Electric Vehicle as an Energy Reservoir: Vehicle-to-grid (V2G)

**Context**

1. General Motors committed to an all-electric and zero-emissions future
2. Vehicle-to-Grid (V2G) describes the process of electric vehicles (EV) discharging excess electricity back to the electricity grid
3. Business opportunities exist for GM as an energy aggregator between electric vehicles’ excess energy and energy utilities buyers

**Motivation**

- **General Motors** is committed to an all-electric and zero-emissions future
- **Vehicle-to-Grid (V2G)** describes the process of electric vehicles (EV) discharging excess electricity back to the electricity grid
- **Business opportunities** exist for GM as an energy aggregator between electric vehicles’ excess energy and energy utilities buyers

**Goals**

- The alignment of daily charging & driving patterns with V2G.
- The amount of excess electricity predicted to provide as an energy aggregator.

**Analytical Approach**

**Clustering Model**
What are typical daily driving & charging behavior patterns?

- 9 driving & charging patterns are extracted from 3.3M days for 22k EVs in California from 2020/12 – 2021/04
- 4 out of identified patterns align with V2G for > 25% of total records
- 2 driving & charging patterns, covering > 57% of total records could turn into preferable behaviors in the future with V2G incentives

**Sample output:** Cluster 5 center behavior
Distance (m)  On grid duration (min)

- Extensive energy saving by implementation of V2G

**Time Series Model**
For each identified pattern, a Facebook Prophet time series model was constructed to reflect daily per-cluster EV volume

**Sample output:** Cluster 5 time series

- **Day-off effect:** During holidays and weekends, the number of people using EV in cluster 5 faces dramatic reduction
  - 3% of reduction during holidays
  - 30-40% of reduction during weekends

- **Workday effect:** During weekdays, the number of people using EV in cluster 5 has been stable and consistently high

**Business Impact**

- Extensive energy saving by implementation of V2G
  - Average yearly excess electricity discharged per EV through V2G: 13 MWh
  - Average yearly electricity consumption per household: 11 MWh
- Novel perspective to guide driver behavior analysis
- Real-time excess energy prediction
  - Provide multiple concurrent predictions, based on different risk tolerance and accuracy requirements

**Sample Output:**

- **Number of EVs in the cluster:**
  - 2021/03/15 - 2021/04/01
  - Testing R² value: 0.94

**Sample Output:**

- **Distance Driven:**
  - 0 to 20

- **On Grid Duration:**
  - 0 to 50

- **Hour of Day:**
  - 0 to 24

**Prediction Interval:**
Statistics of sums of excess electricity yield prediction percentiles between which GM can control risk tolerance levels

**Excess Electricity Prediction vs. Actual Value**

- **Excess Electricity Prediction vs. Actual Value:**
  - 10/04-21/04-23/04-25/04-27/04
  - Prediction
  - Lower Bound Prediction
  - Actual Value

**Excess Electricity Benchmark:**

- **Sum of Excess Electricity for each cluster:**
  - 20000 kWh
  - 21000 kWh
  - 22000 kWh

- **Prediction Interval:**
  - 25 percentile
  - 75 percentile