

ELECTRIC MOBILITY & DEVELOPMENT

AN ENGAGEMENT PAPER
FROM THE WORLD BANK AND
THE INTERNATIONAL ASSOCIATION
OF PUBLIC TRANSPORT



ADVANCING
PUBLIC
TRANSPORT



Energy Sector Management Assistance Program



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December 2018

Foreword

This paper is a collaboration between the World Bank and the International Association of Public Transport (UITP) to assemble evidence, viewpoints, and analysis on eMobility programs. The objective is to contribute towards helping governments design and implement electric mobility programs that are effective at achieving their intended development aims across climate, economic, fiscal, technical, institutional, and policy dimensions. There is a clear global interest in electric mobility and demand for sharing experiences between countries of all income levels. We hope that our paper will contribute towards meeting that demand and facilitate collaboration between governments, development institutions, and other stakeholders under the “Katowice Partnership on E-mobility” that has been established under Poland’s leadership of the 24th Conference of the Parties to the United Nations Framework Convention on Climate Change.

The research approach used to develop the content in this paper included the following activities:

- » **Country cases:** the Research Team undertook studies of individual country experiences using available data, interviews with officials, and field visits;
- » **Interviews with stakeholders:** during interviews, the Team collected general observations as well as verbatim quotations where appropriate. These were then vetted by interview subjects for accuracy, acceptability, and permission to use with direct attribution or with appropriate anonymity. Attributed quotations that appear in the text have come from these interviews;
- » **Surveys administered to the public, transport operators and bus manufacturers:** the Team used social media channels to distribute surveys in several languages (Arabic, Dutch, English, Polish, Portuguese, and Spanish) to capture the perspectives of eMobility users. In addition, UITP surveyed a sample of public transport operators who are deploying electric buses in their fleets. The results of this have been incorporated to showcase customer and operator perspectives;
- » **Direct observations:** members of the Study Team collected experiences using their own observations and interactions with eMobility solutions (i.e. on buses, in cars, and on two-wheelers). In addition to direct field observations, the Team’s on-the-ground research included attempts to purchase electric private vehicles at dealerships to ascertain how the supply chain interacts with customers.

More work remains to be done on eMobility. It is important to note that this paper is neither a judgment on eMobility nor a comprehensive assessment of the demand, technology, and markets that underpin its development. All of these factors are evolving, highly dynamic, and subject to uncertainty. However, there are present opportunities to share experiences that will inform current and future actions on eMobility solutions as part of the effort to tackle the challenge of transport sector emissions. Addressing this problem will depend upon concerted action from the global community.

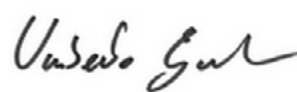
Sincerely,



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List of Abbreviations

BEV	Battery Electric Vehicle
EV	Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
ICE	Internal Combustion Engine
NEV	New Energy Vehicles
OEM	Original Equipment Manufacturer
PHEV	Plug-in Hybrid Electric Vehicle
TB	Trolley Bus
TCO	Total Cost of Ownership
UITP	International Association of Public Transport
V2G	Vehicle-to-Grid

Executive Summary

eMobility is fundamentally changing the traditional interaction between technology, market dynamics, production capacity, government policy, supply chains, manufacturing, and complex political economy. Like many disruptive transitions, there are both opportunities and challenges. These go beyond emissions reduction and include factors such as automotive industry supply chains, jobs, market structures, trade relations between countries, electricity networks, the roles of incumbent firms, and the introduction of new competitors. Uncertainty is an overarching theme above all considering the nascent state of eMobility uptake globally. While there are many unknowns, the analysis and recommendations detailed in this paper highlight the following:

- » **There is potential for governments at all levels of capacity to engage with eMobility.** To date, the global market for eMobility has been underpinned by government interventions. The range of options vary from simply enabling initial uptake through basic regulations and customs procedures, to more advanced measures such as vehicle subsidies, non-price incentives (e.g. parking), support mechanisms for industry, and the development of charging networks. While more advanced programs are likely to steepen the uptake curve, the ability of simple government engagements to kick-start the early stages of uptake should not be underestimated. Above all, there is a need for governments to focus on policy predictability, and where possible, policy stability to support the continued development of eMobility solutions;
- » **eMobility can and should be part of an integrated “avoid, shift, and improve” framework for tackling the challenge of transport sector emissions.** Governments looking to engage with eMobility should ensure that it fits within a broader low-emission transport strategy that has public transport at its heart. The capacity and availability of suitable eMobility solutions provides the opportunity for public transport operators, when supported by their authorities, to deploy new technologies. The development of business models that involve electric vehicle sharing (e.g. e-scooters), are also providing a complement to public transport that authorities can also seek to integrate within an overall low-emission strategy for transport;
- » **While technology matters, shaping perceptions and confidence around eMobility is equally important.** While the financial costs and benefits of eMobility have a significant impact on uptake, addressing perceptions around eMobility’s capacity to meet mobility needs is critically important. Perhaps the most important factor for shaping public perceptions and the potential of eMobility technology to meet customer expectations, is the development and visibility of charging infrastructure. This provides customers with both the means and confidence necessary to catalyse a shift towards eMobility. The institutional, regulatory, and market structures around charging infrastructure (especially as they relate to interoperability) are critical elements in the overall effort to expand charging infrastructure and make it convenient for use;
- » **Engaging different stakeholder groups proactively and continuously is a key element in the success of eMobility programs.** Like many aspects of the transport sector, eMobility has both technical and political economy dimensions. The best strategy for managing these factors is for governments to engage broadly, proactively, and continuously with different stakeholders. Vehicle OEMs, civil society organizations, public transport operators, utilities, local authorities, charging operators, and customers are essential points of contact for any government seeking to play a convening role around eMobility;

- » **A key challenge facing eMobility programs is the alignment between government objectives and what OEMs and the supply chain can credibly deliver.** The global automotive industry involves complex supply chains and economies of scale. EV technologies have been demonstrated as viable, but the supply chains behind these technologies have yet to achieve industrial scale on par with conventional technologies. This is an issue both for the industry's production capability as well as its financial sustainability. There are jobs, companies, and entire industry clusters that are likely to undergo transition if the uptake of eMobility continues to accelerate. While governments may choose different strategies for addressing this, it will be key to have a strategy in place – particularly where automotive sector jobs affect the political economy of eMobility programs;
- » **The sustainability benefits of eMobility are strongly linked to power system emissions as well as factors such as battery lifecycle.** Fully capturing the environmental benefits of eMobility requires parallel effort to make full use of renewable energy sources. In addition, the lifecycle considerations around battery production, second lives, and recycling have important social and environmental consequences that eMobility programs must seek to address;
- » **The power sector has a critical role to play as an enabler of eMobility.** Network investments and modernization (including upgrades, smarter and cleaner grids, metering, standards) are important factors to enabling higher level of eMobility uptake in many countries. Future developments around eMobility may also use the potentially significant storage capacity of EV fleets as a two-way network resource; and
- » **The transformational nature of eMobility opens opportunities for other evolutions in transport and other sectors such as energy.** International experience suggests that this can be used to support important objectives such as increasing female participation, improving access to public transport, and the development of new markets in the energy sector. The new value and supply chains underpinning eMobility offer a new opportunity for embracing principles of social and environmental sustainability in a way that goes beyond what has been achieved for ICE vehicles. Governments should think of eMobility as a lever that can affect broader change in addition to the reduction of emissions. Development partners and civil society organizations can help to achieve this.

The uptake of eMobility around the world appears to be increasing, with the largest fleets in China, the United States, and countries in and around Europe. One of the contributions of this paper is to show how eMobility is also becoming relevant in other locations, serving contexts other than the big markets. Countries such as India, Jordan, Nepal, and Ukraine have engaged with eMobility in different ways that illustrate how eMobility can serve a wide array of mobility needs. The ability of mobility customers to drive change and “make things work” has been particularly encouraging and points to the potential that eMobility has for serving the 6.3 billion people who live in low and middle-income countries around the world.

THE PAST AND PRESENT OF eMOBILITY

1.1 Putting eMobility in context

History informs how policy makers engage with eMobility today. For example, Figure 2 (below) shows how different technologies have penetrated new passenger vehicle sales in the United States. Consumable vehicle components have often enjoyed relatively simple transitions (e.g. radial tires) while the uptake of those technologies that are embedded within a vehicle system (e.g. variable valve timing in engines) has been less straight-forward. The pace of uptake has sometimes involved factors concerning consumer behaviours and their interaction with regulations that are put in place by governments through a political process (e.g. seat belts). The market penetration of modern vehicles that incorporate different eMobility features, shown at the lower right of the Figure, remains nascent, with modern battery EVs barely visible as a share of new vehicle registrations. The curve that eMobility follows, as with other technologies, will reflect the policies that governments put in place around it.

“I think there is great tendency among well-trained commercial people to confuse the conditions and requirements of an established industry... with the conditions that prevail at the inception of an industry when you have got to create demand before the competition comes in.”

Hayden Eames, Address to the Association of Electric Vehicle Manufacturers; (April 1907)

While the mass uptake of modern eMobility remains in early stages, the idea of eMobility itself is not new. A Scottish inventor named Robert Anderson is commonly credited with having invented a rudimentary battery electric carriage in the 1830s. Companies that produced electric cars such as the Pope Manufacturing Company (1897-1916) and the Anderson Carriage Company of Detroit (1907-1939), were contemporaries of the early Ford Motor Company and its predecessors.¹ Prior to the development of Henry Ford’s Model T and the widespread adoption of combustion engines following the First and Second World Wars, it was not clear which technologies would prevail. The famous inventor Thomas Alva Edison—a lifelong friend and one-time employer of Henry Ford—was engaged in the development of early EVs that did not reach mass adoption. This contrasts with the history of eMobility in public transport. The first electric public transport vehicles were introduced in Berlin by Dr. Ernst Werner Siemens in 1882 (his “Elektromote” was an early electric trolleybus). Sarajevo was operating the first electric tramway in 1885. eMobility has been around ever since for public transport, but modern applications of this are allowing for new technologies (e.g. BEV buses) to be employed in new ways.

Interestingly, we can also draw parallels between the Model T’s success—which led to the dominance of fossil fuel engines in transport—and the situation facing contemporary eMobility technologies.

A large part of the Model T's success was not (at least initially) down to the drivetrain technology itself, but by the development of a fuel supply and vehicle production methods that reduced costs and resulted in widespread vehicle availability. In fact, Henry Ford's wife Clara reportedly drove an electric vehicle (made by a company other than Ford) until the 1930's due to a dislike for the Model T's exhaust, noise, and hand cranking requirements. In a twist of irony, Tesla founder and CEO Elon Musk has tweeted that he owns one of Henry Ford's Model Ts in addition to a petrol Jaguar Series 1 1967 E-type Roadster which he described as a "first love".²

Figure 1. Trolleybus n°2 operating on Avenue Dapples in Lausanne, Switzerland (1936)



Source: UITP Historical Archives

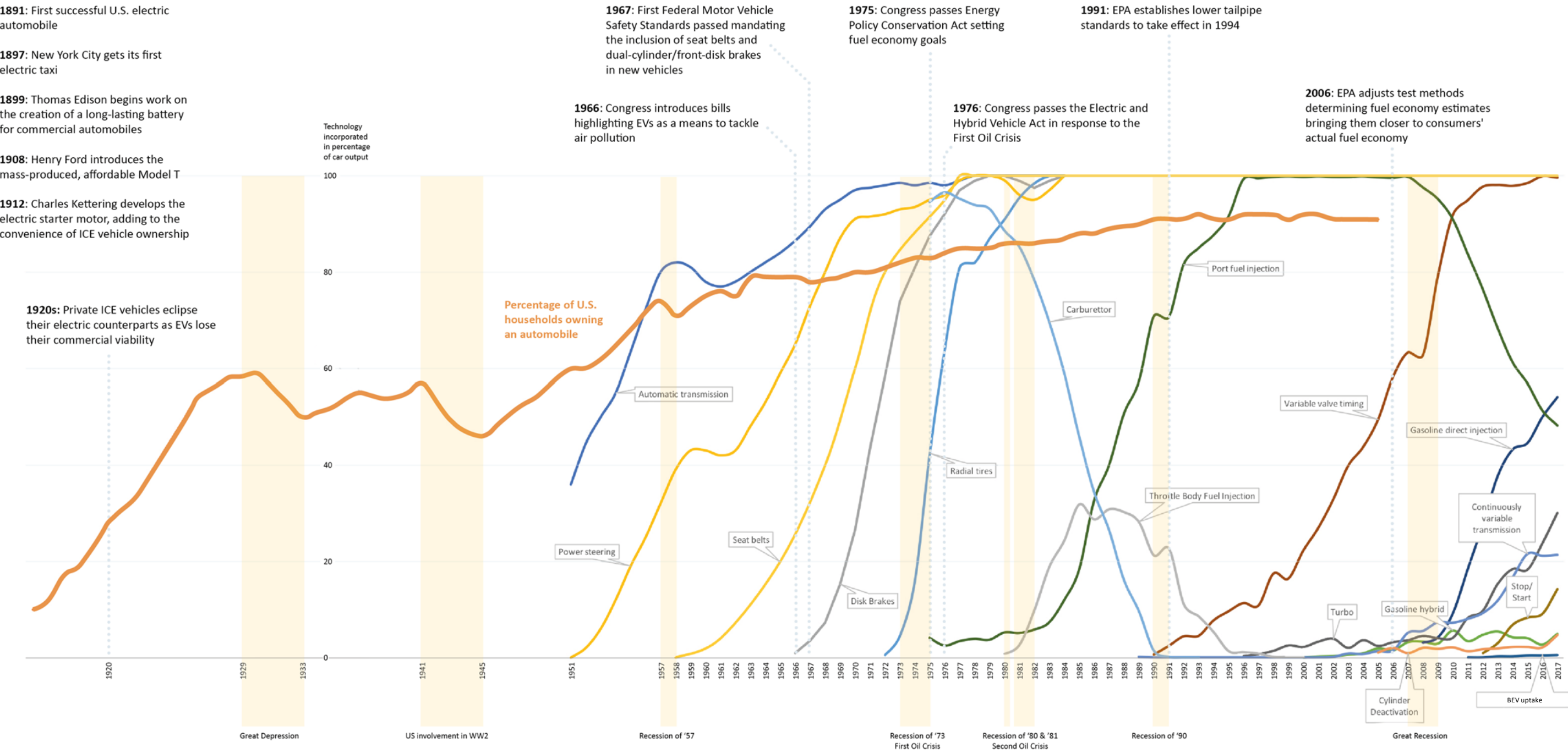
There are factors that differentiate the eMobility of today from its ancestor. Most notably, there is an impetus for the global community to act on switching away from fossil fuels, given that transport is producing an estimated 23% of energy-related CO₂ emissions that contribute to global climate change.³ Developing eMobility offers one avenue for action to help address this challenge. Today's vehicle industry supply chains are complex, globally integrated, and operate at an unprecedented scale. There is little historical experience of value chain transformation of the sort that eMobility is likely to bring about. The shift away from animal-propelled transport to the development and adoption of motorized transport may offer the closest historical parallel. It is clear that the infrastructure required to charge EVs, the supply chains needed to produce them, and the way that consumers interact with them represent a shift of this kind of magnitude.

The challenges facing private EVs are similar to those facing the world of public transport, with the exception that governments often have greater ability to determine fleet composition, either directly or through licensing and contractual terms. The challenges facing eMobility, combined with the global need for action on transport sector emissions, are themselves justifications for strong global partnerships to share experiences and inform the actions that governments take to meet their eMobility objectives. Governments can use and adapt these experiences to their unique context as the world seeks to move beyond fossil fuel-dependent transport.

“Though we can learn from international experiences, the strategy we design and implement must respond to our local conditions.”

Cristina Victoriano, Efficient Transport Coordinator, Sustainable Energy Division; Ministry of Energy, Chile

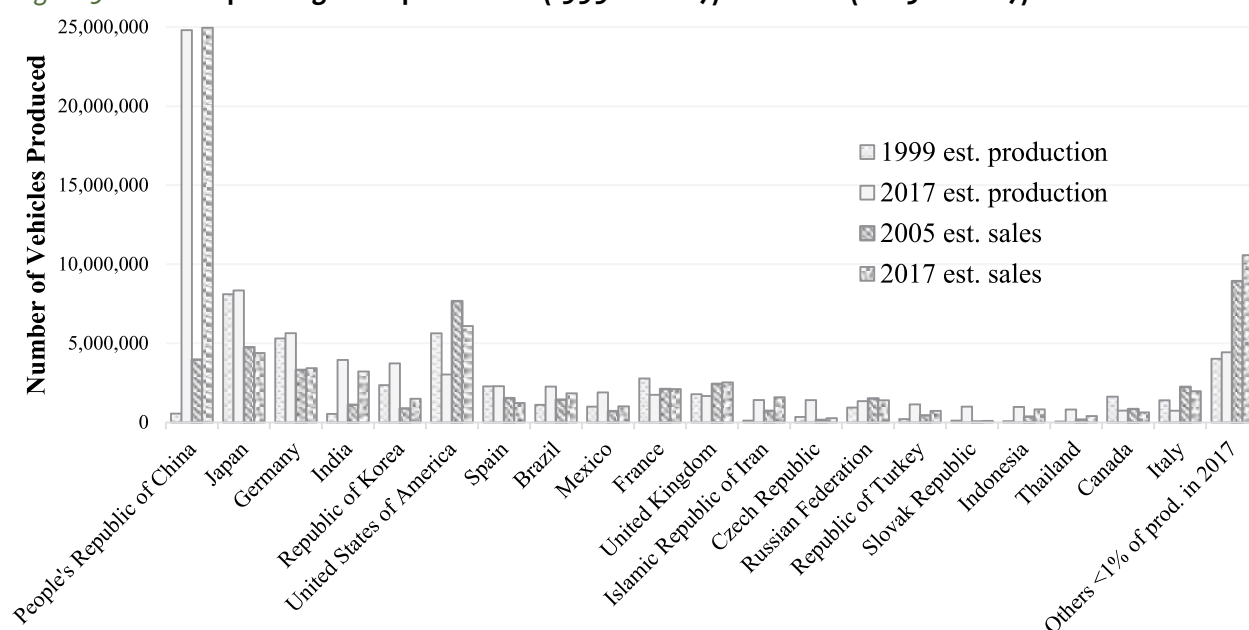
Figure 2. Historic overview of automotive technology uptake in the United States



Source: Compiled by the World Bank using data from the United States Environmental Protection Agency, the Australasian Transport Research Forum and ourworldindata.org, Public Broadcasting Service and U.S. Government

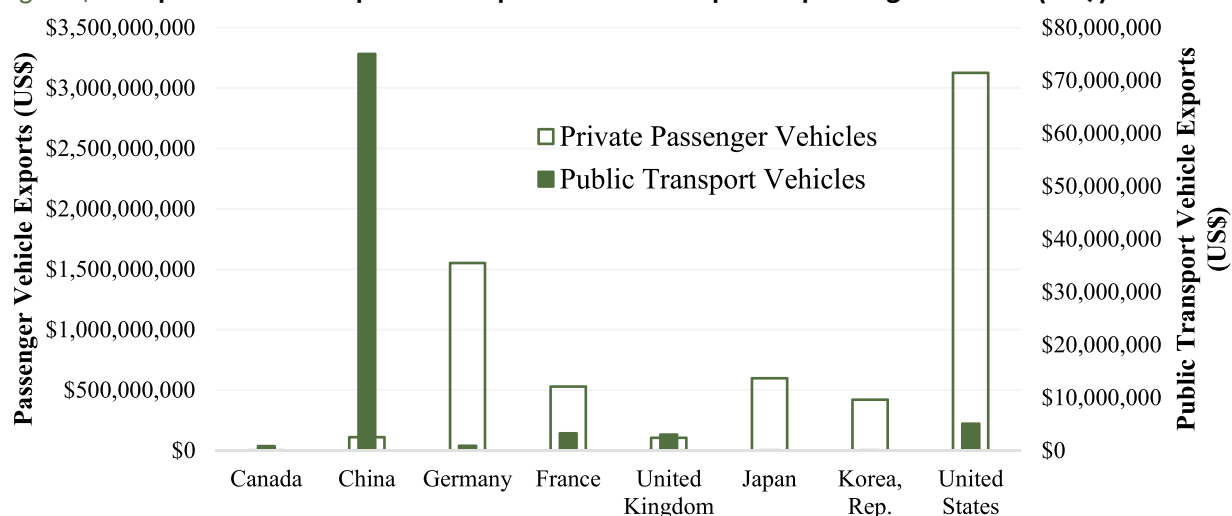
The current uptake of eMobility is following on from other noteworthy transitions in the automotive sector. These include: (i) significant shifts in the geographical location of vehicle production; and (ii) similar shifts in the geographical location of vehicle purchasing. In both cases, China stands out as both a global production hub and, increasingly, as a global hub of vehicle consumption. Between 1999 and 2017, the production of passenger cars in China (of all drivetrain types) increased by more than 4,000% from 565,366 cars to 24.8 million cars per year. Similarly, between 2005 and 2017, sales of passenger vehicles in China increased by more than 500% from approximately 3.97 million cars to 24.96 million cars per year. In several developed markets such as Germany, Japan, and Spain both production and consumption have remained relatively stable over the periods mentioned above. In the United States, there has been a decline in both production and sales of vehicles.

Figure 3. Global passenger car production (1999 vs. 2017) and sales (2005 vs. 2017)



Source: World Bank analysis of data from the Organisation Internationale des Constructeurs d'Automobiles (OICA)
[International Organization of Motor Vehicle Manufacturers]

Figure 4. Exports of electric public transport vehicles and private passenger vehicles (2017)



Source: World Bank analysis of UN COMTRADE data (2017)

China plays different roles for private EVs and electric buses when considering available data on assembled vehicle exports. A defining feature of the Government's eMobility program is a strong domestic industry and consumer market for private EVs, with a dual focus at home and abroad for electric buses. Presently, the United States is the world's leading exporter of private EVs followed by Germany. In the case of the US, this may be due to a single company, Tesla, whose 2017 10K filing with the Securities and Exchange Commission implies that it may be the predominant contributor toward US EV exports. A key question surrounding the global supply chain of private vehicle EVs is at what point China will engage its domestic production capacity in the business of assembled EV exports rather than components.

1.2 Examples of industry and government commitments

Climate change is not the only driving force behind the current push for eMobility. Various governments and industry participants have shown commitments that either target electric mobility directly or objectives that electric mobility can help meet. However, the motivations behind these commitments vary and often include a mix of goals relating to global emissions, localized emissions, and industrial policies. Stated and implied commitments are also expressed in the design of schemes that governments are putting in place to achieve their objectives, as discussed in section 3.

Industry participants have also expressed commitments regarding eMobility-related investments, production and sales. The extent to which industry and government targets have been aligned or coordinated in their development varies considerably by country as highlighted by examples in section 4 of this paper that details stakeholder views. Of specific importance is the question of whether industry's ability to produce vehicles economically can align with both government ambitions and ability to provide support through investments in infrastructure, customer incentives, and various other regulatory and planning interventions.

"The supply chain has to develop at the same time."

OEM representative

The commercial models that underpin vehicle development involve significant upfront investment in both engineering and assets to assemble components from supply chains that themselves must invest to meet new demands. These require return in the form of vehicle sales which, in turn, depends on consumer demand for those vehicles. That demand is a function of complex factors such as costs, convenience, and perceptions. In the case of public transport, operational differences between fossil fuel and EVs also mean that factors such as routes, service schedules, and facilities need to be aligned to deliver an equivalent level of service using new eMobility options. Supply chain capacity appears to be a key constraint on the degree to which government ambitions will intersect with reality for eMobility.

Table A Overview of government commitments to the phase-out of ICE technologies

Countries/Cities	Examples of targets (not exhaustive)
United Kingdom ⁴	Ban on new sales of petrol or diesel vehicles after 2040. London will impose an Ultra-Low Emission Zone (ULEZ) from April 2019
Norway ⁵	All new passenger cars, light commercial vehicles, and city buses should be zero emission by the year 2025
South Africa ⁶	5% reduction of greenhouse gas (GHG) emissions in the transport sector by 2050 [Draft Green Transport Strategy]
People's Republic of China ⁷	Considering a ban on the sale of new petrol and diesel vehicles
Denmark ⁸	Ban on new gasoline and diesel cars by 2030
Germany ⁹	1 million EVs on the road by 2020
Ireland ¹⁰	No new ICEs sold after 2030
India ¹¹	15% of vehicles to be electric by 2023 [proposal]
South Korea ¹²	Government to supply 1 million EVs by 2020
Scotland ¹³	No new petrol or diesel vehicles by 2032
Netherlands ¹⁴	All new vehicles emission free by 2030
France ¹⁵	No new petrol or diesel vehicle sales after 2040
Slovenia ¹⁶	New sales of vehicles to have less than 100 grams of CO ₂ /km by 2025; only low-emission cars (50 grams of CO ₂ /km) by 2030
Mexico City, Paris, Madrid ¹⁷	End use of all diesel vehicles by 2025
Copenhagen ¹⁸	All city-owned vehicles emission free by 2025.
Brussels ¹⁹	Ban diesel vehicles in the capital by 2030
Barcelona ²⁰	All new buses procured will be zero emissions from 2025
Cluj-Napoca ²¹	By 2025, the city's whole public transport fleet will be zero-emission
Copenhagen ²²	From 2019, all new buses procured in Copenhagen will be zero emission vehicles
Quito ²³	After 2025, all new operation contracts signed between public transport operators and the municipality will require only electric bus fleets
Paris ²⁴	Becoming the world leader in green technology with a fleet of 4,700 clean buses by 2025
London, Paris, Los Angeles, Copenhagen, Barcelona, Quito, Vancouver, Mexico City, Milan, Seattle, Auckland & Cape Town ²⁵	Only electric buses will be bought after 2025
Moscow ²⁶	Diesel buses to be substituted with electric buses from 2021
London ²⁷	By 2037 all buses in London (about 8,000) will be zero-emission
Amsterdam ²⁸	All bus fleet of public transport operator GVB will become electric by 2025
Flanders ²⁹	By 2025, all urban buses operated by De Lijn will be only battery electric and plug-in hybrids
50 European Cities and Regions ³⁰	Increase the share of zero emission vehicles in the EU to 30% by 2025 and contribute to the deployment of at least 2,000 zero-emission buses by the end of 2019

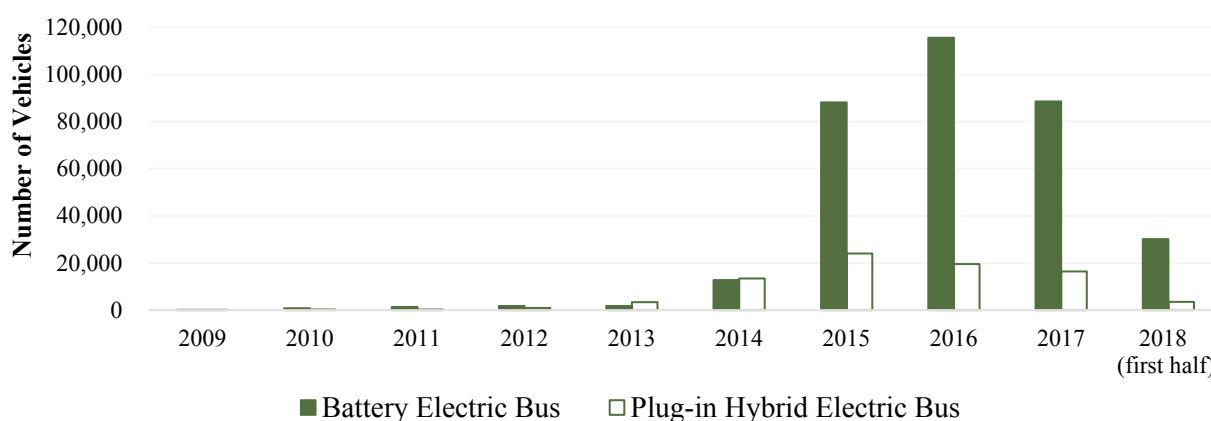
Table B Overview of OEM electric vehicle commitments

Manufacturer	Example of commitments (not exhaustive)
VW Group ³¹	Plans to offer electric versions of its entire model portfolio by 2030.
Ford ³²	Plans to add 13 new electrified vehicles to its product portfolio by 2020.
GM ³³	Plans to phase out gas-powered vehicles for an all-electric future with target of 20 EVs by 2023
Volvo ³⁴	From 2019, all new models will be electric, hybrid EV, or plug-in hybrid EV. Aims for 50% of sales to be electric by 2025
Fiat Chrysler Automobiles ³⁵	From 2022, no diesel cars will be released
BMW ³⁶	Plans to have half a million electrified BMWs and MINIs on the road by the end of 2019.
Ferrari ³⁷	Plans to develop hybrid vehicles and eventually transition to fully EVs
Tata Motors ³⁸	Committed to the Government's vision of achieving full e-mobility by 2030
Honda ³⁹	EVs (including hybrids, plug-in hybrid EVs, battery EVs and fuel cell EVs) will account for two thirds of the 2030 sales
Chinese OEMs ⁴⁰	Announced 4.52 million annual EV sales by 2020
Tesla ⁴¹	Plans 1 million annual electric car sales by 2020
Daimler ⁴²	Private transport: Plans for more than ten different all-EVs by 2022; Plans to invest 2.6 billion euros (US\$3.2billion) in research on electric trucks by 2019; Public transport: Has announced to invest €200 million by 2020 also into development and production of electric buses.
Renault, Nissan and Mitsubishi ⁴³	Automakers plan to release 12 all-electric models by 2022. OEMs will cooperate to develop new systems to use across vehicle lines with focus on pure electric.
Toyota and Mazda ⁴⁴	Pledged US\$1.6 billion for US-based EV and hybrid plant by 2021.
Jaguar Land Rover ⁴⁵	From 2020 all new JLRs will be electrified and hybrid
ABB, Alstom, Autograaf (iBus), BAE Systems, Bolloré, Bombardier, Chariot Motors, Daimler Buses, Dancerbus, Hess AG, Heuliez Bus, Irizar, MAN, Microvast, Piccoli, SAFRA, Scania, Skoda Electric, Solaris, VanHool, VDL, Volvo Buses ⁴⁶	Increase the share of zero emission vehicles in the EU to 30% by 2025 and contribute to the deployment of at least 2,000 zero-emission buses by the end of 2019.

1.3 Examples of trends in public transport uptake

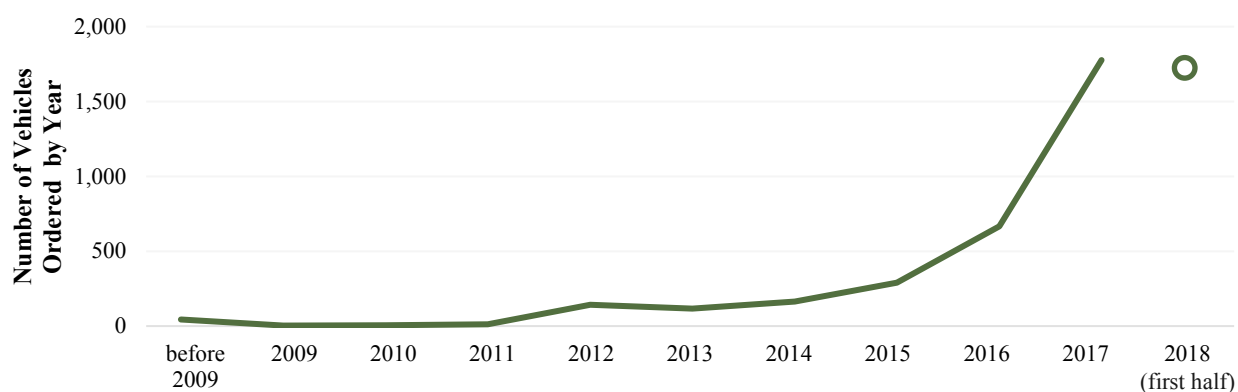
Despite the challenges associated with transitioning to eMobility, the global uptake of electric buses is accelerating in many countries. In 2016, there were an estimated 370,000 buses that incorporated eMobility features globally, according to the International Energy Agency's report *Global EV Outlook 2018*. China has led the deployment of electric bus fleets. As of the first half of 2018, the total number of buses with eMobility features deployed in China is estimated to be about 340,982. The decline of new electric bus uptake in 2017 and 2018 may be linked to a planned reduction in subsidy support, as well as the governance of subsidies. The Ministry of Finance and Ministry of Industry and Information Technology have sought to address issues surrounding the governance of subsidies following investigations into allegations of fraud or misrepresentation concerning this market segment.⁴⁷

Figure 5. Uptake of “New Energy Buses” in China (2009 – June 1, 2018)



Source: World Bank analysis of China Automotive Technology and Research Center: *Blue Book of New Energy Vehicle* (2013-2018)

Figure 6. Electric bus orders in Europe 2009 – first half of 2018¹



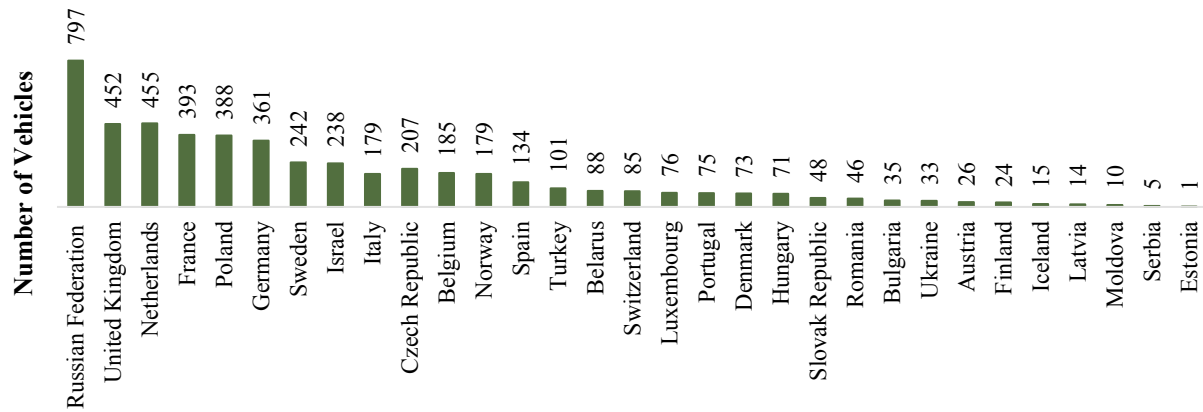
Source: Compiled by UITP using data provided by Stefan Baguette, ADL Market Analyst and Product Manager

In Europe, the uptake of buses with elements of eMobility technology has steadily increased. As of mid-2018, there were an estimated 1,273 buses with eMobility features in Europe which represents a 100% increase over 2015. It is expected that the current share of buses that include eMobility elements will increase from 10-12% of the current bus market to around 40% in 2025, based on current and forecasted order trends. The number of vehicles ordered during the first half of 2018 has already nearly reached the total orders for 2017. Although this type of evolution was predicted by UITP and other stakeholders, the market is growing faster than previously anticipated as current orders have reached

¹Includes BEVs, FCs, PHEVs and TBs

levels originally projected for 2025. This is largely due to the knowledge gained by stakeholders over the past years through different joint initiatives such as the Zero Emissions Urban Bus System (ZeEUS) project. Initiatives such as ZeEUS are helping to overcome barriers posed by the deployment of new technologies. EVs now represent about 10% of the approximately 20,000 buses procured each year in Europe and its neighbouring countries.

Figure 7. Orders of electric buses in Europe, 2002 – first half of 2018 (incl. trolleybuses)

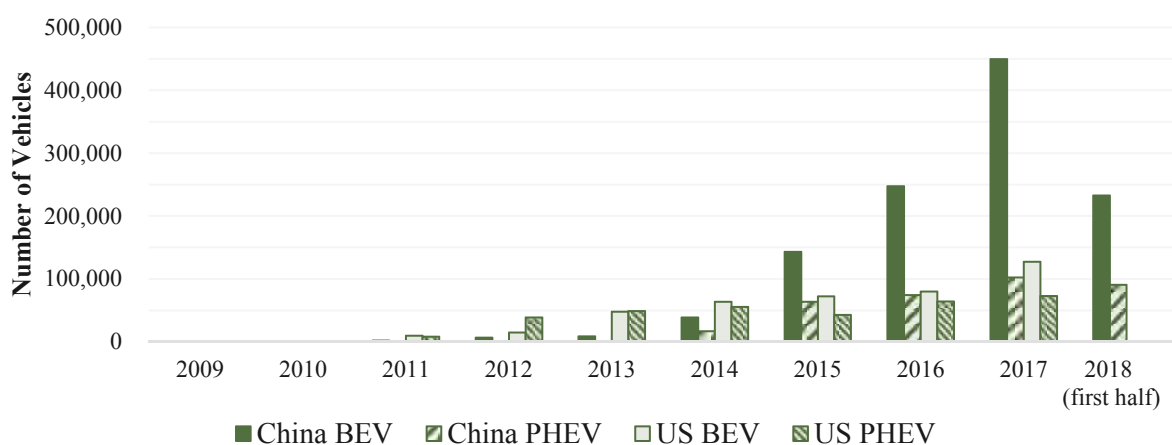


Source: Compiled by UITP using data provided by Stefan Baguette, ADL Market Analyst and Product Manager

Data shows that the top six countries ordering electric buses (including battery TBs) in Europe since 2002 include the Russian Federation, the United Kingdom, the Netherlands, France, Poland, and Germany. Together, these countries have accounted for approximately 56% of all electric bus orders in the region.

1.4 Examples of trends in private transport uptake

Figure 8. Annual uptake of BEVs and PEVs - US & China, 2009-June 1, 2018¹

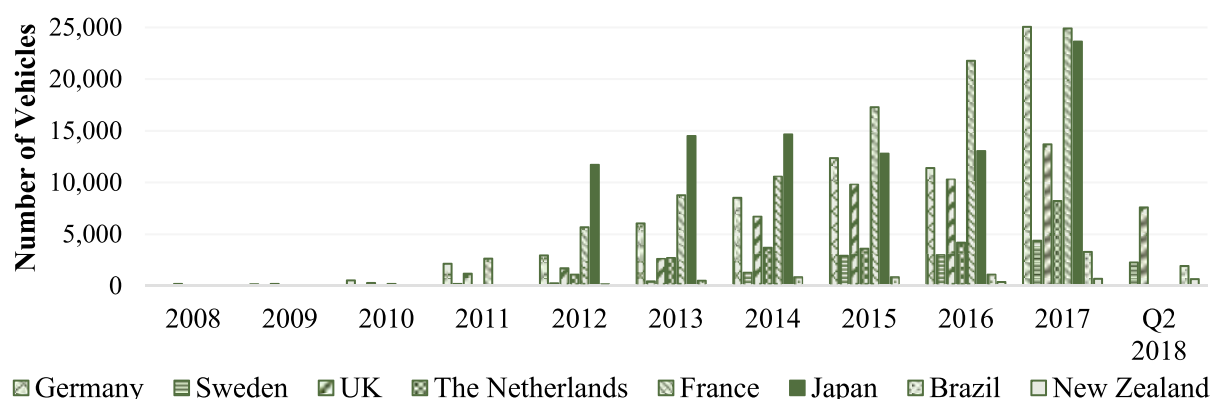


Source: Compiled by the World Bank using data from the China Automotive Technology and Research Centre (Blue Book of New Energy Vehicles 2013-2018); U.S. Department of Energy, Energy Information Administration, Alternative Fuels Data Center, www.afdc.energy.gov/data as of Dec. 26, 2017.

¹Note: (i) China figures based on production statistics; (ii) US Figures for 2017 estimated based on data from www.ev-volumes.com

Today, there are an estimated 3.1 million passenger EVs on the road globally according to the OECD and IEA's 2018 EV outlook.⁴⁸ China alone accounts for an estimated 1.48 million of these vehicles as of the first half of 2018. This reflects a concerted policy push by governments, as well as complementary efforts from elsewhere to develop the supply chain relating to vehicle production together with incentives designed to stimulate customer demand for vehicles. Notably, government policy and market interventions have targeted domestic markets as a priority rather than export markets. In the State of California alone, there are an estimated 171,515 BEVs in addition to 158,564 PHEVs, which reflects a combination of state/federal government incentives and the development of an expanding network for vehicle charging.

Figure 9. New registrations/sales of private BEVs (not incl. PHEVs) (2008-Q2 2018)



Source: World Bank analysis of national vehicle registration data for countries noted; the Next Generation Automobile Promotion Center Japan.

European countries and others are also accelerating their deployment of eMobility. In the European Union, during 2017, there were an estimated 97,143 new battery EVs and a further 126,898 new plug-in hybrid EVs sold. These figures constituted only 1.48% of Europe's new fleet in that year. However, year-on-year registrations of BEVs in quarters one and two of 2018 grew by approximately 40% relative to 2017, according to the European Automobiles Manufacturers' Association. Uptake trends for a selection of countries that publicly disclose vehicle registration data are shown below. Non-European countries such as Brazil and New Zealand are exhibiting increases in EV registrations.

It is important to note that national trends do not exist in isolation; this is particularly true in the case of developing economies. Linkages between early adopters (e.g. high-income countries) are having a knock-on effect on eMobility in middle and low-income countries, which are mainly vehicle importers. Countries like Jordan and Ukraine provide interesting examples of how second-hand markets shape eMobility use. There are also examples of countries that have deployed eMobility solutions that are uniquely their own. Nepal's electric "Safa Tempo" three-wheelers are a remarkable example of how need, ingenuity, enabling action by government, and a bit of support from the international community at the right time can help to meet eMobility needs.

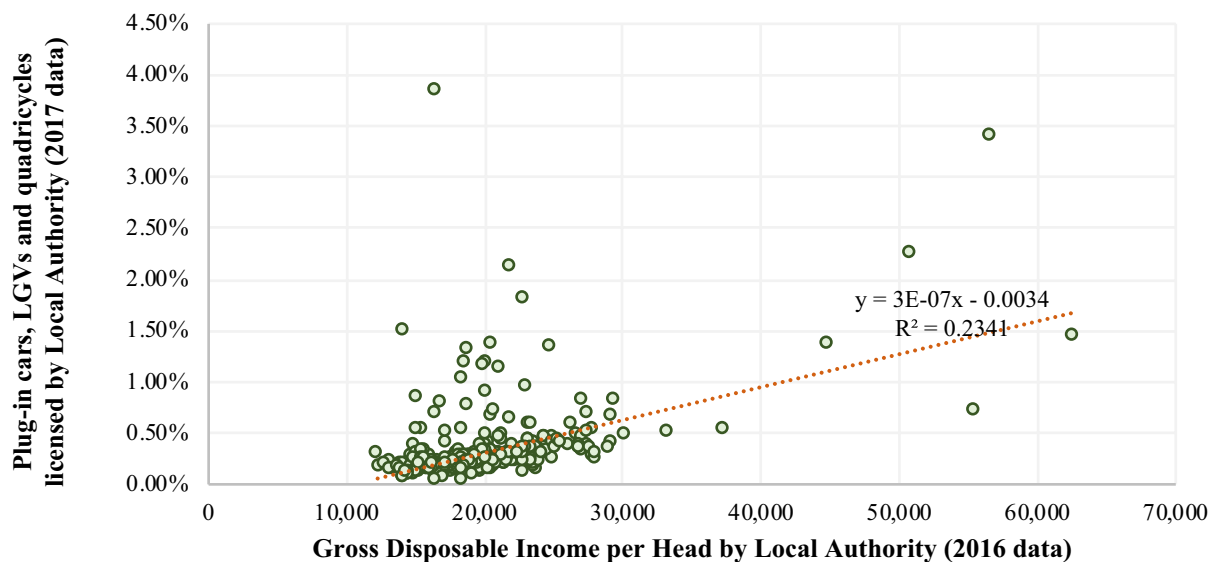
1.5 Examples of granular uptake characteristics

As eMobility increases around the world, it is becoming possible to look at differences in uptake within counties (or sub-sovereign states) to further examine variables around uptake. Figure 10 and Figure 11 plot measures of average income by locality (local authority or post code) against EV registrations as a percentage of total vehicle registrations. The United Kingdom and California were used as ex-

amples because of the availability of detailed data. In both cases, the uptake of private eMobility and income appear positively correlated. This aligns with what is an often-observed trend concerning access to motorized transport in general. However, it should be noted that additional research is needed to control for fixed effects and anomalies such as the registration of a company fleets at addresses that don't correspond to their areas of operation.

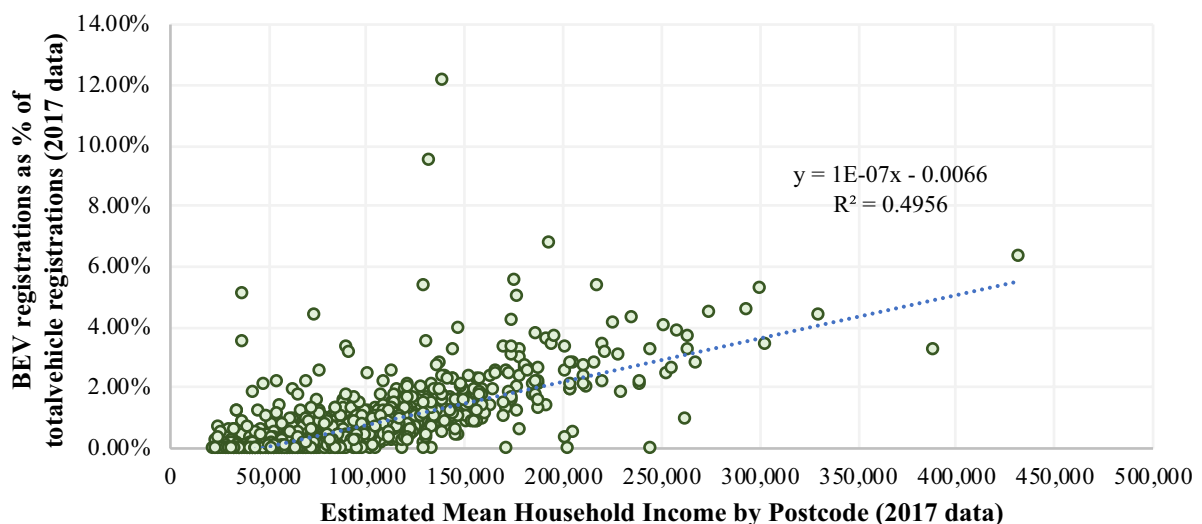
As governments set their eMobility targets and design programs that support their objectives, it is important to recognize that public support for eMobility may be most directly beneficial to higher income households. At the same time, there may be a case for this support in the short-term given the effect that developing the supply chain and charging infrastructure for eMobility can have upon driving down costs and enhancing access for all in the future. In the short run, governments may also wish to consider targeted interventions that provide a wider range of incomes with access to eMobility. The incorporation of EV technologies into public transport fleets could be one way of achieving this. Vehicle sharing schemes may also provide a means by which to widen the reach of an eMobility strategy in places where populations have a low level of access to private transport.

Figure 10. Employee compensation vs. EVs as a % of total vehicles in the UK, 2017



Source: Compiled by the World Bank using UK government data

Figure 11. Estimated mean income vs. EVs as a % of total vehicles in California, 2017



Source: Compiled by the World Bank using California and U.S. government data

1.6 Understanding what affects the attractiveness of eMobility

It is important to understand the factors that shape the attractiveness of eMobility and how government interventions can target them. Figure 12 (below) summarizes a sample of variables that have impact on a “hypothetical” private BEV owner’s Total Cost of Ownership (TCO), compared with that of a conventional ICE car. Assumptions used for this analysis include approximations of OEM published data as well as average “benchmark” values for variables such as petrol price, power prices, annual driving distances, financing parameters, and the assumed opportunity cost of funds for a household in general.¹ Key observations from this analysis include:

- » **Sensitivity to taxes:** because EVs generally have a higher upfront cost relative to ICEs, the impact of taxes levied as a percentage of registered value have greater significance;
- » **Pump price of fuel:** while exogenous factors affect fuel price (e.g. global oil prices), taxes that governments apply to fuel can significantly shift incentives around eMobility for the “average” driver of a private vehicle;
- » **Driving distance and power prices:** both driving distances and power prices have impacts on TCO. However, the general range of driving for most households (10,000 km to 20,000 km per year) and common range of power prices around the world means less impact on TCO when compared to other variables; and
- » **Behavioural and perception-related assumptions:** TCO calculations are assumption dependent. These relate to how consumers perceive expenses, operating differences, and the time value of their money. The validity of assumptions may not align with actual human behaviour – particularly as the eMobility market moves from early adopters towards more mainstream market segments.

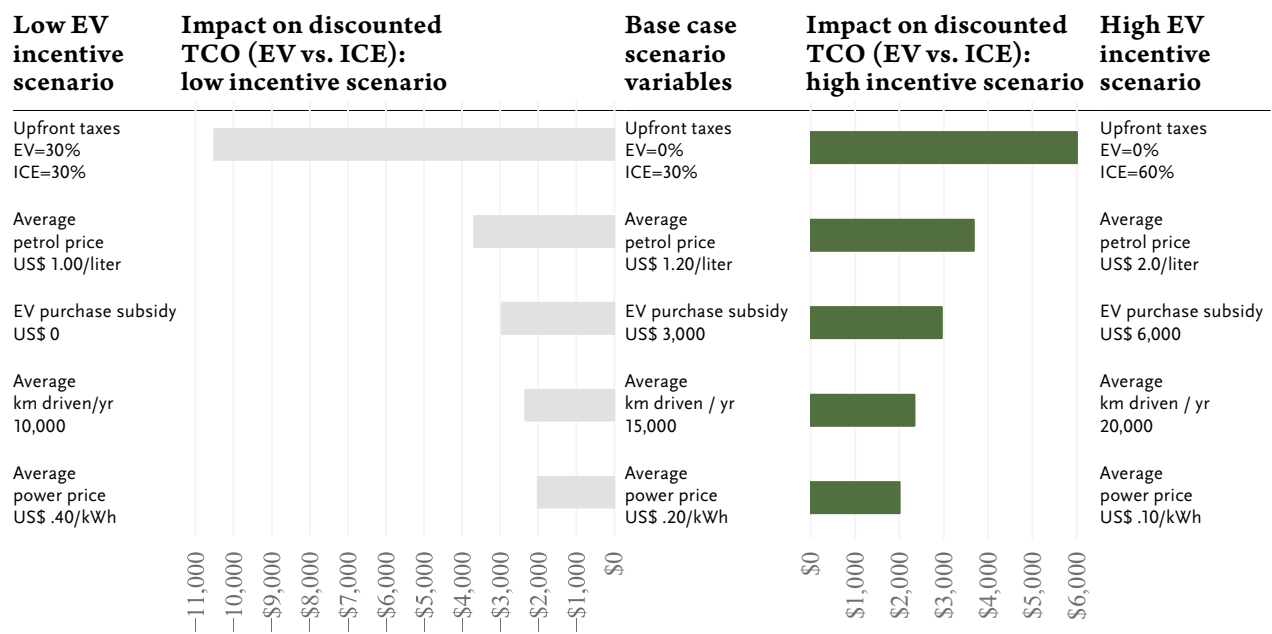
“Customers have to be able to make money with [our] products—they don’t buy the trucks for reasons of environmental sustainability. eMobility needs to have some added value to offer them.”

OEM representative

The analysis below would vary by location and by market segment (passenger cars, freight, public transport, etc.) due to different operating contexts. For example, public transport vehicles and taxis generally accumulate significantly more mileage per year than an average household car (e.g. 30,000 – 60,000 km/yr). Average trip distances and annual distances travelled also vary by countries and cities based on factors such as their geographical characteristics and access to public transport networks. The level of taxation on vehicles and fuel vary considerably around the world. In the case of commercial undertakings, the business case for eMobility will also reflect the business model for which a particular vehicle provides service. eMobility options for road freight vehicles are a clear example of the need for eMobility solutions to find competitive footing in a low-margin, high-competition industry. There is no substitute for thoroughly understanding how local contextual factors affect the market for transport in general when attempting to assess Total Cost of Ownership.

¹Assumptions: (i) BEV economy = 5.5 km/kWh (18.18 kWh/100km); ICE economy 15 km/liter (6.7 liters/100km); vehicle loan interest rate = 5% (nominal); vehicle loan tenor = 3 years; vehicle loan down payment = 25% of net purchase value; opportunity cost of household funds = 6% (for discounting); vehicle life = 10 years; upfront purchase cost of BEV = US\$ 35,000; upfront purchase cost of ICE = US\$ 20,000. Notes: Vehicle loan assumed to finance purchase value net of down payment and any government purchase subsidy. Taxes paid at purchase, all other expenses paid in the year when incurred. Costs discounted at opportunity cost of funds for household to derive present value of Total Cost of Ownership. Volume-based tariff structures for power not modelled.

Figure 12. Looking at what affects household economics of EVs vs. ICE alternatives



Source: World Bank analysis

HIGHLIGHTED LESSONS FROM AROUND THE WORLD

2.1 On the design and targeting of electric mobility programs

International experience is providing valuable lessons on the overall design of eMobility programs and incentives that target those market segments with the potential for switching away from conventional vehicles. Broadly speaking, targeting can include a choice between public and private modes. More precisely, it can include a choice between the smaller segments that exist within modes, such as specific vehicle fleets or public transport services with specific characteristics. This research identified the following features of eMobility programs as particularly important:

- » **Accurate understanding of market segments** that may adopt eMobility. Knowledge of the scale, travel behaviours, demographic characteristics, and commercial considerations that characterize mobility in different market segments is critical;
- » **Sensitivity of target market segments to incentives.** This includes perceptions as well as concrete factors such as price, availability, suitability to a given mobility need, actual emission reduction, etc.;
- » **Enabling and complementary factors** that already exist or can be put in place that influence eMobility use, such as charging infrastructure, the pace of fleet renewal, electricity pricing, travel demand management policies, taxation regimes, vehicle regulations, parking policies; and
- » **Policy credibility to implement targeted solutions.** Specifically, the perceived or actual credibility of government bodies to deliver on what they aim to achieve. The stability and predictability of policy is an important consideration, particularly where firms are expected to make investments that have long-term implications.

For example, in the Netherlands, the company car market segment (i.e. employer-provided cars for personal use) constitutes an opportunity to convert a vehicle fleet to BEVs. This market segment is both highly responsive to taxation policy and oriented towards new vehicle leasing which is amenable to the adoption of emerging technologies due to lower risk of obsolescence. The result of targeting incentives at this segment has been highly effective at driving the adoption of battery electric passenger cars in the Netherlands at one of the fastest rates of uptake in the world to date. Since 2000, Norway has been applying similar targeting to this market segment with a 50% reduction in tax applicable to electric company cars with similar results.

Market segments that government policies can target are not limited to four-wheeled vehicles. For example, India has specifically targeted electric two- and three-wheelers as a segment eligible for subsidy support under its Faster Adoption and Manufacture of (Hybrid and) Electric Vehicles (FAME)

scheme which began in 2015. Two-wheelers are a particularly large and rapidly growing market segment in India (20.2 million sold domestically; 80% of domestic vehicle sales in Fiscal Year 2017-18).⁴⁹ Electric two-wheelers are currently a small fraction of that market but have been showing rapid growth with sales expanding by 138% from the year prior.⁵⁰

The Netherlands: Electric Bus Development

In the Netherlands, there will be approximately 800 electric buses by the end of 2019, a figure which is projected to grow in the next decade. The agreement between all 14 Public Transport Authorities (PTAs) and the Ministry of Infrastructure & Water Management has set the realistic goal of reaching 100% of zero emission buses by 2030. The vehicle tenders made by local public transport operators correspond with these goals. This means that an average of 400 zero-emission buses will be added every year. This undertaking doesn't stem from the central government's direct planning, but is the sum of results from regional public transport tenders and realistic PTA expectations. Moreover, there is a high degree of entrepreneurship and innovation in the country, as several businesses are working on zero-emission development, such as charging solution provider Heliox or bus manufacturer VDL. Two of the most eye-catching pilot projects are the deployment of 43 zero-emission buses in Eindhoven and 100 zero-emission vehicles south of Amsterdam near Schiphol. To stimulate sustainable transport initiatives, the central government has also introduced a "Green Deal" mechanism, whereby companies, stakeholder organizations and local and regional governments can enter into a mutual agreement under private law, defining the objectives and required inputs from each party (e.g. electromobility targets). Energy and mobility are two out of nine themes covered by the Green Deals.

Source: Compiled by UITP, with the support of CROW, the Dutch technology platform for transport, infrastructure and public space

Many countries in Latin America are focusing on high-usage vehicles—particularly public transport buses—given the business case, potential environmental benefits and ease of targeting incentives. For example, the public transportation system in Santiago, Chile, will add 200 electric buses to its fleet by the first semester of 2019. Electric utilities (Enel and Engie) will lease the buses to public transport operators, provide the energy—renewable in the case of Engie—as well as install and maintain the charging infrastructure.⁵¹ Successful pilots resulted not only in the decrease of operation and maintenance costs by 60% when compared with diesel buses, but in less fare fraud; passengers were possibly more willing to pay for a better service delivered by new and more comfortable electric buses. Special clauses for the provision of zero and low-emission buses will be included in the upcoming tender to renew the city's public transport fleet, with the aim of having nearly half (approximately 3,000 buses) that are either electric or Euro VI standard. In Bogota, Colombia, Transmilenio (Bogota's Bus Rapid Transit system) partnered with Enel-Codensa (Bogota's energy utility) to pilot the first 18-meter electric articulated bus that began operations in June 2017.

Policy credibility is an important factor in the effectiveness of eMobility programs. An example of this comes from London under the Mayor's plan to establish London's taxi fleet as the greenest in the world (see box below). Transport for London's jurisdiction extends to cover the entire transport system within London (taxis, buses, underground, roads, congestion charging, etc.) and provides strong policy credibility. Transport for London's direct political accountability to the Mayor of London and the Mayor's own personal electoral mandate add to this credibility. The convening power this provides is evident in the Mayor's EV Taskforce which brings together national and local public authorities, utilities, business consortia, industry consortia, regulatory bodies, and civil society groups to facilitate joined up planning and execution.

London: Targeting the “black cab” fleet and Private Hire Vehicles

The Mayor of London has set out his ambition for greening the black cab fleet in his recent Mayor’s Transport Strategy. This is primarily to help clean up the city’s air to improve the health of Londoners, and help it meet the air quality standards set by the European Union for nitrogen dioxide. Transport for London (TfL) has aimed to make all taxis and private hire vehicles (PHVs) zero emission-capable by 2033 and have initiated this by only licensing black cabs if they are zero emissions-capable since January 2018. The pace of transition to zero emission has been established through dialogue with the taxi operators, the automotive industry, and other key stakeholders. The scheme has been supported with a delicensing fund for old vehicles and a subsidy on new zero emissions-capable taxi purchase. A rapid charging network for taxis is being deployed and TfL has committed to at least 300 rapid charging points by the end of 2020.

Sources: Mayor’s Transport Strategy 2020 & interview with Transport for London

Perhaps the most powerful example of policy credibility comes from the People’s Republic of China, where the government put in place successive and iterative policies to support eMobility while intervening to develop different elements of the eMobility supply chain and stimulate customer demand. These began in the year 2009 when the State Council (the highest policy making institution across government) released the ‘Automobile Industry Restructuring and Revitalization plan’ which set out to transform the eMobility sub-sector. Initial incentive packages were geographically targeted at 10 pilot cities which sought to electrify their conventional bus fleets. Following the results of this, the State Council officially released the ‘Energy-saving and NEV Industry Development Plan (2012-2020)’ which was significant in that it laid out a target of 500,000 New Energy Vehicles (NEV) by 2015 and 5,000,000 by 2020. This signalled a clear policy intent to the supply chain which was backed by significant investments in the eMobility supply chain. This was followed by an expansion of eMobility pilots to 39 additional cities. In 2015, the ‘New Pure Electric Passenger Vehicle Enterprise Management Regulation’ was produced followed in 2017 by the ‘Plan for the Middle and Long-term Development of the Automobile Industry.’ Both plans were intended to accelerate research, develop and industrialize NEV technologies, implement power battery upgrade projects, and promote the deployment of NEVs.

Following China’s most recent policy interventions, any private company can apply for a license to innovate and manufacture component parts. These policies catalyzed growth in EVs and were followed by regulations which offered tax and other incentives to vehicle purchasers. For example, EVs get several exemptions which include not being subject to the ‘odd and even’ license plate entry restrictions for cities, tax rebates for charging, credits for avoided pollution, and a 10% reduction in the sale price of vehicles. Provinces have also been allowed to design subsidy and incentive mechanisms, and pursue private investment to introduce new industry players. These most recent interventions are believed to have contributed significantly to a rapid uptake of EVs in 2017 and 2018.

“[The People’s Republic of China] has incentives in place that you simply cannot ignore.”

OEM representative

Electric bus uptake in Poland

- » A highly dynamic market of electric urban bus mobility in Poland is strongly supported by several Ministries and government institutions, thereby increasing economies of scale and making the Polish electric bus market one of the largest, as well as fastest growing in Europe in terms of operating and contracted electric bus fleets. Currently, around 189 electric buses (battery EVs, plug-in hybrid EVs and battery trolleybuses) are operating in Polish cities, with an additional 390 vehicles procured and/or to be delivered by end 2019.
- » The implementation of a national eMobility strategy, including electric public transport and related infrastructure uptake, is currently backed up by approximately €2.3 billion worth of government financial incentives for the period 2018-2028, mainly supported by the Low-Emission Transport Fund (for electromobility, but also compressed natural gas (CNG), liquefied natural gas (LNG), biofuels and hydrogen). Further sources of electromobility financing include the Emission-Free Public Transport (BTP) program as well as the European Structural and Investment Funds.
- » Poland is recognized for having created a functional industrial ecosystem encompassing both production and construction facilities as well as cross-sectoral cooperation schemes. Poland has a mature and well-developed supply-side market, with major OEMs encompassing Solaris Bus & Coach, Ursus Bus and Autosan, all of which have a long industrial history and predominantly powered by Polish engineers and innovation.
- » In 2017, the Ministry of Entrepreneurship and Technology launched a large-scale electric bus program: Polish Electric Bus, coordinated by the Polish Development Fund (PFR). The main aim of this program is to design, build and deploy an electric bus with key components being manufactured by local Polish suppliers and R&D centers. A strategic goal is to create a Polish electric bus market worth €583 million by 2025. The companies involved are expected to create an additional 5,000 new jobs in the sector and produce up to 1,000 new electric buses annually, with the first 1,000 electric buses on the streets by 2025. In the long run, the national electromobility plan for both EVs and BEVs envisages the creation of 81,000 new jobs and a GDP growth of 1.1%.
- » Urban mobility electrification is also one of the key regulatory priorities of the central government, with the January 2018 Act on Electromobility and Alternative Fuels, obliging local governments to develop zero-emission mobility. By 2021, local bus operators in 80 cities with more than 50,000 inhabitants each will be required to ensure 5% of zero-emission buses in their fleets, a figure that will rise to 30% by 2028.
- » Electromobility is developing hand-in-hand with gas mobility, with as much as 350 CNG and LNG buses currently in operation in Polish cities.

Source: Compiled by UITP, using data from the Ministry of Energy, National Centre for Research and Development, National Fund for Environmental Protection and Water Management, Ministry of Entrepreneurship and Technology and the Polish Development Fund

It is important to note that strategies for governments to engage with eMobility are also available when the factors affecting program design and the targeting of incentives pose challenges. For example, market segments may not be well understood, enabling factors may not be in place, and a government may lack policy credibility. The ambition and nature of an eMobility program may need to reflect these conditions. In the first instance, a government may aim to simply enable electric mobility solutions to enter the market through customs or taxation policies or by implementing smaller pilot schemes that are narrowly focused within larger private or public transport fleets. This may offer a way to learn and develop an electric mobility program progressively after a period of initial uptake. It may also demonstrate solutions that shape market segments incrementally. The successive evolution of scheme design could introduce greater complexities and more sophisticated approaches to government interventions if desirable.

2.2 On the technology and its deployment

As EVs become more numerous around the world, so too are the lessons relating to the deployment of EV technologies in different country contexts. These relate to both technical and non-technical factors such as behaviours, complementary transitions, and the power of human ingenuity to make eMobility work. Some of the key lessons captured in this research include:

- » **Simple eMobility technologies** have proven highly sustainable and effective in difficult operating contexts;
- » **Consumers have shown remarkable ingenuity** and an ability to “make things work” around eMobility when governments are able to provide the basic enabling conditions; and
- » **Used private EVs** and re-export markets are providing an important point of access in countries where lower incomes may otherwise stymie the adoption of eMobility.

Electric mobility does not necessarily require complex technology. Nepal provides an example of how simple solutions can also be effective and sustainable – particularly in a low-income country context. Nepal imports all of its fossil fuel in tanker trucks via its road network. In 1989, border disruptions that impacted the supply of fuel led a group of engineers to explore alternatives – beginning with the conversion of an old petrol car into an electric vehicle in 1992. In 1993, the Global Resources Institute, with assistance from the United States Agency for International Development (USAID), piloted the conversion of fossil fuel powered three-wheel public transport vehicles (called “tempos”) into full battery electric public transport vehicles (renamed the “Safa Tempo”). During the late 90s, the fleet of Safa Tempos significantly increased in response to a government policy of restricting the registration of conventional tempo vehicles. Today, there are 714 Safa Tempos registered within Kathmandu Valley. The long history of Safa Tempos and their sustainability are a remarkable example of the sustainability and effectiveness of simple eMobility solutions.

Safa Tempos have been assembled locally in Nepal with electrical components imported from India and the United States. Each Safa Tempo uses two sets of batteries that are swappable using hand-operated lifts, allowing for near continuous operation. Battery banks provide about 60 km of operation after which time the tempo goes back to a charging station to load another set of batteries. Privately operated garages charge battery banks at a cost of NPR 3.50 (US\$ 3) in addition to a fixed NPR 1,500 (US\$ 15) monthly fee that drivers pay for accessing garages. On average, Safa Tempos carry 90,200 passengers per day. The service runs from 7:30 AM in the morning until 8 PM at night. The average fare is NPR 14 (US\$ 0.14) per 4 km travelled, which is affordable for large segments of the population and not subsidized by government.

Figure 13. 'Safa Tempos,' electric public transport in Nepal



Source: World Bank

Jordan: government has initially enabled, and eMobility users are making it work

Jordan's experience of eMobility is unique for several reasons. Firstly, the majority of EVs in Jordan are second-hand Nissan Leafs (about 88% of all EVs). Secondly, the primary market segment that is driving the uptake of electric mobility consists of younger, less well-off individuals who pursue EVs as a budget solution to meeting their private transport needs. Thirdly, the community of EV users in Jordan is very active on social media and use this as a platform to assist each other on issues such as purchasing second-hand vehicles and troubleshooting vehicle problems. As of November 2018, this group had 66,733 members. Some members within the group have made their home charging point available to others as a means of enabling longer trips into areas not well covered by public charging points.

<https://www.facebook.com/groups/leafjordan/>

The Government of Jordan's approach to developing electric mobility has been evolving since 2015 when tax and custom duties exemption for battery EVs and charging equipment were put in place. Since then, Jordan's EV uptake has expanded to more than 7,000 vehicles despite a very limited number of public charging points in the country (approximately 8). Used Nissan Leafs can be purchased for approximately JOD 7,000 – 10,000 (US\$10,000 – 14,000) making them more accessible than conventional vehicles of similar age to young professionals. The price of electricity in Jordan is subsidized, meaning that the purchase and use of second-hand EVs offers a low-cost solution for customers looking for private mobility options. In addition to the social media community, there are also local mechanics shops (unaffiliated with any manufacturer) who have become skilled at second-hand vehicle maintenance and repair.

Source: The World Bank with special thanks to Mr. Ahmad Abu Raddad

Customers themselves can play a key role in supporting electric mobility objectives and addressing challenges to implementation. One example of this comes from Jordan where a social media group is providing a support network for electric mobility users, many of who are accessing EVs through the second-hand vehicle market. This has anchored the use of second-hand EVs in Jordan within a market segment primarily comprised of budget-conscious younger professionals. While the electricity sector in Jordan has many structural issues that may need to be addressed in order to support the widespread up-

take of EVs, it is clear that this customer-led initiative has established initial uptake, generated knowledge and familiarity with eMobility, and pioneered new approaches that offer valuable lessons for the global community.

“... there is a need to fully incorporate consumers, as their perceptions, beliefs and behaviors strongly determine the success of e-mobility: run demonstration programs, raise awareness on the benefits of new technologies, facilitate their use in cities, [these] are key to promote uptake of new green technologies.”

Maris Strigunova, Sustainability Programmes Manager, Fédération Internationale de l'Automobile (FIA)

2.3 On the deployment of electric buses

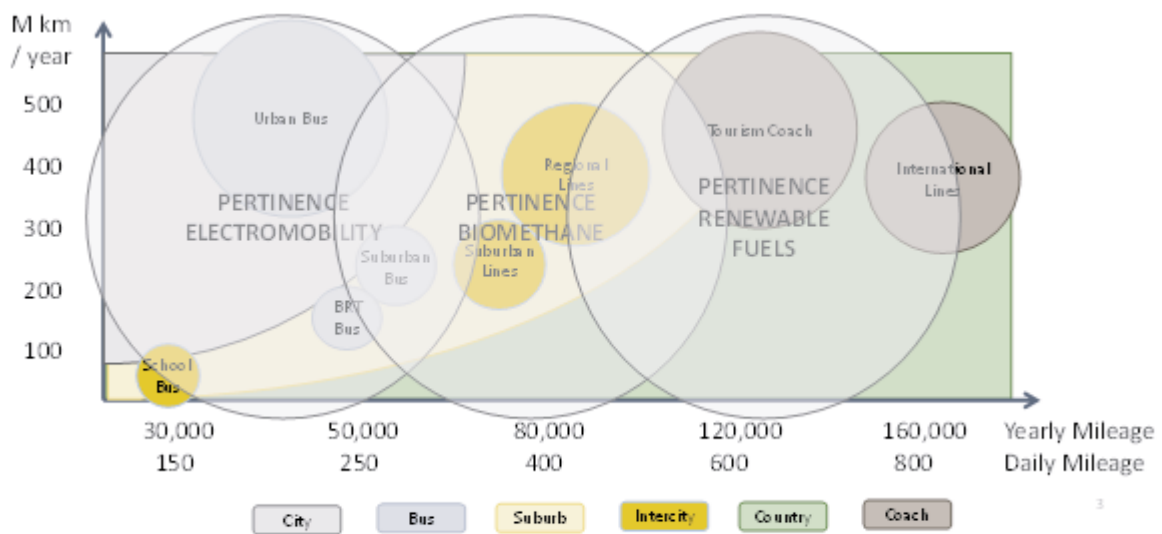
eMobility is not new to public transport. Many cities are already familiar with electrified modes such as metros, trams, and trolleybuses. Cities with an existing trolleybus infrastructure, such as Moscow and Geneva, are finding synergies with integrating battery trolleybuses in their systems. In other cities, the deployment of e-buses has come with challenges. Some of the key learnings on electric bus deployment to come out of this research include:

- » **The foremost challenge surrounding electric bus deployment is the need to adapt new vehicles and related charging infrastructure to networks, while maintaining the same level of service.** A good example is the challenge of maintaining an equivalent passenger capacity with the added weight of battery packs;
- » **Electric bus deployment and operating requirements often differ heavily across different operational contexts.** For example, topography, temperature, right of way, etc. affect performance. Selecting the right technology according to these factors is critical;
- » **A key to successful electric bus deployment is finding solutions that can be smoothly integrated** into the existing public transport network, without negatively impacting its daily operations. The daily mileage and route characteristics of buses that an operator may target for conversion are key considerations that determine the suitability of eMobility;
- » **To date, electric buses are more relevant for urban applications with less application for long inter-city trips.** However, advances in battery technology to extend travel range may change this;⁵² and
- » **Utilization and service quality determine the relative environmental benefits** that converting to electric buses can deliver. There is currently a “sweet spot” in operating conditions (duty cycle, range, passenger loads) where eMobility options make the most sense.

Experience of electric buses to date suggests that there is a trade-off both in terms of environmental benefits and TCO. From an environmental standpoint, electric buses currently have higher manufacturing-related emissions than conventional vehicles, but lower emissions from use, and fewer greenhouse gases and air pollutants overall during the course of their lifetime provided that their level of

utilization is sufficient. UITP estimates that roughly 70% of a “typical” vehicle’s impact can be attributed to the electricity production, and another 15% to the production of the battery. Future developments may see the supply chain for electric buses become increasingly sustainable. With respect to financial performance, the European Commission Clean Bus Expert Group, in which UITP plays an active role, estimates that “electric buses with daily duty cycles of less than 165km are already cost-competitive with diesel on a TCO basis. Falling battery costs mean that this will apply to duty cycles above 165km per day, within 2-3 years.” For duty cycles above roughly 165km per day, services may require multiple buses which, in the case of electric options, may currently mean more emissions where those buses are not fully utilized. Alternatively, additional investments in charging infrastructure along routes may provide for range extension but these require additional capital investment.

Figure 14. Buses and coaches: missions and ranges



Source: Deliverable 1, European Commission Clean Bus Expert Group, STF (Sustainable Transport Forum), DG MOVE

There are four established powertrain technologies available on the public transport EV market today: PHEV, BEV, FCEV and TBs with batteries for off-wire operation. Experience suggests that each of these solutions has different advantages and drawbacks that make them more or less well-suited to different operating contexts as summarized below.

- » **Plug-in Hybrid Vehicles:** Plug-in hybrid buses are hybrid EVs that use rechargeable batteries or other energy storage devices. These are recharged by connecting to an external source of electric power. In many applications, plug-in hybrid EV buses are able to run 70% of their required range on electric energy when provided with charging opportunities on route or at route terminus / origin points (e.g. recharging lasting up to 6 minutes during schedule recovery periods). Plug-in hybrid EV buses share the characteristics of conventional hybrid EVs, and similarly use an electric motor in combination with a combustion engine to support when needed.⁵³ The electric range of plug-in hybrid buses depends on the energy strategy and management that an operator ultimately must design into routes and operating procedures. Modern plug-in hybrid EV buses also feature functionality that allows for pre-programming the switch between electric and diesel propulsion depending on a route’s characteristics. Parameters such as weight, passenger capacity, heating and cooling, and line length are the variables that operators generally find most relevant in this process. Plug-in hybrid EV buses have demonstrated flexibility and adaptability. However, this comes with high upfront costs and the requirement of maintaining both conventional and electric systems.
- » **Full Battery Electric Vehicles:** Full battery electric buses have an electric propulsion system,

using chemical energy stored in rechargeable battery packs. Battery EVs use electric motors and motor controllers instead of internal combustion engines for propulsion and derive all power from battery packs. They are charged statically (e.g. overnight) or on-route, using mechanical and electrical equipment. Fully electric buses are zero local tailpipe emission. However, their ability to provide service depends on both overnight charging and charging opportunities on route where they are required to operate for distances beyond their optimal battery range. The management of battery state of charge for battery electric bus options is a particularly critical concern for operators in order to maximize the useful life of those batteries. Battery electric bus operators have found “sweet spot” applications in fleets where required range and / or the opportunity to put in place on-route charging has created optimal conditions for their deployment.

- » **Fuel Cell Electric Vehicles:** Fuel cell electric buses include both a fuel cell and batteries. All the energy required for the buses to operate or recharge the batteries is provided by hydrogen stored on board. FCEVs produce no tailpipe emissions and are a promising option for long-range applications. At the moment, the TCO of these vehicles is higher than that of diesel Euro VI buses, but this is changing as the technology continues to mature.⁵⁴ Fuel cell buses have a similar range, refuelling time and operational flexibility as diesel buses. However, a key disadvantage has been the supply chain and infrastructure required for hydrogen fuel. In one example from Canada, hydrogen was being trucked across great distances (using diesel trucks and at great expense) in order to supply a pilot fleet of hydrogen buses;⁵⁵
- » **In-Motion Charging Battery Trolleybuses:** IMC battery trolleybuses draw power from overhead wires via roof-mounted poles. They are charged dynamically or, in other words, while in-motion, using the existing trolleybus overhead lines, or in a static position with a device to connect to the electrical grid. Power is supplied from a central power source that is not on board the vehicle, or via on-board rechargeable batteries (when the bus is not in contact with overhead lines). This enables the vehicle to run electrically and independently for part of its route.

Table C Comparison between different types of fuels/propulsion technologies

Consideration	Euro VI	CNG	Bio-methane	Biofuel (HVO)	Electric	Hydrogen	Plug-in hybrid
Energy Consumption	benchmark	-	-	=	+++	++	+
TCO euro/km	benchmark	++	+	-	--	---	-
TCO trends	benchmark	++	++	-	+++	+++	+
Noise standing	benchmark	+	+	=	+++	+++	++
Noise passing by	benchmark	+	+	=	+	+	+
Energy security	benchmark	++	++	+	++	++	n.a.
Range	benchmark	=	=	=	--	=	=
Zero emissions range	n.a.	n.a.	n.a.	n.a.	+++	+++	+
Route flexibility	benchmark	=	=	=	-	=	=
Recharging/Refuelling time	benchmark	=	=	=	--	=	-
Service lifetime	benchmark	=	=	=	?	?	=

Source: European Commission Clean Bus Expert Group, STF (Sustainable Transport Forum), DG MOVE.

Note: The Euro VI engine comparison baseline is the minimum legal requirement for new EU buses to respect emission limits.⁵⁶

Table C presents a summary of low emissions bus options (including Euro VI, and alternative liquid fuels) and summarizes some of the common experiences around key issues such as range, upfront costs, and energy consumption.

2.4 On new business models, new players, and new market structures

The transition to eMobility is presenting opportunities for new competitors and new business models across the value chain. This includes entirely new business models as well as nuanced versions of existing models. Some of the global experiences observed to date include:

- » **New models around eMobility are bringing both complementarity and disruption** to the mobility value chain. Existing business such as mobility service providers are finding ways of integrating eMobility in to their business models. At the same time, eMobility is having a disruptive effect on traditional automotive sectors;
- » **The transition to eMobility offers parallel opportunities** for aspects of the transport sector in transition (unrelated to vehicle technology) that can be captured through targeted interventions. For example, these can include participation by different groups (e.g. women) in the market for transport services; and
- » **Enabling or revising market structures** that pertain to eMobility solutions. These are evolving but, in many cases, not as quickly as technologies. This is an area where government action may be lagging behind. The role of incumbents is an issue that governments looking to engage with electric mobility are likely to face.

Electric mobility has disruptive potential for firms engaged in the production of conventional vehicles and their components. There are elements of EVs that are comparable to conventional vehicles such as interior trim and body panelling. However, drive train components, cooling systems, braking, and the absence of any systems relating to liquid fuel and exhaust make the supply chain around EV production significantly different. EVs also tend to have fewer components (e.g. 20+ parts in an electric motor vs. 200+ parts in a simple conventional petrol engine). These differences have implications for jobs. For example, a 2015 study from Germany suggested that a potential ban on new conventional vehicles would affect an estimated 7.5% of overall manufacturing employment in Germany and approximately 426,000 workers in the domestic automotive industry.⁵⁷ On the other hand, several countries have identified the opportunities that the disruption can offer to develop new industry and jobs around eMobility.

“[electric mobility]—it’s like starting the automotive industry anew.”

Stakeholder from Rimac Automobili

“The shift towards low carbon and EVs is seen as an economic opportunity for supply chain development, to diversify and safeguard jobs.”

Robert Evans, CEO, Cenex

International experience also provides lessons about how electric mobility can nuance business models and operations within market segments. For example, in Kyiv, enterprises that own vehicles used for ride hailing services are making use of the market for used battery EVs that have been imported into

Ukraine. This lowers the costs associated with accessing electric vehicle technology and can generate cost savings when compared with conventional vehicles. The business model that has been developed for this service also involves a partnership with a local charging operator as well as the use of a messaging application to address challenges associated with limited charging infrastructure and the need to identify available charge points during peak hours.

“[Shared mobility] offers citizens the travel flexibility and convenience of the private car, without its negative externalities, such as congestion, emissions and wasteful parking requirements.”

UITP, Policy brief: Public transport at the heart of the integrated mobility solution, 2016

New mobility services such as car and bike-sharing, shared taxi services, carpooling and demand responsive transport are becoming omnipresent in many cities, many of which are offering eMobility solutions to customers. For this purpose, partnerships/cooperation with local providers, physical integration (interchanges/areas with access to all transport modes, bike and car-sharing stations next to public transport stations) and integrated ticketing are some of the key elements needed for the efficient integration of new mobility services into traditional public transport systems.

Ukraine: electric mobility being integrated in the business models for ride hailing services

Ukraine's capital city of Kyiv hosts ride hailing where electric mobility is emerging as a solution for vehicles that provide services. One company studied in the research has procured a fleet of approximately 30 used Nissan Leafs. The company that owns these vehicles hires drivers to operate the fleet while rides and payment are arranged via Uber.

On average, vehicles are obtaining about 100 km per charge and require 4 charging cycles per day. Cold weather during Kyiv's winter months affects this and is reported to reduce range available per charge by about 15%. The company that owns vehicles has entered into agreement with an operator of fast charging infrastructure that serves approximately 20 locations in the Kyiv area. This provides each driver with a smartcard that is used to transact at charging points.

On average the cost per km of service associated with charging is about UAH .10 (US\$.0036) which represents a cost savings over conventional fuel. Vehicles charge for approximately 20-30 minutes. However, during peak hours it is not uncommon to experience an additional 20-30 minute waiting time while queuing for a charging station to become available. This represents a loss of revenue for drivers who seek to mitigate the impact on their earnings by communicating with each-other over Viber (an online messaging service) to report on which charging stations are experiencing high or low demand.

Source: World Bank study team with special thanks to their driver who kindly endured many questions

The disruption of eMobility offers parallel opportunities to advance other objectives within the transport sector. The transitioning of Kathmandu's tempos from internal combustion to battery electric operations is an example of this. Transitioning between technologies provided a parallel opportunity to also introduce a greater level of participation by female drivers and vehicle-owning entrepreneurs. Government, international development partners, and domestic development partners participated in

the transition and helped to achieve these dual objectives simultaneously. Formula E racing has also achieved a similar parallel transition by increasing the number of female drivers that compete in its championship.

Kathmandu's female Safa Tempo drivers and entrepreneurs

There are currently 775 women out of the total 1,302 full- and part-time drivers employed in the operation of Kathmandu's Safa Tempo fleet (i.e. Kathmandu's fully electric three-wheeler public transport vehicles). Of this group, 210 women own and run their own Tempo business. The involvement of women in the operation and ownership of Safa Tempos began in the late 1990s and grew in parallel with the growth of electric mobility. Originally, a group of seven women bought and ran their own Safa Tempos at a cost of approximately US\$ 5,000 per vehicle. Later, this was extended to 16 additional women - with a Swiss funded (Helvetas, Nepal) project providing free training to women operators and entrepreneurs.

Safa Tempo drivers earn an average of roughly NPR 12,000 (US\$ 1,200) per month—a good income by local standards. Most of the female drivers who operate Safa Tempos report being primary earners in their households. The World Bank conducted a study on Gender and Public Transport in Kathmandu that analyzes the situation of the city's public transport. During this study, women also reported a preference for using Safa Tempos to make public transport trips as the face-to-face seating arrangement for a Safa Tempo's 12 passengers provides for greater personal security. The video link is below for those curious to learn more about urban transport in Kathmandu and the challenges faced by women as well as men:

<https://www.youtube.com/watch?v=BTqh1kAMp-U>



Source: World Bank Nepal country office interviews with drivers, entrepreneurs, and Nepal's Department of Transport Management

The business model being deployed by Felyx e-scooter sharing in Amsterdam exemplifies how firms that provide eMobility services can work in close collaboration with public authorities and their

objectives. Felyx operates a fleet of shared e-scooters which offer point-to-point services for customers. Customers initiate the rental of a scooter using a smartphone application and subsequently end their rental using the same application once they have reached an eligible drop-off area. The scheme makes use of “geofencing” such that areas where customers can pick-up and drop off e-scooters are defined, and a customer’s rental cannot be ended in any other area. Felyx seeks to target key locations for pickup and drop off such as points of integration with public transport service where customers may be looking to begin or end their trips. Working in very close cooperation with local authorities is critical to Felyx’s business model as scooters are parked in public spaces where space is at a premium. In exchange, Felyx helps public authorities to expand the access that their populations have to zero-emissions transport solutions – particularly in core urban areas where policy objectives involve reduced emissions.⁵⁸

“If you really want to change behaviour, this means working together.”

*Luc van Emmerik, Global Head of Expansion,
Felyx e-scooter sharing*

2.5 On the energy-transport nexus

The electrification of transport is part of a broader long-term transition towards an increased electrification and decarbonization of economies. Though the uptake of EVs is still nascent in most countries, early adopters are already seeing strong linkages and impacts between power and transport systems. Some of the emerging issues and experiences observed include:

- » **Decarbonization of power generation complements decarbonization of transport.** There can be a trade-off between reduced tailpipe emissions and increased upstream emissions, particularly in power grids with a high share of fossil-fuel powered generation;
- » **The eMobility related challenges and opportunities facing the energy sector are different across countries.** In part, this reflects differences in existing infrastructure as well as the expected growth in electricity demand (e.g. stable or declining in high-income countries, as opposed to fast growth in low and middle-income countries). Differences in the level and nature of eMobility uptake between countries also affects challenges and opportunities for the energy sector;
- » **The interaction of EVs with the grid is creating significant opportunities to disrupt the power industry.** Examples include new market participants as well as new technical solutions to old problems such as managing peak loads. In addition, batteries in EVs are a resource that enables new business models and ways of operating the power system; and
- » **Rate structures and charging patterns are also changing in response to eMobility.** Smart charging is seen as key to avoiding disruptions and making a better use of existing charging infrastructure. Utilities are also keenly aware of the need for rate structures to send the right signals to eMobility consumers regarding when and how to charge.

The upstream impacts on emissions that result from eMobility via power requirements are key considerations for the associated environmental objectives. The net reductions of pollutants (i.e. the difference between the well-to-tank and tank-to-wheel emissions of electric and ICE vehicles) will depend on several factors among which the carbon intensity of the power system is a crucial variable. At the same time this poses a challenge, it also represents a business opportunity for companies such as Fastned in the Netherlands and Engie in Chile, both of whom have committed to delivering 100% renewable ener-

gy to their charge points, to increase their value proposition to clients. Similarly, solutions are also starting to take shape in island-states that import all the fuel they use in their transport systems, such as the Maldives. There, the replacement of ICE two-wheelers with electric equivalents will occur in tandem with the installation of photovoltaic power generators to charge batteries.

Net emissions assessment is particularly relevant in countries with a high share of coal-fired electricity generation, including China and India. Estimates show that by 2040, coal will continue to represent a large share of the total energy production mix in these two countries (40% and 48%, respectively) despite a significant increase in power generation from renewables. These are also places where a large share of the world's EV fleet could be deployed in the coming decades.⁵⁹ A more comprehensive analysis should also consider lifecycle emissions of production and use of the vehicle, including battery manufacture. Several indicative estimates show that lifecycle GHG emissions of EVs are lower than ICE vehicles, even in countries with “dirty” grids (i.e. with a high share of coal-fired electricity generation). Such is the case of Poland, where an electric car is estimated to emit 25% less CO₂ than a diesel car over its lifetime.⁶⁰ Here, apart from the carbon intensity of electricity supply, a key variable is how long the vehicle has been in operation. In countries like Norway, where the share of hydroelectricity is nearly 100%, the comparison of GHG emissions between electric and internal combustion engine cars is favorable for the former. Estimates show that the break-even point of GHG emissions of electric cars is achieved after approximately 2.5 years. However, in Germany with a high share of coal-fired generation, the break-even point is only achieved after 10 years.⁶¹ A key takeaway from this is that countries looking to decarbonize their transport sector should work to decarbonize their power grids in parallel, to more fully reap the environmental benefits of the transition.

Countries that look to engage with eMobility will also need to assess the preparedness of their generation, transmission and distribution networks. This will involve identifying generation capacity needs, congestion problems, or the need for last-mile upgrades (e.g. transformers). An advantage that some low and middle-income countries may have, is that they will be able to plan for and factor in the new demand generated by EVs before fully constructing their networks. This will allow them to avoid the need for adjustments to existing and consolidated grids like in higher-income countries, which can be costlier and suboptimal.

Projecting the future energy impact of EVs is essential for understanding the points of intersection between eMobility and energy infrastructure. The “New Policies Scenario” put forward by the International Energy Agency in its World Energy Outlook 2018, shows that the estimated 300 million electric cars on the road in 2040 (15% of the total car fleet), could displace 3.3 million barrels of oil per day, or approximately 3% of the total oil demand that year. To put this in a policy options context, if governments were to put more stringent fuel economy standards to ICE vehicles, the reduction would be three times larger. In terms of electricity demand, the over 3 million electric cars today account for 0.1% of total electricity demand, while the 300 million in 2040 would account for 3%. But here again geographical distinctions must be made, as most of the net increase in total electricity demand will come from developing countries, notably China and India.⁶²

The integration of EVs into the grid is creating significant opportunities to disrupt the power industry. Some utilities are already looking beyond the traditional model, where power flows only from the grid to the load, to a bidirectional flow (vehicle-to-grid, or V2G). Under this new model, vehicle batteries constitute movable flexible loads and decentralized storage which can serve as a resource that can provide numerous services to the grid (load management, storage for renewable electricity generation, contingency reserve, etc.). Smart and coordinated charging, as well as the need for standard communication protocols, are being flagged early on as key enablers. Though utilities and other stakeholders see the potential of V2G (and more broadly vehicle-to-everything, V2X), its large-scale uptake will take some time as there are still technical and regulatory hurdles to be solved. There is a need to better understand costs and benefits, and the number of EVs to make the business viable is still insufficient.

This disruption created by eMobility is enabling the entry of new actors to the market, such as the

EV aggregators. Companies like eMotorWerks are applying vehicle grid integration technologies, using smart charging to dynamically adjust charging loads to balance grid demand in real time, bringing the cost of electricity down while absorbing some of the spikes caused by intermittent renewable electricity generation. eMotorWerks deployed a 30 MW / 70 MWh virtual energy storage battery load by aggregating EVs on the California Independent System Operator (CAISO) market.

Rate structures are also a consideration for the development of eMobility. Traditional tiered rates that promote energy efficiency (where rates go up as customers use more electricity), can present disincentives for eMobility owners that want to reduce energy costs, as one electric car can increase the annual consumption of a household by 1.5 to 2 times. Flat rates under unmanaged charging further increase existing peaks, especially in the evening when the car returns home and is plugged in to charge. Utilities then introduced time-of-use rates to shift charging to off-peak periods. However, this created new peak hours and steep demand ramp ups, as all users programmed the charging of their vehicles as soon as the low rates kicked in. These are not serious issues while EV numbers are low, but could present problems when this number grows, or when EVs are clustered and have local effects in distribution networks. Dynamic electricity pricing can be an important enabler of smart charging, where changing price signals along the day reflect the conditions of the grid in a particular moment, optimizing the process of charging and discharging the batteries in the vehicles. Many utility rates use demand-based charges to recover fixed costs, which can negatively impact low-usage EV charging stations like public fast-chargers and fleet charging stations where electricity costs can exceed gas or diesel costs. To address this situation, PG&E in California proposed an innovative commercial EV rate design that uses a lower-cost “subscription” model, similar to a mobile phone plan. The rate helps commercial users to reduce costs, is simpler and more consistent than current rates, and encourages users to charge at mid-day with lower rates that coincide with higher solar generation on the grid.⁶³

STAKEHOLDER PERSPECTIVES ON eMOBILITY

A key aim of this research was to bring together the insights of those stakeholders whose interactions will be key to making the mass uptake of electric mobility a reality. This section includes a summary of key issues from the perspective of six stakeholder categories that play critical roles in the development of eMobility around the world.

3.1 Public authorities and public institutions

The decisions and actions, or inactions, of governments, regulators, and public institutions leave defining marks on the roles that other stakeholders play in the transition toward eMobility. They are the architects of the policies that shape the uptake of eMobility technologies. They operate in a complex environment in which standards need to reflect local needs and concerns with a view to international factors such as cross border connectivity and trade relationships. Some of the viewpoints collected from public authorities and institutions included:

- » **Uncertainty and its role in decision making is a central challenge** for government authorities. More sophisticated government programs entail forecasting models, but these are inherently imperfect tools due to the unprecedented nature of the transition to eMobility. In addition, there is significant uncertainty around technologies and demand which both constitute moving targets;
- » **Interoperability and especially charging standards are key issues** that governments have sought to address in the design of more advanced eMobility programs, either through complete standardization, interoperability, or in some cases, limited intervention;
- » **The domestic and international political economy of eMobility plays a major role** in the way that public authorities and institutions develop and implement eMobility programs. In seeking to manage this, more advanced programs are using open and transparent engagement with industry, the public, and political actors as well as strategic alliances across borders;
- » **Governments are finding a role in supporting industry innovation** in more advanced eMobility programs. This often targets both emissions policy and industrial policy with the specific aim of developing jobs and domestic industry;
- » **Distributional impacts** of subsidies are rightly an area of concern for many governments in the way that they craft programs around eMobility; and
- » **Public authorities are critical for creating the financing and incentive frameworks** for electric bus up-take in urban and suburban areas.

“We haven’t been through this kind of transition before, it’s not easy...We’re talking about a whole new value chain ... the biggest industry shift in 100 years.”

Government policy unit

The foremost challenge facing public authorities and institutions is uncertainty due to the unprecedented and complex nature of the transition to eMobility. This exists at many levels such as the future performance of technology, actual responsiveness of consumers to incentives, industry and supply chain capacity to deliver eMobility products, and the capacity of other public institutions to deliver supporting interventions concurrently. Nevertheless, public authorities and institutions are tasked with taking actions amidst uncertainty in order to achieve policy objectives that governments set through the political process. While the technical arms of governments can inform that process, they also commonly find benefit in designing schemes that include measures for flexibility. An emerging best practice from some governments in this regard is for programs to remain “technology neutral” such that they may support the development of eMobility solutions without prescribing eMobility as the only solution for emissions reduction in the transport sector. More specifically, this means program design that leaves room for broad ranges of technologies (e.g. beyond battery EVs) to participate provided that their end result supports intended outcomes.

“Governments need to facilitate cooperation between stakeholders and show the way ...”

City of Amsterdam

The incompatibility of elements within the market for eMobility products is a further challenge that public authorities and institutions identified as a key concern in the design of eMobility programs. This is particularly important in the case of charging infrastructure where interoperability can occur in the vehicle to charger interface or in back-end systems for customer payment. It also affects cross border connectivity with neighbours who may have different objectives. The experience of the Netherlands provides one example of a government managing such issues. Interoperability has been a key priority due to the Netherlands’ geographical characteristics, population size, domestic automotive industry characteristics, and membership in the European Union. Public authorities at both national and subnational levels have accordingly made interoperability a centrepiece of eMobility policy. It is also important to note that the nature of charging infrastructure in the Netherlands has predominantly focused on regular charge points as opposed to fast charging which reflects consideration for average trip characteristics, investment costs, and electricity distribution infrastructure requirements. Managing the interoperability of fast charging is also more technologically complex as the rate of power transfer between charge points and vehicles requires advanced software and hardware interfaces that cannot be managed via a plug adapter. For example, only about 2.6% of public or semi-public charge points in the Netherlands are fast chargers.

“Interoperability is key.”

*Cristina Victoriano, Efficient Transport Coordinator,
Sustainable Energy Division; Ministry of Energy,
Chile*

Public authorities and institutions noted that the interoperability of fast chargers represented a key challenge which has been reflected in both investments and industry interventions. At present, there are four main technologies competing in this space that have linkages to geopolitical considerations and company strategies in the eMobility market. These include: (i) CHArge de MOve (CHAdeMO) that was originally developed in Japan but has since expanded in geographical breadth; (ii) Combined Charging System

(CCS) that has been led by European, North American, and OEMs in the Republic of Korea; (iii) the Tesla Supercharger which was developed by a single OEM, Tesla; and (iv) GuóbiāoTuijiàn (GB/T) which is the standard developed by the People's Republic of China. Each technology entails different power transfer characteristics, different plug interfaces, and the different use of either Direct or Alternating Current (or both). The nascent state of eMobility in all countries has meant that the interoperability of fast charging has been a particular challenge for most eMobility programs and many public authorities have sought to deploy infrastructure that can accommodate multiple technologies, which comes with additional cost.

Figure 15. A fast charging installation with multiple technology options



Source: The World Bank

Countries have adopted different approaches to the standardization of domestic fleets and charging infrastructure based on their unique context either through “de jure” mechanisms or through the “de facto” application of technologies in their eMobility markets. The foremost example of different approaches are China and India. The government of the People's Republic of China has focused on standardization across its domestic industry and building infrastructure networks around official GB/T standards. This has been the predominant standard for fast charging and vehicles in China's domestic market. In contrast, the Indian market to date has been characterized as a near perfect democracy of technologies and charging standards. Cooperation and interoperability of fast charging infrastructure is also a dynamic space. For example, in 2018 the CHAdeMO Association announced its intention to develop a Memorandum of Understanding with the China Electricity Council (CEC) around collaboration to develop a next generation of ultra-fast charging technology.⁶⁴ Similarly, India's Central Electricity Authority has recommended the adoption of the Combined Charging System (CCS) that is commonly used by OEMs in Europe, North America, and the Republic of Korea.

“You need cooperation at the international level because you may struggle to get from points ‘A’ to ‘B’ across a border.”

Krzysztof Bolesta, Vice President, Fundacja Promocji Pojazdów Elektrycznych (FPPE)

Unsurprisingly, public authorities commonly expressed environmental concerns as being the driving force behind eMobility programs. However, there is also an industrial policy agenda that often explicitly accompanies environmental objectives. As one example, the Netherlands releases a bi-annual report detailing the contribution of eMobility to the domestic economy in the form of jobs and other economic activity. It also highlights the operations of national champions in the sector.

**“[Policy]
uncertainty is
even worse than
doing nothing.”**

Government Technical Researcher

National authorities included in the research also recognized the need for consistent, predictable policy to create confidence around investments needed in vehicle development and infrastructure. Key constraints that affect to deliver this include fiscal capacity, political cycles, and the inherent unknowns of the transition to eMobility. Experiences with government support for renewable energy have influenced the approaches that public authorities are taking (see box below on solar installations). For example, in the United Kingdom, the Office for Low Emission Vehicles has sought to design in buffers that affect financial support schemes (e.g. continuing support for 2.5 months of projected demand). Advanced notice of when subsidies will be reviewed also serves to inform the market. Under consideration is a scheme whereby the maximum number of vehicles targeted for support would be communicated in advance in order to provide certainty to stakeholders as well as the government’s fiscal obligation.

As mentioned by other stakeholder groups, public authorities also noted the importance of broad stakeholder communication and feedback in the design of public eMobility programs. Beyond outright financial support for eMobility, their roles included convening to establish dialogue, share data, and coordinate disparate activities both within government itself and beyond. The interface between national and local authorities was a particularly important point in this regard.

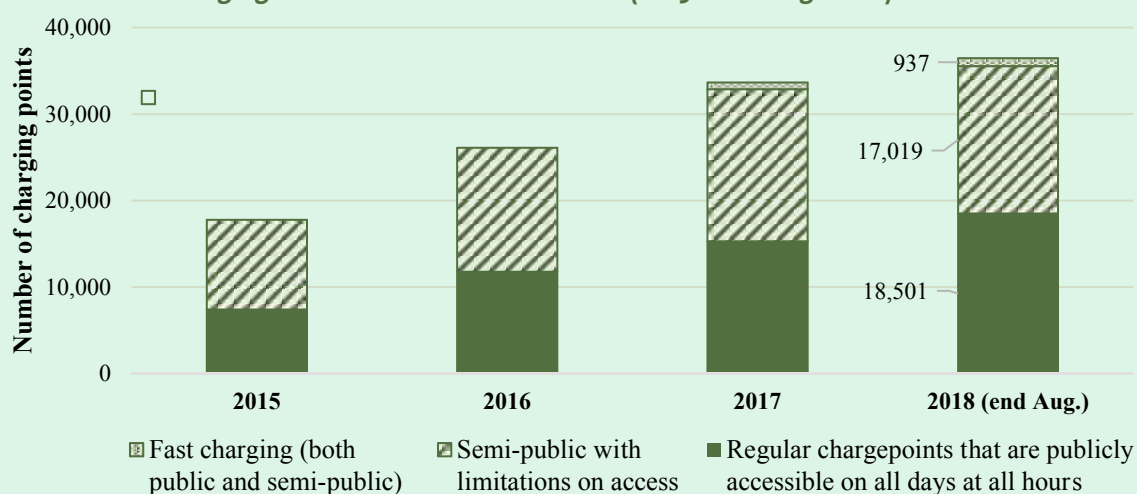
The Netherlands: Interoperability charging infrastructure and advanced public charging infrastructure

The Netherlands has achieved interoperability of public charging networks through three actions. First, all procurement tenders for public charging infrastructure have required interoperability in contracts. Secondly, a universal standard has been developed by the market for communication between charge point operators which entails a common Radio Frequency Identification (RFID) card for payment. The third measure was the establishment of a special entity named E-violin as a governing body to regulate interoperability agreements.

For eMobility customers, this offers the convenience of using any public or semi-public charging station with a single card which has helped mitigate concerns over charge anxiety. A key reason for why this is important is that an estimated 70% of the eMobility customers in the Netherlands are dependent on public street parking – especially for meeting critical overnight charging needs. To support this, Dutch cities like Amsterdam and Rotterdam have invested in an extensive public charging network. As a whole, the Netherlands has the highest ratio between public regular charging points and vehicles with eMobility features in circulation (i.e. 134,009 battery EVs and plug-in hybrid EVs relative to 19,812 public chargers, RVO, 2018).

Three factors have influenced how the Netherlands' charging network has developed. First, cities have co-financed basic charging infrastructure. Secondly, public-private partnership models used in the network's development have, from the outset, been designed for evolution towards fully commercial non-subsidized market structures. Third, government established a national platform known as "The Netherlands Knowledge Platform for Public Charging Infrastructure EV" (NKL) to convene stakeholders and work towards cost reduction, innovation, and knowledge exchange.

Evolution of charging networks in the Netherlands (2015 - end Aug. 2018)



Sources: "Visie op de laadinfrastructuur voor elektrisch vervoer; Beleidsagenda richting 2020; Voor slim en schoon vervoer" Ministerie van Economische Zaken, November 2016.

Netherlands Knowledge Platform for Public Charging Infrastructure EV

Financing electric bus deployment in the United Kingdom

The UK government is providing a series of grants for the purchase of low/zero emission vehicles, including EVs:

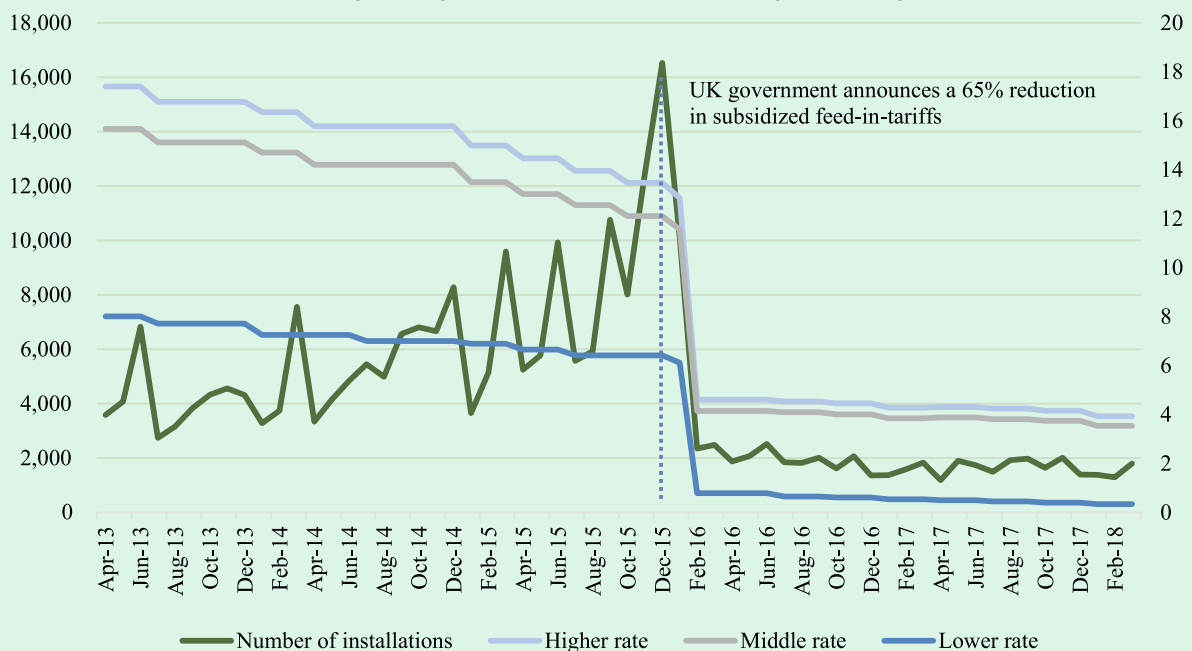
- » The Bus Service Operators Grant Low Carbon Emission Bus (LCEB) Incentive was launched in 2009 to encourage improvements in fleet fuel efficiency and introducing a level playing field for low carbon emission buses, providing bus operators with a payment of 6 pence per kilometer operated with a low carbon bus.
- » The Green Bus Fund (2009 – 2013) enabled around 1,250 low emission buses to be delivered in England.
- » Following the footsteps of the Green Bus Fund, the Department for Transport and the Office for Low Emission Vehicles have awarded £30 million to 13 local authorities and operators for the period 2016-2019 through the Low Emission Bus Scheme (published in 2015), to encourage the uptake of low emission vehicles and infrastructure, improve air quality and attract investments to the UK. Over 300 low-emission buses are consequently expected to be introduced in England and Wales.
- » In 2016, £150 million were earmarked for buses and taxis, £11 million of which were awarded for the procurement of 153 electric and gas buses in Bristol, York, Brighton, Surrey, Denbighshire and Wiltshire.
- » Under the Clean Bus Technology Fund, £40 million were awarded to 20 local authorities in 2018 for the retrofitting of vehicles with cleaner technologies.
- » The Low Carbon Bus Calculator is a tool provided by the government to encourage local authorities and operators to invest in low emission vehicles, which allows them to calculate the benefits of such investments.
- » Simultaneously, the government is funding the research & development efforts of a variety of stakeholders developing innovative technologies. £24 million were invested in vehicle manufacturers, suppliers and universities in 2010, with a further £11 million in 2015. This funding allowed notably the development of an electric bus with fuel cell range extender.
- » In 2017, the government has allocated £40 million for projects aiming at improving the life-time of batteries under the Industrial Strategy Challenge fund.

Source: Compiled by UITP, using data from L. Butcher, S. Hinson, D. Hirst, Electric vehicles and infrastructure, Briefing paper N°CBP07480, 20 February 2018, House of Commons Library

Policy shifts and the impact on solar panel installations in the United Kingdom

The United Kingdom's 2008 Energy Act made favorable feed-in-tariffs available to those households and businesses generating electricity using, among other renewable technologies, solar panels in 2010. Beginning in 2011, these incentives were progressively cut by small increments and then reduced by 65% in early 2016. Most recently, the Department of Business, Energy and Industrial Strategy then announced that the scheme will be closed on the 1st of April 2019. These shifts in policy resulted in a situation where those generating electricity from renewable sources were eligible for a patchwork of different subsidies for the same generation/export activities.

Small Solar PV Installations (0-4kW) & Feed-in-Tariff in the UK (2013-2018)



Source: Compiled by the World Bank using UK Government/OFGEM data

Prior to the 2016 cut, the UK's Department of Energy and Climate Change conducted an impact assessment which projected a loss of between 30 and 58% of solar installation jobs. Cutting subsidies before the market price of solar technologies had dropped sufficiently had a significant impact upon the uptake of small domestic solar energy technologies.

Source: OFGEM, Department for Business, Energy & Industrial Strategy (BEIS),
Department of Energy and Climate Change (DECC)

3.2 OEMs and the supply chain

OEMs are the firms that produce EVs. These include the traditional automotive industry brands that make both conventional and EVs as well as established, new, or nascent firms that have focused exclusively on electric mobility. Key viewpoints that this stakeholder group expressed during interviews included:

- » **Overall commitment to eMobility** and the objectives of taking emissions out of transport with the dual objectives of remaining financially viable and enhancing the social, environmental, and technical sustainability of supply chains;
- » **Pace of transition is a key concern** and specifically the rate at which governments are targeting fleet transition. There was also concern on whether the economic and physical limitations that apply to the industry and within individual firms can match those ambitions;
- » **Jobs and labor rigidity** during the transition were also a point of concern. Specifically, the ultimate number, location, and nature of jobs is expected to be different between conventional and EV production which is a challenge, particularly for legacy industry players;
- » **Scale, reliability, and quality of the supply chain** are key issues as most firms that produce EVs as a final product depend on interactions with other firms that produce basic components;
- » **Policy consistency and predictability**, particularly around the incentives used to stimulate market demand was a key concern particularly as this has linkages to political cycles. The large and long-lived nature of investment needed for developing and producing vehicles exposes OEMs to significant risk of policy changes that affect market demand; and
- » **The “chicken and egg” problem of charging infrastructure** and its role in underpinning larger levels of market demand is something that OEMs are acutely aware of.

“We are committed to electric mobility [and sustainability]... we look down the supply chain all the way to the mines”

OEM representative

The level of commitment publicly expressed by OEMs as well as the implied commitment of investment in developing forthcoming EV platforms suggests a strong overall push by industry toward the development of eMobility technologies. How fast, how far, and how disruptive the transition to electric mobility proceeds was a foremost concern identified in interviews with OEMs and stakeholders that work closely with them.

Interestingly, the root causes of tension are both molecular in scale, at the level of combustion within a conventional engine cylinder as well as macroscopic in scale at the level of balance sheets and political processes. There has historically been a trade-off in engine design and technology selection between different forms of emissions. For example, hotter, more complete combustion at higher compression ratios¹ and temperature has offered a technical solution for reducing the emission of CO² and unburned hydrocarbons while increasing fuel economy and power (which customers generally like). However, this has historically come with a trade-off in other emissions such as NO_x due to higher corresponding temperature of combustion reactions.

¹ Compression ratio is the relative measure of an engine cylinder’s maximum and minimum volume as a piston moves from its lowest position to highest position during a compression stroke. This affects the pressure and temperature of a mixed fuel and air charge that either autoignites (in the case of diesel) or is ignited by a spark plug (in the case of petrol). Diesel engines generally operate at higher compression ratios than petrol engines which reflects the different temperatures for autoignition of petrol vs. diesel fuels. Different emissions cocktails result from differences in the chemical composition of fuels as well as the temperature, speed, and charge mixing of the combustion reactions.

“There has been a policy alignment that favored diesel.”

Robert Evans, CEO Cenex

“Since the diesel crisis, there is less trust in the industry.”

OEM representative

Industry has devoted large investment in engine and exhaust treatment technologies toward winning the war on both fronts by using engineering measures to mitigate trade-offs. There is a concern that the threat of local or national government bans on conventional vehicle technologies could reduce the value of these investments (whether de jure or de facto). Regulatory limits on emissions such as NO_x and particulates that affect diesel engines most specifically are at the heart of this. There was also a view that prior government policies have encouraged investment in diesel engine technology in response to government targets on CO₂ emissions and fuel economy. The ability of OEMs to recover returns from these legacy investments was noted as critical to supporting the development and upscaling of EV production. At the same time, there is also a perception within the industry that the “Dieselgate” scandal and the resulting loss of trust is a factor which may be challenging policy alignment around recovering returns from legacy investments.

“We need to buy batteries today to put in vehicles tomorrow. We cannot wait with purchase decisions until new cell manufacturing has developed in Europe...”

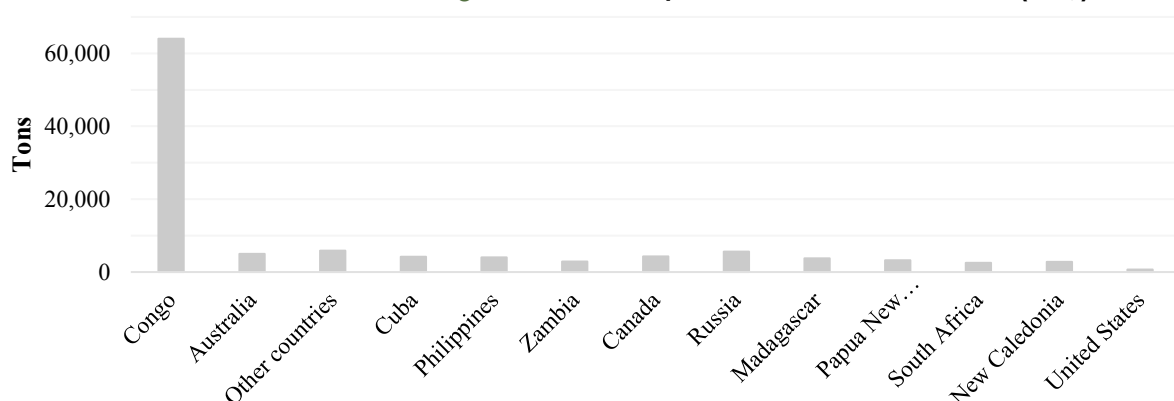
OEM representative

“It’s more out of a laboratory than an industry solution.”

OEM representative

The supply chains that characterise the automotive industry are long, complex, and international in their reach. Interviews identified this as a key constraint on how quickly the industry can react to both customer demand and government policy objectives. Dimensions of this issue included the capacity of component manufacturers to produce at scale as well as the reliability and quality of new components. There was also concern regarding sustainability and the political economy of international trade relationships that introduce non-technical dimensions to supply chain constraints. In this respect the sustainability commitments of many OEMs that go beyond emissions alone, are necessitating extensive due diligence all the way to the sourcing of raw materials themselves from mines (especially in the case of battery production). Global supplies of cobalt in particular are a challenge in this regard due to their concentration in the Democratic Republic of Congo, which has driven innovation around the use of alternative minerals (e.g. barium, strontium).⁶⁵

Figure 16. Cobalt production around the world (2017)



Source: World Bank analysis of United States Geological Survey; National Minerals Information Center

OEMs and the supply chain developing technical partnership to “close lifecycle loops” for batteries

Vehicle OEMs such as BMW and Audi have sought to develop technical partnerships within the supply chain of batteries used in battery EVs and plug-in hybrid EVs to ensure sustainability. In the case of BMW this entails tripartite cooperation with the battery producer Northvolt and battery component producer and recycler Umicore. Audi has a similar bilateral partnership with Umicore. These partnerships target the engineering and production of batteries that are designed for low carbon production, second life, and ultimate recyclability. For their part, OEMs have committed to designing in and sourcing batteries that have been engineered for recyclability. The European Commission’s EU Battery Alliance has helped to support the development of such partnerships. The European Investment Bank has also deployed financing to Northvolt’s production capacity under its InnovFin lending program that targets demonstration projects in energy system transformation.

Sources: press releases of companies named and the European Investment Bank

Efforts to improve the sustainability of supply chains extends beyond the production and sale of vehicles into what happens to components at the end of their useful life. Governments have a key role to play in this process. For example, initiatives such as the European Battery Alliance sponsored by the European Commission have sought to bring together OEMs, battery producers, and battery recyclers to develop partnerships for addressing key sustainability issues (see case box above).⁶⁶

“We need the right infrastructure in the right place”

Former OEM engineer

OEM stakeholders also noted the key role of charging infrastructure to underpin demand for eMobility products. OEMs are aware that they are relying upon other stakeholders to make their eMobility products viable and attractive to the mass market. In some cases, OEMs have sought to forward integrate in the value chain for this reason and have made strategic investments in third-party charging businesses. The efficiency and location of these services are part of the industry’s response to range and charge anxiety that customers express as key concerns.

One example of an OEM-utility partnership is ChargeForward which has brought together BMW and the Pacific Gas and Electric Company (PG&E). ChargeForward is providing both parties with a platform to exchange expertise, collect data and better their understanding of how consumers’ use of charging infrastructure can harness the availability of energy generated by renewable sources and improve the ownership experience for their customers. Respondents highlighted the need for government to ensure that legal and market structures will allow for the creation of a business case around charging infrastructure. OEMs in Europe are actively pushing for the setting of standards that will support the case for interoperability and widen the pool of customers available to infrastructure owners and operators.

“We don’t see a hard stop in terms of the science.”

OEM representative

Interestingly, the OEM stakeholders interviewed in this research did not perceive technical challenges or vehicle design as being their foremost concern. There is a common perception that the current rapid pace of technological progress will continue, and that technologies are maturing toward the point where they can support mass market adoption.

3.3 Utility companies

The role that utility companies play in eMobility is critical. Beyond supplying power, utilities are playing key roles in planning and developing charging infrastructure, shaping customer charging behaviours, and collaborating on programs to achieve social objectives around eMobility. Depending on a country's market structure for charging, utilities may also play a supporting role for other enterprises that compete as independent charge point operators. In other cases, utilities may also compete directly with those same independent operators. Points of view shared by utility companies that were interviewed under this research included:

- » **Identifying where and when to invest is a critical challenge.** At the heart of this is overlaying knowledge of electricity supply infrastructure with the combination of transport demand, eMobility uptake projections, and land availability for new charging infrastructure;
- » **The multitude of local jurisdictions was reported as a significant, but manageable issue** in the development of eMobility infrastructure where national or subnational government bodies with cross jurisdictional mandates can provide support;
- » **Generation capacity needed to support eMobility was perceived differently** with less concern by utilities in higher income countries over the near-term future. In the case of developing countries with rapidly growing electricity demand in general this may not be the case;
- » **Utility stakeholders noted the need for eMobility solutions to also cross income divides** at the same time that eMobility progresses as a broader solution. Initiatives that combined infrastructure development with schemes to provide access to vehicles (e.g. sharing) were viewed as socially important; and
- » **Utility companies are an essential partner for the implementation of electric buses in public transport systems.** Synergies can be created between energy providers and public transport operators for an efficient use of the grid.

“The biggest issue is knowing where to invest ... the challenge with this new load group is that it moves.”

UK Power Networks (UKPN)

“The peak load of EV passenger cars in 2025 is nothing to worry about.”

John Shipman, EV Program Lead, ConEdison

Planning and delivering on the deployment and reinforcement of charging infrastructure is a key focus of many electricity utilities given associated capital expenditure and lead times. The question of “where” is particularly sensitive when utilities need to respond to market demands or government initiatives around charging infrastructure. Deciding where to put infrastructure (both the customer-facing and back-end varieties) to serve eMobility is more complex than serving other electricity customers. This is because the “right” locations are at the intersection of travel demand, grid capacity, demand for eMobility, and availability of land for the infrastructure itself which is particularly difficult in dense urban areas. On top of that, eMobility has the added challenge of a load group that moves geographically, often together, around the peak hours of daily electricity demand.

The energy sector in many countries is transitioning along with the transport sector by introducing smart-grid technologies to optimize the system, including smart charging which can vary the electricity delivered to a load group of EVs -both in time and in space- such that overall system constraints are not exceeded. Several European utilities reported that if they can deploy smart charging effectively, the need to upgrade back-end infrastructure will, with the exception of some public transport applications, be significantly lower than the current public debate suggests with local, low-voltage grids being the first of the back-end infrastructure that will need reinforce-

ment. By minimizing the need to upgrade when demand projections remain uncertain, flexible use of the grid can also help to avoid stranded assets. This money saved can be used for example to further incentivize flexible charging. As discussed previously, a different situation may be faced by utilities in low- and middle-income countries, where electricity demand is growing rapidly and where smart-charging solutions may take longer to implement due to competing needs. Additional loads from large numbers of EVs may further strain existing networks both locally, and more broadly by creating a need for more generation capacity.

“Disadvantaged communities are places where there’s a real case for the infrastructure to come first.”

Stephanie Green, Director of Clean Transportation, PG&E

Stakeholder utilities recognized the need for broadening the geographical coverage of charge points in general despite currently low utilization rates in many locations. Viewpoints expressed during interviews also noted that this was not only necessary for the practicalities of eMobility in general, but also for shaping “who” eMobility is meant to serve. Extending charging infrastructure into poorer communities is increasingly seen as a way to enhance the inclusive characteristics of eMobility, especially when combined with programs such as vehicle leasing or sharing that can potentially allow lower-income regions to benefit from benefits of eMobility including lower fuelling costs and / or localized environmental benefits. The broader social aim would be to intervene and prevent a “green” divide from existing between more and less affluent segments of society. For example, PG&E will be installing up to 35% of the chargers it has planned under its EV Charge Network Program (2,625 out of 7,500) at workplaces and apartment buildings in disadvantaged communities.

“No charging operator can make money without subsidies at the moment.”

*Deputy Director of the
International Department, China
Nari Group*

At a time when the supply of and demand for charging infrastructure are still crystalizing, a key constraint is funding initial rollout that cannot be supported entirely by rates the eMobility users pay at charging points. This is linked to low rates of utilization at present due to relatively small eMobility fleets. The unprofitably low utilization rates facing ConEdison in New York and UKPN in London echo the challenges faced in China. Funding remains a key issue. In each context, government subsidies are seen as necessary for underpinning credible business cases. Similar to other stakeholder groups, utilities also reported the need for stable or at least predictable government policies around financial support to eMobility. This is because forecasting tools used to target infrastructure investments rely on assumptions about the uptake of vehicles and the rollout of charge points that are subject to government policies.

Local government policy and regulations also has important impacts on utility companies and their ability to support eMobility infrastructure. Specifically, local jurisdictions play a role in setting the relevant codes that influence the design of infrastructure, the availability of land for charging operations, and the regulation of land use around charge points which affects the attractiveness of given locations for customers. The nature of current charging technologies means that the place value of adjoining land use is an even greater Transit Oriented Development concern relative to conventional fuelling stations.

“At the local level, there have been some permitting challenges.”

Stephanie Green, Director of Clean Transportation, PG&E

Regarding urban public transport, the energy sector must be brought on-board in the early stages of electromobility strategy and planning. The objective is to come to a system where the supply of en-

ergy itself is low/zero carbon. Therefore, sustainable zero-emission mobility planning and CO₂ emission targets should go beyond low/zero-emission vehicles and align with greening the grid via an uptake of renewable electricity production and distribution. One of the best examples of such a synergy are electric buses running in the Dutch province of Utrecht, all of which are powered by wind energy. In Amsterdam, all electrified public transport modes, including metro, trams and electric buses will be supplied from local renewable energy sources as of January 1, 2019.

3.4 Non-utility owners and / or operators of charging infrastructure

In countries with unbundled market structures for charging, firms that operate (and in some cases own) charging infrastructure play a key role in interfacing directly with customers and with utilities who supply electricity. Points of view expressed by this stakeholder group included:

- » **The importance of location and adjoining place value was a key concern for operators.** The time currently required to charge EVs makes the place value of charging points particularly important to attracting customers;
- » **Freedom to operate 24/7 is considered critical for full use of fixed assets.** Operators cited the importance of legal provisions, permitting, and physical space that will allow for round the clock operations to make full use of infrastructure;
- » **Operators are conscious of the need for future-proofing grid connections to accommodate technological evolution.** The level of power supplied through fast chargers currently ranges from 40-60 kilowatts up to 120 kilowatts in the case of Direct Current fast charging offered by Tesla Superchargers. There are additional plans for 350 kW charging that may appear in the future to provide for the potential to charge within 10 minutes or less but these will require corresponding grid connections to support high rates of power transfer;
- » **Length of concessions or contract periods that can underpin upfront investment** was a key determinant of business case for operator investment. The present business case for many charging operators demands on future EV uptake and future returns from envisaged charging. The length of time provided to pay back investment costs and deliver returns therefore influences the level of investment they can make; and
- » **Market structures that follow from government regulations and procurement decisions** significantly affect the ability of charging operators to compete. Charging operators reported this as a key challenge even in highly developed countries.

The current nature of EV charging as an activity is significantly different than fuelling a conventional vehicle. In the instance of fast charging, customers spend 20-30 minutes at a charging point. In contrast, regular charging requires times amenable with overnight durations, workdays, or extended periods of complementary activity (e.g. shopping, fitness, school attendance, etc.). In both instances, the place value of land use around a charging point becomes important for charging operators to attract customers. This also means that placing chargers where people want to visit for other purposes or in route to such locations is essential. Securing the right locations was noted as a key constraint faced by charging operators. In one case, a stakeholder also noted that interpretation of regulations and a contractual framework had explicitly prohibited the development of complementary business to enhance place value at fast charging points that they had developed under a concession structure.

“The spirit of the EU’s regulations [on competition] needs to be enforced.”

Arnaud Mora, CEO, Freshmile

As relatively new market entrants, non-utility owners and operators of charging infrastructure have reported experiencing competition-related barriers to operation and expansion. In one European example, an operator is resorting to legal action to challenge a case in which fast charging concessions were handed to an incumbent who operates existing refuelling infrastructure, which forced new entrants to opt for less attractive locations. Weaknesses in the competitive process for tenders (even in very advanced economies) and other contracts is something that a number of private operators reported as an issue. One stakeholder proposed establishing an independent body with responsibility for managing tender processes as a possible solution. In some instances, stakeholders reported a deliberate pursuit of state-backed venture capital and partnering with public entities to improve their influence on government policy.

Unbundling Utility Services in Sweden

The 1990s saw a wave of privatization and an unbundling of electricity supply/generation operations in Europe. While charging infrastructure operators did not perceive this to have made a meaningful difference to market access in all cases, the unbundling of Sweden’s state-owned utility ‘Vattenfall’ was cited as an example that successfully exposed an incumbent operator to competition. Companies engaged in the generation and distribution of electricity in Sweden must be legally and financially distinct from one another, and those responsible for distributing electricity across the grid are mandated by the Swedish Electricity Act to publish an annual report detailing the measures they have taken to avoid discriminatory behavior against other actors in the market.

Sources: Swedish Energy Markets Inspectorate: https://www.ei.se/PageFiles/303476/Ei%20R2016_10.pdf

Legal and regulatory regimes that govern the sale of electricity were also a concern for charging operators particularly as they look to the future of interaction between vehicles and the electricity grid. Specifically, this concern applied to “behind-the-meter” operations where the trade of kilowatt-hours between vehicles and / or other users of electricity could become mainstream. In many jurisdictions such a trade in kilowatt hours could present an issue of double taxation or fall within the scope of activity that legally would be regulated as an energy utility.

“Fiscally we don’t know how to treat these peer-to-peer kWh transactions.”

*Director of Business Development,
charging operator*

Stakeholders also expressed pragmatic views on how to manage the market structure for charging based on a view for what different parties are best suited to handle. For example, established utility companies with large balance sheets, lower cost of capital, and expertise in delivering capital projects may have an advantage in infrastructure development whereas smaller firms may be better placed to manage charge points themselves. While both actors will undoubtedly have roles to play, non-utility operators did not feel that this is likely to be an adequate solution, as experience suggests that grid operators sometimes struggle with capacity issues given the other pressures on their operations and, depending upon the context, are not always incentivized to invest in infrastructure for which there is, currently, as much of a psychological as a technical need.

3.5 Civil society and other important stakeholders

This section brings together the perspectives of civil society representatives, industry experts, international organizations, the Formula E motorsport body, and fleet operators of private vehicles, and fire and rescue services. Points of view expressed by this stakeholder group included:

- » **eMobility can be made inclusive of different income groups** through targeting car sharing schemes that use eMobility at low income groups who may lack the means for other forms of adoption;
- » **There is a need for fire and rescue procedures and practices to catch up with eMobility technology.** The design of EVs differs considerably from conventional vehicles and the nature of eMobility charging infrastructure itself presents a new challenge for fire and rescue services; and
- » **In the shift to eMobility perceptions matter as much as technology** which was seen as a key role for civil society organizations and the Formula E racing championship. Racing in particular can offer a dual benefit to both.

Stakeholders identified car sharing schemes as one of the ways that the benefits of eMobility technologies can be broadly accessible in the short term. In addition to avoiding challenges associated with private ownership, sharing schemes were also identified as a way to serve groups who do not have access to off-street parking which often requires property ownership or has additional costs (e.g. parking rental). While sharing schemes were identified as a mechanism to enhance inclusion, stakeholders also noted that issues around state aid in some jurisdictions could hold back their deployment for eMobility. A specific point of concern is whether government-provided dedicated parking/charging spots violate competition rules by disadvantaging conventional vehicle sharing services. As identified by other stakeholder groups, uncertainty was perceived as a barrier to further investment and pilots.

“In order to meet climate and air pollution targets and tackle congestion, poor communities can’t be left out.”

Keith Budden, Head of Business Development, CENEX

The rapid development of eMobility has left some regulatory frameworks struggling to keep pace. Fire and rescue services in particular face the challenge of staying abreast of technological change. The information provided to first- and second-responders by OEMs is yet to be standardized, which makes for a chaotic environment in which fire and rescue crews may be called to respond without adequate understanding of the technologies involved in an incident. Stakeholders noted limited sharing of safety tests, and limited engagement with first- and second-responders directly in the development of new vehicle technologies as key impediments.

While some OEMs are experimenting with the installation of hardware that would allow for the injection of water into battery packs, the main challenge facing fire and rescue services responding to EV fires involves the quick location and submersion of the battery pack (cited as a common source of electric vehicle-related fires). Interviews suggested that tension may exist between some OEMs and fire and rescue services due to market pressures for innovation and vehicle production. One specific point of tension was the pressure facing OEMs to install larger battery capacities in vehicles to extend range and catalyze uptake, while a large concentration of unsegregated cells can increase the risk of a post-crash fire.

Motorsports and other high-performance vehicles also have an important role to play in the development of eMobility, both by shifting perceptions around the technology itself as well as driving technological innovation. As

“Formula E is a kind of technological laboratory ... technological transfer will be a legacy of the championship.”

Sustainability Manager, Formula E

has historically been the case, high-performance applications (in particular, motorsports with a presence in popular culture) will play a role in the development, refinement and dissemination of eMobility technologies. Many existing mainstream automotive technologies were first developed for high-performance applications, of which Formula One is a good example that is now being replicated for eMobility.

Creating a business case for low-income EV car sharing

Inclusive EV was a pan-European EIT Climate KIC-funded project designed to demonstrate the business case for electric car sharing services in low-income areas. 90 EVs were deployed in Solihull (UK), Modena (Italy) and Valencia (Spain) to test consumer demand with a view to developing a business model that could open up a new market of 13.5 million households.

The attraction of an EV sharing scheme can differ from context to context; while the security and reliability of alternate modes can be the deciding factor in one area, cleanliness and the distance of local public transport stops might be the main issues in another. The study identified a number of factors crucial to success—these include:

- » Well-positioned, accessible charging infrastructure
- » A minimum of four cars per location (with 30+ active users per vehicle)
- » 2,000 households within 0.5km of the vehicles
- » Flexible payment methods (including pre-payment cards) and no membership fee
- » An appropriate pricing structure that is competitive with taxis/Uber and works with existing public transport services
- » The provision of real time information on the state of charge of the vehicle and thus the distance it can drive
- » Community involvement and participation of local businesses and public organizations as vehicle users
- » 20% use of vehicles at €5 an hour is required for breakeven

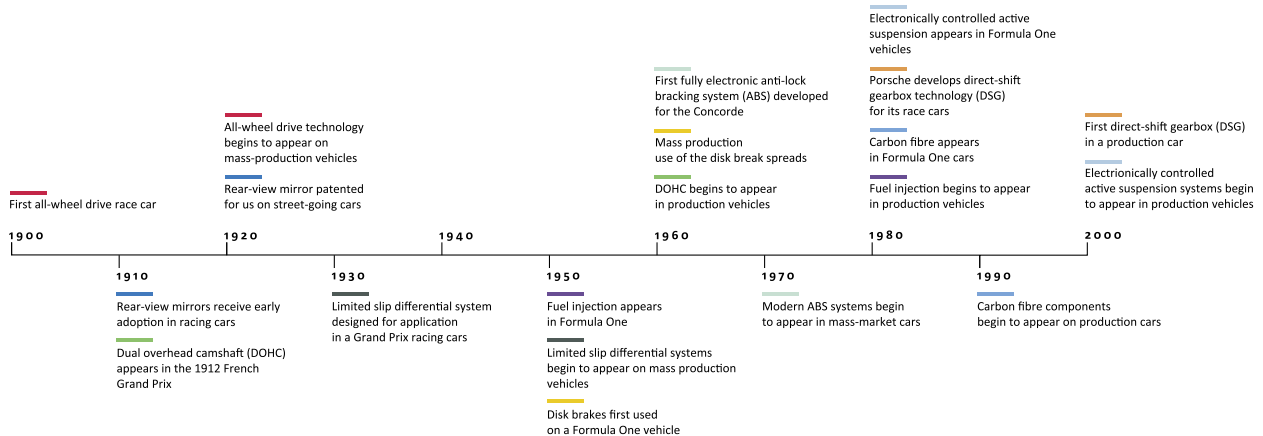
Source: CENEX,
<https://www.cenex.co.uk/innovation/mobility-energy-service/>

“Electric vehicles need to become cool.”

Siegfried Quillet, Head of Vehicle-to-Grid Product Line, Delta

Formula E was established with this in mind; the maintenance costs and technologies employed by OEMs are closer to their road-going counterparts than in Formula One racing because of an express intent to use Formula E as a platform to spur the development of eMobility technologies. The configuration of Formula E vehicles is strictly controlled, with only select components being unique to each vehicle (e.g. drive-train components) to ensure that R&D efforts are concentrated around certain technologies. In four seasons of racing (2014-2018), the capacity of race car batteries has effectively doubled, meaning that drivers no longer need to switch race cars half-way through a race. This tightly monitored environment provides a unique opportunity to understand the lifecycle of eMobility technologies—detailed usage data is available for the entire lifespan of Formula E batteries.

Figure 17. Diffusion of technologies from racing to mass production vehicles (1900s-2000s)



Source: Compiled by World Bank team using various media sources

The role that eMobility solutions play in shaping perceptions also applies to public transport – just as in racing. For example, a recent public transport passenger survey in Poland carried out by Censuswide for Volvo Buses in mid- 2018, reported that 96% of passengers were aware of the importance of the air quality, while 71% declared being ready to pay more in fares, congestion charging or road tax to see more EVs on the streets.⁶⁷

3.6 Private vehicle customers

To better understand the patterns of use and experiences of private EV customers, surveys were distributed via social media channels in several languages. 593 responses were collected in total. The responses gathered reflect the unique qualities of each context. The following section focuses on those respondent groups for which there was a significant sample size.

Who are the customers?

- » The EV user community in Jordan is relatively young; 57% of EV-using respondents were under 34, and 85% were under 44.
- » In Norway, 55% of respondents were over 45. Only 11% were under 34, with 8% of these being electric bike users.
- » 68% of respondents in the Netherlands were over 45.

“...today we must educate the user, not in the sense of exciting his interest, because he is keenly interested. Everywhere we go we always find them interested, but still there is doubt as to just what to do.”

Hayden Eames, Address to the Association of Electric Vehicle Manufacturers; (April 1907)

Which EVs are customers using?

- » The vast majority of respondents in Jordan own second-hand electric cars (87%). 11% bought new electric cars.
- » Norway also has an ownership-driven uptake model, with 79% having bought a new EV.
- » While 66% of Dutch respondents own their EVs, 32% lease their EVs, the majority of which are on a business lease.

Why did customers opt for eMobility?

- » By a factor of more than 2, the lower costs associated with the operation and maintenance of electric cars was the top reason for those in Jordan to have opted for EVs.
- » In Norway, respondents gave the environment, government-backup financial support and the lower costs of EV ownership roughly equal weight when asked why they had opted to use an EV.
- » Environmental considerations were the top reason cited for the uptake of EVs in the Netherlands.

“People need help shaking off their prejudices around EVs. These are often outdated.”

Dutch Customer

Where are customers sourcing their EV-related information from?

- » Though internet research and information from family and friends are the main sources for respondents in all three countries, 10% of those in Norway received their information from government-backed sources.

“The cost of charging needs to drop [further] below the cost of refueling”

Jordanian Respondent

What do customers say about their EV experience?

- » A lack of available charging infrastructure and the time required to charge an electric vehicle together accounted for 82% of reasons given for most significant disadvantages associated with EV use in Jordan. Of the 15% who responded ‘no’ or ‘maybe’ when asked if they’d consider an EV when next buying a vehicle, 23% described range and charging infrastructure issues as being behind their hesitation to purchase an EV in the future. Owners of new and second-hand EVs were equally likely to consider another EV.
- » By comparison, there is no consensus around the main disadvantages of EV ownership among Norwegian or Dutch customers. 98% of Norwegian and 99% of Dutch customers would consider another EV when next purchasing a vehicle.

How could uptake be accelerated?

- » 77% of respondents cited the improvement of charging infrastructure as being important to accelerating EV uptake in Jordan.
- » Improving the availability of EVs features was the most frequent suggestion in both Norway and the Netherlands.

“Is it possible to speed up [EV uptake] in Norway?”

Norwegian Respondent

3.7 The buyer's experience

An important point of human contact for vehicle consumers wishing to purchase a new electric vehicle are the car dealerships that sell them. To understand this experience, members of the research team attempted to buy EVs in different countries from dealerships affiliated with different OEMs. Key findings from this experience included:

- » **In several instances dealership staff discouraged the purchase of EVs** by focusing on range, cost, charging network deficiencies, and lead time to delivery due to limited supply;
- » **Knowledge of eMobility products was often limited.** In one instance a sales representative resorted to internet searching the vehicles made by the dealership's affiliated OEM; and
- » **In addition to government incentives, OEMs and dealers are targeting schemes** around key buyer concerns such as technology obsolescence, battery life, and range anxiety for longer trips.

The scope of research involved visits to approximately thirteen European and US-based dealerships that offered EVs (both BEVs and PHEVs). Team members role-played both as educated buyers as well as buyers who were looking for information and options to meet their general mobility needs.

It was often the case that salespeople did not suggest eMobility options until prompted by the buyer. In other instances, dealerships were more inclined to promote their EVs. Across dealerships there was a large variance in the specificity, consistency and quality of EV-related information provided by salespeople. While some dealerships had a designated salesperson with knowledge of their electric vehicle(s), this person was not always available.

“EVs are the future, but they're definitely not for everyone right now.”

Salesperson

“Car dealers are paid bonuses for selling diesel vehicles ... this model needs to change.”

European Federation for Transport and Environment

Echoing some of the feedback provided by other stakeholder groups, one salesperson confirmed that the profit margin on EVs is lower than that associated with conventional ICE vehicles, and that this can impact upon how salespeople are incentivized by industry trends to sell different vehicle types.

Similarly, available data on industry marketing shows that less than two percent of the marketing budgets worldwide are being allocated to zero emission vehicles by OEMs themselves. This suggests that the overall marketing and sales push around eMobility products may be in a state of development in parallel with supply chains and the production capacity needed to deliver those vehicles in quantity and at costs needed for widespread uptake.

“It's impossible that we'll leave diesel behind.”

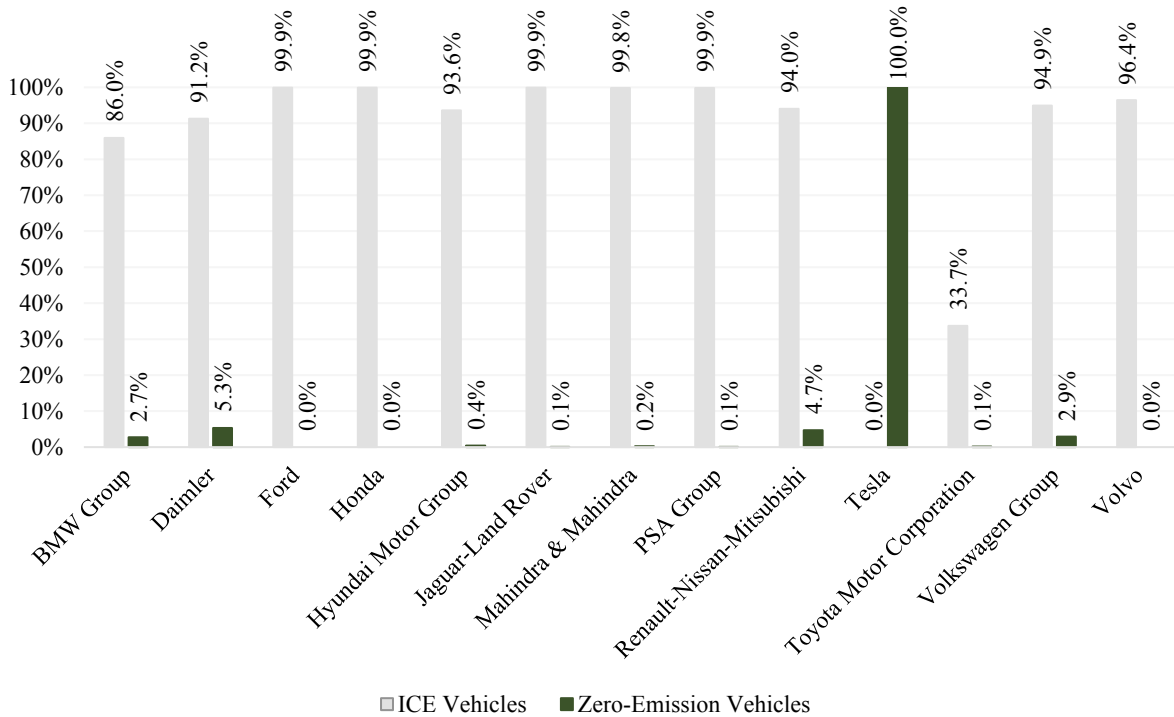
Salesperson

At the same time, there did appear to be dealer and OEM schemes in place to enable greater uptake among initial market segments. For example, to offset the upfront cost of its flagship EV, one OEM allows customers to lease the battery in their car at a cost of EUR 90 – 120 per month depending on usage, cutting EUR 8,500 from the up-front cost. The salesperson responsible for this vehicle reported that the vast majority of customers opted for the battery leasing option. This same sales person also emphasized that charging costs were reported as being between 46% and 74% lower than the equivalent ICE vehicle.

“If you’re going to be taking long trips outside the city, forget about an electric car.”

Salesperson

Figure 18. Advertising spending allocation by OEM, 2017



Source: European Federation for Transport and Environment

Dealerships and the OEMs underwriting some of their financing approaches are designing schemes that address key customer concerns such as battery life. These included after-sale vehicle warranties that covered a vehicle’s battery for between 2 to 2.7 times longer than the rest of the vehicle, in order to alleviate consumers’ concerns around battery reliability and degeneration. One OEM pledges to replace the batteries in its flagship EV model vehicles when they have 75% or 66% of their original capacity left, depending upon whether the customer leases or owns the battery respectively. While battery replacement is technically possible in a large number of consumer EVs, this is prohibitively expensive and could—as one OEM warned—be made difficult by legal constraints that govern vehicle modifications that go beyond original configurations. To tackle range concerns, one dealership’s financing plans included the lease of a conventional ICE vehicle for 20 days per year when needed for longer trips. This was not an option advertised elsewhere.

“Once you try, you’ll want to buy.”

Salesperson

With the exception of one dealer whose vehicles were described as being reliable, cost-effective, and future-proof, salespeople were more likely to focus on the sporty performance and exciting driving experience that their EVs had to offer drivers rather than tax deductions, preferential access benefits, or environmental credentials.

3.8 Public transit operators

As part of this research, UITP interviewed a panel of predominantly in-house (publicly owned) transport operators in order to present a snapshot of their overall experience with electric buses. The respondents operate in city centres, metropolitan and urban areas in Barcelona, Bratislava, Budapest, Campinas, Eindhoven –Arnhem, Geneva, London, Montevideo, Moscow, Santiago, Shenzhen, Warsaw, and West Covina California, with populations ranging from 300,000 inhabitants to over 10 million. In most cases, the average topography of their operated lines is flat to moderate, the only case of hilly roads being in Santiago, Chile. All respondents have introduced full battery electric buses. The size of their electric fleets varies from small pilots (Montevideo and Santiago) to a fully electric 16,359 bus fleet in Shenzhen, China. Shenzhen has the largest electric bus fleet in the world, while London, with its 135 battery EVs and 10 fuel cell EVs, has the largest electric bus fleet in Europe of any single city. All other respondents have introduced medium-sized fleets of 10 to 40 units. It is worth noting that the Shenzhen Bus Group is also electrifying its fleet of 5,000 taxis. While facing high up-front costs, the roll-out of electric bus mobility has been ensured by the financial support of various tiers of government and supra-national institutions (e.g. EU funds), the best examples of which can be found in Warsaw, Moscow and Barcelona.

“The most important thing is to have the support of local authorities.”

Operator in Moscow, Russian Federation

Transports Metropolitans de Barcelona is the only respondent to have prioritized plug-in hybrid buses, with a 346 plug-in hybrid EV fleet. Fuel cell buses are also less common in public transport fleets; amongst respondents, they were only introduced in London and Eindhoven. BKV Budapest, TPG Geneva, and Mosgortrans Moscow have fleets of In-Motion Charging trolleybuses (IMCs). These operators are benefitting from this prior experience with conventional trolleybuses. This has gone some way to flattening the learning curve associated with the integration of IMCs in the network and connecting other EVs to the grid. The vast majority of electric buses run an average of 200km per vehicle per day, a rough approximation of the distance normally run by diesel buses. The 30 BEVs of West Covina’s Foothill Transit, California, run the highest mileage, with an average of 305km/vehicle/day.

Although the interviewed operators have adopted a variety of different strategies to adapt to change and face different local conditions, there are a number of issues that they have identified in common:

- » **The need to define relationships with new partners**
- » **The need to plan for new models of operation**
- » **New maintenance profiles and a demand for new skills**
- » **The need to have access to appropriate funding sources**
- » **Uncertainty around battery technologies**

It has been crucial for operators to define the relationships they have with new partners in the value chain—particularly energy providers. This is facilitating the sharing of expertise needed to navigate a new and complex ecosystem and allows for the operator’s needs to be determined in advance and assessed in parallel with the network’s capacity. This partnership needs to develop

“Electric vehicles have proven to be significantly more complex than our CNG fleet ... start with small-scale deployments and expect to learn a lot along the way”

Operator in West Covina, CA

at an early stage in the project to ensure that standardization be built into the system from the start (this includes establishing protocols for communication with the grid). A number of operators stressed the importance of this to contain future costs and allow for interoperability.

It is not uncommon for fleets to include different types of electric powertrain, alongside conventional and alternatively-fuelled vehicles. Likewise, it is not uncommon for fleets to be composed of vehicles from different manufacturers, which, in the case of eMobility, highlights the importance of interoperable standards. EMDEC, Campinas' bus operator, has recently signed an agreement with the local energy distributor to develop a specific model for transportation services.

The nature of the contract between the operator and utility company has taken a number of different forms across contexts; one European operator stresses the importance of defining the relationship, (level of service requirements etc.) clearly in a maintenance contract. In some cases, operators bear the costs of electricity and infrastructure within their contract prices. Budapest is one example of this where the operator has access to 10kV at its depot and pays an average price of €0.12/km for its electric midi buses.

West Covina's electricity utility became a partner in the development of the operator's program to electrify and has been providing all necessary infrastructure up to the point of the chargers themselves. Similarly, in Santiago, the city's energy distributor provided financial support for the procurement of charging infrastructure, both within the city and at terminals, as well as for the buses themselves. Elsewhere, the up-front cost of buses has been covered through a blend of financing sources including the operator's own funds, lease agreements, government subsidies and, in the case of Bratislava, Barcelona and Warsaw, EU funding.

“[We needed to reach] around 300 drivers who will have to manage charging infrastructure ... the main challenge is how to run in an energy-efficient way.”

Operator in Santiago

Operators have had to adapt their scheduling and operating tasks, largely due to a need to take charging times into account. In Moscow, for example, in order to maintain the same interval between buses and avoid additional waiting time for passengers, the number of buses on the line on which Mosgortrans' 19 battery EVs operate had to be increased. To avoid increasing the number of buses on a line, Bratislava has chosen a different approach for its battery EVs. The fleet has been arranged into shifts, with electric buses in operation during 4-5 hours in the morning and afternoon during peak hours. The buses recharge in the middle of the day when transport demand is lower, at which time conventional diesel buses are operated. MZA in Warsaw was cooperating with the Warsaw University of Technology to optimize the size of batteries and charging time to fit the existing timetables, including to provide services during special events when traffic might be disrupted/rerouted (for example during the Warsaw marathon).

“The electrification of a bus line is possible without making changes to timetables with properly designed technical and operational solutions... the 1:1 replacement of diesel with electric buses is therefore feasible.”

Operator in Warsaw

The availability and placement of charging infrastructure is also a key variable affecting the operations of electric buses. The most widespread charging systems across respondents' networks are opportunity charger with pantographs at the terminal, depot and/or selected bus stops, and overnight charging with a plug at the depot. Only in London is the charging done via opportunity charging through induction at terminals/depots/selected stops (along with overnight plug-in charging at the depot). One of the main chal-

allenges reported with regard to charging infrastructure, is the space its installation requires, especially in public spaces. Several operators have found that special attention needs to be brought to this issue at the very beginning of the planning phase, and that the early involvement of the competent authorities – urban planning and energy providers, for instance, is crucial.

Charging buses at the depot also implies an adaptation of the logistics with regards to the parking and release of vehicles, taking into account the charging method and time required to charge each bus.

Bus OEMs are, in many cases, responsible for the maintenance of electric vehicles. Some operators have expressed the intention to take over at a later stage. A long-term cooperation clause with the vehicle manufacturer is, in most instances, specified in the tender. In some cases, however, cooperation clauses are specified independently for the vehicle and battery maintenance, outside or after the tender.

“We now look for profiles with knowledge of electrical systems [when hiring our technical staff].”

Operator in Barcelona

In West Covina, the maintenance of the electric buses has not been vastly different from that of their traditional fleet and, in some cases, has even been easier. However, the maintenance and management of electric infrastructure is something that most bus operators have not traditionally been responsible for. This is a new skill set that the industry will need to develop or import. Santiago’s operator has been hiring specialized new staff to maintain its charging system. In the case of Bratislava, the OEM has been providing training for its maintenance staff. Operators have highlighted the necessity of cooperating with electric bus OEMs at several stages of projects that involve electric bus rollout, from finding the right product to the maintenance of vehicles.

This learning curve extends beyond maintenance to the use of new equipment. Drivers are also having to re-tool to make the most of these new technologies, particularly in terms of incorporating energy-efficient practices into their driving. Metbus Santiago, with support from the Energy Center at the University of Chile, developed a training program to promote the use of new driving techniques among its drivers. Furthermore, drivers have had to adapt their driving, since the silence of electric buses, much appreciated by passengers and drivers alike, also means that pedestrians don’t necessarily hear them approaching.

“[Bus drivers] needed to make 5-10 runs [in the new electric bus] to learn about the system.”

Operator in Geneva

Operators are also re-defining the relationships they have with OEMs. The sharing of responsibility with OEMs has been underlined as a pre-requisite for the successful operation of electric buses. Uncertainty surrounding the range/life span of batteries in real-world conditions makes this support particularly necessary. The impact of climate differentials on EV performance make field tests an often-necessary component of route modelling and vehicle deployment plans. To safeguard the viability of its operational plans, DPB Bratislava established penalties in its performance contract. These can be applied to the vehicle manufacturer in the case of a charge delivering less than a stipulated range (160km) in real-world conditions. TMB Barcelona asks OEMs to detail the performance of their vehicles in terms of the actual bus route that it is to be deployed on (feasible headways, time necessary to recharge, etc.). In Campinas, EMDEC has introduced a fleet of 15 battery EVs, following the installation of a BYD manufacturing plant in the city and the establishment of an operational leasing arrangement between them, BYD and a private concessionaire. This has allowed all involved parties to share the risks and costs related to the project.

“Battery life maximization is a key parameter to fulfil the environmental challenge.”

Operator in Geneva

3.9 Electric bus OEMs

UITP interviewed three bus OEMs—BYD Company Limited (China), Solaris Bus & Coach (Poland) and AB Volvo (Sweden). The companies were asked to outline the challenges facing their operations and their perspectives on the development of the electric bus market. BYD's EV line-up consists of 30 full-battery EVs, in a variety of sizes (7, 8, 10, 12, 13 and 18 meters). Up-front costs for a single vehicle unit range from US\$ 400,000 to US\$ 500,000. BYD typically sells its buses without including a maintenance clause in the tender, leaving maintenance tasks to the operator. Solaris has a catalogue of 9 alternatively-fuelled buses, including 4 electric bus types: battery EVs, plug-in hybrid EVs, fuel cell EVs and IMCs, in 8.9, 12, 18, and 18.75 meter varieties. Electric bus sales represent 10 to 20% of their total sales, but Solaris foresees that this figure will increase by 50% or more in the next decade, driven particularly by the demand for eMobility in Poland. Volvo provides 8 alternative-fuelled vehicles, including 3 electric bus types: battery EVs, plug-in hybrid EVs and IMCs in 12 and 18 meter varieties. Electric bus sales represent 5 to 10% of their total sales, a figure which they foresee will increase by 50% or more in the next decade. Some of the key viewpoints expressed by these OEMs included:

- » **Like the operators that use their products, bus OEMs expressed the need to re-skill elements of their workforce and to develop their supply chains** to meet the increasing demand for vehicles with none-conventional means of propulsion;
- » **An increase in battery capacity, the standardization of battery packs and the creation of a market for second-hand batteries** are among the developments that OEMs expect to surface in the coming years; and
- » **Not unlike the market for passenger vehicles, electric bus OEMs see a role for government in generating demand and perpetuating the shift towards zero-emission vehicles;** this includes bolstering the role of public transport authorities in developing infrastructure.

Electric bus OEMs perceived that the up-front costs of eMobility present the foremost market barrier preventing cities from purchasing electric buses. The implementation of an electric bus system requires not only the purchase of buses, but also charging infrastructure, and installation costs, making the up-front capital costs much higher than for conventionally-fuelled buses. OEMs advocate for a total cost of ownership (TCO) approach to determining costs. In Santiago for instance, the total operating and maintenance costs are estimated to have been reduced by 60%, compared to diesel buses, and in Bratislava, Slovakia, conventional fuel consumption amounts to 0,35€-0,40€/km, while electricity costs for the city's 18 battery EVs amount to 0,15€/km.

“The e-bus market will continue to grow and, with technical developments, the limitations [associated with the use of e-buses] will be reduced.”

Bus OEM

Up-front costs, in parallel with technical challenges and concerns around the complexities of adopting electric bus technologies, can pose a barrier for their adoption. Manufacturers point to the role that a combination of incentives, emission limits and purchase targets could play in alleviating this barrier to adoption. Beyond technological and operational concerns, legal and political factors also influence manufacturers' product development processes, such as the implementation of compulsory purchase targets for clean buses by local fleets. The further deployment of electric buses also relies on the political willingness to face the up-front costs associated with moving away from conventional means of propulsion. One European operator emphasized three ingredients necessary at the level of government to spur adoption: (i) establish the political will to go electric; (ii) include environmental costs in the TCO calculation; and (iii) support a shift to eMobility with “green” funds.

Government Support for Electric Bus Fleets in Poland

Poland's Low-Emission Transport Fund (established in 2017) aims at supporting the mass adoption of private and public EVs, with the goal of getting 1,000 electric buses onto Poland's streets by 2025. In tandem with this, the 2018 Act on Electromobility and Alternative Fuels will oblige bus operators in 80 cities to ensure that 5% of their fleets comprise zero-emission buses by 2021, and 30% by 2028, under the condition that a required local cost-benefit analysis proves the convenience of deploying zero-emission vehicles in a particular urban context.

Source: Compiled by UITP, using information by the National Centre for Research and Development (Poland)

RECOMMENDATIONS

The evolution of eMobility shows both promising opportunities as well as challenges for countries and the international community in the effort to tackle transport sector emissions while improving transport systems. The recommendations that the World Bank and International Association of Public Transport would like to offer for working with countries and key stakeholders on this important agenda are the following:

- » **eMobility offers tremendous opportunities but will only be part of the solution to the challenges of mobility and transport sector emissions even under optimistic scenarios of uptake.** Other challenges include providing inclusive accessibility to mobility in general, mitigating congestion, integrating land use with transport systems, and integrating transport networks across borders. Most notably, there remains a need for public transport and non-motorized transport to feature prominently in government policy agendas and interventions to have truly comprehensive solutions. The “avoid, shift, improve” methodology of avoiding the need for motorized trips (e.g. integrated land use planning), shifting to public transport and sustainable travel modes, and improving mass transit capacity, quality and service provision is still advisable. Including non-motorized modes and emerging alternatives such as shared mobility also enhance this approach.
- » **Engage broadly, continuously, and across borders, with consumers, industry, operators, companies across the value chain, all levels of government, and the broader public.** This is particularly important to ensuring that industry and supply chain capacities can support what governments seek to achieve. eMobility solutions delivered must align with what consumers are willing to pay for, and what the political economy around eMobility programs requires in order to meet the need for policy continuity. Different levels of government will also be better placed to implement different interventions because of their existing remit and different levels of fiscal capacity (e.g. land use planning for local governments and taxes and customs for national governments). Joined up approaches between levels of government, civil society, utilities, and industry are essential in this regard. Likewise, the greening of the energy sector is a key component for eMobility strategies to succeed and scale-up.
- » **Segment the market for mobility and aim eMobility programs at points of transition where intervention can be most effective.** Different technologies can be used to target different market segments as well as different types of customers within individual segments. Early on in a country’s transition targeting smaller market segments that are more sensitive to switching and / or responsive to government policies (including taxes) can be a good strategy for developing initial uptake. Similarly working on eMobility solutions across public and private transport modes can also offer potential for cross learning and consumer education.
- » **The sustainability benefits of eMobility are strongly linked to power system emissions.** Fully capturing the environmental benefits of eMobility requires parallel effort to make full use of renewable energy sources. eMobility also shows potential to complement greater introduction of renewables if Vehicle-2-Grid solutions can reach full maturity.

- » **Use the transition to eMobility to accomplish other important transitions.** In the transport sector, these may relate to the service quality or public perceptions of public transport, participation of different groups in the delivery of transport services (e.g. women), improvements in the land use, regional integration, first and last-mile connectivity, inclusivity of transport access, and others. Development of eMobility infrastructure and the technology trends offered by increasing storage potential in batteries is also an opportunity to rethink significant transitions in the energy sector. These include renewal of power distribution networks, sector regulation, market structures, new actors and business models, and long-term capital planning for utilities. More broadly, eMobility is likely to be an increasingly important element in the electrification of economies and their transition away from fossil fuels.
- » **Simple eMobility solutions can also be elegant, affordable, and highly sustainable.** eMobility solutions that are presently available extend well beyond the latest four-wheel passenger vehicles. Used vehicle markets, two- and three-wheelers are an opportunity for countries with lower average incomes where upfront affordability is an issue. Government initiatives to enable initial eMobility uptake also need not be fiscally expensive. At a bare minimum, any government interested in eMobility can seek to enable solutions to enter their markets without significant fiscal costs through enabling policies, regulations, standards for home and workplace charging, and basic consumer protection frameworks. Even a small simple start can develop the initial learning that provides for incrementally increasing the sophistication of a government's eMobility program in the future.
- » **Enable public transport operators to succeed with eMobility.** Operators deliver services in a constrained environment. Supporting them to succeed amidst those constraints is critical in the case of deploying eMobility solutions. A key risk that governments need to be cautious of is demanding higher rates of bus fleet conversion than an operator is ready to sustain. An operator's capacity depends on operating experience with eMobility, charging facilities, maintenance systems, and network characteristics that cannot practicably change overnight. A dominant strategy that experienced operators have expressed during this research is to learn incrementally through the introduction of smaller fleets before attempting to scale up. Inter-city and international cooperation between operators can also be a very beneficial strategy for sharing learning and building capacity to deploy eMobility solutions effectively. As public transport operators are ultimately required to provide a cost-efficient service and cater for a higher demand, the end goal is to improve modal shift based on sustainable mass transit, which can also be achieved by deploying electric bus fleets.
- » **Governments need ways and means of avoiding additional financial strain on public transport operators in the switch to eMobility.** The present cost of electric bus solutions remains considerably higher than conventional vehicles. There is a role for governments to play in providing support to the transition (e.g. with grant funding) such that the strain is neither born by operators or customers who pay fares. The different fiscal capacities of local vs. national governments also need to be taken into account such that the costs of electric bus solutions are broadly shared as well as the benefits.
- » **The impact that transitioning to eMobility can potentially have on jobs and output in the automotive sector is something that countries need to actively plan for.** For some countries this may be an opportunity to develop new industries while for others it may represent a risk to established firms and the economic linkages they have to elements of regional and national economies. It will be necessary to target policies accordingly. In addition to social and economic considerations, the ramification of such transitions on the political economy of eMobility could affect a government's ability to maintain policy credibility and continuity.

- » **Consumer-led initiatives and the integration of different technologies into the eMobility value chain should be embraced and encouraged.** Where a government's capability to support eMobility may be limited, these factors have shown remarkable ability to compensate when provided with basic enabling conditions.
- » **Technology neutrality is emerging as a best practice for many countries.** An emerging best practice is for programs to remain "technology neutral" such that they may support the development of eMobility solutions without prescribing eMobility as the only solution for emissions reduction in the transport sector. This does not mean avoiding direct investments that support eMobility such as purchase subsidies or charging infrastructure. Rather it means program design that leaves room for broad ranges of technologies (e.g. beyond battery EVs) to participate provided that their end result supports intended outcomes. The aim should be to have multiple "horses in the race" in an effort to address the challenge of transport sector emissions.
- » **The sustainability of eMobility neither starts nor stops on the road.** The environmental, economic and social implications of the entire supply chain are key considerations particularly as they relate to battery lifecycle. The opportunity offered by transforming the supply chain around eMobility should be taken as an opportunity to deploy sustainability principles in a way that was not comprehensively achieved during the development of supply chains for fossil fuels and fossil fuel-powered vehicles.

eMobility is, at its core, a disruptive transition. That is a good thing. Transport's share of global emissions continues to rise and "business as usual" will not achieve the results needed for meeting Paris Agreement targets. There is also no credible scenario whereby limiting the effects of climate change to a 2° centigrade change in global temperatures is possible unless the transport sector can correct course. As governments around the world engage with eMobility, there is an acute need for international cooperation around using the potential that eMobility offers to its fullest. In the simplest forms this entails sharing experiences and lessons learned. Increasingly it will also require concerted efforts around investments in vehicle infrastructure, supply chains, and behaviour changes to achieve the promise that eMobility offers. For this reason the World Bank and the International Association of Public Transport welcome the *Katowice Partnership on E-Mobility* and will look forward to supporting its success.

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OEMs

Anonymous OEM
 Anonymous OEM
 Anonymous OEM
 Anonymous OEM
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 UK Power Networks, U.K.
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Public Transport Operators

Transport Metropolitans de Barcelona, Barcelona
 Empresa Municipal de Desenvolvimento de Campinas, Campinas
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Government Departments

Office for Low Emission Vehicles, U.K.
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Charging Infrastructure Operators

Delta
 The New Motion
 ABB
 Emotorwerks
 Freshmile
 Fastned

Civil Society and Other Important Stakeholders

National Renewable Energy Laboratory (NREL)
 International Technical Committee for the Prevention and Extinction of Fire (CTIF)
 Eurelectric
 Centre of Excellence for Low Carbon and Fuel Cell Technologies (Cenex)
 Norwegian Electric Vehicle Association
 Felyx E-scooter Sharing
 Picnic
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"EV SHARING SCHEMES SHOULD BE SEEN AS A WAY TO COMPLEMENT RATHER THAN REPLACE PUBLIC TRANSPORT."

RESEARCH AND PROGRAM IMPLEMENTATION ORGANIZATION

"AN EV IS STILL A BLACK BOX FOR MANY PEOPLE."

CHARGING INFRASTRUCTURE OPERATOR

"DIESEL IS THE CASH COW THAT ALLOWED FOR INVESTMENT IN EVS."

RESEARCH AND PROGRAM IMPLEMENTATION ORGANIZATION

"IN 1985 A VW GOLF COULDN'T DO 180KM ON A SINGLE TANK"

ELECTRICITY UTILITY

"THIS REPRESENTS A MUCH BIGGER SHIFT THAN WITH THE INTRODUCTION OF ANY PREVIOUS INCREMENTAL AUTOMOTIVE TECHNOLOGY."

FORMER ELECTRIC VEHICLE OEM ENGINEER

"THE MOST IMPORTANT THING IS TO HAVE THE SUPPORT OF LOCAL AUTHORITIES."

PUBLIC TRANSPORT OPERATOR USING ELECTRIC VEHICLES

"FLAT-RATE PRICING IS LIKE CHARGING THE SAME AMOUNT FOR A LITER OF WATER IN A DESERT AS DURING A TSUNAMI."

CHARGING INFRASTRUCTURE OPERATOR

"SINCE THE DIESEL CRISIS, THERE IS LESS TRUST IN THE INDUSTRY."

ELECTRIC VEHICLE OEM

"I COULD POWER [A] HOUSEHOLD THROUGH AN IPHONE CABLE IF THE DEMAND COULD BE SMOOTHED."

CHARGING INFRASTRUCTURE OPERATOR

"WHAT IS A RISK FOR ONE STAKEHOLDER IS A COMMERCIAL OPPORTUNITY FOR ANOTHER."

FIRE AND RESCUE SERVICE REPRESENTATIVE

"IT IS NOT THE CASE THAT ONE TECHNOLOGY SUPERSEDES ANOTHER ONE, BUT RATHER THAT DIFFERENT TECHNOLOGIES HELP TO SATISFY A WIDE RANGE OF DEMANDS."

AUTOMOTIVE ASSOCIATION

"THERE'S LESS CERTAINITY AROUND THE FUTURE FOR TRUCKS."

ELECTRIC VEHICLE OEM

"CREATE A NEW PLAYING FIELD FOR THE NEW PLAYERS AND LET THEM PLAY."

CHARGING INFRASTRUCTURE OPERATOR

"CUSTOMERS HAVE TO BE ABLE TO MAKE MONEY WITH [OUR PRODUCTS]—THEY DON'T BUY THE TRUCKS FOR REASONS OF ENVIRONMENTAL SUSTAINABILITY."

ELECTRIC VEHICLE OEM

"THE BIGGEST ISSUE IS KNOWING WHERE TO INVEST ... THE CHALLENGE WITH THIS NEW LOAD GROUP IS THAT IT MOVES."

ELECTRICITY UTILITY

"SOME [MUNICIPAL GOVERNMENTS] LEARNED THE HARD WAY WITH UBER."

E-SCOOTER RIDE-SHARING SERVICE

"THE BEST USED CAR YOU CAN BUY IS PROBABLY AN ELECTRIC CAR."

ELECTRIC VEHICLE OEM

"[V2G] IS TURNING THE LAST MILE OF THE ELECTRICITY SYSTEM INTO THE FIRST MILE ... INVESTMENT SHOULD ALIGN WITH THESE CHANGING USE PATTERNS."

ELECTRICITY UTILITY

"IT'S NICE TO SHARE SUCCESSES, BUT PEOPLE LEARN MORE BY FACING CHALLENGES."

MOTORSPORT BODY