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# Capacity of Colombia's power distribution networks to accommodate electric vehicles

**The bottom line.** Transport must be decarbonized if climate commitments are to be met. Colombia is a leader in the adoption of electric vehicles in Latin America. However, the growth of the EV market can create operational and planning challenges for the power grid. Fortunately, recent analyses show that Colombia's distribution grids have the capacity to accommodate the increased power demand created by electric vehicles in the short and medium terms, paving the way for achievement of climate targets. The results of simulations suggest that network operators can plan effectively for the future by considering the growing penetration of EVs in the design of new grids.

## Can Colombia's power distribution networks accommodate growing demand from electric vehicles?

*The country's national planning department requested World Bank support to find out*

The World Bank has been providing technical advice and expertise to help Colombia and its National Planning Department advance the country's energy transition. The objective of the technical assistance involves support for digitalizing and decentralizing the demand for electricity while also making demand more efficient. In the context of this effort, the National Planning Department assessed the capacity of the country's distribution networks to meet the growing demand associated with electric mobility. The resulting report was completed in late 2022 (World Bank 2022).

In the first phase of the evaluation, four scenarios were defined to project the growth of EVs in the country and the associated demand for electricity from the power grid. In the second part, with the support of four representative electricity network operators (NOs), a spatial and temporal model was developed to identify the demand increase on specific electrical circuits associated with growing EV penetration. Based on these projections, impact assessments were carried out to gauge the impact of demand for EV charging systems on the selected power grids. Finally, recommendations were made to meet future needs for electrical infrastructure.

The four EV penetration scenarios are described below and illustrated in figure 1.

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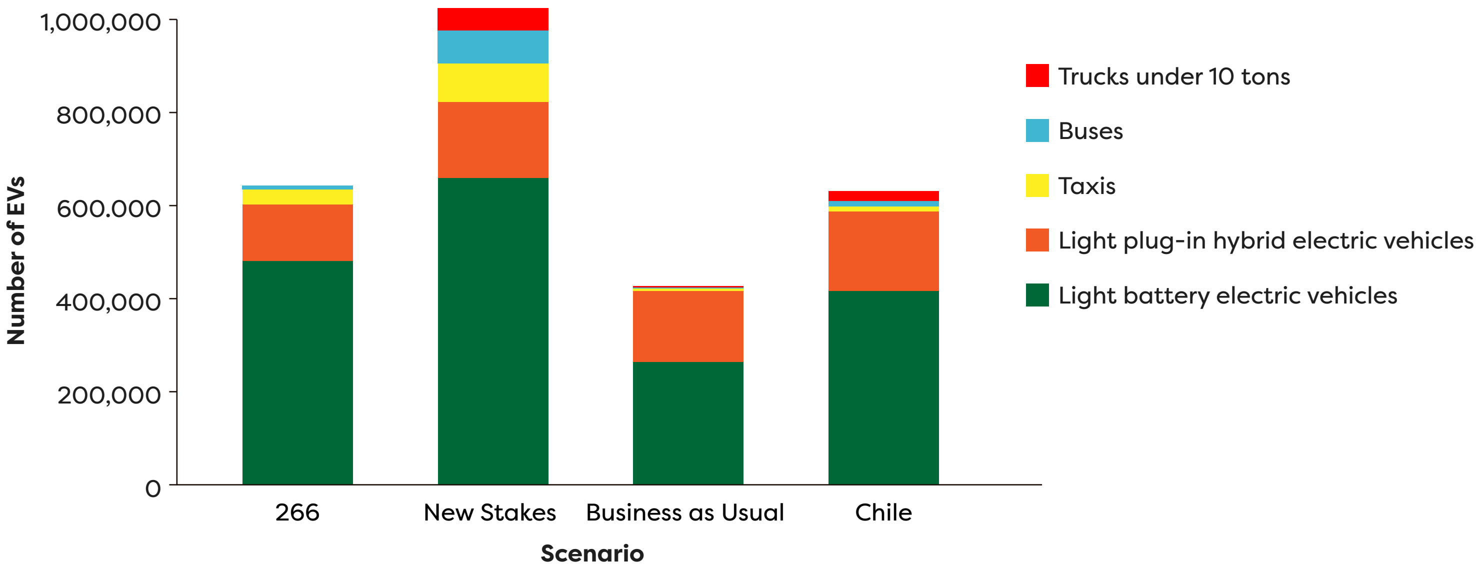
## Figure 1. EV penetration in Colombia: four scenarios




**Scenario 266** is based on the COP21 emissions-reduction target (266 million tons by 2030) as well as the targets outlined in the green growth plans of Colombia's National Council of Economic and Social Policy, which foresee 600,000 EVs in the country by 2030.

**The New Stakes Scenario (NS)** is based on the 2020–50 National Energy Plan, which sets higher EV penetration targets, reaching 600,000 light battery electric vehicles alone by 2030. The policies aim to reduce GHG emissions and atmospheric pollutants as well as to meet the conditional target of the Paris Agreement, which would result in a 30 percent reduction of GHG emissions by 2030.

**The Business-as-Usual Scenario (BaU)** is similar to Scenario 266 but takes into account the drop in EV sales in 2020 due to the COVID-19 pandemic, followed by a slow recovery in growth rates through 2023, when the scenario resumes with the growth rates projected in Scenario 266.

**The Reference Country (Chile) Scenario** is based on the targets established in the Electric Mobility Study in Chile 2018, which foresees that 20 percent of the country's fleet in all sectors will be electric by 2050.

For these scenarios, a load curve for EV charging was constructed based on usage habits, charging patterns, and the specifications of EVs sold in Colombia. The usage habits take into account the start and end times of trips; the arrival time of EVs at homes, work sites, parking lots and spaces (depending on the EV segment); and the daily distance traveled. With this data, energy consumption can be estimated by using the specifications of each EV segment. Charging patterns are determined based on EV power capacity, charging locations, and the estimated time needed to charge EVs according to their specifications. Using this as a base, the energy and power demand curve was generated.

As an example, in 2030 under Scenario 266, the energy demand curve for EVs in Bogota will resemble that presented in figure 2.

The demand for electric power peaks at 8 p.m. for light vehicles, but if electric buses are taken into account, the peak hour shifts to 10 p.m (22:00).

By combining the load curves with EV projections, the overall projection scenarios of peak power and energy consumed by EVs in Colombia can be determined (figure 3).

**Figure 2. Power demand curve for EVs in Bogota in 2030 under one of the analyzed scenarios (Scenario 266)**

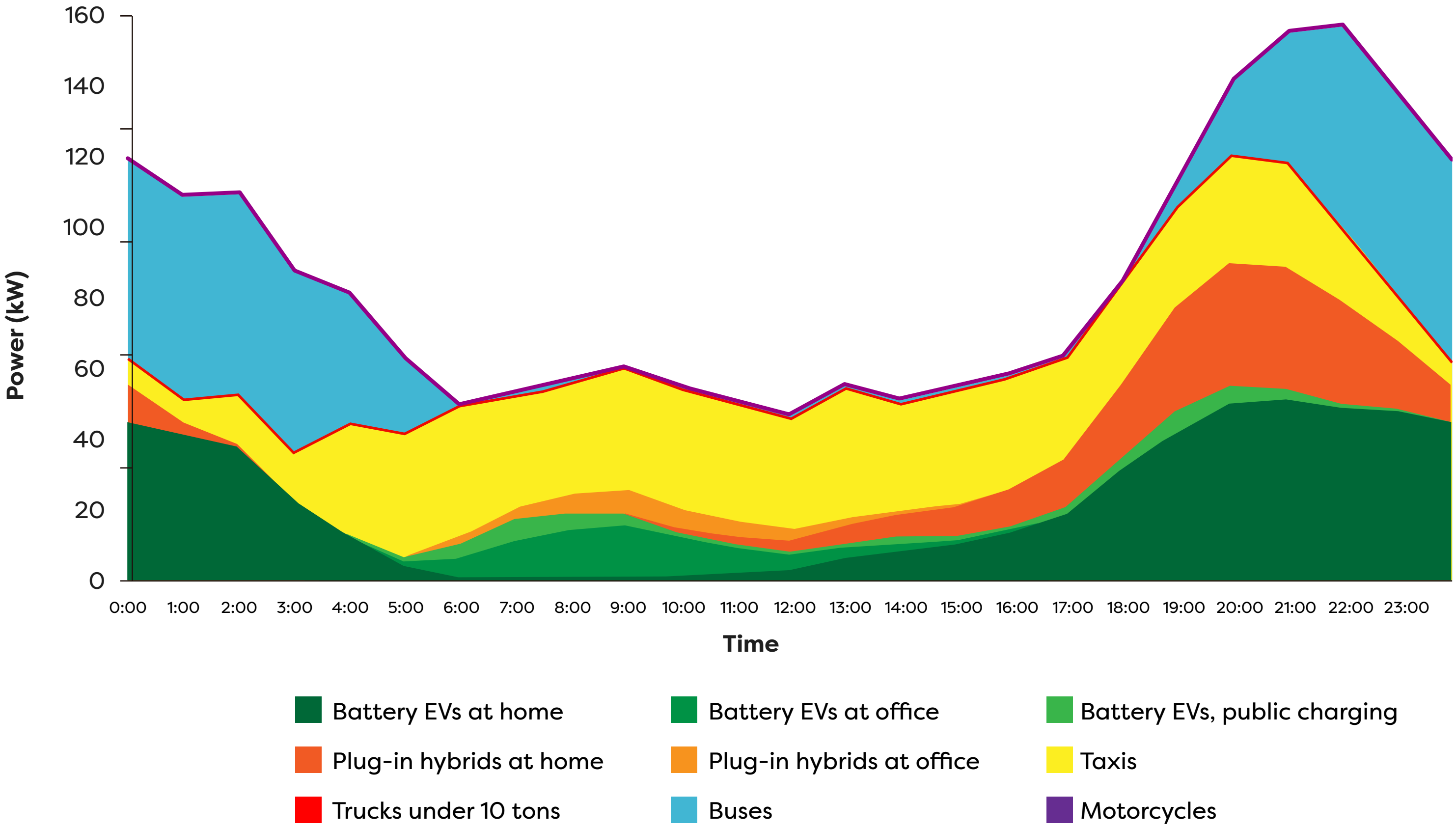
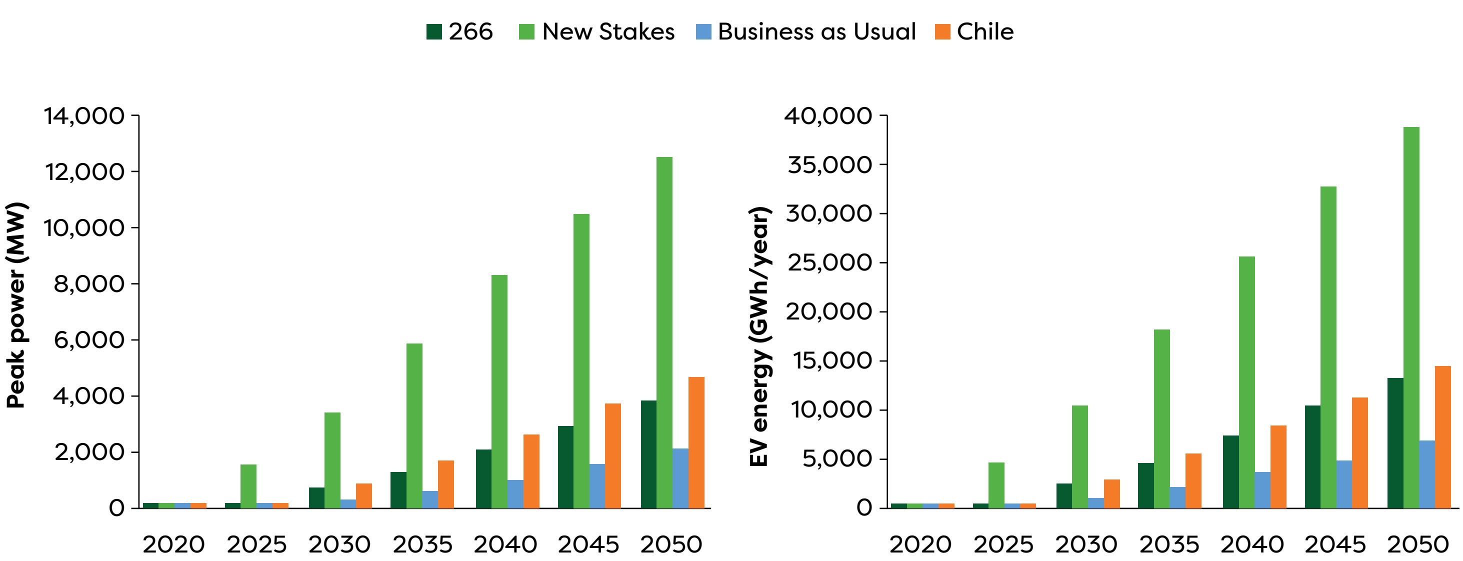



**Figure 3. Comparison of peak power and EV demand, by scenario and year**



The additional power requirements for 2030 vary from a 500 to 4,000 MW peak, depending on the penetration scenario. In terms of energy, this range varies from 100 GWh/year to 10,000 GWh/year for the same year (0.11 percent to 9.6 percent of projected demand for 2030, respectively).

**For the EV penetration levels predicted in the scenarios considered, this study concludes that no widespread impact on the distribution networks is expected in the short and medium term. However, it is possible that specific problems may emerge in the networks, which operators would have to address.**

## How was EV load on power systems tested?

*Demand simulations were generated using a spatial demand model*

Spatial demand is determined by (i) the types of users, such as light vehicles, taxis, trucks, and public transportation; (ii) transportation routes; (iii) parking locations; and (iv) electrical charging requirements.

Colombia has 29 distribution network operators (NOs) responsible for the planning, investment, operation, and maintenance of the local distribution and regional transmission systems.[1] Among these, Bogota, Antioquia, and Valle del Cauca have the largest number of users connected to the national system and were therefore among the NOs selected for analysis.[2]

To estimate spatial and temporal demand in these NOs, a representative sample of circuits was selected in collaboration with the NOs, including a variety of EV load combinations. For each circuit the following were analyzed: (i) four penetration scenarios: 266, NS, BaU, Chile; (ii) three periods of time: 2030, 2040, 2050; (iii) three types of days: weekdays, Saturdays, holidays; and (iv) the 24 hours of the day, for a total of nearly 860 cases per circuit.

The impact of EV penetration on the networks was measured for the three types of elements identified: medium voltage (MV) line segments, links (connections between the MV circuits and the distribution circuit), and distribution circuit transformers.

## What do the simulations suggest for electricity distribution planning?

*Urgent action is not needed, but planning will help anticipate possible network constraints in the future*

For the EV penetration levels predicted in the scenarios considered, this study concludes that no widespread impact on the distribution networks is expected through 2050. No major additional investments to the distribution networks are needed over this period, above those needed to supply the natural growth of conventional demand. Variations in average load of MV circuits owing to VE scenarios were observed in a range of less than 0.5 percent of the capacity, while in distribution center transformers the average load increased by up to 1.5 percent.

However, it is possible that specific constraints may emerge in the networks, which operators would have to address. Indeed, in some cases, components of the grid, such as substations, were found to have high load levels, which may require additional investments or the implementation of proactive actions (such as variable rates) to limit charging power and disincentivize quick charging.

Additional analyses of extreme scenarios made it possible to identify the most sensitive network components given the characteristics of each distribution system and, therefore, to devise potential alternatives for strengthening the networks accordingly. Different actions are called for in the face of specific constraints.

1. Local power distribution involves the lines, substations, and associated equipment operating at voltage levels 1, 2, and 3 and used to provide commercial services. The regional transmission system consists of the assets connecting NOs with the regional and national transmission system operating at voltage level 4.

2. Bogota, Antioquia, and Valle del Cauca have 2,092,214 users, 1,747,341 users, and 1,059,168 users, respectively.

- ✓ **Saturation of power supply lines from substations.** This situation indicates that the effect on the network could be significant since, over time, it would require a reinforcement of the feeder circuit, thus affecting the entire area—and even the MV substation itself if other circuits leaving the substation behaved in a similar way.

- ✓ **Saturation of sections of the MV line.** This situation could make it necessary to schedule time-specific replacements for the network as demand increased.

- ✓ **Saturation at the level of the distribution center.** This type of saturation would require the replacement of the affected transformer (or an increase of power through the addition of parallel transformers).

### Recommendations for distribution network planning

Based on the analysis above, NOs could take a wide variety of actions to plan for growing EV penetration:

- ✓ **Incorporating EV penetration scenarios into planning exercises**, especially in areas with the greatest potential for new demand, so as to analyze critical points of constraint in distribution networks. This would allow NOs to make necessary adjustments to the network in response to demand increases stemming from greater EV penetration.

- ✓ **Conducting continuous monitoring and analysis** of both the natural growth of conventional demand and changes in the unit consumption demands of EVs, reflecting the type of vehicles and charging systems entering the market. This should include monitoring the addition of new electric charging points serving EVs in order to stay up to date on the concentration and pace of demand growth in their networks.

- ✓ **Integrating updated communication protocols and management systems** that make it possible to control EV charging and discharging in support of grid operations. Although this would require a significant investment, viable business models are available. The use of night tariffs could help reduce or delay investments.

**The analysis of extreme scenarios makes it possible to identify the most sensitive network components in view of the characteristics of each distribution system and, therefore, to devise potential alternatives for improving the networks.**

- ✓ **Preparing for impacts of changes in charging power and deployment speeds.** Such preparation involves evaluating the impact on the grid of the installation of increasingly powerful chargers and possibly adjusting the specifications of new residential buildings to improve access to the most cost-efficient EV charging systems.

### Recommendations for EV regulations

It is recommended that regulators optimize the use of power infrastructure by taking the following actions:

- ✓ **Make use of time-based variable electricity rates** (day, week, year). Different types of variable rates (time-of-use tariffs) are useful when grid saturation occurs at certain times of the day, week, or year (IRENA 2019). The general concept is to apply high prices at times when the grid is expected to be saturated so as to disincentivize consumption at those times. It can be applied to both consumption for EV charging and conventional demand, differentiating by type of consumer.

- ✓ **Study options for enabling and stimulating differentiated measurement of EV loads.** With respect to residential charging, a specific meter for measuring EV charging would be necessary. This would represent an additional cost for NOs or users, and the allocation of that cost should be analyzed. With respect to EV demand for power in public areas, Colombia's Resolution CREG 171 of 2021 proposes two alternatives for differentiated measurement of the electricity used for EV charging in conventional service stations or bus charging yards (to make it possible, if desired, to apply the discount established by Law 143 of 1994 and allow NOs to evaluate the impact this has on the grid).

- ✓ **Enable vehicle-to-grid (V2G) business models.** These models allow energy to be injected into the grid by discharging the energy stored in EV batteries. Where this option is pursued, "smart grids" are essential, as they make it possible to properly manage V2G systems based on bidirectional converters. Because V2G requires greater investment in infrastructure, it should be undertaken based on demand. There is currently no business model that would lead EV owners to be interested in this technology. Because vehicle batteries are a consumable good with a determined number of cycles, injecting energy into the grid reduces driving time over the battery's useful life. In addition, the purchase price of EVs would be higher if they were equipped with onboard bidirectional converters.

In all, even though the growth of Colombia's EV market, which is a leader in Latin America, will create operational and planning challenges for the power grid, the country's distribution grids have the overall capacity to accommodate growing power demand in the short and medium term. Through adequate planning and regulation, the country can effectively prepare for a future with increasing penetration of EVs.

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## References and sources

Andemos. Informe sector automotor–vehículos BEV PHEV HEV. https://andemos.org/wp-content/uploads/2020/07/Informe-H%C3%ADbridos-y-Electricos-2020-6.pdf.

DANE. 2020. Proyecciones de población. https://www.dane.gov.co/files/investigaciones/poblacion/proyepobla06_20/MProyeccionesMunicipalesedadsexo.pdf.

IEA. 2020. *Global EV Outlook 2020: Entering the Decade of Electric Drive?* International Energy Agency, Paris. https://www.iea.org/reports/global-ev-outlook-2020.

IRENA. 2019. "Innovation landscape brief: Time-of-use tariffs." International Renewable Energy Agency, Abu Dhabi.

UPME. 2019. Plan Energetico Nacional (PEN) 2020-2050—Escenario 266. Bogotá. https://www1.upme.gov.co/DemandaEnergetica/PEN_documento_para_consulta.pdf.

World Bank. 2022. "Evaluación de la capacidad de hospedaje de vehículos eléctricos (VEs) de las redes de distribución para atender las demandas generadas por la electromovilidad en Colombia." USAENE S.A.S. 2022.

XM. 2021. Indicador de demanda por regiones y por OR. https://informeanual.xm.com.co/informe/pages/xm/20-demanda-de-energia-por-regiones.html.

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