Roadmap Theme 4: Environment & Society

Introduction

The technology for 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 technology area is continually evolving and a fair distance from being considered mature. This shift to electrification is also motivated at a local level from issues concerning public health and air quality, and at a national level from considerations such as energy security and energy independence.

Scope and boundaries

The main objective of thematic area Environment & Society 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, in order to enable a large-scale transition of the transportation sector, away from the use of fossil fuels, towards the use of energy carriers based on renewable energy sources, with electricity in a key role.

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 investigate it on a different system level. In fact, the combined outer system boundary of all research activities in this theme can be expected encompass the content all the other thematic areas. This implies that this theme aims to draw lessons from the other themes and their respective strategic research areas. This broad scope for addressing electromobility at the societal level allows this theme's research to provide overview and avoid over-optimization of certain subsystems, leading to undesired or difficult shifts of burden in environmental, economic, or social terms.

Current trends and needs

The rapid implementation of electromobility 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 building. Electrification, increasing levels of vehicle automation, logistics as a service and to some extent also shared mobility (ride sharing services) are prevalent trends which 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, a number of 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.

It is possible to identify a number of 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 flexibility and functionality provided by existing combustion-based propulsion. 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. Furthermore, in light of growing concerns for sustainability and resource availability, there is a 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.

<u>Business trends:</u>

- "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.
- 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 vehicle batteries are now beginning to enter stationary (for example battery parks for grid balancing) and semi-stationary (for example electricity backup on ships) applications
- Less common, but also noticeable, is 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 in order to increase recycling rates
- For delivery of goods "logistics as a service" is the norm. The trend is to deploy electric trucks for urban delivery and refuse collection as these types of vehicles are expected to become cost efficient in near future.
- 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.

- Investments in charging infrastructure is a challenge. Trucks can normally not share charging stations with cars.

Technical trends

- 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.
- 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".
- 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.
- Increased integration of different powertrain components and high focus increasing energy efficiency and lowering manufacturing costs. However, post first use, this increases the challenges of cost-efficient disassembly, remanufacturing and eventually material recycling of all materials.
- For transportation of goods, routes and transport flows are optimized together with specifically designed electrical vehicles and a dedicated charging infrastructure.
- Range anxiety and risk of delays due to cues at charging stations may push transport companies to demand solutions that minimize the risks e.g., battery swapping, e-roads and batteries on trailers.
- Data collection and processing in very large quantities using AI and sensor technologies e.g., for route optimization
- Blockchains are promoted to provide traceability upstream in the life cycles of components, linking responsible sourcing of key raw materials
- Hydrogen is gaining attention for "green processing" in industry and for providing storage capacity for renewable intermittent electricity
- A push for hydrogen by some of the largest truck manufacturers

Other trends

- Measures for the circular economy are being explored in many different industry sectors.
- App based car sharing services and carpools are growing in popularity.
- Climate change awareness and societal focus on long term sustainability are both rising

Strategic research areas

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

1. Understanding technology diffusion and its impact on personal mobility and transports services
2. Measures for resource availability and circular economy
3. Assessment of environmental impact and resource use

The *first* strategic area aims to investigate the interplay between the 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 the benefits of electromobility, as well as how and to what extent they are experiencing limitations which can hinder continued technology diffusion. In the case of heavy vehicles, and for construction equipment, typical customers are transport operators or building firms. Then 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.

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 effects and addressing them strategically with proper action is very important for gaining societal acceptance in each stage of technology implementation and diffusion.

Forecast for the coming decade

For the forecast section, theme 4 has selected to reproduce the executive summary of the Global EV Outlook 2021, published by the International Energy Agency in April 2021.

Strong momentum in electric vehicle markets despite the pandemic

There were 10 million electric cars on the world's roads at the end of 2020, following a decade of rapid growth. Electric car registrations increased by 41% in 2020, despite the pandemic-related worldwide downturn in car sales in which global car sales dropped 16%. Around 3 million electric cars were sold globally (a 4.6% sales share), and Europe overtook the People's Republic of China ("China") as the world's largest electric vehicle (EV) market for the first time. Electric bus and truck registrations also expanded in major markets, reaching global stocks of 600 000 and 31 000 respectively.

The resilience of EV sales in the face of the pandemic rests on three main pillars:

- *Supportive regulatory frameworks: even before the pandemic many countries were strengthening key policies such as CO 2 emissions standards and zero-emission vehicle (ZEV)*

mandates. By the end of 2020, more than 20 countries had announced bans on the sales of conventional cars or mandated all new sales to be ZEVs.

- *Additional incentives to safeguard EV sales from the economic downturn: some European countries increased their purchase incentives and China delayed the phase-out of its subsidy scheme.*
- *The number of EV models expanded and battery cost continued to fall.*

Vehicle manufacturers announced increasingly ambitious electrification plans. Out of the world's top 20 vehicle manufacturers, which represented around 90% of new car registrations in 2020, 18 have stated plans to widen their portfolio of models and to rapidly scale up the production of light -duty electric vehicles. The model availability of electric heavy-duty vehicles is also broadening, with four major truck manufacturers indicating an all-electric future.

Consumer spending on electric car purchases increased to USD 120 billion in 2020. In parallel, governments across the world spent USD 14 billion to support electric car sales, up 25% from 2019, mostly from stronger incentives in Europe. Nonetheless, the share of government incentives in total spending on electric cars has decreased over the past five years, suggesting that EVs are becoming increasingly attractive to consumers.

The near -term outlook for EV sales is bright. In the first-quarter of 2021, global electric car sales rose by around 140% compared to the same period in 2020, driven by sales in China of around 500 000 vehicles and in Europe of around 450 000. US sales more than doubled relative to the first-quarter of 2020, albeit from a much lower base.

EVs are set to be a more common sight on the world's roads in the 2020s

Existing policies around the world suggest healthy growth over this decade: in the Stated Policies Scenario, the EV stock across all modes (except two/three-wheelers) reaches 145 million in 2030, accounting for 7% of the road vehicle fleet.

EV markets could be significantly larger if governments accelerate efforts to reach climate goals. In the Sustainable Development Scenario, the global EV fleet reaches 230 million vehicles in 2030 (excluding two/three-wheelers), a stock share of 12%.

The expanding fleet of EVs will continue to reduce well-to-wheel GHG emissions, with the net savings relative to internal combustion engine (ICE) vehicles increasing over time depending on the pace at which electricity generation decarbonises. In 2030, in the Stated Policies Scenario, the global EV fleet reduces GHG emissions by more than one-third compared to an equivalent ICE vehicle fleet; in the Sustainable Development Scenario, the level rises to two-thirds.

Policies need to leverage momentum to further accelerate electrification

Even with the recent success of EV deployment, reaching a trajectory consistent with climate goals is a formidable challenge. It requires stronger ambition and action from all countries. Advances in battery technology and mass manufacturing will continue to drive down the cost of EVs.

But the 2020s will need to see more than just the mass adoption of electric light-duty vehicles to meet climate goals. Governments will also need to put in place policies to promote the roll-out of zero-emission vehicles in the medium- and heavy-duty vehicle segments and the corresponding fast-charging infrastructure.

In the short term, countries can continue to implement, enforce and tighten measures such as CO 2 and fuel economy standards and EV mandates. Taxing gasoline and diesel at rates that reflect their environmental and human health impacts can provide government revenue, reduce their negative impacts and hasten the transition to electric mobility. Differentiated taxation of vehicles and fuels that reflect their environmental performance can further align markets with the climate benefits of EVs.

In order for electric vehicles to attain their full potential to mitigate carbon emissions, critical progress is required to decarbonize electricity generation, to integrate electric vehicles in power systems, to build charging infrastructure and to advance sustainable battery manufacturing and their recycling