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Electromobility scenarios: research findings to inform policy

Heidi Auvinen [a,*], Tuuli Järvi [a], Matthias Kloetzke [b], Ulrike Kugler [b], Jan-André Bühne [c], Felix Heinl [c], Judith Kurte [d], Klaus Esser [d]

[a]*VTT Technical Research Centre of Finland Ltd, P.O. Box 1000, FI-02044 VTT, Finland*
[b]*German Aerospace Center (DLR), Institute of Vehicle Concepts, Pfaffenwaldring 38-40, 70569 Stuttgart, Germany*
[c]*Federal Highway Research Institute (BAST), Brüderstr. 53, 51427 Bergisch Gladbach, Germany*
[d]*KE-CONSULT Kurte & Esser GbR, Oskar-Jäger-Straße 175, 50825 Cologne, Germany*

Abstract

Research to inform policy is often challenged with how to genuinely use and implement research findings in decision-making and policy-planning. To begin with, the dialogue between researchers and decision-makers is essential to ensure profound understanding and legitimate interpretations of the results. Furthermore, the step to drawing practical conclusions and process them into actions can only succeed if research findings are diffused to decision-making levels with influence on the matter and mechanisms to knowledge transfer in the presence of a stable, favourable policy environment exist.
Research investments into the topic of electromobility in Europe are substantial, and subtopics aiming to inform national policy--makers address a complex set of aspects from environmental and societal to technological and economic. This paper has a two--fold objective, the first of which is to present the results of scenarios to explore electromobility deployment in Finland, Germany and the European Union. The second is to discuss the challenges and solutions to bridge the gap from research findings towards decision-making and policy-planning, using our electromobility scenario work as an example.
The electromobility scenarios were built using the VECTOR21 model (Mock 2010), and the rationale was to simulate vehicle sales and markets under different policy settings and calculate the most economical solution to fulfil regulation on CO_2 emissions as set by the European Commission (2009). The model allows calculating the market diffusion of alternative powertrain technologies to the European market until 2030, taking into account different taxation schemes, incentives and other country--specific characteristics. We also present the cost-benefit-analysis of the modelling results to assess the different scenarios and to show variation between regions regarding profitability of alternative technological or political support and interventions.

* Corresponding author. Tel.: +358-20-722-6016; fax: +358-20-722-700.
E-mail address: heidi.auvinen@vtt.fi

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To proceed from research findings towards decision-making and policy-planning, we made observations relating to transfer of research knowledge and interpretation of our electromobility scenario results in national policy contexts. An evaluation of how the function of research to inform policy in this case succeeded is provided. In addition, the influence of expert opinions on the political decision-making process will be discussed through experiences from an expert questionnaire conducted to survey the importance of costs, time requirement, acceptance and other criteria of promotion measures of electromobility.

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1. Introduction

1.1. Objectives and scope

Scenarios are a means to explore and communicate the multitude of possible futures. Modelling, on the other hand, provides the tools to study further a given futures path of a system. We combine these two approaches to study take-up of electromobility and to thus provide policy advice to decision-making and policy-planning in the national and European context.

The topic of electromobility comes up in the policy agendas as one technological option to reduce environmental impacts of transport. While operating fully electric, electric vehicles are free of exhaust gas emissions and thus eliminate local pollution. This means that emissions that are harmful to natural environment or health are not released from vehicles, the latter of which is of great importance especially in urban environments with much traffic and large populations. Secondly, emissions resulting from electricity production are typically smaller than those from conventional automotive fuels, even if fossil energy sources were used. Electric drives are more efficient, and if sustainable and renewable energy sources and electricity production methods are used, operating an electric vehicle can be completely emission-free and climate-neutral.

Besides the emission-related aspects, decision-making and policy-planning need to acknowledge a multitude of other factors when addressing electromobility. These include potential impacts to transport safety and implications to energy grids. On the other hand there are concerns over energy safety and security, and the structural and economic impacts on automotive industries and energy industries. Interests of different stakeholder groups need to be acknowledged and the positive and negative impacts need to be carefully assessed.

The design of support measures to initiate and accelerate electric vehicle take-up is therefore a sensitive matter, and scenario modelling can be used to experiment with different policy options. Simulations can show how effective a given measure is and how different support measures work in combination. Scenario modelling may also reveal and quantify unwanted impacts or show which actions are insufficient or costly.

In this paper we present the work carried out in the research project eMAP (electromobility – scenario based Market potential, Assessment and Policy options) between 2012 and 2015. Our objective was to analyse deployment paths of electromobility until 2030, using computational vehicle market scenarios with alternative policy options. The project was commissioned by national and regional transport authorities and supported by the European Commission. The objective of the eMAP scenarios is to provide decision-makers and policy-planners with images of the future that show how far approaches relying on technology development or active policy support can take electromobility in the coming years. The economics of vehicle ownership as well as the socio-economic outcomes of different scenarios, when compared to business-as-usual developments, are quantified. The research questions guiding our work are: (1) What is the business-as-usual electromobility deployment in Finland, Germany and the European Union (EU) by 2030 under the currently implemented national and European regulations and policies? (2) With tailored support policies per region, how much can electric vehicle penetration be accelerated and what are the economic impacts? (3) How can the modelling results of business-as-usual and policy-driven scenarios inform and support decision-making and policy-planning?

Our paper begins with the introductory part, accompanied by short overviews on literature on two topics: function of research to inform policy and scenario modelling of electromobility futures. Section 2 explains the methods of our research, i.e. scenario model VECTOR21 and economic impact assessment. The results of the electromobility scenarios for Finland, Germany and the EU are presented in section 3, showing the vehicle market behavior and emission reductions under business-as-usual and policy-driven scenario settings. In section 4 we provide economic evaluation of the scenarios and interpret the overall results of the project. Stakeholder views are exposed and final recommendations for action are formulated. Finally, section 5 concludes with a discussion over the findings and lessons learnt from our electromobility scenario project and its objective to inform policy.

1.2. Research to inform policy

Research to inform policy has the objective to use and implement research findings in decision-making and policy-planning. Success and impact of this knowledge transfer process is determined by a multitude of factors, most importantly participatory and dissemination activities. These aspects have been studied e.g. by Volkery and Ribero (2009), with special focus on scenario planning in public policy-making. Based on their analysis on scenario practitioners' experiences they conclude that many scenario projects remain ad-hoc or isolated exercises and the full potential of scenario planning in support of public policy-making is not utilized.

One of the keys for impactful research is dialogue between researchers and decision-makers. Ideally this is an interactive process throughout the research project, culminating but not limiting to interpretation of the end results into concrete conclusions to be adopted by relevant actors and stakeholders. Direct one-to-one encounters between researchers and decision-makers are essential, as pointed out by Lomas (2000), contributing to profound understanding and legitimate interpretations of the results. This covers also understanding of study boundaries and limitations. Outreach to the right recipients is also important, so that research findings can be diffused to decision--making levels with influence on the matter. Additionally, mechanisms to knowledge transfer in the decision--making organization will work most efficiently in the presence of a stable, favourable policy environment. Accordingly, individuals, organisations and structures can be either enablers or barriers in the knowledge brokering of research evidence to policy (Ward et al. 2009).

The specific case of scenario research, or foresight studies in general, is often criticized by having weak links to short-term, practical decision-making and policy-planning despite the fact that forward-looking research typically aims to connect long-term policy goals to their implications for near-term decisions. Hughes (2013) explores the issue in context of policy relevant low-carbon scenarios and concludes that scenarios can be of practical value especially when providing actor-based views showing how near-term actor decisions build up to long-term pathways. This becomes more and more difficult when addressing societal challenges of global scope and involving various decision-making levels. In such a multi-dimensional case it may be beneficial to use multi-scale scenarios, i.e. a set of scenarios of different spatial scale. Biggs et al. (2007) have studied the advantages and disadvantages of such multi-scale exercises, and in their view it is most efficient when scenarios of different spatial scope relate to the relevant decision-making entities and are loosely linked to one another.

1.3. Scenario research on electromobility

Study of electromobility futures using scenario research and modelling has been getting more attention in the recent years. Focus and objectives of research vary, including e.g. implications of electromobility to electricity generation and grids or impacts of electromobility in cities to traffic safety. For our background review we concentrated on studies on the transport system level, where the consumer choices on car purchase and mobility behavior typically outline the starting point. Secondly, such approaches usually observe take-up of electromobility using vehicle fleet modelling, and the penetration of electric drives can be analysed through developments in the vehicle market.

One example of transport model using system dynamics is ASTRA (see e.g. Fiorello et al. 2010). The ASTRA system has been widely used in assessment of policy options at the European level, with the ability to simulate transport demand, the economy, the vehicle fleet and environmental impacts. ASTRA consists of interlinked modules, and past experiences show how it can be used in combination with other strategic tools.

In fact multidisciplinary research where futures scenarios and modelling constitute one dimension to simulate, concretize and assess different paths is important in order to provide input to modelling and to fully interpret the outcomes. Auvinen et al. (2015) have developed and demonstrated a comprehensive working process that embeds modelling as one interlinked step in research work to support strategic decision-making. Their study shows how a systemic transition towards emission-free urban transport could be achieved by 2050 by integrated transport policies promoting electromobility, biofuels and public transport. Massiani (2015) on the other hand presents a study dedicated to understand policies towards the diffusion of electric vehicles and by conducting a thorough cost- -benefit-assessment. His conclusion of the simulations carried out is that potential of battery electric vehicles is limited, but can be improved by including plug-in hybrids and range-extended vehicles in the scope. The benefit- -cost balance of most of the policies studied was negative, while the influence of the European fleet emission regulation was rather dominant.

2. Methods

2.1. Scenario modelling with VECTOR21

The vehicle technology scenario model VECTOR21 was developed to calculate the future market share of different powertrains (for full description of the model see Mock 2010). Scenarios are built to outline the balance between market supply and demand through five main factors: development of vehicle technologies, development of infrastructure, vehicle manufacturing, customer requirements and policy measures.

Firstly, the vehicle supply side is modelled using three different car segments: small, medium and large. Each segment includes ten different powertrain concepts, covering conventional diesel-, gasoline- and gas-powered vehicles, the respective hybrids, plug-in hybrids, range-extended vehicles, battery electric vehicles and fuel cell vehicles. The model also incorporates technological development in vehicle key components, such as internal combustion engine and traction battery, over time in terms of efficiency and costs. Policies, regulation and taxation in turn set the boundary conditions together with parameters like oil and energy price or the development of the charging and refueling infrastructure.

Secondly, within these settings of market supply and preparedness, an agent-based modelling approach is taken to calculate the market share of the different powertrains in the respective vehicle segments. Vehicle owners as agents are characterized by their annual mileage, their requirements for infrastructure and driving range and their willingness to pay surcharges for vehicles with lower carbon dioxide (CO_2) emissions.

For our scenario work, VECTOR21 was calibrated to model vehicle markets until 2030 on EU-level and nationally for Finland and Germany. For simplification, the EU28 was represented in the model by six countries covering Germany, France, UK, Italy, Poland and Finland, representing 73% of the new passenger car sales in 2014 and about two thirds of the EU28 passenger car stock. The results were then scaled up to represent the entire EU. We present two different scenario settings: (1) '*business-as-usual*' that depicts the baseline developments from the current policy environment, i.e. policies, regulation and taxation in force or ratified to be implemented and (2) '*policy scenarios*' sketching changed policy frameworks respectively for the EU-level and nationally for Finland and Germany.

The main premise imputed in all scenarios was compliance with the EU regulation on CO_2 limits (EC 443/2009) for new passenger cars (European Commission 2009). Hence, the scenario results are showing an economically optimized path from the customers' position, to fulfil the EU-level CO_2 emission targets. The first limit for maximum level of emissions by the current EU regulation is fixed to the value of 130 g/km in 2015. The limit is thereafter reduced to 95 g/km in 2021 and assumed in the business-as-usual scenario to decrease further to 75 g/km in 2030. The policy scenario sketches a changed policy framework, with limit of 60 g/km in 2030. For the energy costs, continuously increasing oil price is assumed, according to IEA (2012), while the actual development until 2015 is taken into account. The technological development follows a baseline path where the efficiency of the respective drivetrains is increasing; hence, the energy consumption of the vehicles is decreasing. At the same time the costs for key electric vehicle components are reduced using learning curves. The price for traction batteries reaches a value of 230 €/kWh in 2029.

For the country-level policy scenarios for Finland and Germany, tailored measures (policy mixes) to support the market penetration of electric vehicles were designed. These measures include for example changes in the taxation scheme which prefer electric vehicles, financial incentives or a raised awareness due to advertisement campaigns and showcase projects.

2.2. Economic impact assessment

The economic impact assessment of scenarios is based on two main methods: cost-benefit-analysis and wider--economic-impact-analysis.

Cost-benefit-analysis is a well-established methodology deriving from welfare economics to determine the efficiency or profitability of certain support measures. Cost-benefit-analysis evaluates the costs and the benefits of a measure in terms of used and saved resources. In our case cost-benefit-analysis shows whether it is profitable to the society to use productive resources, such as labour and capital, to promote electric vehicles and related charging infrastructure to achieve savings of resource consumption, in this case energy and environmental pollution. Costs and benefits are expressed in monetary terms, and a benefit-cost-ratio can be calculated. If benefits exceed the costs, the benefit-cost-ratio is greater than 1, and the case is profitable. If costs exceed the benefits, the benefit-cost-ratio is less than one and the evaluated measures are not profitable from the societal point-of-view.

When comparing two scenarios, the costs of operating and owning as well as the costs of emissions can decrease, which leads to cost savings and thus benefits in a cost-benefit-analysis. Thereby only real costs, not taxes, are included. Costs of operating and owning include all costs, except of purchase costs, that belong to a car as insurance costs, maintenance costs, repair costs and energy costs. Costs of emissions include most importantly CO_2 costs but also other pollutants. Emission costs may incur in the production phase as well as in the use-phase (driving), and it is thus distinguished between well-to-tank costs and tank-to-wheel costs. In addition, costs of noise are taken into account to acknowledge the fact that electric vehicles are more silent compared to conventional combustion cars. As the basis for our evaluation of emission and noise costs we use Update of the Handbook on External Costs of Transport (Korzhenevych et al. 2014). In contrast to the benefits in terms of cost savings, the costs for public and private charging infrastructure and the costs of car production (net costs without taxes and subsidies) can increase.

Wider-economic-impact-analysis extends the scope beyond welfare economical aspects towards macro-economic effects such as employment, production volume, income, profits and fiscal revenues. Changes in car production and car use (incl. infrastructure, operating and maintenance) can lead to direct and indirect employment effects. When comparing two scenarios, also changes in gross value added in the areas of industry and services may occur. Furthermore higher or lower fiscal revenues in terms of car related taxes and other taxes can be identified.

3. Electromobility scenario results

3.1. Business-as-usual scenario

The results of the EU business-as-usual scenario show a start of the diffusion of electric vehicles into the European car market in 2015, where mainly hybrid electric vehicles without external charging device can be found (Fig. 1, left). In the following years, the share of higher electrified vehicles equipped with a charging device increases significantly. In 2030, around 25% of the new vehicles are plug-in hybrids, range-extended electric vehicles or battery electric vehicles. In particular plug-in hybrids show potential for high market shares until 2030. At the same time, the amount of conventional gasoline- and diesel-powered vehicles is reduced. In 2030 only around half of the vehicles are not equipped with an electrified drivetrain.

Fig. 2 shows the share of electric vehicles as percentage of total vehicle stock. Results are shown for the EU, Finland and Germany respectively, taking into account all electric drives with charging equipment and battery storage. Growth curves for the EU and Germany are very similar and show only moderate progress. The share of electric vehicles in these regions reaches 5% no sooner than 2027, and the threshold of 10% will not be met by 2030. The business-as-usual scenario presents a more optimistic baseline for Finland, where earlier take-up enables the 5% milestone to be reached in 2020. By 2030 the steep growth curve assumes up to 23% of the Finnish cars stock to drive electric.

The business-as-usual scenario simulations show that introduction of electric vehicles will be slow in the current policy environment and expected price developments in the vehicle markets. Although incentives to support electromobility exist in some countries, competition with conventionally fuelled vehicles is hard, and the electric vehicle remains a marginal phenomenon in many regions. Finland, however, is an example of a market, where the economics of CO_2-based taxation and low electricity prices provide better opportunities for electromobility. Such regions with relatively more favourable market conditions welcome higher penetration of electric vehicles in response to fulfil the overall EU-level CO_2 limits.

The business-as-usual scenario assumes electric vehicle markets to speed up in sales in the 2020s, and by 2030 21.9 million cars equipped with charging device should be on the roads of the EU. As a result, this electrified fleet together with increasing efficiency of conventional powertrains would result in an overall well-to-wheel CO_2 emission reduction of 29% compared to 2010.

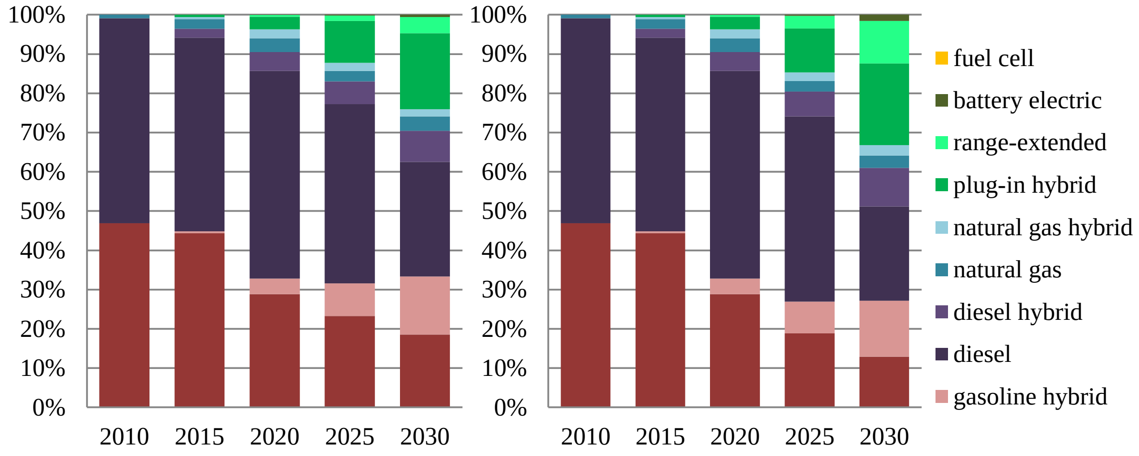

Fig. 1. Market share of different powertrains in the EU until 2030 under the business-as-usual scenario (left) and policy scenario (right).

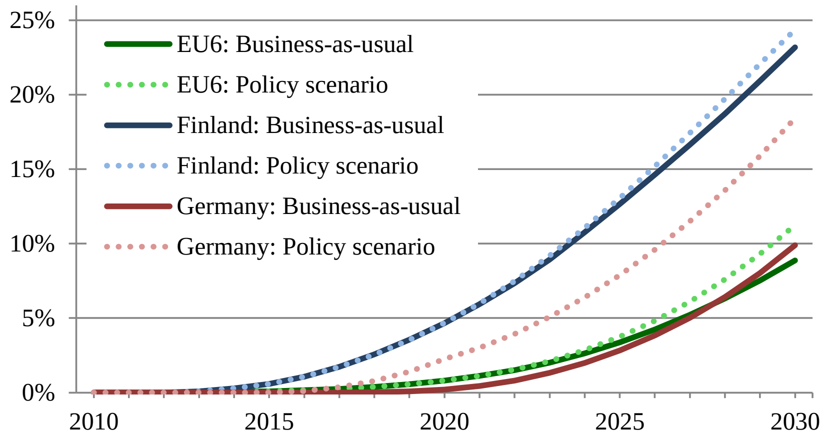

Fig. 2. Share of electric vehicles (percentage of total vehicle stock) in business-as-usual and policy scenarios in the EU, Finland and Germany.

3.2. Policy-driven scenario

The EU-policy scenario assumes that CO_2 emission limits are lowered to 60 g/km in 2030, leading to higher shares of electric vehicles than in the business-as-usual development (Fig. 1, right). In 2030 a share of 60% of the new vehicles sold in the EU are featured with an electrified drivetrain, 33% are vehicles with external charging device. Thereby, the share of battery electric vehicles is still very low and values at less than 2%. The increased share of electric vehicles and the ongoing improvement of vehicle efficiency lead to a significant reduction of the CO_2 emissions of the new vehicles.

Fig. 2 presents the stock-level results of policy scenarios that were defined separately for the EU, Finland and Germany. The graph shows share of electric vehicles out of the total stock in each region, and the baseline of business-as-usual scenarios is also shown for comparison.

By definition, the policy scenario for the EU outperforms the business-as-usual development between 2021 and 2030. This accelerated market growth of electromobility results in a total of 27.8 million electric vehicles in stock by 2030.

The policy package designed to support electromobility in Germany produces a policy scenario with a large impact in favour of electric drives. However, because of the vast size of the German vehicle stock, the production capacity of electric drives poses a bottleneck in the short- to mid-term market development. But as market supply improves, take-up of electromobility speeds up and growth is steep.

The policy scenario for Finland shows only a small increase in electromobility in the late 2020s. The policy measures introduced do not create enough momentum to have a significant impact to the electric vehicle markets that were already favourable in the business-as-usual setting.

4. Contribution to decision-making and policy-planning

4.1. Interpretation of scenarios and economic impact assessment

The cost-benefit-analysis of the EU policy scenario, when compared to the business-as-usual development, shows that costs induced by a more stringent CO_2 emission limit (60 g/km instead of 75 g/km in 2030) were higher than the benefits gained through accelerated electric vehicle penetration and emission reductions. The same applies to the policy scenario for Finland, where the introduced steering measures actually proved inefficient to make any major improvement in electromobility take-up. The cost-benefit-difference, in terms of net present value from 2010 to 2030, accumulates to -22.5 billion euros for the EU and -110 million euros for Finland.

For Germany the policy scenario resulted almost twice as many electric vehicles as the business-as-usual scenario. In monetary terms the policy scenario is a break-even as the total costs of support policies are matched by benefits of equal magnitude.

The wider-economic-impact-analysis shows the distributional effects in the economy that take place when electric drives start to replace conventionally fuelled vehicles. A central consequence is that industries and trade on petroleum products lose their ground in favour of electricity production and trade. The overall impact of this transition to overall employment of added value is nevertheless very small. Significant changes in employment rate could only be identified in the policy scenario for Germany, where additional 70 000 person-years between 2010 and 2030 were created.

The policy scenarios for the EU and Germany lead to tax losses, while the policy scenario for Finland was designed to maintain the same level of tax revenues. Stakeholder assessment also showed that from the societal point of view all policy scenarios were positive, as CO_2 emissions and other negative environmental impacts were reduced by increased electromobility penetration. For the individuals, the economics of car ownership and use followed the current patter, where electric vehicles have a relatively higher purchase price but lower operating costs. The competitive standing between electric drives and conventionally fuelled vehicles, as determined by relevant cost of ownership, varied across time and region.

4.2. Stakeholder views and feedback

The scenario results support the assumption that political decisions could influence the market penetration of electric vehicles substantially. Nevertheless, the use of promotion measures and strategies is not a simple task since political support actions need to meet several feasibility criteria. Therefore, the selection process of specific measures has to consider on the one hand the effectiveness to overcome deployment obstacles to enhance the market penetration and on the other hand accompanied expenses such as time and implementation costs as well as application requirements of the support actions in terms of political acceptance and complexity.

A lot of different stakeholders are involved in the implementation process of electric vehicles. In order to advise decision-makers on appropriate sets of promotion measures, national experts from Finland and Germany were invited to contribute to selection and validation of potential promotion measurers through a questionnaire. We chose to conduct this survey using the qualitative multi-criteria-analysis approach (Adam 1992, San Christóbal 2012), which suits such political decision-making processes containing a widespread number of alternatives that cannot be compared in quantitative terms only. By weighting the importance of each evaluation criteria and the assignment of scores for the effectiveness of each promotion measure with regard to the evaluation criteria, overall utility factors could be derived for each measure (Kurte et al. 2015).

Based on various former studies (Trigg and Telleen 2013, European Parliament 2010, Tsang et al. 2012, National Research Council 2013, Perdiguero and Jiménez 2012) as well as results from a consumer survey (Gruschwitz et al. 2014), a selection of deployment obstacles was made available for weighting by the national experts. The experts in Finland and Germany identified the low battery technology performance and high cost as the main obstacle. Also the insufficient access to charging infrastructure plays a major role in the implementation process in their opinion. In contrast, the insufficient supply and demand of electric vehicles were estimated as less relevant.

Furthermore, the aforementioned feasibility criteria were used considering principles from environmental economics as well as characteristics from policy assessment (Matt et al. 2013). For practical reasons the questionnaire concentrated on four major evaluation criteria concerning the feasibility: time, implementation costs, political acceptance and complexity. The experts from both countries agreed upon the relatively high importance of the factor ‘political acceptance’. In Finland this evaluation criterion was even the most important one for the use of a promotion measure in the field of electromobility. Finally, based on the sum of the total utility values for the effectiveness to overcome the obstacles and the effectiveness of the feasibility criteria, a ranking of the most appropriate measures could be compiled. Table 1 shows the top five promotion measures for Finland and Germany with the highest total score within the multi-criteria-analysis.

Table 1. Overall ranking of measures in Finland and Germany.

Rank	1.	2.	3.	4.	5.
Germany	Research and development	Strategic alliances, cooperation and consortia	Purchase premiums	Charging infrastructure	Lighthouse and showcase projects
Finland	Commercial fleet users	CO_2 taxation	Strategic alliances, cooperation and consortia	Norms and standards	Charging infrastructure

In the opinion of the stakeholder experts from Germany, ‘*research and development*’ and ‘*strategic alliances, cooperation and consortia*’ combine a high effectiveness with regard to the obstacles as well as the feasibility criteria. As financial incentive for boosting the demand in Germany the use of ‘*purchase premiums*’ has been assessed as the most appropriate measure by the experts. Furthermore, ‘*charging infrastructure*’ and ‘*lighthouse and showcase projects*’ were in the top five of appropriate promotion measures for Germany. Especially, the focus on research and development, charging infrastructure as well as lighthouse and showcase projects reflects the current support action strategy which has been applied the last couple of years or is still running in Germany (MacDougall 2015, BMVI 2015).

The Finnish experts addressed their top five measures with higher total multi-criteria-analysis scores compared to the experts from Germany. ‘*Commercial fleet users*’ play a crucial role in the implementation process from the Finnish point of view. Not surprising is the fact, that they assessed ‘*CO_2-based taxation*’ as the best financial incentive for boosting the demand since such taxation scheme is already in place. Private initiatives in terms of ‘*strategic alliances, cooperation and consortia*’ and ‘*norms and standards*’ could contribute to an increasing market deployment of electric vehicles as well.

Finally, the experts were asked to estimate the impact of the different stakeholders (research and development, manufacturing, sales, infrastructure operation, etc.) within the deployment process of electric vehicles. Over all expert guesses within the survey, the role of the automobile manufacturers as well as of the suppliers was rated as the most import one. Nevertheless, the impact of infrastructure providers and the public administration should not be underestimated.

4.3. From conclusions to recommendations for action

In the specific case of interpreting results of our electromobility scenario research into policy advice, fundamental goals promoting carbon-neutrality, liveable urban environments, inclusive mobility, etc. need to be brought to the front. From the societal point of view electromobility as such is not a goal but an instrumental solution that could contribute to many of the previously mentioned societal policy objectives. Communication of the results thus needs to acknowledge the role of electromobility as one constituent of a bigger solution, complemented by e.g. biofuels, hybrid technologies and hydrogen economy. And even more importantly, results and conclusions should be formulated in the context where other means and modes of the transport system are accounted for, so that recommendations for electromobility support measures will for example not impede walking, cycling, public transport or operational efficiency improvements.

As the final outcome of our research, the main conclusions have been translated to recommendations for each region: the EU, Germany and Finland respectively. The policy implications of the results are found strongly dependant on regional characteristics, and aspects such as national strategies, urban form, climate, mobility patterns and availability of technologies and services had to be accounted for. Stakeholder feedback and public acceptance of suggested actions have been emphasized, and electromobility is addressed as one of the sustainable alternatives to be supported towards competitiveness by nationally designed support measures.

Concerning the whole of EU, regulation on CO_2 emissions was proved effective as a measure to encourage vehicle markets to provide vehicles with lower emissions. Electromobility among other cleaner technologies benefits from this support action to oblige manufacturers. It is important that the currently binding, union-wide regulation is extended well beyond 2020s to ensure long-term commitment and that the target level is ambitious enough. In addition, measures on CO_2 among other greenhouse gas emissions should be aligned with measures focussing on local emissions. Regarding the implementation of CO_2 limits, monitoring and follow-up of compliance should be exercised. Further assessment of the impacts of this regulation on different member states is also important, so that aspects of such as shared responsibility and healthy vehicle markets across Europe are addressed.

The business-as-usual scenario results for Finland were very optimistic towards fast electromobility take-up, which contradicts current sales trends and consumer attitudes. The important finding was that the economics of electromobility indeed present Finland as a favourable market for electric vehicle deployment, which is explained by two factors. Firstly, the electricity prices in Finland are significantly lower compared to European average, which combined to high annual mileages in Finland makes the electric drive an economic option in the use phase. Secondly, the Finnish CO_2-based tax scheme favours electric vehicles among other low-emission technologies, an approach that gives competitive edge to electromobility. The recommendations for Finland therefore put the focus on such support measures that raise consumers' awareness on real performance of electric vehicles and total costs of electromobility. Practical demonstrations and showcasing of electric vehicles in everyday life could also help dispel scepticism and promote electric vehicles as a functional alternative.

The main lesson from the scenarios for Germany was that powerful support measures need to be introduced urgently, because the business-as-usual scenario will not meet the ambitious national electromobility goal of one million electric vehicles by 2020. The recommendation is to design support mechanisms that influence both the demand and supply sides. The policy-driven scenario also showed that accelerated electromobility deployment can have a positive impact to employment and value-added, although tax revenues in this scenario decreased mainly due to vehicle taxation. It is therefore recommended that careful ex-ante assessment of impacts to tax is carried out, and that strategies to avoid tax losses by road charging among other options are studied.

5. Discussion

The overall conclusion from the eMAP scenarios was that market penetration of electric vehicles in Europe is low and will not change considerably without substantial technological improvements or massive public support. Electromobility is nevertheless an important part of the complementary technological and behavioural solutions aiming towards decarbonising of transport, addressing environmental and health related problems but also enabling national economies to develop steady and competitive. Coordinated support actions are required, but heterogeneity of regions across Europe also calls for regionally tailored approaches. Most importantly, stakeholder dialogue confirms that wholesome strategies to address electromobility as one building block of future mobility should be highlighted, i.e. electric vehicles as one of the technologies to replace conventionally fuelled vehicles and to complement walking, cycling and public transport.

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