Grid Modernization Laboratory Consortium: Vehicle-to-Grid Integration Pathway (GM0062)

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**Vehicle to Building / PEV
Smart Grid Team**

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Grid Modernization Laboratory Consortium: Vehicle-to-Grid Integration Pathway (GM0062)

Timeline

- Project Start: April 1, 2016
- Project End: March 31, 2019
- Percent complete: 68%

Budget

- Total project funding: $3.4M (DOE)
- FY 2017 Funding: $1M
- FY 2018 Funding: $1M

Barriers

- Building demand charges
- Common integration platforms for smart energy management
- Non-networked EVSE and PEVs without high level communication

Project Partners

- Use cases reviewed and prioritized by 11 industry advisors
- Multi-lab team: ANL, INL, LBNL, NREL & PNNL

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Vehicle-to-Grid Integration Objectives

Project Objective

Promote PEV adoption through developing and demonstrating a standardized, scalable, and interoperable communications and control system architecture including:

- Demonstrated workplace PEV charging methods that minimized demand charges
- Integrated local renewables
- Provided commercial building connectivity and interoperable communications
- Managed power consumption to meet transportation requirements
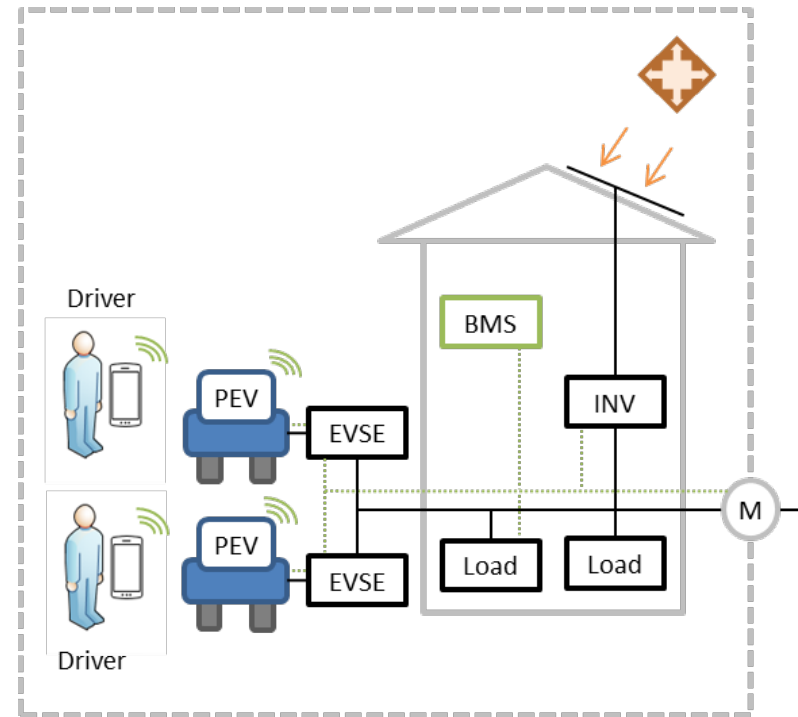
Achievements: infrastructure development and demonstrations of demand response, demand charge mitigation, renewable integration, commercial building connectivity, and maximizing vehicle availability for transportation.

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Vehicle-to-Grid Integration Relevance

- Relevance:
  - The Vehicle Technologies Office (VTO) supports a variety of work to lower the cost and increase the convenience of PEVs.
  - VTO advances the development and use of PEV charging infrastructure from the viewpoints of utilities, vehicle manufacturers, building owners and PEV owners.

- Impact:
  - The project focused on addressing these barriers: managed PEV charging loads, workplace-charging Demand Charge mitigation, and standards-compliant AC conductive charging
  - Met the following targets and milestones:
    - Develop vehicle charging demonstration use cases and communication & control requirements demonstrating PEV charging that minimizes demand charges
    - Three demonstrations: multi-vehicle, workplace demand response (DR) charging, peak demand charge mitigation that prioritizes energy delivery to PEVs with highest energy needs and integration of PV generation with building loads and PEV charging
  - Use case economic analysis showed that the controlled charging had a very positive financial impact over uncontrolled charging.

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Vehicle-to-Grid Integration Pathway Milestones

Milestone Name / Description	End Date	Type
Develop PEV charging demonstration **use cases** and communication and **control requirements** that minimize demand charges	10/1/2016	Annual Milestone
Demonstrate the demand response (DR) use case for workplace charging and aggregated PEVs provide their maximum power variation	4/1/2017	Semiannual Milestone
Demonstrate workplace PEV **demand charge mitigation** use case and prioritizes energy delivery to PEVs with highest energy needs	10/1/2017	Annual Milestone
Demonstrate optimized workplace PEV charging with **variable renewable resources and prioritized building loads** that mitigates demand charges and **prioritize driver's preference for fastest, cheapest or greenest charge.**	9/30/2018	Semiannual Milestone
Demonstrate **Transactive Control** PEV charging methods with variable building loads and renewable resources. Verify PEV energy & schedule are met while prioritizing energy delivered to PEVs with highest energy needs.	3/31/2019	Annual Milestone

Go/No-Go Description	Criteria	Date
The Industry Advisory Board (IAB) (i.e., BPA, DTE, AeroVironment and others) will review the workplace vehicle charging use cases.	The IAB's comments and concerns must be resolved and a consensus obtained for the project's demonstration use cases.	10/1/2016
The control system must mitigate demand charges from building and charging loads with variable renewable resources integrated into workplace PEV charging use cases.	The demonstrations must aggregate building loads, charging loads, and renewable resources and demonstrate demand charges are minimized and the vehicles are fully charged.	10/1/2017

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Vehicle-to-Grid Integration Approach

- Technical Approach:
    - Maximize utilization and uniqueness of each demonstration lab's facilities and capabilities (e.g., NREL parking garage, ANL - smart energy plaza, PNNL - office buildings)
    - Use cases validated and prioritized by industry partners
    - Develop a standardized, scalable, and interoperable communications and control system architecture for workplace PEV charging applications
    - Design methods enabled integration with GM-0085 (Distribution System simulation), GMLC 1.4.2 (Grid Services), and provided analysis configurations for economic and control system ROI analysis efforts
    - Demonstrate local renewables integration, commercial building connectivity, interoperable communications, power consumption prioritized to meet transportation requirements, minimize PEV demand charges and participate in energy / ancillary services markets
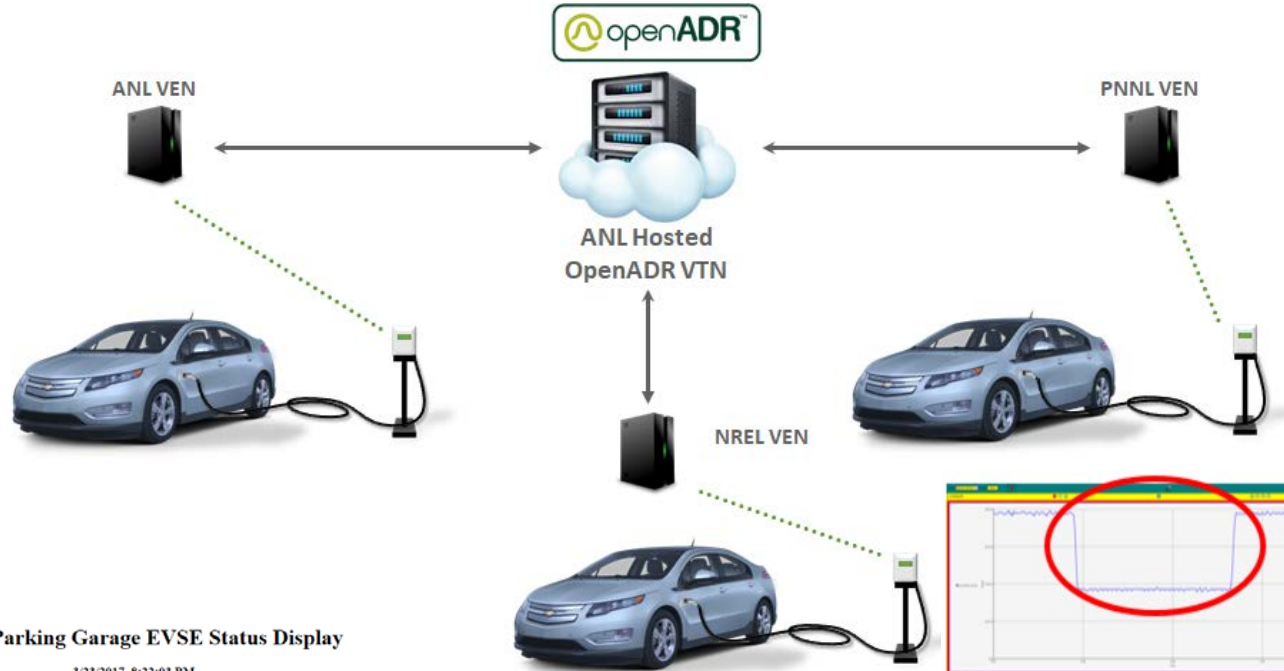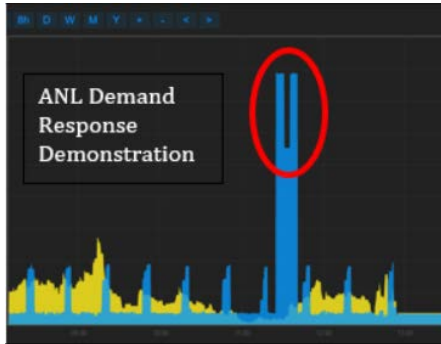
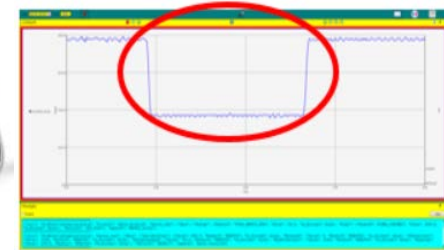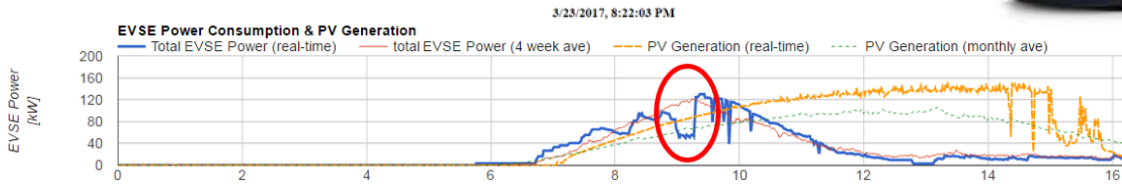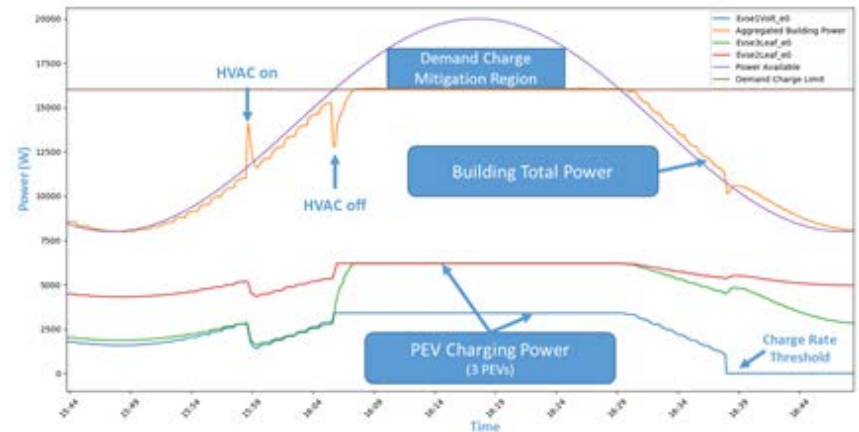**Vehicle to Building / PEV Smart Grid Team**

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Vehicle-to-Grid Integration Accomplishments Demand Response Demo

Demand Response is a common utility-controlled mechanism to temporarily reduce power demand

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Vehicle-to-Grid Integration Accomplishments
Demand Charge Mitigation Demo

- PNNL / ANL / NREL developed and implemented a PEV charging algorithm that mitigated building demand charges while prioritizing PEV driver needs (energy by departure time).

- Each lab utilized a different priority algorithm to determine which PEV was curtailed or increased based on the overall power of the building

Utility-assessed Demand Charges ($/kW) can dramatically shift PEV charging economics

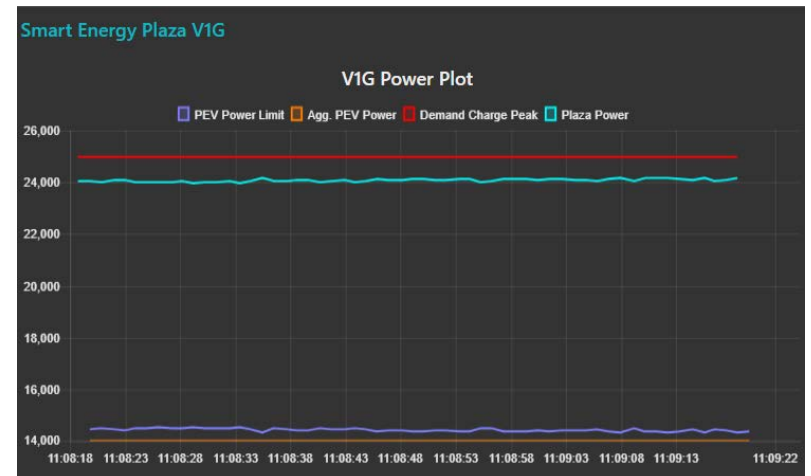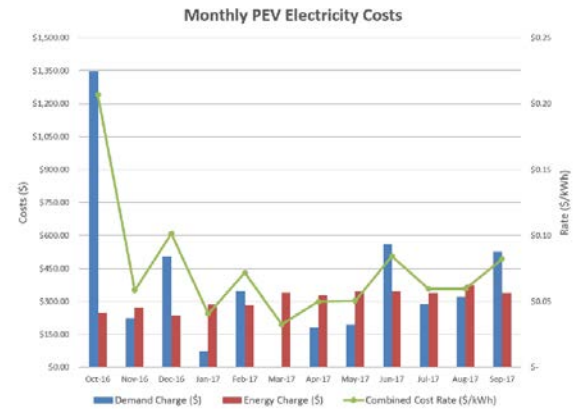**Vehicle to Building / PEV Smart Grid Team**

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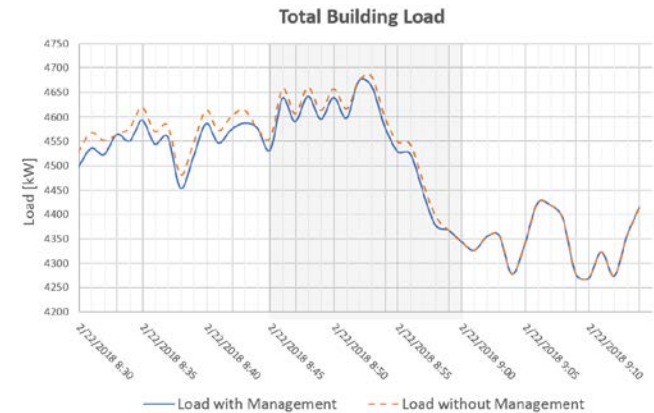
Vehicle-to-Grid Integration Accomplishments
NREL Demand Charge Mitigation

- NREL deployed a charge management algorithm to manage 36 EVSEs to reduce the total campus demand and demand charges. This method reduced annualized average charging cost from about 14¢/kWh to as low as 3.8¢/kWh.

- Daily operation of the system with demand mitigation since Nov. 2017 has resulted in reduction of total campus load during the peak periods in Dec. 2017 and Feb. 2018.

- Control during the February peak demand period resulted in a 20 kW reduction in load representing a $332 charging electricity cost savings or about 4.4¢/kWh for all charging energy in February.

Monthly PEV Electricity Costs

Unmanaged Charging at NREL Garage

Total Building Load

Peak demand period for February 2018

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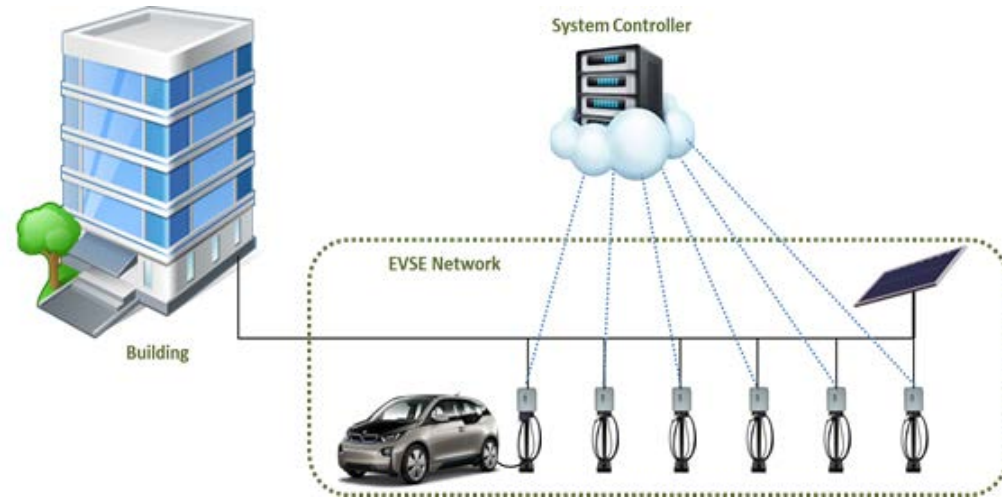This presentation does not contain any proprietary, confidential, or otherwise restricted information

Vehicle-to-Grid Integration Accomplishments
Next: Preference Based Charging Demo

Integrate variable renewable resources and market signals (i.e., energy price) into the workplace charging demonstration.

Goals:
- peak demand charges from vehicle charging are mitigated
- renewable energy delivery prioritized
- the customer's desire for "greenest", "cheapest", or "fastest" charge met
- control algorithms will optimize charging based on the building's priorities, vehicle energy needs, and the PEV driver's preferences.

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Vehicle-to-Grid Integration Accomplishments
ANL V1G Frequency Regulation Demo

ANL Smart Energy Plaza V1G Frequency Regulation
2012 Volt, 2013 i3, 2012 Leaf, 2017 Bolt

Utilizing ANL's Smart Charge Adapter (SCA), 4 PEVs were aggregated on non-networked EVSE to follow the PJM RegD test signal. Control Pilot duty cycle modulation utilized.

Initial results are promising, communication latency and PEV response times (~3 seconds) align with the requirements of this market.

Frequency Regulation is an Ancillary Service provided by Independent System Operators (ISO) in the US. This has typically been the most lucrative grid services market.
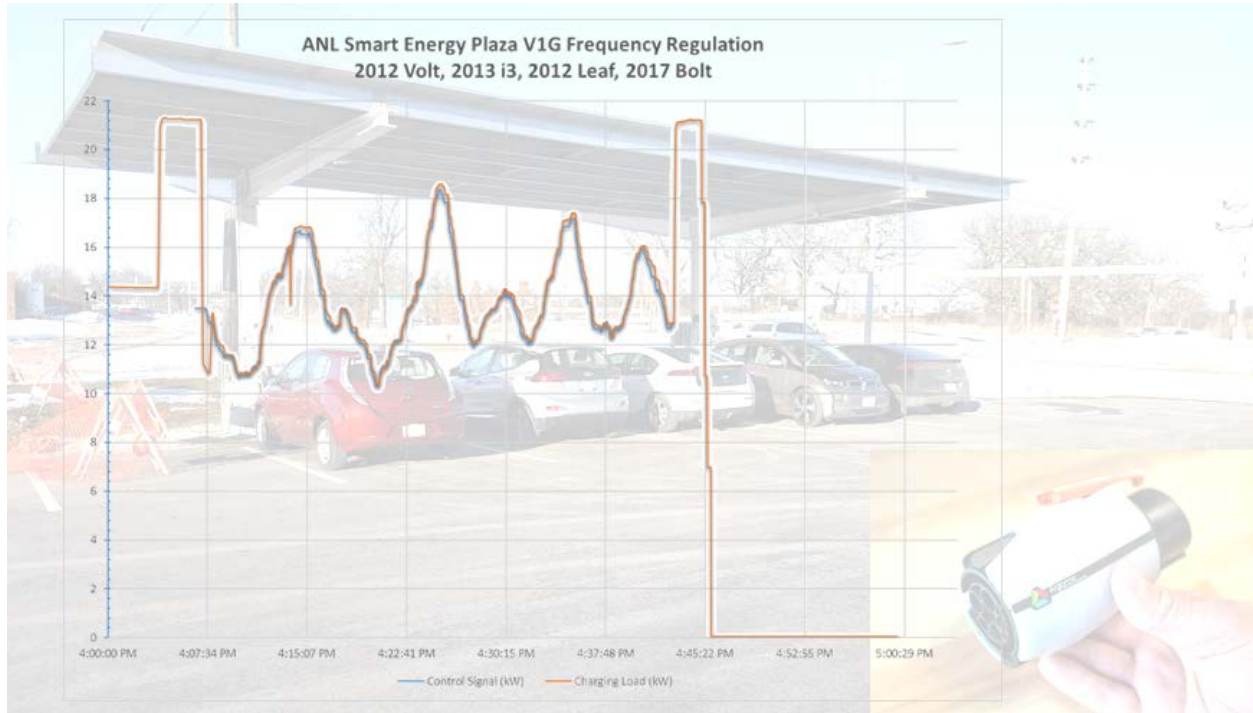
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Vehicle-to-Grid Integration Economic Analysis

- <u>Accomplishments:</u> Simulation & analysis **capability to quantify building-level economic benefits.** *Example:*

<u>Key Assumptions for Example:</u>
- 100 EVs (Alameda County EV pilot), PG&E E-19 rate
- Objective: Building manager seeks to minimize their monthly electricity bill (TOU energy cost + demand charge cost)
- "Best-case" result: Assumes EV control has perfect knowledge of loads and provides full kWh charge demanded by vehicles

<u>Example Results:</u>

gasoline - **$115/mo**

(solar PV could also help reduce peak)

Legend:
- Building base load
- Uncontrolled charging scenario
- Controlled charging scenario

Per building-month:

$2,963	controlled charging energy charge
+$641	controlled charging demand charges
$11,309	total cost for uncontrolled charging

Per vehicle-month:

| **$29.63** |
| **+$6.41** |
| **$113.09** |

uncontrolled charging - $113/mo
controlled charging - $36/mo

<u>Potential margin to share among:</u>

Vehicle owners	Charging network
Building owner	Electric Utility
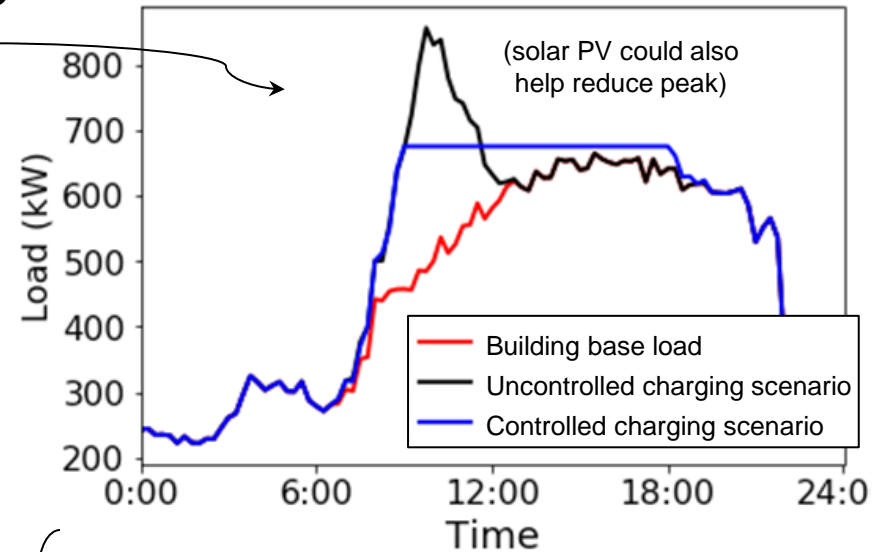
Scenario	Energy Charge / mo.	Demand Charge / mo.	Total / mo.
Base Load	$37,409	$28,375	$65,786
Uncontrolled EVs	$40,167	$36,927	$77,093
Controlled Charging	$40,372	$29,016	$69,388

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Vehicle-to-Grid Integration Prior Year Comment

- This project was presented during the poster session last year, this is the first oral presentation

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Vehicle-to-Grid Integration Collaborations

- Collaborations:
    - ANL, NREL, and PNNL uniquely approached the workplace charging objective to optimize system to meet local requirements
    - Common communication and control protocol enables common message format compatible with BTO sponsored efforts
    - Planned integration with GM - 0085 (Distribution System simulation) can easily leverage common message formats to expand system demonstration beyond individual labs.
    - ANL, NREL and PNNL responded to ANL- hosted Demand Response demonstration

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Vehicle-to-Grid Integration Remaining Challenges and Barriers

- Challenges:
  - Competing objectives between building owners (demand charges, EVSE infrastructure, energy costs); PEV owners (PEV range, power availability and power cost); utility (energy sales, infrastructure limitations); OEMs (vehicle sales, development / warranty costs); and EVSE Provider (system maintenance, availability, billing)
  - Building / campus / PEV load forecasts and PV generation forecasts are needed to improve control strategy effectiveness
  - PEV owner supplied charging requirements were frequently inaccurate

- Barriers:
  - Communication infrastructure between PEV / EVSE not broadly deployed
  - Charging rate control interface currently limited to Telematics or changing the maximum EVSE charge rate signal
  - No common integration platforms and protocols for smart energy management
  - Building EVSE installation is costly and load flexibility depends on capacity and PEV owners willingness for extended charging times
  - Networked solutions for EVSEs installations are limited and few use open communication standards for EVSE control to the local building controller

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Vehicle-to-Grid Integration Future Research

- Implement and evaluate Transactive controls at the aggregator and Energy System Controller levels and how this method benefits PEV owners, EVSE providers, building owners, utilities, etc.
- Industry-prioritized use cases were demonstrated, constraints identified, and tools developed to explore the economic analysis domain, but a more broadly adopted approach to economically evaluate use cases including at the vehicle-to-building level is not currently available.
- Methods are needed to implement PEV charging control at multiple hierarchical levels that simultaneously satisfy use case constraints beyond vehicle-to-building interface: (e.g., operating with limited power, competing constraints, etc.).
- Most vehicles used were privately-owned and owners were inaccurate on providing energy requirements. Alternative methods of obtaining state of charge, vehicle model, charge completion time are needed.
- Methods to reduce control system response times are needed to enable commercial equipment meet some use case latency requirements.
- Transactive controls risk mitigation process includes consulting with other teams

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Vehicle-to-Grid Integration Summary

- Infrastructure supporting performance of industry-prioritized uses cases including PV generation data, building load data, and PEV charging control was developed and tested
- Demand Response and Demand Charge mitigation use cases were performed and analysis methodology developed showing economic value
- Power-sharing algorithms developed were frequently updated to handle limited power conditions
- Minimizing building demand charges required low-latency PEV charging response times in smaller buildings
- Common integration platforms for smart energy management were developed and tested that enabled non-networked EVSE and PEVs without high level communication to perform smart energy management functions

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