Facilitating Decarbonisation in Emerging Economies Through Smart Charging

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Abstract

The IEA Announced Pledges Scenario estimates that increasing electric vehicles stock from 17 million units today to 808 million units by 2040 can contribute to reducing transport emissions by 36%. The benefits of transport decarbonisation are bolstered by the decarbonisation of power systems, which poses an opportunity for emerging and developing economies with ambitious variable renewable energy deployment targets. The diversity of transport modes undergoing electrification, from public transport to personal electric vehicles and two and three-wheelers along with the location of charging infrastructure at the distribution network level will require smart strategies to ensure a smooth and secure integration. This report looks at how deployment of digitalisation smart charging can contribute to improve grid security and decarbonisation and provides a set of policy and regulatory recommendations relevant within the context of emerging and developing economies.

Acknowledgements, contributors and credits

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Digital Demand-Driven Electricity Networks Initiative (3DEN)

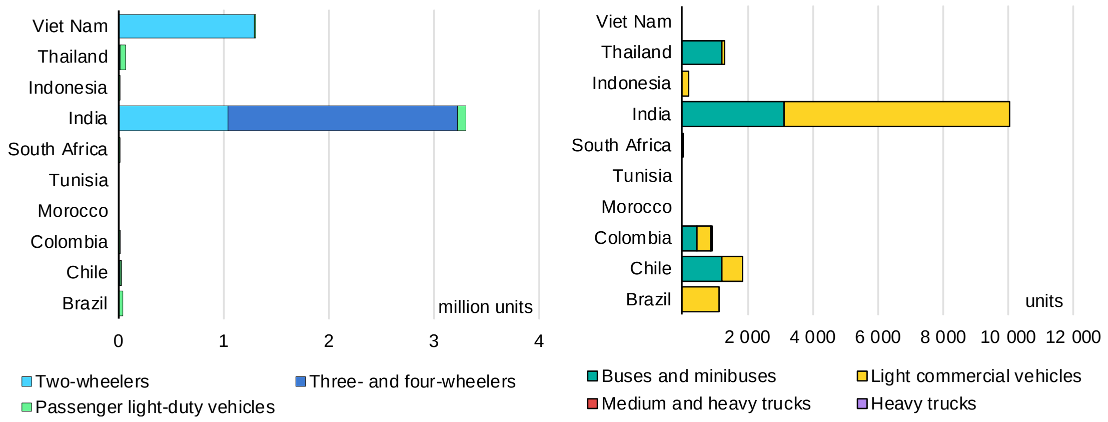
The challenge and opportunity of integrating electric vehicles

Transport electrification is already under way in emerging economies

As countries aim to achieve net zero emissions, electric vehicles (EV) will serve as one of the main levers for road transport decarbonisation. In the International Energy Agency (IEA) Announced Pledges Scenario (APS), increasing the EV stock from 17 million units today to 231 million in 2030 and 808 million units in 2040 reduces transport emissions by 6% in 2030 and 36% in 2040. Transport decarbonisation is aided by the parallel decarbonisation of the power sector, whose emissions would reduce by 21% in 2030 and by 56% by 2040 thanks to increasing uptake of renewables. Part of the power system flexibility to integrate more renewables would come from EVs themselves. Integrating EVs into the power system such that they contribute to the power sector's cost-effective decarbonisation will be necessary as EVs become more common in emerging economies.

While the majority of the uptake of EVs is found in the United States, Europe and the People's Republic of China (hereafter “China”), an increasing number of them are also penetrating markets in emerging economies with unique diffusion patterns. Electric two- and three-wheelers are more common in Asia, with sales of electric three-wheelers constituting 46% of total three-wheeler sales in the fiscal year of 2022. Meanwhile, electric buses are gaining ground in Latin America, where most have reached cost parity with diesel buses. These trends are likely to continue as these economies set more adoption targets by the end of the decade.

Electric vehicle stock in selected countries, 2022

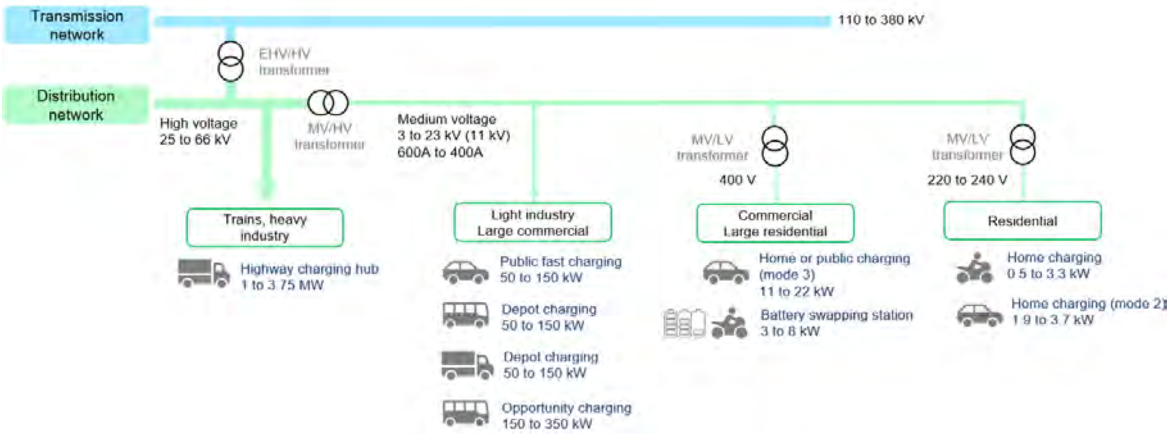


Sources: IEA (2023) Global EV Data Explorer; Government of Colombia (2023), Number of Electric and Hybrid Vehicles.

Charging the incoming fleet highlights the role of the distribution grid

To accommodate the increasing uptake, providing the necessary charging infrastructure will be necessary. While the energy required by EV is low compared with typical daily electricity consumption, ensuring enough grid capacity will be the more important parameter given the high-power requirements that the charging process can take. Charging of two- and three-wheelers may not lead to significant increases in peak load until a high level of penetration but charging of buses will definitely raise peak load and will often require dedicated transformers.

Charging solutions for different vehicle types and their typical connections to the distribution network



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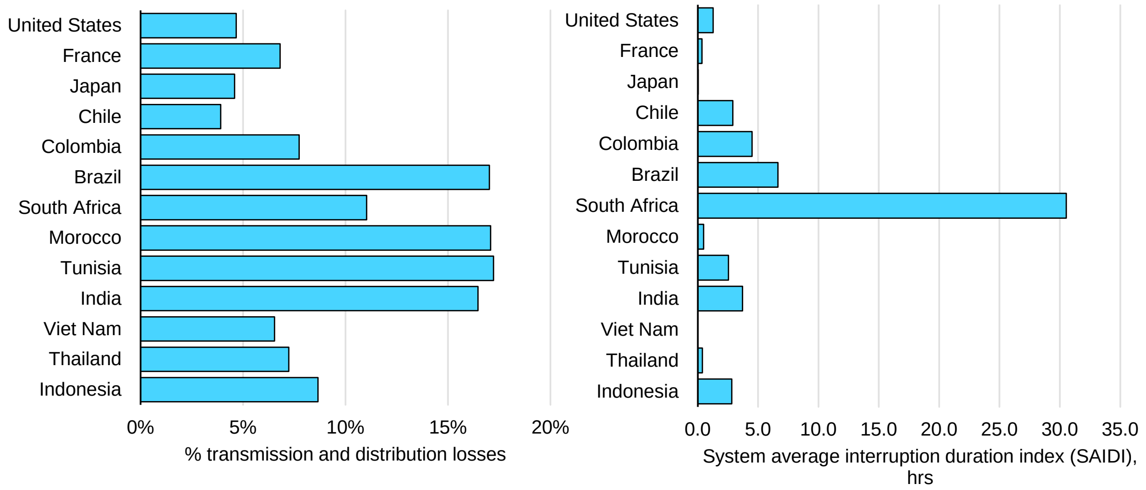
Notes: kV = kilovolts; EHV = extra high voltage; HV = high voltage; MV = medium voltage; A = ampere; LV = low voltage; V = volt; MW = megawatts; kW = kilowatts. The typical configuration of the transmission and distribution networks may vary in voltage and classification across different countries.

The required capacity increase to support the charging infrastructure will entail additional investments in an already challenging environment. Increasing electrification of heating and uptake of appliances and air conditioners pose as new demands on the grid. Grids in emerging economies also already face a range of issues such as high losses and low reliability that affect the financial sustainability of grid and power companies, often limiting the economic growth of electricity users. High rates of non-technical losses or theft, such as in Brazil and India, or frequent load shedding in South Africa highlight the complex challenges in power systems that countries currently face.

Grid losses and system average interruption duration index in selected countries, 2020



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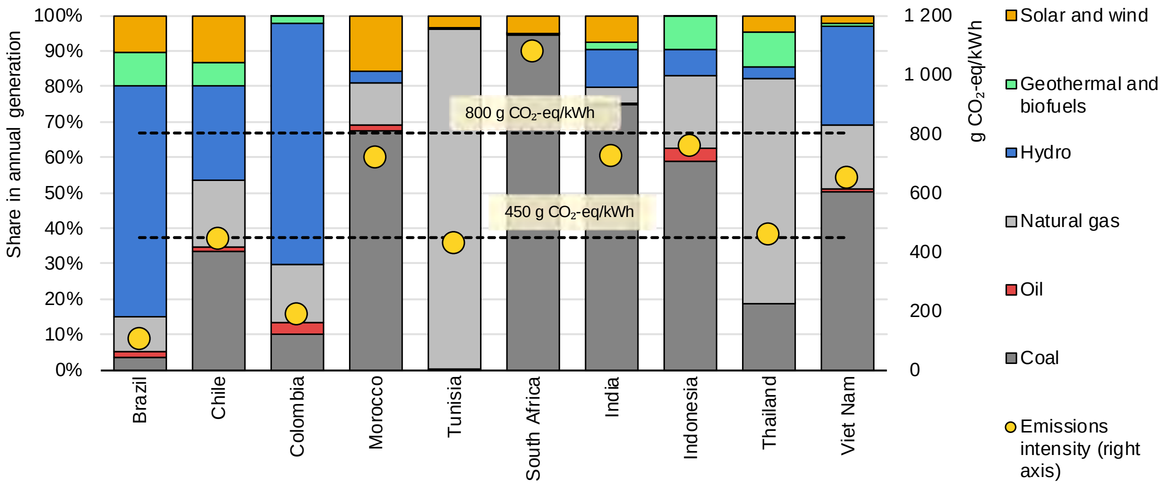
Sources: IEA (2023), World Energy Statistics and Balances, World Bank (2021), Doing Business: Getting Electricity.

Opportunities to decarbonise can happen if the right measures are taken

As emissions are also present in the EV manufacturing and disposal stages, ensuring that the operational emissions of EVs are close to zero, if not negative, helps deepen the decarbonisation of the transport sector. The electricity used for charging hence plays a role, and life-cycle analysis shows that the emissions reduction impact of shifting to EVs is more positive if the average emissions intensity of the electricity used for charging is less than 800 grammes (g) of carbon dioxide equivalent (CO_2-eq) per kilowatt-hour (kWh) (if larger internal combustion engine [ICE] cars are displaced by EVs of equivalent sizes) or less than 450 g CO_2-eq/kWh (if smaller ICE cars are displaced).

While certain Latin American countries already have relatively less emissions-intensive power sectors thanks to abundant hydro, several Asian and African countries have highl emissions-intensive ones due to reliance on unabated fossil fuels. Increasing the capacity and consumption of low-carbon generation such as solar and wind is therefore necessary to lower the operational emissions of the incoming fleet of EV.

Generation mix and emissions intensity of selected countries, 2019



Source: IEA (2023), World Energy Statistics and Balances.

Despite the average emissions intensity of the power sectors in emerging market and developing economies (EMDEs), where and when EVs charge can make a difference. Co-ordinating charging during the hours when renewables are abundant can help keep the indirect emissions of EVs low and helps improve the business case of renewables by reducing potential curtailment. When charging is co-ordinated and co-located with distributed renewables such as solar PV, grid losses can also be reduced. Finally, avoiding EV charging during typical peak periods can reduce emissions and total costs, especially where oil is deployed as the marginal technology.

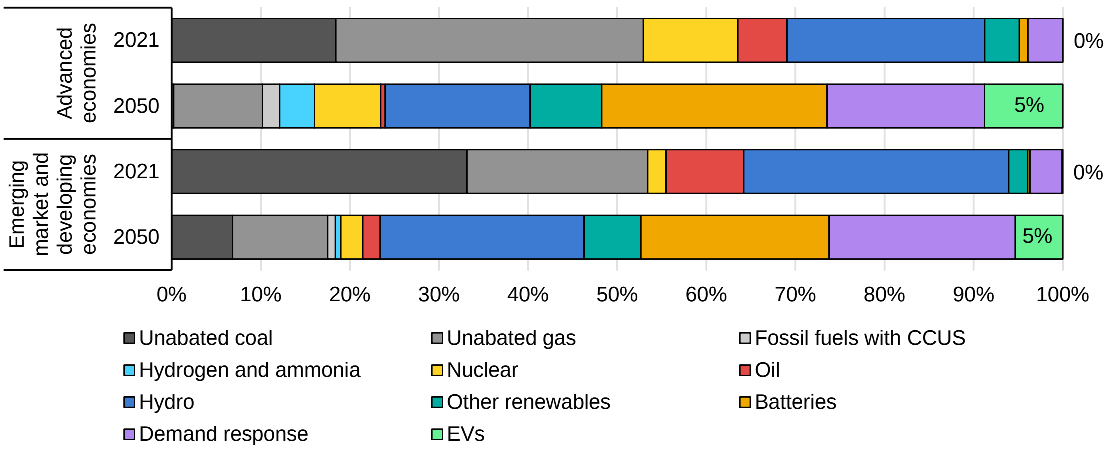
Smart charging as a solution for transport and electricity decarbonisation

Smart charging can support grid performance and uptake of renewables

Managed charging or smart charging is a way of integrating EV into the grid where the charging process could be adjusted to achieve power system objectives. These objectives could be voltage regulation and reduction of local peak in the distribution grid, or they could be frequency regulation and energy arbitrage in the bulk energy system. Smart charging the fleet of EVs can provide a good source of power system flexibility.

In particular, it can increase the uptake of renewables. By providing a reliable load that can consume variable renewable generation, it can increase the confidence of system operators to add more renewables while maintaining stability, and it can also improve the business model of developers knowing that curtailment could be reduced or eliminated. In Korea, for example, smart charging by 2035 based on their announced net zero pledges can help increase the consumption of wind and solar generation, thereby reducing average emissions by 21% and reduce peak costs by USD 18 per megawatt-hour or 30%.

Role of electric vehicles in power system flexibility in the 2050 Announced Pledges Scenario



Note: CCUS = carbon capture, utilisation and storage.
Source: IEA (2022), World Energy Outlook 2022.

In turn, such flexibility benefits to the power system could also be shared to EV users that result in a win-win situation. In various pilot studies and commercial applications, the savings and incentives have been beneficial for the EV users:

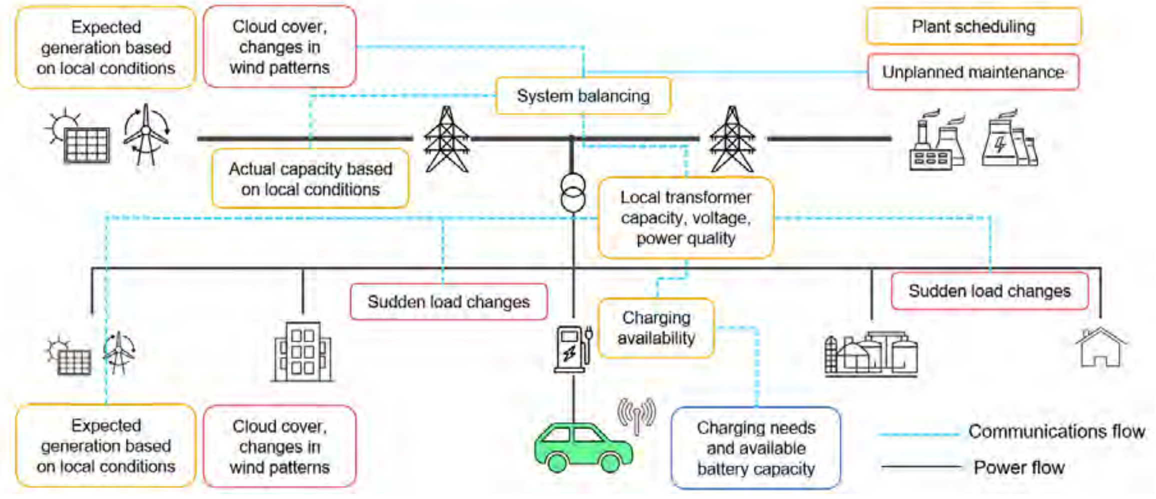
- **Light-duty vehicles**: Smart charging under a critical peak pricing regime in California can save EV users USD 1 125 to USD 1 220 per month while bidirectional charging in Denmark resulted in a range of net savings of EUR 2 304 per EV per year to a net cost of EUR -955 per EV per year, and contributing to power system performance.
- **Buses**: Managing the charging schedules of school buses in California was estimated to save a school USD 31 406 per year for 11 electric buses and expected to save USD 98 727 per year when the school eventually deploys 24 buses in the future, by avoiding demand charges and peak periods.
- **Two-wheelers**: While electric motorcycles generally have a lower impact on the power system due to their low charging power (0.5 kW to 3.7 kW) and energy needs, aggregating enough two-wheeler batteries can provide more services for the grid. For example, about 1.3 gigawatt-hours of storage capacity in battery swapping stations in Chinese Taipei has been contracted for a fee to help support grid stability.

Digitalisation is key to smart charging

Smart charging becomes more valuable to the power system with increasing response time and scale. In terms of response time, delaying charging to off-peak hours can be done manually as it only requires starting and stopping of charging and advanced information of off-peak hours. Meanwhile, providing frequency regulation requires sub-hourly response times. In terms of scale, large co-ordinated charging of hundreds of vehicles can be used for wholesale energy arbitrage or to increase consumption of utility-scale renewables.

For EVs to support larger power system objectives, they need to be able to adjust charging as soon as the system sends a signal. The faster the EVs can react, the more services it can provide. Such high levels of co-ordination can happen only through digitalisation. With the help of telecommunications and connectivity, smart charging service providers can exist to help serve as intermediaries to balance the needs of the EV users, charge point operators and power systems.

Flow of communications in a smart charging ecosystem



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With the increasing focus on electricity security and decarbonisation, having digitally connected and flexible EVs that are able to respond to sudden changes in the power system will be become an important asset for policy makers.

Power sector measures to enable smart charging are not yet fully present in EMDEs

While there are several requirements[1] for smart charging to take place, the power sector has a special role in laying the foundations of how it will use EVs as a resource. Depending on the degree of integration desired, different technological and regulatory frameworks must be deployed to facilitate a fair and efficient smart charging process.

In order to deploy them, the power sector must first provide the conditions and signals on how the charging process should adapt to the latter's needs. Providing signals, as opposed to directly controlling the EV, ensures the equal participation of the user who needs the EV for their primary purpose of transport. The main signals which can serve as rewards or sources of value for the EV users and the smart charging service providers are:

- **Differentiated tariffs**: Tariffs which vary rates based on time of day can incentivise the behaviour of EV users about when to charge their cars. Time-of-use tariffs, dynamic real-time tariffs and critical peak pricing are some of the

[1] Notably, gathering of stakeholders from the transport, buildings and power sectors and improving the power system planning process.

common ways the power sectors convey this signal to obtain implicit demand flexibility. In certain instances, signals on location could also be included.

- **Procurement of local flexibility**: Distribution grid operators enter into contracts with aggregators or charging service providers to manipulate the charging process to achieve local needs such as congestion or local capacity constraints, for which a price signal may not be enough to drive the change needed.
- **Wholesale energy market access**: As power markets are often designed based on large conventional generation and large consumers, access of aggregated EV load in the market requires policy changes in order for vehicles to participate in changing the supply-demand curve to lower peak generation and increase renewables consumption.
- **Ancillary services market access**: Similar to wholesale energy market access, policy changes may be needed to allow aggregated EVs to respond to system services such as frequency response.

While it is not necessary that all enablers are fulfilled to activate smart charging, the diversity of options helps ensure that the users obtain the value regardless of the diversity of driving and charging patterns of the different electric vehicle types.

Power system measures to enable smart charging in selected countries and regions, 2023

Country or region	Market access for aggregators	Ancillary services	Procurement of local flexibility	Differentiated tariff
Advanced economies				
California	●	●	●	●
Korea	◗	◗		●
Netherlands	●	●	●	●
United Kingdom	●	●	●	●
Emerging economies				
Brazil				●
Chile		◗		●
Colombia				
Indonesia				●
Maharashtra				●
Morocco				
South Africa		●		●

Country or region	Market access for aggregators	Ancillary services	Procurement of local flexibility	Differentiated tariff
Tamil Nadu				●
Thailand				●
Tunisia				●
Uttar Pradesh				●
Viet Nam				●

Notes: Certain countries have instituted an EV-specific tariff such as in Indonesia and in India. For India, the three representative states and power sectors of Uttar Pradesh, Maharashtra and Tamil Nadu are shown. Half-circles indicate that power sector features are either in progress or do not completely cover the usage for smart charging. For example, in Indonesia, a differentiated EV tariff exists but only applies to four-wheel light-duty vehicles. Morocco has time-of-use tariffs but only for medium- and high-voltage users

Developing a smart charging ecosystem

Establish a framework for demand response

The fundamental measure to enable smart charging is to create a framework for demand response in the power system, as outlined in the IEA's policy manual for grid integration of electric vehicles. Demand response can be implicit – through variation of tariffs – or explicit – through direct bidding of demand in wholesale and balancing markets. Demand response can be implemented whether the country's power sector is operated by a sole vertically integrated utility or is run by a regulated system operator in an open electricity market. Depending on the country's laws, new legislation and extensive reform may be needed.

Ensure standardisation and interoperability

As different manufacturers of EVs, charging infrastructures and smart communications devices from different countries compete for market share, policy makers have the special role of enforcing standardisation and interoperability in order to ensure that EV users can access a wider variety of charging infrastructures, and that they can access power system services regardless of their choice of vehicle or mobility service provider.

Aside from ensuring the different vehicles can interoperate with different charging infrastructure, ensuring streamlined communication between the charging infrastructure and the power system is also key. Here, the power system relies on common communication protocols to convey the signals needed for smart charging.

Such standards could be set by tying them to charging infrastructure incentives, such as in Belgium and in Luxembourg. They could also be set up as a de facto standard based on public tenders such as in the Netherlands. They could also be legislated directly as a regulation such as in the United Kingdom for public charging infrastructure, and in India for battery swapping stations.

Establish minimum requirements for smart communication and control

Requiring charging infrastructure and EVs to carry a minimum level of communication can ensure that future uptake of vehicles will have the ability to participate in smart charging. For charging infrastructure, the ability to communicate charging needs and provide the grid operator the possibility to remotely control the charging process will help massively in implementing smart charging programmes.

For vehicles such as two-wheelers which may continue to charge using a regular socket, requiring the placement of a start-stop charging control through vehicle telematics may help smart charging operation especially when EV penetration is higher.

Such communication and control requirements are supported by a foundation of data collection. Fundamental accounting and registration of EV still remain a challenge in certain countries in Africa and south Asia where unregistered vehicles on the road are not uncommon. Taking them into account through robust registration systems can improve the effectiveness of power system planning for smart charging.

Ensure matching with clean electricity

Providing signals to charge when clean electricity is available helps encourage charging when consumption is low. These signals could come either from the electricity market through wholesale prices, or from end-consumer electricity prices that reflect the best time to consume clean electricity.

For countries where electricity markets are common, designing markets to allow direct procurement of clean electricity is a step towards closer matching, such as the Green Energy Option Program of the Philippines. Where the option already exists, lowering the threshold for access can help encourage more participation from EVs, such as in India's Green Open Access where the minimum consumption was lowered from 1 MW to 100 kW.

Meanwhile, for vertically integrated utilities, signals to shift consumption during the day could be done through tariffs such as in Azores, where the local utility aims to maximise use of wind energy,

Development of frameworks to monitor emissions from electricity, and more advanced market design improvements in clean electricity matching, can help ensure higher uptake of low-carbon generation capacity such as renewables.

Reform the role of distribution operators

Given the connection of EV on the distribution network, reforming the role of distribution companies from passive owners and providers of network capacity into active managers of an interconnected system can help activate the EVs' full potential.

Regulators can play a key part in reforming the role of distribution companies, starting by reducing the tendency of network operators to simply add new capacity (capital expenditure [CAPEX] bias) since their remunerations are traditionally tied to cost of service. Changing this remuneration to reflect the total expenditure (TOTEX = CAPEX + OPEX [operating expenditure]) can take into account the value of smart charging in saving new capacity and improving utilisation. For example, several European countries adopted a mixture of price or revenue cap regulations to reduce CAPEX bias, while the United Kingdom adopted one that included explicit incentives (i.e. RIIO = revenue using incentives to deliver innovation and outputs) including those for enabling smart charging.

Moreover, developing the capacity of distribution grid operators will be necessary in order to ensure that increasing digitalisation of the assets and connected resources can be properly managed. Creating regulatory incentives tied to capacity building or hiring of qualified staff dedicated to managing the digitalisation of the network can help contribute to a clean, secure and affordable power system.

For further information, please contact: Renewables Integration and Secure Electricity Unit (ems-rise@iea.org).

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