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Perspectives on Demonstration Pathways in the Sociotechnical Transition of Electric Mobility in Finland

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Abstract

A model of sociotechnical change takes into account different sociotechnical configurations and their interactions in a multi-level framework consisting of three major levels: niche innovations, a sociotechnical regime and a sociotechnical landscape. The sociotechnical changes can be analysed by studying the transition pathways along different multi-level interactions. The pressure from the landscape level and niche-innovations from the bottom level reinforce the relationships and operations on the regime level.

This paper discusses the results of the study and illustrates the on-going development and the future changes in sociotechnical regimes of electric mobility in Finland. The regime changes have been analysed using a three-level perspective. The levels comprise an industry level, a value networks level and an end-user level. The results of the regime analysis show that there is a great deal of uncertainty in the operation environment and that new actors and new business models are needed to for the system to work properly.

According to earlier research, sociotechnical transition pathways can be categorised based on the environmental change and the type of transition. In the case of electric mobility, the transition does not fit directly with any of the category types. Electric mobility will most likely follow the reconfiguration transition pathway. The changes in Finland are taking place slowly. This development can be aggregated via governmental support and incentives for organisations and consumers.

Keywords: sociotechnical change, sociotechnical regime, transition pathway, electric mobility

1 Introduction

The introduction of electric mobility varies significantly in different countries and is strongly based on the amount of public support from local governments. The governments have been forced to provide incentives, such as tax reductions for users, because electric vehicles (EV) are far more expensive than comparable conventional internal combustion engine (ICE) vehicles.

Not only the high price of the recent technologies, but also the other limitations they face, such as the energy capacity of batteries, reduces the extent to which EVs have penetrated the market. In addition, the limited availability of vehicles due to

low production volumes and the lack of a charging infrastructure have not helped to accelerate market growth and business opportunities as expected for this area.
This paper describes the progress of electric mobility in Finland and the corresponding on-going transition to low-carbon vehicles. So far, Finland has been in the demonstration phase of this new technology but is moving forward by building preconditions for the wider introduction of the technology and related business growth.

2 The multi-level perspective on transitions

The MLP model used in our study distinguishes between analytical concepts existing at three different levels: niche innovations, sociotechnical regimes and a sociotechnical landscape [1]. Figure 1 illustrates the model, which has become a well-known illustration of the MLP model. On the micro level, technological niches provide seeds for change. The technological transition starts in these niches and provides room for radical novelties. The sociotechnical regimes comprise shared routines and systems within the engineering community and result in technological trajectories that explain directions for development.

The sociotechnical landscape forms an environment for macroeconomics, cultural patterns, environmental factors and macro-political developments. The landscape will change, but more slowly than regimes. Usually changes on this level will take decades.

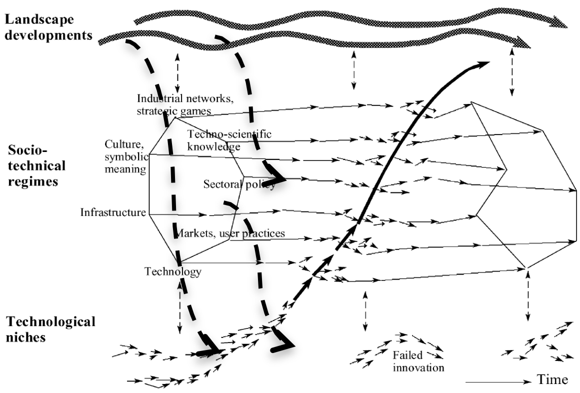

Figure1: The MLP framework [1]

According to the MLP model, the transitions will take place through interactions between the processes at these three levels. Niche innovations at the bottom level will create internal momentum for novelties. Changes at the landscape level will create pressure on the existing regimes. Finally, destabilisation of the regime will create windows of opportunity for niche innovations. The downward arrows in the direction of the niche level indicate that the perceptions of the niche actors and the size of the support networks are influenced by the broader regime and landscape developments [2].

3 Three levels of the socio-technical regime

We have analysed the sociotechnical regime using the three levels illustrated in Fig. 2. These levels consist of an industry level, a value networks level and an end-user level. This approach has been valuable for understanding the on-going changes in the development of electric mobility [3].

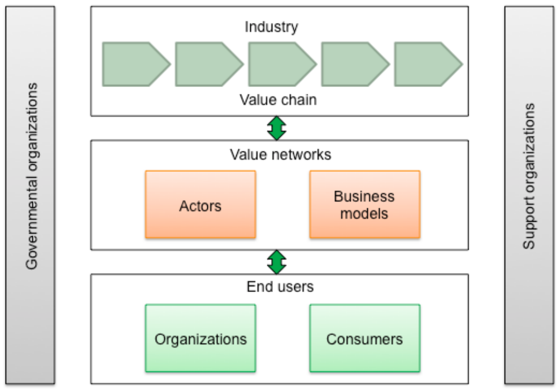

Figure2: Three levels of the sociotechnical regime [3]

3.1 Industry level

The industry level in electric mobility can be analysed via the value chains and their changes within the particular industry [4]. In the case of electric mobility, there is a change going on from an oil-based value chain to an electric-mobility-based value chain. This is a challenge for the oil industry and an opportunity for electricity utilities and other stakeholders linked with electric mobility. The new value chains for electric mobility are not yet ready, and different actors are evaluating their possibilities and building demonstration efforts to learn more about their potential in practice.
The major driver in the change is fuel: fossil oil is going to be replaced by electricity. The fuel delivery infrastructure and the players related to it will be changing in the near future. Due to the

limitations of EVs (e.g. the driving range), different services and service providers will be needed in order to ensure reliable and continuous driving trips for the users.

When it comes to the vehicles, a component and OEM production structure is still lacking for the ICE car industry. Most of the EV models available are designed and manufactured from scratch, making them expensive. The existing technology is also at early stage, making the engineering work challenging and expensive. Industry standard solutions are missing and the reliability and lifetime of EV technology is still unknown on the part of manufactures as well as end users. This also makes it difficult to develop end user services and business models.

The new electricity-based value chain contains new blocks that have not yet been implemented, and the corresponding actors are still missing. Our major finding in this respect is that there is a clear need for integrators and new operators. The new models for integration probably will be established in the near future. Because electric mobility constitutes a new challenge, it will also be challenge for value-chain actors to make profits due to the low volume of business at the beginning.

3.2 Value networks level

While recognizing the value chain changes on the industry level, these changes have to reflect on the value networks as well. On the value-network level, different actors have to select the required parts of the industry value chain they want to be linked to and they must develop their roles and business models accordingly. As an example, large energy utilities are now independently building new charging service points for electric mobility. This means in practice that certain modules of the value chain will be built as separate islands. According to our findings, the value chain has not yet been integrated, and from the end user's point of view, this is not satisfactory and will delay the development of the whole field. However, new actors are appearing in the markets and attempting to integrate the missing links and take care of the system operations. For example, scholars in Finland have been studying a new service integrator model [5].

Remarkable uncertainty is associated with the taxing of traffic. In Finland, the government heavily taxes both traffic fuels and cars. During the early stage of EV penetration, tax reduction can be used as an incentive for boosting the penetration of EVs. But later, similar taxes must be applied to EVs as well. This must be taken into account when developing value networks. They must not be based on low or zero levels of taxation. On the other hand, they must fit environmental policies for reducing greenhouse gas emissions and other negative impacts of car traffic.

Value networks must also follow the possible development of end users' attitudes about driving and car ownership. There are European-wide signals of reduced interest in obtaining a driving license and buying a car. While growing interest in renting a car and car sharing is probably beneficial for the expansion of EVs, it differs from the current structure of the ICE car business.

3.3 End-user level

The bottom level consists of the different types of end users, from consumers to public and private organisations. The electric vehicle as a niche technology varies greatly compared with the ICE vehicle in many respects. The prices of EVs are much higher due to the high battery costs and low production volumes. The driving range is still limited, which constitutes difficult requirements in terms of providing, for example, an adequate charging infrastructure and services. Therefore, there is a strong demand for new operating models and practices from the end-user perspective. New operating models are already appearing, e.g. car sharing, demand-based door-to-door rides, park-and-ride schemes, and so forth. The use and ownership of EVs has to be challenged and reassessed.

At any rate, the challenges compared to ICE cars are consequences of the idea that an EV should simply replace an ICE car without end users needing to change their behaviour. Large and expensive batteries, for example, are necessary so that drivers would not have to visit a charging station any more often than with an ICE car, though electricity consumption for daily commuting can easily be replenished by charging the battery overnight [6]. As soon as the problem of providing sufficient battery capacity for daily driving ranges has been solved, the problem of battery's cost will also have for the most part been solved. This, together with the transition from ownership to renting, will also solve the problem of the resale price uncertainty. In this way, many of the existing obstacles at the sociotechnical level, shown in Figure 1, will be solved and a way forward will be possible.

The scenario mentioned above means that when new technology no longer fits into the structure of the old technology at the end user level, there will be a need to understand the necessity to change end user practices. In the case of charging, there is a need to understand that EVs must not be viewed as all-purpose vehicles when EV technology does not yet support such a variety of uses [6, 7]. Commuting is easy for an EV, but long-distance travelling not. Long-distance driving will increase the need for building a comprehensive charging infrastructure.

When using an EV for long-distance driving, drivers must first consider whether the trip is even possible with the existing charging infrastructure. For this, it is vitally important to have public services that indicate the location of charging stations and the type of charge that is available. Also, the possibility to make a reservation for charging at a certain time will be one of the required service features. Finnish experts currently make use of the Norwegian Nobil database [8], which includes information about all of the existing charging points in Norway and Finland. Nobil is open and free of charge for anyone who is creating applications and services for EV users. The database was initiated and developed and is currently maintained by the Norwegian Electric Vehicle Association.

4 Sociotechnical transition pathways

Electric mobility is an example of an on-going sociotechnical transition. This transition will affect many societal functions related to personal transportation and the transport of goods. The change is at a very early stage, and therefore it is important to increase understanding of the phenomenon, the dimensions affecting it and mechanisms for monitoring and controlling the change. Understanding sociotechnical transition pathways based on different multi-level interactions will help in these efforts.

The electric vehicle itself is not a new invention. Already at the beginning of the 20th century, electric cars and trams were used for personal transportation. What makes EVs a niche innovation today is the development of battery and charging technologies. EVs can be seen as batteries on wheels, i.e. as mobile forms of energy storage. However, the technologies are not yet sufficiently developed to meet the requirements of mass markets.

From the other direction, the landscape level causes pressure at the regime and niche-innovation levels. Climate change and the requirements for lower CO_2 emissions are forcing regimes to adopt more carbon neutral solutions. Reducing the emissions of road traffic is one of the most efficient ways to mitigate climate change. The European Commission is, on the one hand, demanding lower vehicle emissions, while, on the other hand, setting requirements for the construction of a charging infrastructure.

We have analysed the regime changes using a three-level perspective described in the previous section. Landscape pressure opens windows of opportunity for niche innovations, in this case for electric mobility and EVs, and this will change the existing regimes.

Environmental changes can be analysed from different perspectives and using frameworks. Suarez and Oliva [9] distinguish four dimensions of external changes: (1) frequency, i.e. the number of environmental disturbances per unit of time; (2) amplitude, i.e. the magnitude of deviation from the initial conditions caused by a disturbance; (3) speed, i.e. the rate of change of disturbance; and (4) scope, i.e. the number of environmental dimensions that are affected by simultaneous disturbances. Based on whether these attributes of change are high or low, Suarez and Oliva recognize and discuss in more detail five typical combinations: regular combinations, hyperturbulence combinations, specific shock combinations, disruptive combinations and avalanche combinations.

Electric mobility does not fit directly into any of these categories. Similar to disruptive and avalanche types of environmental change, the frequency and amplitude are high for electric mobility types of change. However, while avalanche types of change happen quickly and change multiple dimensions of the environment, the speed of change with respect to electric mobility will be slow. Disruptive change also happens slowly, but it only has a high-intensity effect on a single dimension, whereas EVs and electric mobility will change multiple dimensions of the environment. Gradually, electric mobility will become an essential part of even larger phenomena—smart mobility and smart cities and societies.

This domain change will happen slowly in electric mobility. Geels and Schot [2] have recognised four typical sociotechnical transition paths:

transformation, reconfiguration, technological substitution and de-alignment and re-alignment. As the authors state, these four types of change are more like ideal types, and they do not have to occur in pure form. However, the transition pathways still have a recognisable internal logic, constituted by different combinations of dynamic mechanisms. As such, they can be used as a way to analyse and consider empirical cases. Second, these transition pathways are not deterministic. There are several ways in which they might influence how the future outcome will occur.

Electric mobility will most likely follow the reconfiguration transformation pathway [10]. The existing dominant design, which is based on the internal combustion engine and fossil fuel and the whole infrastructure surrounding them, is strong and will most likely still be developed further. The actors in the industry prefer incremental changes within the bounds of the existing regime. Firms will only further develop niche innovations and green technology slowly. There is no real pressure from any level to make significant changes. Without clear signals and the support of governments and their subsidies, this change could well happen quite slowly indeed. The existing regime is so systemic and interdependent that without strong external support, it just will not have any incentive to change. While landscape pressure comes from different sectors, it is still not strong enough, and therefore, there are no significant regime problems that would cause regime actors to lose faith in the existing system. Climate change and the notion of peak oil are not of sufficient concern worldwide to cause avalanche-like changes. If niche innovations are not sufficiently developed, as in the case of EVs, then there will be no clear substitute for oil. Instead, alternative fuels for electricity, such as biodiesel fuel and biogas, will also compete for the dominant design position. Another problem is related to the first mover disadvantages. The expected growth in the adoption of electric vehicles is still so slow that it does not encourage any major car manufacturers to make even higher investments in the new technology.

5 Electric mobility in Finland

In the 1990s, the Finnish company IVO (today Fortum) built 200 Elcats, an electric vehicle. Fortum closed the Elcat project in 2001, and since then the Finnish electric vehicle cluster has started to re-emerge from various sources [11].

The SIMBe project (2010–2012/3) was the first high-volume research project in Finland focusing on electric mobility in built environments [12]. The SIMBe project took a holistic approach to trying to understand the big picture of electric mobility in the capital area of Helsinki. SIMBe was active in open discussions with different stakeholders, both public and private organisations, and, via these transactions, it helped create a shared understanding between them. However, the introduction of electric mobility did not progress in practice as a result of the SIMBe project due to the lack of EVs and the required infrastructure.

In the spring of 2011, the Finnish Funding Agency for Technology and Innovation (Tekes) initiated the EVE (Electric Vehicle Systems) programme (2011–) [13] and put out a call for demonstration pilots for electric vehicles. In connection with funding for the EVE programme, the Ministry of Employment and the Economy decided to grant the energy investment support for electric vehicles as well as charging infrastructure investments. This combined support was a strategic signal from the government in support of electric mobility in Finland.

The work done for the SIMBe research project is being continued as part of the eSINi research project, where the results from the SIMBe project can be applied in practice as the number of electric vehicles increases and the infrastructure continues to grow in Finland [14]. The eSINi project is a part of the wider Electric Traffic consortium [15], which is being funded by Tekes (see Fig.3). There are also some other smaller pilot demonstrations as part of the EVE programme: Eco Urban Living (EUL), EVELINA in the Tampere region and WintEVE in northern Finland. The Technical Research Centre of Finland's (VTT) Electric Commercial Vehicle (ECV) project is focusing on electric commercial vehicles like e-busses and working machines.

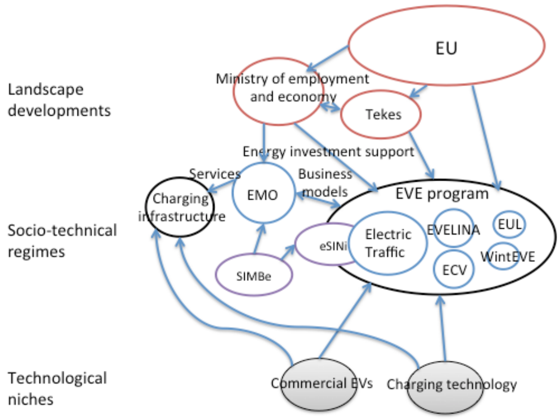

Figure3: The sociotechnical structure of electric mobility in Finland

The Electric Traffic consortium is the largest demonstration bed of the EVE programme. The role of the Electric Traffic consortium has been vitally important in Finland. The Electric Traffic consortium was preceded by the Electric Vehicle Action Group; the major anchor companies and cities were already involved in that group. Both consortiums have been led and coordinated by Eera Ltd, a Finnish consulting company.

Taken together, the EVE programme and the government incentives for investments for organisations have provided a positive step forward for increasing the number of EVs in Finland. At the end of April 2013, the number of EVs on the road was 309, including 124 battery vehicles and 185 plug-in hybrids [16]. This is still a small number and more volume is needed. However, higher volumes cannot be reached until consumers got involved.

6 Perspectives on demonstration pathways in Finland

The types of changes needed in the case of electric mobility have been briefly described in the previous sections. The major landscape pressure comes from the threat of climate change and the public authorities requiring that companies engage in protective activities to combat it. The Finnish government has adopted some proactive developments for addressing climate change and also follows the directives passed by the European Union. It will a great deal of pressure before the oil-based regime for transportation sees a need to change and niche innovations from the bottom level are competing for space to win the battle for relevancy and survive.

The SIMBe project analysed the requirements for electric mobility using the three-level perspective described in section 3. Based on this analysis, those involved in the project suggested that several key links are still missing in the value chain and that both integrators and new operators are needed. As a result of these studies, a new operator model is currently taking shape in Finland: an Electric Mobility Operator (EMO), which is a new service integrator model (see Fig.3). Several dozen utilities have already decided to set up a company for putting this model into practice. Helsinki Energy and Fortum have had a key role in this development. The operator will start its operations at the beginning of the next year.

The problem of putting an adequate charging infrastructure in place is one of the bottlenecks for EV penetration. Without a viable charging infrastructure, EV users will get into trouble in practice. In this respect, cities will be one of the key players in terms of providing an adequate public charging infrastructure. In Finland, the cities involved in the Electric Traffic consortium have already started to plan and build their public charging points. The cities of Helsinki and Vantaa have preliminary plans for over 100 charging points. During the current year, Helsinki will install approximately 30 charging points.

Finland decided to utilize the Norwegian Nobil database for its charging infrastructure because it is open to all service providers. The first applications have already been introduced. Meshworks Wireless Ltd. made the first mobile application showing the nearest charging point for EV users. So far, the application is free of charge and more features are going to be introduced to it in the near future.

The high level of coordination by Eera Oy and the strong level of involvement by regime actors will result in 'an endogenous renewal' transition proposed by Berkhout et al. [17]. An endogenous renewal transition occurs when regime actors are making planned efforts in response to perceived pressures, using regime-internal resources.

As explained earlier, electric mobility will most likely follow the reconfiguration transformation pathway in Finland. The existing oil-based regime is so strong that the actors in the industry prefer to make incremental changes within the bounds of the existing regime rather than to start making heavy investments in niche technologies. If there are no clear signals and support from governments, this change will take place very slowly indeed. That is why it will be vitally important in the near future to continue the investment support for firms and to also get consumers on board by offering attractive new incentives.

7 Discussion

So far, while actions to boost electric mobility in Finland have been handled correctly, the magnitude of operations has been quite limited. Without a significant increase in investments and other activities, Finland will gradually lag behind other countries in electric mobility. Fortunately, being a latecomer so far has not been a problem. There are already countries and regions that have succeeded in getting electric mobility started and, after the initial public support, the infrastructure and EV sales have started to increase on their own in a market-based way. Therefore, the wheel does not have to be reinvented in Finland; rather, the decision has to do with choosing the optimal strategy and adopting supportive actions to support electric mobility to a significant degree.

To get things started, the Finnish government and cities should provide fiscal and non-fiscal benefits for those who buy electric vehicles or construct the charging infrastructure and related services. The private sector and companies are ready to invest and start participating in infrastructure construction and service development once there is a critical mass of vehicles. Tax benefits or other subsidies are a must for getting things started and for encouraging consumers to buy electric cars. At present, the price of the vehicles is so high that the timeframe for reaching a critical mass is too slow.

Other possible benefits for using and owning an electric car are also essential. Permission to drive in the bus lanes is one alternative. Another feasible benefit could be free parking for EVs and even providing some free dedicated parking lots with slow charging poles at select sites. These benefits are valuable for consumers, but they would also indirectly indicate that society is fully supporting the transition to electric mobility. For the time being, municipal authorities have denied all these benefits, which has been an adverse signal for those potentially interested in EVs.

On a broader level, a completely new kind of thinking and new ways of smart transportation with travel chain optimisations are required. It is essential to not only change existing cars into electric vehicles, but also the whole way of travelling. Private cars and public transportation should work in combination so that people could use park-and-ride schemes and route optimisation based on their personal preferences. Enhancing ICT may actually make public transportation more attractive in the future when passengers having mobile devices can use them for work or entertainment (games, movies, social media) while travelling—something that is not possible as a driver of a passenger car. Transport authorities and municipal decision makers should learn about and understand this opportunity. At the moment city and transportation planners in cities are rather focusing on current traffic system technologies than even leaving flexibility into the city plans and traffic solutions to be able to adopt future practices that EVs and electric mobility as a whole will bring.

One of the most important and logical solutions is to continue communicating the need to invest in infrastructure and offer possible subsidies and other benefits. This will encourage consumers to act when they know that their decision to buy a new vehicle will pay off in the future. The decision to only offer tax breaks to companies but not to consumers buying the electric cars seems strange. Therefore, potential buyers of EVs in Finland are at the moment waiting for the decision about possible subsidies and this has for the most part brought the sale of BEVs to a halt. Mixed communication and clearly false signals, both positive and negative, have made the electric mobility field more uncertain in the eyes of consumers. As a result of this, manufacturers are also not very eager to put effort into marketing their electric cars in Finland.

Ownership of the vehicles should be thought of differently in Finland. Many families have two or more cars. Car sharing clubs with electric car alternatives would meet the needs of many drivers. Most trips are quite short in nature, and EVs are then a good solution. A car sharing service could provide electric vehicles for short distances and, on the other hand, ordinary ICE cars for long-distance trips that EV owners might take every now and then. The public sector could enhance the adoption of EVs by actively supporting such car sharing clubs. An example of such a working arrangement is Autolib, a public-private partnership in Paris. Another example is Moveabout, a company operating in Norway, Denmark, Sweden and Germany. The company also provides EVs for corporate needs, and therefore even more people are getting used to driving an EV, thus advancing consumer awareness.

Consumers in Finland have very little experience with driving an electric vehicle. To increase the awareness, people should be provided with an opportunity to test drive EVs. Also, reliable information should be provided about the benefits and shortcomings of EVs in comparison with other transport alternatives. Different information campaigns together with car manufacturers are needed. This approach has worked in Norway, and Estonia is also applying a similar approach.

However, investing in charging infrastructure is a chicken and egg problem. The public sector is not willing to invest because there are no cars, and there are no cars because there is no required infrastructure. Even if the batteries can for the most part be recharged slowly during the night at home, the availability of a dense, fast-charging network is mentally important for consumers. EV traffic between Oslo and Halden in Norway tripled in just a few months after a fast-charging point was installed along the highway. Similar examples from elsewhere in Norway indicate that investing in a fast-charging network is a necessity in order to overcome the anxiety of consumers. Estonia overcame this challenge by installing an extensive fast-charging infrastructure everywhere in the country. Finland has not yet decided what kind of strategy to follow regarding fast-charging infrastructure construction. Some companies in Finland, such as the ABC chain, which is a part of the S-Group, have plans to install fast-charging stations along the main roads out of Helsinki in the next few years.

The public sector and municipal authorities could take better advantage of EVs. Home healthcare and many other services have daily driving distances that are well within the driving range of a typical new BEV. EVs would be a perfect match with conventional ICE cars in a fleet of cars. Municipal authorities, however, have not yet been willing to invest in EVs. This is unfortunate, as this would increase customer awareness about the possibilities of electric cars.

Currently, the Finnish public sector is doing an overwhelming amount of planning for electric mobility, but very few concrete actions have actually been taken. The best way to change this would be to make low-level, stepping-stone investments and see what happens. The future is so uncertain that it is not rational to overanalyse everything in advance instead of just rolling up our sleeves and getting to work. Finland, similarly to Sweden, has taken the approach of letting the markets handle the situation, while offering very few subsidies and support. Numerous analyses have been done and reports written on the topic, but hardly any true investments and commitment have been made on the issue. Without a significant change in this policy, Finland will remain a bystander in the field of electric mobility.

8 Conclusions

Electric mobility is an example of an on-going sociotechnical transition. The MLP framework describes this transition quite well via multidimensional interactions. The change is currently at a very early stage and we currently have an excellent opportunity to follow the change and analyse the dimensions affecting it as well as the mechanisms for controlling the change.

In this paper, we have described the situation in Finland in the field of electric mobility and explained theories and perspectives for analysing the development pathways for this change.

According to our analysis, electric mobility is likely will most likely follow the reconfiguration transformation pathway. The existing oil-based industry value chain is strong and will continue to develop in the future. That is why the networks and actors in the industry prefer making incremental changes within the bounds of the existing regime. The change required for the transition calls for new actors, new business models and a new infrastructure. Also, the practices of end users have to change to meet the new alignments. But if there is no real pressure from any level to change, this all will happen slowly.

Without any clear signals and incentives from governments, there can be no stimulation for the growth to occur. The growth in electric mobility definitely requires that both organisations and consumers be involved in order for an aggregated change to take place in the complex environment of smart traffic, smart energy management and smart cities.

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