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Overcoming the Barriers of Mass EV Introduction

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Summary

The **most important driver** for a switch to electric road vehicles is their underlying **economics**. Based on a TCO analysis Ecofys/Navigant Research expect **global PEV population** to rise to near **44 million by 2026.** This Ecofys/Navigant Research paper also highlights other main barriers to global mass EV adoption and how to overcome them.

Widespread, **convenient charging accessibility** is critical for the uptake of electric mobility, among others **work and public charging** need to be developed further. We also suggest to stimulate **carsharing** and **automated driving**, since they very likely lead to electrically powered vehicles.

Keywords: market development, mass market, EV (electric vehicle), EVSE (electric vehicle supply equipment), automated

1 Electrification of the Light Duty Vehicle Market Continues

Declining costs have positioned the battery EV (BEV) for dramatic market success in the years to come. Long-range BEVs are now price-competitive among economy brands after subsidies. This milestone marks a threshold likely to **move BEVs from a niche vehicle option to the next vehicle option** for many light duty vehicle consumers. Additionally, over 500,000 preorders of Tesla's Model 3 indicate that affordable 350-plus km BEVs will have a big impact on the vehicle market.

Beyond the attention-grabbing headlines of the long-range BEVs, however, **plug-in hybrids (PHEVs) are also making significant advances**, with the global 2016 market estimated to be around 50% larger than the prior-year market. Continued market expansion is likely to result from expanding OEM applications of the powertrain in new, larger vehicle body types where BEVs typically do not compete.

Meanwhile, sales of conventional plug-less hybrids (HEVs) have slowed. A contraction in 2015 likely had multiple drivers, including the increasing popularity of plug-in EVs (PEVs: BEVs and PHEVs), OEM adoption of alternative fuel efficiency technologies (e.g., downsizing and turbocharging), and sustained low oil prices. Despite these market pressures, revelations of emissions test cheating software in fuel efficient diesel vehicles have buoyed HEV market potential in Western Europe, and **HEV sales in the region have been on the rise**.

1.1 Paper Scope and Definitions

This paper examines the next decade of the light duty vehicle market, with a specific focus on how to overcome the barriers to mass EV adoption. The following vehicle platforms are covered in this paper:

1. **PHEVs:** An advanced version of the HEV, the PHEV has a larger battery that can be charged from off-vehicle sources. The PHEV typically provides 25-50 km of all-electric range in addition to the 300- to 400-mile range provided by the internal combustion engine (ICE). The longest all-electric range on a PHEV is found in the Chevrolet Volt/Opel Ampera, with a range estimate of 53 miles.
2. **BEVs:** This vehicle platform has a large battery and no ICE. Outside of a few instances, the BEV range is typically around 100 miles, though new BEVs with extended ranges are expected soon.

2 Economics: A Precursor for Mass Adoption

Ecofys and Navigant Research use total cost of ownership (TCO) analysis to determine when certain users will switch to EVs based on a breakeven analysis. The first model that serves as a basis for this analysis was presented in Ecofys' paper, *Cost Effective Introduction of Electric Vehicles* [1]. Navigant Research's model, which is often used in market forecasts, is described in more detail in its report, *Market Data: Electric Vehicle Market Forecasts* [2]. **The mass EV introduction results are determined by evaluating each powertrain-fuel combination's TCO in addition to consumer sacrifices born from either range limitations or scarcity of refueling infrastructure.** Of note, though useful vehicle life is usually around 1-2 decades, Ecofys' and Navigant Research's TCO analysis is based on a 60,000 km travel period (roughly 3 years), reflecting typical fleet purchasing patterns and the high percentage of PEVs purchased through lease. Powertrain costs are assumed to be constant through all markets. The final TCO analysis is best represented in the following high level equation:

$$\textbf{TCO = (Purchase Cost + Operating Cost - Resale Value) / (km Traveled)} \quad (1)$$

2.1 Purchase Costs

BEV prices have dropped significantly in the past years because of cheaper batteries. However, the battery remains the most important cost driver: $27,000 for a large 80 kWh battery in 2017. With the cost coming down rapidly, it is more important to look at a more detailed TCO, which Ecofys/Navigant Research used in its analysis of the Netherlands and Norway.

Ecofys and Navigant Research projections on battery prices (which includes battery cells and packs) for BEVs **show a gradual decline through 2025 to around $175 per kWh, almost half of the costs today** [3].

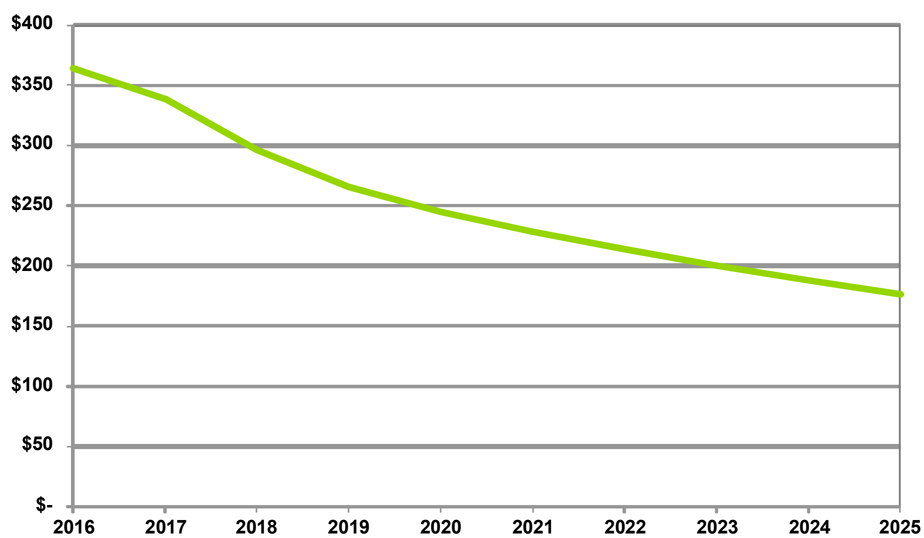

Figure 1: BEV Battery Pack Price by Scenario, World Markets: 2016-2025

Although PEVs are costlier than conventional platforms and BEVs require some convenience sacrifices for the average vehicle consumer, the market for these technologies has developed a solid foundation, largely due to government support. Interest in oil displacement for environmental, geopolitical, or economic reasons has fueled widespread funding of battery R&D, EV supply equipment (EVSE) infrastructure expansion, purchase subsidies, and ownership benefits from many governing bodies.

2.2 Subsidies, Incentives, and Policies

Government taxes and subsidies vary significantly from market to market. Therefore, it is important to bring this aspect into the model to project market uptake. Ecofys/Navigant Research analyzed the e-mobility uptake in the European Union (EU) based on a large variety of parameters, spanning from number of supporting incentives for electric cars to availability of recharging infrastructure. The results (front-runners in green and laggards in red) are visualized in Figure 2. In 2016, Ecofys investigated the appropriateness of current policies related to the deployment of recharging infrastructure for electric road vehicles for the Dutch [4] and Norwegian [5] governments (the front-runners).

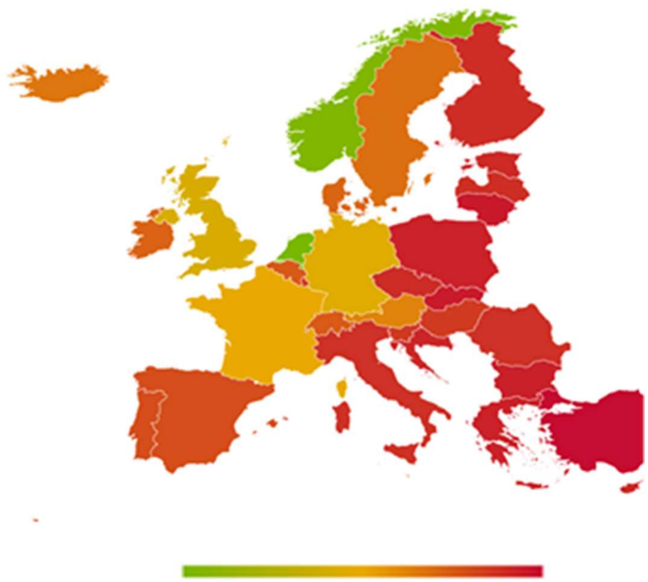

Figure 2: EV Front-runner and laggard countries in Europe (analysis by Ecofys)

3 Charging Infrastructure Dependant on User Group Needs

Ecofys'/Navigant Research's TCO model can be adopted when zooming in on a certain country or particular user groups. For instance, in the Netherlands, we distinguished three types of users for passenger cars, business drivers, commuters, and private drivers, based on their annual mileage, type, and lengths of trips. For vans, a distinction was made between three types of users: contractors, delivery vans, and service providers.

In the base analysis scenario, the TCO of fully electric vehicles breaks even with the TCO of conventional vehicles for business drivers from 2017, for commuters from 2019, for private drivers from 2027, and for vans from 2023 [4].

In order to determine which charging infrastructure will be used per car user type, rules were set to determine the order in user's loading preferences. The following order in load preferences was established:

1. Most preferred option is to charge at home or at work (at the normal work location and elsewhere as a business visitor).

2. Charging at a public location (including semi-public) is the second most preferred option, in case home or at work charging is not possible.
3. The least preferred alternative is fast charging. Ecofys and Navigant Research assume assume a PHEV can drive on the ICE and therefore will not use a fast charger often along the highway.

Ecofys and Navigant can forecast the required charging infrastructure in detail, based on a certain number of drivers and their charge patterns. Changes in battery sizes and charge power can be added to the model to see what happens at various timelines.

4 Significant Investments Required in Charging Infrastructure

A few key stakeholders with the potential to make significant investments in charging infrastructure will continue to play a major role in the charging market over the next few years while the PEV market grows. **Governments, utilities, and automakers are making major commitments to charging deployments, either through funding support or direct rollouts.**

Policymakers are developing programs to recognize the necessary coupling of two huge markets—transportation and power—through policies and incentives that have far-reaching implications for each. Within this transportation-utility nexus, advanced analytics will be used to coordinate the energy demand of powering the electrified transit fleets, delivery vehicles, and marine vessels with that of smarter city infrastructure to enable a holistic view of regional energy demands across the Energy Cloud [6].

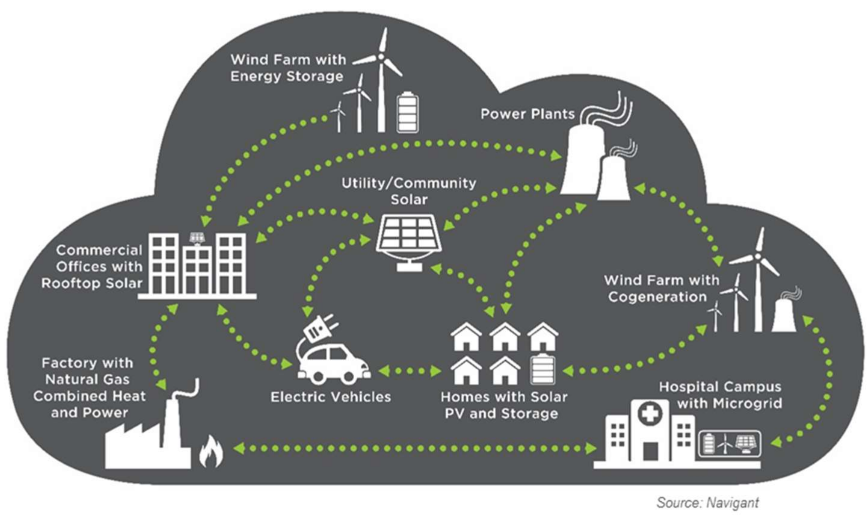

Figure 3: The Energy Cloud

EV charging technology options fall into three main categories in this paper: alternating current (AC) charging, direct current (DC) charging, and wireless charging. Descriptions of these technologies are in the sections that follow, along with a discussion of the technology issues surrounding networked charging.

4.1 AC Charging

AC charging is the most common EVSE type due to its relative affordability, compared to other options, and because the most basic units require no grid infrastructure upgrades. AC EVSE capacity is limited by the onboard vehicle charger that converts the grid-supplied AC power into battery compatible DC power. Onboard AC charging capacity was initially limited to 3.3 kW. Given the standard efficiency range of electric drive, this provides about 10 miles of range per hour of charging. However, the automotive industry was quick to double onboard charging capacity to 6.6 kW. Certain EVs are capable of handling higher loads, like the BMW i3 (7.2 kW), the Tesla Model S (20 kW), and the Renault ZOE (22 kW).

4.2 DC Charging

DC charging offers the closest experience to conventional refueling. In this method, charging capacity is only limited by the supporting grid infrastructure. Most DC charging available is rated under 50 kW, except for Tesla Supercharger stations capable of 120 kW. There are DC charging stations for buses capable of 350 kW or more.

Automakers are currently pushing hard toward high power fast charging, with 350 kW charging networks planned in North America and Europe. These networks are likely to focus on intercity locations, which would make long-range, electrically powered road trips possible.

4.3 Wireless Charging

In comparison with conventional corded solutions, **wireless charging offers gains in convenience**. With the lack of cord management—which has proven to be a significant issue for users—wireless charging is becoming an attractive option. For wireless charging to compete against the current field of charging technologies, the automotive industry will need to agree on standards that allow wireless chargers to be readily deployed across the spectrum of PEVs and either bring down costs or absorb the costs as part of the vehicle price.

Commercial fleets are also a target market, as there may be a good value proposition for fleet vehicles to access wireless charging on daily driving routes, effectively extending the vehicle range. For example, taxis or other shared mobility fleets may find wireless charging desirable.

5 Automated Driving Has a Huge Impact on Electrification

Ecofys' and Navigant Research's analysis shows that developments in carsharing and automated driving could reduce the number of cars needed in the Netherlands up to 50% by 2050. As a result, demand for charging infrastructure could also be significantly reduced: up to 25% less home, work, and (semi-) public chargers by 2035 in a high uptake scenario for carsharing and automated driving compared to a low uptake scenario. **Carsharing vehicles have a high annual mileage and are therefore likely to be electric as a result of their favorable TCO over conventional vehicles.**

Assuming that automated driving will be available at full autonomy, automated electric taxi service can be offered at the equivalent per-kilometer cost of private vehicle ownership for low kilometer households, and thus be competitive with current manually driven carsharing services and significantly cheaper than on-demand driver-operated transportation services [7]. Low kilometer households have a relatively high share of fixed cost that increases the cost per-kilometer, while high kilometer households have the lowest cost per-kilometer.

The development of automated driving can further enhance the use of carsharing, as it adds to the functionality of the car by picking up another user at their preferred location. **Ecofys and Navigant Research expect fully automated vehicles to become commercially available between 2020 and 2025 in the most positive scenario, but between 2030 and 2035 at the latest.** Driving automation will likely stimulate the use of fast charging infrastructure, as a large number of cars could be serviced with a single station. However, the implementation of automated driving will be highly dependent on the development of legislation that allows fully automated vehicles to be used on public roads.

It is likely that the lead adopting markets will require zero emissions capabilities, as automation has the potential to increase transportation energy consumption [8]. But, regardless of how this technology disrupts the industry, the disruption will take years to emerge and mature [9]. Within the forecast period of this paper, the impact of the technology on charging equipment markets is effectively negligible.

6 Market Forecast: Exponential Growth

For this paper, Ecofys and Navigant Research used their base case PEV forecasts, which assumes low and stable real oil prices through 2026 and lithium ion battery pack prices that decline from around \$350/kWh to around \$200/kWh by 2026. As shown in Figure 4, **the global PEV population is expected to rise to near**

44 million by 2026. It is anticipated to be highly concentrated in the developed markets of Asia Pacific, North America, and Western Europe [3].

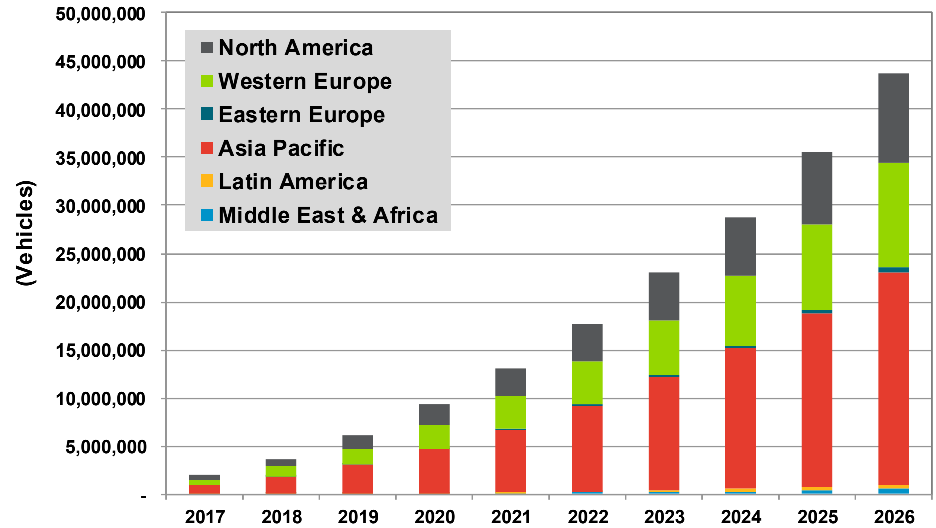

Figure 4: PEV Population by Region, World Markets: 2017-2026

Ecofys and Navigant Research expect the global market for EVSE for light, medium, and heavy duty PEVs to grow from around 875,000 unit sales in 2017 to over 6 million in 2026 [3]. This includes sales to individuals, fleets, and end users that offer EV charging for private or public charging, but does not include cordsets that come with the PEV purchase. The North American and European markets are expected to be similar in size. Asia Pacific is likely the largest market, propelled by China's demand for fleet PEVs—mainly buses and taxis.

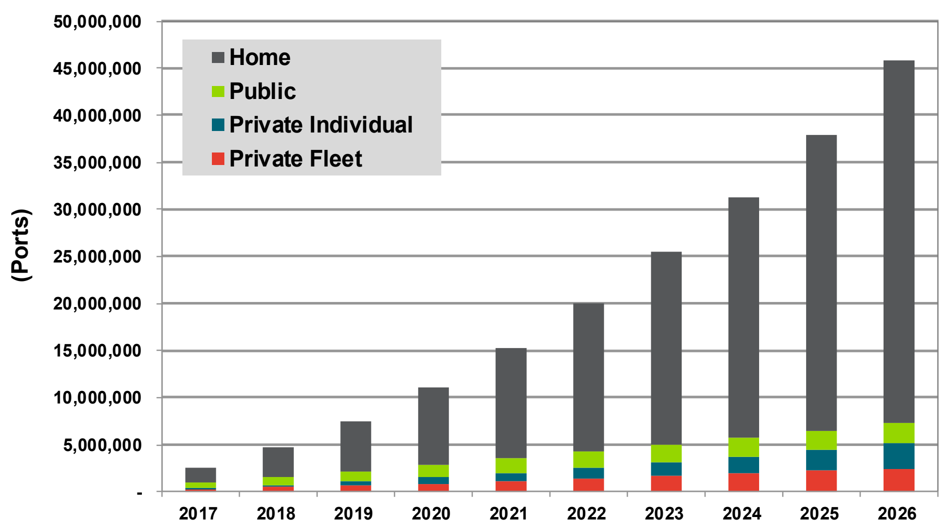

Figure 5: Installed EVSE Ports by Access Type, World Markets: 2017-2026

7 Conclusions

The methodology presented in this Ecofys/Navigant Research paper can be used for **analyzing how much charging infrastructure is needed at certain levels of PEV penetration**—from minor to mass adoption.

Significant investments in charging infrastructure will continue to play a major role in the charging market over the next few years while the PEV market grows. Based on the profile of a country and the available incentives, the scenarios identify hotspots where barriers for charging infrastructure introduction need to be removed.

Our analysis shows that strong electrification of the market for passenger vehicles and vans can be expected in the coming years. Depending on the **policy incentives** and the **development of EV technology, the turning point for a large-scale uptake of EVs could take place before 2020, but will certainly happen between 2020 and 2025**. **Carsharing**, enhanced by the development **of automated driving**, could lead to a **disruptive trend** in which the number of vehicles declines and the intensity of vehicle use increases.

The developments above can bring **positive contributions to governmental goals on air quality and greenhouse gas reduction**, among others. To accelerate these trends, Ecofys and Navigant Research recommend the following measures:

1. Incentivize vehicle charging at work
2. Facilitate public charging
3. Create a network of fast charging infrastructure on highways (corridor chargers)
4. Inform consumers on the TCO of EVs
5. Facilitate smart charging
6. Stimulate carsharing and automated driving (amend existing legislation)

According to our research, business travelers and commuters are expected to be among the first ones to switch to EVs.

Automated driving promises great potential to reduce the amount of cars, since they are used more intensively (e.g., through carsharing). **Smart charging** is a way to reduce the operating costs for EV users and thereby improves the TCO of EVs, while at the same time facilitating the uptake of renewable energy.

Acknowledgments

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Authors

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Maarten Cuijpers started working as a consultant at Ecofys in 2012 after finalizing his University of Utrecht MSc degree in Energy Science, in which he gained broad insight into energy-related problems and opportunities. In the business area of urban energy, Maarten works on projects in the road, shipping, and aviation sectors. His key areas of expertise include alternative fuels, energy modeling, environmental policy, and lifecycle assessment. Maarten's broad education background in sustainable energy allows him to analyze problems in detail without losing the connection with the bigger picture. He regularly does work outside the area of sustainable transport and has been involved in strategic studies for the WWF Climate Savers program and the German KfW Development Bank. Maarten also holds a BSc degree in Innovation Management from the University of Utrecht.

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