A comparative, simulation supported study on the diffusion of battery electric vehicles in Norway and Sweden

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Introduction

BEV (Battery Electric Vehicle) uptake is a main factor of interest in energy transition studies. The road towards zero emission transport meets extensive challenges and inertia (Struben & Sterman, 2006). While improvements in battery technology and cost reductions make BEVs an increasingly attractive alternative to Internal Combustion Engine Vehicles (ICEVs), there are many other factors that influence the adoption of these alternatives, such as consumer awareness, infrastructure availability, range, speed, safety, and service (Pasaoglu, et al., 2015). The problem is therefore rich in complexity and dynamics. It is no surprise that forecasts for the future of BEVs diverge so broadly, from sales dominance in Europe before 2025 (DNV GL, 2017) to disappearance (International Energy Agency, 2016; Nykvist & Nilsson, 2016; Pasaoglu, et al., 2015).

Norway and Sweden's different policies represent a natural experiment: their current battery electric vehicle (BEV) policies differ. Sharing a past of period of 100% fossil fuel use, Sweden adopted a technologically neutral transportation strategy, while Norway policy efforts have concentrated on BEV. The costly policies have given results in both countries: BEVs represent Swedish 7% of new car sales (Andersson, 2017), and a world record of 21% in Norway for 2017 (Norwegian Information Council for Road Traffic/ OFV, 2018). Understanding the drivers behind this difference can provide policy guidance to support BEVs. What policies are determinant for a sustained BEV adoption, whether we can expect a permanent take-off of the BEV market, and at what speed this transition can happen, are all questions that this research proposes to investigate.

The present approach integrates knowledge contributions from a range of fields: system dynamics (SD) (Forrester, 1961), consumer choice theory (Samuelson, 1938), diffusion theory (Rogers, 2010) and transport economics theory (Meyer, 1959). The study develops a system dynamics model to represent and quantitatively analyse the interrelatedness between policy, consumer behaviour, social dynamics, competition forces and cost and performance developments in Norway and Sweden.

Governmental subsidies in the early commercialization period of EVs will nudge sales as to reach a mass market (Hidrue & et al., 2011; International Energy Agency, 2015). Kampmann and Sterman (2014) show however, that nudging levels typically are insufficient: consumer responses are not instantaneous and good policies should compensate for the misbeliefs and miscalculations of people.

Lovin and Andersson (2017) describe two categories of disadvantages related to BEVs: (i) cost-related disadvantages, specifically purchase price, operational costs and second-hand value; (ii) disadvantages related to vehicle performance attributes, e.g. travel range, technological lifetime, model diversity, and comfort. Other behavioural theories can support in understanding how people choose between options that involve risk: Prospect theory (Kahneman & Tversky, 1979) and Diffusion of Innovation theory (Rogers, 1976). Also, consumer theory points to peer-to-peer contact as an important mechanism that drives adoption.

Model description

The market setting is the competition between two vehicle alternatives: a market incumbent, the ICEV, and a market entrant, the BEV. The ICEV is in this study applied as an umbrella term for both traditional gasoline, diesel, and newer biofuel-driven and hybrid-electric cars. ICEVs and complementary resources (petrol stations, reparation services, technical knowledge) are well-established, while the corresponding

BEV resources need to be built. The model structure of the two vehicle alternatives is therefore not symmetrical.

The model is built around the decision makers' environment. The main decision maker is the vehicle buyer and she acts sequentially: first, where the individual compares vehicles' attributes, and makes a choice; second, there is a vehicle market in which the purchase happens, and that determines the balance of vehicle types in the national fleet; finally, there is the utilization stage of the vehicle, of which the complementary infrastructure makes a key component. Attributes of utilization feeds back to the choice stage. There are two main reinforcing feedback processes in the model: Word of Mouth and Chicken-and-Egg dynamics. Balancing processes also determine the behaviour of the system: competition, risk aversion and gap-closing behavior.

Model simulation results

In addition to comparison with historical data, the model has also been used to investigate the effectiveness of the policies implemented until 2017 by "altering history": what if no policies had been implemented? The result is a significant difference, especially in the Norwegian context: the total BEV fleet results in 2016 in 2 600 vehicles, less than 3% of what actually happened. This simulation supports the hypothesis that policy action made a considerable impact.

A series of alternative scenarios have been developed in which different policy strategies are explored with the objective to evaluate the effectiveness of the existing policies and assess what regulative conditions are required to achieve the stated goals in the two contexts considered. These are: (1) full policy support on BEVs between 2020 and 2050 (2); removal of all incentives from 2020; (3) the Norwegian strategy as of 2015 applied to the Swedish context from year 2020.The study finds that countries will achieve their 2050 zero emission goals for road transport if current policies are prolonged. Under accelerated policies, BEV fleet penetration rates will reach 100% within two decades: the international drivers of longer BEV range and lower prices will wash out Sweden's current trailing of EV uptake.

Comparing Norway and Sweden, one can see that multiple factors need to be in place contemporarily to allow a strong growth in BEV sales: not only the BEV must be competitive in both price, costs and performance attributes, but costumer confidence needs also to be high. The alignment of these requirements to adoption is one of the main challenges for BEV diffusion.

The inertia of the transition can only marginally be overcome. Policy action can anticipate by many years the cost and performance parity of the BEV and the ICEV and thereby give strong momentum to the growth.

Secondly, the market share of the BEV will grow over time under all scenarios. The diffusion of the BEV is driven by strong reinforcing mechanisms involving consumers, infrastructure operators and the vehicle fleet. Today, these mechanisms are starting to run in both contexts, and policy action only drives the initial push. The transition seems therefore "unstoppable".

The model simulation has also brought understanding on the differences and similarities between the Norwegian and Swedish vehicle system. Sweden's technologically neutral policy strategy has not given the BEV the competitive advantage that it has in Norway, where policy efforts have been concentrated on the BEV only. Today, Sweden faces a poor density of charging infrastructure, acting as bottleneck for consumer confidence. On the other hand, the two countries show a similar long-term behaviour to 2050: the growth in the BEV appears inevitable once international cost dynamics play out given the expected returns on investment. However, experiences from the head start established in Norway can be used in Sweden – a sustained set of policies will lead to full BEV sales dominance within a decade. This will push the ICEV out. The study concludes that a future of coexistence between the ICEV and the BEV technologies is not probable.

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