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Electric Car Market Analysis Using Open Data: Sales, Volatility Assessment, and Forecasting

Dmitry V. Pelegov 1,* and Jean-Jacques Chanaron 2

1 Institute of Natural Sciences and Mathematics, Ural Federal University, 19 Mira Street, 620002 Ekaterinburg, Russia
2 Grenoble Ecole de Management, 12 rue Pierre Sémard, 38000 Grenoble, France
* Correspondence: dmitry.pelegov@urfu.ru

Abstract: In the context of the growing popularity of electric cars, it is important to track the sustainability of this emerging industry. This work presents the results of electric vehicle sales up to and including 2021, proposes volatility assessment and short-term forecasting using normalized monthly sales analysis, and discusses why quantitative long-term forecasting is impossible. In cases where authorities and regulators are the main driving forces of change, the electric car market does not need forecasting, but instead requires proper goal setting and timely published market data with open access.

Keywords: electric vehicles; electromobility; goalsetting; forecasting; governmental policy

1. Introduction

Electric vehicles and renewables symbolize the global shift toward sustainability. People want to live in a safe world, but uneven distribution of oil reserves makes the political situation less stable and causes wars and political conflicts. People want to breathe clean air, but conventional automobiles with internal combustion engines have become one of the major sources of air pollution in large cities. The decrease in air pollution during the COVID-19 lockdowns clearly illustrated that not using fossil fuels can make the air cleaner [1], but most people want to make the world better without losing mobility.

Electric vehicles (EV) make zero-emission mobility possible and are becoming more and more popular. In 2021, global sales of electric cars reached 6.6 million or almost 9% of the global car market. People do not want to wait; however, the phasing out of burning fossil fuels is a great challenge. It will take a long time, and the technological inertia of the global automobile industry slows down radical innovations [2].

Will our world become sustainable in our lifetime? Can one predict what will happen with EV production and sales within the next decade or two? Some predictions and estimations can be found in the annual outlooks prepared by international organizations and analytical companies. Two of the most popular outlooks are published by Bloomberg New Energy Finance (BNEF) and the International Energy Agency (IEA). The Electric Vehicle Outlook, reported by BNEF, provides full data to subscribers only, but also has a free interactive executive summary available online [3]. Global EV Outlook [4], published by IEA, is an open-access annual report.

Another source of EV market analysis is scientific publications, but academic researchers, contrary to industrial ones, usually avoid forecasting and outlooks. Possibly, this is due to lack of market data published in scientific publications, or concern for personal reputation. The main part of published scientific papers with EV market analysis and outlook can be roughly divided into two groups. The first group represents technology overviews with cautious qualitative evaluation of EV prospects (see, for example, early papers [5–8]). The second group includes numerous publications with quantitative
forecasts, made using simulation and modeling [9–14]. In such theoretical papers, researchers study how a model can be used for EV market growth forecasting and how this forecast will change with variation of the model’s parameters, e.g., car cost, energy price, and pollution regulation standards. In this case, the responsibility for forecasting effectiveness is shifted from researchers to the model used.

The significant problem of “academic” forecasting and outlooks for the EV market is that they lag behind industrial outlooks and market reports. There is about a half-year lag from year’s end to annual market report releases. After that, researchers spend a half-year or more to perform analysis and prepare the paper. Another half-year is spent for revisions, resubmissions, and paper publication. An almost two-year lag together with the young age of the EV industry has led to the lack of real market data in most articles published in previous years. As a result, early papers often were focused on conventional hybrids, which arrived on the market a decade earlier than EV [9,15,16]. Only recently, the accumulated market data have achieved some critical value, enabling a new wave of research papers focused on EV prospects and outlooks [12,17–23].

Besides the shortage of annual EV sales data, the young age of the EV industry could be responsible for another problem: incomplete utilization of all the available market data. Annual EV sales are just one integral parameter characterizing the EV industry. In addition, one can find scattered sales data by brand, model, and monthly sales by region. Monthly EV sales charts be found, for example, at such open sources as the European Alternative Fuels Observatory [24] (Europe only, since 2013), EV-sales [25] (global and local data, from 2013 to 2021), insideEVs [26] (US only, since 2011), and CleanTechnica [27]. In 2022, one can find monthly sales data for about the last nine years. This is not much, but it is enough for some simple statistical analysis. As a result, now, EV sales peculiarities can be analyzed at two timescale regions, but the market behavior at a monthly timescale is less intensively studied in both industrial outlooks and research papers.

This paper is conceived as three in one; therefore, it consists of three main parts covering the past, present, and future of the global EV market. First, it uses the EV sales data up to and including 2021. Second, monthly EV sales data is studied using a novel approach to assessing the volatility of local EV markets. Finally, the paper aims to understand what to expect in the future.

2. Methods

Quantitative sales analysis and outlook require data. In this work, we used open-source data. We recommend reports within the Electric Vehicles Initiative by International Energy Agency (IEA) [4], data from the European Alternative Fuels Observatory (EAFO) by the European Commission [24] (detailed statistics for European countries), EV sales blog [25]—the open source version of EV Volumes database, insideEVs [26], and CleanTechnica [27]. The analytical company Bloomberg New Energy Finance (BNEF) provides an open-access executive summary of its Electric Vehicle Outlook [3]. Furthermore, some previous academic research on electric vehicles (since 1973) is used [28,29].

In this work, we introduce a normalized monthly sales parameter $V_{\text{norm}}(i)$, which we propose to use for quantitative characterization and analysis of EV sales during twelve months. For a full year, $V_{\text{norm}}(i)$ is defined as the EV sales volume in the $i$-th month, divided by the average monthly EV sales volume for this year. This normalized parameter $V_{\text{norm}}$ allows us to compare EV sales in different years, average this parameter over years, and use the obtained averaged dependences for a volatility assessment and short-term forecasting.

Hereinafter, electric vehicles are abbreviated as EV and used to indicate plug-in cars—pure electric and plug-in hybrids cars combined (without conventional hybrids).
3. Results and Discussion

3.1. Past: EV Sales

Before looking into the future, one must first look back. As one can see in Figure 1, global EV sales demonstrate fast growth. Global EV sales reached 6.6 million per year in 2021 or about 8.5% of annual global car sales. Slow-down of EV adoption rates in 2019 was later compensated by impressive growth in 2020 despite the COVID-19 pandemic. The steady growth for eleven consecutive years is impressive, but the difference between 2019 and 2018 was less than 200,000 plug-in cars. In the same year, Tesla alone produced 367,000 electric cars (about 17% of global EV production), and without its efforts, one would witness the regression of the global EV market in 2019. Thus, can one consider the EV market sustainable if, a few years ago, its progress heavily relied on the success of an emerging carmaker? Of course, Tesla is the symbol of the burgeoning popularity of EV, but is it a stable company that can ensure sustainable EV growth at a global scale?

While global sales summarize local ones in different countries and regions, here, we analyze the data from three of the main contributors to global EV sales, namely, China, Europe (jointly), and the United States. The US initially led the global EV market but was overtaken in 2015 by China and Europe. In the following years, China was the main driver of EV market growth except for 2020, when Europe overtook China. Jointly, Europe and China were responsible for about 65% of the global EV market in 2020, and 85% in 2021.

3.1.1. The United States

In the United States, annual EV sales have demonstrated steady linear growth with a year-over-year sales increase of about 35,000 plug-in cars since 2010 (Figure 1, straight blue line). The positive divergence that occurred in 2018 suggested a sales curve deflection toward faster rates of EV adoption, but sales in 2019 and 2020 demonstrated this was a one-time random deviation. This local peak can be explained by the success of the Tesla Model 3 before the expiration of federal EV tax credit for all Tesla’s models in the USA. Unfortunately, this stability of growth is rather ambiguous due to low national EV market...
share (about 3%), about three times below the global share (about 8.5%). Due to such a slow growth rate, the US EV market was overtaken not only by China and Europe (jointly) but also by Germany in 2020 and 2021. The results of 2021, preliminary results of 2022, the Inflation Reduction Act of 2022 [30], and the important announcements of legacy US automakers to create joint ventures with major lithium battery manufactures indicate a change in growth rates in 2022 and beyond.

3.1.2. Europe

First registrations of EV in Europe are dated 2008 [24]. In 2021, the European EV market reached a solid 18% share and became an indicator of the further growth of the global EV market. Norway, with its 86% EV market share in 2021 (62% for pure electric cars alone) [24], is a role model for EV-adopting countries. Germany became a new European leader in 2019 and its EV share reached 25% in 2021 (Figure 2a). Even the Netherlands and Denmark have demonstrated four years of growth after two years of decay (Figure 2b). As a result of joint efforts, steady but slow linear growth from 2012 to 2018 with a year-over-year increment of about 70,000 units (green line in Figure 1) was followed by much faster growth in 2020 and 2021.

![Figure 2. Annual plug-in cars sales in some (a) persistent and (b) inconsistent local EV markets. The data are taken from open sources described in the first paragraph of Section 2.](image)

EV sales in the European countries were stimulated by both local and EU authorities. During the first decade of EV adoption, the local initiatives dominated EU policy. The most explicit example is Norway, with its elaborate EV adoption program. The opposite example of inconsistent local governmental policy is the Netherlands, with pronounced
instability of EV sales (Figure 2b). Since 2019, the situation has changed, and the role of EU policy increased due to a new emission regulation, setting a EU fleet-wide target of 95 g CO₂/km for the average emissions of new passenger cars [31]. As a result of this policy, the European countries have had the highest EV market share in the early 2020s.

3.1.3. China

The introduction of the “The thousands of vehicles, tens of cities” program in 2009 can be considered the starting point of the EV market in China [32,33]. As seen in Figure 1, the first decade (up to and including 2018) was rather sustainable and could be characterized by an optimistic exponential growth in sales (Figure 1, red line) [17]. This exponential growth ended in 2019. Such a slowdown was rather expected, since the stagnation in sales was caused by a change in the national EV policy and it was planned years ago [21,32,34–39]. Briefly, the main change is the transition from subsidies to credits. Subsidy means that the government pays consumers (via carmakers) to make the purchase less expensive. Credit policy implies that a carmaker that is producing an insufficient number of electric cars pays another one that is producing more electric cars than required.

The automobile industry in China needed some time to adapt to such a drastic change in regulation policy. On one hand, the 2021 results were very optimistic and the national EV sales exceeded 3 million, and the EV market share reached 15% of new car sales, slightly below Europe (18%) but well above the global value (almost 9%) and the United States (3%). On the other hand, this growth was supported by the extension of national subsidies [40]. There is still the question of whether the EV market in China has returned to fast growth or whether the postponed change of EV policy, repeated lockdowns, and increased political instability will affect the sustainability of EV market growth.

3.1.4. Other Countries

Among other countries, we want to mention South Korea, Canada, and Japan. EV sales in South Korea reached almost 115,000 units, resulting in more than 7% market share in 2021 [41,42]. In Canada, the EV market share reached 5.6% or 74,000 units [43,44]. Japan is the most unusual example of EV adoption. Japan led the global EV market in 2010 and 2011, but further growth was replaced by a decrease in 2015 and 2016. EV sales growth in 2017 was followed by steady a decrease up to and including 2021 (Figure 2b). We suppose that the decisive role of Toyota Motor Company, with its commitment to traditional hybrids and doubts about the future of all-electric models, and the correlation between the global sales of Toyota Prius Prime and the EV sales in Japan (Figure S3) somehow justify this point of view. Nonetheless, the peculiarity of electric vehicle sales in Japan deserves detailed study, and this work can provide an important contribution to the understanding of the sustainability of the global EV market.

South Korea, Canada, Japan, and many other countries are interesting objects for EV market study, but the lack of open data complicates accurate analysis for these local markets.

3.2. Present: Monthly Scale Volatility Tracking

After a decade of EV sales, the accumulated market data allowed for a simple statistical analysis. In this work, the analysis of normalized monthly sales helps to assess the volatility of national EV markets. The normalized monthly sales value \( V_{\text{norm}} \) is defined as

\[
V_{\text{norm}}(\text{year})_i = V(\text{year})_i \times 12/V_{\text{annual}}(\text{year})
\]

where \( V(\text{year})_i \) is the EV sales volume in the \( i \)-th month of the year and \( V_{\text{annual}} \) is the annual EV sales for this year (Figures 1 and 2). The proposed normalization excludes year-over-year growth from consideration and helps to focus on a sub-year timescale. The
underlying concept is very simple. A stable market is expected to be characterized by a reproducible $V_{\text{norm}}$ curve, while market instability is supposed to be accompanied by perturbations.

Figures 3 and S1 present the results of $V_{\text{norm}}$ curve analysis for various countries. Filled black squares correspond to mean values of $V_{\text{norm}}$ (hereafter, $\langle V_{\text{norm}} \rangle$). The averaging was made over six years (from 2015 to 2021, except 2019) for China (Figure 3a, Figure S1a), and over eight years (from 2013 to 2021, except 2020) for the United States (Figure 3b, Figure S1b) and European countries (Figure 3c–i, Figure S1c–i). Anomalous years (2019 for China, 2020 for the United States and Europe) were removed from averaging due to their deviation from usual behavior (Figure 3).

![Figure 3](image-url)

Figure 3. Normalized monthly EV sales in (a) China, (b) USA, (c) Europe, (d) Germany, (e) Norway, (f) France, (g) UK, (h) Sweden, and (i) the Netherlands. Real monthly sales are divided into average monthly sales for the given year. A filled black square line corresponds to averaging over previous years (excluding 2019 for China and 2020 for the others). The $V_{\text{norm}}$ curves for years from 2013 to 2019 are shown in Figure S1. The data are taken from open sources described in the first paragraph of Section 2.
The turbulence of the Chinese EV market in 2019 can be illustrated by Figure 3a (upward-pointing triangles). EV sales during the first six months were significantly above the average due to the declared end of subsidies in July 2019. These above-normal sales were later balanced by below-normal sales during the second half of 2019. In order to mitigate the negative effect of the pandemic and to smooth the transition from subsidies to credits, Chinese authorities extended its tax exemption and prolonged subsidy policy to the end of 2022 [45]. As a result, in 2020 (downward-pointing triangles) and 2021 (filled circles), the monthly EV sales curve returned to its normal behavior (Figure 3a).

EV markets in the United States and Europe perturbed during the pandemic in 2020 (downward-pointing triangles in Figure 3b–i) with a significant drop in sales in April and May due to lockdowns. Later, this drop was balanced by EV sales growth in the second half of the year. In China, \( V_{\text{norm}}(2020) \) also deviated from the average, but on a much smaller scale. In 2021, all major EV markets returned to the usual shape of their \( V_{\text{norm}} \) curves (filled circles in Figure 3).

Anxiety of the local EV market was observed in some of previous years but mainly due to local events (Figure S1). For example, there was a notable deviation of \( V_{\text{norm}}(2019) \) from \( <V_{\text{norm}}\) in the United States (Figure S1b). This jump in June 2019 was driven by Tesla alone and helped Tesla to report record deliveries in Q2 2019, somehow compensating a further post about a larger-than-expected loss. For the US too, the deviation of \( V_{\text{norm}}(2018) \) from \( <V_{\text{norm}}\) (right triangles) can be noted. The \( V_{\text{norm}}(2018) \) value was below average in the first half and above in the second half of the year. This peculiarity can be explained, again, by analysis of Tesla sales. Tesla Model 3 entered production in late 2017, and the following year became known as “production hell” for Tesla. Production jumped from almost 10,000 units in 2018 Q1 to 53,000 in 2018 Q3 and 61,000 in 2018 Q4 [46].

Monthly sales curves \( V_{\text{norm}} \) for joint European EV market were rather consistent (reproducible) from 2014 to 2019 (Figure S1c–j). The pronounced deviations of \( V_{\text{norm}}(2013) \) (crosses in Figure S1) can be explained by EV market immaturity and low sales volumes resulting in insufficient statistics. For example, in Norway the \( V_{\text{norm}} \) curve deviates from typical behavior throughout 2013. From 2014 to 2019, \( V_{\text{norm}} \) curves became rather reproducible for overall European sales (Figure 3c, Figure S1c), as for local European markets (Figure 3d–i, Figure S1d–i). At the same time, there were anomalies even in this relatively stable period. The \( V_{\text{norm}}(2014) \) for the Netherlands (pentagrams in Figure S1i) and the \( V_{\text{norm}}(2015) \) for Sweden (asterisks in Figure S1h) abnormally peaked in December, possibly due to expected local policy changes in both cases.

Normalized monthly sales enables not only qualitative but also quantitative analysis. We propose to use the standard deviation (SD) of \( V_{\text{norm}} \), which allows one to track changes over years and compare EV market volatility between countries (Figure 4).

\[
\text{SD (year)} = \sqrt{\frac{1}{12} \sum_{i=1}^{12} (V_{\text{norm}}(\text{year})_i - \langle V_{\text{norm}}(\text{year}) \rangle)^2}
\]

As one can see, the EV market in the United States was the most consistent for years, but since 2018, there is a trend of deviation growth. A similar effect is observed for Europe. China has also demonstrated reproducibility of \( V_{\text{norm}} \) curves with low standard deviation, but the change of national EV policy made 2019 a year of upheaval. In 2021, the Chinese EV market regained stability, but the question is how long this stability will last.
Figure 4. The SD calculated using Equation (2) for the main EV markets. The data are taken from open sources described in the first paragraph of Section 2.

3.3. Present: Near-Term Forecasting

The reproducibility of local EV sales on a sub-annual scale raises concerns about a near-term forecast. How accurate can an assessment of year-end results be using the results of the first few months? Figure 5 helps to estimate the accuracy of forecasts based on averaged $V_{\text{norm}}$ curves.

In the $i$-th month of the year, the forecast of the full-year results $V_{\text{est\,ann\,(year)}}$ can be made using the factual monthly sales $V(\text{year month})$:

$$V_{\text{est\,ann\,(year)}} = \sum_{j=1}^{i} V(\text{year month}) \cdot \frac{12}{\sum_{j=1}^{12} (V_{\text{norm}})}$$ (3)

For example, EV sales in the United States in January 2021 indicated as $V(2021)_{1}$ amounted to 25,000 units. $<V_{\text{norm}}>$ for the US is 0.54. Thus, the estimated annual sales $V_{\text{est\,ann\,(2021)}}$ were 556,000 units or 17% less than actual sales volume (672,000). In March 2021, the three-month cumulative EV sales amounted to 127,000 units and $V_{\text{est\,ann\,(2021)}}$ was 686,000; thus, the assessment error decreased to about 2%. Forecast error can be estimated as a percentage:

$$\delta(\text{year}) = \frac{\{V_{\text{est\,ann\,(year)}}/V_{\text{act\,ann\,(year)}} - 1\} \times 100\%}{\delta(\text{year})}$$ (4)

As shown in Figures 5 and S2, the forecast error is minimal for the most predictable US EV market. It did not exceed 26% even in the turbulent year of 2020. Europe (jointly), Germany, Norway, and, somehow, France are also rather predictable markets, but in anxious years, error may reach 50%. The UK and Sweden are less predictable, and the Netherlands is the most unpredictable country among the largest European EV markets (Figure S2).
Figure 5. The error of annual EV sales forecasting using Equation (3) for (a) China, (b) the USA, and (c) Europe (jointly). Results for major European EV markets are shown in Figure S2. The data are taken from open sources described in the first paragraph of Section 2.

The near-term forecasting of global EV sales is difficult due to the lack of monthly global EV sales data. At the same time, in recent years, China, Europe, and the United States jointly contributed about 94% of global EV sales, so the near-term forecasting of the global scale using Equation (3) is also possible. To estimate year-end results of the global EV market, one can summarize $V\text{est\,ann}$ values for China, Europe, and the United States. The sustainability of the global EV market can be obtained when a drop in sales in one major EV market is offset by growth in sales in two others. In terms of forecasting, an overly optimistic estimation can be balanced by an overly pessimistic one. As shown in Figure 6, balancing somehow works, except for turbulent years. Forecasts for the global EV market made using results of first few months can be both overly optimistic (2016, 2019, 2021) and overly pessimistic (2017, 2020). In stable years, the error is below 25% and decreases to about 10% in the first half of each year. In turbulent years, the error can reach 100%, mainly due to the leading role and specificity of the Chinese EV market.

Figure 6. Statistical analysis of the forecasting error using Equation (4) for three major EV markets: China, Europe, and the United States. The data are taken from open sources described in the first paragraph of Section 2.
3.4. Future and the Problems of Quantitative Mid- and Long-Term Forecasting

Measuring the sustainability or volatility of the electric vehicle market can be a valuable analytical tool, but the main challenge is to answer the question “What is next?” Can EV sales be predicted for the next few years, a decade or even more distant in the future?

Some organizations try to predict them to be prepared for upcoming challenges. Mid-term outlook of the growing EV market can be found in the open-access annual report, Global EV Outlook [4], of the IEA. In the 2022 edition, three different scenarios consider how implementation of announced policies can drive EV sales growth. The projected 2030 annual EV sales are supposed to surpass 30 million (over 20% of sales) or 45 million (about 33% of sales) depending on the scenario. It is worth noting that even a conservative forecast assumes a fivefold increase in annual sales in less than a decade.

Another outlook together with demonstrative comparison of different long-term projections can be found in Electric Vehicle Outlook [3], prepared by BNEF. Its near-term outlook estimates that global EV sales will exceed 20 million (23% market share) in 2025. China and Europe are expected to account for almost 80% of the global EV market. The long-term outlook predicts about 40 million in 2030 and more than 70 million in 2040 (about 40% and 70% of the market share, respectively).

It should be noted that almost all forecasts are becoming increasingly optimistic year by year. In 2019, BNEF provided a comparison of the various EV outlook transformations from relatively pessimistic in 2016 to more optimistic in 2018 (for all projections), thus demonstrating that such outlooks are rather expectations/estimations of the industry experts, but not scientific analysis of the existing market data [47]. The same BNEF forecast for 2040 grew from 57% in 2019 to over 70% in 2022.

How precise can the forecast be? Unfortunately, even such a leading think-tank in the field of electromobility as BNEF can make mistakes, even in the short-term outlook. In 2020, they correctly estimated the drop in global automobile sales due to the pandemic, but the estimation of EV sales was too discreet and pessimistic. BNEF expected that EV sales would decrease to 1.8 million, but they grew to about 3.1 million, and the year-over-year growth was observed both in Europe and China. EV sales in the US decreased in 2020, but not by the expected 18%, but only by about 1%.

Thus, can anyone correctly estimate future EV sales? At first glance, the correct answer is “more likely no than yes”, at least at the global scale. One can project past sales curves to the next decade only supposing the same conditions and driving forces. Among major local EV markets, this requirement was somehow fulfilled only for the US with its slow but relatively sustainable growth (Figures 1 and 3b). In the case of the European countries, the projections were relevant due to market sustainability until 2019 (Figure 3c–f), but the growth of EV sales in 2020 was clearly abnormal, with a new emission regulation [31] combined with the pandemic strongly affecting the European automobile market in 2020 and 2021. China, the key EV market today, is far from being predictable even on a monthly scale. The support of EV adoption in China was steady [48], but this has not resulted in smooth and predictable growth of the local EV market (Figure 1). The designed switch from subsidy-based to credits-based policy is still not complete and the Chinese EV market (Figure 3a) must first restore medium-term stability, and only after that can the forecasts become reasonable.

Another consideration is the existence of factors that limit sustainable EV market growth. The main ones are production capacities for EVs, their traction batteries and critical materials. The abovementioned periodicity of monthly EV sales suggests that limited EV production capacity restrains faster EV adoption rates (at least for the US and Europe). The recent fast growth of the lithium battery industry makes the problem of traction battery undercapacity less likely, but one has to keep in mind various risks of the critical material supply chain [49–51]. While most authors agree on low supply risks for lithium, cobalt, and nickel resources [51–55], the mining industry could still have some limitations in terms of growth rates [50,54]. The recent announcement made by the largest EV manufacturer, Tesla, on using LFP-based batteries instead of NCA ones illustrates that the
industry does not fully share the researchers’ optimism about sustainability of nickel production and/or price.

Another often-underestimated factor impeding electromobility growth is a crossover between the EV industry and renewable energy generation. This coupling between two industries can both enhance and impede the other. Slow growth of renewables’ share in energy mix limits the ecological, economic, and political benefits of EV adoption. Fast EV market growth will drive the growth of vehicle-to-grid solutions, and it can become the key component for balancing the instability of renewables. Too-fast EV adoption rates will increase the demand for traction lithium batteries, thus limiting its price decrease and, possibly, resulting in lithium battery underproduction. It will negatively impact the market of stationary energy storage systems, which is very important, again, for balancing the instability of renewables.

There are many other factors limiting EV market growth, including high insurance cost for EV, insufficiently studied fire risk of batteries [56], traction battery degradation rate in various conditions, and availability of fast charging slots. The EV market is an emerging industry and, during its maturation, all of the abovementioned limiting factors could slow growth rates and make the global EV market more volatile.

3.5. Future: From Forecasting to Goalsetting

The fast-growing EV market is an interesting object for detailed study, but very complicated for correct description of ongoing processes. It is like a physical multicomponent system with varying driving forces and unknown boundary conditions experiencing a series of spatially distributed phase transformations at different rates. One can somehow try to model it or make near-term projections for subsystems (local markets), but the proper description of the whole system appears to be impossible. However, this is not required.

The main driving force of EV adoption is the necessity in sustainable development. Society is not a bystander, but the motivating power for change. This idea is explicitly stated in the 20th KPMG Global Automotive Executive Survey [57]. In the “Underestimated driving forces” section, the survey says that 77% of the global automobile industry executives agree that, currently, the future technological agenda is formulated by regulators. Thereby, the EV market today does not need forecasting. The EV market needs proper goalsetting by local and global regulators. The new EV era was initiated by the California Air Resource Board in 1990 by clear goal formulation in the Zero Emission Vehicles rules and targets [58,59].

From this perspective, the IEA’s Global Energy and Climate (GEC) model [60] is balanced enough to be considered as a reference. This model explores three scenarios, namely, Net Zero Emissions by 2050 Scenario (NZE), Announced Pledges Scenario (APS), and the Stated Policies Scenario (STEPS). The NZE is normative, while the APS and the STEPS are exploratory scenarios, based on pledged commitments and implemented policies.

3.6. Future: Progress Tracking and the Need for Open Data

In the case of clearly indicated targets, analysts and researchers will be able to track progress. However, there are at least two problems. First, there is a clear lack of properly defined short-, mid-, and long-term targets with milestones. Second, there is a shortage of open data.

In the United States, the EV adoption goals and corresponding driving forces are formulated in California [61] and other “ZEV states”, but not at a federal level. As a result, California can boast of the national’s highest EV market share (7.1% [62]), but the overall EV sales in the US (2.2% nationwide) lagged behind the other major automobile markets. The Inflation Reduction Act of 2022 [30] could boost EV production and sales, but clear goalsetting is still required. Besides proper goalsetting by federal regulators, there is a lack of open data for EV market. EV monthly sales can be found at [25,26], but only up to 2019...
and without a breakdown of state sales, which is so important for analysis. Since 2020, [25,26] ceased the publication of the US sales scoreboards due to a lack of available data. The US monthly sales are still published by Auto Alliance [63], but with a half-year lag.

The European Union (EU) set targets for EV sales, and the “European Green Deal” is one of six European Commission priorities for 2019-24 [64]. These targets are common to all EU countries and voluntary [61], but while such a compliance flexibility mechanism helps automakers to adopt new regulations, it also obstructs EV adoption tracking. Open data for EV sales in the Europe can be found at the European Commission’s European Alternative Fuels Observatory [24], providing well-structured and timely data. Unfortunately, in 2022, the EAFO changed its publication policy and their well-structured data are either not available any more or hidden. Pontes’ blog [25] was an alternative source of early open data with some additional details and analytics but was closed in 2021.

Chinese “The thousands of vehicles, tens of cities” program [32,33,65], utilizing the main ideas of its Californian forerunner, was an example of effective goalsetting. Proper agenda setting enabled exponential growth of the Chinese EV market up to and including 2018. Unfortunately, this growth slowed in 2019 and 2020. These EV sales perturbations in China happened when the previous agenda became outdated and a new one had not yet been clearly formulated. In 2021 and 2022, the Chinese EV market returned to rapid growth, and Chinese authorities have extended stimulus measures until the end of 2023 [66]. Unfortunately, there is still a lack of up-to-date and detailed open data for nationwide and local EV sales in China (at least, in English). The same problem of the EV market data shortage has been observed for Japan, South Korea, India, and many other large and small markets.

4. Conclusions

Electromobility is emerging as one of the key elements of a sustainable society, but the question is whether the EV market itself is sustainable. Global EV sales reached 6.6 million in 2021, but this means less than 10% of all sold cars were plug-ins. The phenomenal progress in Europe, achieved despite the COVID-19 pandemic, and uneven but steady growth of the EV market in China was counterbalanced by stagnation in the United States and depression in Japan.

To analyze and track the volatility of global and local EV markets, we proposed a novel approach based on the analysis of normalized monthly sales data. The applicability of this approach is limited only by the availability of monthly sales data. This analysis demonstrated the notable EV market perturbations in 2019 for China and in 2020 for Europe.

One of the main results for 2020 is that the global EV market demonstrated a surprising stability in the face of such a global challenge as the COVID-19 pandemic. This stability became a vivid demonstration that forecasting the sales of electric cars remains a perilous exercise. However, because the current transformation of the automobile industry at local and global scales is driven by regulators, the sustainable development of electromobility does not need forecasting, but instead requires clear goalsetting and advanced tools for controlling progress. Furthermore, to monitor inevitable market perturbations and provide agile adjustment of governmental policies, if required, both the research community and decision makers need properly formulated short-, mid-, and long-term targets together with timely published open data about sales and production of both vehicles and their traction batteries.

Without clearly defined goals and milestones, and with the lack of open data, academic researchers can hardly properly estimate EV market prospects for such key markets as China, the United States, and Japan. In terms of how researchers can contribute, first, they must motivate authorities in relation to reasonable goalsetting. Second, they must request data sharing for the EV and lithium battery industries. Information is a key element of modern society, and its sustainable development needs proper and timely information sharing among the industry, the authorities, and the research community.
Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/ie.15010399/s1, Figure S1: Normalized monthly EV sales till 2019; Figure S2: The error of annual EV sales forecasting using Equation (3); Figure S3: The comparison of global sales of Toyota Prius Prime and the EV sales in Japan.

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