Estonian Experience with Electric Mobility: Is There a First-Mover Advantage with EVs?

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Introduction

Electrification of the transportation sector is an important strategy in Estonia, as the country needs to honor its international climate commitments. Estonia, a country the size of Switzerland but with a population of 1.3 million, is a signatory to both the Paris Agreement (UN, 2015) and the pan-European plan to achieve net zero emissions by 2050 (Bloomberg, 2019). Estonia's energy sector is facing two main challenges: integration of renewable energy (RE) into the transportation sector and elimination of the country's reliance on domestic oil shale, a carbon-rich fossil fuel (European Commission, 2020). To strategically plan for its energy future, Estonia has developed an ambitious energy and climate plan with 11 energy-related targets for 2030, which include a substantial increase of RE in the transportation sector (Ministry of the Environment of Estonia).

Known for its vibrant start-up culture, Estonia has been widely recognized as a hub for digital innovation in multiple domains (Forbes, 2017), including e-governance (World Bank, 2016), blockchain (Digigeenius, 2018), and smart cities (National Geographic, 2018). The country was among the top OECD performers with respect to environmental R&D and related technologies in 2005-2015 (Pliousis et al., 2019). Universal adoption of smart meters in the Estonian distribution grid has offered insights into user behavior, consumption patterns, and use predictive analytics to evaluate impacts from higher EV adoption. Prior to that, in the early 2010s, Estonia pioneered the adoption of country-wide electric vehicle infrastructure, ahead of most other countries. Contrary to expectations, early adoption of EV technology did not create a vibrant market for EVs, even though this 'experiment' resulted in positive knowledge and climate benefits. This article examines lessons learned from Estonia's early endeavors in the EV landscape and discusses opportunities for future developments.

Did Estonia misaddress barriers to EV adoption?

Many researchers have grappled with the barriers to EV adoption, listing range anxiety, lack of charging infrastructure and high upfront costs as the main factors that slow EV adoption (Rezvani et al., 2015). All of these challenges were also relevant to Estonia in the early 2010s: (1) most EV driving ranges did not exceed 100 km (Pearre et al., 2011); (2) unlike abundant petrol stations, charging infrastructure was non-existent; and (3) upfront cost for EVs was considerably higher than conventional fossil-fueled cars (Rezvani et al., 2015).

As early as 2010, Estonian policy-makers decided to address two of the above-mentioned barriers: increase availability of the charging stations, as well as create a subsidy scheme to reduce the price tag for EVs. By 2013, Estonia had built the world's first nation-wide fast-charging network for EVs that included 165 charging stations (ABB, 2013). It was believed that the consumers' range anxiety could be considerably reduced if the charging infrastructure strategically covered both urban centers and rural areas (Figure 1). At the same time, acquisition of EVs was subsidized: up to €18,000[1] (ca. $25,000) or 50% of the EV's listed price was reimbursed, with an average subsidy of €16,500 (ca. $23,000) (KredEx, 2018a). This program was funded by trading 10 million tonnes of Estonia's CO_2 emissions quota with Japan. The transaction yielded €12 million (ca. $16.7 mln), which were earmarked to be spent on electromobility in Estonia (Mitsubishi, 2011). The initial program was extended with an undisclosed amount of additional funds until the end of 2014 (KredEx, 2012). As a result, in the period 2011 to 2014, 650 EVs were purchased for private use and 507 EVs were acquired by the Estonian government. An additional EV rental program was implemented to make Estonian drivers more familiar

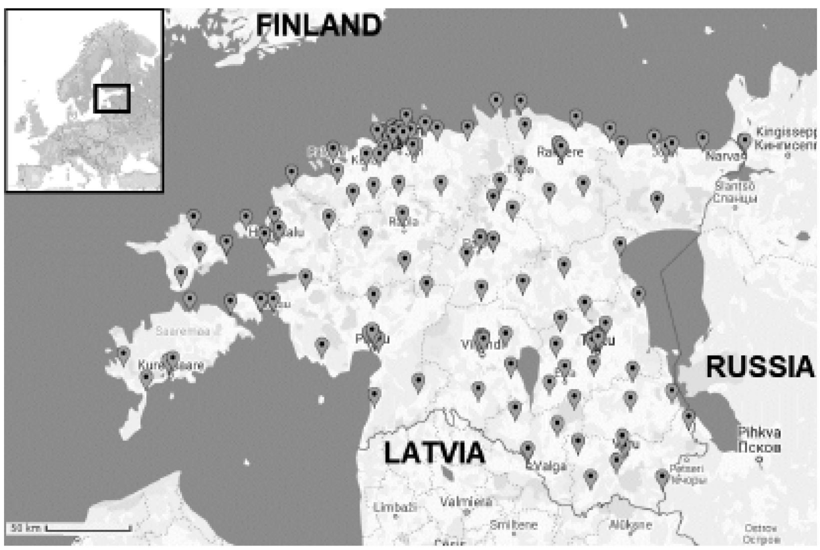

FIGURE 1: Map of Estonia's public fast-charging stations, as built by 2013. Source: authors' depiction based on Google Maps.

with electric mobility. This was achieved by allowing Estonian drivers to rent EVs as short-term rentals. The program attracted over 8,000 users, who cumulatively drove 2.5 million km spread over 255,000 rental hours. However, only 24 customers used rental EVs more than occasionally, that is more than once a week (KredEx, nd). Lacking a long-term financing strategy, the designated funds were depleted by the end of 2014. Thereafter, EV market growth tapered off quickly, especially when compared to Estonia's northern neighbor Finland, see Figure 2. The rental service and EV fleet were subsequently privatized via an auction (KredEx, nd).

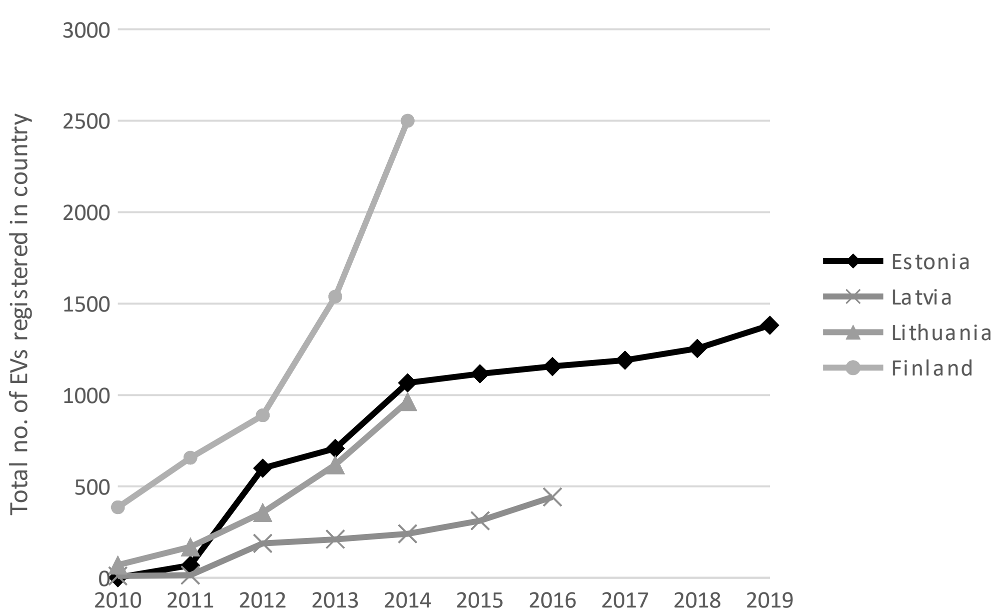

FIGURE 2: Number of registered electric vehicles in Estonia and neighboring countries. Source: Eurostat

In hindsight, in spite of its pioneering efforts, Estonia based its EV program on several assumptions that failed to materialize. First, it was expected that EV prices would drop much faster and that subsidies would not be necessary after a few initial years. In reality, car sales prices remained comparatively high in 2014, when the program ended. The importance of subsidies is evident from the growth of EV markets in the Netherlands and Norway, where a subsidy or a tax benefit will be offered until the end of 2020 and 2021 respectively, helping put tens of thousands of EVs on the road (Norsk Elbilforening, 2012, Cleantechnica, 2019). Estonia could not keep up with the public investment needed for this effort. According to a recent survey most Estonians still see higher acquisition cost of EVs (relative to fossil- or biogas-fueled cars) as the highest barrier to electric mobility (Postimees, 2019).

Secondly, the EV program incorrectly interpreted core consumer preferences with respect to range anxiety and the convenience of charging. In spite of relatively high gasoline and diesel prices in Estonia, car owners were not ready to accept relatively short EV driving ranges and frequent charging, which lasted several times longer compared to visiting a conventional gas station. EVs were mostly purchased by those who had the opportunity to charge at home, while the residents of apartment buildings, which are numerous in Estonia's largest cities, did not purchase EVs regardless of the availability of the public charging infrastructure.

Next, the program adopted a Japanese charging standard. In the early 2010s, there was no universal charging standard in Europe, and Estonia chose to build its fast charging network based on the ChaDeMo protocol, which had been successfully implemented in Japan and has been used in several other countries (Mitsubishi, 2011). In hindsight, the decision turned out to be ill-fated, as European policymakers nominated the Combo-2 standard to be the new European-wide standard in 2014 (EU, 2014).

Finally, equity considerations could have received more attention. Subsidies were designated for purchases of passenger vehicles (either privately or publicly owned), while they could have been dedicated to further electrification of Estonia's public transportation, which is mostly utilized in urban centers by low- and moderate- income populations. Estonia's capital city, Tallinn, already had electrified 9 trolleybus lines, 4 tram lines, and a suburban rail network, resulting in 40 GWh of annual electricity consumption (Eurostat, 2020).

From the grid operator's perspective, demand for electricity that stemmed from electric transportation at that time was small, predictable and easily manageable, and was dwarfed by the country's total annual electricity consumption of 8 TWh (Ibid.). After the program's end in 2014, the impact from the use of 1,100 EVs on the electricity distribution grid was almost non-existent. By 2018, ca. 1 GWh of electricity was consumed per year by the public EV charging network (KredEx, 2020). EV charging in private locations (e.g., homes, office buildings) has not been officially tracked, but it is possible to attempt a back-of-the envelope calculation for electricity consumption by adopting the popular 20-80 ratio (McKinsey, 2018). If 20% of charging occurs in public locations and it amounts to 1 GWh of electric consumption per year, then the remaining

80% - private EV charging - would consume about 4 GWh annually. To reiterate, at that point in time, the electricity consumption by EVs was several orders of magnitude smaller than consumption of the remainder of existing electrified transport (trolleybuses, trams, and trains).

It can be argued that Estonia's early adoption of EVs was a bit 'ahead of its time'. After about 10 years of use, older EV batteries are now due to be recycled, which is another challenge that wasn't strategically considered upfront. On the other hand, learning-by-doing in the early 2010s allowed the country to gather non-monetary knowledge about the necessary EV and charging technology, grow human capital, and support further innovation (Porter Hypothesis). Clearly, addition of EVs on the road instead of fossil-fueled cars resulted in climate benefits in the form of avoided CO_2 emissions, since only electricity from RE sources was used in the public chargers.

Second Wave: Outlook for EVs in Estonia

Nearly a decade later, the EV market has experienced a dramatic change: driving ranges have increased to well over 200 km, with several car models stretching a single charge to 300-400 km (EV Database, 2020). Model selection now includes small city cars to family sedans to cargo vans and SUVs, with manufacturers from different parts of the world (Ibid.).

In an attempt to boost the EV market and create significant carbon savings, the Estonian government recently re-introduced subsidies to EV owners who commit to driving at least 80,000 km over a 4-year period (KIK, 2020a). The subsidy has been popular and the available funds for the full year 2020 were depleted in a matter of days. As a result, 232 new EVs were added to Estonian roads, partially balancing out the fleet of retiring decade-old EVs (KIK, 2020b). Although a second round is planned (KIK, 2020c), this subsidy scheme contributes to the stop-and-go cycle in EV development.

In 2018, the Estonian government held an auction to sell the nation-wide public charging network that was built in 2011-2014 to the highest bidder (KredEx, 2018a). There was only one qualified bid – from Estonia's largest distribution grid operator, Elektrilevi (KredEx, 2018b). Lack of additional interest in bidding could be explained by high investment needs to maintain and upgrade the charging infrastructure. Namely, the new owner needed to commit to operating and maintaining the charging service at 165 charging stations for at least the 5 following years, which effectively meant updating the aging technology that has evolved since 2011, and upgrading the network to a new European standard (Combo 2) to allow newer EVs to charge. Elektrilevi, as a grid operator, has a long-term investment perspective – the company became an owner and operator of the aging charging network so that it could learn more about its customers (e.g., where and how often Estonian EV drivers require charging) to facilitate long-term grid planning.

Next, electric car ownership has also been criticized as regressive, benefitting relatively wealthy consumers (Holland et al., 2019). Electrification of public transportation with strong government involvement might be a good alternative to the current approach. Most cities in Estonia have a developed network of buses that provides reliable transportation to all members of society (not only to those with lower incomes, but also schoolchildren, senior citizens and other white- and blue-collar commuters working in the heart of the city, where limited parking places discourage personal car use). Utilization of electric buses and further development of other electric public transportation lines – such as trams and suburban railways – could result in urban air quality improvements, especially if electricity came from renewable energy sources. Construction of new tram and railway lines is costly and time-consuming, while switching to electric buses would likely be faster and more cost-efficient, since buses do not require rail infrastructure. Despite a nearly twofold difference in sales price between an electric and a diesel bus (Quarles et al., 2020), usage of electric busses on routes with the heaviest traffic can be economically viable already today, even with low or no subsidies to bus acquisition (Ibid.). Introduction of electric buses would require fast chargers at bus terminals, as well as planning of grid connection with sufficient capacity. If government's intensions for electrification are clearly delineated, grid planning can be optimized compared to planning based on private EV purchases, which tend to fluctuate depending on subsidy availability.

Conclusions

Estonia was a pioneer in building a nation-wide fast-charging network for EVs in early 2010, which was paired with subsidies for EV purchases. However, without a long-term funding source, the EV market failed to grow after the initial 1,100-odd vehicles were purchased. Currently, Estonia's EV penetration is comparable to its Baltic neighbors, which didn't develop public charging infrastructure this aggressively. In hindsight, EV adoption in Estonia has been slowed by a number of challenges, ranging from technological (short driving range), to economic (high upfront cost), to consumer preferences (long charging times, limited model selection). Being the first mover has not created a vibrant EV market in Estonia, but it has likely resulted in positive knowledge spillovers about electric mobility (learning by doing) and non-market benefits (reduced air pollution, carbon savings).

Neary a decade later, the importance of these past barriers has decreased significantly. This might create a possibility for renewed EV momentum in the country. With improvements in battery technology, range anxiety has decreased. On the other hand, the country's fast-charging stations require renewed attention due to aging technology. Estonia spent millions of euros on a fast-charging network that needs to be rebuilt, in order to integrate a different charging standard, Combo-2, used by most new EVs (EV

Database, 2020). This upgrade is underway, as several local companies have started installing fast and ultra-fast chargers, and large multinational players (Tesla, Ionity) have announced plans to build their charging stations in Estonia (TechCrunch, 2018; The Baltic Course, 2020).

As private actors re-build the public charging infrastructure and car manufacturers introduce new, more cost-effective EV models, governments could focus on electrification of public transportation, which offers lucrative opportunities for large-scale electrification of the transportation sector. Value-for-money considerations also favor electrifying public rather than private transportation. From a grid operations' perspective, a clear long-term transportation electrification policy is paramount for planning grid investments, so as to keep up with increasing demand for electrification.

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