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## Roadmap for thematic area 4: Electromobility in society

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### 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. While the technology in fact has existed for decades, its widespread application and adoption in the society as a viable alternative in the transport sector is occurring only now. Still, it 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.

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 societal adoption. For electric cars, there is a need to know more about the users' behavior and their willingness to deselect the well-established and a functionally sufficient combustion-based propulsion. For heavy duty vehicles there is a need to understand the impact of electromobility on transport efficiency. Addressing these knowledge gaps involves holistic analysis of electromobility, not just as technical challenges in the vehicles, or at the infrastructural level, but also understanding the users from a systems perspective, and assessing how the technology needs to evolve to match current and future behavior and expectations. Furthermore, in light of growing concerns for sustainability and resource availability, there is a need to design and adapt the vehicle subsystems, 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.

### Scope of the thematic area

The research activities covered by *Electromobility in society* 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-optimizing certain subsystems, leading to undesired or difficult shifts of burden in environmental, economic or social terms.

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

1. Understanding user adoption and transport 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 technology and users. This includes understanding how and to what extent car users are changing or are willing to change 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 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 an environmentally sound future transport system. The main long-term goal and societal driving force for electrifying vehicles is to decouple them from inherent fossil fuel use and to reduce greenhouse gas emissions. Inevitably, a rapid transition to electromobility may sometimes mean that progress is made by taking two steps forward and one step backward in terms of environmental load. Understanding the effects of each such step while still aiming for a long-term goal of no climate impact and negligible other burden, is clearly very important, both for building, communicating and gaining societal accept for strategies of sustainability throughout the automotive industry, as well as taking proper action in each stage of technology implementation and diffusion.

## Trends in the area

There are three clear and prevalent transitions occurring simultaneously in the transport sector in the last few years. These include electrification, growing emphasis on ride sharing and the development of increasingly autonomous vehicles. While technical advancements in the field are enabling these parallel transitions, they are also based on innovative business models and governed by policy directives. Some of these trends are further exemplified in the following:

## **Business trends**

- Mobility as a service, i.e. integration of rental cars, taxis or ride sharing with the existing public transport service. This gives the users the ability to request cars at train, bus or tram stations using their mobile phones. In the future, this service could be provided by autonomous vehicles.
- Battery manufacturers and other sub-system providers talk about upstream “vertical integration” 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 “transportation 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<sub>2</sub> emissions for heavy duty trucks and busses from 2025. The target is to reduce CO<sub>2</sub> from commercial transports with 15% from 2025 and with 30% 2030 will force a technology shift and push for electrified vehicles. Investments in suitable 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, but possibly also that higher electric power will be requested for charging, shifting the requirements set on the charging equipment (in or outside the vehicle) as well as the grid and its ability 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.

## **Other trends**

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

## Objectives

The main objective of this thematic area is to help steer the development of electromobility towards long term sustainability hand in hand with meeting the needs of the users of the transport system, 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 overarching goal in the medium time frame is to support significant reductions in greenhouse gas emissions from vehicles.

Current proposed specific goals relating to the strategic areas of the theme are:

- a) Increase the knowledge about electric vehicle customer expectations, and their driving and charging behavior, or expected operation patterns to provide certain transport services, to support industry and agency work with product development, standardization and regulation of charging infrastructure and battery technology.
- b) Describe the role of different actors and their strategies for product development and deployment of electromobility, or policy instruments on different levels, to better understand the interplay of technology management and user adoption.
- c) Explore the effects of electrification technology on the transportation of goods and the need for new measures to support the deployment of electromobility in freight transport
- d) Explore the systemic effects of new business models for and on electromobility – both regarding new ways of using vehicles and consuming mobility, as well as to promote circular economy.
- e) Investigate measures for circular economy which can be applied on different technical levels and subcomponents for electrification, for example prolonged life and multiple use (in one or different applications), and how these measures impact on design requirements, cost and environmental load.
- f) Search for general principles in electric powertrain component design when aiming both for easy disassembly and increased lifetime at the same time, or how trade-offs between these two goals can be balanced, in order to support remanufacturing and improved material recycling.
- g) Continuously assess the development of different options for vehicle electrification to support ongoing industrial development and policy making in minimizing resource use and environmental impact over time.
- h) Critically evaluate the selection of methods and indicators used when trying to assess and guide ongoing technical development towards long term sustainability at each stage, i.e. identify relevant assessment criteria for resources, environmental load and societal aspects.

## Current status

At the end of February 2020, the theme research consists of six ongoing projects.

The number in the brackets indicates the strategic area to which the project contributes, and the letter if it matches any of the current proposed specific goals in the previous section.

Funded PhD student projects:

- Charging behavior and infrastructure need for plug-in electric vehicles [1, a]
- E-machine design for enhanced recyclability and minimized environmental impact (also connected to thematic area 2) [2, e, f]
- Life Cycle Assessment of Large-Scale Lithium-Ion Battery Production and Recycling [3, g, h]

Associated projects:

- Towards a sustainable use of electric vehicles [1, 3, a, g]
- Innovation system for electric distribution trucks: integration as a central process [1, b]

Thematic area research project:

- Environmental Assessment of Electromobility Charging Systems [3, f]

## Gap analysis, research needs and critical actions

Ongoing activities in the theme involves all strategic research areas 1-3. Comparing the list of projects with the proposed specific goals it can be noted that different aspects of goals a, b, e, f, g and h are being addressed in existing projects. At the same time, going more into detail of each goal, it can be noted that a large number of questions and topics remain unexplored. Foremost, no ongoing activities match any aspects of goals c and d. Addressing these gaps and additional aspects of all goals a-h are important tasks for the thematic area in the current phase of the center.

## Theme group members

Thematic leaders: Anders Nordelöf and Magnus Blinge

Thematic researcher(s): Vacant, to be appointed during the spring 2020

Project leaders of theme funded projects: Francis Sprei, Anders Nordelöf, Torbjörn Thiringer

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