Department of Defense
Plug-in Electric Vehicle-Vehicle to Grid (PEV–V2G)

LAAFB Technical Update

Second Annual California Multi-Agency Update on Vehicle-Grid Integration Research

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CTC Concurrent Technologies Corporation

Agenda

- PEV-V2G Program Overview
  - Participants
  - Vehicles
  - Accomplishments
- LAAFB
  - Status
  - Benefits
  - Expected Market Participation
  - Next Steps
- Findings Related to VGI Research and Development

DoD PEV-V2G Participants

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V2G integration is complex and technically challenging. Success is a reflection of collaborative communication by all parties to develop solutions and overcome obstacles.

Consortium PEV-V2G Achievements

- Accelerating the nation's adoption of electric vehicles
- Advancing the state of electric vehicles and charging stations
- Advancing the state of engineering and software applications
- Providing installations with a means to lower energy and fleet vehicle costs
- Providing utility operators with an alternative energy solution for electric distribution system stability
- Promoting energy surety across the nation

Who are the Public-Private Consortium members deploying V2G technology?

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Department of Defense Organizations

- Air Force Civil Engineer Center (AFCEC)
- Air Force Research Laboratory – Advanced Power Technologies Office (AFRL - APTO)
- Air Force Vehicle and Equipment Management Support Office (VEMSO)
- Army Engineer Research and Development Center-Construction Engineering Research Laboratory (ERDC-CERL)
- Army Tank Automotive Research, Development, and Engineering Center (TARDEC)
- Fort Carson (SPIDERS)
- Fort Hood
- General Services Administration (GSA)
- Joint Base Andrews
- Joint Base McGuire-Dix-Lakehurst (JB MDL)
- Los Angeles Air Force Base (LAAFB)
- Office of the Secretary of Defense (OSD)
- Secretary of the Air Force Installations, Environment, and Logistics (SAF I/E)
- Secretary of the Army Installations, Energy & Environment (ASA [IE&E])

State Government and National Laboratories

- California Energy Commission (CEC)
- Lawrence Berkeley National Laboratory (LBNL)
- Massachusetts Institute of Technology Lincoln Laboratory (MIT LL)

Private Industry

- ACDD
- Akuacom, Inc.
- Bel Fuse Inc.
- Clean Wave Technologies, Inc
- Concurrent Technologies Corporation (CTC)
- Coritech Services, Inc.
- Eaton Corporation
- Electric Vehicle Add-On Systems, Inc (EVAOS)
- Electric Vehicles International LLC (EVI)
- Electricore, Inc.
- Ford® Motor Company
- Kisensum, Inc.
- Nissan® Motor Corporation
- Phoenix Motorcars, LLC
- Princeton Power Systems, Inc. (PPS)
- VIA Motors Inc.

Energy Providers and Regulators

- California Independent System Operator (CAISO)
- California Public Utilities Commission (CPUC)
- Electric Reliability Council of Texas (ERCOT)
- Oncor Electric Delivery Company (Oncor)
- Pepco
- PJM Interconnection LLC (PJM)
- Southern California Edison (SCE)
- Viridity Energy Inc

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DoD PEV-V2G Vision

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What Plug-In Electric Vehicles (PEVs) and Plug-In Hybrid Electric Vehicles (PHEVs) are in the V2G fleet?

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	Nissan LEAF Sedan	Ford F-Series Trucks with EVAOS PHEV kits	VIA Motors VTRUX Van	Electric Vehicle International (EVI) Range Extended Electric Vehicle (REEV)	Phoenix Motorcars Electric Shuttle
Range Description	PEV electric range: 75 miles fuel efficiency: 99 MPGe	PHEV electric range: N/A fuel efficiency: 45 MPG**	PHEV* electric range: 31 miles fuel efficiency: 38 MPG**	PHEV* electric range: 40 miles fuel efficiency: 43 MPG**	PEV electric range: 100 miles fuel efficiency: 32 MPGe
General Purpose Fleet Role	23.6 cubic feet cargo capacity	1500 to 2800 lbs payload	2650 lbs payload (cargo van only)	5300 lbs payload	116 cubic feet cargo capacity
	5 seats	3 seat standard cab 6 seats crew cab	2 seat cargo 12 seat passenger	2 seats	visitor transport: 12 passengers + driver
Battery Capacity	24 kWh	27 kWh	21 kWh	54 kWh	102 kWh
# at Locations					
LAAFB	13	5	11	4	1
Fort Hood	8	14	- - -	- - -	- - -
JB Andrews	8	5	- - -	- - -	- - -
JB MDL	- - -	8	- - -	- - -	- - -

Miles per gallon (MPG), Miles per gallon equivalent (MPGe), Kilowatt-hours (kWh)
Los Angeles Air Force Base (LAAFB), Joint Base Andrews (JB Andrews), Joint Base McGuire-Dix-Lakehurst (JB MDL)

*Fuel used only when electric range exceeded
**Averaged over 60 miles

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PEV–V2G Accomplishments

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- **Technology developed**
  - Bidirectional PEVs in use and paired with UL-certified Inverters
  - Software proven to charge/discharge PEVs via Inverter/Electric vehicle support equipment (EVSE) pair
  - LAAFB actively using & expanding fleet management system
  - Simulated certification tests confirmed system is ready for market participation at LAAFB & Fort Hood
- **Technology standardized**
  - Satisfies both American (SEP 2.0) & International (OCPP) standards
  - Standard application depends on vehicle requirement
- **Technology matured and best practices captured**
  - Converted a concept into a working reality in 4 years
  - Catalogued and deployed best practices to date (continuing effort)

PEV–V2G Accomplishments

- **V2G market participation capacity achieved at 3 of 4 sites**
  - Vehicles have been delivered and are commissioned
  - 77 EVSE/charging station units have been installed
    - 4 remaining to be installed at LAAFB

LAAFB Status

- **SCE Commissioning Test – Successful**
  - Completed 25 Sep 2015 for Phoenix, EVI, Nissan, VIA
    - SCE Conditional Permission to Operate letter received on 25 Sept 2015 and submitted to CAISO New Resource Implementation (NRI)
    - SCE Initial Synchronization letter received on 25 Sept 2015 and submitted to CAISO NRI
      - Provides written approval to synchronize and operate in parallel with the CAISO grid
- **CAISO Pre-Certification Test – Successful**
  - Passed pretest on 25 Sep 2015
    - 30-minute charge test at an average of 500 kW (Max 561 kW)
    - 30-minute discharge test at an average of 500 kW (Max -513 kW)
- **CAISO Formal Certification Test – Successful**
  - Passed certification test on 15 Oct 2015
- **CAISO Commercial Operation Date (COD)**
  - Expected 18 Dec 2015

Expected Benefits

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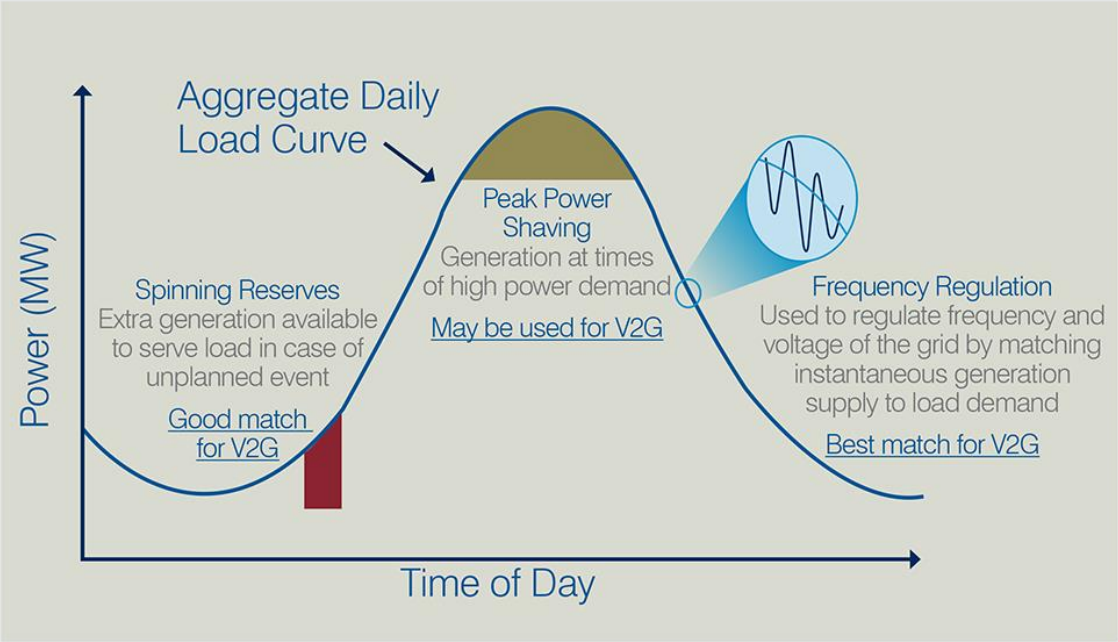
What benefits will the DoD obtain from future large-scale V2G implementation?



Frequency regulation is a continuous adjustment of power generation or electrical demand to maintain the grid frequency at or near the nominal 60 hertz standard.

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Cuts Installation Electricity Costs
- Earns energy revenue to offset installation utility expenses
- Increases penetration of energy storage systems
- Encourages use of lower cost, off-peak electricity

Increases Resiliency & Reliability
- Overcomes natural disasters and intentional threats with on-site power support
- Serves as backup power to mission critical facilities during outages

Aids Energy System Stabilization
- Reduces failure and degradation of system's electrical devices with bi-directional power flow
- Increases power distribution efficiency with on-demand reserve supplies
- Supports ancillary services market that provides grid operators with real-time adjustment capabilities
- Cuts electrical generation operational costs

Provides a Positive Environmental Impact
- Promotes use of renewable energy
- Supports the national goal of reducing fossil fuel and energy consumption
- Reduces dependence on foreign energy sources
- Reduces greenhouse gas emissions

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Expected Market Participation – kW/kWh Overview at LAAFB

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Vehicles	Vehicle Type	EVSE Vendor*/ Size/Type	Quantity	System Capacity Rating (kW)**	Total System Charge*** Capacity (kW)	Stored Energy (Battery) Rating (kWh)**	Total Storage Capacity (kWh)	ISO/ Average $ Bid
Los Angeles Air Force Base			**34**		**657**		**996**	CAISO 0.016/kWh ($16 MWh) **Historical price**
Nissan LEAF sedan (5 passenger)	PEV	P 15 kW DC	13	15	195	24	312	
F-150 Ford Pickup Truck with EVAOS Energy Storage Module (ESM)	PHEV	C 15 kW AC	2	16.6	16.6	27	54	
F-250 Ford Pickup Truck with EVAOS ESM	PHEV	C 15 kW AC	3	16.6	66.4	27	81	
VIA vans (12 passenger)	PHEV	C 15 kW AC	11	14	154	21	231	
EVI Stake Bed Truck	PHEV	C 50 kW DC	2	47	94	54	108	
EVI Box Delivery Vehicle	PHEV	C 50 kW DC	2	47	94	54	108	
Phoenix Bus (12 passenger + driver)	PEV	C 50 kW DC	1	37	37	102	102	

P = Princeton Power Systems ; C = Coritech Services
** Electrical system components can affect system capacity (e.g., breaker limitation)

Projected Participation: DEC 2015 in a phased approach to 24/7 operation per vehicle availability

LAAFB Next Steps

- **Data Collection & Analysis**
  - Vehicle Data
  - Battery Performance
  - User Feedback
  - Expanded CBA

- **Operation, Transition, & Sustainment**
  - Develop Transition Support Plan
  - Sustain software system, charging stations, and vehicles
  - Satisfy cybersecurity accreditation requirements

Findings Related to VGI R&D –
Track 1: Determine VGI Value and Potential

- **Lessons Learned**
  - Determine Vehicle Portfolio
    - Capacity will differ by RTO/ISO territory
    - Assure vehicle power delivery to meet ISO requirements
  - Determine market potential
  - Develop optimized business model
- **Gaps/Areas for Improvement**
  - Lack of data
  - Consistent market programs
  - LAAFB demo will validate market potential for a fleet application
  - LAAFB Demo will validate and optimized business model for a fleet application

Findings Related to VGI R&D – Track 2: Develop Enabling Policies, Regulations and Business Processes

- **Lessons Learned**
  - Recognize the DoD's certification & accreditation process will affect the software deployment schedule
    - IATTs, GIG Waivers, and ATOs are some critical milestones
    - Air Force & Army have different interpretations on when cybersecurity requirements must be implemented
    - Assure the availability for continuous cybersecurity needs
- **Gaps/Areas for Improvement**
  - Operation in varying broad regulation arenas reqiures significant effort to determine per location
    - RTO/ISO requirements will affect commercialization
    - Each RTO/ISO has its own defined process for marketplace entry; in general, entry will take at least 18-24 months
    - Not all RTOs/ISOs have an ancillary services market
    - V2G services is a new concept and some RTO/ISOs' processes need to be modified to allow their inclusion

Findings Related to VGI R&D –
Track 3: Support Enabling Technology Development

- **Lessons Learned/Accomplishments**
  - Bidirectional capability in existing distribution system is not a standard engineering practice
  - Bidirectional EVSE/charging stations did not exist
    - Coritech and PPS prototypes
    - Power and communication transfer over standard connections
  - Bidirectional vehicles were not commercial
    - Nissan had bidirectional capability but required firmware upgrades
    - Other vehicles required hardware upgrades
  - Fleet management software developed to control market participation
  - All technology developed satisfies both American (SEP 2.0) & International (OCPP) standards

Findings Related to VGI R&D –
Track 3: Support Enabling Technology Development

- **Gaps/Areas for Improvement**
  - Standardization to single communication protocol (server to distributed energy resource)
  - Expect V2G products to mature & standards to evolve
    - The pilot program is using first-generation products with no field track record
  - Technologies implemented within closed system still require certification by SEP 2.0 governing body
  - Unique vehicle operational challenges in executing V2G mode need to characterized
  - LAAFB demonstration will test system and individual technology performance
    - Challenges/resolutions catalogued
    - Results published

Additional lessons learned are detailed in the PEV-V2G System Implementation Approach and Demonstration Report.

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Back-Up Slides

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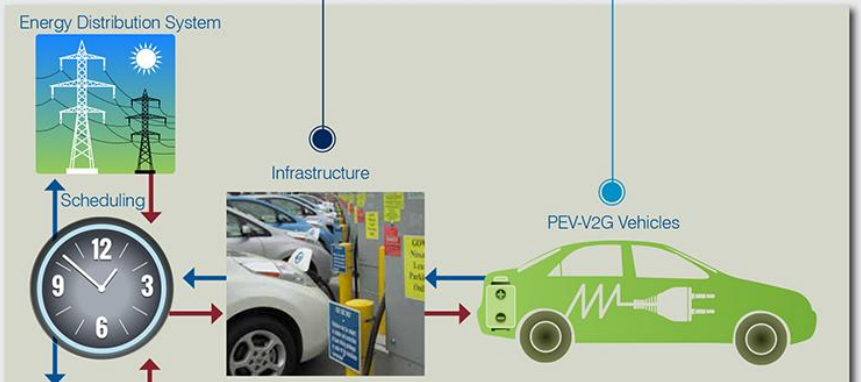
What is Plug-in Electric Vehicle – Vehicle to Grid (PEV-V2G)?

Charging Stations



PEV-V2G Vehicles

With V2G, PEVs can receive or provide power to the grid.

Energy providers will **PAY** for V2G services – vehicle batteries provide an energy source to stabilize the grid.

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Software Capabilities

- Fleet Management System
- Charge Control
- Grid Scheduling
- EV Asset Coordination
- Grid Interface

Sites

- Los Angeles Air Force Base (LAAFB), California
- Fort Hood, Texas
- Joint Base (JB) Andrews, Maryland
- JB McGuire-Dix-Lakehurst (MDL), New Jersey

Through its V2G services, a military base **REDUCES** its energy costs and greenhouse gas emissions.

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How is the V2G infrastructure controlled?

Introduction

A V2G system is comprised of plug-in electric vehicles (PEVs), bi-directional charging stations, and software controls that enable an installation to compete in utility ancillary services markets. Customized for each base, the OB-EVI provides the communication and software controls needed for all aspects of V2G.

Goal

Meet utility system operator's charge and discharge requirements

- Fulfill base fleet mission requirements
- Maximize ancillary services revenues
- Minimize non-conformance penalties

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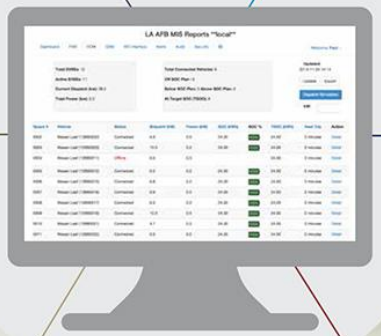
On Base-Electric Vehicle Infrastructure (OB-EVI)

Performance Reporting

OB-EVI includes a dashboard and detailed reports that provide system status, V2G participation and financial performance information.

PEV Fleet Reservations

Base personnel reserve cars/trucks in advance of use. OB-EVI ensures V2G participation does not prevent the fleet from meeting mission requirements.



Vehicle to Grid

OB-EVI supplies power stored in vehicle batteries to the grid according to the award signal.

Power Sent from Battery to Grid

Charge Management

OB-EVI develops an optimal charge schedule to ensure mission readiness and maximize financial benefit of V2G participation. OB-EVI controls EVSE charge/discharge according to schedule.

Charge Vehicle Battery Discharge Vehicle Battery

Managing fleets & participation in the ancillary services market

Award Signal

Utility system operator responds to submitted bid with award signal.

Bid Submission

OB-EVI prepares a detailed next day bid using planned vehicle availability information and submits to utility system operator.

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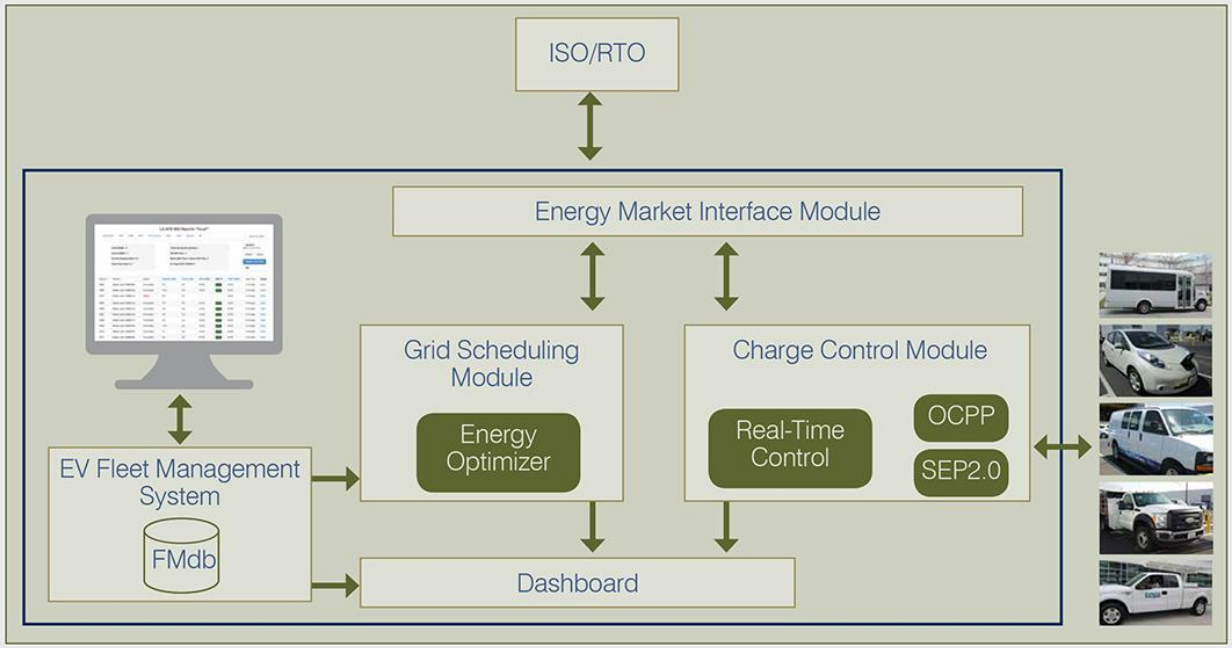
On Base-Electric Vehicle Infrastructure (OB-EVI)

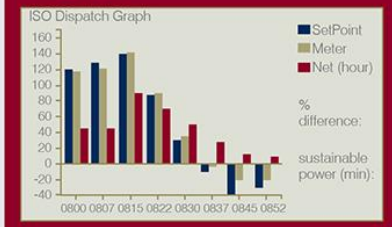
The software that enables V2G integration

KISENSUM



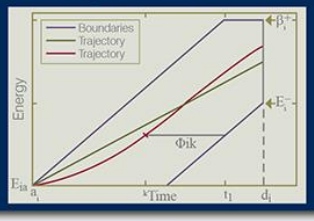
Energy Market Interface Module

- Supporting CAISO, PJM, ERCOT
- Bid-Award in Ancillary Services Energy Market
- Demand Response Market to Frequency Regulation Market Support



Charge Control Module

- Calculate optimal charging and discharging trajectories for both operational requirements and market participation
- Manage the aggregated state of charge across the entire fleet (Virtual Battery)
- Controls the EV Charging Station (EVSE) through industry standard protocols



EV Fleet Management System

- Support for base vehicle fleet
- Vehicle management to accomplish operational mission
- Assigns available vehicles to energy market participation

Grid Scheduling Module

- Day ahead and real-time bidding into energy markets
- Continuous monitoring and re-optimization based on actual vehicle status
- Complies with FERC-ISO rules in each energy market

Dashboard

- Tracks revenue generation in the energy markets
- Management tool for system monitoring and control
- Detailed views of vehicle usage, energy trading history, forthcoming schedules, audits, alerts, and dispatches

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