V2G School Bus & V2x Project Updates

First Annual California Multi-Agency Update
on Vehicle-Grid Integration Research
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EV Grid: Optimizing the Value of EV Batteries

ELECTRIC VEHICLE DEPLOYMENTS

BATTERY DEVELOPMENT & SERVICES

ENERGY STORAGE MANAGEMENT

COMMUNICATIONS, CONTROL & METERING

STANDARDS & POLICY SUPPORT

EV Grid works with OEMs and site operators to develop and supply technology for grid-tied, mobile and stationary battery systems.

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Moving EV Energy Storage into the fast lane…

Will we ever have enough vehicles?

What about batteries?

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Cupertino, CA – September 20th, 2014 GUINNESS WORLD RECORDS® Largest EV Parade
Photo: SF BayLEAFs / EAASV - Frank Moyota / 360° Bruce Southwick

EV Grid Employees: 6 EVs **360 View:** http://bit.ly/GWR-Cupertino-2014

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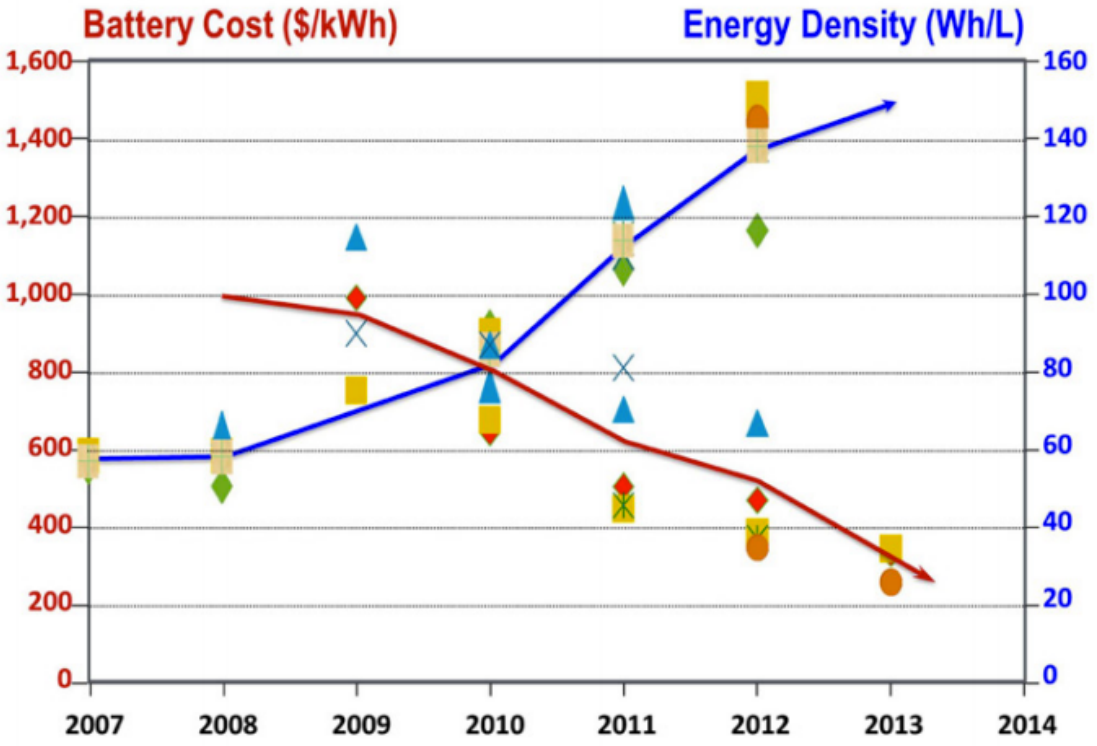
Batteries: Progress is real…

"DOE R&D has reduced the cost of PEV batteries by approximately 50% over the last four years….

Concurrently, the size and weight of PEV batteries have also been reduced by over 60%.

Battery energy density has increased from 60 Wh/liter in 2008, to 150 Wh/liter in 2013."



DOE EV Everywhere Grand Challenge

http://energy.gov/sites/prod/files/2014/02/f8/eveverywhere_road_to_success.pdf

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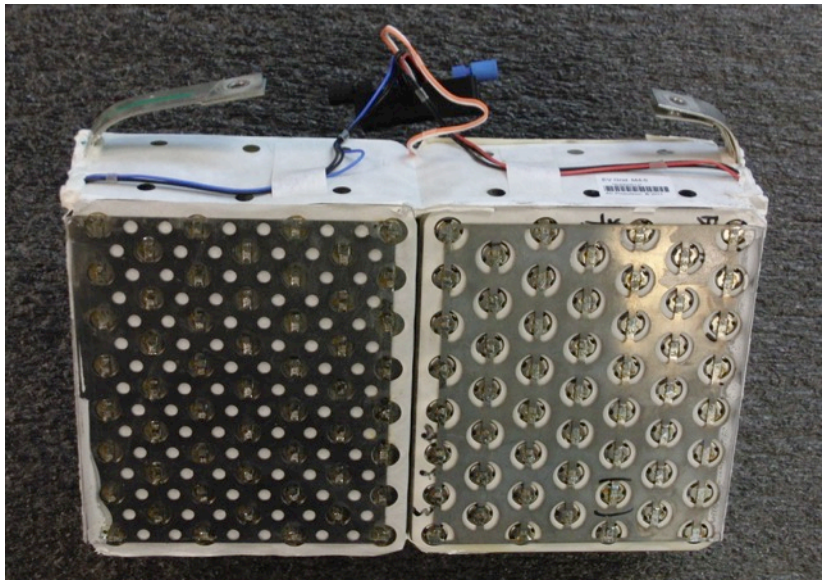
Batteries: Progress is real…

…real world example.

EV Grid pairs the latest 18650 cell performance with our advanced battery management system and module designs to build battery packs.

Compared to prior generation we are seeing:

- Twice the capacity
- Same weight or less
- Faster charging rates
- Built in thermal management
- Custom modules of any shape
- Stationary or mobile optimization
- Lower Cost



EV Grid Battery Module
(shown w/o packaging)

Degradation *will vary.* More work needed on battery-nomics.

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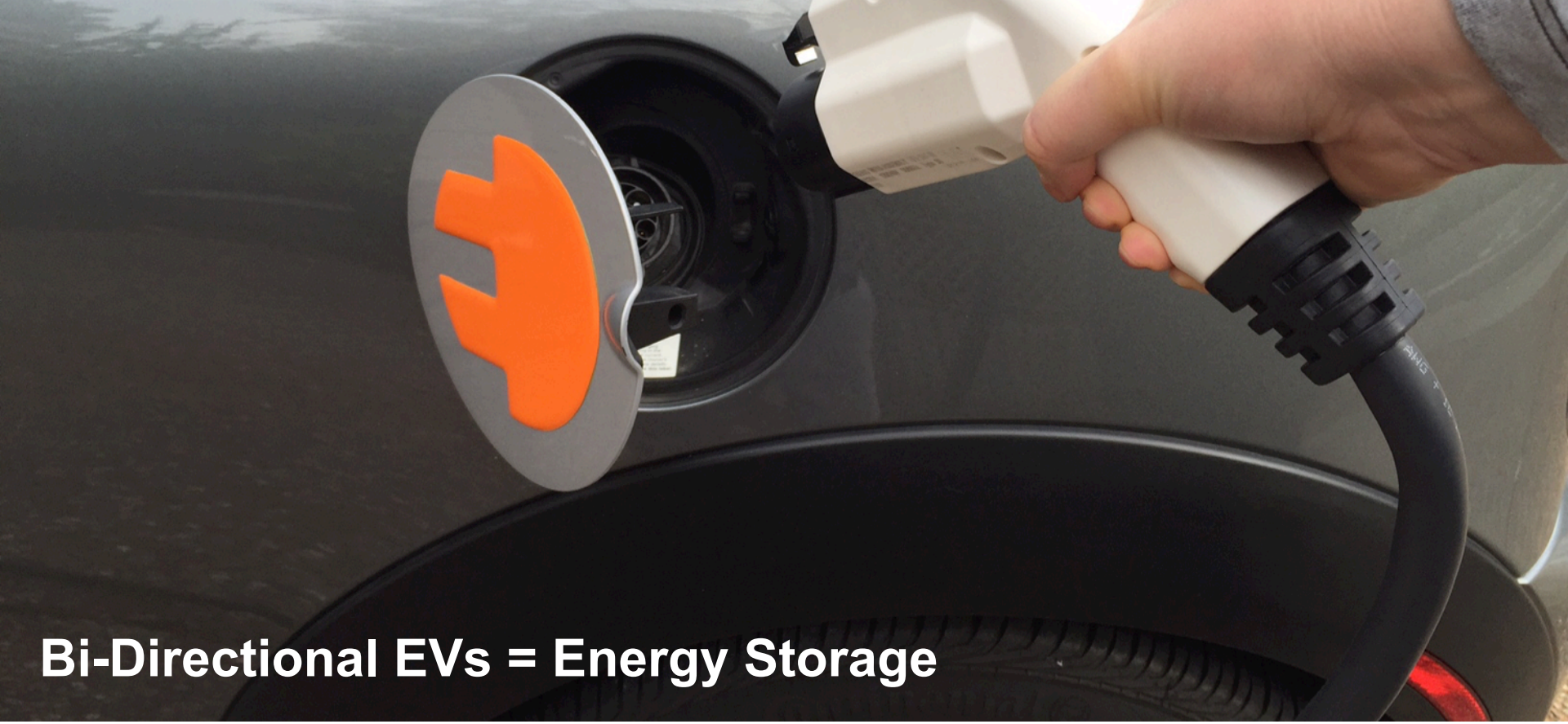

Bi-Directional EVs = Energy Storage

- Bi-Directional EVs have been confirmed as “Energy Storage” in the CPUC Energy Storage proceeding
- As California considers “Energy Storage”, Bi-Directional EVs, by definition, are included as resources
- V2x will help California achieve GHG and ZEV adoption goals sooner with compounded benefits accruing to the grid and transportation.

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University of Delaware Project: Grid on Wheels

2013 ESNA Innovation Award

- Develop and demonstrate vehicle-to-grid technology in PJM in order to:
  - ***Provide revenue to electric vehicle owners.***
  - ***Support integration of variable renewable resources.***
- Automaker participants include BMW and Honda, actively working to engage others.
- Technology developed by Univ. of Delaware, licensed by NRG, automakers, EVSE makers.
- Measuring and optimizing losses, wear, and dispatch performance

GRID ON WHEELS
power up the future

Powered by EVGRID

University of Delaware Project: Grid on Wheels

- Grossing $5/car/day in behind-the-meter grid markets.
- Value of losses from frequency regulation measured at ~30% of gross revenue.
- Optimization estimated to cut losses by a factor of 2, boost revenue by 20%.

Early Financial Results

Balance of Power

The numbers behind the University of Delaware program using cars as a money-making reserve for the electric grid

Cars used	23 (19 all-electric Mini E's, 3 modified Scion xB's, 1 experimental Honda Accord plug-in hybrid)
What they do	Store or discharge electricity according to grid needs
Special equipment needed	Control board, $200-$300 per car
Power of car batteries	12 kilowatts per vehicle*
Minimum capacity needed for a grid "bank"	100 kilowatts/9 cars
Time connected to grid	24/7 except when being driven
Average daily driving time	About an hour per car
Monthly revenue per car from grid operator	About $150
Monthly electricity cost/car	About $40
Monthly profit	About $110 per car/$2,500 total

*For Minis and Scions. Honda power not disclosed.

Source: University of Delaware — The Wall Street Journal

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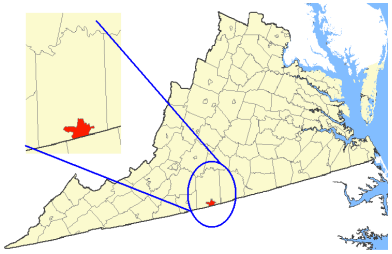
Fermata Project: V2G Commercialization Program

- Fermata, EV Grid, University of Virginia, City of Danville and Partners
- 3 Year Vehicle Development Program
- AC/DC V2G, Virtual V2G & J1772 Storage
- Storage & V2G Value Stream Building
- Located in PJM territory
- Tobacco Indemnification and Community Revitalization Commission Grant
- $4.6 Million Project Funding



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CGI Project: V2G School Bus National Demo

Under the Clinton Global Initiative – America, the following have committed to prove the economic viability of zero emissions school buses in the US fleet:

CGI AMERICA
CLINTON GLOBAL INITIATIVE

Policy Support by EVGRID

CGI Project: V2G School Bus Project Overview

Working in four States to identify School Districts, funding and partnerships in California, Massachusetts, Illinois & Texas

- Utilize existing “C” or “D” sized bus
- Install EV drive train, power electronics, batteries, V2G, V2B, and regenerative braking system
- Battery size estimated at 100 – 125 kwh
- Bi-directional charger at 60 kw
- Estimated range of school bus on a single charge – 80 miles

Current models indicate that V2G revenue can range from $5,000 to $20,000 per bus per year.

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CGI Project: V2G School Bus Update

Transportation Power, Inc.

California School Districts: Torrance, Kings Canyon & Napa each with two school buses.
Project activities:

- Kick-off meeting
- Working Groups established
- Vehicle acquisition
- Disassembly & engineering
- Preliminary site reviews
- Early interconnection discussions
- 1st Vehicle Q2 2015

Project team includes: National Strategies, NRG, E&Y, PJM, EV Grid, EPRI, CEC, CPUC, CAISO, PG&E, SCE, School Districts. California Vehicle builder: TransPower

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EV Grid Project: Indianapolis IndyGo Batteries

- High energy density 18650 cells
- Reduced battery size, cost & weight
- 250 kWh usable capacity
- 130 mile range
- Low-cost centralized charging
- Small Cells + Big Bus = Long Range

Successful battery program for MINI E

50% more energy per cell
6 times as many cells

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EV Grid Project: Battery 2nd Use

BMW GROUP

UC San Diego

ESNA 2014 Finalist

2014 Finalist: *Customer Sited Most Innovative Energy Storage Project in North America*

- 5 years old, 10k to 25K miles
- Used in CA or NY/NJ
- Well-controlled battery environment
- <20% deterioration
- De-rated to 25 kWh for 2nd use

6 Packs =
150 kWh, 100 kW

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EV Grid Facility Energy Project

COMMERCIAL FACILITY WITH WORKPLACE V2X

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Distributed Energy Generation

2nd Life Batteries & J1772 Energy Storage

$VV2X_1$ $VV2X_2$

OEM V2X Fleet Vehicles (AC & DC EVSE)

EV_1 EV_2 EV_3 EV_n

Employee Workplace V2X

Energy Applications
Peak Shaving
Renewables Storage
Time Shift
Vehicle Charging
ER Power Backup
Vehicle to Vehicle
Vehicle to Building
Grid Services

Facility Loads
Administration, R&D,
Battery Production

Data Collection
Energy
Power Quality
Employee EVMT
Fleet TCO & EVMT
GPS, Route & Efficiency
Utility Bill

Workplace Charging Challenge
U.S. DEPARTMENT OF ENERGY

What else do we need to accelerate V2x?

Education
Policy Support

Hint: ***The largest barriers are not technical.***

Business Models & Technical Matters

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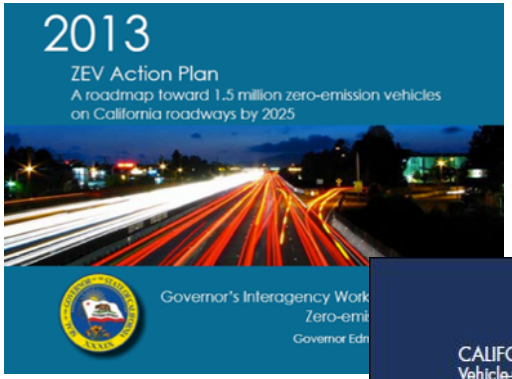
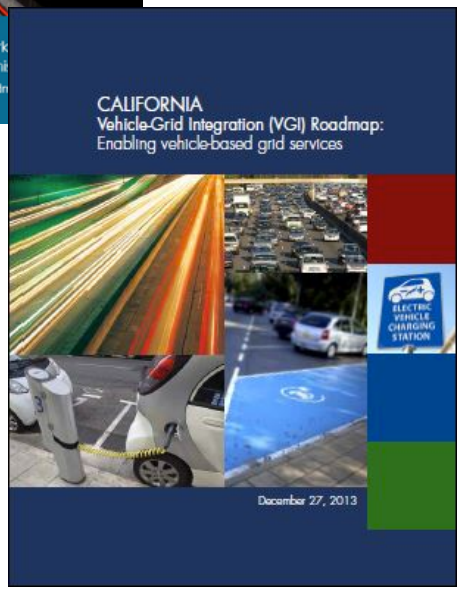
Education: Policy & Industry Participation

Stakeholder and Policy Activities

California Energy Storage Alliance
CA Governor's ZEV Action Plan
CA VGI Road Map
CA Energy Storage Road Map
NIST USNWG EV Fueling & Submetering
ARB Stakeholder Participant
CPUC Alternative Fuels Vehicle Proceeding
DOE Workplace Charging Challenge
California Energy Commission

And more…





CESA
CALIFORNIA ENERGY STORAGE ALLIANCE

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

California Environmental Protection Agency
Air Resources Board

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Education: Understanding V2x Value

… and removing barriers

Education needed across the entire EV ecosystem

- V2x is not easy and therefore not for everyone, ***yet.*** Early adopters will have early access to value streams.
- Fleets of V2x vehicles have the potential to provide Distributed Energy Storage at the lowest cost, period.
- V2x provides 8 to 12x the power, energy, and GHG reductions potential of V1G + additional value streams not available with V1G.
- V2x vehicles and EVSE infrastructure are expected to be V1G compatible.

Battery Degradation, Range Anxiety and Battery Economics

- Energy density and cost reductions compounded every year
- Most expensive component – work to optimize the value over life time of the battery
- **"Don't touch my battery" -> "Please use my battery!"**

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Education: Value Streams – Without Policy Changes

When Electric Vehicles become bi-directional, what values are unlocked?

- Vehicle to Vehicle (V2V)
- Vehicle to Emergency Response (V2ER)
- Vehicle to Power Export (V2P-EXP)
- Vehicle to Home (V2H)
- Vehicle to Building, Micro/Nano Grid (V2B)
- Vehicle to X + Energy Storage (V2X+ES)

Requirements: Energy Application – AC or DC, bi-directional capable vehicle, safe connection and control system that matches application.

Honda Smart Home at UC Davis
Photos courtesy of
American Honda Motor Co., Inc.

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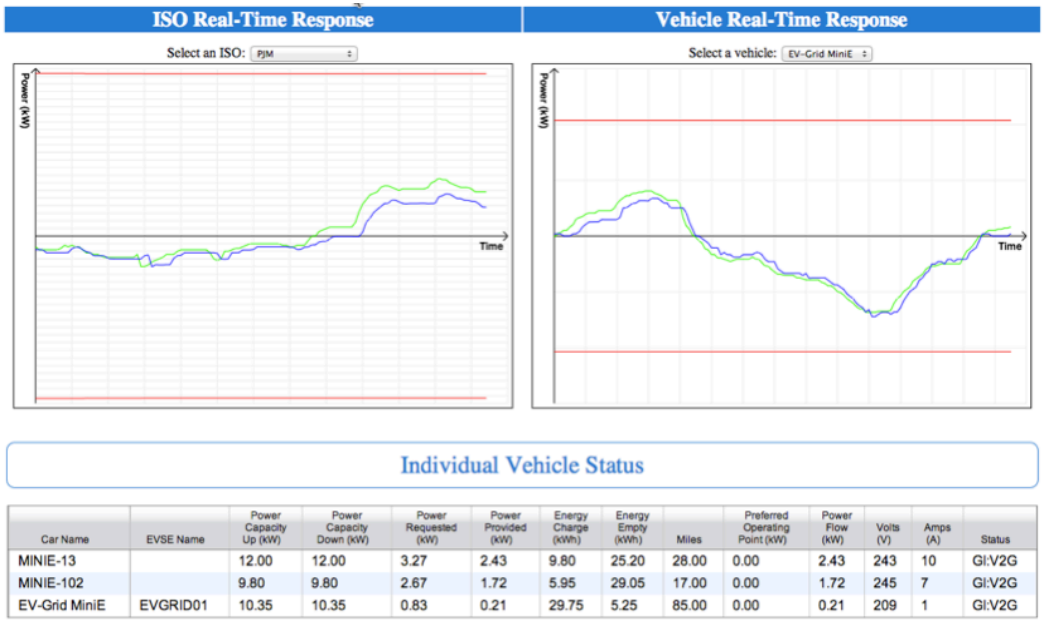
Education: Value Streams – Beyond the Meter

Vehicle to Grid (Energy Storage) Opportunities

- Lowest cost batteries
- Capacity Markets
- Energy Markets
- Grid locational values
- High value, fast responding resource
- Retail and wholesale programs
- Optimization across fleet of assets



Car Name	EVSE Name	Power Capacity Up (kW)	Power Capacity Down (kW)	Power Requested (kW)	Power Provided (kW)	Energy Charge (kWh)	Energy Empty (kWh)	Miles	Preferred Operating Point (kW)	Power Flow (kW)	Volts (V)	Amps (A)	Status
MINIE-13		12.00	12.00	3.27	2.43	9.80	25.20	28.00	0.00	2.43	243	10	GI:V2G
MINIE-102		9.80	9.80	2.67	1.72	5.95	29.05	17.00	0.00	1.72	245	7	GI:V2G
EV-Grid MiniE	EVGRID01	10.35	10.35	0.83	0.21	29.75	5.25	85.00	0.00	0.21	209	1	GI:V2G

University of Delaware
Real-Time Vehicles & ISO Response

- Different rules for different markets, policy changes required to maximize benefits

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Education: Mobile Storage is Unique

- Energy Storage with wheels has unique characteristic with unique benefits that, over time will far outweigh their integration challenges
- V2G is just one of the value streams in an entire suite of V2X opportunities that open up with vehicles that offer bi-directional otherwise have V2n (nothing)
- "Smart Inverter" policy must be aware of the mobile use case and not preclude interconnections with in-appropriate requirements
- Standards bodies are embracing the challenge and V2X related working groups are making progress

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Policy: Challenges & Opportunities

- Connections / Permitting – Building codes, electrical capacity accounting for bi-directional
- Cost Effective & Timely Interconnections – Behind the meter and exporting applications, retail / wholesale markets access
- Rate & Tariff Design Beyond TOU – Compatible with fueling, energy services and smart charging
- Net Energy Metering – Co-located renewables integration (PV+EV)
- Energy storage integration – Allowing multiple non-generating resources (ES+EV, Ideally PV+ES+EV)
- Isolating transportation energy from energy services
- Access to green transportation energy tariffs

- Consider incentives for vehicles and infrastructure that offer advanced energy features contributing most towards policy goals

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Business & Technical: Challenges & Opportunities

- Business model development that includes all value streams starting with those that are available today
- Reducing the cost of metering, communications and telemetry
- Developing cost effective aggregation platforms for early market
- Energy pool creation with small fleets, enable with stationary
- Capturing transportation savings AND bankable energy storage value to invest in infrastructure. Connected vehicles provide value.
- Batteries - Degradation modeling and amortizing across battery life
- Component Cost Reductions – Bi-directional inverters, power electronics, EVSEs
- Standards – Automotive, Utilities, EVSEs, Communications

- **Biggest risk: Waiting until everything is "Ideal".**

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V2X History: How do we continue moving forward?

1997 Kempton (Univ. of Delaware) & Letendre
First paper on vehicle-to-grid

2001 AC Propulsion first test bi-directional AC150 Gen 2

2002 AC Propulsion demo of grid regulation by EV

2003 AC Propulsion demo of grid-tied and stand-alone power from PHEV

2005 Seattle Electric Vehicle to Grid Forum

2008 EV does V2G at Plug-In 2008 Conference (July, 2008, San Jose, CA)

2010 Development of SAE J1772 compliant, V2G-capable EVSE

2013 Grid on Wheels
First revenue producing V2G fleet @ University of Delaware
ESNA Innovation Award

2014 EV Grid Announces Multiple Storage Projects @ ESNA

1997 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2013 2014

2001 DaimlerChrysler - "We can use the energy unit in this car for homes."

2001 EPRI: "The Car of the Future May Help Power Your Home"

2002 General Motors – Grid connection for fuel cell cars

2004 SCE, Austin Energy discuss a 2nd generation of connected cars with V2G

2006 GM, Delmarva, University of Delaware, AC Propulsion discuss future of V2G

2007 PHI, University of Delaware demo live grid regulation with eBox at FERC, Washington DC

2009 Fleet of 5 EVs operates in revenue generating V2G mode in PJM grid

2011 NRG & Univ. of Delaware launch eV2g

2014 US EV Sales reach 250,000

2014 DOD & Air Force launch V2G program

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Energy storage in the fast lane.

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Thank you!

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