

Impact of electromobility deployment scenarios in the power system of Uruguay by 2028

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Abstract— Electric vehicle deployment globally has grown exponentially during the past decade due to climate change goals, efficiency improvements and cost reductions, among other. Uruguay is in a privileged position in this regard due to electricity surpluses produced by non-conventional renewable energies during the early morning, which coincidentally is the period of lowest demand. This paper analyses the impact of electromobility deployment scenarios in the power system of Uruguay. In the most ambitious scenario, the study suggests that the fleet of electric vehicles of the country could increase from approximately 4,300 to 88,000 by 2028, accounting for up to 2% of total electricity demand and provide a significant reduction in fuel consumption without significantly increasing the marginal cost of electricity supply.

Keywords — *Electromobility, electric vehicles, wind generation, energy surplus, second energy transition.*

I. INTRODUCTION

During the last decade, there has been notable progress in terms of electromobility competitiveness. Efficiency gains, cost-reduction of batteries and high engagement of several countries worldwide have enabled greater autonomy and a sharp decrease in the cost of electric vehicles (EV).

The International Energy Agency (IEA) in 2020 published the “Global EV Outlook 2020 - Entering the decade of electric drive?” [1] report. In this study the IEA reports the evolution of Battery Electric Vehicles (BEV) and Plug-in Hybrid Electric Vehicles (PHEV) throughout the last decade, and forecasted scenarios for 2030.

Fig. 1 shows the evolution of the global EV fleet for the 2010 – 2019 period according to IEA’s report.

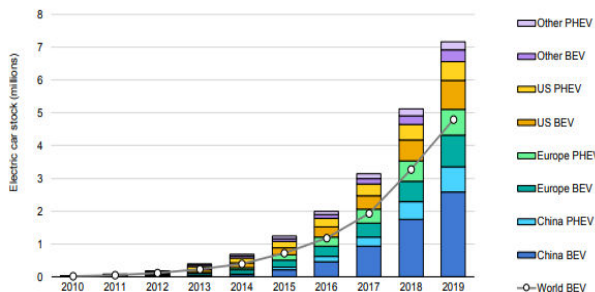


Fig. 1: Electric car stock (millions)

As portrayed, EV sales globally have grown exponentially during the past decade, from 17,000 in 2010 to 7.2 million in 2019, Approximately 65% of the total

stock of EVs are BEVs. It is observed that China is leading the race, and has 47% of the global share of EVs.

Fig. 2 shows the forecasted global stock of EVs by 2030 for the two scenarios carried by IEA: Stated Policies Scenario and Sustainable Development Scenario. The Stated Policies Scenario is the base case, and considers the current policies and regulations, as well as the expected effects of announced targets and plans. The Sustainable Development Scenario is an ambitious scenario based on limiting the global temperature rise to below 1.7 / 1.8 degrees Celsius with 66% probability.

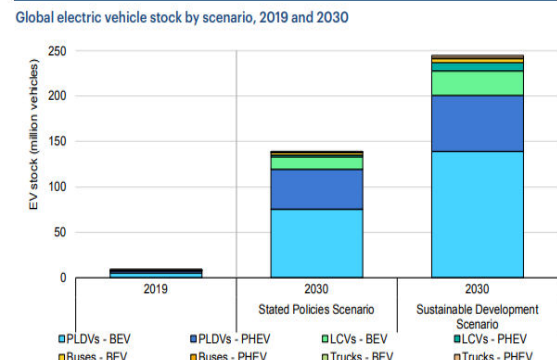


Fig. 2: Global electric vehicle by scenario to 2030.

Where

PLDVs – Passenger Light duty Vehicles

LCVs – Light Commercial Vehicles

In both scenarios, the forecast for 2030 shows an ambitious deployment of EVs, especially PLDVs (both BEV and PHEV).

II. ELECTROMOBILITY IN URUGUAY

The Efficient and Sustainable Mobility project (MOVES, acronym in Spanish) [2] financed by the Global Environment Facility (GEF) and implemented by key local institutions, is a clear example of Uruguay’s interest in increasing the share of EVs. In recent years, the country has progressed in the development of public charging infrastructure, regulatory and technical adaptations, capacity building, government incentives, among several other mechanisms to promote electromobility.

The Uruguayan electricity utility, the National Administration of Power Plants and Electrical Transmissions (UTE, acronym in Spanish) has a special electromobility tariff [3] for charging electric vehicles at public charging stations. The energy charge of this tariff is distributed in three hourly periods: peak, mid-peak and off-peak. The off-peak period goes from 0:00 to 6:00 AM and

has an energy charge of 7.2 USDcent/kWh¹. There are also multi-hourly electricity tariffs for residential and industrial clients with similar hour-blocks.

Uruguay is in a privileged position for the deployment of EVs due to the high integration of renewable energy sources in its electricity mix (which accounted for approximately 95% of electricity demand in 2020), further renewable energy capacity under construction, low electricity demand in the early morning hours (off-peak period) and a high share of wind generation, especially during that same period.

Fig. 3 shows the average hourly demand of the Uruguayan power system based on historical data of 2019 and 2020 (orange-coloured line), average wind generation (blue-coloured line) and the difference between both (grey-coloured line).

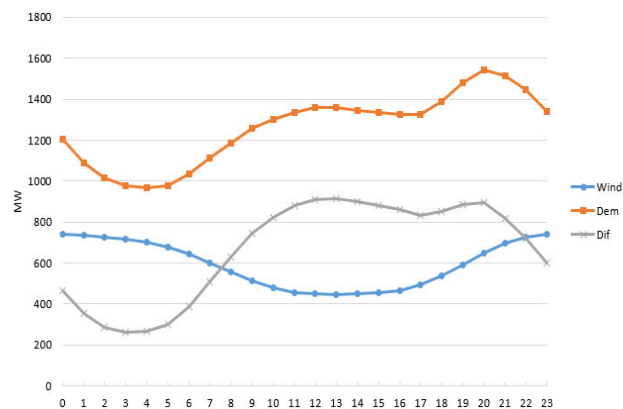


Fig. 3: Average hourly wind generation and electricity demand.

As portrayed, the difference between average demand and wind generation ranges between 250MW and 450MW during the off-peak period. A medium term-study of the Uruguayan power system carried out by the Observatory of Energy and Sustainable Development of the Catholic University of Uruguay [4] shows that due to the characteristics of the power system, at least during the next five years there is an excellent opportunity for the deployment of new demands in the off-peak period due to energy surpluses during these hours.

Therefore, a low tariff during off-peak hours is expected in the upcoming years. This incentivises electromobility deployment in Uruguay, given that EVs can be charged during hours of coincidentally low demand, which is beneficial for the system, and low electricity tariffs, which is beneficial for the end-user.

III. ELECTROMOBILITY DEPLOYMENT SCENARIOS IN URUGUAY BY 2028

TABLE I shows the stock of EVs in Uruguay as of 2020 and forecasted scenarios by 2028. The forecast was constructed based on data published in 2018 by the National Energy Directorate of the Ministry of Industry, Energy and Mining of Uruguay [5] and the MOVES project.

This analysis is carried out in 2028 given that it is the last year of official electricity demand forecasts available at

the time of producing this study. Due to COVID 19, previous long-term demand forecasts have deviations with the current electricity demand and thus were not considered.

TABLE I. FLEET OF ELECTRIC VEHICLES IN 2020 AND FORECASTED SCENARIOS BY 2028.

	2020	Scenarios 2028		
		Base	Policy	NDC-Conditional
PLDs - BEV	302	3,495	4,551	34,943
LCVs-BEV	75	149	212	352
Buses-BEV	32	186	399	179
Motos	1,232	1,428	6,379	6,379
PLDs - PHEV	2,650	38,654	39,998	39,998
LCVs-PHEV	8	15	22	36
Buses-PHEV	12	72	155	70
Total	4,311	43,999	51,715	81,956

This study includes three forecast scenarios. The Base case scenario projects the current trend of EV deployment. The Policy scenario considers energy efficiency policies undergoing in Uruguay which promote EV deployment. Lastly, the NDC-Conditional scenario considers - in addition to the goals of the Policy scenario - further specific targets such as Uruguay's Nationally Determined Contributions (NDC) to the Paris Agreement.

As showed, EVs would grow at a Compounded Annual Growth Rate (CAGR) of 35.8%, 40.4% and 81.1% in each scenario respectively. It is worth noting that the government is currently announcing new electromobility measures, such as tax exemptions, which are not portrayed in our analysis given that no official projections included them were available at the time of producing this study.

For comparison purposes, it is assumed that the generation capacity and electricity demand are the same across scenarios, the latter differing only in respect to the consumption of EVs.

Furthermore, it is assumed that EVs are charged during 0:00 and 6:00 AM, with the frequency and battery capacity indicated in TABLE II.

TABLE II. NEW ELECTRICITY DEMAND – ASSUMPTIONS

	Battery capacity (kWh)	Charging frequency (#/day)	Scenarios 2028		
			EVs daily energy (MWh)		
			Base	Policy	NDC-Conditional
PLDs - BEV	50	0.2	34.9	45.5	349.4
LCVs-BEV	60	1	8.9	12.7	21.1
Buses-BEV	300	1	55.7	119.6	53.6
Motos	4	0.33	1.9	8.4	8.4
PLDs - PHEV	5	0.33	63.8	66.0	66.0
LCVs-PHEV	5	1	0.1	0.1	0.2
Buses-PHEV	50	1	3.6	7.8	3.5
Total Energy (MWh)			169	260	502
Number of hours per complete charge = 6					
Hourly demand (MW)			28	43	84

As showed, by 2028 EVs would incur in an additional daily demand of 169 MWh, 260 MWh and 502 MWh in the Base, Policy and NDC-Conditional scenario respectively.

¹ Exchange rate for United States Dollar (USD) to Uruguayan Peso: 1 USD = 43.8 Pesos

This is equivalent to a yearly demand of 62 GWh, 75 GWh and 183 GWh respectively. Considering that the yearly electricity demand in 2020 in Uruguay was 10,969 GWh and it is expected to reach 12,800 GWh by 2028, the EVs electricity demand under the most ambitious scenario would still represent less than 2% of the total demand.

IV. MODELLING

To analyse the impact of EVs on the power system of Uruguay, simulations were carried in SimSEE [6] (Simulation of Electric Power Systems, acronym in Spanish) model.

SimSEE is a power system planning and dispatch model developed by the Faculty of Engineering of the University of the Republic of Uruguay. It is an Open Source model and is used in Uruguay by the Electricity Market Administrator (ADME, acronym in Spanish) since 2010 and promoted by the Latin American Energy Organization (OLADE, acronym in Spanish).

The power system is modelled considering an hourly time step and public information published by ADME in the May-October 2021 seasonal programming report [7] and the 2021 Security of Supply report [8].

For simplicity purposes, the system is modelled as an isolated system with a single node to which the electricity demand (both system and electromobility demand) and generators are connected and it is not possible to import energy and the energy surpluses price is zero.

Electromobility demand is modelled between 0:00 to 6:00 AM (6 hours) as a constant demand of 28MW and 84MW in the Base and NDC-Conditional scenarios respectively, and 0 MW during the remaining hours². The Policy scenario is not considered in the for simplicity purposes, given that its electricity demand is in between the demand of the Base and NDC-Condition scenarios.

The possibility of using the batteries of electric vehicles to supply electricity demand during peak hours is not considered.

V. SIMULATION RESULTS

This section shows the comparison of electricity surpluses, marginal cost of the system and thermal generation dispatched under three scenarios. From this point on, the Base scenario is referred to as Low Electric Vehicles deployment (LVE), the NDC-Conditional scenario is referred to as High Electric Vehicles deployment (HVE) and a scenario with the 2020 EV stock referred to as No Electric Vehicle deployment (NoVE).

Fig. 4 shows the evolution of the average surpluses per hour with Exceedance Probability³ 20% (Pe20%, the three lines grouped in the lower part of the figure), 50% (Pe50%, the three lines grouped in the mid-part of the figure) and

80% (Pe80%, the three lines grouped in the higher part of the figure) for each scenario.

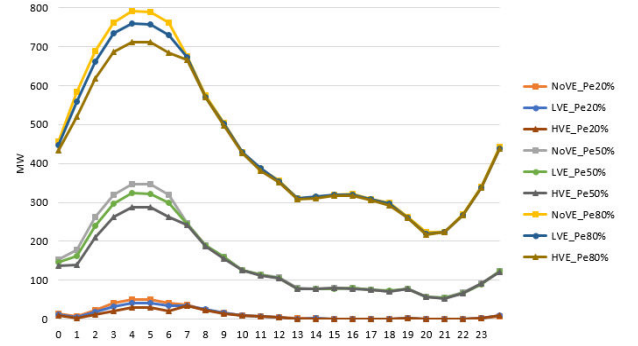


Fig. 4: Average hourly surplus generation.

As showed, the differences in energy surpluses between scenarios appear solely in early morning hours, which coincides with EV electricity demand. With Pe50%, between 3:00 and 4:00 AM the difference between the LVE and HVE scenarios ranges between 25MW and 60MW (EVs demand ranges between 28MW and 84MW respectively). In other words, over 70% of the expected EV electricity demand would be met with surpluses.

Fig. 5 shows the marginal costs (MC) per hour with Pe20% (again, the three lines grouped in the higher part of the figure, and so forth), Pe50% and Pe80% for each scenario.

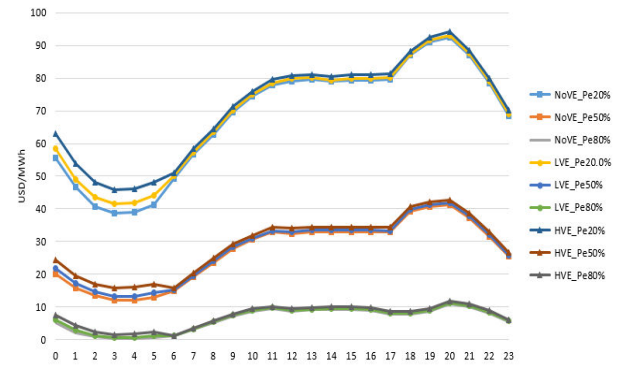


Fig. 5: Average hourly marginal cost.

As intuitively expected, the highest marginal cost occurs at peak hours. With Pe20% the MC ranging between 39 and 93 USD/MWh, whereas with Pe80% it ranges between 0 USD/MWh and 11/MWh. Furthermore, the differences in the marginal cost between scenarios are negligible outside early morning hours. In this period, the maximum difference between the marginal cost of the HVE and NoVE scenarios is less than 8 USD/MWh with Pe20%, less than 5 USD/MWh with Pe50%, and less than 2 USD/MWh with Pe80%.

TABLE III suggests that EVs' electricity demand would increase thermal generation by 2.3% in the LVE scenario and 6.5% in the HVE scenario.

² Technical distribution losses incurred in the supplied of EV demand are not considered.

³ Exceedance Probability is the probability that a certain value will be exceeded in a predefined time. In this case 2028.

TABLE III. THERMAL GENERATION EXPECTED VALUE IN THE THREE SCENARIOS.

	NoVE	LVE	HVE
Thermal dispatch (MWh)	761168	778829	810283
Delta Thermal (MWh)		17661	49115
EV Demand (MWh)		61647	183325
Delta Thermal (%Demand)		29%	27%

In order to analyse the impact of EV deployment in oil consumption, an efficiency of 18% is assumed for conventional combustion-engine vehicles, and 40% for dispatched thermal plants (which includes own consumption and losses). The Heat Rate considered for gasoline and diesel generation was 9.2 and 10 kWh/lt respectively.

TABLE IV compares the total annual consumption of fuel under the LVE and HVE scenarios, with a counterfactual scenario where EVs are replaced by conventional cars.

TABLE IV. FUEL SAVINGS

	LVE	HVE
Additional Fuel Demand (million lts)	4.5	12.4
Counterfactual Demand (million lts)	10.8	30.0
Fuel Savings (million lts)	6.4	17.6

As showed, EVs would save between 6.4 and 17.6 million liters of fuel per year, compared to the counterfactual scenario. The environmental impacts of these savings are shown in TABLE V.

TABLE V. EMISSIONS SAVINGS⁴

	LVE	HVE
Emissions savings (tCO ₂)	14720	40480

The financial aspects of the fuel and emissions savings are not considered in this analysis, but are considerable given that Uruguay is an oil importer.

VI. CONCLUSIONS

In order to assess the impact of different scenarios of electromobility deployment in Uruguay, a forecast that the stock of EVs in Uruguay by 2028 could increase from a current stock of 4,311 (including hybrids), to approximately 44,000 in the low penetration scenario and 82,000 in the high penetration scenario is considered.

According to our assumptions of battery capacity, frequency of charging, fleet, scenarios, among other described in the study, EVs' electricity demand would range between 62 GWh and 183 GWh by 2028. The total

electricity demand of the country in that year is estimated at 12,800 GWh. Consequently, the electricity demanded by EVs under the most ambitious scenario would represent less than 2% of the total electricity demand.

Due to low electricity costs and energy surpluses during the off-peak period (from 0:00 to 6:00 AM), Uruguay is in a privileged position for the deployment of EVs, given that they could be charged during these hours at a low tariff. In fact, the country already has this signal implemented in its tariff decree.

The analysis carried shows that differences in the exceedance probability of surplus electricity are found solely in the early morning hours. With Pe50%, over 70% of EV electricity demand would be met by surplus generation.

The simulations suggest that outside the off-peak period, the marginal cost does not vary significantly either for the different probabilities considered. During off-peak hours the marginal cost increases 2 USD/MWh and 8 USD/MWh between Pe20% and Pe80% respectively.

EVs would save between 6.4 and 17.6 million liters of fuel per year, compared to a counterfactual scenario where only combustion-engine vehicles are deployed. This would represent an emission saving of 14720 and 40480 tons of CO₂.

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⁴ Gasoline emission factor: 2.3 kg/CO₂