# Energy and environmental aspects of distributed generation and electric-vehicle integration from a LCA perspective. A case study in Mendoza, Argentina

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**Abstract**

The energy sector is moving from a rigid, concentrated system towards a flexible, decentralized one enabling the exchange of energy between many actors. Distributed renewable energy generation is a key element in this new system, offering many (potential) technical, environmental and economic advantages, but their intermittent character and the lack of synchronicity between demand and supply introduce new challenges to the utilities. Storage systems could help mitigating these negative issues, but they require additional costs, and incorporate new environmental problems.

Another key factor in the new energy sector is represented by the growing number of electric vehicles which are populating the urban space, which will need to charge their batteries, thus challenging the electric system's capacity. However, these vehicles will remain idle most of the time, thus offering an opportunity to electricity storage on their underutilized batteries.

In this paper the environmental consequences of distributed FV generation and storage in electric vehicles in Argentina are explored, following a life cycle perspective. Results show that the Vehicle-to-Grid and Grid-for-Vehicle management strategies will play an important role on demand curve peak-shaving. The scenarios analysis show that the transition to the electric vehicle alone does not ensure lower emissions, if advances in the electricity decarbonization are not accomplished.

**Keywords:** Distributed generation, electric vehicle, storage, Life Cycle Assessment

## 1. Introduction

Distributed generation from renewable energy in the residential sector is growing in many countries, offering many (potential) technical, environmental and economic advantages. However, their intermittent character and the lack of synchronicity between demand and supply introduce some concern to the utilities.

The residential PV market in Argentina is in its infancy. One of the main drivers is the possibility of selling electricity when the generation exceeds the consumption of the house, and of buying when the opposite occurs. However, the high subsidy of electricity determines a spread between PV feed-in tariffs and what the user pays when buying electricity. In this context, it becomes more attractive to increase the local consumption of electricity than to feed it into the grid, but the limited simultaneity between PV generation and electricity demand restrains the potential of this strategy. The obvious solution to overcome this drawback is to shift the consumption to periods with PV surpluses, but the deferrable loads in houses are scarce.

Another thread to the utilities is the emerging sectors of electricity consumption such as electric vehicles. But this is offering also an opportunity, since typical cars remain parked most of the time.

## 2. Case study for Argentina

This study considers the framework proposed by the publication of the Ministry of Energy and Mining of the Nation (Miner 2015), to explore the possible energetic and environmental consequences associated with the penetration of electric vehicles, and their interaction with the electrical network from both a Grid-to-Vehicle (G2V) and a Vehicle-to-Grid (V2G) perspectives. That publication reports projections of a series of variables such as energy consumption, and economic, population, automobile fleet, and renewable energies penetration growth. For this study we considered a 5% of electric vehicles penetration. The publication considers the following Scenario for 2025:

Population: 47.5 Million
Automotive park: 305 cars per 1000 inhabitants
Average emission System: 0.399 kgCO2eq / kWh
Growth in electricity demand, without the incorporation of electric vehicles: 3.8% per year (BAU)
Electricity consumption growth: 192 TWh (3.8%)
The penetration of 5% of electric vehicles would represent 724375 units by 2015, which substitute conventional vehicles. In order to maintain the average age of the automotive fleet, 952000 new vehicles must be incorporated every year, of which 86.7% cars

The 2025 total power installed in the electrical system would be 24.2 GW. In order to comply with Law 27191 of renewable energies, by 2025 the installed thermal power would reach 9.2 GW, nuclear power would increase by 0.8 GW, hydro power by 2.9 GW and solar and wind by 11.3 GW.

## 3. Methodology

The hourly coverage data of the real demand peak for an intermediate day of the year (20/10/2017), obtained from the Wholesale Electric Market Management Company (CAMMESA 2015), has been considered as the starting point of this study. A 14.33% loss was considered for transmission and distribution of electricity (World Bank, 2014).

An intermediate-range model (Chevrolet Volt) was considered, with a gross battery capacity of 17.15 kWh, with a recharge time in about 4.5 hours.

The conventional car fleet was modeled considering a gasoline-fueled compact car of the same manufacturer (Chevrolet Sonic s6 1.4), with a consumption range between 8.67 (urban) and 6.3 l/100 km (extra urban).

We considered two vehicle use pattern scenarios.

*Vehicle Scenario 1*: 12 km daily commutation, with a displacement at 8 am and return at 5:00 p.m. It includes a 4.5 km night use between 8 pm and 10 pm. The vehicle connection to the grid is established (at the work site), from 9 a.m. to 5 p.m.

*Vehicle Scenario2*: 40 km daily commutation, with a one-way trip at 9 AM, and return at 6 PM. In this scenario, night use is not considered.

In both scenarios, it is considered that 30% of the route is made in the city and the remaining 70% by highway.

The PEV-CIM v2.0 software has been used for the analysis of the impact G2V and V2G.

For the life cycle impact associated with each one of the considered vehicles, the SimaPro 9.0 software from Pré Consultants has been used.

## 4. Analysis of Results

In scenario 1, the substitution of conventional vehicles with electric ones, would produce a reduction of 2340 CO2 ton/day. For comparison purposes, the GHG emissions balance was also evaluated for a grid with a higher fossil share (54 % coal, 19 % natural gas and the rest run-off hydroelectric production). In this case, the replacement would cause an increase of 1730 CO2 tons/day. This shows that the electric vehicle penetration does not ensure GHG emission reduction.

The maximum storage power V2G is 2.39 GW, while the demand peak without EV is 25.11 GW, that is, potentially the EV can reduce the demand peak by 9.5%. However, since in this scenario there is a mismatch between the connection schedule and the occurrence of peak demand, this reduction does not occur.

Now analyzing the EV as an energy consumer for compensating the consumption due to the traveled distance established in the driving scenario, a maximum power of 2,79 GW is required, 11% of peak demand. The electricity consumed by EV is 7,53 GWh/day. The mismatch between the connection schedule and the occurrence of peak demand produce no increase in the demand peak, but an earlier demand peak could appear.

In scenario 2, the incorporation of 725,000 electric vehicles would reduce GHG emissions by 3993 ton/day representing 2340 Gton CO2/day saved. V2G would allow using the 2.39 GW batteries power stored for peak shaving. For the G2V case, 2,79 GW are required, representing 11% of peak demand. The new demand peak is 27,9 GW

For comparing the environmental impact of the two cars, we adapted datasets from the Ecoinvent database. Results show that 0.34 kg CO2eq/km are emitted for the conventional car (including construction and operation), against 0.185 kg CO2eq/km for the electric car

## 5. Conclusions

The transition to electric vehicles does not ensure a reduction in GHG emissions, if not accompanied by a higher renewable energy share

The contribution of the storage capacity of electric vehicles does not ensure a decrease in demand peaks, if the loading and unloading process is not managed adequately.

If the Argentinean program for renewable energy are met, the incorporation of electric vehicles would reduce the GHG emissions from a Life Cycle perspective, and it could smooth the influence of solar energy variability on the grid, and could reduce the demand peak.

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