Journal of Cleaner Production 261 (2020) 121038

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Forecasting the trajectory of electric vehicle sales and the consequences for worldwide CO_2 emissions

Nele Rietmann*, Beatrice Hügler, Theo Lieven

University of St. Gallen, Institute for Customer Insight, Bahnhofstr. 8, CH-9000, St. Gallen, Switzerland

A R T I C L E I N F O

Article history:
Received 9 September 2019
Received in revised form
26 February 2020
Accepted 9 March 2020
Available online 19 March 2020

Handling editor: Giorgio Besagni

Keywords:
Electric vehicles (EVs)
Logistic growth model
Sales prediction
Market share
CO_2 emissions
Cross-national

A B S T R A C T

Over the past decade, global sales of electric vehicles (EVs) have experienced significant growth. However, predictions of future sales developments, which are needed for the planning of EV production as well as supporting policies and a sufficient energy supply, are still sparse. In this study, a long-term forecast of the EV inventory in 26 countries across five continents is provided by means of a logistic growth model. Using actual sales data from 2010 to 2018, predictions were made for these countries until 2035. Findings indicate that, overall, 30% of the worldwide passenger vehicle fleet will be EVs in 2032. However, results also display vast differences between countries, which can particularly be attributed to divergences in governmental support. EV growth predictions were additionally analyzed in terms of sustainability impacts. The analysis showed that reductions in CO_2 emissions can be achieved with the predicted EV growth, given that countries invest heavily in renewable energy sources. Given the current energy mixes though, worldwide CO_2 emissions will continue to rise until 2035 despite a nearly 50% share of EVs. The paper further discusses the amount of energy that will be required to meet the growing demand and highlights that the production of EV batteries will be the key bottleneck in the development of EVs. Finally, important implications for policymakers, marketers and future research are derived.

1. Introduction

The development of the market for electric vehicles (EVs) has gained increasing attention by policymakers and consumers over the past years, especially due to their potential to reduce greenhouse gas (GHG) emissions (Ellingsen et al., 2016). Yet, it is still unclear how exactly this trend will evolve in the future (IEA IA-HEV, 2018; Rezvani et al., 2015). Predicting EV sales over time is key for various stakeholders, including automobile producers, policymakers, and energy providers, to plan the production of EVs, set appropriate policies, and deliver a sufficient energy supply (Eggers and Eggers, 2011; Higgins et al., 2012). Furthermore, it is not clear how the reduction in the fleet of combustion chamber engines (ICEs) burning fossil fuels and the increase in the EV fleet will affect CO_2 emissions. The present study aims to provide a long-term forecast of the EV inventory in 26 countries across five continents and examines its implications on environmental sustainability, particularly carbon dioxide (CO_2) emissions due to their high impact on global warming (Florides and Christodoulides, 2009; Shakun et al., 2012).

Prior studies have already proposed means to estimate the EV market penetration. This includes stochastic models based on consumer preferences, such as discrete choice or agent-based models, and models depicting the diffusion of innovations, such as exponential or logistic growth models (Al-Alawi and Bradley, 2013; Geroski, 2000). Consumer preference models are useful to illustrate decision-making, purchase motives and potential barriers (Lieven et al., 2011). Nonetheless, they are less transparent than diffusion models and the underlying data often do not accurately depict actual demand (Geroski, 2000; Gnann et al., 2015). Moreover, they typically only represent behavior at one point in time (Qian and Soopramanien, 2014).

In contrast, diffusion models describe the development of products' market acceptance over time and are particularly useful if there are already sales data available (Al-Alawi and Bradley, 2013; Qian and Soopramanien, 2014). These models also have some drawbacks, including the need to endogenously estimate the peak of sales and the ultimate market potential. Diffusion models are, however, comparatively easy to implement and can be based on historical data of the innovation or a similar product (Al-Alawi and Bradley, 2013). Moreover, their relevance for EV predictions has been demonstrated in prior studies (e.g., Jensen et al., 2017; Massiani and Gohs, 2015).

Although various models have been developed to forecast EV diffusion, they have almost exclusively focused on individual countries. The current study investigates EV growth in 26 countries across

* Corresponding author.
E-mail addresses: nele.rietmann@unisg.ch (N. Rietmann), beatrice.huegler@unisg.ch (B. Hügler), theo.lieven@unisg.ch (T. Lieven).

https://doi.org/10.1016/j.jclepro.2020.121038
0959-6526/

five continents using a logistic growth model. This allows comparing national differences and predicting EV sales in late-adopting countries with data from early-adopting countries (Meade and Islam, 2006). Moreover, this study evaluates sustainability implications of the predicted EV growth. This has not yet been examined in previous research forecasting EV sales, despite the ever-increasing relevance and prevalence of this issue (Faria et al., 2013; Huo et al., 2015; Wu et al., 2018).

In the following analysis, the term EV refers to both full battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). The consolidation of these two categories seems appropriate as BEVs are expected to replace PHEVs in the long-term, as indicated by recent trends (EV-Volumes, 2019). Hence, it is assumed that consumers who were willing to acquire a PHEV will soon switch to BEVs. As the focus is on consumers' EV adoption, only passenger cars are considered, referring to road motor vehicles carrying up to nine passengers (OECD, 2013). Moreover, this study's calculations are based on data from 2010 to 2018 when the EV market had a clear uptrend. We concentrate on CO_2 emissions from ICEs and EVs during their use phase and do not consider production-based CO_2 emissions to avoid overcomplexity.

Conceptually, we start with the predicted growth of the vehicle fleet for all countries. Each country has its own limit at which the demand for vehicles is saturated. Based on this limit, existing data on EV sales from 2010 to 2018 will be used to estimate an EV inventory growth in each country, thereby estimating the total vehicle fleet of ICEs and EVs in 2035. We calculate CO_2 emissions in 2018 based on each country's electricity mix and compare them with the total vehicle fleet of ICEs and EVs that are predicted by our growth model in 2035.

In what follows, growth models and the impact of EV growth on sustainability will firstly be discussed in more detail. Afterwards, a logistic growth model is applied to forecast EV sales in 26 countries until 2035. Furthermore, implications of the predicted EV growth will be discussed, particularly on CO_2 emissions as well as the required energy and battery production.

2. Logistic growth models

To forecast the diffusion of innovations, various growth models have been developed since the 1960s (Meade and Islam, 2006). Most models employ a logistic or other S-shaped function to depict innovation adoption over time (Muller and Mahajan, 1979). Some scholars argue that this shape represents the population's dynamics, analogous to an epidemic. Alternatively, it has been proposed that individuals simply have different, normally distributed thresholds for adopting new products (Meade and Islam, 2006). Both explanations make this type of curve particularly suitable to explore long-term EV adoption.

Various studies have already successfully employed logistic models to forecast innovation sales. For example, Boretos (2007) uses such a model to predict the number of active mobile phone accounts in China and Europe until 2010 based on existing data from 1992 to 2004. Overall, results display high accuracy and a high coefficient of determination. Similarly, Yang and Williams (2009) forecast sales of obsolete computers in the United States (USA) until 2050 with a logistic model using sales data from 1978 to 2008. To and Lee (2014) later confirm the results' validity. Furthermore, Qian and Soopramanien (2014) applied a Gompertz model, a logistic model, and a Bass model to predict car sales in China. The former two are also explored in an extended version, which additionally includes time and GDP. Results indicate that the extended logistic growth model is the most accurate forecast model for car sales as it provides the smallest median and mean values of performance metrics.

In sum, several studies accurately forecast product sales with the logistic growth model. In all cases, results are examined regarding their plausibility. Models with maximum and minimum parameter levels allow for potential uncertainties caused by external factors such as economic changes and natural catastrophes (Bloom, 2014). Forecasts also have to be adjusted when results significantly exceed realistic predictions. Taking this into account, the logistic growth model is a suitable EV sales predictor.

3. Impact of EV growth on sustainability

The predicted EV growth has important sustainability implications, as indicated by previous research. Wu et al. (2018) used the lifecycle analysis (LCA) method to analyze GHG emissions of BEVs and conventional internal combustion engine (ICE) cars in China in 2010, 2014 and 2020. They find that total lifecycle GHG emissions of EVs will gradually decrease over time, compared to ICEs, and that BEVs may provide long-term environmental benefits, especially if the electricity mix is improved. Further LCA studies draw similar conclusions (e.g., Faria et al., 2013; Huo et al., 2015).

Moreover, Casals et al. (2016) examined EV emissions compared to ICEs on a national scale across Europe, based on electric power plant fleet and use-phase efficiency. Their results indicate that some countries (e.g., Norway, Sweden) are better suited for EV adoption and that others (e.g., Germany, UK) will need to adapt their electricity mix in order for environmental benefits to show over time. Similarly, Nanaki and Koroneos (2013) argue that environmental improvements of EVs would be enormous if carbon-free electricity was used.

Furthermore, environmental impacts of EVs' production and operation phases have been discussed. According to Ellingsen et al. (2016), EVs' production phase is more environmentally costly compared to ICEs'. However, they argue that this is over-compensated in the use phase. Onat et al. (2014) also find that the operation phase has the highest environmental impact, leading to a total advantage of EVs over ICEs. Overall, CO_2 emissions from an EV fleet have been shown to potentially be 10–26 times lower than those from an ICE fleet (Teixeira and Sodré, 2018). This result is based on the assumption of a 5% annual increase in CO_2 emissions and the neglect of a possible increase in ICE efficiency, which could reduce CO_2 emissions.

Global EV growth may also cause some issues. Firstly, increased EV usage may impact grid stability due to excessive demand for electricity (Dharmakeerthi et al., 2014). Concomitantly, there will be a potential overload of distribution lines and increased power system losses (Pieltain Fernández et al., 2011). Secondly, the production of EV batteries depends on raw materials including rare earths (Egbue and Long, 2012). The necessity of certain raw materials leads to growing concerns about resource scarcity and dependency on suppliers, potentially resulting in a vulnerability of the industry (Ziemann et al., 2013).

Nevertheless, a growing EV inventory worldwide is expected to have substantial positive implications on global environmental sustainability. In this study, a long-term analysis will be provided based on the proposed growth model.

4. Methodology

4.1. Selection of growth model

To develop the logistic growth model, data was collected from secondary sources for 26 countries (see Table 2). They were selected because they are among the OECD or BRICS countries representing five continents overall, for which relevant data was available. Hong Kong and Taiwan were additionally included due to their strong growth in the gross domestic product (GDP) over the past decades (Government of Taiwan, 2019; The World Bank, 2019). For all countries, the following existing data for 2010 to 2018 was

Table 1
Vehicle inventory in China (in 1000 units).

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Total	21,325	26,196	31,960	38,389	48,451	61,634	74,850	87,376	101,361	117,482	135,805	156,772	178,031	198,421
EVs						1.111	5.292	16.907	30.773	94.486	284.212	655.543	1303.980	2465.753

Sources: OICA (2019), Statista (2019), EV-Volumes (2019).

used: Total car inventory (MarkLines, 2019; OICA, 2018; Statista, 2019), EV inventory, EV market share, annual EV sales, and EV sales growth (EV-Volumes, 2019). This was required for the prediction of future sales for 2019–2035.

China served as an example to demonstrate the prediction procedure. The country was selected as it currently represents the largest car market worldwide. Moreover, in terms of EV growth so far China is no significant outlier. Using countries such as Norway with an already large base or Australia with a small base of existing EVs to demonstrate the prediction procedure would be less appropriate than China with its significant growth. Initially, the saturation limit of all car inventories was predicted via a logistic growth model using the total passenger car inventories from 2005 to 2018. It was assumed that this limit is identical with that for EVs. This limit and the actual EV sales from 2010 to 2018 served to estimate a logistic growth function for EVs in China.

The initial growth function was amended by a second growth function with a flatter curve. This ensured that predicted sales did not substantially exceed yearly ICE sales. Accordingly, a predictive calculation with actual data was computed with the logistic growth model for all remaining 25 countries. For these countries, a forecast for total car inventory, EV inventory and EV sales was determined. To test the results' robustness, sensitivity analyses were conducted by repeating the procedure with sales data from (1) 2010–2015, (2) 2010–2016, and (3) 2010–2017, as well as adjusting the saturation limit.

Not all factors influencing EV sales can be predicted over the long-term, including technological advancements, GDP growth and policy measures. These are, however, implicitly included in the model as maximum and minimum parameters account for such external uncertainties (Bloom, 2014; To and Lee, 2014). Moreover, it needs to be noticed that national purchasing power is an important factor influencing the growth of a country's EV fleet as it increases the effects of public policy measures to promote electric mobility (Rietmann and Lieven, 2019).

4.2. Calculation of CO_2 emissions and electricity demand

To calculate sustainability impacts, this study focused on CO_2 emissions during car usage as this is the crucial phase regarding long-term emissions (Ellingsen et al., 2016; Onat et al., 2014). For each country, the following data were collected from secondary sources: ICE fuel consumption per 100 km (km), CO_2 emissions per km, EVs' average energy used per km, CO_2 emissions per kg from electricity production (based on current energy mix), and average distance travelled annually by car. Details and references are summarized in Table 2 and Appendix D. Calculations differed between ICEs and EVs. For ICEs, about 2.45 kg of CO_2 are assumed per liter, given a mixture of gasoline and diesel engines (IPPC, 2014). As cars have different fuel consumptions across countries, lge (liters gasoline equivalent) per 100 km and gram CO_2/km data were collected from the International Energy Agency (IEA, 2019a). On average, EVs need 0.185 kWh/km (Electric Vehicle Database, 2019). Furthermore, each country has a different energy mix and thus, CO_2 emissions from electricity generation (g/kWh) were determined individually from 2014, for which data is available (OECD, 2019, Table 2). Table 2 compares CO_2 emissions of the total car fleet in 2035–2018. Moreover, a comparison is made to a scenario, in which all passenger cars are assumed to be ICEs in 2035. The rule of ceteris paribus applies here: It is assumed that in 2035 carbon intensity of electricity generation (column 5 in Table 2) and EV electricity consumption (0.185 kWh/km; Electric Vehicle Database, 2019) will be the same as in 2018.

The subsequent calculation of the EV electricity demand in 2035 was performed by multiplying each country's predicted EV inventory with the energy required for an EV annually, given an average mileage of 17,000 km (Electric Vehicle Database, 2019, Table 2). The resulting figure was compared to the total electricity production in 2017 (Dudley, 2019).

4.3. Modelling the EV inventory

The model of the EV inventory forecasts is based on a logistic growth function. Growth increases slowly in the beginning, then more rapidly, and finally more slowly again after the inventory has passed the inflection point and reaches the saturation limit (see Fig. 1).

The logistic growth function is:

$$I(t) = \frac{L}{1 + \left(\frac{L}{I(0)} - 1\right) \cdot e^{-k \cdot L \cdot t}} \tag{1}$$

with $I(t)$ = Inventory at time t, L = Saturation Limit, $I(0)$ = Inventory at the beginning ($t = 0$), k = growth factor.

The predicted EV sales for the 26 countries were determined with the following procedure:

a) Estimate the saturation limit L which is the maximum expected number of all passenger vehicles in the country.[1]
b) Estimate a logistic growth function with L and actual EV sales in recent years.[1] This is done by calculating a trend line that fits a curve to existing data, leading to a function - in this case a logistic growth function. This results in the parameters $I(0)$ and k.
c) Adjust EV growth functions according to the existing market potential of total annual car sales.

The procedure is demonstrated with data from China, where about 200 million passenger cars were in use at the end of 2018, compared to 21 million at the end of 2005. Thus, the vehicle inventory has increased tenfold within 13 years. Significant EV sales started in 2010, although only 1,111, which increased to 2.47 million in 2018. Table 1 displays China's inventory figures.

In a first step, total inventories were predicted by a logistic growth function using actual total car inventories from 2005 to 2018 (Table 1). For China, this resulted in a predicted upper limit L = 355 million to be reached in 2060. The symmetric growth function has its inflection point in 2015 with about 175 million units (Function I, i.e. (I) Total Inventory, Fig. 2). Fig. 2 displays the passenger car inventory until 2060, as this is when the saturation limit is predicted to be reached.

Using L = 355 million and actual EV inventories from 2010 to 2018 (Table 1) for a logistic growth function resulted in $I(0)$ = 23.108 and growth factor $k = 1.612739878 \times 10^{-6}$.

[1] This can be done using software packages such as GeoGebra (geogebra.org).

Table 2
Overview of each country's CO_2 emissions of the passenger vehicle fleet in 2018 vs. 2035.

Country	Avg. annual km travelled	ICE fuel consump-tion per 100 km (lge)[1]	ICE CO_2 emission per 1 km (kg)[1]	CO_2 emission per 1 kWh electricity (kg)[2]	EV Inventory 2018 (million)	ICE Inventory 2018 (million)	Total Inventory 2018 (million)	EV Inventory 2035 (million)	ICE Inventory 2035 (million)	Total Inventory 2035 (million)	Year when 50% EVs are reached	Total CO_2 2018 (million tons)	Total CO_2 2035 (million tons)	Change in CO_2 emission 2018–2035 (%)	Total CO_2 2035 for ICEs only (million tons)	CO_2 emission 2035 compared to ICEs only (%)
Australia	13,301[3]	7.9	0.188	0.798	0.012	14.2	14.2	6.9	10.4	17.3	>2035	35.6	39.5	**10.9%**	43.2	**−8.6%**
Austria	14,311[4]	5.7	0.136	0.166	0.030	4.9	4.9	3.4	2.2	5.6	2033	9.6	5.8	**−39.3%**	11.0	**−47.1%**
Belgium	14,500[5]	5.6	0.133	0.199	0.047	5.8	5.8	5.5	1.1	6.6	2030	11.1	5.1	**−54.2%**	12.7	**−59.9%**
Brazil	20,000[6]	7.6	0.179	0.134	0.001	37.4	37.4	7.1	40.7	47.8	>2035	133.7	149.1	**11.5%**	171.1	**−12.8%**
Canada	15,200[7]	8.9	0.206	0.158	0.090	22.6	22.7	7.9	16.5	24.4	>2035	70.7	55.2	**−21.8%**	76.5	**−27.8%**
China	18,778[8]	7.6	0.175	0.711	2.466	196.0	198.4	177.8	171.5	349.3	2035	650.0	1002.6	**54.2%**	1147.7	**−12.6%**
Denmark	14,000[9]	5.2	0.124	0.300	0.015	2.5	2.5	2.0	0.9	2.9	2033	4.4	3.1	**−28.6%**	5.1	**−38.4%**
Finland	17,611[10]	5.8	0.135	0.175	0.012	2.6	2.6	1.8	1.0	2.8	2033	6.3	3.5	**−45.0%**	6.7	**−48.3%**
France	12,977[11]	5.3	0.126	0.064	0.205	32.4	32.6	19.7	14.2	33.9	2034	53.0	26.3	**−50.5%**	55.4	**−52.6%**
Germany	14,107[12]	5.9	0.140	0.486	0.211	46.4	46.6	34.6	17.6	52.2	2032	91.9	78.6	**−14.5%**	103.0	**−23.7%**
Hong Kong	18,060[13]	7.8	0.180	0.975	0.010	0.6	0.6	0.5	0.2	0.8	2033	1.9	2.5	**29.0%**	2.5	**0.1%**
India	20,800[14]	5.6	0.135	0.791	0.006	27.3	27.3	2.3	60.1	62.4	>2035	76.6	175.7	**129.5%**	175.2	**0.3%**
Italy	9,596[15]	5.2	0.124	0.343	0.028	37.9	37.9	15.8	24.4	40.2	>2035	45.1	38.6	**−14.4%**	47.8	**−19.2%**
Japan	9,228[16]	6.2	0.144	0.572	0.261	62.0	62.3	17.0	51.1	68.1	>2035	82.7	84.5	**2.2%**	90.5	**−6.6%**
Netherlands	13,022[18]	5.4	0.127	0.452	0.149	8.5	8.6	5.3	4.3	9.7	2034	14.2	13.0	**−8.6%**	16.0	**−18.8%**
Norway	12,140[19]	5.1	0.121	0.008	0.254	2.4	2.6	2.5	0.4	2.9	2026	3.5	0.7	**−80.2%**	4.2	**−83.5%**
Portugal	21,606[20]	5.0	0.119	0.281	0.017	4.7	4.7	3.0	2.2	5.2	2034	12.1	9.0	**−25.8%**	13.3	**−32.7%**
Russia	17,500[21]	8.2	0.192	0.439	0.002	46.4	46.4	14.7	39.0	53.7	>2035	155.8	152.0	**−2.4%**	180.5	**−15.8%**
South Africa	25,000[22]	7.4	0.176	0.926	0.001	6.8	6.8	0.3	8.4	8.7	>2035	30.0	38.2	**27.3%**	38.3	**−0.1%**
South Korea	12,184[17]	6.3	0.147	0.536	0.060	18.2	18.2	4.6	21.2	25.7	>2035	32.6	43.5	**33.3%**	46.1	**−5.8%**
Spain	12,535[23]	5.4	0.130	0.247	0.035	23.1	23.1	12.5	14.0	26.6	>2035	37.6	30.1	**−20.2%**	43.3	**−30.6%**
Sweden	12,240[24]	5.9	0.139	0.013	0.081	4.8	4.9	4.5	0.9	5.4	2029	8.2	1.7	**−79.1%**	9.2	**−81.5%**
Switzerland	13,469[25]	6.4	0.152	0.024	0.036	4.7	4.7	3.2	1.7	4.9	2033	9.5	3.7	**−61.2%**	10.1	**−63.4%**
Taiwan	16,167[26]	7.3	0.170	0.906	0.001	6.8	6.8	0.1	7.4	7.6	>2035	18.6	20.8	**11.6%**	20.8	**0.0%**
UK	13,177[27]	5.8	0.137	0.459	0.203	34.5	34.7	24.3	14.1	38.4	2033	62.5	52.6	**−15.8%**	69.2	**−24.1%**
USA	21,682[28]	8.6	0.198	0.489	1.126	123.9	125.0	62.0	68.0	130.0	>2035	534.0	413.6	**−22.5%**	558.1	**−25.9%**
Total	16,980	7.1	0.165	0.584	5.357	777.1	782.4	439.2	593.7	1032.9	>2035	**2191.2**	**2449.0**	**11.8%**	2957.4	**−17.2%**

Note lge = liters gasoline equivalent. References 1) and 2) are listed in Appendix D.

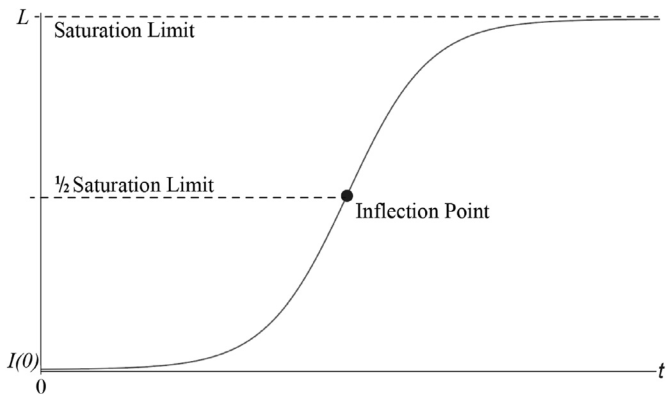

Fig. 1. Logistic growth function.

5. Results

Applying the above-described procedure to all 26 countries resulted in the numbers reported in Appendix B. Across all countries, in 2018, 2.1 million EVs were sold with a total end-of-year inventory of 5.4 million. By 2035, an inventory of 440 million EVs is expected, which then represents 42.5% of the total car inventory. Globally, 30% of all passenger vehicles will be EVs in 2032.

Sensitivity analyses supported the results' robustness and showed that the curve continuously shifted to the right each year (see Appendix C). Specifically, the inflection point moved to the right from function (1) to (2) by 17 months, from (2) to (3) by 11 months, and from (3) to (4) by 4 months. Similarly, the point when a total inventory of 300 million EVs will be reached moves to the right. Hence, the more data points from previous years are available, the more stable the results.

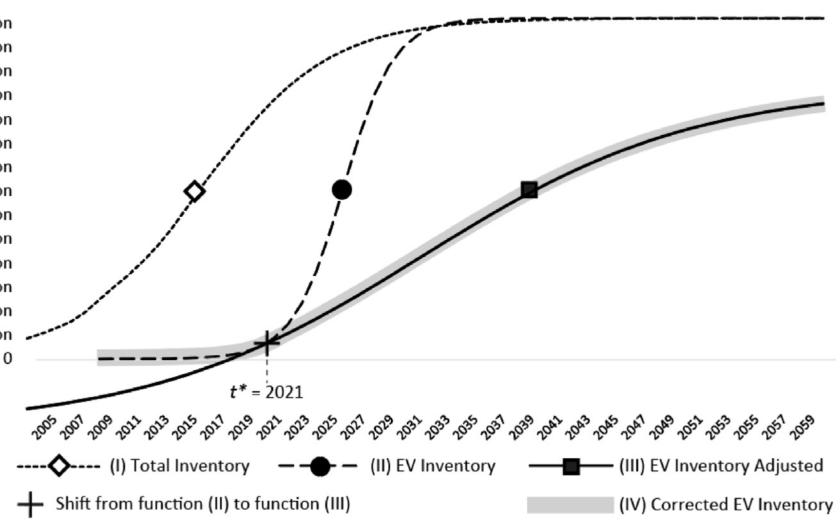

Fig. 2. Actual inventories (2005–2018) and forecasts in China ($L = 355$ million).

$$I_{II}(t) = \frac{355,000}{1 + \left(\frac{355.000}{23.108} - 1\right) \cdot e^{-1.612739878 \times 10^{-6} \cdot 355,000 \cdot t}} \tag{2}$$

(Note: L and $I(0)$ are denoted in 1000 units).

Applying (2) with $t = 0$ for the year 2010 to estimate sales from 2019 onward (Function II, i.e. (II) EV Inventory, Fig. 2) predicts EV sales of 33.5 million in 2025. This is much higher than the maximum number of total passenger cars sold so far in China (2017: 24.7 million, 2018: 23.7 million, 2019: predicted 21.3 million; Statista, 2019). An upper limit of 22 million total annual car sales can be expected in China and EV sales should be below this number. The slope of the EV inventory function (II) was replaced accordingly by a flatter function from 2021 onwards, when both functions have the same predicted inventory and the same growth rate (at $t = t^*$).[2] Appendix A displays detailed calculations. The resulting EV inventory forecast is shown as function IV (grey shaded) in Fig. 2. Respective numbers (inventories, sales, EV market shares, sales growth) for China are shown in Appendix B. Fig. 3 further shows inventories and EV sales in China from 2010-2035.[3]

Regarding sustainability implications, significant variations were found between countries (see Table 2). For the majority of countries, a reduction in CO_2 emissions of the entire vehicle fleet is predicted. In some countries, however, the opposite or no significant change is expected.

5.1. Results per country

In order to highlight cross-national differences, the 26 countries were clustered into six groups, based on their EV penetration pace (fast = 50% penetration until 2035 vs. slow = 50% later than 2035) and change in CO_2 emissions (high reduction, moderate reduction, nearly no reduction, increase, strong increase; each change considered relative within the sample). Each cluster will subsequently be discussed in more detail.

5.1.1. Fast EV penetration and high CO_2 reduction (Norway, Sweden, Switzerland, Belgium, France, Finland)

A number of countries show strong EV growth and a high CO_2 emission reduction. Norway displays a particularly high EV adoption, mainly due to policy measures that have been implemented since the 1990s (Figenbaum et al., 2015; Rietmann and Lieven, 2019). Moreover, Norway aims to have all new cars emission-free by 2025 (Milne, 2017) and to be carbon-neutral by 2050 (Figenbaum et al., 2015). The country's goal was to have 200,000 EVs on the roads by 2020 (van der Steen et al., 2015), which has already been exceeded in 2018 with an

[2] See Appendix A, Mathematica was used for calculations (http://www.wolfram.com/mathematica/).

[3] Note: To calculate the growth function, all years until the saturation point (in 2060) is reached have to be included. To reasonably predict inventories and sales the forecast was narrowed until 2035.

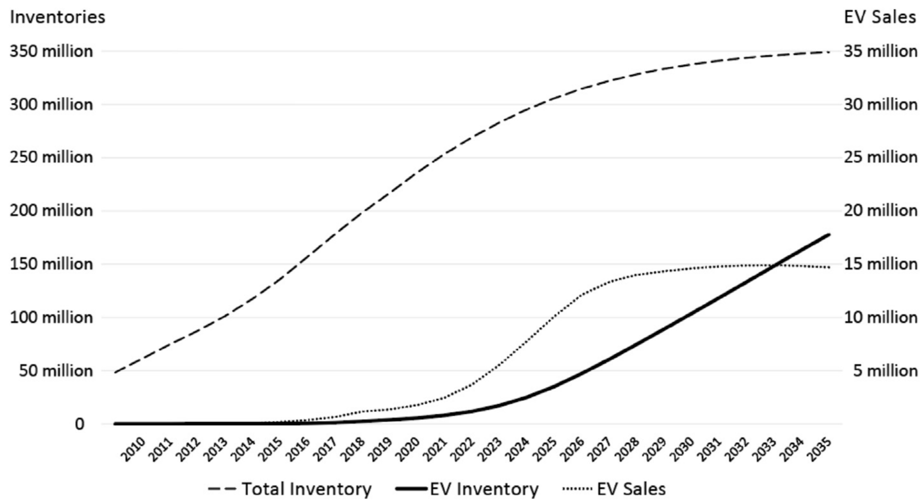

Fig. 3. Inventories and EV sales in China 2010–2035.

EV inventory of 254,000.

Furthermore, Norway produces 96% of energy using hydropower, resulting in only 8 g CO_2/kWh emissions (Energifakta Norge, 2019; OECD, 2019). Thus, the country will have reduced CO_2 emissions by more than 80% until 2035. Fig. 4 shows EV vs. ICE inventories from 2018 to 2035 and CO_2 emissions, which are expected to drop significantly with the predicted EV growth. Other countries in this cluster (Sweden, Switzerland, Belgium, France, Finland) show similar results and improvements in CO_2 reductions (see Table 2). This can particularly be attributed to the low emissions of their energy mixes, which all lie significantly below the OECD average of 432 g/kWh (OECD, 2019). There are, however, some differences in the energy generation. While Norway, Sweden and Switzerland mostly rely on renewable sources (hydropower, wind energy), France and Belgium primarily use nuclear energy.

5.1.2. *Fast EV penetration and moderate CO_2 reduction (Austria, Denmark, Portugal, UK, Germany, Netherlands)*

Another cluster displays fast EV penetration until 2035 but a comparatively low CO_2 reduction (less than 50%). Austria, for instance, has implemented various policy measures throughout the past years (EAFO, 2019). This is also the case in Denmark, Portugal, the UK, Germany, and the Netherlands. However, in all of these countries, the energy mixes result in higher CO_2 emissions compared to the first country cluster (166–486 g CO_2/kWh; OECD, 2019). Thus, emission reductions will not be as significant as in the first cluster if no improvements are made to the energy mixes.

5.1.3. *Slow EV penetration and moderate CO_2 reduction (USA, Canada, Spain, Italy)*

The next cluster exhibits slower growth and is expected to reach a 50% EV penetration only after 2035. Although policy measures have been implemented in all of these countries, they lack a sufficient charging infrastructure. For example, Spain only has 6 fast public charging points per 100 km highway, compared to 382 in Norway (EAFO, 2019). Nonetheless, the countries display low to moderate CO_2 emissions from their electricity generation (about 20% reduction until 2035), thereby leading to an overall moderate reduction in emissions over time. For example, 82% of Canada's energy mix consists of non-GHG emitting sources (Government of Canada, 2019). Hence, there is a lot of potential in these countries to improve sustainability with further EV growth.

5.1.4. *Slow EV penetration and nearly no CO_2 reduction (Russia, Japan)*

Russia and Japan have so far shown very low EV market shares with close to 0% and 0.4% in 2018, respectively (Appendix B). Japan has only recently implemented monetary incentives to support EV adoption (IEA IA-HEV, 2018) and Russia still lacks significant governmental support. Both countries rely heavily on fossil fuels to generate energy (Energy Information Administration, 2017; Ministry of Economy Trade and Industry, 2017). In order for sustainability improvements of EV growth to show in the long-term, the countries' energy mixes therefore need to be improved, and political incentives be strengthened.

5.1.5. *Slow EV penetration and CO_2 increase (Australia, Brazil, Taiwan, South Africa, Hong Kong, korea)*

Another cluster shows rather low EV growth and CO_2 increases over time. Reasons for this vary. Australia, South Africa, Korea and Hong Kong use very few renewable energy sources. For example, in Hong Kong 53% of the energy is produced from coal and only 2% from renewable sources (Government of Hong Kong, 2015). Other countries, such as Brazil, have installed large hydropower plants that account for approximately 80% of the domestic electricity generation (IEA, 2019b). Hence, there is potential to reduce CO_2 emissions with a large-scale EV adoption over time. However, as the traditional automotive industry is very large in Brazil (OICA, 2019), the government shows very little interest in supporting EVs (Domingues and Pecorelli-Peres, 2013). Each country in this cluster must therefore tackle different issues to raise EV adoption sustainably.

5.1.6. *Slow EV penetration and strong CO_2 increase (China, India)*

Finally, China and India currently show the highest hurdles in terms of long-term, sustainable EV adoption. The Indian government has provided comparatively low, and mostly local, support for EVs (Government of NCT of Delhi, 2016). China has also implemented a subsidy scheme in 2009 and further incentives since then (Hao et al., 2014; Zhu et al., 2017). In 2019, however, China has reduced EV incentives dramatically, leading to a sales drop (Toh, 2019). While EV sales increased by 50% annually from January to June 2019, it declined by 25% between July and October 2019. In this study, numbers have been adjusted accordingly to a reasonable scenario, in which sales rise (maximum 50% annual growth), however, not as strongly as previously (80%).

Nonetheless, even if EV sales were supported more strongly in these countries, further growth with the current electricity mixes

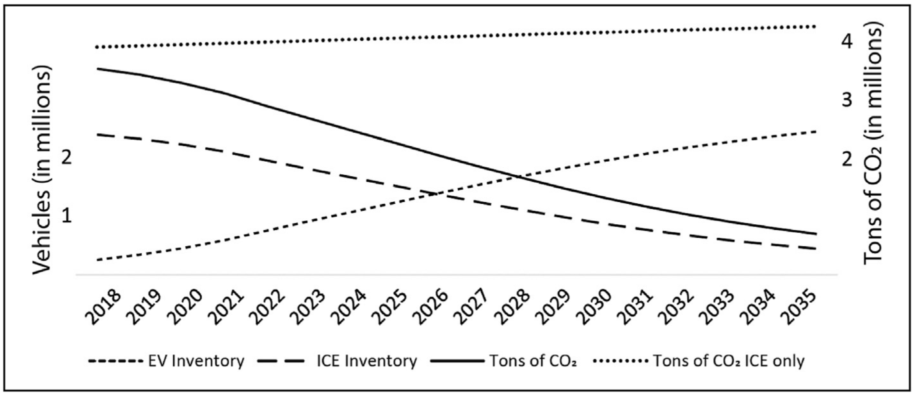

Fig. 4. EV vs. ICE inventories and CO_2 emissions in Norway (in millions).

would be unsustainable. Coal accounts for 70–80% of the energy generation in China (Wu et al., 2018) and 56% in India (BP, 2019). While China will reach a 50% EV share of the car inventory in 2035, CO_2 emissions will grow by 54.2%. Compared to an ICE-only inventory in 2035, the EV growth is still favorable though (−12.6% CO_2 emissions). Countries such as China and India should therefore simultaneously raise EV sales and switch to more renewable energy sources. Although Norway and China are difficult to compare because of their size, Figs. 4 and 5 represent the extreme opposites in sustainability development among all countries.

Fig. 6 finally summarizes results for all 26 countries. Although the EV inventory reaches 42.5% in 2035, CO_2 emissions rise by 11.8% between 2018 and 2035. A peak is reached in 2028, after which emissions gradually decrease. Compared to an ICE-only fleet, however, the CO_2 reduction is significant (−17.2% by 2035).

5.2. Implications for electricity and battery production

The predicted EV growth will boost electricity demand in the coming years. In 2020, about 3.5 million EVs are expected to be sold in the 26 countries examined here. This figure is predicted to be about 20 million in 2025 and 42 million in 2035. Assuming that each EV is equipped with a 70-kWh battery for a range of about 300–400 km, this would require the production of a total battery capacity of 2.94 Terawatt hours (TWh) in 2035. Even with the largest existing battery giga-factory, about 1% of this is produced today (35 GWh) and 5% (150 GWh) are planned to be produced annually in the coming years (Techcrunch, 2019).

Furthermore, a vehicle's annual mileage must be considered which is approximately 17,000 km (Table 2). Electricity consumption per km is about 185 Wh (Electric Vehicle Database, 2019) which adds up to 1381 TWh in 2035 (assuming a total EV inventory of 439 million). For each country, this will be an average charging demand of 7% of today's total electricity production, as shown in Table 3. In this table, the electricity production in 2017/18 is compared to 2000. While some countries have seen a strong increase in production, other countries produced more electricity in 2000 than today. However, the latter should be able to reach this level again, based on their former higher production rates. In other countries, raising electricity production may be more difficult (e.g. UK). Hence, they should tackle this issue now. Although grid problems such as the distribution to the last mile could pose new challenges in the future, most countries should be able to cope with the additional electricity demand caused by the EV growth.

The major bottleneck in the EV development seems to be the battery production. Besides the provision of sufficient production capacity in more giga–factories, availability of basic raw materials may become a crucial issue. Battery production is becoming a new industrial sector. Assuming that the cost for 1 kWh declines from today's US$ 200 to about US$ 100 in 2030 (Union of Concerned Scientists, 2019), this would result in a total yearly revenue of US$ 294 billion for this new industry in the 26 countries alone.

6. Discussion and conclusion

EV sales will increase significantly in the coming years. By 2035, the EV market share is expected to reach 42.5% worldwide. This study importantly shows that CO_2 emissions from the passenger car fleet across all 26 countries will still increase until 2035. Nonetheless, some countries will see significant CO_2 reductions.

Norway and Sweden, for instance, will reach a 50% market share prior to 2035, which can particularly be attributed to strong governmental support (Lieven, 2015; Rietmann and Lieven, 2019). Due to the nations' favorable energy mixes, CO_2 emissions will fall drastically

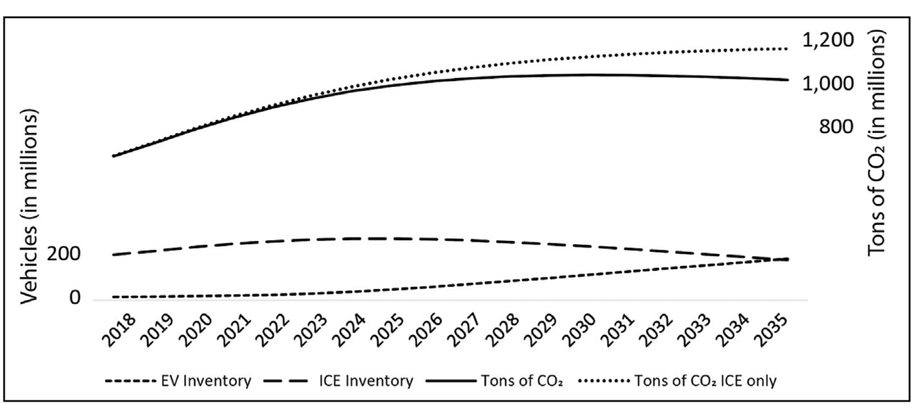

Fig. 5. EV vs. ICE inventories and CO_2 emissions in China (in millions).

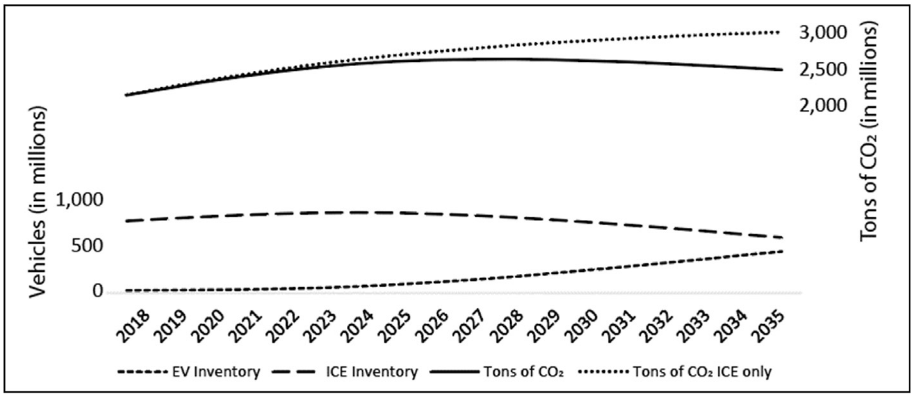

Fig. 6. EV vs. ICE inventories and CO_2 emissions in all 26 countries (in millions).

Table 3
Electricity production and charging demand.

Country	Electricity production in 2000 (TWh)	Electricity production in 2017/18 (TWh)	Total inventory EVs in 2035 (in 1000)	Charging demand in 2035 (TWh)	% from total production in 2017/18
Australia	210.2	261.1	6913	21.7	8.3%
Austria	61.3	68.6	3438	10.8	15.8%
Belgium	84.0	75.0	5457	17.2	22.9%
Brazil	348.9	601.4	7104	22.3	3.7%
Canada	605.7	650.8	7917	24.9	3.8%
China	1387.1	6671.9	177,776	559.1	8.4%
Denmark	36.1	30.0	2033	6.4	21.3%
Finland	70.0	70.0	1782	5.6	8.0%
France	540.0	580.7	19,670	61.9	10.7%
Germany	576.5	649.9	34,615	108.9	16.8%
Hong Kong	31.3	37.0	524	1.6	4.5%
India	569.7	1532.2	2302	7.2	0.5%
Italy	276.6	290.6	15,792	49.7	17.1%
Japan	1067.8	1025.8	17,031	53.6	5.2%
Korea	290.1	579.9	4557	14.3	2.5%
Netherlands	89.6	113.5	5333	16.8	14.8%
Norway	143.0	147.5	2400	7.5	5.1%
Portugal	43.8	59.8	3010	9.5	15.8%
Russia	877.8	1109.2	14,675	46.2	4.2%
South Africa	210.7	255.1	281	0.9	0.3%
Spain	224.5	273.8	12,510	39.3	14.4%
Sweden	145.3	159.3	4492	14.1	8.9%
Switzerland	67.5	69.2	3223	10.1	14.6%
Taiwan	238.3	270.3	125	0.4	0.1%
UK	377.1	333.9	24,276	76.3	22.9%
USA	4052.7	4434.9	61,970	194.9	4.4%
Total	12,625.4	20,351.7	439,206	1381.3	6.8%

Source (Dudley, 2019; IEA, 2019c):

between 2018 and 2035 (−80% in Norway). In other countries (e.g. South Africa, Brazil), EV adoption will be much slower. Moreover, benefits of a rising EV inventory crucially depend on a nation's energy mix. Countries such as China and India, which rely strongly on coal to generate energy, will not reap major benefits from introducing a large-scale EV fleet with their current energy mixes, except that the EV fleet will lead to a less strong increase in CO_2 emissions compared to an ICE-only fleet. The adoption of more renewable energy sources would have significant environmental advantages, as the example of Norway highlights. In some countries, however, the journey will be long. China, for instance, has implemented various laws and policies to establish more renewable energy sources but these have substantial issues such as fragmentation and lack of operability (Liu, 2019).

Although the predicted EV market shares may seem surprisingly high, our predictions can be deemed thorough. Firstly, the forecast of a logistic growth model can be considered conservative. Although an exponential model may also represent the current growth quite well (e.g., yearly sales growth of 40%), it may overestimate growth rates at the end of the cycle.[4] The logistic growth function fits much better because a saturation limit can be expected.

Secondly, our results can be described as rather conservative. As the estimated growth functions were too steep in most countries, they were flattened from a specific year onward when EV sales exceeded those that were currently seen. Consequently, this study's estimations are mostly corrected downwards and below predictions based on actual EV sales.

Moreover, there are some specialties in the reporting of EV sales that need mentioning. For example, in the USA, SUVs are summarized under the light truck group. In other countries, SUVs are reported under the passenger car category. As this study only considered passenger cars, the EV market share may have been overestimated in the USA. This only holds for total inventory shares though.

Regarding CO_2 emissions, we did not compare the entire EV vs. ICE lifecycle but focused on the cars' use phase. Including all factors influencing emissions (e.g., combustion engine vs. battery

[4] The second derivative of the exponential function is always positive while it is positive for the logistic growth function at the beginning, equals zero at the inflection point and is negative at the end.

production, transport of crude oil to refineries and gas stations, etc.) would have been far beyond this study's scope. We suggest that future research should investigate this more deeply based on our growth projections.

The most challenging limitation lies in the nature of the curve-fitting of a logistic growth function based on existing data. The more data available, the better the predicted model. Sensitivity analyses showed that the growth curve shifted to the right each year. Consequently, further shifts may occur in the future, possibly causing a delay of the forecasted rapid growth by six months to an entire year. If the shift of four months annually occurs, the growth curves have to be shifted forward by one year in 2022. This, however, may be compensated to some extent by our conservative estimations.

Another crucial point is the estimation of saturation limits. In developed countries, this may not be problematic since this limit has almost been reached (130 million in the USA). In China or India, predicting this saturation is more difficult. Discussing this issue with market experts showed consensus that China will see about 250 cars per 1,000 population which may result in the expected 355 million passenger cars in the future. India, however, is nearly impossible to predict. The assumed saturation of 100 million may be underestimated. Sensitivity analyses show that this saturation limit will not have a strong effect in the next decade. Growth functions for a worldwide limit of 1200 and 800 million are nearly identical when the EV inventory reaches 300 million EVs (Appendix C). Hence, the difficulty of finding an appropriate saturation will only become important in later years.

Furthermore, there are some uncertainties that should be considered in future studies. For example, it is unclear whether all countries would be able to actually accommodate the estimated growth in passenger vehicles. Also, technological disruptions such as autonomous cars and trends toward carsharing may have significant implications on car sales in the future (Burns, 2013; Shaheen and Cohen, 2013). Moreover, this study assumed that carbon intensity of electricity generation and electricity consumption of EVs will be the same in 2035 as in 2018. Future research could further investigate an improvement of these factors and account for it in the calculation. Yet, EV outlook numbers from 2019 as predicted by the IEA indicate a certain level of validity for this study's data (OECD/IEA, 2019).

To conclude, this paper presents a long-term forecast of EV sales in 26 countries until 2035. The logistic growth model, which was based on actual sales data from 2010 to 2018, predicts that 30% of all passenger vehicles will be EVs in 2032. Furthermore, significant cross-national differences are established regarding sustainability implications. In order for the rising EV inventory to be sustainable, countries must invest in large-scale renewable energy sources. Future studies should continuously investigate market developments as various factors influence EV growth, such as changes in policy measures. At the same time, EV producers and energy providers should monitor these predictions over time and adapt their production plans accordingly. Finally, governments should consider this study's findings to plan investments and policies which both support EV growth as well as the development of more renewable energy mixes.

Appendix A. Growth function calculations

Given is a growth function

$$I_{II}(t) = \frac{L}{1 + \left(\frac{L}{I_{II}(0)} - 1\right) \cdot e^{-k\cdot(L)\cdot t}} \tag{A1}$$

with $I_{II}(t)$ = Inventory at time t, L = Saturation Limit, $I_{II}(0)$ = Inventory at the beginning ($t = 0$), k = growth factor.

Find a less steep growth function I_{III} being tangent to I_{II} at a chosen point t^* where function values and the respective derivatives are equal:

$$I_{III}(t^*) = I_{II}(t^*) \text{ and } I'_{III}(t^*) = I'_{II}(t^*) \tag{A2}$$

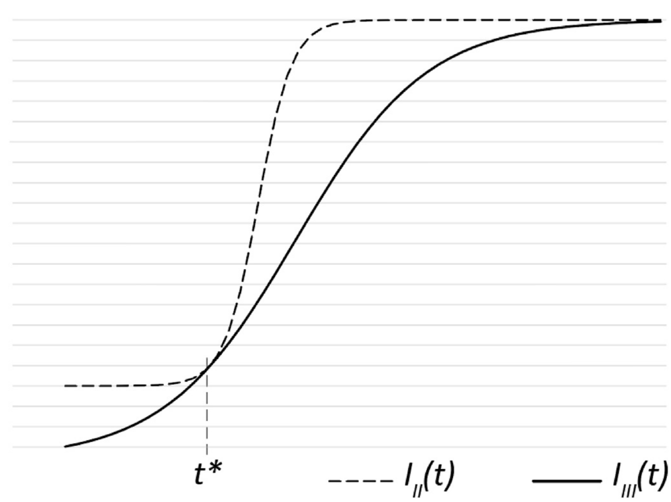

Fig. A1. Two tangential growth functions

Define the growth function I_{III} with a higher saturation limit $L + c$ and subtract c from the function value. By this, I_{III} will start below 0 at $t = 0$, however, converge to the original saturation limit L.

$$I_{III}(t) = \frac{L + c}{1 + \left(\frac{L+c}{I_{III}(0)} - 1\right) \cdot e^{-k\cdot(L+c)\cdot t}} - c \tag{A3}$$

Solve (A3) for $I_{III}(0)$ under the condition that $I_{III}(t^*) = I_{II}(t^*)$:

$$I_{III}(0) = \frac{(L + c)\cdot(c + I_{II}(t^*))}{c + I_{II}(t^*) - e^{k(L+c)t}\cdot I_{II}(t^*) + e^{k(L+c)t}\cdot L} \tag{A4}$$

The derivative of I_{III} is:

$$I'_{III}\left(t\right) = \frac{e^{-k(L+c)t} k\cdot(L + c)^2\cdot\left(-1 + \frac{L+c}{I_{III}(0)}\right)}{\left(1 + e^{-k(L+c)t}\cdot\left(-1 + \frac{L+c}{I_{III}(0)}\right)\right)^2} \tag{A5}$$

Solve (A5) for k under the condition that $I'_{III}(t^*) = I'_{II}(t^*)$:

$$k = \frac{I'_{II}(t^*)}{(L - I_{II}(t^*))\cdot(c + I_{II}(t^*))} \tag{A6}$$

and insert k in (A4) to find $I_{III}(0)$:

$$I_{III}(0) = \frac{(L + c)\cdot(c + I_{II}(t^*))}{c + I_{II}(t^*) - e^{\frac{I'_{II}(t^*)\cdot(L+c)\cdot t^*}{(L-I_{II}(t^*))\cdot(c+I_{II}(t^*))}}\cdot I_{II}(t^*) + e^{\frac{I'_{II}(t^*)\cdot(L+c)t^*}{(L-I_{II}(t^*))\cdot(c+I_{II}(t^*))}}\cdot L} \tag{A7}$$

Appendix B. Total and EV inventories, EV market share, annual EV sales in thousand units, and annual EV sales growth rate

Australia	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Total Inventory	12,269	12,474	12,714	13,000	13,297	13,549	13,781	14,010	14,240	14,465	14,684	14,897	15,105	15,307	15,503	15,694	15,878	16,057	16,229	16,396	16,557	16,712	16,861	17,005	17,144	17,277
EV Inventory	0	0	0	1	2	4	5	8	12	18	28	44	68	105	163	252	389	598	914	1384	2071	2924	3845	4825	5852	6913
EV Market Share	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.2%	0.3%	0.4%	0.7%	1.1%	1.6%	2.5%	3.7%	5.6%	8.4%	12.5%	17.5%	22.8%	28.4%	34.1%	40.0%
Annual EV Sales	0	0	0	0	1	2	1	2	4	6	10	16	24	37	58	89	137	209	316	471	687	853	921	980	1028	1061
EV Sales Growth		−48.2%	344.8%	17.8%	303.9%	41.7%	−17.6%	69.0%	65.4%	56.0%	60.7%	55.1%	55.0%	54.8%	54.6%	54.2%	53.6%	52.6%	51.2%	49.0%	45.9%	24.3%	7.9%	6.4%	4.9%	3.3%
Austria	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Total Inventory	4441	4513	4584	4641	4695	4748	4811	4878	4943	5004	5063	5119	5173	5223	5271	5316	5359	5399	5438	5474	5507	5539	5569	5597	5624	5649
EV Inventory	0	1	2	3	5	8	13	20	30	44	66	100	150	225	335	495	720	993	1282	1584	1895	2212	2528	2841	3146	3438
EV Market Share	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.3%	0.4%	0.6%	0.9%	1.3%	2.0%	2.9%	4.3%	6.4%	9.3%	13.4%	18.4%	23.6%	28.9%	34.4%	39.9%	45.4%	50.8%	55.9%	60.9%
Annual EV Sales	0	1	1	1	2	3	5	8	9	14	22	34	50	75	110	159	225	273	289	302	311	316	317	313	305	293
EV Sales Growth		315.0%	82.7%	−36.2%	97.1%	69.6%	85.7%	44.5%	24.8%	50.5%	58.8%	50.4%	49.6%	48.6%	47.0%	44.7%	41.5%	21.2%	5.8%	4.5%	3.0%	1.6%	0.2%	−1.2%	−2.6%	−4.0%
Belgium	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Total Inventory	5279	5359	5393	5439	5511	5587	5658	5729	5800	5868	5933	5995	6054	6110	6163	6214	6261	6307	6349	6390	6428	6463	6497	6529	6559	6587
EV Inventory	0	0	2	2	5	8	18	33	47	66	101	154	234	354	530	784	1138	1610	2154	2709	3258	3785	4275	4721	5115	5457
EV Market Share	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.3%	0.6%	0.8%	1.1%	1.7%	2.6%	3.9%	5.8%	8.6%	12.6%	18.2%	25.5%	33.9%	42.4%	50.7%	58.6%	65.8%	72.3%	78.0%	82.8%
Annual EV Sales	0	0	1	1	2	4	10	15	14	19	35	53	80	120	176	254	354	472	545	555	549	526	491	445	394	342
EV Sales Growth		800.0%	366.7%	−53.9%	210.6%	84.4%	147.2%	55.1%	−6.9%	37.8%	83.2%	51.9%	50.9%	49.4%	47.1%	43.9%	39.4%	33.4%	15.4%	1.9%	−1.1%	−4.1%	−6.8%	−9.2%	−11.4%	−13.3%
Brazil	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Total Inventory	26,888	28,946	31,123	33,092	34,676	35,471	36,058	36,704	37,351	37,997	38,641	39,282	39,921	40,556	41,187	41,815	42,437	43,055	43,668	44,275	44,876	45,471	46,059	46,640	47,214	47,781
EV Inventory	0	0	0	0	0	0	0	0	1	1	2	5	9	19	38	77	155	310	622	1240	2110	3024	3980	4980	6021	7104
EV Market Share	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.4%	0.7%	1.4%	2.8%	4.7%	6.7%	8.6%	10.7%	12.8%	14.9%
Annual EV Sales	0	0	0	0	0	0	0	0	0,31	0.62	1	2	5	10	19	39	78	156	311	618	871	914	956	999	1042	1083
EV Sales Growth			0,0%	−100%		−100%		58,3%	306,6%	101.6%	85.2%	104.2%	101.4%	101.3%	101.3%	101.2%	101.0%	100.6%	99.8%	98.2%	41.0%	4.9%	4.7%	4.5%	4.2%	4.0%
Canada	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Total Inventory	20,268	20,608	20,652	21,262	21,730	22,068	22,266	22,458	22,653	22,834	23,003	23,160	23,305	23,439	23,564	23,679	23,785	23,884	23,974	24,058	24,135	24,206	24,271	24,331	24,386	24,437
EV Inventory	0	1	2	5	11	18	29	48	90	140	233	398	662	1070	1523	1999	2499	3023	3569	4137	4725	5333	5958	6598	7252	7917
EV Market Share	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.4%	0.6%	1.0%	1.7%	2.8%	4.6%	6.5%	8.4%	10.5%	12.7%	14.9%	17.2%	19.6%	22.0%	24.5%	27.1%	29.7%	32.4%
Annual EV Sales	0	1	2	3	5	7	11	19	43	49	93	165	265	408	453	477	500	524	546	568	588	608	625	640	654	665
EV Sales Growth			259.7%	62.3%	72.1%	33.0%	55.7%	76.0%	124.1%	15.4%	88.9%	76.8%	60.5%	54.1%	11.1%	5.3%	5.0%	4.7%	4.3%	4.0%	3.6%	3.3%	2.9%	2.5%	2.1%	1.7%
China	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Total Inventory	61,634	74,850	87,376	101,361	117,482	135,805	156,772	178,031	198,421	216,773	236,101	253,420	269,133	283,105	295,308	305,800	314,699	322,162	328,359	333,466	337,645	341,047	343,804	346,031	347,824	349,264
EV Inventory	1	5	17	31	94	284	656	1304	2466	3846	5610	8079	11,783	17,338	25,115	35,226	47,359	60,705	74,718	89,060	103,660	118,443	133,327	148,233	163,076	177,777
EV Market Share	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.4%	0.7%	1.2%	1.8%	2.4%	3.2%	4.4%	6.1%	8.5%	11.5%	15.0%	18.8%	22.8%	26.7%	30.7%	34.7%	38.8%	42.8%	46.9%	50.9%
Annual EV Sales	1	4	12	14	64	190	371	648	1162	1381	1764	2469	3704	5555	7777	10,111	12,133	13,346	14,013	14,342	14,600	14,782	14,885	14,905	14,844	14,701
EV Sales Growth		293.3%	177.8%	19.4%	359.5%	197.8%	95.7%	74.6%	79.2%	18.8%	27.7%	40.0%	50.0%	50.0%	40.0%	30.0%	20.0%	10.0%	5.0%	2.3%	1.8%	1.2%	0.7%	0.1%	−0.4%	−1.0%
Denmark	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Total Inventory	2,169	2,203	2,240	2,280	2,321	2,392	2,441	2,490	2,538	2,582	2,623	2,660	2,694	2,725	2,753	2,779	2,802	2,823	2,841	2,858	2,873	2,88	72,899	2,910	2,920	2,928
EV Inventory	0	0	1	2	3	8	9	11	15	24	34	49	71	101	144	204	287	398	543	759	976	1,200	1,424	1,642	1,846	2,033
EV Market Share	0.0%	0.0%	0.0%	0.1%	0.1%	0.3%	0.4%	0.4%	0.6%	0.9%	1.3%	1.9%	2.6%	3.7%	5.2%	7.4%	10.2%	14.1%	19.1%	26.6%	34.0%	41.6%	49.1%	56.4%	63.2%	69.4%
Annual EV Sales	0	0	1	1	2	5	1	1	5	9	10	15	21	31	43	60	82	111	145	216	217	224	224	217	204	187
EV Sales Growth			41.1%	−8.8%	207.2%	189.9%	−69.7%	−29.6%	365.6%	78.6%	23.3%	43.4%	42.8%	42.1%	41.0%	39.5%	37.4%	34.6%	31.0%	48.5%	0.7%	3.1%	0.0%	−3.1%	−5.9%	−8.6%
Finland	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Total Inventory	2,486	2,532	2,560	2,576	2,596	2,613	2,625	2,637	2,649	2,660	2,672	2,683	2,694	2,704	2,714	2,724	2,733	2,742	2,751	2,760	2,768	2,776	2,784	2,792	2,799	2,806
EV Inventory	0	0	0	0	1	1	3	6	12	19	34	60	105	183	287	400	522	651	787	928	1,072	1,218	1,364	1,508	1,647	1,782
EV Market Share	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.4%	0.7%	1.3%	2.2%	3.9%	6.8%	10.6%	14.7%	19.1%	23.7%	28.6%	33.6%	38.7%	43.9%	49.0%	54.0%	58.9%	63.5%
Annual EV Sales	0	0	0	0	0	1	1	3	6	7	15	26	45	78	104	113	122	129	136	141	144	146	146	144	140	134
EV Sales Growth		123.1%	517.2%	1.7%	133.5%	53.6%	118.8%	116.1%	84.5%	29.6%	100.5%	76.1%	74.2%	71.0%	34.1%	8.6%	7.5%	6.3%	5.1%	3.8%	2.5%	1.2%	−0.2%	−1.5%	−2.7%	−4.0%
France	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Total Inventory	31,300	31,550	31,600	31,650	31,800	32,000	32,202	32,413	32,630	32,819	32,982	33,124	33,246	33,351	33,442	33,521	33,588	33,646	33,696	33,739	33,776	33,808	33,835	33,859	33,879	33,896
EV Inventory	1	5	17	32	48	75	109	152	205	275	398	560	785	1,099	1,531	2,123	2,923	3,987	5,372	7,122	9,126	11,224	13,375	15,531	17,644	19,670
EV Market Share	0.0%	0.0%	0.1%	0.1%	0.2%	0.2%	0.3%	0.5%	0.6%	0.8%	1.2%	1.7%	2.4%	3.3%	4.6%	6.3%	8.7%	11.9%	15.9%	21.1%	27.0%	33.2%	39.5%	45.9%	52.1%	58.0%
Annual EV Sales	1	4	12	15	16	27	34	43	54	69	124	162	226	313	433	592	800	1,064	1,384	1,751	2,004	2,098	2,151	2,156	2,113	2,026
EV Sales Growth		454.7%	197.6%	26.6%	8.1%	66.9%	26.7%	24.8%	25.4%	29.2%	78.9%	30.6%	39.6%	39.0%	38.1%	36.8%	35.2%	33.0%	30.1%	26.5%	14.4%	4.7%	2.5%	0.2%	−2.0%	−4.1%
Germany	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Total Inventory	42,302	42,928	43,431	43,851	44,403	45,071	45,574	46,090	46,606	47,096	47,563	48,006	48,426	48,825	49,202	49,558	49,895	50,214	50,514	50,796	51,063	51,314	51,549	51,771	51,979	52,175
EV Inventory	0	2	9	16	29	53	81	139	211	325	511	801	1253	1948	3005	4581	6864	9690	12,739	15,956	19,272	22,605	25,874	29,005	31,934	34,615
EV Market Share	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.3%	0.5%	0.7%	1.1%	1.7%	2.6%	4.0%	6.1%	9.2%	13.8%	19.3%	25.2%	31.4%	37.7%	44.1%	50.2%	56.0%	61.4%	66.3%
Annual EV Sales	0	2	6	7	13	24	28	58	72	114	186	290	451	695	1,057	1,576	2,283	2,826	3,049	3,218	3,315	3,333	3,270	3,131	2,929	2,681
EV Sales Growth			209.7%	3.7%	97.4%	82.3%	15.9%	107.6%	23.6%	57.8%	63.5%	56.2%	55.4%	54.1%	52.1%	49.1%	44.8%	23.8%	7.9%	5.5%	3.0%	0.5%	−1.9%	−4.2%	−6.4%	−8.4%
Hong Kong	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Total Inventory	433	453	473	494	513	540	558	578	597	616	633	633	664	678	691	702	712	722	730	738	745	751	756	761	766	770

EV Inventory	0	0	0	0	1	4	5	10	10	11	12	14	18	25	37	55	85	127	172	222	273	323	373	423	473	524
EV Market Share	0.0%	0.0%	0.0%	0.1%	0.2%	0.7%	1.0%	1.7%	1.7%	1.7%	1.9%	2.3%	2.8%	3.7%	5.3%	7.9%	11.9%	17.5%	23.6%	30.1%	36.6%	43.0%	49.3%	55.6%	61.8%	68.0%
Annual EV Sales	0	0	0	0	0.78	3	2	0	0.31	0.77	1	2	4	7	12	19	30	41	46	50	50	50	50	50	50	50
EV Sales Growth				110.1%	316.0%	231.5%	−33.5%	−95.6%	306.6%	149.2%	80.0%	70.0%	70.0%	70.0%	70.0%	60.0%	60.0%	40.0%	10.0%	10.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
India	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Total Inventory	13,268	15,027	16,896	18,918	20,442	22,468	23,951	25,565	27,265	29,034	30,869	32,767	34,722	36,730	38,786	40,882	43,012	45,168	47,343	49,528	51,714	53,894	56,059	58,201	60,313	62,387
EV Inventory	0	0	0	0	0	1	2	4	6	6	8	11	15	20	29	43	63	92	137	205	305	457	684	1,025	1,535	2,302
EV Market Share	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.2%	0.3%	0.4%	0.6%	0.8%	1.2%	1.8%	2.5%	3.7%
Annual EV Sales	0	0	0	0	0.400	0.375	1.023	2.352	1.797	0.303	1.750	2.625	3.938	5.906	8.859	13	20	30	45	67	101	151	227	341	511	766
EV Sales Growth						−6.3%	172.8%	129.9%	−23.6%	−83.1%	477.6%	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%
Italy	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Total Inventory	36,751	37,113	37,078	36,963	37,081	37,351	37,534	37,731	37,922	38,105	38,281	38,450	38,611	38,766	38,915	39,057	39,193	39,323	39,448	39,567	39,681	39,790	39,894	39,993	40,088	40,179
EV Inventory	0	0	2	4	6	8	12	17	28	44	69	108	169	263	411	639	992	1,532	2,347	3,556	5,242	7,134	9,163	11,304	13,526	15,792
EV Market Share	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.3%	0.4%	0.7%	1.1%	1.6%	2.5%	3.9%	5.9%	9.0%	13.2%	17.9%	23.0%	28.3%	33.7%	39.3%
Annual EV Sales	0	0	2.348	1.445	1.649	2.627	3.463	5.392	10.500	16.574	24.890	38.904	60.754	94.743	147	229	353	540	815	1209	1685	1892	2029	2141	2222	2266
EV Sales Growth		17.5%		−38.5%	14.1%	59.3%	31.8%	55.7%	94.7%	57.8%	50.2%	56.3%	56.2%	55.9%	55.6%	55.1%	54.3%	53.0%	51.1%	48.3%	39.4%	12.3%	7.2%	5.5%	3.8%	2.0%
Japan	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Total Inventory	58,347	58,670	59,421	60,036	60,668	60,988	61,403	61,842	62,282	62,710	63,126	63,531	63,925	64,307	64,679	65,039	65,389	65,728	66,057	66,376	66,684	66,983	67,273	67,553	67,824	68,087
EV Inventory	3	18	39	69	102	127	151	208	261	306	390	530	716	929	1,206	1,563	2,022	2,611	3,363	4,318	5,523	7,027	8,884	11,146	13,855	17,031
EV Market Share	0.0%	0.0%	0.1%	0.1%	0.2%	0.2%	0.2%	0.3%	0.4%	0.5%	0.6%	0.8%	1.1%	1.4%	1.9%	2.4%	3.1%	4.0%	5.1%	6.5%	8.3%	10.5%	13.2%	16.5%	20.4%	25.0%
Annual EV Sales	3	15	21	30	32	26	23	57	54	45	84	140	186	214	276	357	459	589	752	955	1204	1504	1858	2262	2708	3177
EV Sales Growth		477.5%	42.7%	42.7%	7.6%	−20.8%	−8.7%	142.7%	−5.9%	−16.5%	87.9%	66.6%	32.6%	15.1%	29.3%	29.1%	28.7%	28.3%	27.7%	27.0%	26.1%	24.9%	23.5%	21.8%	19.7%	17.3%
Korea	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Total Inventory	13,632	14,136	14,577	15,078	15,747	16,562	16,835	17,525	18,214	18,882	19,525	20,142	20,731	21,290	21,819	22,318	22,785	23,223	23,631	24,010	24,361	24,686	24,985	25,260	25,513	25,744
EV Inventory	0	0	1	1	2	6	12	26	60	101	165	286	515	835	1,137	1,407	1,686	1,972	2,268	2,571	2,882	3,202	3,529	3,864	4,207	4,557
EV Market Share	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.3%	0.5%	0.8%	1.4%	2.5%	3.9%	5.2%	6.3%	7.4%	8.5%	9.6%	10.7%	11.8%	13.0%	14.1%	15.3%	16.5%	17.7%
Annual EV Sales	0	0	1	1	1	3	6	14	34	41	64	121	229	320	302	270	279	287	295	303	312	320	327	335	343	350
EV Sales Growth				32.3%	66.9%	171.7%	85.8%	134.0%	137.4%	20.8%	55.9%	89.3%	89.3%	39.7%	−5.7%	−10.4%	3.1%	3.0%	2.9%	2.8%	2.7%	2.6%	2.5%	2.3%	2.2%	2.1%
Netherlands	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Total Inventory	7,736	7,859	7,916	8,154	8,193	8,336	8,432	8,535	8,646	8,750	8,847	8,937	9,021	9,099	9,172	9,239	9,301	9,358	9,411	9,460	9,505	9,546	9,584	9,619	9,652	9,681
EV Inventory	0	1	7	30	45	88	111	121	149	204	280	374	496	657	864	1,129	1,462	1,844	2,248	2,669	3,105	3,550	4,001	4,452	4,897	5,333
EV Market Share	0.0%	0.0%	0.1%	0.4%	0.5%	1.1%	1.3%	1.4%	1.7%	2.3%	3.2%	4.2%	5.5%	7.2%	9.4%	12.2%	15.7%	19.7%	23.9%	28.2%	32.7%	37.2%	41.7%	46.3%	50.7%	55.1%
Annual EV Sales	0	1	6	23	15	43	23	10	28	55	77	93	123	160	207	265	333	382	403	421	436	446	451	451	446	436
EV Sales Growth		884.9%	559.1%	314.7%	−33.9%	182.7%	−46.6%	−57.9%	185.4%	97.3%	39.5%	21.9%	31.6%	30.6%	29.4%	27.8%	25.8%	14.7%	5.5%	4.5%	3.4%	2.3%	1.1%	0.0%	−1.1%	−2.2%
Norway	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Total Inventory	2,305	2,370	2,433	2,487	2,540	2,592	2,608	2,624	2,639	2,653	2,668	2,682	2,697	2,711	2,726	2,740	2,754	2,768	2,782	2,796	2,810	2,823	2,837	2,850	2,864	2,877
EV Inventory	1	3	7	16	36	70	116	179	254	340	450	585	751	910	1,066	1,222	1,377	1,528	1,674	1,813	1,942	2,061	2,170	2,268	2,356	2,433
EV Market Share	0.0%	0.1%	0.3%	0.6%	1.4%	2.7%	4.5%	6.8%	9.6%	12.8%	16.9%	21.8%	27.8%	33.6%	39.1%	44.6%	50.0%	55.2%	60.2%	64.8%	69.1%	73.0%	76.5%	79.6%	82.3%	84.6%
Annual EV Sales	1	2	4	9	20	34	46	63	75	86	110	135	166	159	156	156	155	152	146	138	129	119	109	98	88	77
EV Sales Growth		272.1%	101.7%	99.8%	131.7%	71.0%	33.1%	38.4%	18.0%	15.1%	28.3%	22.5%	23.0%	−4.2%	−2.0%	0.0%	−0.6%	−2.2%	−3.7%	−5.2%	−6.5%	−7.7%	−8.9%	−9.9%	−10.8%	−11.6%
Portugal	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Total Inventory	4,480	4,522	4,497	4,480	4,496	4,593	4,630	4,670	4,712	4,751	4,789	4,825	4,859	4,892	4,924	4,954	4,982	5,010	5,036	5,060	5,084	5,106	5,127	5,147	5,167	5,185
EV Inventory	0	0	0	1	1	2	4	9	17	32	60	114	213	370	545	734	936	1,149	1,372	1,603	1,840	2,080	2,319	2,556	2,787	3,010
EV Market Share	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.4%	0.7%	1.3%	2.4%	4.4%	7.6%	11.1%	14.8%	18.8%	22.9%	27.3%	31.7%	36.2%	40.7%	45.2%	49.7%	53.9%	58.1%
Annual EV Sales	0	0	0	0	0	1	2	4	8	14	28	54	99	158	175	189	202	213	223	231	237	240	240	237	231	223
EV Sales Growth			−24.1%	39.1%	60.3%	263.0%	48.1%	126.2%	94.5%	70.6%	96.4%	88.2%	85.5%	58.6%	11.1%	7.8%	6.9%	5.8%	4.7%	3.5%	2.4%	1.2%	0.0%	−1.2%	−2.3%	−3.4%
Russia	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Total Inventory	34,354	36,415	38,482	41,225	43,384	44,253	44,873	45,570	46,356	47,918	48,741	49,468	50,109	50,671	51,162	51,591	51,964	52,287	52,568	52,811	53,020	53,201	53,357	53,492	53,607	53,707
EV Inventory	0	0	0	0	0	0	1	1	2	4	8	16	33	66	134	268	536	1,068	2,105	3,577	5,165	6,867	8,678	10,591	12,594	14,675
EV Market Share	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.3%	0.5%	1.0%	2.0%	4.0%	6.8%	9.7%	12.9%	16.3%	19.8%	23.5%	27.3%
Annual EV Sales	0	0	0	0	0	0	0	0	1	2	4	8	17	33	67	134	268	531	1,038	1,472	1,588	1,702	1,811	1,913	2,003	2,081
EV Sales Growth			19.5%	−100%			103.8%	−66.4%	664.3%	95.6%	90.8%	102.7%	101.0%	100.9%	100.8%	100.4%	99.6%	98.1%	95.2%	41.9%	7.9%	7.2%	6.4%	5.6%	4.8%	3.9%
South Africa	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Total Inventory	5,319	5,507	5,733	5,967	6,188	6,384	6,528	6,676	6,822	6,965	7,104	7,239	7,370	7,497	7,620	7,738	7,853	7,963	8,069	8,170	8,268	8,361	8,450	8,535	8,617	8,694
EV Inventory	0	0	0	0	0	0	1	1	1	1	2	2	3	5	7	9	13	19	26	37	52	73	102	143	201	281
EV Market Share	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.2%	0.2%	0.3%	0.4%	0.6%	0.9%	1.2%	1.7%	2.3%	3.2%
Annual EV Sales	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	3	4	5	8	11	15	21	29	41	58	80
EV Sales Growth						67.9%	−32.3%	17.0%	−46.8%	273.2%	31.8%	41.0%	41.0%	41.0%	40.9%	40.9%	40.9%	40.8%	40.8%	40.7%	40.6%	40.4%	40.2%	39.9%	39.4%	38.8%
Spain	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Total Inventory	22,147	22,277	22,248	22,025	22,030	22,356	22,585	22,832	23,096	23,354	23,604	23,848	24,084	24,314	24,537	24,752	24,961	25,164	25,360	25,549	25,732	25,908	26,079	26,243	26,401	26,554

(continued on next page)

(*continued*)

EV Inventory	0	1	2	4	6	8	13	21	35	57	94	153	249	404	655	1,054	1,681	2,602	3,643	4,762	5,953	7,204	8,502	9,831	11,173	12,510
EV Market Share	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.2%	0.4%	0.6%	1.0%	1.7%	2.7%	4.3%	6.7%	10.3%	14.4%	18.6%	23.1%	27.8%	32.6%	37.5%	42.3%	47.1%
Annual EV Sales	0	1	2	1	2	3	5	8	13	23	36	59	96	156	250	399	627	921	1,041	1,119	1,191	1,251	1,298	1,329	1,342	1,337
EV Sales Growth			185.8%	−23.4%	53.3%	50.3%	54.1%	84.5%	58.5%	72.2%	59.2%	62.9%	62.5%	61.9%	61.0%	59.5%	57.1%	46.8%	13.0%	7.6%	6.4%	5.1%	3.7%	2.4%	1.0%	−0.4%
Sweden	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Total Inventory	4,335	4,401	4,447	4,495	4,586	4,669	4,744	4,819	4,890	4,954	5,013	5,065	5,112	5,155	5,193	5,227	5,257	5,285	5,309	5,331	5,350	5,367	5,382	5,396	5,408	5,418
EV Inventory	0	0	1	3	8	17	31	51	81	126	207	330	520	792	1,100	1,432	1,781	2,139	2,499	2,852	3,191	3,507	3,798	4,059	4,291	4,492
EV Market Share	0.0%	0.0%	0.0%	0.1%	0.2%	0.4%	0.7%	1.1%	1.7%	2.6%	4.1%	6.5%	10.2%	15.4%	21.2%	27.4%	33.9%	40.5%	47.1%	53.5%	59.6%	65.4%	70.6%	75.2%	79.3%	82.9%
Annual EV Sales	0	0	1	2	5	9	14	20	30	46	80	123	190	272	308	332	349	359	360	353	338	317	291	261	231	201
EV Sales Growth		222.8%	558.7%	58.6%	161.7%	79.0%	51.3%	49.5%	45.0%	54.2%	76.1%	53.9%	53.9%	43.3%	13.4%	7.5%	5.2%	2.8%	0.4%	−2.0%	−4.2%	−6.3%	−8.3%	−10.0%	−11.6%	−12.9%
Switzerland	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Total Inventory	4,120	4,210	4,300	4,367	4,430	4,504	4,567	4,630	4,690	4,704	4,718	4,732	4,747	4,761	4,775	4,789	4,804	4,818	4,833	4,847	4,862	4,876	4,891	4,906	4,920	4,935
EV Inventory	0	1	2	3	6	12	18	26	36	52	78	115	168	245	355	509	719	971	1,241	1,525	1,817	2,113	2,407	2,693	2,966	3,223
EV Market Share	0.0%	0.0%	0.0%	0.1%	0.1%	0.3%	0.4%	0.6%	0.8%	1.1%	1.7%	2.4%	3.5%	5.2%	7.4%	10.6%	15.0%	20.2%	25.7%	31.5%	37.4%	43.3%	49.2%	54.9%	60.3%	65.3%
Annual EV Sales	0	0	1	1	2	6	6	8	10	16	26	37	53	77	110	154	210	252	270	284	293	296	294	286	273	257
EV Sales Growth		262.6%	228.0%	−6.5%	66.1%	179.9%	−11.1%	49.4%	15.6%	64.5%	61.7%	41.4%	45.5%	44.3%	42.5%	40.0%	36.6%	20.0%	7.0%	5.1%	3.2%	1.2%	−0.7%	−2.6%	−4.4%	−6.1%
Taiwan	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Total Inventory	5,803	5,960	6,091	6,237	6,406	6,574	6,636	6,698	6,768	6,836	6,900	6,961	7,019	7,075	7,128	7,178	7,225	7,270	7,313	7,353	7,391	7,428	7,462	7,494	7,524	7,553
EV Inventory	0	0	0	0	0	0	0	0	1	1	2	2	3	4	5	7	9	13	17	22	30	40	53	70	94	125
EV Market Share	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.2%	0.2%	0.3%	0.4%	0.5%	0.7%	0.9%	1.2%	1.6%
Annual EV Sales	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	2	2	3	4	6	7	10	13	18	23	31
EV Sales Growth				−67.7%	−40.7%	−37.5%	−90.0%	9450%	20.9%	137.1%	−23.9%	33.5%	33.5%	33.5%	33.4%	33.4%	33.4%	33.4%	33.4%	33.3%	33.3%	33.2%	33.1%	33.0%	32.8%	32.6%
UK	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Total Inventory	31,258	31,363	31,482	32,103	32,613	33,542	33,946	34,327	34,682	35,018	35,336	35,636	35,919	36,185	36,436	36,672	36,894	37,102	37,297	37,480	37,651	37,811	37,961	38,101	38,232	38,355
EV Inventory	0	1	4	8	23	53	92	141	203	262	412	612	906	1,337	1,962	2,858	4,119	5,848	7,928	10,154	12,492	14,900	17,331	19,734	22,063	24,276
EV Market Share	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.3%	0.4%	0.6%	0.7%	1.2%	1.7%	2.5%	3.7%	5.4%	7.8%	11.2%	15.8%	21.3%	27.1%	33.2%	39.4%	45.7%	51.8%	57.7%	63.3%
Annual EV Sales	0	1	3	4	15	30	39	49	61	59	150	200	294	431	625	896	1,261	1,730	2,080	2,226	2,338	2,408	2,431	2,404	2329	2213
EV Sales Growth		864.0%	170.3%	25.7%	309.8%	93.1%	32.7%	25.5%	24.7%	−3.8%	154.4%	32.8%	47.3%	46.4%	45.2%	43.3%	40.7%	37.2%	20.2%	7.0%	5.0%	3.0%	0.9%	−1.1%	−3.1%	−5.0%
USA	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Total Inventory	129,053	127,577	120,902	120,214	120,984	122,322	123,000	124,000	125,000	126,000	127,000	128,000	129,000	130,000	130,000	130,000	130,000	130,000	130,000	130,000	130,000	130,000	130,000	130,000	130,000	130,000
EV Inventory	1	19	74	170	289	405	563	765	1,126	1,478	1,975	2,796	4,120	6,196	8,938	12,390	16,512	20,900	25,535	30,392	35,437	40,631	45,931	51,287	56,651	61,970
EV Market Share	0.0%	0.0%	0.1%	0.1%	0.2%	0.3%	0.5%	0.6%	0.9%	1.2%	1.6%	2.2%	3.2%	4.8%	6.9%	9.5%	12.7%	16.1%	19.6%	23.4%	27.3%	31.3%	35.3%	39.5%	43.6%	47.7%
Annual EV Sales	1	18	55	96	119	116	158	202	361	352	497	821	1,324	2,076	2,742	3,452	4,122	4,388	4,635	4,857	5,045	5,194	5,300	5,357	5,363	5,320
EV Sales Growth			199.6%	74.7%	23.9%	−2.9%	37.1%	27.7%	78.6%	−2.5%	41.3%	65.1%	61.3%	56.8%	32.1%	25.9%	19.4%	6.5%	5.6%	4.8%	3.9%	3.0%	2.0%	1.1%	0.1%	−0.8%
26 Countries	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
Total Inventory	582,378	603,823	618,649	642,394	668,811	697,339	725,017	754,060	782,412	809,350	836,419	861,263	884,341	905,479	923,669	939,977	954,526	967,477	979,005	989,285	998,485	1,006,754	1,014,227	1,021,018	1,027,224	1,032,926
EV Inventory	9	60	192	402	724	1,263	2,055	3,302	5,357	7,783	11,229	16,297	24,016	35,502	51,123	71,461	96,848	126,380	159,276	195,158	233,414	273,136	313,877	355,329	397,202	439,240
EV Market Share	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.3%	0.4%	0.7%	1.0%	1.3%	1.9%	2.7%	3.9%	5.5%	7.6%	10.1%	13.1%	16.3%	19.7%	23.4%	27.1%	30.9%	34.8%	38.7%	42.5%
Annual EV Sales	7	51	132	210	321	539	792	1,247	2,055	2,426	3,446	5,068	7,719	11,486	15,621	20,338	25,387	29,532	32,896	35,883	38,255	39,722	40,741	41,453	41,873	42,037
EV Sales Growth			159.0%	58.8%	53.1%	67.7%	46.9%	57.4%	64.8%	18.0%	42.1%	47.0%	52.3%	48.8%	36.0%	30.2%	24.8%	16.3%	11.4%	9.1%	6.6%	3.8%	2.6%	1.7%	1.0%	0.4%

Appendix C. Sensitivity analyses regarding number of datapoints and saturation limit

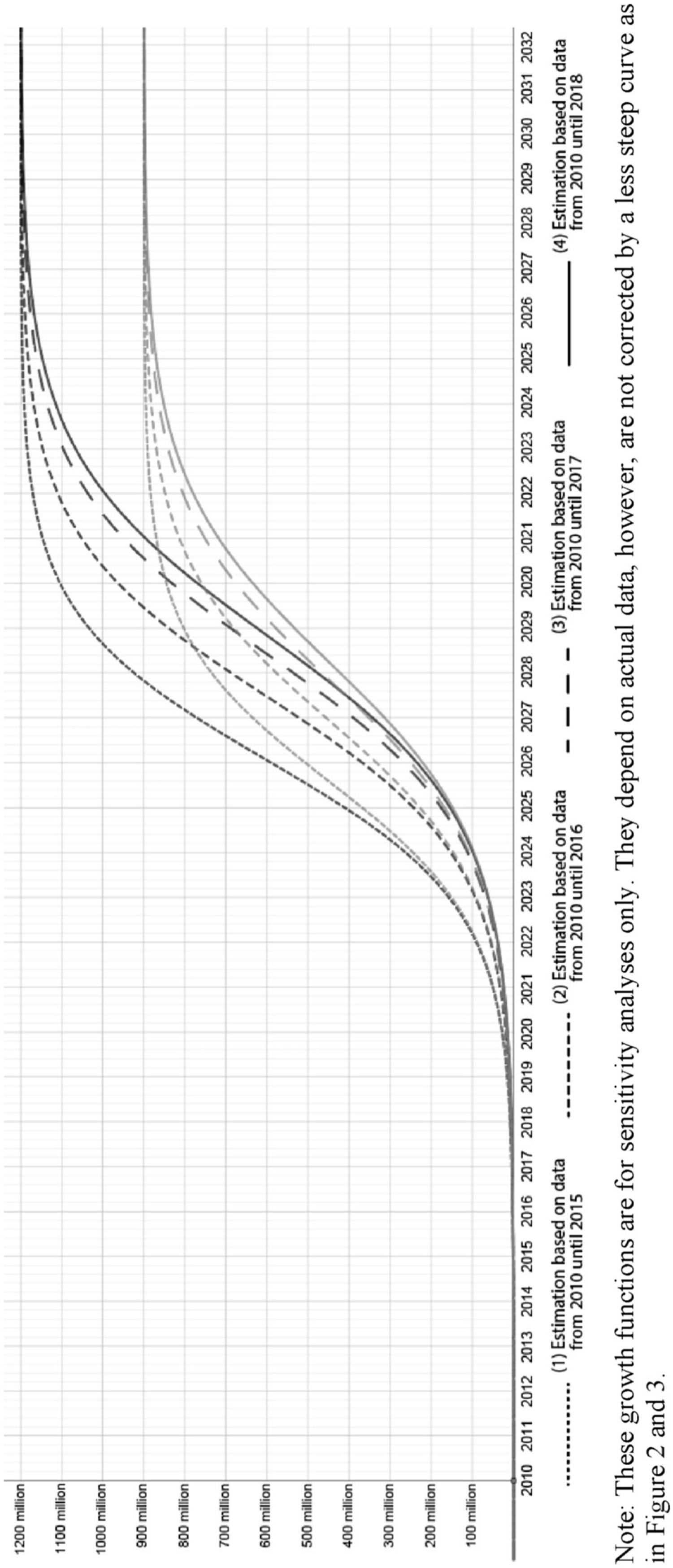

Fig. C1.

Table C1
Milestones for growth functions with saturation limit of 1200 million EVs

	Growth function I		Growth function II		Growth function III		Growth function IV
Reaches inflection point	Jan 2026	+17 months	May 2027	+11 months	May 2028	+4 months	Oct 2028
Reaches inventory of 300 million EVs	Mar 2024	+14 months	May 2025	+9 months	Mar 2026	+4 months	Jul 2026

Table C2
Milestones compared for functions with 1200 million and 800 million saturation

	L = 1200 million	L = 1200 million	L = 1200 million	L = 1200 million
Reaches inflection point	Jan 2026	May 2027	May 2028	Oct 2028
	L = 900 million	L = 900 million	L = 900 million	L = 900 million
	- 6 months	- 6 months	- 4 months	- 5 months
Reaches inflection point	Jul 2025	Nov 2026	Jan 2028	Feb 2028
	L = 1200 million	L = 1200 million	L = 1200 million	L = 1200 million
Reaches inventory of 300 million EVs	Mar 24	May 25	Mar 2026	Jul 26
	L = 900 million	L = 900 million	L = 900 million	L = 900 million
	+2 months	+3 months	+4 months	+3 months
Reaches inventory of 300 million EVs	May 2024	Aug 2025	Jul 2026	Oct 2026

Appendix D. References for Table 2

1) IEA International Energy Agency, 2019. Fuel Economy in Major Car Markets [WWW Document]. URL https://webstore.iea.org/download/direct/2458?fileName=Fuel_Economy_in_Major_Car_Markets.pdf; Lge = liters of gasoline equivalent%22 (accessed 12.2.19).
2) OECD, 2019. Compare your country - Electricity [WWW Document]. URL http://www.compareyourcountry.org/climate-policies?cr = oecd&lg = en&page = 2&visited = 1 (accessed 11.18.19).
3) Budget Direct, 2019. Average kilometers travelled per day/per year in Australia [WWW Document]. URL https://www.budgetdirect.com.au/car-insurance/research/average-kilometers-driven.html#:~:targetText = Average kilometers travelled,day in Australia in 2018 (accessed 11.30.19).
4) Enerdata, 2019. Change in distance travelled by car [WWW Document]. Odyssee-Mure. URL https://www.odyssee-mure.eu/publications/efficiency-by-sector/transport/distance-travelled-by-car.html (accessed 11.30.19).
5) Schoefs, S., 2015. Average used car in Belgium is 8-year-old VW with 116,000 km [WWW Document]. Fleet Eur. URL https://www.fleeteurope.com/en/news/average-used-car-belgium-8-year-old-vw-116000-km?a = SSC01&t%5B0%5D = CarPass&curl = 1 (accessed 11.30.19).
6) Tadano, Y.S., Mazza, R.A., Tomaz, E., 2011. Evaluation of Air Quality: Simulation of Air Pollutants Dispersion in Paulinia Brazil) Using ISCST3, in: Proceedings of the 21st Brazilian Congress of Mechanical Engineering. ABCM, Natal, RN, Brazil.
7) ahainsurance, 2019. What's the average mileage per year in Canada? [WWW Document]. URL https://www.ahainsurance.ca/car-insurance/average-mileage-per-year-canada/#:~:targetText = According to Natural Resources Canada%2C Office of Energy Resources%2C the,with only 13% 2C100 km travelled (accessed 11.30.19).
8) Cox, W., 2019. Average Chinese car travels as much as American car [WWW Document]. New Geogr. URL https://www.newgeography.com/content/006420-average-chinese-car-travels-much-american-car (accessed 11.30.19).
9) Statistical Yearbook, 2012. Transport [WWW Document]. URL https://www.dst.dk/Site/Dst/Udgivelser/GetPubFile.aspx?id=16251&sid=13tra (accessed 11.28.19).
10) Autoalan Tiedotuskeskus, 2014. Finnish Road Network and Its Use [WWW Document]. URL http://www.aut.fi/en/road_transport/road_transport_in_finland#:~:targetText = The total mileage in Finland,54%2C000 million kilometres per year (accessed 11.29.19).
11) Enerdata, 2019. Change in distance travelled by car [WWW Document]. Odyssee-Mure. URL https://www.odyssee-mure.eu/publications/efficiency-by-sector/transport/distance-travelled-by-car.html (accessed 11.30.19).
12) Enerdata, 2019. Change in distance travelled by car [WWW Document]. Odyssee-Mure. URL https://www.odyssee-mure.eu/publications/efficiency-by-sector/transport/distance-travelled-by-car.html (accessed 11.30.19).
13) Transport Department, 2017. The Annual Traffic Census 2016 [WWW Document]. URL https://www.td.gov.hk/filemanager/en/content_4875/annual traffic census 2016.pdf (accessed 11.30.19).
14) Statista, 2014. Average annual mileage of passenger cars in India as of December 2014 (in kilometers) [WWW Document]. URL https://www.statista.com/statistics/611800/passenger-passenger-car-annual-mileage/(accessed 11.30.19).
15) Enerdata, 2019. Change in distance travelled by car [WWW Document]. Odyssee-Mure. URL https://www.odyssee-mure.eu/publications/efficiency-by-sector/transport/distance-travelled-by-car.html (accessed 11.30.19).
16) Statista, 2014. Distribution of passenger car average usage per year in Japan as of December 2014 (in kilometers) [WWW Document]. URL https://www.statista.com/statistics/645317/japan-share-passenger-car-travel-distance/(accessed 11.30.19).
17) OECD, 2019a. Road Safety Annual Report 2019-Korea [WWW Document]. URL https://www.itf-oecd.org/sites/default/files/korea-road-safety.pdf (accessed 11.29.19).
18) Enerdata, 2019. Change in distance travelled by car [WWW Document]. Odyssee-Mure. URL https://www.odyssee-mure.eu/publications/efficiency-by-sector/transport/distance-travelled-by-car.html (accessed 11.30.19).
19) Statistisk sentralbyra, 2019. Road traffic volumes [WWW Document]. URL https://www.ssb.no/en/transport-og-reiseliv/statistikker/klreg (accessed 11.28.19).

20) OECD, 2019b. Passenger transport [WWW Document]. URL https://data.oecd.org/transport/passenger-transport.htm (accessed 12.1.19).
21) Autostat, 2019. Average car mileage in Russia is 17,500 km per year [WWW Document]. URL https://eng.autostat.ru/news/17121/www.autostat.ru/www.autostat.ru/(accessed 11.30.19).
22) Writer, S., 2017. How to know when to sell or trade-in your car in South Africa [WWW Document]. Businesstech. URL https://businesstech.co.za/news/motoring/160779/how-to-know-when-to-sell-or-trade-in-your-car-in-south-africa/ (accessed 12.1.19).
23) Enerdata, 2019. Change in distance travelled by car [WWW Document]. Odyssee-Mure. URL https://www.odyssee-mure.eu/publications/efficiency-by-sector/transport/distance-travelled-by-car.html (accessed 11.30.19).
24) ACEA, 2019. Vehicles in use Europe 2018 [WWW Document]. URL https://www.acea.be/uploads/statistic_documents/ACEA_Report_Vehicles_in_use-Europe_2018.pdf (accessed 11.28.19).
25) Neue Zürcher Zeitung (NZZ), 2002. Schweizer Fahrzeuge fahren pro Jahr 55 Milliarden Kilometer [WWW Document]. URL https://www.nzz.ch/newzzD5GEZYDI-12-1.419614#:~:targetText = Weniger als einer von zehn,469 Kilometer pro Jahr zurück.&targetText = Vom Total der gefahrenen Kilometer, zehn Prozent auf den Gütertransport.1.419614%23:~:targetText = Weniger als einer von zehn,469 Kilometer pro Jahr zurück.&targetText = Vom Total der gefahrenen Kilometer, zehn Prozent auf den Gütertransport (accessed 11.29.19).
26) Lemaire, J., Park, S.C., Wang, K., 2015. The Use of Annual Mileage as a Rating Variable. ASTIN Bull. 46, 39–69. https://doi.org/10.1017/asb.2015.25
27) Enerdata, 2019. Change in distance travelled by car [WWW Document]. Odyssee-Mure. URL https://www.odyssee-mure.eu/publications/efficiency-by-sector/transport/distance-travelled-by-car.html (accessed 11.30.19).
28) U.S. Department of Transportation (2018). Average Annual Miles per Driver by Age Group [WWW Document]. URL https://www.fhwa.dot.gov/ohim/onh00/bar8.htm (accessed 11.30.19).

References

Al-Alawi, B.M., Bradley, T.H., 2013. Review of hybrid, plug-in hybrid, and electric vehicle market modeling Studies. Renew. Sustain. Energy Rev. 21, 190–203. https://doi.org/10.1016/j.rser.2012.12.048.

Bloom, N., 2014. Fluctuations in uncertainty. J. Econ. Perspect. 28, 153–176. https://doi.org/10.1257/jep.28.2.153.

Boretos, G.P., 2007. The future of the mobile phone business. Technol. Forecast. Soc. Change 74, 331–340. https://doi.org/10.1016/j.techfore.2005.11.005.

BP, 2019. BP Energy Outlook - 2019 [WWW Document].

Burns, L.D., 2013. A vision of our transport future. Nature 497, 181–182. https://doi.org/10.1038/497181a.

Casals, L.C., Martinez-Laserna, E., Amante García, B., Nieto, N., 2016. Sustainability analysis of the electric vehicle use in Europe for CO2 emissions reduction. J. Clean. Prod. 127, 425–437. https://doi.org/10.1016/j.jclepro.2016.03.120.

Dharmakeerthi, C.H., Mithulananthan, N., Saha, T.K., 2014. Impact of electric vehicle fast charging on power system voltage stability. Int. J. Electr. Power Energy Syst. 57, 241–249. https://doi.org/10.1016/j.ijepes.2013.12.005.

Domingues, J.M., Pecorelli-Peres, L.A., 2013. Electric vehicles, energy efficiency, taxes, and public policy in Brazil. Law Bus. Rev. Am. 19, 55–80.

Dudley, B., 2019. BP Statistical Review of World Energy [WWW Document].

EAFO, 2019. Country detail incentives [WWW Document].

Egbue, O., Long, S., 2012. Critical issues in the supply chain of lithium for electric vehicle batteries. EMJ - Eng. Manag. Jpn. 24, 52–62. https://doi.org/10.1080/10429247.2012.11431947.

Eggers, Felix, Eggers, Fabian, 2011. Where have all the flowers gone? Forecasting green trends in the automobile industry with a choice-based conjoint adoption model. Technol. Forecast. Soc. Change 78, 51–62. https://doi.org/10.1016/j.techfore.2010.06.014.

Electric Vehicle Database, 2019. Energy consumption of full electric vehicles [WWW Document].

Ellingsen, L.A.-W., Singh, B., Strømman, A.H., 2016. The size and range effect: life-cycle greenhouse gas emissions of electric vehicles. Environ. Res. Lett. 11, 1–7. https://doi.org/10.1088/1748-9326/11/5/054010.

Energy Information Administration, 2017. Russia [WWW Document].

EV-Volumes, 2019. EV Sales Worldwide [WWW Document].

Faria, R., Marques, P., Moura, P., Freire, F., Delgado, J., De Almeida, A.T., 2013. Impact of the electricity mix and use profile in the life-cycle assessment of electric vehicles. Renew. Sustain. Energy Rev. 24, 271–287. https://doi.org/10.1016/j.rser.2013.03.063.

Figenbaum, E., Assum, T., Kolbenstvedt, M., 2015. Electromobility in Norway: Experiences and Opportunities. Res. Transp. Econ 50, 29–38. https://doi.org/10.1016/j.retrec.2015.06.004.

Florides, G.A., Christodoulides, P., 2009. Global warming and carbon dioxide through sciences. Environ. Int. 35, 390–401. https://doi.org/10.1016/j.envint.2008.07.007.

Geroski, P.A., 2000. Models of technology diffusion. Res. Pol. 29, 603–625. https://doi.org/10.1016/S0048-7333(99)00092-X.

Gnann, T., Plötz, P., Kühn, A., Wietschel, M., 2015. Modelling market diffusion of electric vehicles with real world driving data - German market and policy options. Transport. Res. Part A Policy Pract 77, 95–112. https://doi.org/10.1016/j.tra.2015.04.001.

Government of Canada, 2019. Electricity facts [WWW Document], Nat. Resour. Canada.

Government of Hong Kong, 2015. Report on the Public Consultation on Future Fuel Mix for Electricity Generation in Hong Kong [WWW Document].

Government of NCT of Delhi, 2016. Budget 2016-2017 [WWW Document].

Government of Taiwan, 2019. National Statistics [WWW Document].

Hao, H., Ou, X., Du, J., Wang, H., Ouyang, M., 2014. China's electric vehicle subsidy scheme: rationale and impacts. Energy Pol. 73, 722–732. https://doi.org/10.1016/j.enpol.2014.05.022.

Higgins, A., Paevere, P., Gardner, J., Quezada, G., 2012. Combining choice modelling and multi-criteria analysis for technology diffusion: an application to the uptake of electric vehicles. Technol. Forecast. Soc. Change 79, 1399–1412. https://doi.org/10.1016/j.techfore.2012.04.008.

Huo, H., Cai, H., Zhang, Q., Liu, F., He, K., 2015. Life-cycle assessment of greenhouse gas and air emissions of electric vehicles: a comparison between China and the U.S. Atmos. Environ. Times 108, 107–116. https://doi.org/10.1016/j.atmosenv.2015.02.073.

IEA, 2019a. Fuel Economy in Major Car Markets [WWW Document], Glob. Fuel Econ. Initiat. - Int. Energy Agency.

IEA, 2019b. Brazil [WWW Document], Key energy Stat. 2018.

IEA, 2019c. World energy statistics 2019 [WWW Document].

IEA IA-HEV, 2018. Annual Report 2017: Hybrid and Electric Vehicles - The Electric Drive Automates [WWW Document].

IPPC, 2014. Emission Factors for Greenhouse Gas Inventories [WWW Document].

Jensen, A.F., Cherchi, E., Mabit, S.L., de Dios Ortúzar, J., 2017. Predicting the potential market for electric vehicles. Transp. Sci. 51, 427–440. https://doi.org/10.1287/trsc.2015.0659.

Lieven, T., 2015. Policy measures to promote electric mobility - a global perspective. Transport. Res. Part A Policy Pract 82, 78–93. https://doi.org/10.1016/j.tra.2015.09.008.

Lieven, T., Mühlmeier, S., Henkel, S., Waller, J.F., 2011. Who will buy electric cars? An empirical study in Germany. Transp. Res. Part D Transp. Environ. Times 16, 236–243. https://doi.org/10.1016/j.trd.2010.12.001.

Liu, J., 2019. China's renewable energy law and policy: a critical review. Renew. Sustain. Energy Rev. 99, 212–219. https://doi.org/10.1016/j.rser.2018.10.007.

MarkLines, 2019. Vehicle Sales data [WWW Document].

Massiani, J., Gohs, A., 2015. The choice of Bass model coefficients to forecast diffusion for innovative products: an empirical investigation for new automotive technologies. Res. Transp. Econ 50, 17–28. https://doi.org/10.1016/j.retrec.2015.06.003.

Meade, N., Islam, T., 2006. Modelling and forecasting the diffusion of innovation - a 25-year review. Int. J. Forecast. 22, 519–545. https://doi.org/10.1016/j.ijforecast.2006.01.005.

Milne, R., 2017. Reality of subsidies drives Norway's electric car dream [WWW Document], Financ. Times.

Ministry of Economy Trade and Industry, 2017. Japan's Energy [WWW Document].

Muller, E., Mahajan, V., 1979. Innovation diffusion and new product growth models in marketing. J. Mark 43, 55–68.

Nanaki, E.A., Koroneos, C.J., 2013. Comparative economic and environmental analysis of conventional, hybrid and electric vehicles - the case study of Greece. J. Clean. Prod. 53, 261–266. https://doi.org/10.1016/j.jclepro.2013.04.010.

Norge, Energifakta, 2019. Electricity production [WWW Document].

OECD, 2013. Passenger Car [WWW Document], Gloss. Stat. Terms.

OECD, 2019. Compare your country - Electricity [WWW Document].

OECD/IEA, 2019. Global EV Outlook 2019 Scaling-up the transition to electric mobility. OECD iea.org 232.

OICA, 2018. Sales of new vehicles 2005-2017 [WWW Document], Organ. Int. des Constr. d'Automobiles.

OICA, 2019. 2018 Production Statistics [WWW Document].

Onat, N.C., Kucukvar, M., Tatari, O., 2014. Towards life cycle sustainability assessment of alternative passenger vehicles. Sustainability 6, 9305–9342. https://

doi.org/10.3390/su6129305.
Pieltain Fernández, L., Gómez San Román, T., Cossent, R., Mateo Domingo, C., Frías, P., 2011. Assessment of the impact of plug-in electric vehicles on distribution networks. IEEE Trans. Power Syst. 26, 206–213. https://doi.org/10.1109/TPWRS.2010.2049133.
Qian, L., Soopramanien, D., 2014. Using diffusion models to forecast market size in emerging markets with applications to the Chinese car market. J. Bus. Res. 67, 1226–1232. https://doi.org/10.1016/j.jbusres.2013.04.008.
Rezvani, Z., Jansson, J., Bodin, J., 2015. Advances in consumer electric vehicle adoption research: a review and research agenda. Transp. Res. Part D Transp. Environ. Times 34, 122–136. https://doi.org/10.1016/j.trd.2014.10.010.
Rietmann, N., Lieven, T., 2019. How policy measures succeeded to promote electric mobility – worldwide review and outlook. J. Clean. Prod. 206, 66–75. https://doi.org/10.1016/j.jclepro.2018.09.121.
Shaheen, S.A., Cohen, A.P., 2013. Carsharing and personal vehicle services: worldwide market developments and emerging trends. Int. J. Sustain. Transp 7, 5–34. https://doi.org/10.1080/15568318.2012.660103.
Shakun, J.D., Clark, P.U., He, F., Marcott, S.A., Mix, A.C., Liu, Z., Otto-Bliesner, B., Schmittner, A., Bard, E., 2012. Global warming preceded by increasing carbon dioxide concentrations during the last deglaciation. Nature 484, 49–54. https://doi.org/10.1038/nature10915.
Statista, 2019. Car sales (passenger and commercial vehicles) in China from 2009 to April 2019 (in million units) [WWW Document].
Techcrunch, 2019. Tesla, Panasonic modify expansion plans for gigafactory [WWW Document].
Teixeira, A.C.R., Sodré, J.R., 2018. Impacts of replacement of engine powered vehicles by electric vehicles on energy consumption and CO2 emissions. Transp. Res. Part D Transp. Environ. Times 59, 375–384. https://doi.org/10.1016/j.trd.2018.01.004.
The World Bank, 2019. Hong Kong SAR, China [WWW Document], Data.
To, W.M., Lee, P.K.C., 2014. Diffusion of ISO 14001 environmental management system: global, regional and country-level analyses. J. Clean. Prod. 66, 489–498. https://doi.org/10.1016/j.jclepro.2013.11.076.
Toh, M., 2019. China has been slashing its electric car subsidies. That could backfire [WWW Document], CNN Bus.
Union of Concerned Scientists, 2019. Electric Vehicle Battery: Materials, Cost, Lifespan [WWW Document].
van der Steen, M., van Schelven, R.M., Kotter, R., van Twist, M.J.W., van Deventer, P., 2015. EV policy compared: an international comparison of governments' policy strategy towards E-mobility. In: Filho, W.L., Kotter, R. (Eds.), E-mobility in Europe: Trends and Good Practice. Springer, pp. 27–53. Cham.
Wu, Z., Wang, M., Zheng, J., Sun, X., Zhao, M., Wang, X., 2018. Life cycle greenhouse gas emission reduction potential of battery electric vehicle. J. Clean. Prod. 190, 462–470. https://doi.org/10.1016/j.jclepro.2018.04.036.
Yang, Y., Williams, E., 2009. Logistic model-based forecast of sales and generation of obsolete computers in the U.S. Technol. Forecast. Soc. Change 76, 1105–1114. https://doi.org/10.1016/j.techfore.2009.03.004.
Zhu, G., Hein, C.T., Ding, Q., 2017. Case Study - China's regulatory impact on electric mobility development and the effects on power generation and the distribution grid. In: Liebl, J. (Ed.), Grid Integration of Electric Mobility: 1st International ATZ Conference. Springer, Wiesbaden, pp. 13–29.
Ziemann, S., Grunwald, A., Schebek, L., Müller, D.B., Weil, M., 2013. The future of mobility and its critical raw materials. Rev. Metall. Cah. D'Informations Tech 110, 47–54. https://doi.org/10.1051/metal/2013052.