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Large-scale electrification of Swedish transports: Analysing Policy Areas of Concern

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Executive Summary

This study examines how a large-scale electrification of Swedish transports affects different areas in society. Starting from today's mainly fossil-based transport system, it analyses which consequences that appear when the electrification of transport becomes large-scale. Societal transition, changes in fuel and charging infrastructure, demand for energy and land, future costs for different users and resilience in the transport system reveal policy areas of concern for the electrification to succeed.

Keywords: Electric vehicles, Public policy and promotion, Consumer behaviour, Trends and Forecasting of e-mobility, Education skills and labour market, Energy management, Climate change, Sustainable energy

1 Introduction

Climate objectives in the European Union as well as in Sweden call for a transition to renewable energy in the transport sector. To achieve the targets and the green transition the Swedish Government is planning for a large-scale electrification initially of road traffic and later also shipping and aviation. Basically, all Swedish railways are already electrified. According to estimations, the Swedish electricity demand will be 300 TWh in 2045 which means twice as much as today, and with 10 percent estimated for the transport sector [1].

In this study, we aim to identify how a large-scale electrification of Swedish transports affects different areas in society and to highlight important issues to consider for the transition to an electrified transport system to succeed. Main questions for the study are: What actors and systems will be of importance in a large-scale electrified transport system compared with today? Which consequences will arise? Starting with these questions the consequences for the different modes of transportation can be identified and analysed. As the rate of transition and choice of paths affect the consequences, our analysis also includes a discussion on aspects and drivers of transition based on previous research [2, 3, 4].

With the large-scale electrification of Swedish transport as an example, the study aims to further develop the knowledge on such transitions from a systems perspective and reveal policy areas of concern for the electrification to succeed.

1.1 Aspects and drivers of transition

According to its climate target Sweden will achieve net zero emissions in 2045. This requires a green transition. One way to understand drivers of transition is to investigate connections between megatrends, existing systems and how new technology succeeds in society, seen from a multi-level perspective.

The theory of a multi-level perspective on societal change points to the importance of barriers and clarifies what drives development forward on macro as well as micro levels [4]. Interactions between different levels cause dynamics in how production and consumption systems change. On the overall level "landscape", there are long-term megatrends of social, economic or environmental origin. It includes sudden shocks like escalating climate crises or pandemics, a disruption that changes the direction of development. At the underlying level "regime", we find our existing systems with technologies, policies, infrastructure, behaviour and business models, co-evolved in society over time.

New technology develops in the underlying level called “niches”. The theory implies that for the new technology to succeed things need to occur on the landscape level that create cracks or problems in the dominating regimes, thus creating prerequisites for the new technology to cross the barrier, see Fig. 1. The way the different levels connects makes it difficult to foresee exactly when and how technology will make it through the barrier, although society actively can create suitable prerequisites [2]. The rate of the transition to large-scale electrification and how the route will look is not given beforehand.

However, we can state that due to the megatrend climate change [5], society has changed direction towards fossil free fuels. We have net zero emission targets and policy packages like Fit for 55 aiming at helping the European Union to reach its targets in a fair, cost-efficient and competitive way [6].

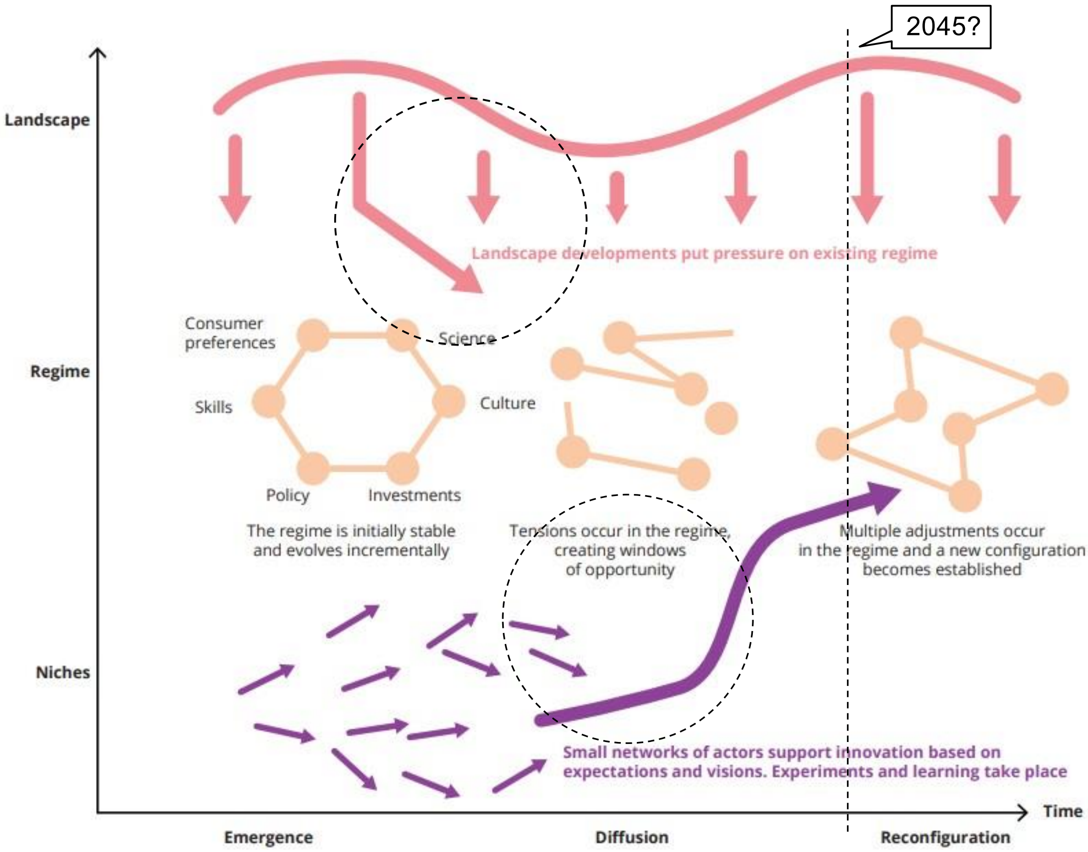

Figure 1. The multilevel perspective on sustainable transition. Source: [2, 4]

A recent publication from the European Environment Agency states that core systems of production and consumption are deeply intertwined, which means that interventions in one system will have multiple knock-on effects on other systems. It concludes that to navigate processes of systemic change and build resilience to future disruptions there is a need to strengthen societal capacities in key areas, for example collaborative and anticipatory governance, societal engagement and creativity, spatial planning and multifunctional land use, AI and digitalization, and preparedness for shocks [7].

1.2 **Lessons from societal transitions**

Transition will not take place without new policies and research, and learning from the actions taken is crucial. Traditional evaluation approaches were not developed for radical changes, which implies that an interdisciplinary and systemic approach is needed [3].

Transitions have occurred earlier in society. A Swedish example is the transition of heating systems for private households from mainly individual oil boilers to for example distant heating. Recently, major digitalization has also occurred which is still on-going. The diffusion of a specific technology takes place parallel to other new technologies which generally makes it difficult to delineate which aspects will be of crucial importance for the choice of technology and thus for the consequences. Economic, environmental and convenience aspects may for example have different priorities for a homeowner’s choice of technology [8].

Transition to new heating systems and digitalization are both about grid extension, individuals’ decision to invest in a new technology, policy instruments and the occurrence of parallel technologies during the transition phase but also afterwards. A main driver connected to digitalization has also been the development of business models. Experience tells us that transition may have a different pace in cities compared to sparsely populated areas and that some geographical areas need other solutions than the dominating technology can offer. Based on the policy instruments for transformation of the transport system the development may vary in different parts of a country [9]. Socio-technical analyses of transport systems, exploring the strategies and beliefs of crucial actors such as car manufacturers, local and national governments, citizens, car drivers, transport planners and civil society can develop the understanding of transition [10].

Different parts of the transport systems may compete for the same limited fuel resources as they seek to decarbonize. Therefore, governments should consider developing a cross-sectoral regulatory framework for energy resources following a merit order principle to manage such scarcity and guide markets to better allocate scarce resources [11].

2 **Methods**

We consider large-scale electrification as a level when Sweden in the year 2045 has achieved its target of net zero emissions with electrification as the main key to transition of the Swedish transport sector, but with other fossil free fuels used as a complement. Shipping and aviation will be partly electrified.

System boundaries are delineated by the key components infrastructure, vehicle/craft and fuel as well as ancillary services like production, distribution, service, education, etcetera, needed for their maintenance. The assumption is that by starting from these components and their ancillary services the main areas for consequences will be included. Data, estimations and definitions used in the study originate from Swedish government agencies. The following definition of electrification is used: The concept of electrification means that electricity replaces fossil fuels in those processes where this is possible.

2.1 **Mapping the current situation and 2045**

The mapping of key players and systems for road traffic, shipping and aviation was performed by investigating infrastructure, vehicle/craft and fuel as well as ancillary services both backward in the supply chain and forward to a disposal point. After that, the mapping of a 2045 situation was performed in the same manner. Likely key players and systems for 2024 and their ancillary services were identified using the following assisting questions about the future transport systems: 1) What new available technologies are being used? 2) What solutions are there in society for using the new available technology? 3) What technologies are prototypes but not put into use at full scale? 4) What policy and regulation are there that affect the key components of the transport system? 5) What is particularly important when it comes to land use, electrical grid and preparedness? 6) Are there differences nationally, regionally, and locally? “Solutions in society” may concern for example digitalized applications and platforms for carpools, or intermodality, or changed behaviour, of importance for the design of transport systems.

Based on the two steps of mapping both present and future key players and systems, different areas in society where consequences may occur have been identified. A selection of areas was further analysed: current and future fuels, future costs for transport system users, land use, electrical grids, and preparedness [12].

3 **Results**

Policy areas of concern for different modes of transportation have both similarities and differences. All actors in the fossil fuel chain are affected as well as competence concerning electric vehicles/craft and fuels. The labour market is affected. Traffic flows will relocate as well as fuel logistics, and decontamination of fuel tanks will be an issue. New business models will appear. Taxation and shipping fees may need adjustment. Government agencies will meet new areas of authorization as well as contingency consideration. Producers, suppliers, carriers, landowners, power grid companies, educators and government agencies will all be important actors. A quantification of the transition for the fleet of passenger cars is shown in Fig. 2.

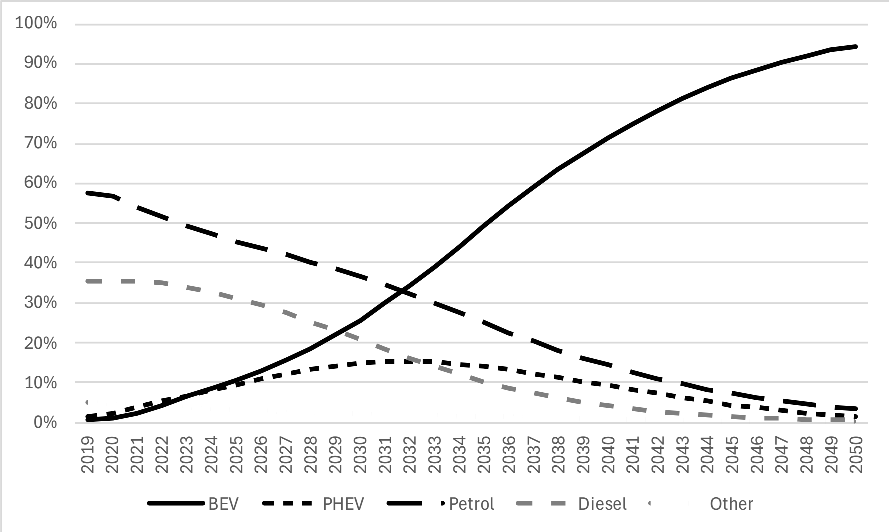

Figure 2. A quantification of the transition for the fleet of passenger cars. Source: [12, 13]

The Swedish Transport Administration estimates that the passenger car fleet in 2050 will consist of just over 6.2 million vehicles. Most of these vehicles will be battery electric (BEV). However, it is only around the mid-2030s that the share of battery-electric vehicles will exceed the share of petrol and diesel vehicles in the fleet. This is expected to happen around the same time as plug-in hybrids (PHEVs) reach their maximum. PHEV will then be phased out by 2050.

The transition for light lorries follows the same pattern as for the passenger car. For the heavy lorries, especially those used for long distance transport, it is expected that a share of around 20 percent of the vehicles by the year 2050 still will have an ICE.

Nearly all buses used in city traffic will be battery electric by 2050 whereas buses used for long distance traffic still will ha a proportion of around 15 percent of buses with ICE.

3.1 **Current actors and systems compared to 2045**

An overview of changes concerning road traffic in the present system compared to the future system is presented in Fig. 3 and 4. Key components are shown in the inner circle and ancillary services in the middle circle. The outer circle shows areas in society where consequences will occur. Both the consequences in present areas and future areas are of concern.

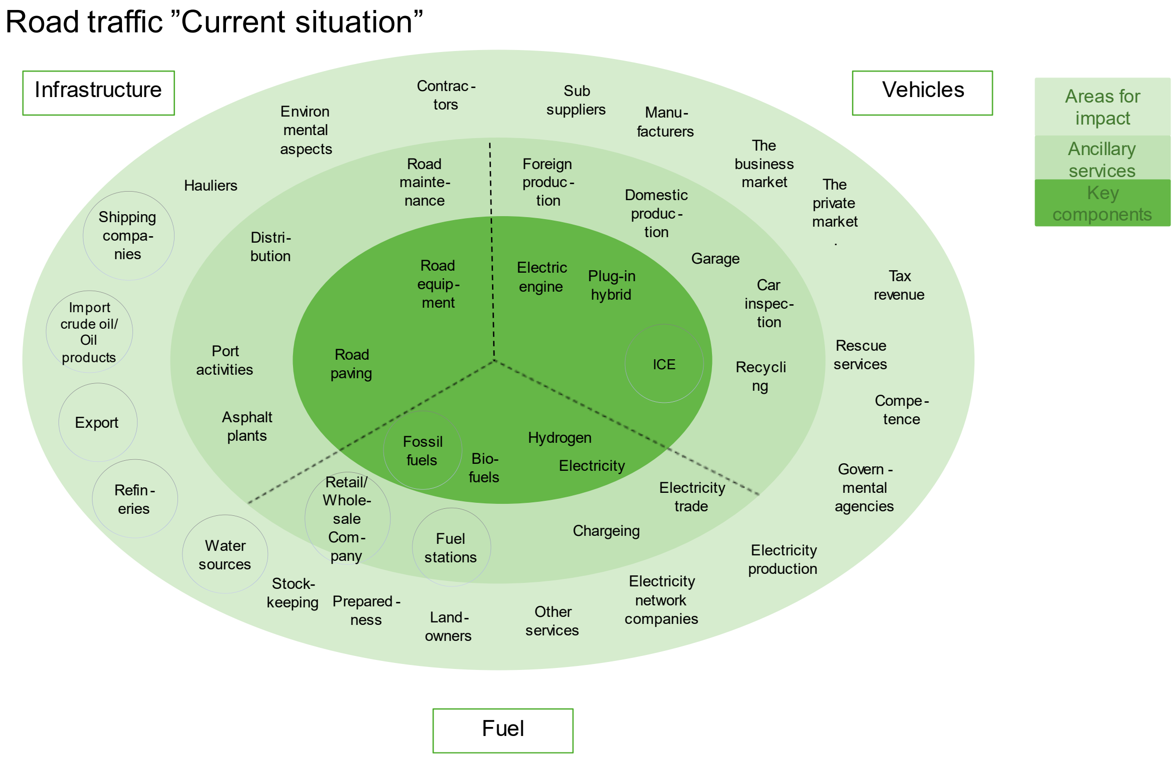

Figure 3. Overview of road traffic in the present system. Disappearing areas are marked with a circle.

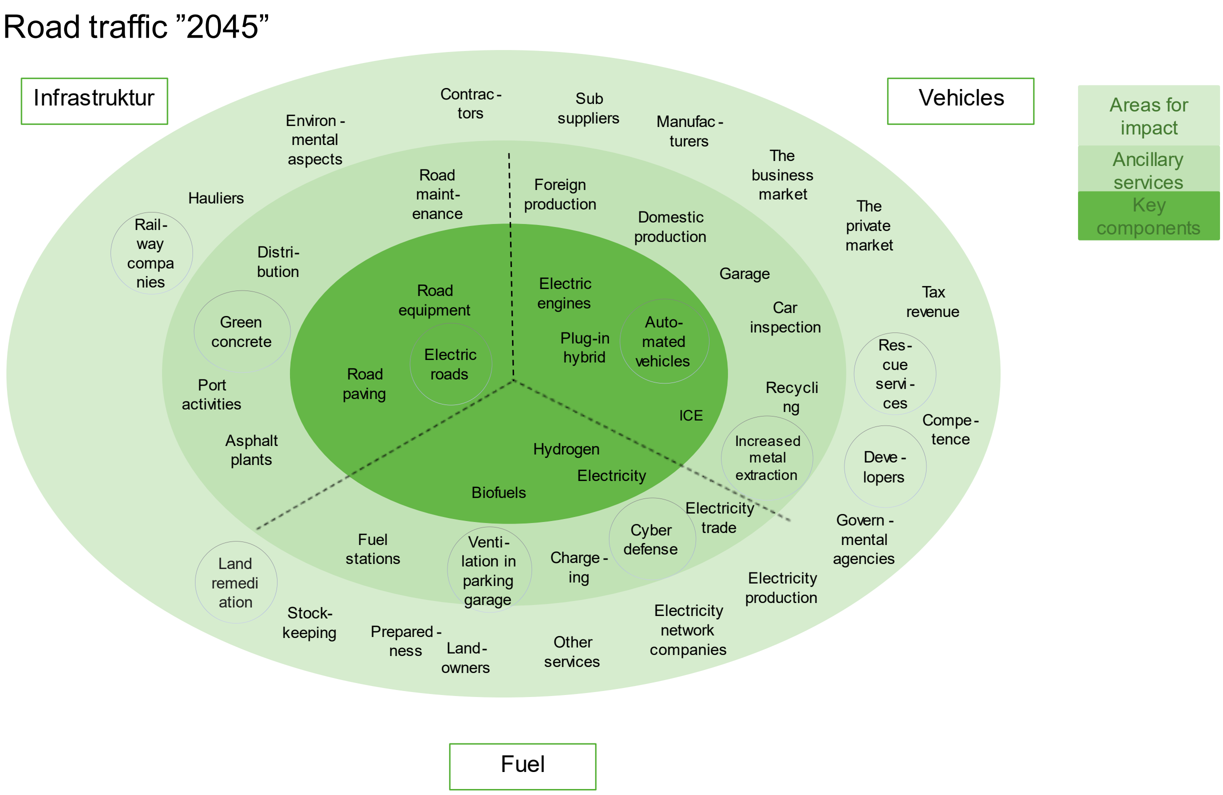

Figure 4. Overview of road traffic in 2045. Up-coming areas concerning future systems are marked with a circle.

The cost of new construction and maintenance of the infrastructure may be affected by the transition to fossil-free concrete and asphalt. The weight of the batteries means that electric road vehicles are heavier than equivalent vehicles with internal combustion engines. If the picture is the same in 2045, wear and tear on the roads will probably increase, which may also contribute to increased maintenance costs.

When smaller amounts of fossil fuel are transported in tankers on the roads, the risk of contamination of water sources from possible leakage in traffic accidents is reduced.

An increasing proportion of the vehicles that are scrapped will be electric cars, which places demands on new skills in the industry. The EU regulation concerning batteries and waste batteries (EU 2023/1542), which will begin to apply in August 2025, introduces producer responsibility for, among other things, electric vehicle batteries. Producer responsibility means that the first producer to put the battery on the market is given a responsibility to take care of it when it is no longer in use

The transition is expected to affect the frequency of car service and the training of mechanics. Car repair shops should mainly be able to handle electric vehicles, which reduces the need for traditionally trained mechanics and increases the need for competence to handle electric vehicles. The vehicles need for service is also expected to decrease as electric cars generally require less routine maintenance. Competence also needs to be strengthened in other areas to be able to handle electric vehicles, for example, the emergency services need to be able to handle accidents with electric vehicles where there is a risk of gas development or contact with high voltage.

When production shifts to mainly electrified vehicles, the development can change the established production patterns and thus also trade and transport patterns both globally and nationally.

3.2 **Current and future fuels**

Decreased dependence on fossil fuels is impacting our society's transport flows and the conditions and assumptions surrounding companies and the labour market. A changed labour market puts the emphasis on competence supply and altered conditions and assumptions surrounding employment.

The greatly reduced handling of fuel will affect several ancillary services related to retail and wholesale trade, fuel stations, charging and electricity trading. This, in turn, can affect other services at fuel stations for drivers and society in general.

The current flows of crude oil and petroleum products will largely cease. An uncertainty in this context is what a more large-scale production and distribution of biofuels will look like. Will it replace parts of the public transport flow, or will completely new transport patterns emerge? One assessment is that the production of biofuels will take place at the current fuel refineries. There are high quality requirements for fuel production and the inspections are costly, which speaks in favour of large-scale production.

The electrification of the transport system will require access to land to establish charging infrastructure - this involves both expanding infrastructure on existing land and the need for new land for the construction of infrastructure. One challenge will probably be about charging opportunities in urban areas, where land access is limited. There may be competition for land between the transport sector and other sectors, such as food production.

There is a clear connection between the transport sector's use of fossil fuels and the impact on shipping, since the import to Sweden takes place by shipping. Today's transport flow of petroleum is primarily created by fuel needs in road traffic. Therefore, large-scale electrification is linked to the demand for maritime transport, which also affects the conditions for maritime infrastructure.

3.3 **Future costs for transport system users**

A phase-out of fossil fuels and vehicles could necessitate changes in tax bases if the State is to be able to fund the welfare system. In such a revision process it is important, in order to achieve the set goals, that the taxes be formulated in a manner that promotes the continued introduction of electric vehicles.

A number of factors are of significance for the future cost structure: electrification will likely reduce the cost of driving, even though a constant or lower petroleum price is anticipated in the future as demand decreases. The price of emission allowances within EU ETS will have a major influence on transport costs, as it is assumed that the price of these allowances will increase in the coming decades. In addition, the price of electricity is expected to rise in parallel with increasing demand. These costs will vary during the transition process, something that is important to consider when formulating taxes.

If the prices of alternative fuels are changed as a result of the transition, that will in turn impact on the financial situations of companies and households, both directly and indirectly. The impact of rising transport costs will be affected by the ways in which transport companies, transport buyers and households can adapt to such higher costs. This is also related to their ability to invest in new vehicles and/or change their travel habits and transport needs.

3.4 **Land use, electrical grids, and preparedness**

For land use the biggest consequences come from mining of innovation-critical metals and minerals. Negative environmental impacts and different land use claims arise in connection with such extraction operations.

Land use is also a challenge when it comes to charging heavy-duty vehicles. The large power requirements that arise in the places where heavy trucks will charge the batteries will require larger areas adjacent to each charging station. These needs are both site-specific, develop over time and depend on the opportunities that the electricity grid will be able to offer. To foresee and estimate how the power demand will evolve geographically is challenging.

Increased electrification in the transport sector has several significant effects on military and civil defence. First, redundancy in society is reduced if two partially parallel energy systems, electricity and fuel, are replaced to a greater extent by one. This leads to an even greater societal dependence on a well-functioning electricity supply. On the other hand, electric vehicles will play an important role as energy stock.

4 Conclusions

The analysis of the transition to a large-scale electrification of Swedish transports using a systems perspective has revealed policy areas of concern for the electrification to succeed. The interplay between megatrends, policy instruments and technologies in existing systems will affect how the transition takes place, as will the levels of maturity attained by new technologies. Clearly defined goals and long-term policy instruments leading to large-scale electrification are already in place, primarily via the Fit for 55 package, as are the technologies needed to electrify road transport on a large scale.

The competitiveness of road transport may, at least initially, be enhanced as a result of that mode of transport being expected to achieve large-scale electrification sooner than other types of transport. Investment in charging infrastructure is extensive and is driving the transition. For road traffic, the biggest challenge for electrification is about cooperation and the cost relation between electricity and fossil fuels.

However, sudden disruptions and new trends may result in deviations from the technology choices initially planned for by society. Early introduced technologies might become transitory and all investments in new technologies will not become large-scale. The development curve might not be straightforward. It is essential that we apply the lessons learnt from previous transitions and the experience gained as the electrification process moves forward.

Transition rate will vary at different geographical levels and consequently also the appearance of consequences and policy areas of concern. A number of key issues are of particular importance to manage the consequences of a large-scale electrification of the transport sector:

- How can policymakers implement measures to promote and maintain a balanced transport system in which all modes of transport fulfil an important function, even as we perceive that electrification per se could create imbalances (e.g. in that road transport is expected to transition sooner)?

- The introduction of electric vehicles on the world market could entail changes in the established pattern of vehicle production and trade. How will major changes in the global economy impact the conditions and assumptions that the Swedish automotive industry is facing?

- As the customer base for fuel stations shrinks, challenges may arise in certain sparsely populated areas that have a high degree of at-home charging with respect to other services such as package delivery, grocery sales and other vehicle services. Given these risks, how can the transition process in sparsely populated areas be supported?

- Reduced petroleum dependency will have consequences for actors in the maritime transport sector and will also affect the shipping of petroleum products by road. What might this entail, e.g. for the evolution of transport mileage for goods, and for long-term infrastructure investments?

- The electrification of the transport system will entail a greater need for cooperation between the energy and transport systems. These systems have traditionally been separated in terms of both actors and business models, a situation that will now change. New and as-yet unknown issues will arise as new markets are developed. Is it worth considering new solutions from the public sector in order to address new issues that arise? Such issues will not always have an obvious place to belong, so how can these new solutions be configured?

- In practice, the electrical power supply for the transport system is part of the power supply for the entire society. This means that, as opposed to the situation previously, the prioritization of fuel use within the transport sector in crisis situations must be weighed against other needs within our society. How can the public sector take these and other aspects of vulnerability into account in the process of electrifying the transport system?

- A phase-out of fossil fuels and associated vehicles may necessitate changes in tax bases if the State is to be able to fund the welfare system. How should future tax policy be configured so that it continues to generate the needed revenues without hampering the introduction of electric vehicles?
- Innovation-critical metals and minerals are a basic precondition for the large-scale electrification process. How can such access be secured in such a way that our overall societal objectives are achieved?
- So-called energy hubs and road vehicles could both assume important roles in terms of energy storage. What additional measures are required from the public sector to support this opportunity?
- Collaboration and cooperation will assume a major role in a large-scale electrified transport sector. The more efficient the coordination, the greater the resilience when crises arise. How can efficient cooperation be strengthened between actors from different levels and sectors?
- In a major transition to an electrified transport sector, continual monitoring will be essential to ensure that the process progresses in a manner consistent with transport policy objectives. What new factors might be important to consider?

References

[1] Svenska Kraftnät, *Långsiktig marknadsanalys, Scenarier för kraftsystemets utveckling fram till 2050*, Ärende Nr 2023/4164, 2024

[2] European Environment Agency. *The European environment – state and outlook 2020, Knowledge for transition to a sustainable Europe*, ISBN: 978-92-9480-090-9, Luxembourg, Publications Office of the European Union, 2019.

[3] P. Mickwitz et.al., *A theory-based approach to evaluations intended to inform transitions toward sustainability*, Evaluation, ISSN: 1356-3890, 27(2021), 281-306.

[4] F. W. Geels, *Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study*, Research Policy 31(2002), 1257-1274.

[5] European Environment Agency. *Drivers of change of relevance for Europe's environment and sustainability*, EEA Report No 25/2019, ISBN: 978-92-9480-219-4, European Environment Agency, 2019.

[6] European Commission. *'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality*, COM(2021) 550 final.

[7] European Environment Agency. *Imagining a sustainable Europe in 2050: exploring implications for core production and consumption systems*, EEA report 03/2025, ISBN: 978-92-9480-709-0, European Environment Agency, 2025.

[8] K. Mahapatra. *Diffusion of innovative domestic heating systems and multi-storey wood-framed buildings i Sweden*, Mid Sweden University Doctoral Thesis 33, ISBN 978-91-85317-66-0, 2007

[9] J. Forsberg. *On The road to climate neutral Swedish transportation: Energy system modelling to support the transition at national, regional, and local levels*. Doctoral Thesis, Luleå University of Technology, ISBN: 978-91-8048-441-1, 2023

[10] F.W. Geels et.al., *Automobility in transition? A socio-technical analysis of sustainable transport*, New York, Routledge, 2012.

[11] ITF, *Managing Competing Sectoral Demands for Energy Resources: Transitioning to Sustainable Transport*, ITF Roundtable Reports, No. 143, Paris, OECD Publishing, 2024.

[12] Trafikanalys. *Storskalig elektrifiering av transportsektorn – ett kunskapsunderlag*. Trafikanalys Rapport 2024:9, 2024

[13] Trafikverket, https://bransch.trafikverket.se/for-dig-i-branschen/miljo---for-dig-i-branschen/minskad-klimatpaverkan/emissionsberakningsmodellen-hbefa/, accessed on 2025-04-23.

[14] European Union. *Regulation (EU) 2023/1542 of the European Parliament and of the Council of 12 July 2023 concerning batteries and waste batteries, amending Directive 2008/98/EC and Regulation (EU) 2019/1020 and repealing Directive 2006/66/EC*. Official Journal of the European Union.

Presenter Biography

Lisa Eriksson works as a Senior Adviser at the governmental agency Transport Analysis in Sweden, focusing on questions relating to Fit for 55, climate policy and sustainable transportation. She has a background in policy evaluation, foresight and systems analysis. Eriksson has a PhD in Ecotechnology and Environmental Science from Mid Sweden University.

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