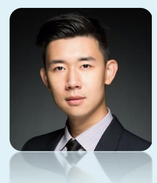
Electric Vehicle as an Energy Reservoir: Vehicle-to-Grid (V2G)

General Motors Team
Robert Kleinbaum
Aaron Wolf
Derek Hazard

MIT Advisor
Prof. Georgia Perakis
Leann Thayaparan

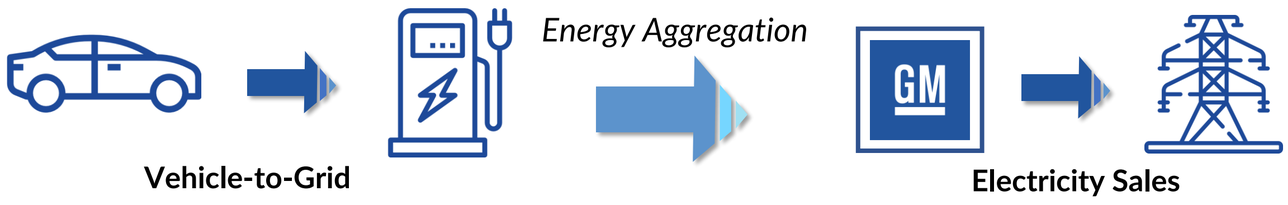
MBAn Student Team
Xiaming (Garfield) Jin
Ming Da (Tim) Li

MIT MANAGEMENT SLOAN SCHOOL

GM Problem Statement

Context

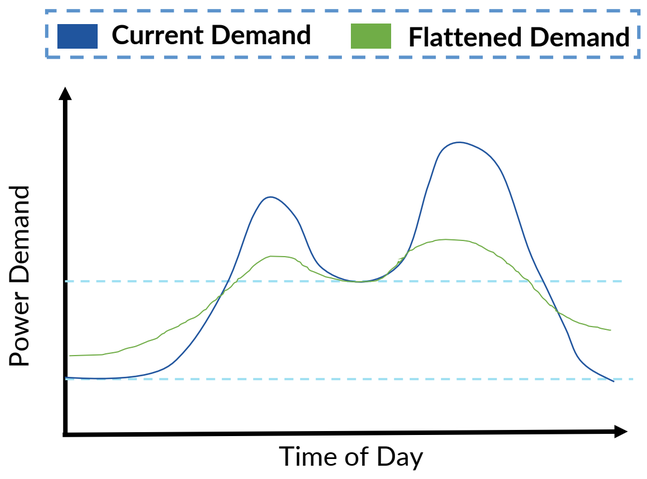


1. General Motors is committed to an all-electric and zero-emissions future

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



V2G

achieves ***demand curve flattening***
Charging at *low demand* (off-peak hours)
Discharging at *high demand* (peak hours)

achieves ***environment protection***
Reduction of *carbon footprint*
Reduction of *electricity production*

achieves ***monetary benefits***
Budget reduction for *investors*
Profits raise for *car production firms*

Goals

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

GM Analytical Approach

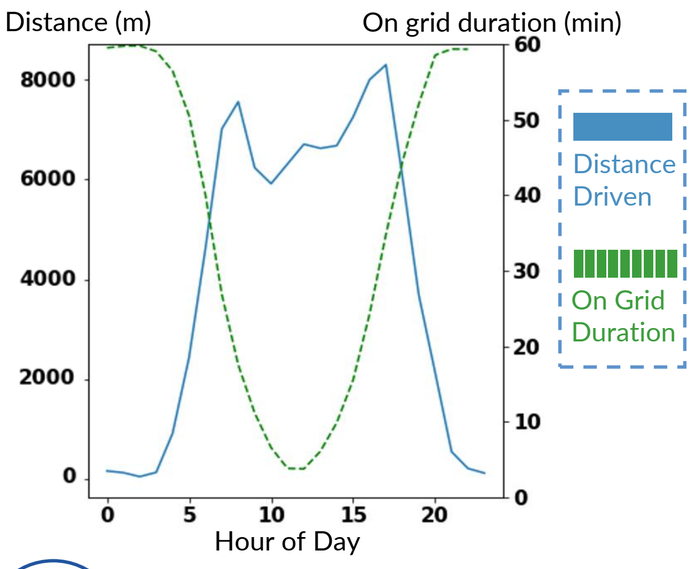
Clustering Model

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*

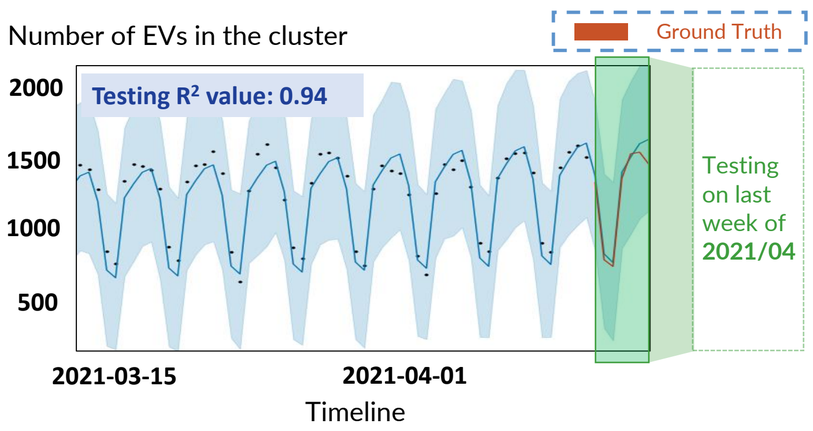


Time Series Model

How many people in each driving & charging pattern?

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

Bootstrapping

How much excess energy to expect?

Objective of Excess Energy Per EV

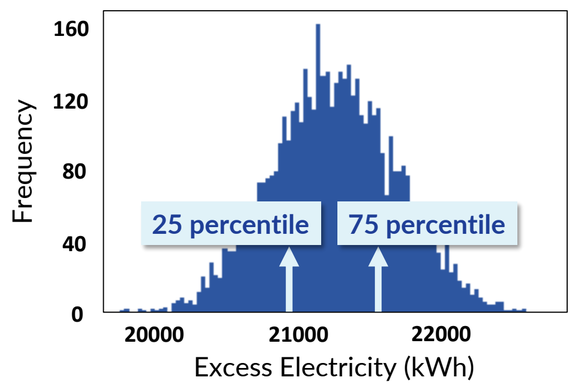
EV's available electricity in battery at **4pm**
EV's **traveling distance** during peak hours
EV's **connect-to-grid** time during peak hours

$$\text{MIN}\left(B_i - sf * D_i * b,\ G_i * r\right)$$

safety factor ensuring EV has enough driving electricity
unit of battery needed to power EV per km *(kWh/km)*
discharge rate of EVs *(kWh/hr)*

Bootstrapped Distribution: *Sum of excess electricity for each cluster*

Sum of Excess Electricity Bootstrap Distribution



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

GM 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

Accessing to real-time and dynamic driving & charging behavior data enables *responsive insight gathering* at previously untapped granular level

Real-time excess energy prediction

Provide multiple concurrent predictions, based on *different risk tolerance and accuracy requirements*

Excess Electricity Prediction vs. Actual Value