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E-VEHICLES AND THE ENERGY TRANSFORMATION

KRISTINE BERZINA, PETER CHASE, GIOVANNI COPPOLA, DANIELA DI ROSA,
DOUGLAS HENGEL, GIUSEPPE MONTESANO

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Please direct inquiries to:

The German Marshall Fund of the United States
1744 R Street, NW
Washington, DC 20009
T 1 202 683 2650
F 1 202 265 1662
E info@gmfus.org

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About the Authors

Kristine Berzina, Peter Chase and Douglas Hengel are senior fellows at the German Marshall Fund of the United States.

Giuseppe Montesano is deputy director of the Enel Foundation.

Daniela Di Rosa is senior researcher at Enel Foundation.

Giovanni Coppola is e-mobility strategy program manager at Enel X.

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E-Vehicles and the Energy Transformation

Kristine Berzina, Peter Chase, Giovanni Coppola,
Daniela Di Rosa, Douglas Hengel, Giuseppe Montesano

Digitalization is transforming the energy sector in Europe and the United States, with major implications for energy security, climate change, economies and indeed societies. As important as renewable energy is for climate change, getting the most out of it depends on the use of batteries, and the digital technologies that can manage the renewables and batteries as distributed energy resources—a new decentralized approach to electricity that is also transforming the traditional model of electricity generation and distribution.

Here, the electric vehicle (e-vehicle) has an important role to play, beyond its function of reducing greenhouse-gas and pollutants emissions from the transport sector. For an e-vehicle is essentially a battery on wheels. Seen merely as a mode of transport, it represents potentially huge additional demand for more electricity. But seen as a part of the electricity network, e-vehicles as batteries help integrate renewable energy into the system, storing power while demand is low, and feeding it back into the system when demand is high but the primary resource is not available.

Recognizing and facilitating this broader role of the e-vehicle in the energy system should be a priority for European and U.S. politicians and policymakers. Doing so will underscore the importance of key steps to promote the (already burgeoning) uptake of e-vehicles, including by:

- encouraging decentralized consumer-based electricity production and consumption (“prosumers”) as well as the platforms that can aggregate and manage these distributed energy resources,
- promoting smart metering,
- adopting appropriate tariff pricing structures,
- understanding the role of data in this decentralized distributed energy world,
- stimulating investment in charging infrastructure,
- considering in this context buildings and energy as part of an ecosystem,
- building on the scale of fleets (including importantly public transport), and
- permitting governments at all levels to lead in adopting policies that achieve these goals.

E-Vehicles and the Energy Transformation

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The Potential Role of E-Vehicles in the Energy System

The energy sector, once considered staid and resistant to change, is undergoing a major transition in Europe, the United States and elsewhere. Electricity is becoming increasingly important to economies and societies, renewables such as solar and wind power are now major sources of electricity generation, and digitalization enables a shift away from the traditional model of centralized power generation sending electricity down one-way wires to passive end-users to one that is more distributed, in which “prosumers” generate, self-consume, store and even inject electricity back to the grid.¹

These changes are driven in part by concerns about climate change and a desire to move away from the fossil fuels (coal, oil, and gas) that cause it, as well as ever-increasing computer power and the digitalization that is creating the “internet of things.” These two major trends, once separate, are now coalescing in the energy sector.

Electric vehicles, or e-vehicles, are destined to play a major role in this process, and the full import of that role is only now becoming understood. Electric propulsion of vehicles is not new. Metropolitan subway systems are all electrified, and in Europe (in particular) trains and trams have long been powered by overhead wires, moving on defined tracks and receiving electricity as they do so. The major change today is the shift to putting electric motors in cars, trucks, and buses that move free of any built-in electricity infrastructure. This shift has been motivated

largely by concerns about climate change as well as local pollution and energy efficiency. Politicians and policymakers increasingly focus on the need to move the transport sector away from internal combustion engines that run on gasoline and diesel fuels to something cleaner, especially as renewables become more important in power generation.

But the need to “decarbonize” transport is only a part of the story of e-vehicles. While shifting cars and trucks to electric motors may eliminate tailpipe emissions, the overall impact on greenhouse-gas accumulations might be minimal if the additional demand e-vehicles represent for electricity is met by fossil-fuel power stations.

It is here that the significance of e-vehicles extends well beyond their “clean mobility” role; in fact, they could also be critical to integrating the renewables that will make them truly green into the electricity grid.

As more solar and wind power has been brought onto the grid, the difficulties with renewables have become increasingly apparent. The problem with their variability was always understood—solar power is generated only during daytime, while wind power depends on the weather. But as more solar panels and wind turbines came online in various areas, they began generating large amounts of electricity in the same places at the same times – often well in excess of local demand at those times of the day. Since electricity must be used as it is generated, utility companies must turn off (“curtail”) or find a way to store these green sources of energy.

The answer to this dilemma is to use batteries and other technologies to store the surplus electricity generated by renewables so it can be supplied back to the grid when

¹ See Guillaume Xavier-Bender et al, *Creative Destruction in the Energy Sector: From Disruption to Transformation*, GMF, 2014, and Kristine Berzina and Peter Chase, *Transatlantic Policy Challenges of the Digital Energy Nexus*, GMF July 2017.

the demand is there (often early in the morning and in the evening) but when solar panels and wind turbines are not generating. In the past few years, “renewables plus storage” has proven in a growing number of cases more economical than more traditional power-generating plants, many of which have been canceled in the face of this new competition.²

The advent of e-vehicles has had a significant impact on the energy system in two ways. First, it helped reduce the cost of batteries dramatically by increasing demand for them, thus making them more generally available to the electricity system. Further, with appropriate use and the digitalization of the energy sector, e-vehicle batteries can be a “distributed energy resource” in their own right, taking power from the grid when it is in surplus and supplying it back when needed.

In sum, e-vehicles can have a dramatic effect on electricity demand and supply, and on the future of grids. An influx of electric and digitally enabled vehicles can add significant demand to the electricity grid, especially if they are seen as “dumb” appliances plugged in at the same time of the evening when commuters return home from their day at the office. This can be managed through smart tariffs and automated mechanisms to spread charging through the day, and especially at night. On the other hand, the growing number of e-vehicle batteries could provide valuable grid services (vehicle-to-grid, or V2G), from frequency and voltage regulation to distribution level services, without compromising driving experience or capability. The addition of electric mobility to the energy system has the potential to accelerate the energy transition, reorganize society around more cooperative and flexible transportation models, and achieve larger climate, health and innovation policy goals.

This paper focuses on the extent to which e-vehicles are playing this broader role in the energy system of Europe and the United States. What are the factors affecting the uptake of e-vehicles in the two regions, what challenges and opportunities does that uptake present, and are

² See, for example, Robert Walton, [Report: Minnesota Storage+Solar Could be More Cost-Effective Than Peaking Plants After 2022](#), Utility Dive Brief, July 11, 2017, and Julian Spector, [Just How Much Business Can Batteries Take From Gas Peakers](#), GreenTech Media, May 16, 2018.

existing policies sufficient to exploit the role e-vehicles could play in integrating renewable energy into the system, in general and as an important factor in a new, more distributed, energy model, especially through more sophisticated V2G services?

In general, while e-vehicles are gradually becoming more important in clean mobility in Europe and the United States, the broader role they could play as distributed energy resources through V2G services is under-appreciated. Europe and the United States can and should do more to accelerate this evolution.

The Current Policy Framework

The European Union

The European Union seeks solutions to meet its ambitious emissions, renewable-energy, and energy-efficiency goals for 2030. It initially pledged to achieve by 2020 20 percent reductions in greenhouse-gas emissions (compared with 1990 levels), 20 percent of final energy consumption from renewable energy, and 20 percent improvements in energy efficiency (the 20-20-20 climate and energy package). These targets have been revised recently and will now rise to 40, 32, and 32.5 percent respectively by 2030.³

The EU has proposed several policies to facilitate the transition to cleaner energy and mobility sectors. Equally significant is its financial support for new technologies and for infrastructure in member states. Although these policies and support schemes do not provide a specific roadmap to a new energy system anchored by integrated e-vehicles, many elements are helpful in achieving that goal.

The power-generation sector and, to some extent, the residential one were the low-hanging fruit for achieving the EU’s efficiency and renewables targets—and many

³ European Commission, [Europe Leads the Global Clean Energy Transition: Commission Welcomes Ambitious Agreement on Further Renewable Energy Development in the EU](#), Strasbourg, June 14, 2018. European Commission, [Energy Efficiency First: Commission Welcomes Agreement on Energy Efficiency](#), Statement, Brussels, June 19, 2018.

member states saw booming rates of solar photovoltaic (PV) and wind installation in the last decade. But European leaders have recognized that meeting the next targets will require expanding green technologies to other sectors, in particular the transport one through e-vehicles and clean mobility.

The European Commission is approaching mobility and the energy transition through two main policy packages. The Third Clean Mobility Package seeks to “ensure a smooth transition towards a mobility system which is safe, clean, connected and automated,” and it links the digital transformation of mobility to clean mobility. It includes emission standards for vehicles and public-procurement requirements, as well as an action plan to promote research into and development of battery technology in Europe.⁴ On the energy side, the EU’s electricity market design proposals seek to create a more consumer-centric energy system that would allow individuals to attain greater control over their energy use and become more active energy “prosumers.” Providing clear price signals to consumers is a critical element of the legislation.⁵ Also, energy-efficiency directives address e-mobility. In particular, the Energy Performance of Buildings Directive sets requirements for charging infrastructure. Finally, the Connecting Europe Facility is a key mechanism for funding new energy and mobility infrastructures. As a part of the new mobility package, the EU allocated €450 million to projects that promote the aims of the policy package, including digitalization.⁶

The United States

In the United States, the promotion of e-vehicles was a key component of the Obama administration’s plan to create a cleaner, more sustainable transportation system. In 2012, it adopted Corporate Average Fuel Economy rules that sought to double the average fuel efficiency of automakers’ fleets to about 50 miles per gallon (about 21 km per liter) by 2025. Those rules included a review by April 2018 as to whether the efficiency goals in the final years of the plan were feasible

⁴ European Commission, [Europe on the Move: Commission completes its agenda for safe, clean and connected mobility](#), 17 May 2018.

⁵ European Commission, [Commission proposes new rules for consumer centred clean energy transition](#), 30 November 2016.

⁶ European Commission, [2018 CEF Transport call for proposals](#).

or not. As part of this effort, the federal government and several states offered incentives, including tax credits, for purchasing e-vehicles. The amount of the federal tax credit depends on the size of the vehicle and its battery capacity, and it is available until 200,000 qualified e-vehicles have been sold by each manufacturer, at which point the credit begins to phase out for that manufacturer.⁷ California has adopted a mandate for zero-emissions vehicles, targeting the deployment of 1.5 million of them by 2025, the vast majority of which will be plug-in e-vehicles.

The Trump administration has gone in the other direction. In early 2018 it declared that the higher emissions standards adopted under the Obama administration, which were set to take effect for cars built from 2021 and 2026, were unreasonable for economic and safety reasons. It proposed freezing the standards at their planned 2020 level. In addition, the administration proposed to end the ability of California and other states to enact stricter emissions standards than the federal government, including by requiring manufacturers to sell more e-vehicles in those states. California and several other like-minded states are challenging this in court. If enacted, a freeze on fuel-efficiency standards alone is not expected to have a significant impact on sales of e-vehicles in the United States according to most experts. However, if California (the world’s eighth-largest economy) cannot institute stricter emissions rules and e-vehicle mandates, that could have an impact on the uptake of e-vehicles.

A Small, but Rapidly Expanding Reality

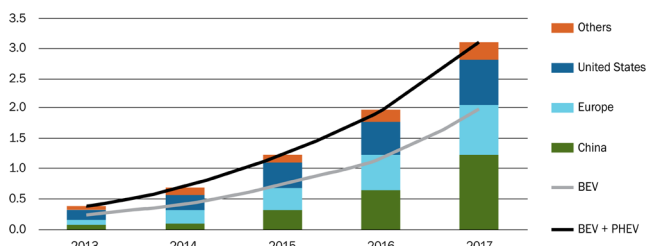
In part because of these and other incentives, sales of electric vehicles—plug-in electric hybrid vehicles (PEHVs), which have batteries to power their electric motors as well as internal combustion engines, and battery-electric vehicles (BEVs)—are expanding rapidly. According to the International Energy Agency (IEA), sales of e-vehicles surpassed 1 million globally in 2017, a 54 percent increase over 2016.⁸ The current

⁷ There are proposals in the U.S. Congress to eliminate that phase-out in an effort to boost e-vehicle sales, but there is also proposed legislation to end any federal tax incentives for them.

⁸ Pierpaolo Cazzola et al, [Global EV Outlook 2018](#), International Energy Agency, May 2018, page 9.

Figure 1: Stock of E-vehicles, by Region, 2013-2017

Figure 1 – Stock of Electric Vehicles, By Region, 2013–2017



Source: IEA analysis based on country submissions, complemented by ACEA (2018); EAFO (2018A)

stock of these vehicles globally has grown to more than 3 million (see Figure 1).

Sales of e-vehicles in the United States are expected to grow by 60 percent in 2018 to 300,000,⁹ about half of which will be in California. Sales in Europe are higher and are expected to remain so in coming years. For example, by the end of 2017, every second passenger car sold in Norway (Europe’s single largest home to e-vehicles) was electric, and growth in Germany (Europe’s second largest e-vehicle market) is accelerating.¹⁰ Public policy has had a significant role in the growth of popularity of e-vehicles. Countries including Belgium, France, Germany, and the United Kingdom have provided grants to incentivize purchases; others including Norway and the Netherlands have provided tax incentives.¹¹

All forecasts see the number of e-vehicles growing significantly in the coming years. According to one, 14 percent of passenger vehicles sold in Europe by 2025 will be electric, 30 million will be sold in 2030, and the number in use globally could rise to 559 million by 2040, representing a third of the global car fleet.¹² The IEA estimates more conservatively that 125–220 million

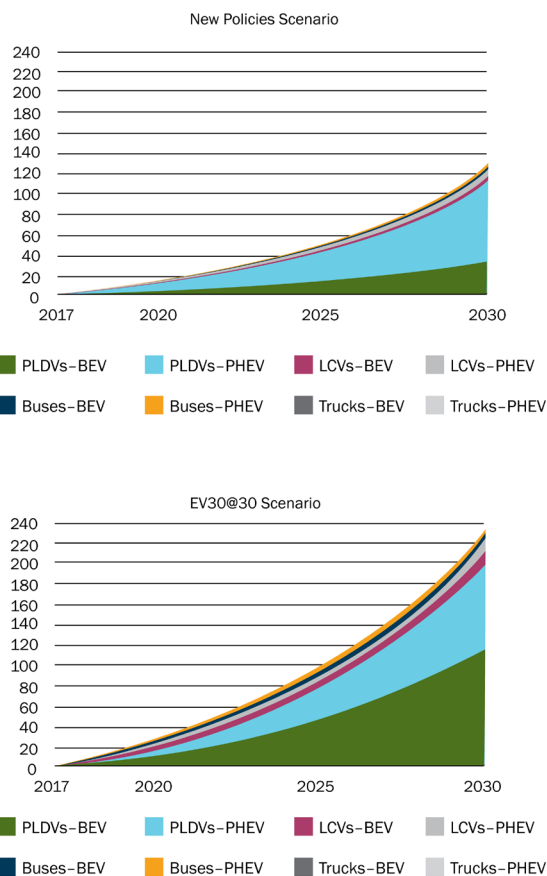
9 Comment at Washington workshop.

10 Patrick Hertzke, Nicolai Müller, Stephanie Schenk, and Ting Wu, *The global electric-vehicle market is amped up and on the rise*, McKinsey & Company, May 2018.

11 Sam Morgan, *Europe’s attempts to spark an electric vehicle revolution*, Euractiv, 22 May 2018.

12 Salim Morsy, “Global Sales Outlook” in *Electric Vehicle Outlook 2018*, Bloomberg New Energy Finance.

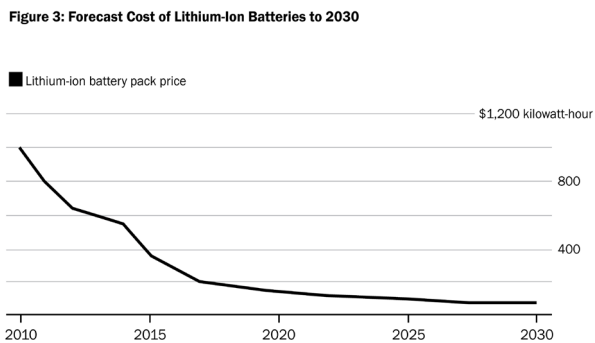
Figure 2: E-vehicles Sales Forecast, 2017-2030.



Source: IEA analysis developed with the IEA Mobility Model (IEA, 2018b)

light-duty e-vehicles (e-cars) will be on the road in 2030, depending on a “current policy” or the “EV30@30 Campaign” scenarios (see Figure 2). The latter is an effort launched at the Eighth Clean Energy Ministerial in 2017, when governments participating in its Electric Vehicles Initiative—Canada, China, Finland, France, Germany, India, Japan, Mexico, Netherlands, Norway, Sweden, the United Kingdom, and the United States—pledged to bring e-vehicles to a 30 percent share of all vehicles in their markets by 2030.

Figure 3: Forecast Cost of Lithium-Ion Batteries to 2030



Source: Bloomberg New Energy Finance

Factors Affecting Uptake of E-Vehicles

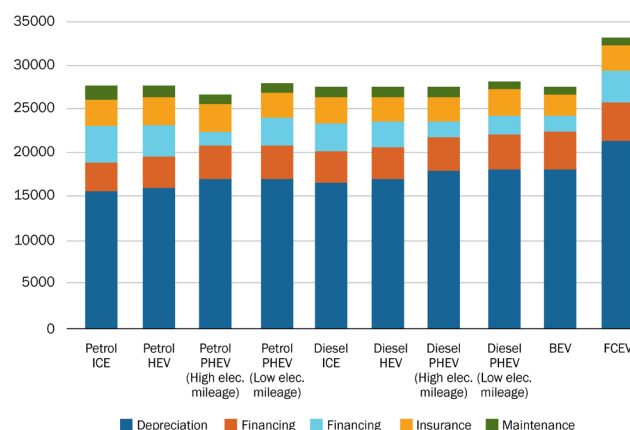
Although government support for e-vehicles is important, one of the key factors encouraging their uptake is the dramatic drop in battery prices—their major cost component—in recent years. Until recently, this cost was a limiting factor in the development of e-vehicles and distributed energy systems. But in this decade the cost of lithium-ion batteries has declined significantly, from over \$1,000 per kilowatt hour (kWh) in 2010 to \$176 per kWh in 2018.¹³ The cost of batteries could fall below \$100 per kWh by 2025 (see Figure 3).¹⁴ This is critical for the affordability of e-vehicles.

By driving down the cost of lithium-ion batteries Chinese producers, which are the major players, have stimulated demand for e-vehicles. However, this also has had the side effect of making other promising technologies for larger-scale storage less viable. This dominant-technology or lock-in issue, however, is considered more of a challenge for grid storage than for e-vehicles, at least for now, since lithium-ion batteries are well suited to vehicles and continue to improve in terms of size, weight, power, and capacity, which increases drive time and distance.

13 Bloomberg BNEF. Energy Storage: 10 Things to Watch in 2019

14 Mark Chediak, *The Latest Bull Case for Electric Cars: the Cheapest Batteries Ever*, Bloomberg, December 5, 2017.

Figure 4: Cost of Owning and Running a Mid-size Car over Four Years with Various Powertrains in 2030



Source: *Low-Carbon Cars in Europe, 2018, page 59 (under TECH scenario)*

Together with the reduction in the cost of lithium-ion batteries, the cost of electric cars will also decrease with economies of scale. While battery-electric and fuel-cell vehicles will still be significantly more expensive than diesel and petrol vehicles and their hybrid variants in 2020, by 2030 the price difference will be reduced, in part as diesel and gasoline cars become more expensive as a result of more stringent limits on air pollution and CO₂ emissions.

But this is just in terms of the purchase price. A more holistic approach¹⁵ considers not only the purchase price but also the costs of refueling/charging, financing, maintenance and resale value to arrive at the “total cost of ownership.” Figure 4 shows this perspective for an ownership period of four years with 15,000 kilometers traveled each year. When considering this overall cost, battery-electric vehicles compare favorably to their

15 Jon Stenning et al, *Low-Carbon Cars in Europe: A Socio-Economic Assessment*, study conducted by Cambridge Econometrics and ElementEnergy for the European Climate Foundation, February 2018, page 56.

traditional internal combustion engine counterparts, both gasoline (petrol) and diesel.

A New Resource for the Energy System

While the focus of most politicians, the IEA, and others is on the impact the uptake of e-vehicles will have in reducing oil consumption, greenhouse gas emissions, and pollution, the implications go far beyond that. An e-vehicle, in addition to being more efficient than the alternatives and dramatically reducing emissions, especially in urban areas, can also serve as a portable battery that can play a key role in energy storage and grid balancing. A vehicle with a 30 kWh battery stores as much electricity as the average U.S. residence consumes in a day.¹⁶ Determining how and when the e-vehicle's battery is charged, and who has access to it, is critical for ensuring that it meets its full social and environmental potential.

In an ideal scenario, an electric battery would be charged when there is plentiful, cheap, and (best of all) renewable electricity available on the grid and when demand is otherwise low. For example, in areas where there are wind farms, vehicles could be charged overnight using wind power. Essentially, e-vehicles could serve as a buffering system for wind power at a time of day when there are few other uses for the electricity. This kind of smart charging, which charges batteries when electricity is plentiful and ideally green, can be achieved in homes and offices using digital technologies.

E-vehicles could play an even larger role in communities through vehicle-to-grid (V2G) integration technologies. With smart charging and V2G technology, not only can batteries take electricity from the grid when demand is low, but a vehicle could return electricity to the grid when demand is high and/or provide ancillary services such as frequency-control regulation or demand response. All these services to the grid can be monetized for the car owner or can be used to compensate charging station owners for providing flexibility. This scenario would allow vehicles to play a significant role in the electricity sector by serving as a source of energy, similar to a small power plant. The role of an individual car may be limited, but the effect of monetizing the charging according to grid

¹⁶ Chris Nelder, James Newcomb, and Garrett Fitzgerald, [Electric Vehicles as Distributed Energy Resources](#), Rocky Mountain Institute, 2016.

constraints when aggregated at a community, city or regional level could be significant. This is especially the case when fleets of buses or delivery vehicles behave as large batteries together.

One study has found that in France battery electric vehicles produce two to three times less global-warming pollution than diesel or gasoline vehicles over the course of their lifetimes. The lithium-ion batteries that power e-vehicles can store energy and reduce emissions while they are in use in the vehicle, but the energy-system role of the battery extends ever further. It is possible for car batteries to be re-purposed for renewable-energy storage once they are no longer being used in vehicles (i.e. second-life batteries).¹⁷

Another recent study has determined that California could meet its grid-storage mandate of 1.3 GW of stationary storage by 2024, which is meant to facilitate the continued growth of intermittent renewable energy production, by relying mostly on e-vehicle batteries.¹⁸ This synergistic opportunity presents itself because California also has a zero-emissions vehicle (ZEV) mandate, as mentioned earlier, targeting the deployment of 1.5 million ZEVs by 2025, the vast majority of which will be plug-in e-vehicles. If these are used to provide grid storage to mitigate renewables intermittency and are charged when renewal energy production peaks during the day, this could displace the need for construction of most, perhaps all, new stationary grid storage. The study's authors note that the capital investment for stationary storage can instead be redirected to accelerate the deployment of clean vehicles and V2G integration, and perhaps even to pay owners when their e-vehicles provide power to the grid.

Integrating E-Vehicles: The Digital Energy Nexus

Much of the technology required to make the scenario of close interconnection between electricity and the

¹⁷ Marie Chéron and Abrial Gilbert-d'Halluin, [From cradle to grave: e-mobility and the French energy transition](#), European Climate Foundation, January 2018.

¹⁸ Jonathan Coignard et al. [Clean Vehicles as an Enabler for a Clean Electricity Grid](#), Environmental Research Letters, 2018.

transport system a reality is already in place. Aside from electric vehicles and the battery technologies that power them, two elements are key: digitalized energy systems and attractive, consumer-friendly platforms.

Digitalization

The digitalization of the energy sector is interconnecting energy producers, suppliers, and consumers in unprecedented ways. Whereas consumers once merely purchased energy from a utility company through a grid, today's energy system—in particular through second-

generation smart meters—allows for more complex relationships. Households can produce their own energy through solar PV and sell the excess back to the grid. Or they can install batteries to store that power and use it at a later stage, even disconnecting from the grid. In an even more revolutionary development, groups of households or businesses can create microgrids to generate and share electricity among themselves. This kind of digitalization is booming in the electricity sector. The IEA has found that “global investment in digital electricity infrastructure and software has grown by over 20 percent annually since 2014,” with investments in digital infrastructure vastly

Box 1. Making V2G a Reality

The application of dynamic two-way vehicle-to-grid (V2G) interactions is still in the early stages, but it appears to be on the verge of commercialization. By the end of 2018, some 50 V2G test projects were identified, 25 in Europe (primarily the Netherlands, Denmark, the United Kingdom, and Germany), 18 in North America and 7 in Asia.^a The projects all involved car manufacturers, local utilities, charging infrastructure, and aggregators to provide the software to bring all these distributed energy resources together. The Nissan Leaf was one of the main vehicles used, in over half the projects, followed by BMW, Honda, and Peugeot (Groupe PSA) vehicles. Two-way charge points were provided by companies including ENEL, EVTEC, GE, Hitachi, Magnum Cap, Mitsubishi Electric, Mobis, and PNE, while the aggregator software was most often provided by Nuvve. The projects—variously at the research, testing, proven, and commercial stages—looked at how these vehicles could supply services back to the grid, including through providing reserves, frequency response, arbitrage, distribution services, and time-shifting of demand/supply. The technical viability of V2G services was basically demonstrated during projects between 2012 and 2015; more recent projects have focused on commercial viability.

One of the most exhaustive and promising of these demonstrations is the 2016–2018 Parker Project in Copenhagen, Denmark, which published its final report in January 2019.^b Importantly, the project was centered around the world's first commercial pilot utilization, the Frederiksberg Forsyning V2G Hub, as part of the research into the economic viability of the grid applications that could be provided by four different models of currently available e-vehicles (Nissan Leaf, Nissan Evalia, Peugeot iOn, and Mitsubishi Outlander). The partners in the project included the car manufacturers and the V2G hub, but also Nuvve as the provider of the software, ENEL for the chargers, and Insero A/S and DTU Electrical Engineering. The project demonstrated that a mix of vehicles could provide even technically difficult frequency response services to the grid (with 13,000 hours of service per car generating an average revenue of about €1,860, or over \$2,200, per year), while also helping integrate renewable energy supplies into the electrical grid. The project also helped develop a certificate (Grid Integrated Vehicle) that worldwide car manufacturers can use to signal the vehicles' ability to support the grid. Importantly, the project also evaluated these technologies as being replicable and scalable, with other services like voltage regulation becoming mature in less than two years, and even more advanced services such as reactive power doable in under five years. The project found, however, that the ability of the cars to provide these services will depend considerably on the regulatory environment governing the local utilities.

a. Sjoerd Moorman and Paul Reynolds, et al, [V2G Global Roundtrip: Around the World in 50 Projects](#), An Everoze and EVConsult Report, October 2018. For an inventory focused on V2G projects in Europe, see [SEEV4 Newsflash: V2G Repository Presents 18 European Vehicle-to-Grid Projects](#), Polis Cities and Regions for Transport Innovation, March 14, 2018.

b. Peter Bach Anderson, et al, [The Parker Project Final Report](#), Energy Technology Development and Demonstration Program (EUDP), January 31, 2019.

exceeding investments in traditional areas such as gas-fired power generation.¹⁹ The role of the grid in enabling these digital functions appears to be key.

Platforms

The actors involved in the energy system also are evolving. Even as smart meters and “internet of things” (IOT) devices give households control over when and how they use electricity, the need to ensure that these devices – from water heaters to vehicles to grids – and communities speak to each other has led to the development of user-friendly platforms to manage usage. Internet and communications companies such as Google and Oracle have made big investments and acquisitions in energy-management functions (e.g. Nest and Opower), as well as investing in renewable energy for their own operations.²⁰ Utility companies too are developing a role for themselves in this field, much as information and communications technology companies are taking on traditional energy roles. Enel, for example, has created Enel X, a new business line that not only sets up e-vehicle charging stations but provides services that aggregate electricity capacity, control frequency, manage grid connection, integrate renewables and provide other features to make an interconnected energy system work.²¹

Connecting this to e-vehicles, Enel X has set up a dedicated platform (Juicenet) for controlling charging processes on a global scale, in order to provide V2G integration. In the United States, V2G projects are at the pilot stage and not yet commercial. Grid services are provided through different silos and vested interests often resist distributed resources. Evolving regulatory and policy approaches, in particular in the states of California and New York, offer promise to stimulate the provision of V2G services.

The Importance of Fleets

Commercial operators of vehicle fleets are shifting to electrification, driven by technology and improving economics based on a more favorable total cost of

¹⁹ International Energy Agency, *Digitalization and Energy*, November 2017, page 25.

²⁰ IEA, *ibid*, page 25.

²¹ Enel X, *Our Business*.

ownership.²² Climate risks and sustainability goals are other important drivers of this shift. One study has found that daily return-to-base urban cycles below 100 miles are well suited for battery-electric drivetrains and that the electrification of freight trucks has the potential to revolutionize the industry just as diesel engines did in the 1940s and 1950s.²³ The cost of ownership for e-trucks could be on a par with alternative drivetrains soon, and adoption is being enabled by country-level emission regulations and local access policies.²⁴ Fleet electrification could be accelerated by utility companies and city planners working with fleet operators to encourage electrification of delivery vans, urban buses, and emergency vehicles.²⁵

Fleet operators are more strategic in their thinking than individuals and are thus more likely to factor in the total cost of ownership. Fleet owners may also be able to use smaller batteries depending on the number of miles driven daily, which would also reduce costs. Further, fleet owners are attractive partners for utility companies as the total amount of battery storage capacity they control could more easily provide services to the grid. Being able to monetize this function would, of course, help incentivize fleet e-vehicle uptake.

On the other hand, fleet owners want to use their vehicles as much as possible, decreasing the time during which they could provide grid services. This could be especially true as autonomous vehicle technology advances, as this allows vehicles to operate longer hours than manually driven ones. Fleet owners are also more likely to want to charge their vehicles at night when solar power is not available, unlike individual owners whose vehicles could be more easily charged during the day.

European countries and cities generally devote more effort to encourage cooperation among stakeholders to spur electrification. For example, the continent’s city and local governments are using public-private partnerships

²² UPS/Green Biz Oct 2018 report.

²³ North American Council for Freight Efficiency, *Second Guidance Report: Medium-Duty Electric Trucks - Cost of Ownership*, October 2018

²⁴ Bernd Heid, et al, *What's Sparking Electric-Vehicle Adoption in the Truck Industry?* McKinsey, September 2017

²⁵ Scott Smith et al, *Powering the Future of Mobility*, Deloitte Insights, October 16, 2017

to share data with fleet operators so these can decide when they should charge their vehicles, and they work together to ensure adequate charging infrastructure is available. In the United States, municipal-owned utility companies and other players could lead the way on similar public-private partnerships to capture the value of fleet electrification. The role of cities is therefore critical.

Business models need to incentivize daytime charging to capture the estimated \$200–1,200 per year of the value of energy stored in e-vehicle batteries that could be used by the grid.

Cities are concerned also about congestion so a simple substitution of e-vehicles for internal combustion engine cars is not sufficient. One idea for that could help resolve this tension is to place most charging infrastructure near transit points like metro or bus stations where parking is available so as to incentivize fewer vehicles entering cities.

Public Transport

A special case for fleets is, of course, public transport. While only about 0.4 percent of municipal buses in the United States currently are electric, 8 percent of buses on order have electric drivetrains, and their number is expected to rise quickly to 12 percent.²⁶ In Europe, cities are introducing e-buses as a signal of their intention to contribute to emissions reduction in urban environments. There were more than 2,100 urban e-buses in service in Europe in 2017, with full battery-electric ones making up the majority with 1,560 units. Cities are of course concerned about the limitations that go with e-vehicles: limited range notwithstanding improvements in batteries, recharge times, battery life, and battery cost. However, public transport has features that may help the uptake of electric traction: fixed paths, known distances, known and usually necessary stops, and scheduling of activities (driver rest) at terminals and depots. Further, while the high purchase price of e-buses compared to diesel is a stumbling block for limited municipal budgets, they have a lower total cost of ownership (€0.85/km) than diesel (€0.90/km) or compressed natural gas (€1.02/km) ones.²⁷

²⁶ Comment at Washington workshop.

²⁷ Lorenzo Tavazzi et al, *Electrify 2030*, The European House - Ambrosetti, page 158.

Box 2. Electrifying Buses in Chile

One of the projects not included in the inventory described in Box 1 is Enel's experience in Chile, an example of how electric mobility can be integrated into metropolitan public transportation systems through a public-private partnership. The first fully commercial e-bus service in Latin America was created through the collaboration of Enel X, the e-vehicle producer BYD Chile and the Chilean public transport company, Metbus. The system consists of 100 e-buses supplied by BYD, two e-bus depots for night-charging activities, maintenance, and repair of the e-buses, and 40 new smart stops equipped with LED lighting, real-time information screens, wi-fi, USB charging plugs, etc. The bus depots have solar parks that supply the electricity for charging the batteries and powering the infrastructure, including smart control technology that manages vehicle capacity and monitors the battery levels in real time, optimizing consumption. Besides the significant economic savings, as the e-buses consume 70 percent less energy than their predecessors, the system is quiet, reducing noise pollution in the densely populated area..

Key Challenges

Technological and policy developments give reason for optimism about the potential of e-vehicles to change the energy system in Europe and the United States. However, several challenges loom.

Cost of Vehicles

High purchase prices continue to dissuade consumers from purchasing e-vehicles. The question is not merely one of absolute cost but of consumer psychology. Depending on the region, the cost difference between an e-vehicle and traditional car can level out when the total cost of ownership (not just purchase price) is considered. Looking at battery and fuel cost estimates, the cost of ownership for both types of vehicle should achieve parity by the mid-2020s. But even then consumers may not opt for e-vehicles because they remain focused on the (higher)

purchase price. This is a structural challenge. Corporations or fleet operators are in a better position to evaluate such long-term price signals and may, therefore, be first movers.

The higher up-front cost of e-vehicles also presents a socio-economic challenge, especially when their uptake is subsidized up to a point. The initial group of buyers will tend to be higher-income given the high purchase price, but their enjoying the subsidy while lower-income later movers do not could be cause for complaint. However, fleets based on “sharing” models are already helping democratize access to e-vehicles.

Difficulty in Passing Benefits to Consumers

The integration of e-vehicles into the grid can bring economic benefits to the energy system. When Enel tested V2G technology in Denmark with Nissan, it found that it generated €1,000–1,400 revenue per year to the system per vehicle.²⁸ The challenge, however, lies in passing that benefit on to the customer or car owner. Utility, energy distribution and transmission, and car companies will need to create structures and pricing models that translate system savings to consumers who are investing in the e-vehicles and to companies building the charging facilities. Regulation has a key role to play in making this possible.

Charging Infrastructure

Also critical to consumer decisions is having the required infrastructure in place, given the current technological limitations on the distances e-vehicles can travel.

Certain areas may be better suited to e-vehicles based on their housing stock, wealth and population density. In areas with many private homes, plugging in vehicles so that they can have an effect on an energy system’s flexibility is relatively simple. In the United States, for example, many families live in single-family homes. In countries such as Spain and Italy, where far fewer households live in houses with driveways, public charging plays a far more important role. Public charging facilities are more challenging to set up and this could be a limiting factor in the uptake of e-vehicles.

²⁸ Stephen Edelstein, *This Is How Parked Electric Cars Are Earning Money in Denmark*, The Drive, 15 August 2017.

Policymakers and industry need to think through the implications of it being more expensive and therefore more challenging to install charging infrastructure in less populated or poorer areas. Energy and mobility planners can learn about some of the risks by looking at the difficulty that the telecommunications industry has had in providing widespread access to broadband.

Charging infrastructure is not a major challenge to e-vehicles in the United States at this time. The upscale demographic purchasing them has access to charging at home and/or work. E-vehicles are generally also the second or third vehicle in the family. For them to further penetrate into the market and become the only vehicle in the household, however, public charging must assume greater importance.

Complexity and Planning

For e-vehicles to increase the efficiency and flexibility of the energy system, smart-charging facilities and coordination will be essential. If all users drive home from work at rush hour and plug in their cars to be charged at the same time, utility companies will need to generate more power to keep up with the spike in electricity demand. Not only is generation an issue, but more copper would need to be installed to facilitate large-scale rapid charging. This is costly and inefficient. Policymakers and the private sector will need to prioritize smart charging over rapid charging to achieve climate and grid balancing benefits.

In addition, new relationships need to be fostered between non-traditional energy actors to achieve a more integrated energy and transportation sector. The operators of delivery fleets and bus depots that own the fleet battery storage capacity, for example, will need to develop relationships with utility companies or other energy platforms that seek to maximize the energy supply/demand equation. In these new relationships, the most challenging questions will be who manages the transformation of the energy and transit system, and who pays for new infrastructure.

Data

E-vehicles generate data. This data is essential for efficient management of the electricity system, but data protection policies and skeptical public opinion can hinder sharing and accessing it. The free flow of data between IOT devices, including vehicles, can allow households to manage their energy use most efficiently. The industry will need to comply with data protection and privacy standards while also convincing consumers that sharing access to their data will provide individual and systems benefits.

Strategies of the Automotive Industry

Unlike the very expensive engineering that goes into an internal combustion engine, the highest-value component in an e-vehicle (the battery) does not belong to the vehicle manufacturer. Further, electric-motor powered cars are relatively simple to build and maintain, allowing new entrants into a traditionally very capital-intensive industry. Not surprisingly, some traditional manufacturers, while introducing e-models, are fighting to maintain the status quo for as long as possible, as can be seen, for instance, in the incentive structures given dealers for sales of traditional versus electric vehicles.²⁹

European industry lags behind in developing e-vehicle technology, and there is still a limited selection of models to choose from for mass transit and for personal use. For individuals, the lack of models can make it unattractive to transition. For public authorities, the lack of European e-vehicle options can disincentivize switching to electric transportation systems. China does not face the same inertia of a legacy industry and has been adopting e-vehicle technologies, especially for buses, much more quickly than either Europe or the United States, which could put those two regions at a competitive disadvantage in this new industry.

Inadequate Political Support

Policymakers in EU member states and at the union level support a range of lower-carbon transportation options without prioritizing any technology. This may have made sense in the early years, but as the number of e-vehicles grows

and the need for coordination increases, specific policies that help incentivize the grid-balancing and efficiency benefits of e-vehicles would be useful. Overall, more ambitious policies on CO² reduction and air quality would also create a better environment for e-vehicles to prosper.

In the United States, many of the challenges for the penetration of e-vehicles are similar to those for Europe; e.g. the cost of vehicles, especially for the less affluent; inadequate coordination among governments, utility companies, car manufacturers and fleet operators; data sharing; and, in some cases, insufficient political support. Government policy and regulations could help address this, but with the current administration seeking to freeze emissions standards, e-mobility advocates are unlikely to receive a policy push from Washington and will need to rely on state-level efforts.

If enacted, efforts to have e-vehicle owners contribute to the U.S. Highway Trust Fund, which is funded by a federal fuel tax to pay for highway maintenance, could also slow the uptake of e-vehicles by increasing their costs. Proponents of this effort argue that the e-vehicle tax credit largely benefits wealthier Americans who can afford to contribute to the fund. On the other hand, this also will further delay the uptake of e-vehicles. While at some point it would only be fair that e-vehicle owners contribute to the trust fund, the revenue loss is not significant given the small numbers of e-vehicles on the road at present.

Management of Batteries

The use of e-vehicle batteries in vehicle-to-grid services may present problems through accelerated battery degradation and the need to recycle batteries. Although using a battery repeatedly for V2G power-supply undoubtedly wears it out, computer programs are being developed to minimize this. This approach relies upon the development of accurate battery prognostic models and further advances in understanding the causes, mechanisms, and impacts of degradation.³⁰ Re-using and recycling batteries is currently not a problem but it will become more so as the number of vehicles on the road increases.

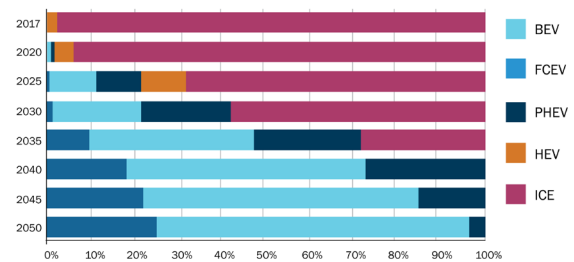
³⁰ Kotub Uddin, et al, *The viability of vehicle-to-grid operations from a battery technology and policy perspective*, Energy Policy, February 2018.

²⁹ Discussed at length during the Washington roundtable.

Box 3. E-Vehicles, Air Quality, and Health

In addition to reducing greenhouse gas emissions and helping manage the energy system, e-vehicles also play a major role in improving air quality, and thus human health. According to recent projections made by the ENEL Foundation in “Fueling Italy’s Future,” even with the moderate “TECH” scenario of uptake of different types of e-vehicles over the next 30 years (battery electric vehicles—BEV, fuel cell electric vehicles—FCEV, and plug-in hybrid electric vehicles—PHEV), it is estimated that the vehicle stock in Italy in 2030 would emit one-third less carbon-dioxide, one half the amount of nitrogen oxides and 63 percent less of the larger particulates that can be so harmful to human health. These reductions in nitrogen oxides and particulates emissions would allow Italy to avoid 1,100 premature deaths in 2030; similarly, incidence of lung cancer, chronic bronchitis and asthma would be lower, and 1.63 million days of absence from work due to illness would be avoided. The total annual savings from these benefits is expected to be €8.5 billion in 2025, increasing to €10.5 billion in 2030 and up to €13.5 billion in 2050.

Figure 5: Percentage of New Vehicle Sales in Italy under TECH Scenarios



Source: Kotub Uddin, et al, The viability of vehicle-to-grid operations from a battery technology and policy perspective, Energy Policy, Feb 2018

Source: *Fuelling Italy's Future*, https://www.enelfoundation.org/en/news/Low-carbon_mobility_boost_economic_growth_in_Italy

Recommendations for Next Steps in Europe

The full range of challenges standing between today’s energy system and an integrated e-mobility and clean energy future cannot be addressed all at once. However, there are simple steps policymakers and industry in Europe can take to accelerate the transition.

Focus Initially on Unidirectional Charging

Smart unidirectional charging (V1G) can provide significant balancing and efficiency benefits to the grid, and it can benefit vehicle owners. Moreover, for mass rollout in the near term, it is cheaper and simpler than bidirectional (V2G) charging. Ongoing trials of V2G should be continued, especially for fleets and corporate operators.

Institute Dynamic Pricing for Electricity

To incentivize smart charging and other more energy-efficient activities, including those that integrate e-vehicles and their batteries to the grid, “prosumers” need clear price

signals. Dynamic pricing is critical in this respect. This needs to reflect the prices for the electricity as well as the cost of maintaining the network, considering both supply/demand balances and grid stress conditions. Platforms that can aggregate distributed energy resources such as e-vehicle batteries should have non-discriminatory access to provide flexibility services to the grid. Network operators (often subject to regulated pricing systems tied to their investments) may need to be incentivized to procure these ancillary services from these new market participants, including through performance-based systems that reward them for integrating distributed energy resources.

Roll Out Smart Meters That Are Truly Smart

Smart charging is good for the energy system, can be lucrative for vehicle owners, and, most importantly, is convenient for consumers. Initial waves of installation deployed smart meters that would require vehicle owners to respond to price signals by plugging in a car in the middle of the night. Better smart meters should be installed so that charging can be managed automatically.

Support the Deployment of Public Charging Infrastructure

Public charging infrastructure today has limited financial sustainability and programs such as those of Connecting Europe Facilities have been of paramount importance in facilitating the adoption of the technology and providing a minimum backbone of fast and ultra-fast public charging infrastructure in Europe. Special attention should be made to the deployment of recharging infrastructure along core highway networks, in cities and near urban areas, as this would accelerate deployment of zero emission electric vehicles.

Improve Incentives for E-Vehicles

National tax incentives are particularly effective in increasing the attractiveness of e-vehicles for personal use. Countries with strong tax incentives, like Norway, have seen a dramatic rise in use.

Concentrate on Fleets and Mass Transit

It would be easier to focus first on moving to e-vehicles in corporate fleets and mass transit, as well as on building relationships between energy providers and the fleet operators. Key areas include taxis, delivery services, municipal (garbage and transit) vehicles, bike and car sharing services, public transportation, and freight.

Integrate Building and Vehicle Energy Efficiency Recommendations

The increasing integration of smart homes, IOT devices and vehicles calls for a more unified policy approach towards energy-efficiency regulations. Policymakers should take a holistic and coherent approach as they design efficiency guidelines, incentives, and standards for buildings and vehicles, seeing them as two sides of the same coin.

Recommendations for Next Steps in the United States

The recommendations above to drive the deeper penetration of e-mobility options for Europe also apply to

the United States but there are additional elements that are important in the case of the latter.

Clarify Federal and State Government Policies on Emissions Standards

The uncertainty over emissions standards at the federal level, and the ability of individual states (especially California) to develop their own tougher standards may result in a slower uptake of e-vehicles. Ideally, an agreement between the federal government and those states that continue to raise emissions and mileage standards, even if less so than under the Obama administration's rule, would be helpful to the industry.

Promote Coordination Among Stakeholders

This has to be done in particular between cities, utility companies, regulators, and fleet operators. It is particularly important to encourage the faster electrification of fleet vehicles that offer the greatest promise for V2G services. It will be slower to develop appropriate business models without strong stakeholder cooperation.

Help Utility Companies Compete

The viability of traditional electric utility companies in the United States is threatened by numerous factors, including digitalization and more consumer choices. This may be a good and natural trend as digitalization allows new entrants into the market. But it will be a difficult transition. If they are able to shape and manage the load as e-vehicles are added to the grid, the latter could become a powerful resource that can add flexibility and resilience while enabling owners to derive additional value from their vehicles.³¹ To some extent, they are hampered from properly adjusting due to regulatory requirements, and regulators should create incentives for them to invest in infrastructure, such as charging stations, and to modify their business models to take advantage of these new opportunities.

³¹ Scott Smith, et al, [Powering the Future of Mobility](#), Deloitte Insights, October 2017.

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