USAID COLOMBIA YOUNG LEADERS WORKFORCE TRAINING PROGRAM ACTION PLANS: PLANNING FOR ELECTRIC VEHICLE CHARGING INFRASTRUCTURE IN BOGOTÁ

INTRODUCTION

As part of the U.S. Agency for International Development (USAID)-National Renewable Energy Laboratory (NREL) Young Leaders Workforce Training Program in Colombia,[1] the Grupo Energía Bogotá (GEB) participants leveraged their training and professional experience to develop an action plan for modeling and evaluating Bogotá's projected electric vehicle (EV) charging needs to meet future demand. GEB was one of four teams selected by the training program development team to receive continued technical assistance and strategic advisory support from the USAID-NREL Partnership for action plan implementation.

GEB is an integrated electric and gas utility with generation, transmission, and distribution assets throughout Latin America. In the Colombian capital of Bogotá, GEB is working in close partnership with the Bogotá Department of Transportation Mobility Secretariat (SDM), and the distribution utility, Enel, to coordinate and build out EV charging infrastructure across the city. Bogotá is targeting the addition of 300,000 EVs by 2030, half of Colombia's nationwide goal of reaching 600,000 EVs over the same timeframe. Timely and strategic investments in supportive EV supply equipment (EVSE) infrastructure are critical to achieving this goal.

This inter-institutional consortium brought together public and private sector expertise to address key EVSE planning questions, such as:

- How much charging infrastructure will be needed, and when?
- What types of charging stations will be needed?
- Where should charging stations be located, and what sectors should they serve (e.g., buses, private light-duty vehicles)?
- What impacts could EV have on the grid and end-use electricity demand?

SDM IS THE PUBLIC DEPARTMENT RESPONSIBLE FOR MOBILITY POLICY DEVELOPMENT AND IMPLEMENTATION IN THE CITY OF BOGOTÁ.

Bogotá is at the forefront of sustainable mobility in Colombia. More than two-thirds (67% in 2019) of travelers utilize sustainable modes of transportation, and Bogotá has the greatest total length of cycling paths (551 kilometers) in Latin America—recording more than 420,000 bicycle trips per day. Read more about the Mobility Secretariat's efforts to advance sustainable mobility in Bogotá here: www.movilidadbogota.gov.co/web/.

OBJECTIVES

USAID-NREL is working in collaboration with GEB, the Mobility Secretariat, and Enel to:

1. Estimate EV charging station needs to meet projected future EV sales in the city of Bogotá
2. Determine high-priority locations within the greater Bogotá metropolitan area for planning and applying EVSE investment and installation.

DECISION-MAKING METRICS

Leadership and technical advisory staff from GEB and the SDM held several discussions to determine the most critical metrics to inform EVSE planning and deployment strategies in Bogotá. The key metric for this analysis was EV charging station expansion by geographic location. Researchers used the spatial data to identify optimal locations where GEB and other EVSE developers could install new stations. These spots were optimized based on location

1. English: https://www.nrel.gov/docs/fy22osti/82855.pdf; Spanish: https://www.nrel.gov/usaid-partnership/assets/pdfs/nrel-usaid-colombia-brochure-fy22.pdf.

within the existing transportation and EV infrastructure network in Bogotá, travel patterns, and location within the community based on socio-economic parameters and land use. The outputs from the analysis were near-term, high-utility locations for new stations that would translate to relatively easy implementation for GEB and high utilization and impact for the community.

The socio-economic parameters were used to provide three scenarios for different EV charger locations based on which communities GEB serves. One scenario optimized for optimal location based on high-income households, which are most likely to be early EV adopters. The other two scenarios were optimized to provide public charging for middle-income and then low-income households who are likely to adopt EVs at lower initial rates due to economic barriers and the higher upfront cost for most EVs. This approach first identified areas near important roadways that were also far from current EVSE. Then, the analysis took the available travel data for Bogota to identify frequent destination areas for each of the three scenarios. Finally, these areas were intersected for each scenario, which resulted in areas that met the spatial criteria for being in areas near major roads, far from current EVSE, and within the socio-demographic parameters for the specific scenario. The land use data will be used to further refine the analysis to trim the results to only areas or lots that have clear potential for public EV chargers, such as retail areas, parking lots, or other public locations.

METHODOLOGY

At the beginning of the project, GEB and SDM identified four key questions that were priorities for the electric mobility sector in Bogotá:

1. What types of charging stations, distances from other stations, and locations would be ideal in Bogotá?
2. What considerations are needed for the long-term financial feasibility of EV infrastructure build-out (in terms of return on investment, net present value)
3. What are optimal deployment scenarios for different types of EVs, focusing on private light-duty vehicles, public transit, freight transport, and motorcycles, given the current electric grid infrastructure?
4. What are optimal deployment scenarios for different types of EVs, focusing on private light-duty vehicles, public transit, freight transport, and motorcycles, given the current electric grid infrastructure?

The NREL team then researched available tools and literature that could be applied or adapted to the Colombia context to address these questions. The list of identified tools is available in **Appendix A**. NREL then worked with the inter-institutional consortium to select the optimal tool for application in Bogotá and eventual adoption by GEB, SDM, and other interested stakeholders. After reviewing each of the tools, their data needs, outputs, and other parameters, the consortium identified the EVI-Pro model as the optimal tool to address the EV and EVSE challenges in Bogotá.

EVI-PRO COLOMBIA

Currently, NREL's Electric Vehicle Infrastructure Projection Tool EVI-Pro (www.nrel.gov/transportation/evi-pro.html) is being adapted for specific application in Colombia. The EVI-Pro tool was initially developed to be used in the United States; however, in collaboration with local partners, this tool has been adapted, and, for the first time, will be applied outside of the United States to evaluate electric charging infrastructure demands in Bogotá. When completed (targeted for October 2022), GEB and others will be able to independently use the tool to estimate future charging station needs and the related additional load on the electrical grid due to charging. This effort was a result of the work done in collaboration with GEB and the SDM, and will help similar organizations support the adoption of EVs in Bogotá and throughout Colombia.

NREL's EVI-Pro tool evaluates multiple layers of transport infrastructure and consumer geospatial data to identify potential public, commercial, and/or residential locations for new EV chargers. EVI Pro was used to model EVSE demand and deployment cost for four possible scenarios:

- **Scenario 0.** Base Case: Identifies high-traffic locations for general EV siting outside the current EV infrastructure range. Does not consider sociodemographic criteria.
- **Scenario 1.** "Easy Win": This scenario highlights potential locations of new EV chargers where they might be most convenient for upper-income citizens (Strata[2] 5 and 6), who are often the earliest to adopt EV technology.
- **Scenario 2.** "Unlock Potential": This scenario highlights potential locations of new EV chargers where they might increase exposure to middle-class citizens (Strata 3 and 4), who may be more likely to adopt EVs with more incentives.

2. Legal framework instrument that allows a Colombian municipality or district to classify its users of public services into distinct groups or strata based on the characteristics of the dwelling and the surrounding area in which the user resides. Colombia classifies its population into Stratas 1 (low-income) through 6 (high income). The law allows for cross-class subsidies to provide support to lower-income Stratas.

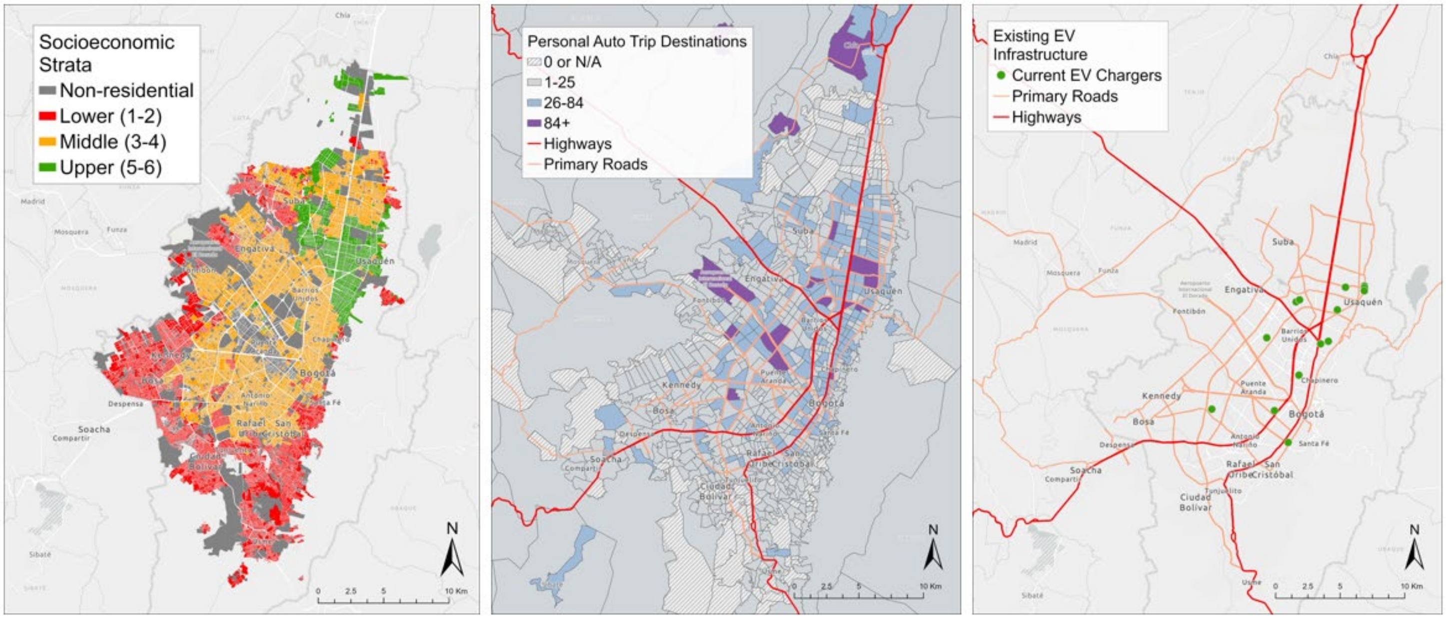

Figure 1. Key input datasets for the initial GEB analysis: demographic strata (left), vehicle travel data (center), existing EV infrastructure (left)

- **Scenario 3.** "Create Opportunity": This scenario shows areas outside of current EV infrastructure range where lower-income residents (Strata 1 and 2) travel. This group is typically not an early adopter of EVs but should be included in the effort to expand EV access.

DATA

The following key datasets were utilized for the study:

- **Urban socio-economic data:** This data came in the form of block stratum data for the Bogotá area. This data included an "Strata" category, which is a categorical variable ranging from 1 to 6, with 1 being the lowest economic class, and 6 being the highest.
- **Travel data:** GEB provided the data and reports from their 2019 Mobility Survey for Bogotá. This is a multimodal travel survey that provides trip origins and destinations for participants, along with demographic information about them. The travel data also includes an expansion factor that was used to scale up the number of trips
- **Travel infrastructure and existing station data:** This data includes primary roads and existing EV stations used as the core network around which to base new EV station locations.

To further strengthen the analysis, additional data could be incorporated into the model. Other data that could be informative includes: vehicle registration data, more comprehensive demographic and housing data to estimate home charging availability and areas more accurately with higher likelihood for early EV adoption, and survey data from residents regarding their interest in adopting EVs.

KEY DATASETS FOR EV CHARGING INFRASTRUCTURE ANALYSIS

Future vehicle fleet projection: A projection of vehicles on the road split by hybrid gasoline, hybrid diesel, EV, commercial EV, and EV taxis. Data was provided annually from 2020–2050.

Future estimated km traveled: Estimations of the future system-wide travel totals for private autos, motos, and taxis were provided and used to scale the data from the travel survey for simulating EV charging demand in the future with EVI-Pro. This data was also provided disaggregated by Transportation Analysis Zones, which is the most granular level of zoning used in Bogotá.

Historical EV Sales: The quantity of EVs sold each year by vehicle make and model was used to estimate the types of vehicles that might typically be sold in Bogotá as the market grows.

EV registration data: A key dataset that was missing from this analysis was EV registration data from Bogotá. Current and potential EV adoption criteria in the analysis were based on assumptions from the socio-economic stratum data. Having EV registration data would allow us to refine the analysis by being able to explicitly identify where EVs are being purchased and driven.

KEY OUTCOMES/IMPACT

In Bogotá, in the case of potential public charging in residential areas, clear clusters represent three socio-economic classes. High-income areas are grouped in north Bogotá, middle-income areas are in central Bogotá with a group to the north as well, and low-income areas are in southern Bogotá. Initial placement of EV chargers will be informed by the concentration of early EV adoption in the city. Given the high upfront cost of EV ownership, early adopters are likely to live in high-income areas. In the case of potential public charging in commercial areas, there is significant overlap between each scenario, where most of the non-residential locations are common destinations for all three socio-economic classes. Placement of public EV charging stations here may serve many of the people in each of these classes at once. However, the data currently available does not describe the specific uses of these non-residential areas, so it is not clear if they are industrial, retail, recreational, or some other use. When more land-use and/or cadastral data is available, the analysis can be refined to pinpoint more optimal charging locations within these areas.

In addition to this analysis on EV charging infrastructure in Bogotá, the EVI-Pro tool can be used to estimate projected charging infrastructure needs at the Transportation Analysis Zone level for specific future years as the EV fleet expands and travel behavior evolves. The tool will be provided to GEB, SDM, and other interested stakeholders, along with thorough training and documentation to enable stakeholders to conduct their own customized simulation runs. These runs can also be made more specific and impactful for future planning with the most updated data sources available (as described in the data section). Results can then be used to directly inform the progressive buildout of the EV charging network around Bogotá, ensuring stations are built in the areas where they will have high use. This includes destinations with high travel demand and long dwell times to maximize the potential utilization of stations and their utility for EV owners. Additionally, the upstream demand on the electrical grid on weekends and weekdays resulting from the use of the charging network is an additional output from EVI-Pro. This output can estimate the impact on the grid based on changes in EV adoption, home charging availability, travel behavior, or other factors that GEB and other stakeholders in Bogotá can use for long-term planning. With ambitious EV adoption goals, the grid could require significant upgrades; using EVI-Pro to estimate those needs based on various scenarios can greatly inform the planning process and mitigate uncertainty around upstream transmission impacts.

WHAT'S NEXT?

NREL is currently developing and adapting the Colombia-specific EVI-Pro model inputs to ensure the assumptions and data transformations made for the simulation are accurate and useful. If travel data for Colombia becomes available, the model can also be adapted for assessment of EV infrastructure buildout nationwide. A user interface for the EVI-Pro model is also under development to make the model easier and faster to run, with different scenarios for users who are not familiar with the python coding language. Once completed, the model and interface will be shared with GEB, SDM, and other interested stakeholders. Live virtual training sessions will be held and documentation provided to ensure that relevant users are comfortable operating the model.

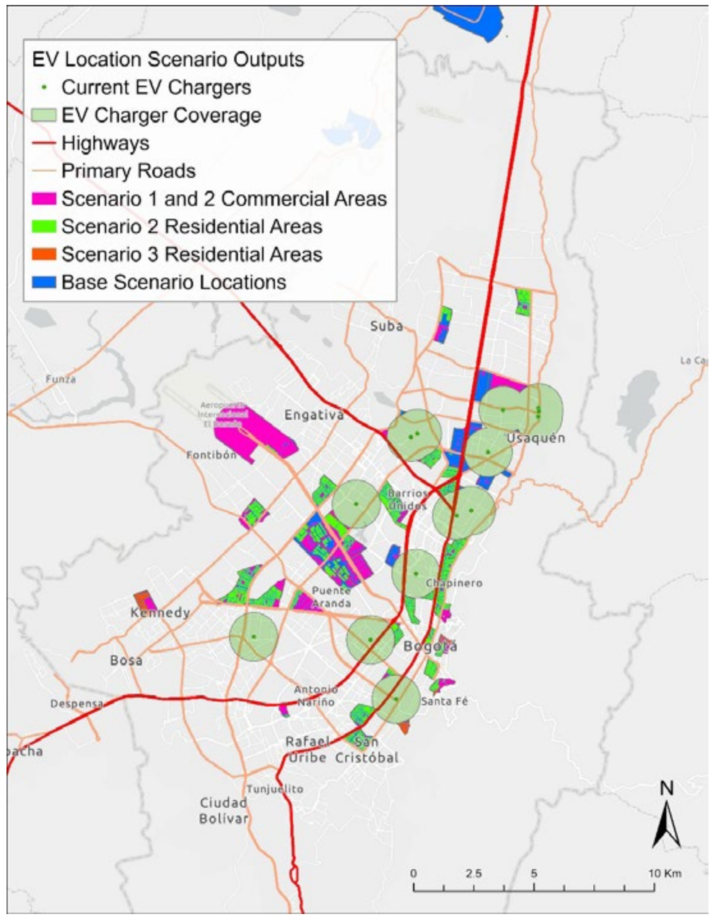

Figure 2. Map showing the results for each scenario from the GEB analysis. The magenta areas on the map represent the overlapping commercial areas that are frequent destinations for auto trips by residents in Stratas 3 through 6 (middle- and upper-income range). The lime green areas on the map represent the residential areas identified in the second scenario, which are frequent destinations for auto trips by residents in the middle-income range (Stratas 3 and 4). The orange areas represent the residential areas identified in the third scenario, which are frequent destinations for auto trips by residents in Stratas 1 and 2 (low-income areas). The blue areas represent the base scenario results, which are areas of high traffic that are far from existing infrastructure but with no consideration for other social or demographic traits. Existing EV chargers are represented by the green dots and their assumed special coverage is illustrated by the green circles.

APPENDIX A. EV AND EVSE TOOLS

The following tables provide summary information on available tools and publications the project team identified as being applicable to EV and EVSE modeling, evaluation, and analysis.

TOOL NAME	TYPE	DESCRIPTION	OWNER
Dashboard for Rapid Vehicle Electrification (DRVE)	Model	Evaluates financial and environmental impacts of light-, medium-, and heavy-duty vehicle fleet procurements across an entire fleet based on a variety of ownership structures, vehicle types, EV charging configurations, and more.	Atlas Public Policy
Future Mobility Calculator	Model	For a given city, determines the quantity and cost of infrastructure necessary to accommodate future EV adoption	World Resources Institute and Siemens
EVI-X Modeling Suite of Electric Vehicle Charging Infrastructure Analysis Tools	Model of Models	Suite of integrated tools informing large-scale EV charging infrastructure deployment, identifying the number and type of chargers needed to meet a given demand, financials, efficient locations, and mitigation of grid impacts.	NREL
REVISE-II	Model	Helps infrastructure planners decide where and when to locate EV charging stations along interstate highways across the United States	Oak Ridge National Laboratory
Transportation Energy & Mobility Pathway Options (TEMPO) Model	Model	Provides long-term pathway options to achieve transportation, energy, and environmental objectives across the energy supply, characterizing opportunities for existing and future fuels, technologies, and business models across transportation sub-sectors.	NREL
Greenhouse gases, Regulated Emissions, and Energy use in Technologies (GREET) Model	Model	Existing fleet greenhouse gas inventory tool simulating energy use and emissions output of various vehicle and fuel combinations.	Argonne National Laboratory
POLARIS Transportation System Simulation Tool	Model	Agent-based modeling suite for simulating large-scale transportation systems, enabling creation of integration transportation systems models to evaluate the energy impact of vehicle and transportation technologies in a multi-agent context, from small neighborhoods to large metropolitan areas.	Argonne National Laboratory
Route Energy Prediction Model (RouteE) Model	Model	Predicts energy consumption of a given vehicle over a proposed route for any vehicle type where route drive cycle data may be unavailable. Can be applied to optimize and choose vehicle routes, such as for public transportation fleets.	NREL
Electric Vehicle Deployment Guidebook	Guide	A guidebook to inform policymakers and regulators in developing countries with a holistic, actionable framework for how to plan, implement, and scale EV deployment in their jurisdictions.	NREL
EV Hub	Website	Provides up-to-date market data, policies and regulations, and news regarding the EV industry.	Atlas Public Policy
Modeling Framework for Behavior, Energy, Autonomy, and Mobility (BEAM)	Model	Modular software framework enabling efficient, scalable simulation of regional transportation systems, allowing transportation planners and service providers to simulate traveler behavior and technology deployment to understand congestion, energy, and emissions implications of novel mobility technologies and services from individual scale to entire transportation systems.	Lawrence Berkeley National Laboratory
Market Acceptance of Advanced Automotive Technologies (MA3T) Model	Model	Considers technology, infrastructure, consumer behavior, and policy inputs to simulate purchasing behaviors amongst individuals in an automotive marketplace.	Oak Ridge National Laboratory
Electric Vehicle Toolkit	Toolkit	Provides studies, tools, trainings, and guides to assist stakeholders in navigating key topics related to EVs and charging infrastructure.	NREL
Automotive Deployment Options Projection Tool (ADOPT)	Model	Estimates the impact of private, light-duty vehicle technology improvements on future U.S. vehicle sales, energy use, and emissions through 2050 at the county, state, or national level.	NREL
LEDS-GP Transportation Toolkit	Toolkit	Provides case studies, guides, and resources on policy strategies to support the development of low-emissions transportation systems at national and local levels.	Lawrence Berkeley National Laboratory
Techno-Economic Assessment of Deep Electrification of Passenger Vehicles in India	Case Study	Case study assessing grid, emissions, and financial impacts of full electrification of passenger vehicle sales in India by 2030 using two models: Plug-in Electric Vehicle Infrastructure Model (PEVI) and PLEXOS-Electricity Production Cost Model.	NREL
Global Change Analysis Model (GCAM)	Model	Global model representing behavior of and interactions between five systems and their responses to global changes: energy, water, agriculture and land use, the economy, and the climate	Pacific Northwest National Laboratory
Future Automotive Systems Technology Simulator (FASTSim)	Model	Compares powertrains and estimates impact of technology improvements on vehicle efficiency, performance, cost, and battery life for light-, medium-, and heavy-duty vehicles. FASTSim can model conventional, electric, and hydrogen fuel cell vehicles.	NREL

Image from iStock 1182337590

INTEGRACIÓN EFICIENTE DE ENERGÍAS RENOVABLES VARIABLES AL SISTEMA COLOMBIANO

CONTACT INFORMATION

The USAID-NREL Partnership
usaid.nrel@nrel.gov

To learn more, visit:
www.nrel.gov/usaid-partnership/project-colombia.html

Designated Authors: Jeff Cappellucci, Dustin Weigl, Sean Esterly, Hallie Lucas

Acknowledgments: Holly Darrow

This work was authored, in part, by the National Renewable Energy Laboratory (NREL), operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the United States Agency for International Development (USAID) under Contract No. IAG-22-22434. The views expressed in this report do not necessarily represent the views of the DOE or the U.S. Government, or any agency thereof, including

NREL/TP-5400-84325 • February 2023