75% of the heavy-duty trucks and busses operating in the EU from 2025. The target is to reduce CO_2 from commercial transports with 15% from 2025 and with 30% 2030 will force a technology shift and push for electrified vehicles. The EU has decided to ban the sale of new combustion engine cars and vans from 2035.

Additional policy proposals within the EU "fit for 55 package" is under final negotiations. Several of the proposed policies will have an impact on electrification and infrastructure of the transport sector.

The AI act is also being developed; the current proposal does not include vehicles but road traffic management systems. Political subsidies in European countries are increasing, with increases in number of EVs, where Europe had the highest increase in EV sales by a compound annual growth rate (CAGR[1]) of 61% compared to 58% in China, mentioned in the EV Global Outlook, 2022.

Research has shown that subsidies are important to increase the EV market share. There is a growing concern that the removed bonus-malus might have an impact on the EV shares of Sweden.

Strategic research areas

This thematic area broadly covers four strategic areas for socio-economic-technical systems research within the field of electromobility:

1. Understanding technology diffusion and its impact on personal mobility, transport services, and society. How do new technologies impact behavior and business models?
2. Securing resource availability, through efficient resource use and circularity
3. Assessment of environmental impact
4. Evaluation of policies and legislation to speed up sustainable electrification of transport

The *first* strategic area aims to investigate the interplay between technology and various actors in society. This includes understanding how and to what extent car users are shifting or are willing to shift their behavior to harvest personal and societal benefits of electromobility, as well as how and to what extent they are experiencing limitations that can hinder continued technology diffusion. What solutions are best

[1] CAGR, the mean annual growth rate of an investment over a specified period of time longer than one year

for society, and how can the required shift in user behavior be supported? In the case of heavy vehicles, and for construction equipment, typical customers are transport operators or building firms. For these actors, the vehicle's total cost of ownership is in focus, and it is important to investigate how shifts in costs and the ability to provide specific transport services impacts the adoption of the new technology. Similar questions are also becoming increasingly relevant for cars, as new business models introduce mobility as a service for private users. It is furthermore important to improve the understanding of adoption of chargeable vehicles and the use and charging patterns of existing users of such cars.

The *second* strategic area of the theme is aiming to research various strategies to secure the raw materials of electromobility with a long-term perspective by promoting circular material flows. It is directed at pre-empting future material availability issues that could arise from resource competition relating to key electromobility subsystems such as batteries and motors. This includes the integration of life cycle thinking into current product development and adding requirements on the design process to consider production, reuse in multiple applications, remanufacturing, and material recycling. It also encompasses research on other measures aiming for a circular economy, for example business models.

The *third* strategic area of the theme is the monitoring of environmental impact and resource use of electromobility, with the aim of guiding ongoing development towards minimized environmental burdens. A main societal driving force for electrifying vehicles is to decouple them from fossil fuel use and to enable reductions of greenhouse gas emissions. Inevitably, a rapid transition to electromobility may sometimes lead to undesired environmental side effects. Understanding such goal conflicts and addressing them strategically with proper action, e.g. by cost-efficient policies is very important for gaining societal acceptance in each stage of technology implementation and diffusion.

The *fourth* strategic area of the theme is about studying measures, regulations and policy instruments that could be efficiently used to speed up the electrification. It is equally important to understand the possible side-effects or goal conflicts between different policies, as well as understanding for how long such incentives are being cost-effective.

How will implementation of standards and the use of these standards (harmonization) affect environment and society? What new regulations and policies are coming? We see several proposals related to sustainability, with the new Battery regulation, Product environmental footprint, and the new Ecodesign for Sustainable Products Regulation (Ecodesign for sustainable products | European Commission (europa.eu)).

Outlook on global developments for electrification of transport

For the forecast section, theme 4 has selected to lift out a few areas of interest mentioned by the International Energy Agency IEA's Global EV Outlook, 2022.

Supply chain interruptions

The car industry has been much impacted by the disrupted global supply chains due to the the Covid pandemic and which subsequently has been enhanced by the war in Ukraine. This might according to IEA have an impact on EV sales. They also mention that the EV market will continue to grow, due to governmental and corporate efforts to electrify transport.

Sales keep rising, but much more needs to be done to support charging infrastructure and heavy-duty vehicles

The amount of public charging infrastructure that has been announced might be insufficient to power the size of the EV market being targeted. The Global EV Outlook 2022 mentions that much of the demand will be taken care of with charging at home or at the workplace, but there will still be a need for a large number of public chargers. They mention a need for a ninefold expansion to over 15 million units in 2030, to reach the needs set in the Announced Pledges Scenarios stated by the IEA which are based on existing climate focused policy pledges and announcements.

It is further mentioned that the combination of the electrification of road transport with the deployment of decentralized variable renewables such as solar panels will be more complex to manage. This is where the digital grid technologies and smart charging will play important parts in making a grid integration challenge to an opportunity for grid management.

Focus is on critical minerals as battery markets expand

When it comes to material and resource use the critical minerals are mentioned as a focus area as the EV market expands and the availability of critical minerals are further affected by the War in Ukraine as Russia supplies 20% of global high purity nickel.

It is however interesting to mention that IEA also suggests that if the current high prices continue it might push for a shift in cathode chemistries, towards less mineral intensive options. Such could for instance be manganese-rich cathode or sodium-ion batteries. Such chemistries come with lower energy density and will therefore be best suited for shorter range and could also demand a change in behavior from the driver. It is also mentioned that recycling is another way to minimize the pressure on the mining industry.