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

Michael Genseal
Executive Director, Energy & Environment

Scott Kenner
Director, Power & Energy

December 2015
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

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?

#### 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/E)
- Secretary of the Army Installations, Energy & Environment (ASA IE&E)

#### Private Industry
- ACCD
- Akumax.com, 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

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

<table>
<thead>
<tr>
<th>PEV</th>
<th>PHEV</th>
<th>PHEV*</th>
<th>PEV*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nissan LEAF Sedan</strong></td>
<td><strong>Ford F-Series Trucks with EVAOS PHEV kits</strong></td>
<td><strong>VIA Motors VTRUX Van</strong></td>
<td><strong>Electric Vehicle International (EVI) Range Extended Electric Vehicle (REEV)</strong></td>
</tr>
<tr>
<td>PEV electric range: 75 miles</td>
<td>PHEV electric range: N/A</td>
<td>PHEV* electric range: 31 miles</td>
<td>PHEV* electric range: 40 miles</td>
</tr>
<tr>
<td>fuel efficiency: 99 MPGe</td>
<td>fuel efficiency: 45 MPG**</td>
<td>fuel efficiency: 38 MPG**</td>
<td>fuel efficiency: 43 MPG**</td>
</tr>
<tr>
<td>General Purpose Fleet Role</td>
<td>23.6 cubic feet cargo capacity</td>
<td>1500 to 2800 lbs payload</td>
<td>2650 lbs payload (cargo van only)</td>
</tr>
<tr>
<td>5 seats</td>
<td>3 seat standard cab 6 seats crew cab</td>
<td>2 seat cargo 12 seat passenger</td>
<td>2 seats</td>
</tr>
<tr>
<td>Battery Capacity</td>
<td>24 kWh</td>
<td>27 kWh</td>
<td>21 kWh</td>
</tr>
<tr>
<td># at Locations</td>
<td>LAAFB 13</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>Fort Hood 8</td>
<td>14</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>JB Andrews 8</td>
<td>5</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>JB MDL - - - - - - - - - - - - - -</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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
PEV–V2G Accomplishments

• **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
      o 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

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.

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
## Expected Market Participation – kW/kWh Overview at LAAFB

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

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

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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 requires 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
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.
For more information contact:

Michael Genseal, EA, CEM, CDSM, CSDP
Executive Director, Energy & Environment

Michael Genseal, EA, CEM, CDSM, CSDP
Executive Director, Energy & Environment
gensealm@ctc.com (209) 456-5113

Scott Kenner, PMP
Director, Power & Energy

Scott Kenner, PMP
Director, Power & Energy
kenners@ctc.com (814) 262-2891
Back-Up Slides
What is Plug-in Electric Vehicle – Vehicle to Grid (PEV-V2G)?

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

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

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

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

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

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

On Base-Electric Vehicle Infrastructure (OB-EVI)

Managing fleets & participation in the ancillary services market

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.

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

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.

Award Signal
Utility system operator responds to submitted bid with award signal.

Power Sent from Battery to Grid
On Base-Electric Vehicle Infrastructure (OB-EVI)

The software that enables V2G integration

**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

**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

**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

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

**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