Electric Vehicles and Vehicle to (Grid/Bldg)

Presented by

Ted Bohn, Principal Engineer

Center for Transportation Research,
Argonne National Laboratory

March 20, 2013

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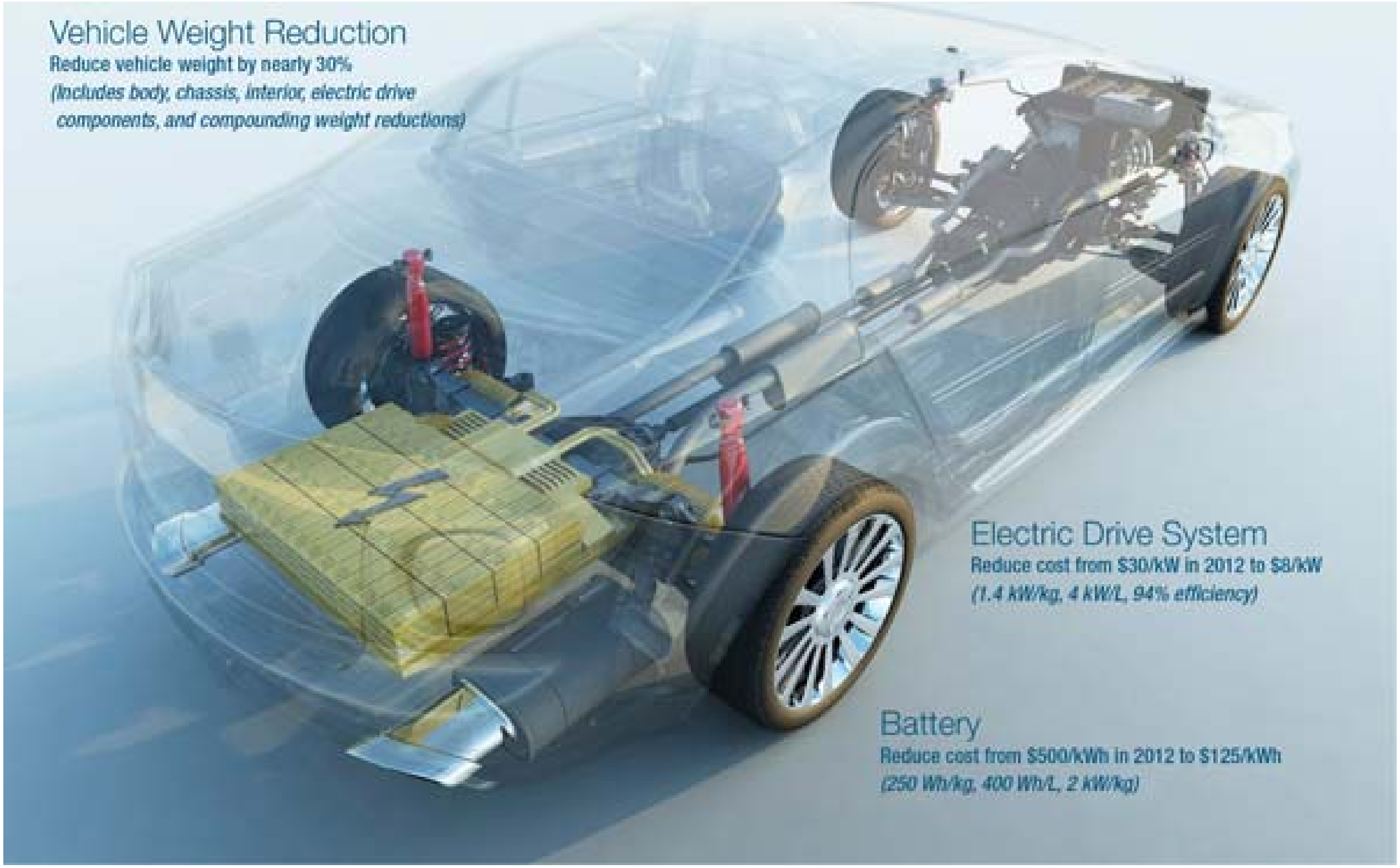
About the Lecturer…

- Ted Bohn is a former student of IIT - Electrical Engineering (circa 1984- via Fermilab)
- Received Bachelors and Masters in Electrical Engineering at University of Wisconsin-Madison and currently holds an adjunct position at UW-Madison.
- Has worked for each of the Big-3 US Vehicle OEMs
- Has over 30 years experience with electric vehicle and related power electronics applications
- Heads several SAE standards committees and the EV-Smart Grid Interoperability Center at ANL.

Legacy of DOE Technology Programs

- **Partnership for New Generation Vehicles** (PNGV; 1993-2001) {Clinton era, canceled by Bush}
  3 liter/100km (~80mpg) vehicle goal by 2003
- **FreedomCAR** (focus on Fuel Cells 2001-2010) (2010 budget called for zero FCEV funds, -60%)
- **USDRIVE** *Driving Research and Innovation for Vehicle efficiency and Energy sustainability (2011-)*
- **EV Everywhere Challenge**: 2012- 5 year ROI on EVs
  $125/kWhr, 250Wh/kg, 400Wh/L, 2kW/kg

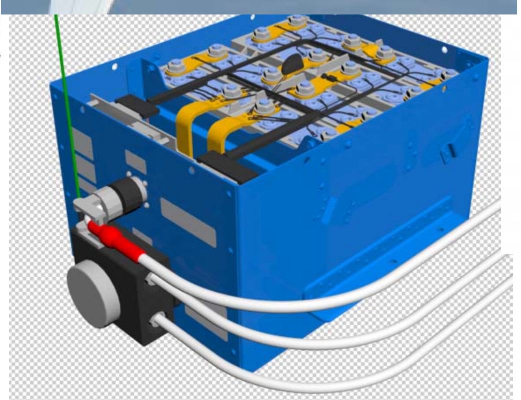
EV Everywhere Cost/Weight Goals

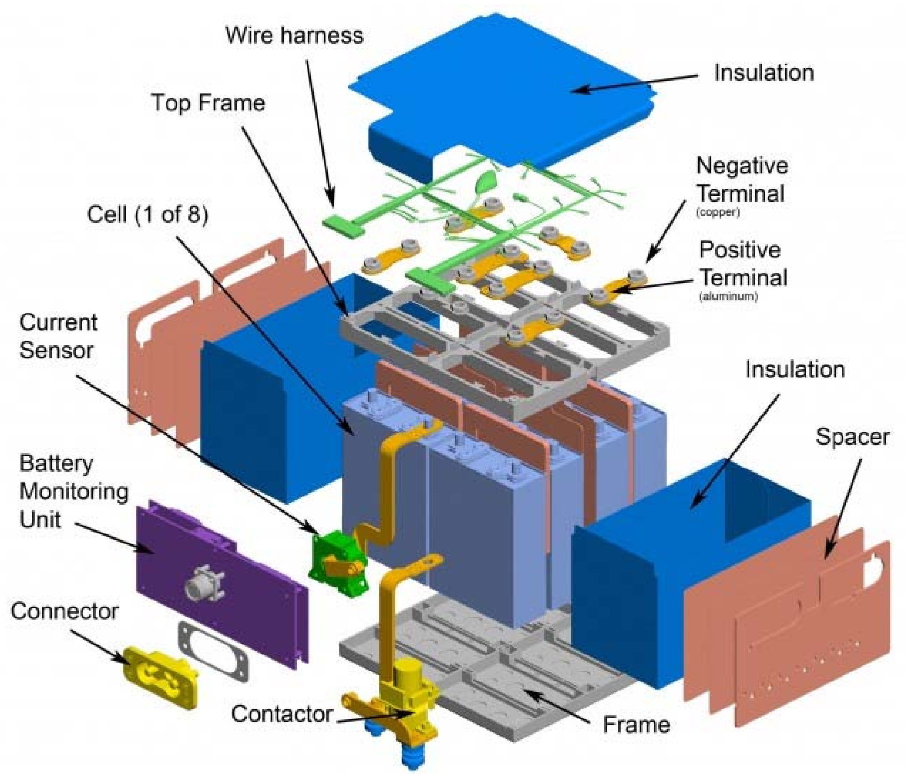


Context for Relevant Battery Standards

Boeing 787 Dreamliner: 8 cells, 32.2v/65Ahr Li-ion

Cell#6 short circuit 500+degF 'issue'





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DEPARTMENT OF ENERGY UNITED STATES OF AMERICA

Historical Perspective- GM Electrovair

~50 Years Ago

- Batteries in front and rear of vehicle, rear drive motor and rear electronics/cooling

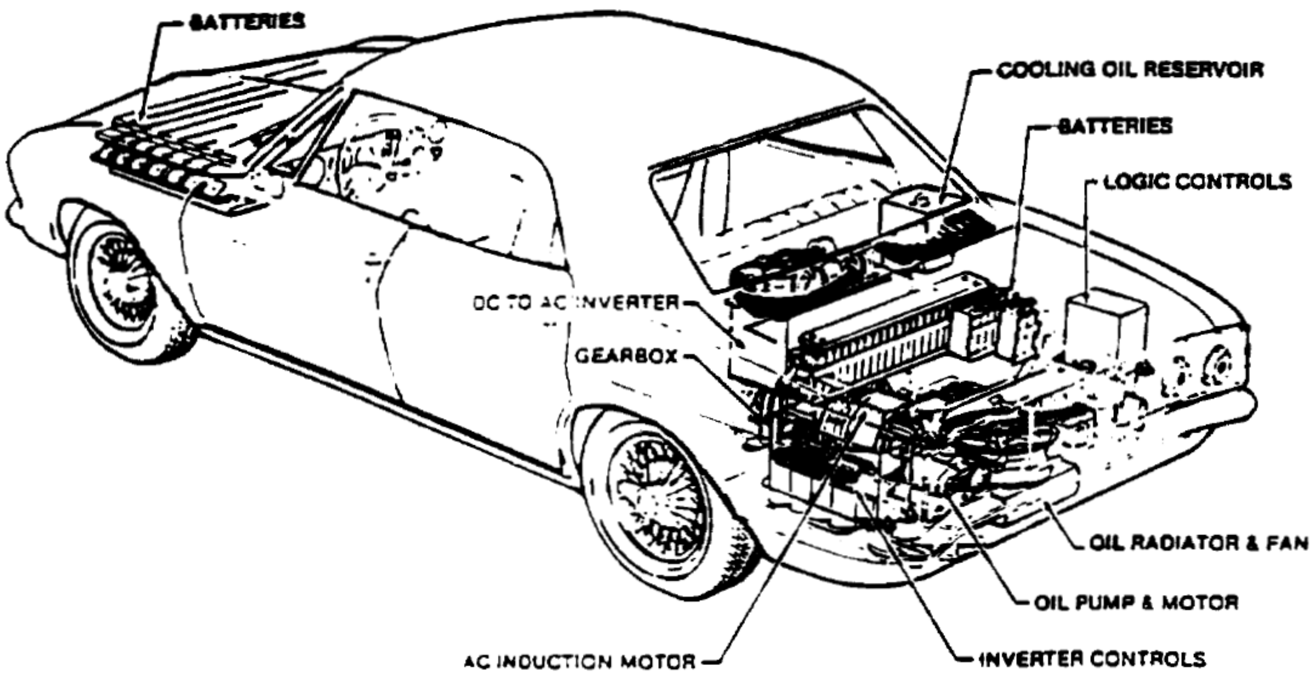
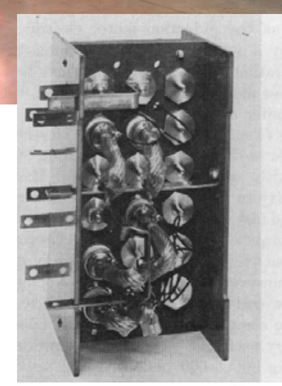
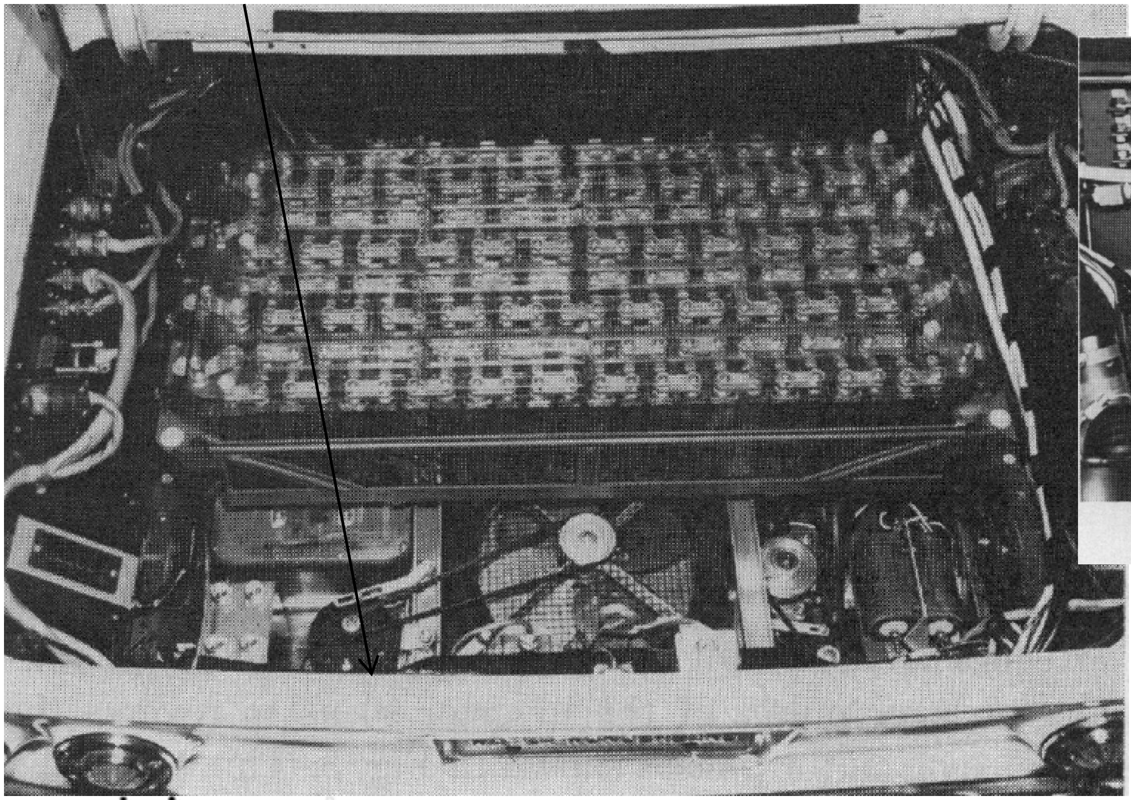


Fig. 1 CUTAWAY VIEW OF GENERAL MOTORS ELECTROVAIR



Electrovair Electronics Packaging
532V Silver Zinc Batteries

- Batteries in center of rear of Corvair, electronics wrapped on the sides, motor below (belt driven fan)



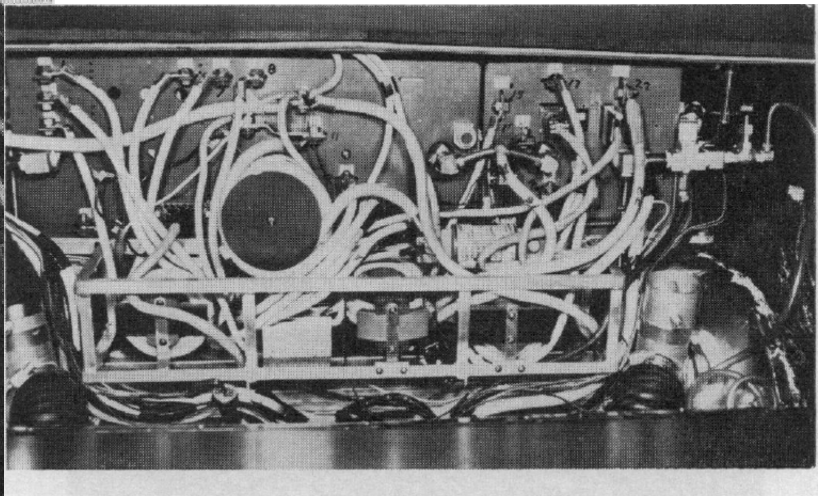
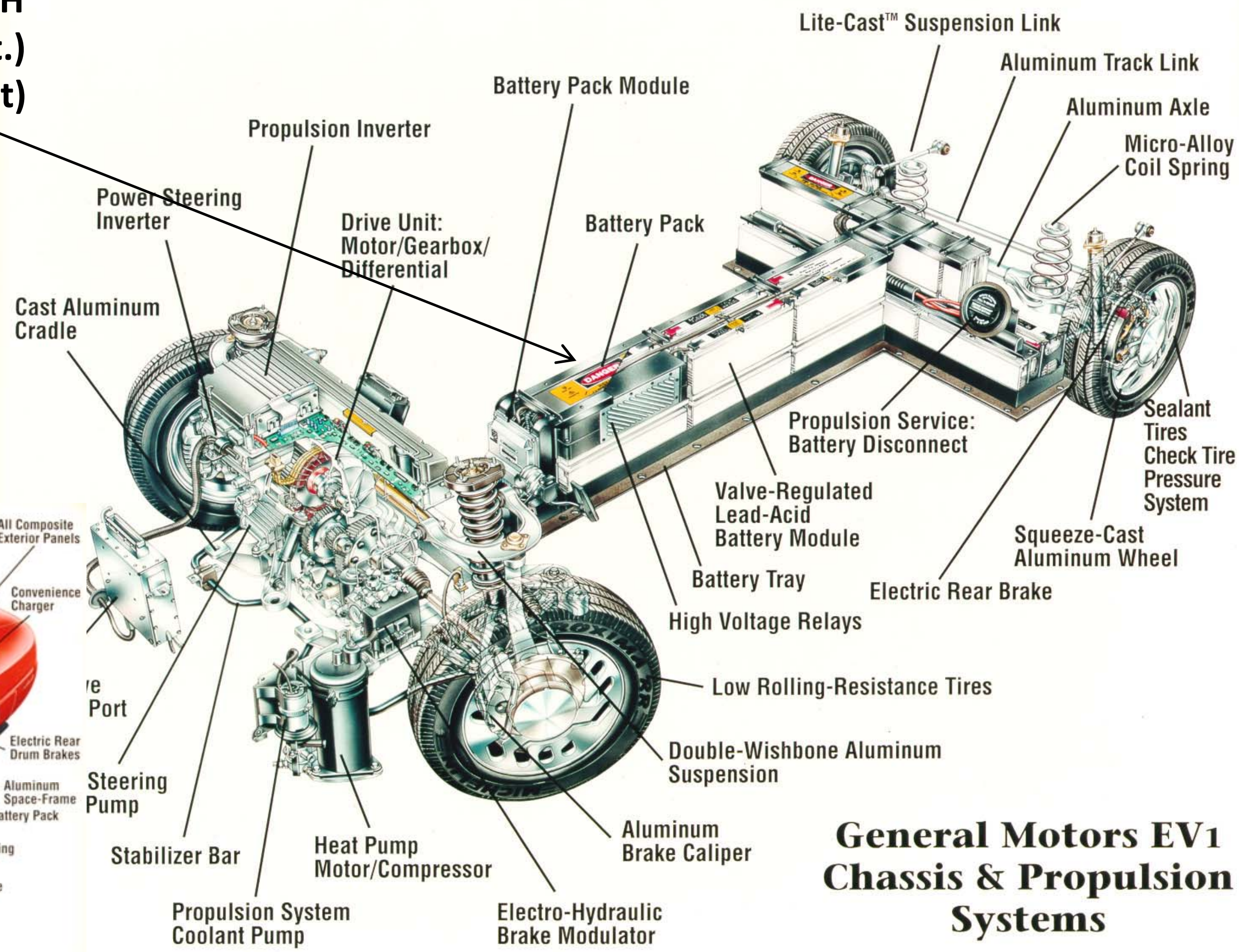


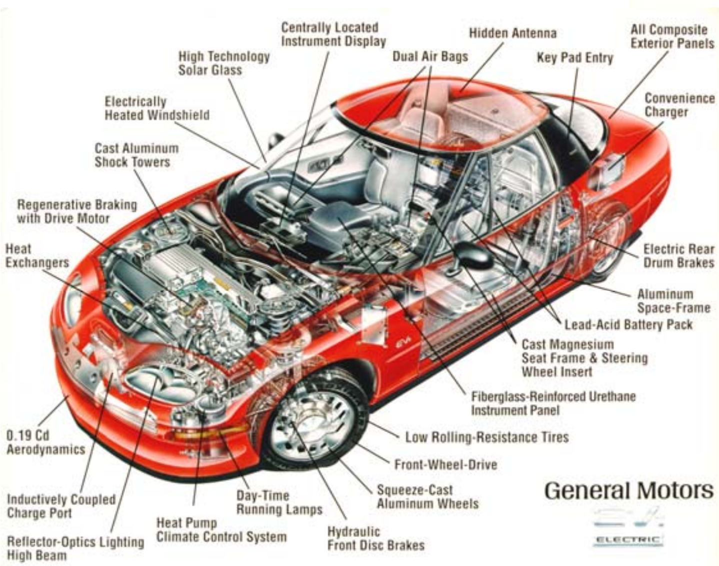
Fig. 12. Layout of modulator and inverter.

[2]. T. Salihi, P.D. Agarwal et al, " Induction Motor Control Scheme for Battery Powered Electric Car (GM - Electrovair I)", IEEE Trans. on Industry and General Applications, Sept./Oct. 1967, PP. 463-469.

GM EV-1 Powertrain (~ 30 years ago)

Gen 1 Lead Acid 1310lb, Gen 2 NiMH
- PbA- 16.5kWhr (3086 lbs curb wt.)
- NiMH- 26.4kWhr (2908 lbs curb wt)





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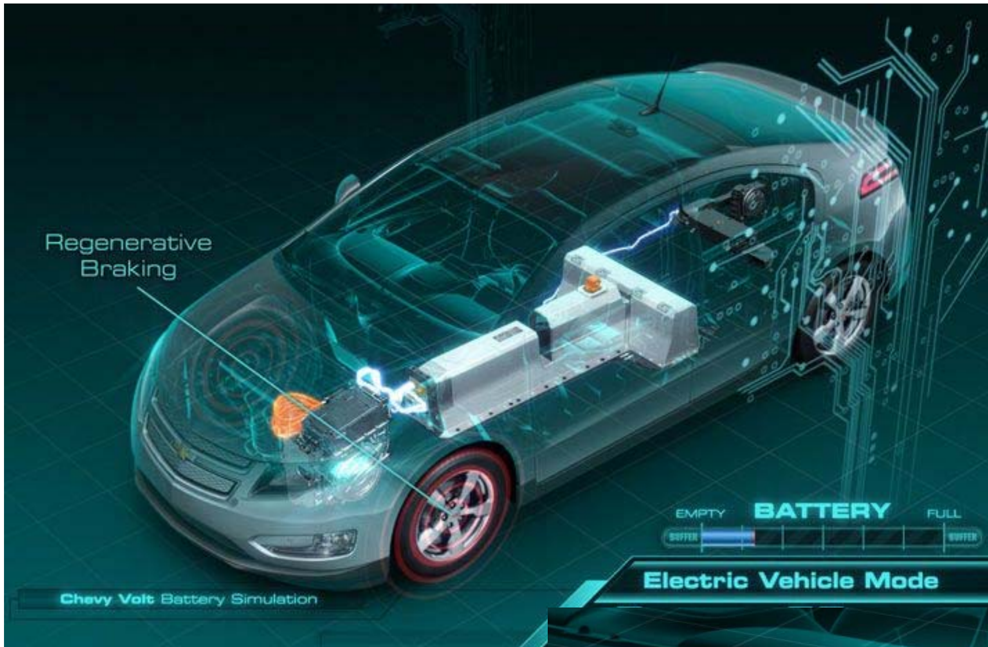
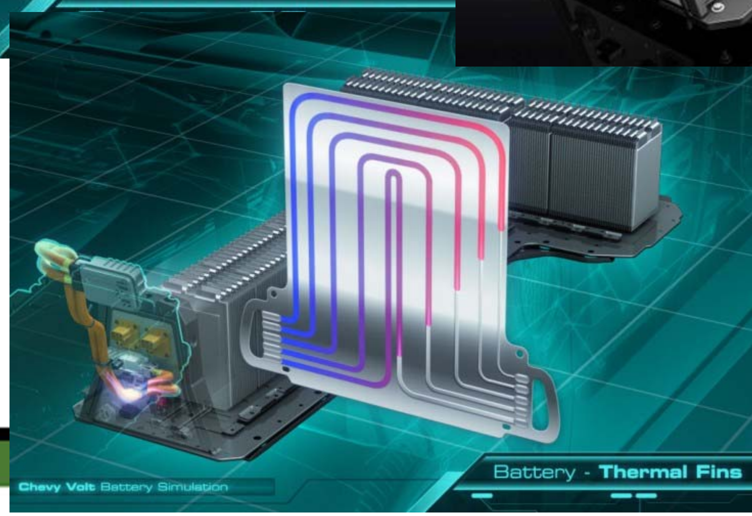
Chevy Volt (~ 6 years ago)

288 cells, 9 modules, 345v/45Ahr, 16kWhr, 435lb





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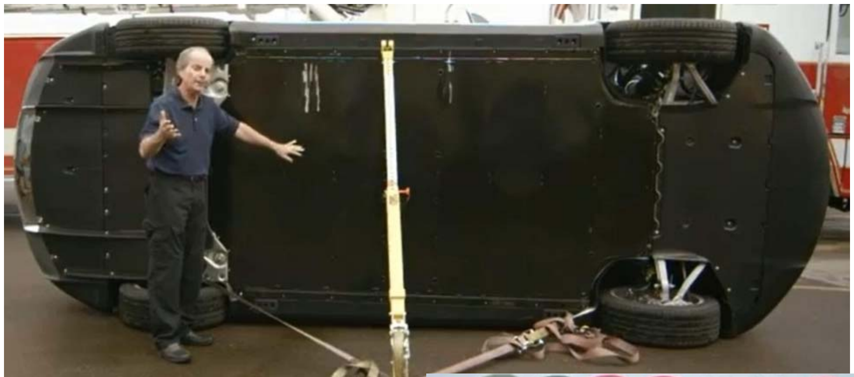
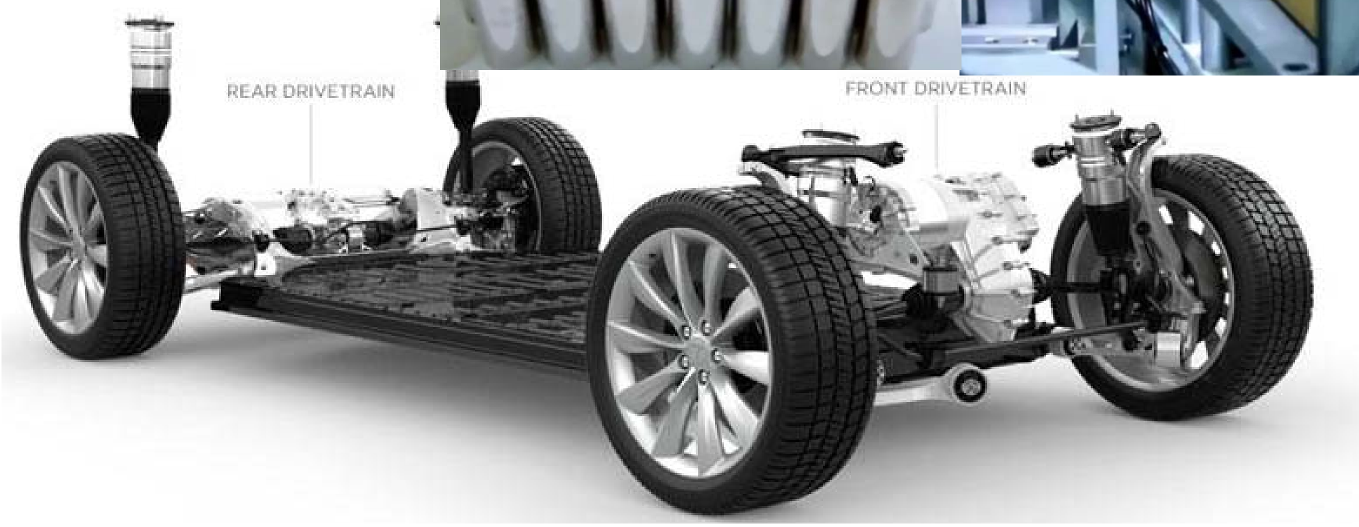
Today- Tesla Model S- 85kWhr

~8000 (18650. 3.1Ahr, 735Whr/L) cells, ~1 module, 400v/212Ahr, 85kWhr





Back to the Future of Electric Vehicles- Gull Wing Doors or Wing Tip Shoes?

EV Prices Inflation Adjusted vs Gasoline Vehicles (Harpers Magazine- 1914)

1914 Detroit Electric:$2500=**$56,825** (2012)

1914 Model T Ford:$550=$12,500 (2012)

($22.73:$1 conversion factor)

Columbia Electric Price Range

Runabout; $900=$20,500 (2012)

Surrey; $1700=$38,641 (2012)

IN the past 12 months there have been twice as many Detroit Electrics sold as any other make of electric car. This greater volume reduces manufacturing costs and also reduces selling expenses—two vital reasons why we offer *better* cars at *lower prices.*

Purchasers for 1914 have their choice of *worm* or *bevel* gear axles, Detroit Duplex Drive, front or rear seat drive. New equipment includes electric hand brake, longer wheel base, yet a 12-foot shorter turning radius than heretofore; larger tires, increased battery capacity (washing unnecessary); all battery cells accessible by raising hoods; Hanlon patented rain-vision shield, oval crowned fenders and deep Turkish cushions.

Note the Prices:

With Bevel Gear Axle		With Worm Gear Axle	
Victoria	$2300	Gentleman's Roadster	$2500
4-pass. Brougham Rear Seat Drive	2550	4-pass. Brougham Rear Seat Drive	2850
5-pass. Brougham Front Seat Drive	2800	5-pass. Brougham Detroit Duplex Drive	3000

(Prices f.o.b. Detroit)

These cars are on exhibition at our branch offices and selling representatives of the Company in over 175 cities. Demonstrations gladly furnished any time. Send for our new catalog in colors.

Anderson Electric Car Company, Detroit, U.S.A.

Builders of the "Detroit Electric"

Largest manufacturers of electric pleasure vehicles in the world

PRICE LIST

COLUMBIA GASOLENE CARS AND ELECTRIC PLEASURE VEHICLES

DECEMBER 1, 1904

Columbia Touring Car, Mark XLI	$3500
Columbia Touring Car, Mark XLI, with Limousine Body	4500
Columbia Touring Car, Mark XLII	4000
Columbia Touring Car, Mark XLII, with Side Door Entrances to Rear Seat, Wood Body	4200
Columbia Touring Car, Mark XLII, with Side Door Entrances to Rear Seat, Aluminum Body	4500
Columbia Touring Car, Mark XLII, with Limousine Body	5000
Columbia Light Gasolene Tonneau, Mark XLIII	1750
Columbia Light Gasolene Tonneau, Mark XLIII, with Canopy Top	1950
Columbia Electric Runabout, Mark LX	900
Columbia Electric Runabout, Mark LX, with Top	$975 and 1000
Columbia Electric Victoria, Mark XXXI, without Hood	1500
Columbia Electric Victoria, Mark XXXI, with Hood	1600
Columbia Electric Surrey, Mark XIX	1500
Columbia Electric Surrey, Mark XIX, with Underslung Battery	1700

Surrey Canopy Top, with Side Curtains, $100 extra.

Net F. O. B. Cars Factory, Hartford, Conn.

Some Current Production PEVs

Model	Base price after tax credit	Electric range (miles)	Total range (miles)	MPGe (electric)	Top speed	Hours to charge, 120V	Hours to charge, 240V
Mitsubishi MiEV	$21,625	62	62	112	80	23	7
Nissan Leaf	$27,700	73	73	99	93	20	7
Honda Fit Electric	$29,125	76	76	116	92	15	3
Toyota Prius Plug-In	$29,500	12	540	95	112	3	2
Chevy Volt	$31,645	35	379	93	100	10	4
Ford Focus Electric	$32,495	76	76	105	84	20	4
Tesla Model S 40 kWh	$49,900	125*	125*	108	110	?	~5
Tesla Model S 60 kWh	$59,900	187*	187*	89*	120	?	~7.5
Tesla Model S 85 kWh	$69,900	265	265	89	125	?	~10



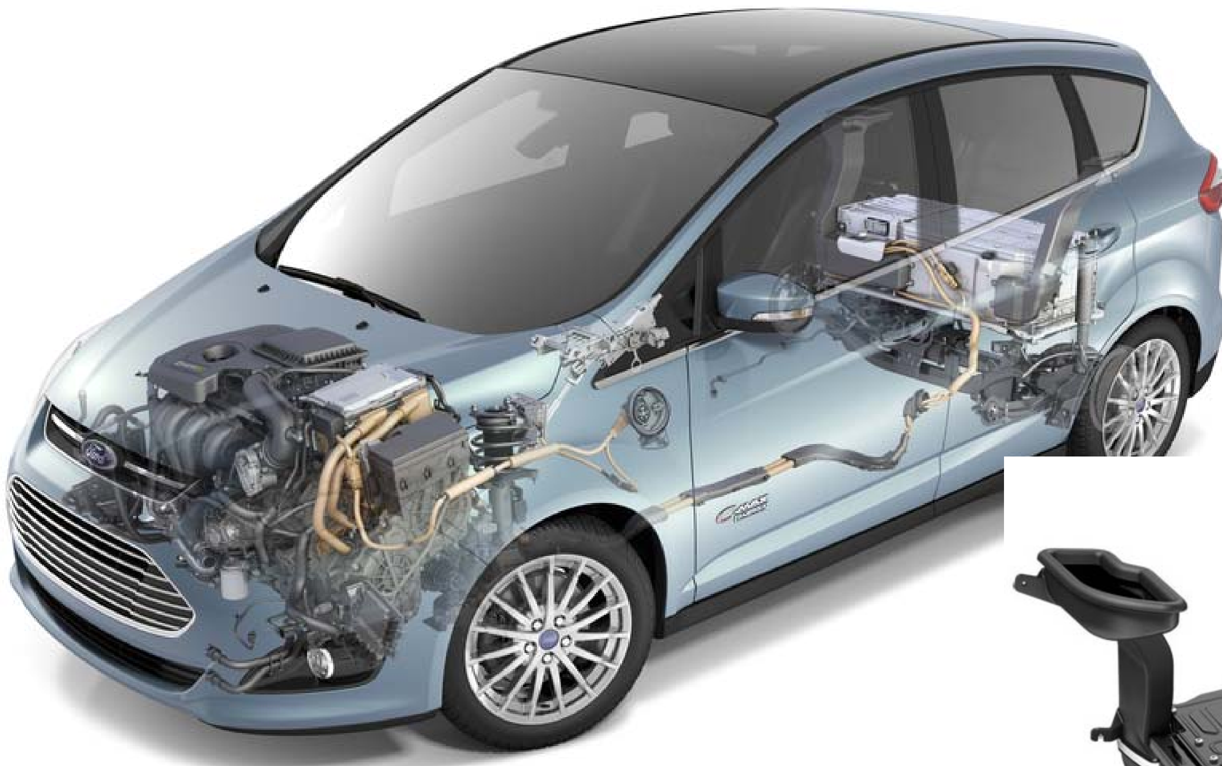
Plugin Vehicle Battery Requires Appropriate Charging Rates

- **Plug in Hybrid Electric Vehicle (PHEV)**
  - Very limited electric range – small battery 5-10 kWhr
  - Charge power 1-3 kW

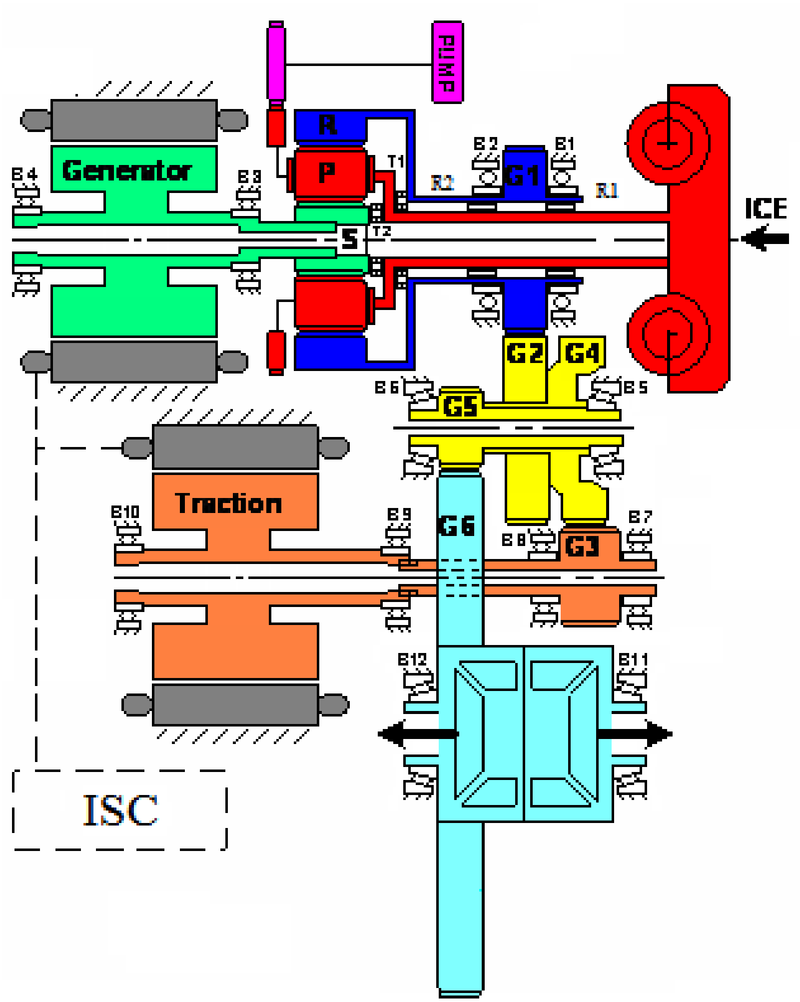
- **Extended Range Electric Vehicle (EREV)**
  - Increased electric range – medium battery 10-20 kWhr
  - Charge power up to 6 kW

- **Battery Electric Vehicle (BEV)**
  - All electric range – large battery >20kWhr
  - Charge power > 6 kW

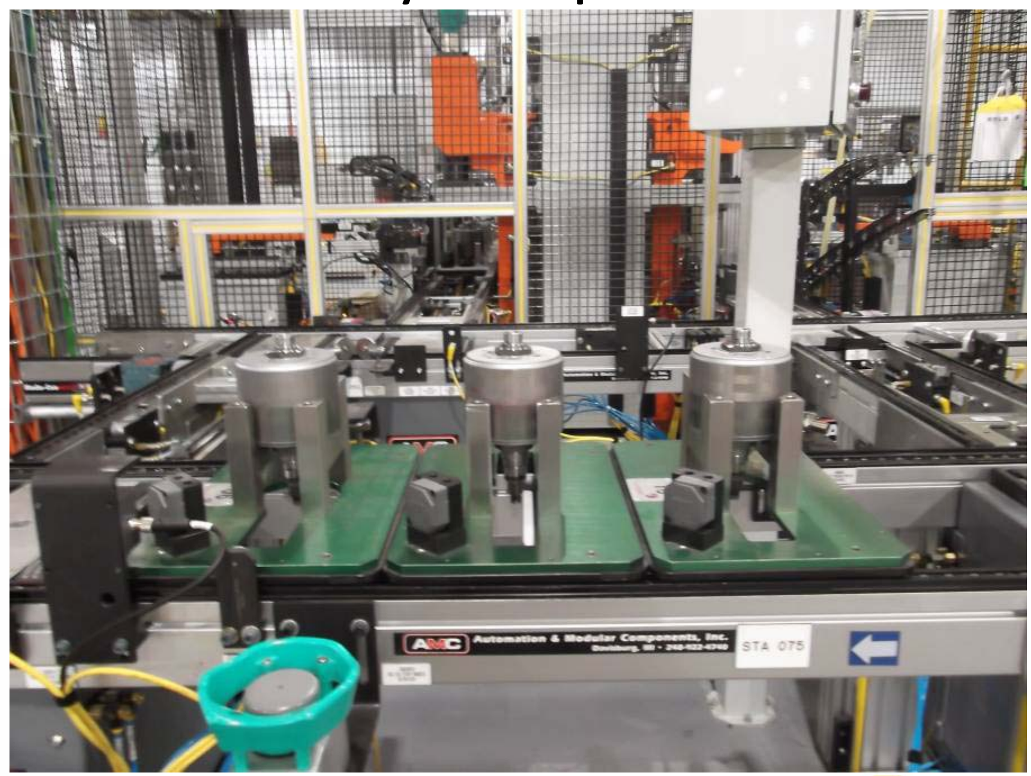
Ford C-Max Energi PHEV-21



Ford HF35 modular transmission
Produced on Same Assembly Line as 6 speed.



- 134 New Parts
- 43 Carryover parts



EV Battery Standards

Standards? We've got hundreds of them…

EV Battery Related Standards

(Some stds apply to multiple chemistries, some only Li-ion)

- SAE J2464 ***Electric Vehicle Battery Abuse Testing***
  http://standards.sae.org/j2464_200911/ (1999/2009)
- SAE J2380 ***Vibration Testing of Electric Vehicle Batteries***
- SAE J2929 - ***Safety Standard for Electric and Hybrid Vehicle Propulsion Battery Systems Utilizing Lithium-based Rechargeable Cells***
- SAE J2990- ***Hybrid and EV First and Second Responder Recommended Practice*** which offers recommended practices for emergency personnel responding to incidents involving hybrid or electric vehicles.

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EV Battery Standards

- SAE J3009 ***Stranded Energy - Reporting and Extraction From Vehicle Electrochemical Storage Systems***
  SAE Battery Field Discharge and Disconnect Committee
- SAE J1797 ***Recommended Practice for Packaging of Electric Vehicle Battery Modules***
- SAE J1797 Recommended Practice for Packaging of Electric Vehicle Battery Modules provides for common battery designs through the description of dimensions, termination, retention, venting system, and other features required in an electric vehicle app...
- SAE J2344 ***Guidelines for Electric Vehicle Safety***
- SAE J2910- ***Recommended Practice for the Design and Test of Hybrid Electric and Electric Truck and Buses for Electrical Safety***

SAE J3009- Stranded Energy Extraction

Establishment of recommended practices to enable safe field procedures to:

- Determine whether capability of field discharge of a propulsion battery is necessary and useful
- Should field discharge capability be determined necessary and useful, develop standardized methods, interfaces, and design guidelines to enable same.

- The effort shall be focused on high voltage propulsion systems in light duty vehicles exceeding 60V DC. In addition to evaluating the value of standardized methods, interfaces, and design guidelines, the committee shall also consider required capability of any end-user expected to utilize developed field procedures. The depowering device is assumed to be external to the vehicle.
- The committee will evaluate the value of standardization of various attributes such as, level of discharge sophistication ("smart"/"dumb"), interface characteristics, and level of required user training. It is anticipated the committee will coordinate closely with, and compliment the work of, the Hybrid and EV First and Second Responder Task Force (SAEJ2990).

NHTSA-ANL Trapped Energy Project

1) Generate a logic diagram describing all safety critical conditions and expected actions for a *common* safety assessment and handling of a RESS in terms of stranded energy

- Vehicle Mechanical Failure not involving the RESS
- End of Life – Second Use or Recycle
- Minor Vehicle Crash (not involving the RESS)
- Major Vehicle Crash
- RESS Damage or Malfunction
- RESS extreme damage (Fire or physical separation)

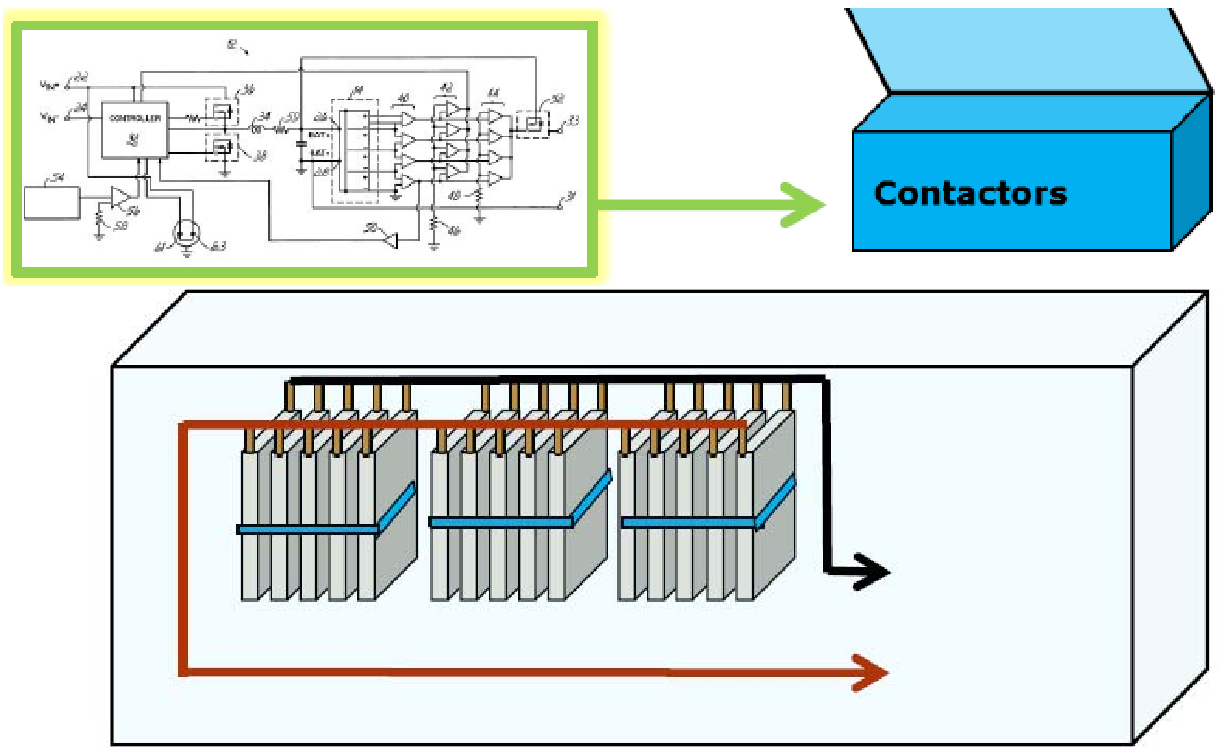
2) Define diagnostic assessment criteria for determining the stability and condition of the RESS

- Identity of the RESS
- Variables
- Protocol
- Architecture

3) Define a common Interface to support diagnostics and discharge functions

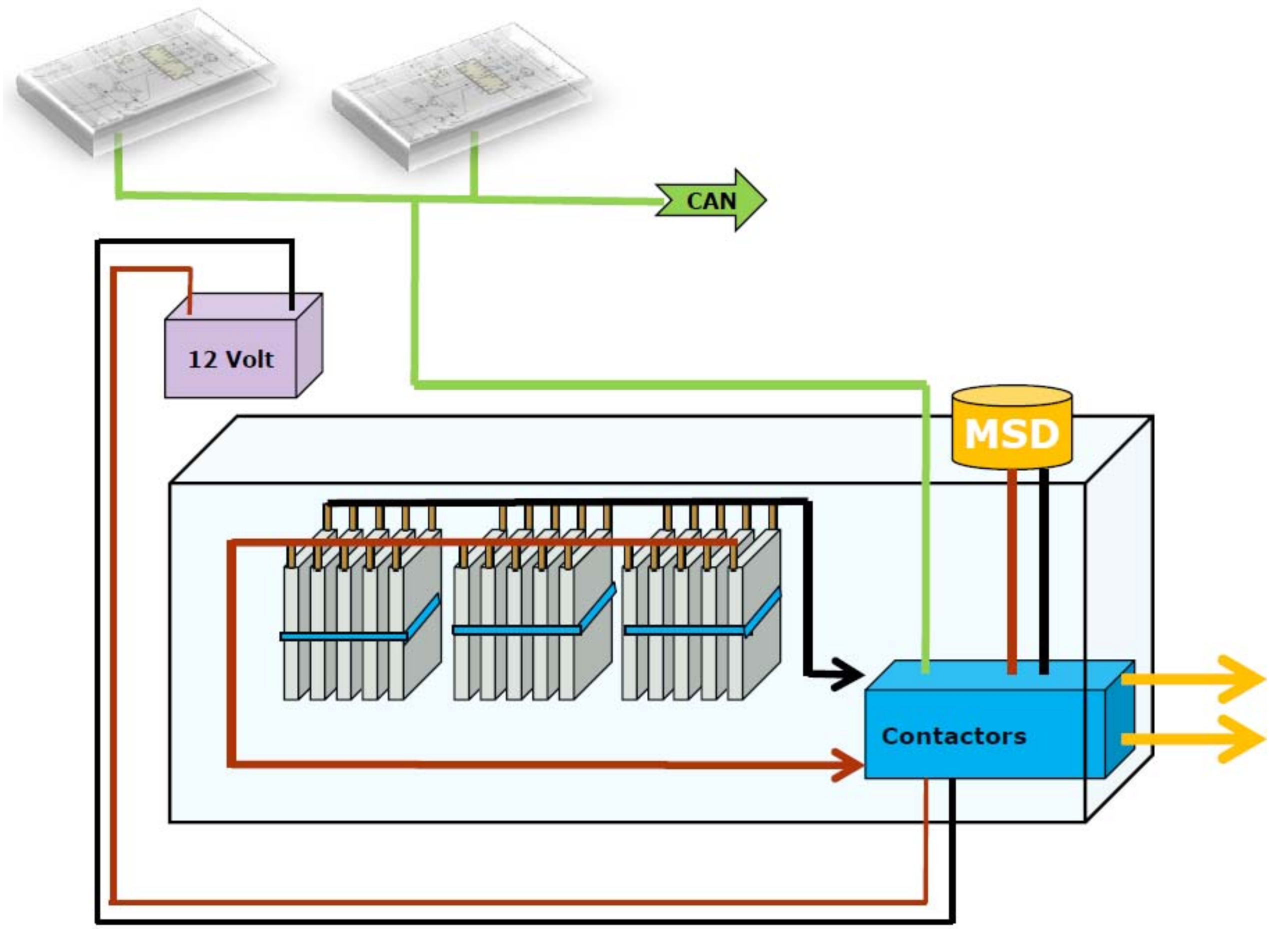
Challenge to Isolate/Identify Cells that May Cascade Runaway to Other Cells

- BMS, Contactors, Cells- lack of Standardized interface



Depowering Procedure Has Several Use Cases, Depending on System Integrity

1) Happy Full Function Pack/System

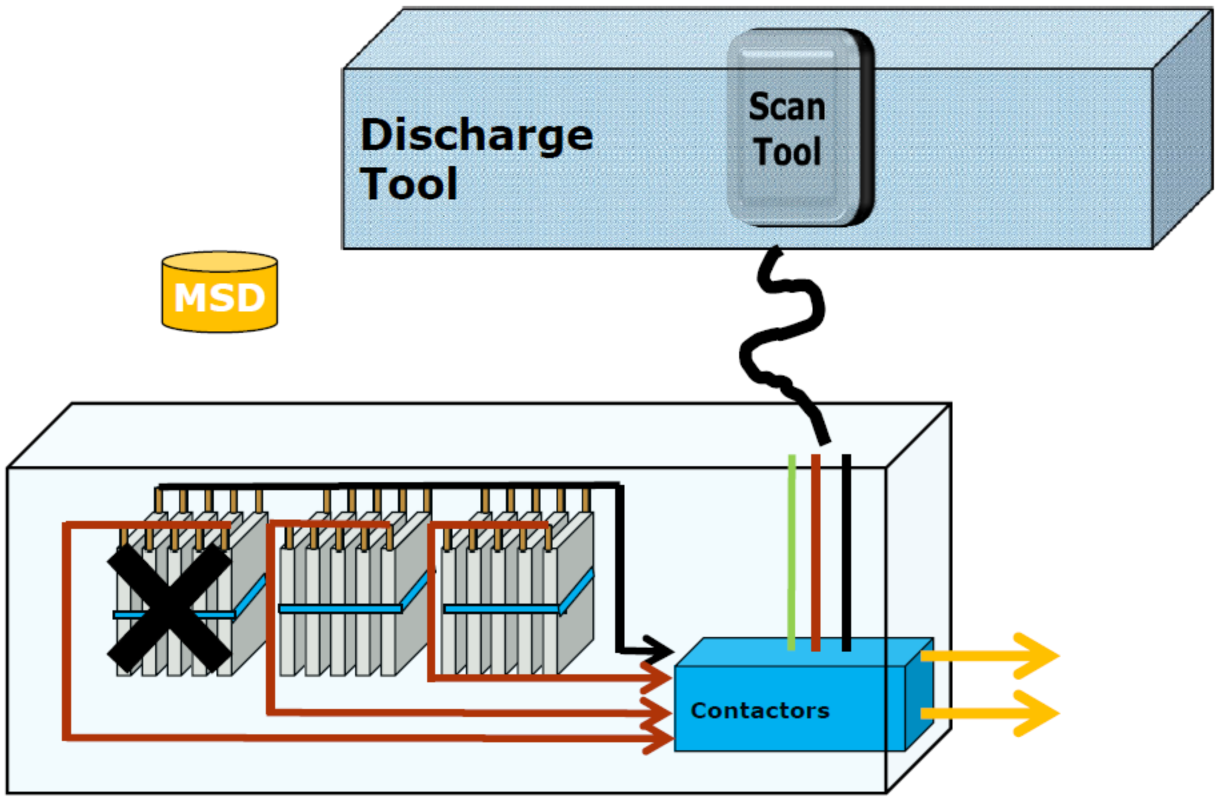


Depowering Procedure Has Several Use Cases, Depending on System Integrity

2) No diagnostics

Partial Function

Pack/System



Purpose built ($10K+) tools exist, NHTSA Project to create universal tool

- Midtronics GRX-5100HD (7.5A, 384vdc discharge)

View Pack Info: Captures the vehicle VIN and generates a detailed status report for the vehicle's battery pack, including temperature sensors and individual cell voltages.

Supported Vehicles

Make	*Model*
Alpheon	Alpheon
Buick	Regal, LaCrosse
Chevrolet	Malibu, Volt
Opel	Ampera
Vauxhall	Ampera

FMVSS 305
ELECTRIC POWERED VEHICLES: ELECTROLYTE SPILLAGE AND ELECTRICAL SHOCK PROTECTION

- Reference- http://www.nhtsa.gov/DOT/NHTSA/Vehicle%20Safety/Test%20Procedures/Associated%20Files/TP-305-01.pdf
- **Digest**: When an electric vehicle is in a collision three requirements are important:

  1) Don't spill electrolyte; especially on occupants.
  2) Battery modules inside the passenger compartment must stay where they are. Ones outside, stay outside.
  3) Maintain electrical isolation from passengers (500Ω/V)

- *I.e. After collision, minimize acid leaving vehicle, no batteries entering or moving in passenger compartment, no shocking the occupants or safety workers.*

NFPA-SAE Annual EV Safety Summit

- www.sae.org/events/nevss/ Detroit MI; Oct 2010-2013

Past presentations (Including by T. Bohn-ANL)

- (2010) http://www.nfpa.org/assets/files/PDF/Research/RFUSNEVSSSummit.pdf
- (2011) www.nfpa.org/assets/files/research%20foundation/2ndevsssummitreport.pdf
- (2012) http://www.nfpa.org/itemDetail.asp?categoryID=2715&itemID=58903&URL=Training/Conferences/Electric%20Vehicle%20Safety%20Standards%20Summit&cookie%5Ftest=1

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Post-SuperStorm Sandy

One precipitating event, many outcomes

- 336 Fisker Karmas gone

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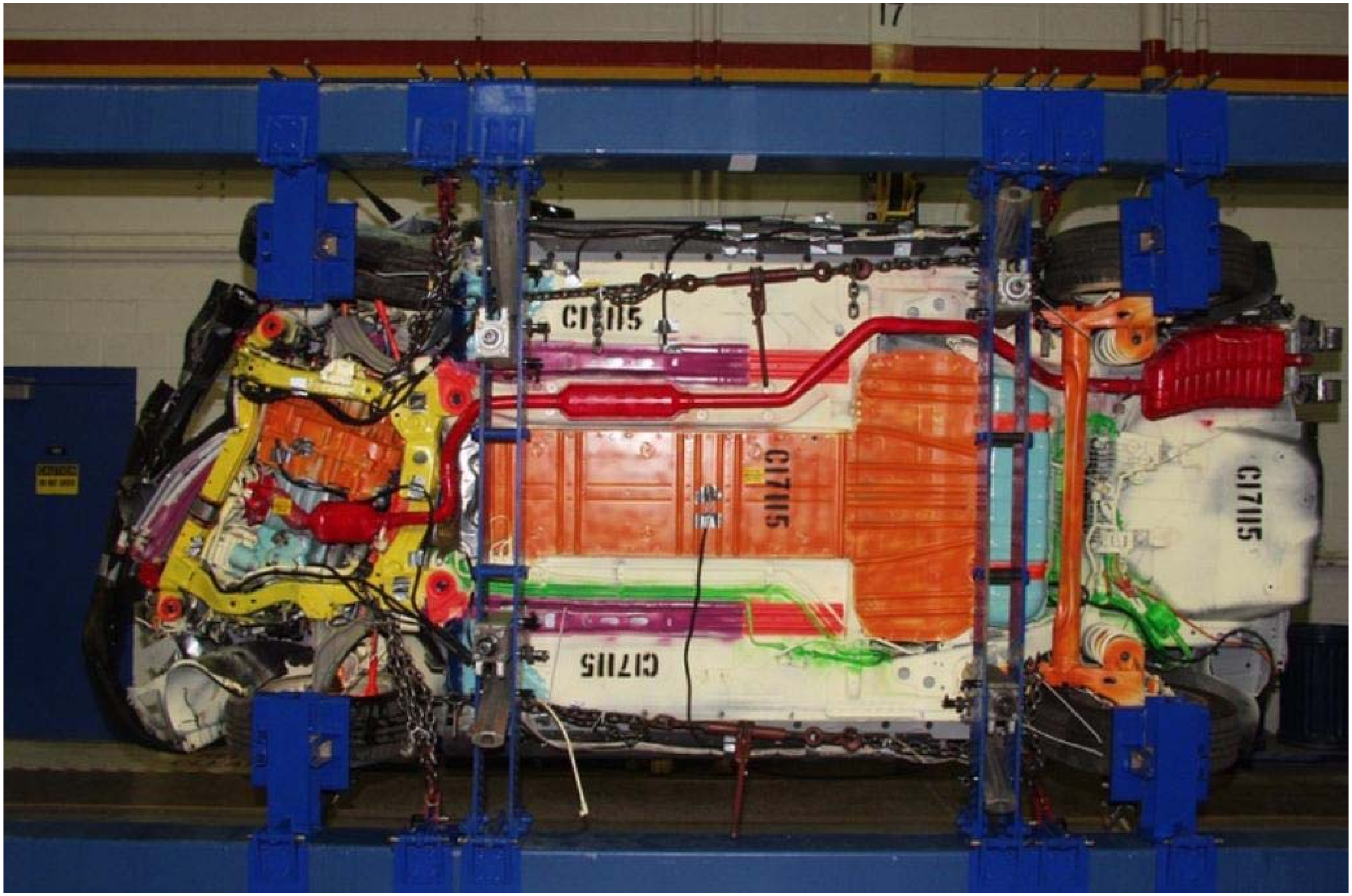
Volt Front Impact Test- Battery Intact



Chevy Volt Side Impact: Case Study

http://greentransportation.wdfiles.com/local--files/chevy-volt-battery-pack-fire-in-2011/Final_Reports.pdf

Chevrolet Volt NCAP Pole Test - Pretest	Chevrolet Volt NCAP Pole Test – Post-test
	

Chevy Volt Side Impact: Case Study

http://greentransportation.wdfiles.com/local--files/chevy-volt-battery-pack-fire-in-2011/Final_Reports.pdf

0 degrees	90 degrees	180 degrees	270 degrees	360 degrees

Figure 2.04 Post-crash rollover test

Before	After

Chevy Volt Side Impact: Case Study

http://greentransportation.wdfiles.com/local--files/chevy-volt-battery-pack-fire-in-2011/Final_Reports.pdf

Intrusion into the tunnel section

Opening between the battery and occupant compartments

GM Added stiffener as a safety augmentation to prevent future intrusions into battery pack/cells

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Replicating Battery Intrusion Event

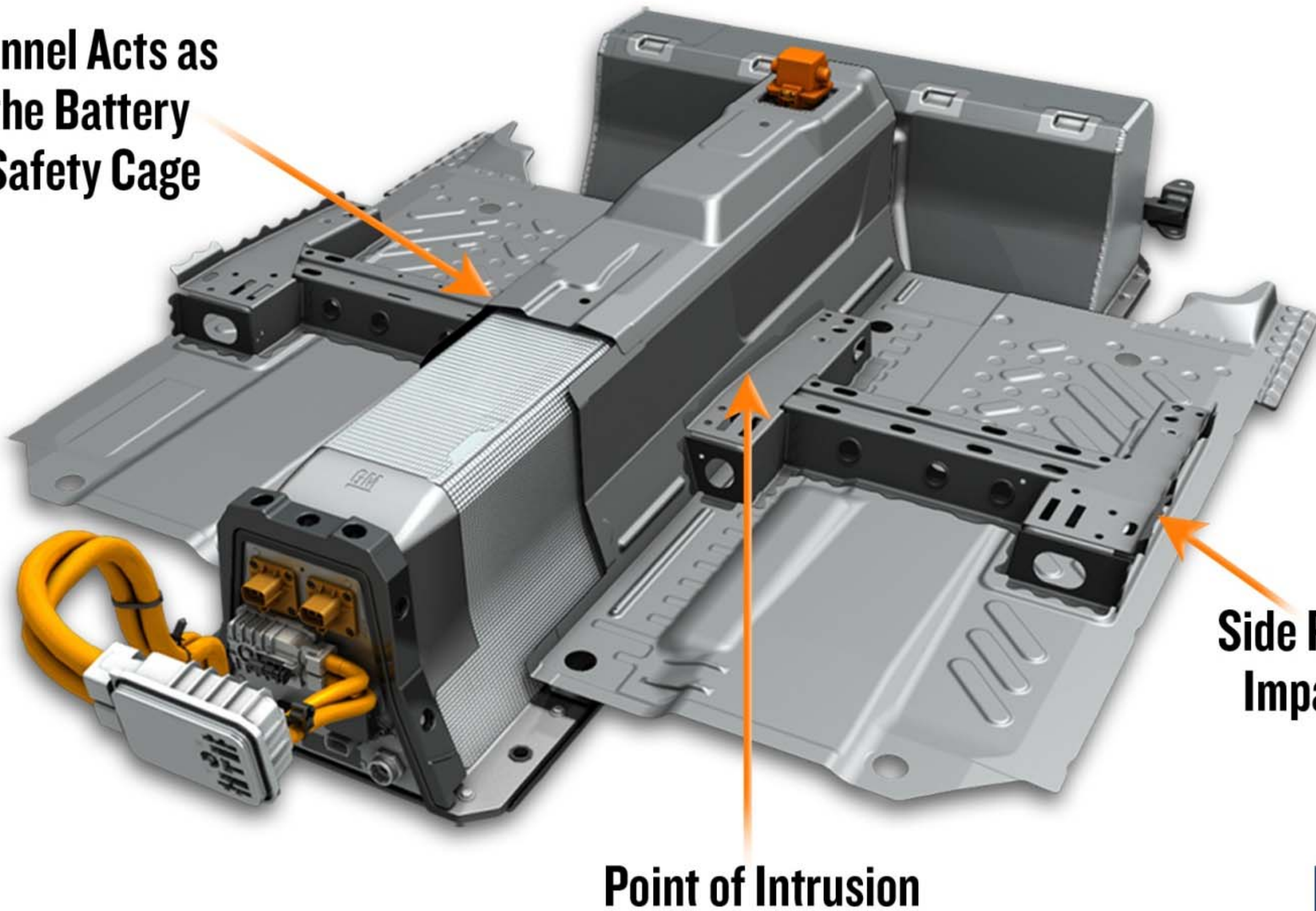
(Concluded that arcing possible, not venting)

Figure 5.01 Battery Ready for Impact

Figure 5.04 Battery 3 Arcing Event

Volt Rear Compartment, post fire

VOLT STRUCTURE ENHANCEMENTS



View Shown: Current Volt Underbody

GM

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USABC Manuals

- USABC Manuals (http://www.uscar.org/guest/article_view.php?articles_id=86)

  Battery Technology Life Verification Test Manual

  U.S. DRIVE (FreedomCAR) Battery Test Manual for Plug-in HEVs
- Electric Vehicle Battery Test Procedures Manual

  Energy Storage Abuse Test Manual for HEV Applications

  FreedomCAR Power Assist Battery Test Manual

  USABC Abuse Test Procedures Manual

  Battery Hazard Modes & Risk Mitigation Analysis

  USABC Lithium Battery Separator Shut Down Test Procedure
- USABC Systems Configuration Guidelines for Batteries

LithSafe-X

- Fire suppressed storage and transportation systems, training, emergency planning, fire suppression systems, and emergency process development geared for mitigating, preparing for, and responding to multiple battery platform (lithium-Ion, lithium, nickel metals, etc.), combustible metals, and alternative fuel source fires.
- We integrate multiple disciplines to provide the best fire/safety management solutions for our customers. While we understand the threat posed by these technologies, we are not in the business of demonizing state-of-the-art battery (and other) technology; in fact, we think it represents a great alternative energy solution and our power sources of the future. We are, however, in the business of keeping people, fleets, and businesses safe, so we advocate preparedness.

Some Battery Test Labs

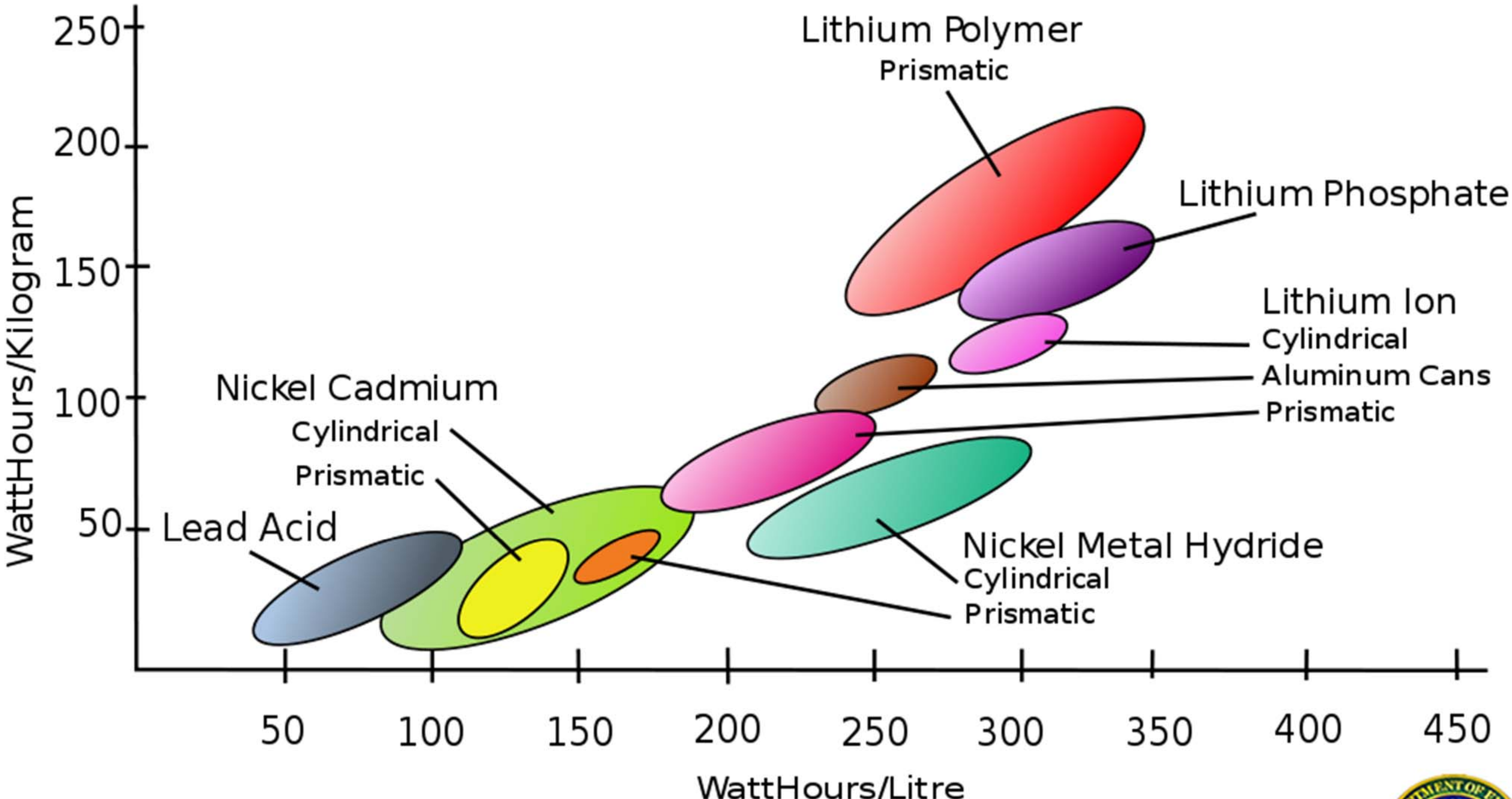
National Labs:

- ANL
- Sandia
- NREL
- INL
- USCAR funded research
- TUV SUD

Secondary Use Battery Systems

- Volt Battery covers used as planters,
  - Bat(tery) houses

Every Battery Presentation Needs an Energy Mass/Volume Density Plot



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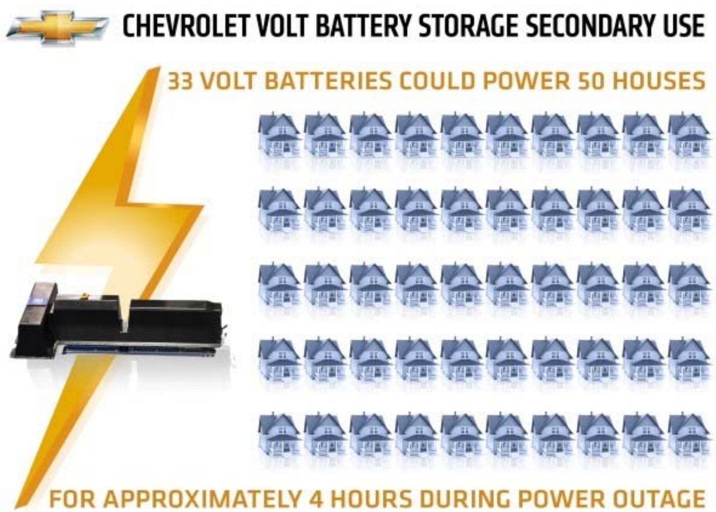
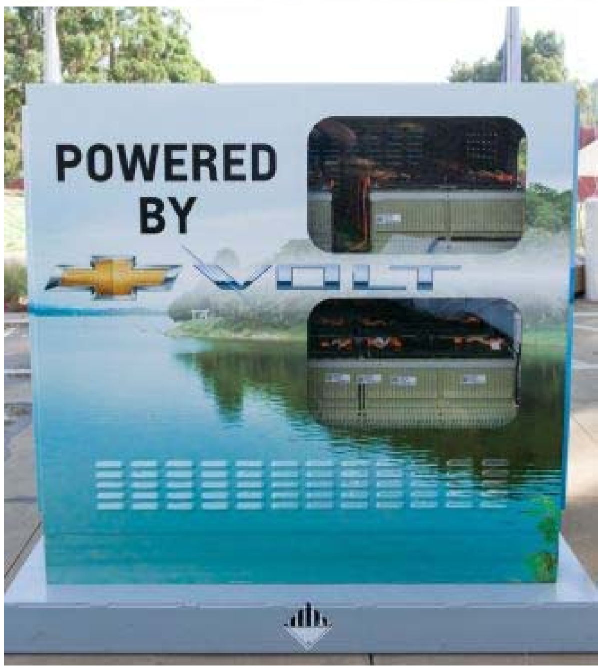
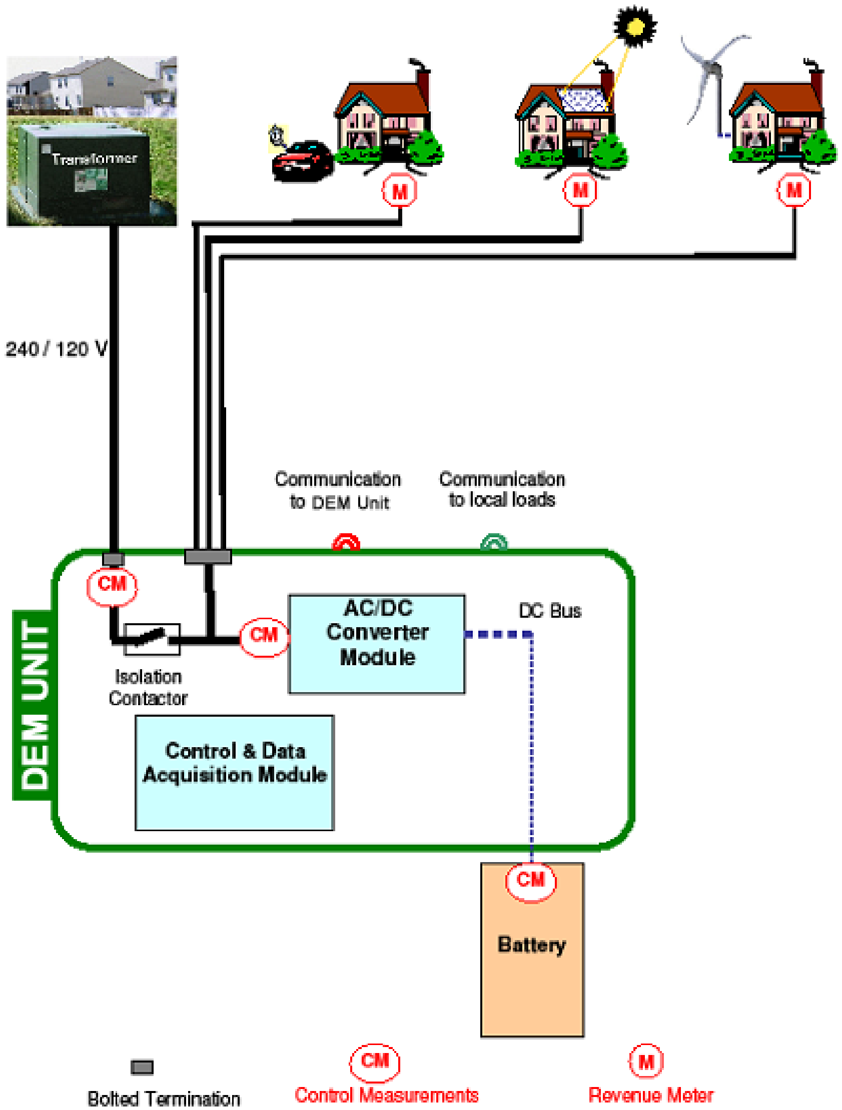
Secondary Use Battery Systems





Community Energy Storage Including Electric Vehicles: S & C Electric



Take Away Points- Battery Safety

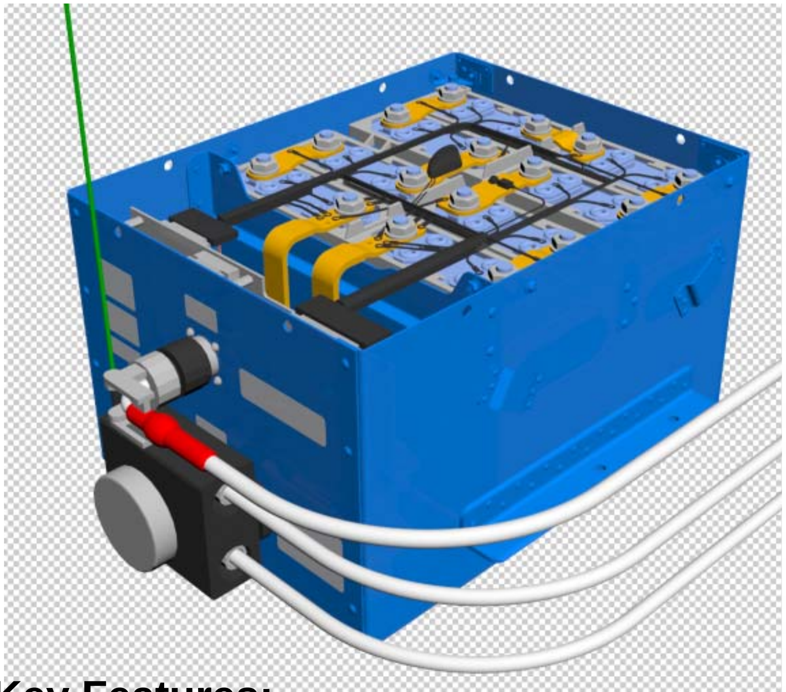
- SAE, NEC, ISO, IEC standards apply to various parts of energy storage systems. Depending on application and context, different standards apply (i.e. automotive, telcom, mobile electronics, stationary UPS, Aerospace)
- Fewer connections result in higher safety and reliability.
- ***90% of Electrical problems are mechanical in nature.***

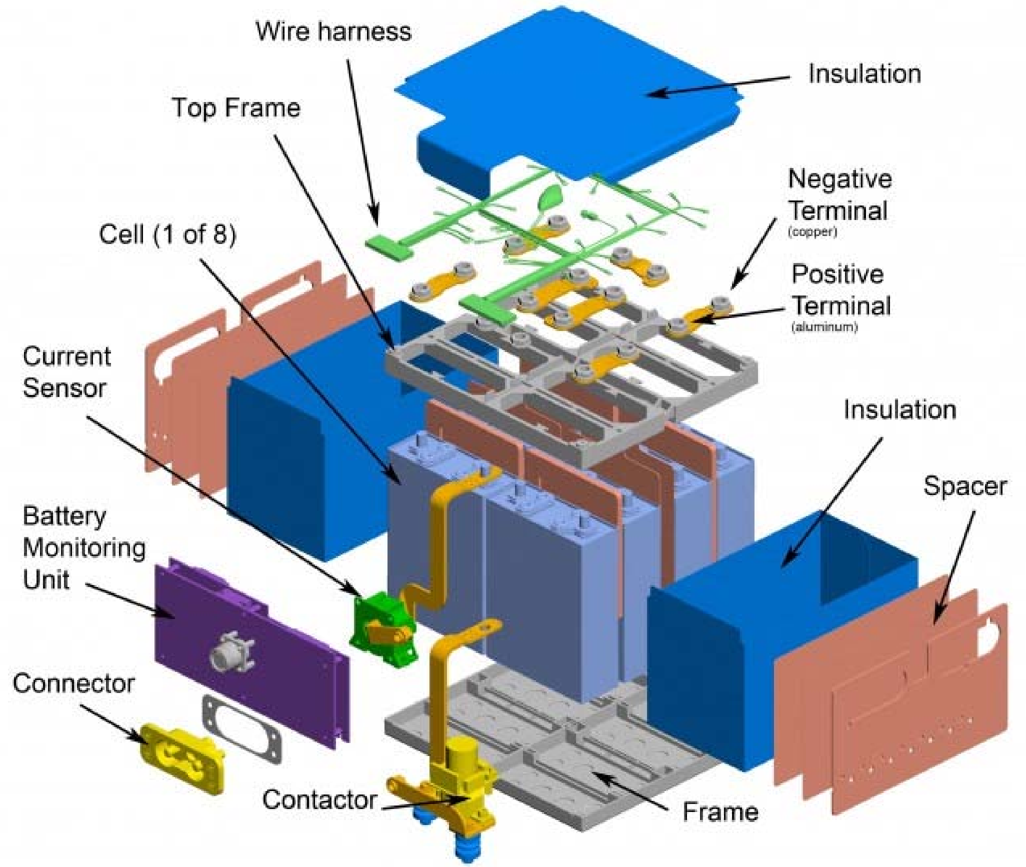
Table of PEV Voltages (not CS Hybrids)

Manufacturer	Model/notes	BEV PHEV	Charger kW	Battery kWhr	Battery Voltage	Ahr	Cell count	Pack Weight lbs
BMW	i3	BEV	6.6					
BMW	i8	BEV	6.6					
BYD	e6	BEV	3.3	60				
Chrysler-Fiat	Fiat 500e	BEV	6.6	24	364			
Coda	Coda	BEV	6.6	31	333	93		
Daimler	Smart ED3	BEV	3.3(22)	17.6	339			
Fisker	Karma	PHEV	6.6	20.1	340			
Ford	Focus EV	BEV	6.6	24	350			
Ford	Cmax Energi	PHEV	6.6	7.6	308		84	
Ford	FusionEnergi	PHEV	6.6	7.6	308			
Ford	Transit Connect	BEV	6.6	28	345			
GM/Chevy	Spark EV	BEV	6.6	20	406		336	560
GM/Chevy	Volt	PHEV	3.3	16	348	45	288	435
Honda	Fit-EV	BEV	6.6	20	339			
Honda	Accord PHEV	PHEV	6.6	6.7				
Mitsubishi	iMIEV	BEV	3.3	16	330		88	500
Mitsubishi	Outlander	PHEV	3.3	12	300		80	
Nissan	Leaf	BEV	3.3	24	364.8	66.2	192	647
Nissan		BEV	6.6?					
Tesla	Model S-60	BEV	20	60	400			
Tesla	Model S-85	BEV	20	85	400		8000	
Tesla	Roadster	BEV	20	53			6800	
Th!nk	City	BEV	3.3	23	400	70		630
Toyota	Scion iQ EV	BEV	3.3	12	277			
Toyota	RAV4 BEV	BEV	6.?	41.8	386		4500	845
Toyota	Prius PHEV	PHEV	3.3	5.2	207		56	176
Wheego	Wheego LiFe	BEV	3.105	30	115	260	36	712.8

Battery Safety-Packaging

Boeing 787 Dreamliner: 8 cells, 32.2v/65Ahr Li-ion



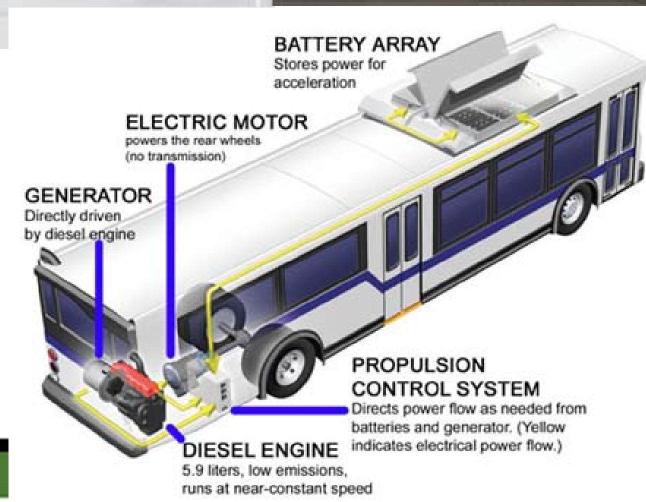


Key Features:

- Containment/separation of cells
- Battery monitoring/management
- Current Sensor
- Bus bars, output contactor

A123 Cell Format Small to Huge

BAE Roof Mount Bus Pack



Fisker 20kWhr

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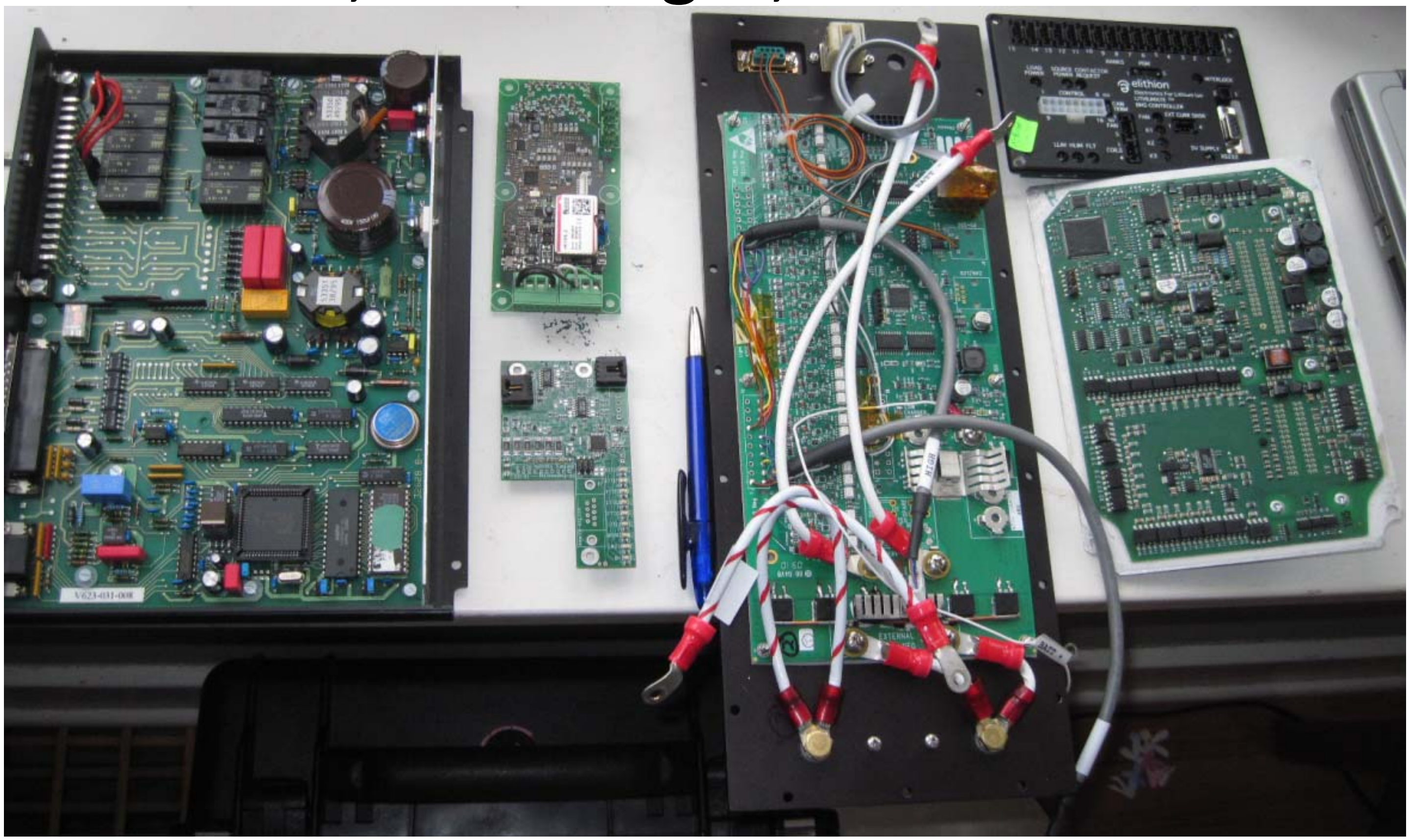
Battery System Components

- Evolution of Battery Management Systems- Old to new, left to right; 1990- 2012 solutions



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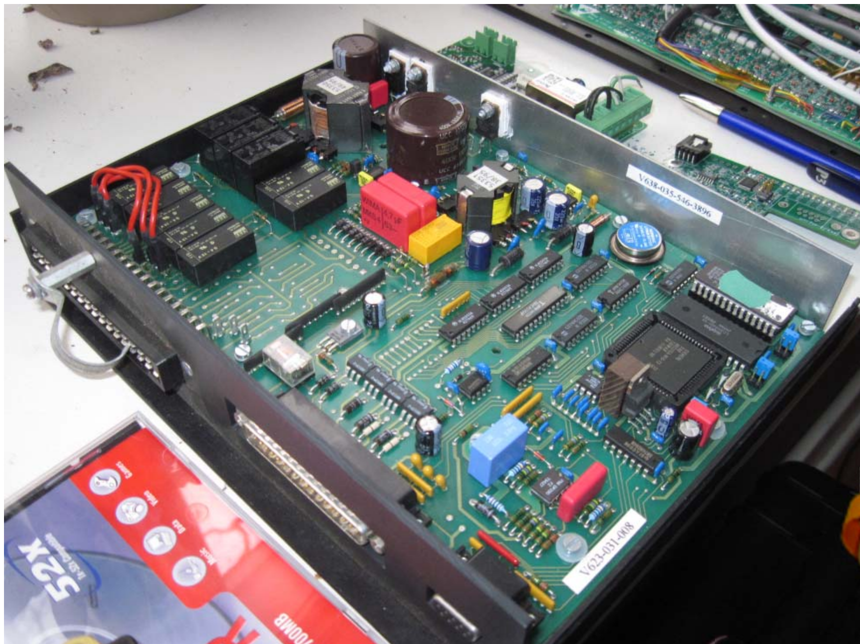
Distributed BMS- fewest wires
Central controller vs battery mounted



Fiber Optic data bus, Terminals/monitoring on single power/signal board

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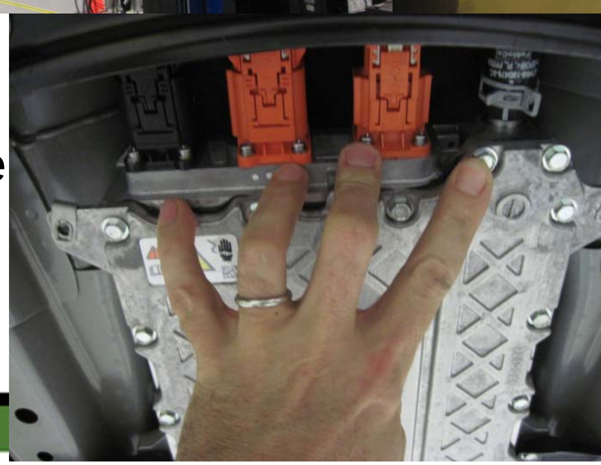
Chinese modules/packaging/BMS

Photo Essay- Safety Aspects Focus BEV

View of Focus BEV- 6.6kW
charger in 'exhaust tunne
since there is no exhaust
in an Electric Car



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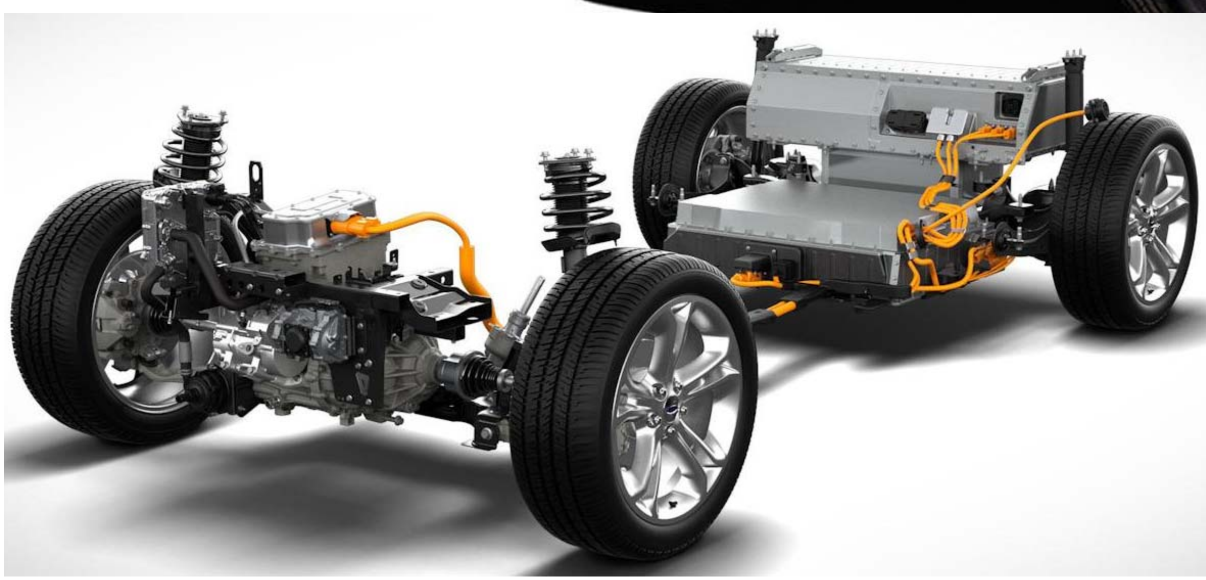
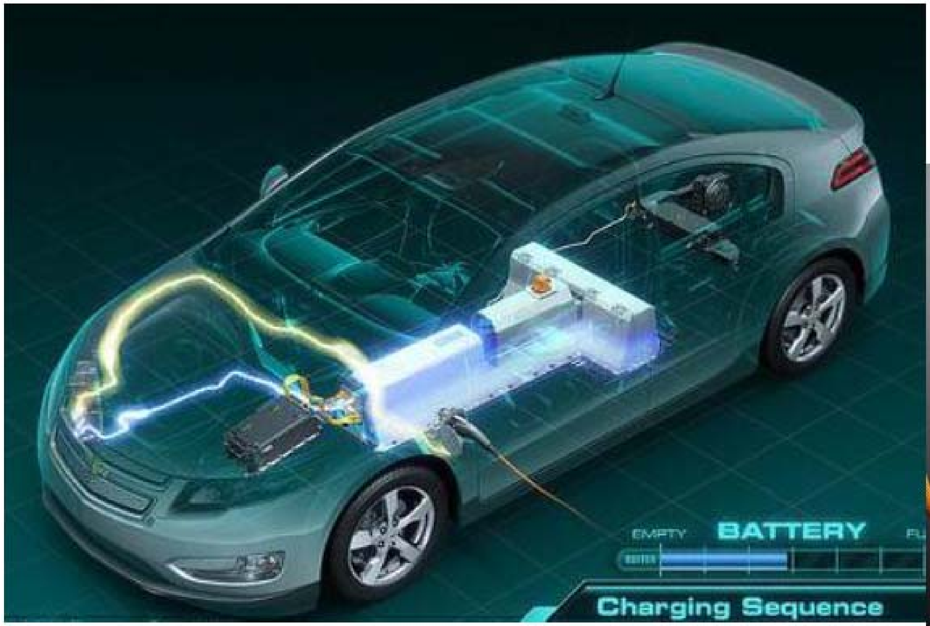
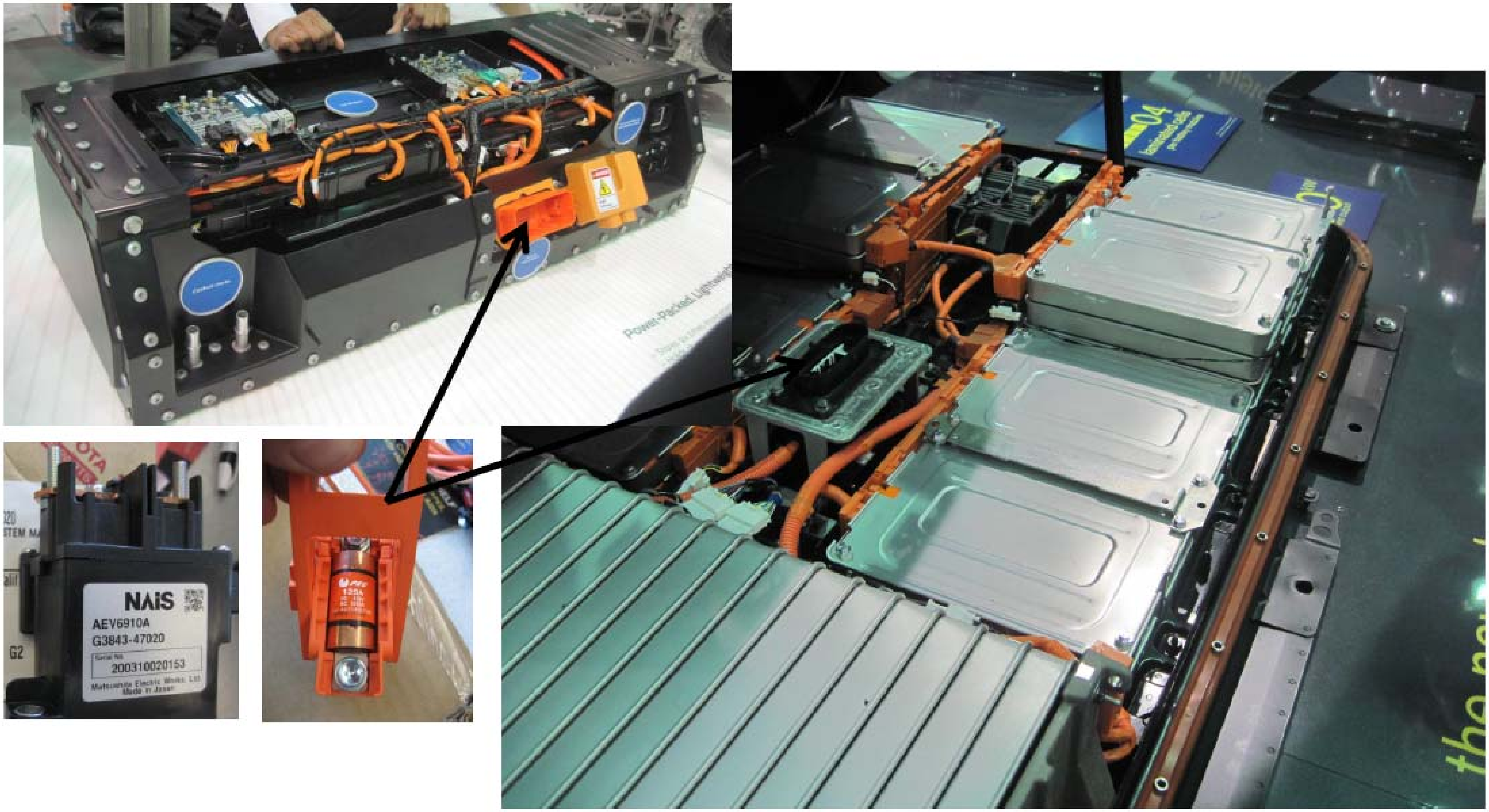
Focus BEV Components- Battery in Rear



Battery Packaging References- Cabling Access Issues

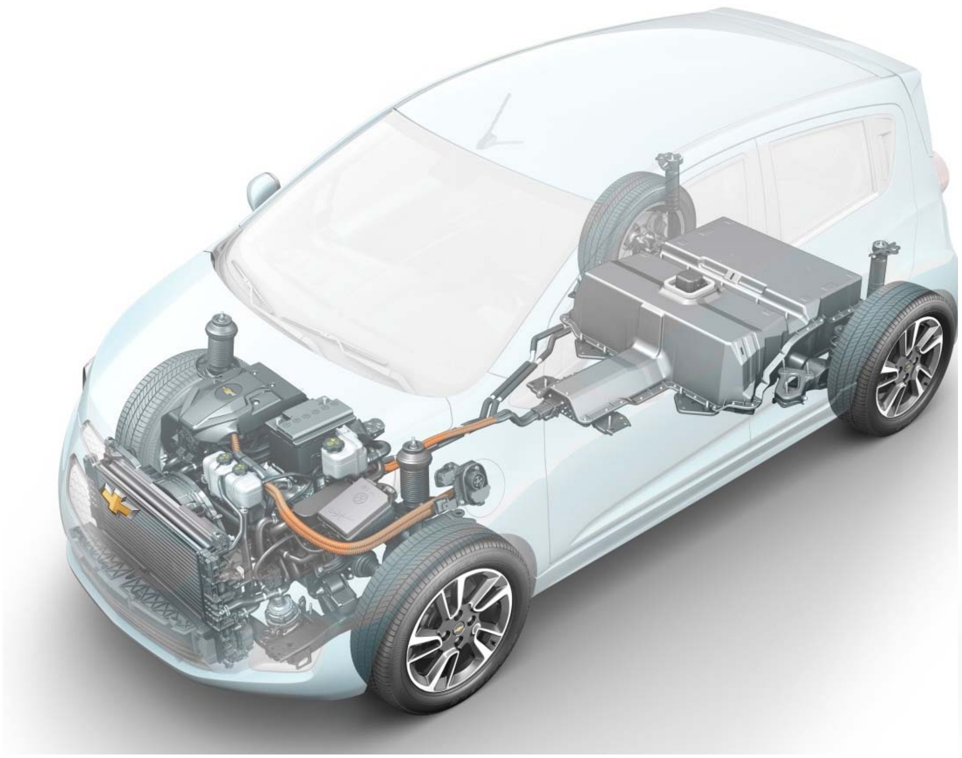


Battery Packaging/Safety Systems: Conductor Access

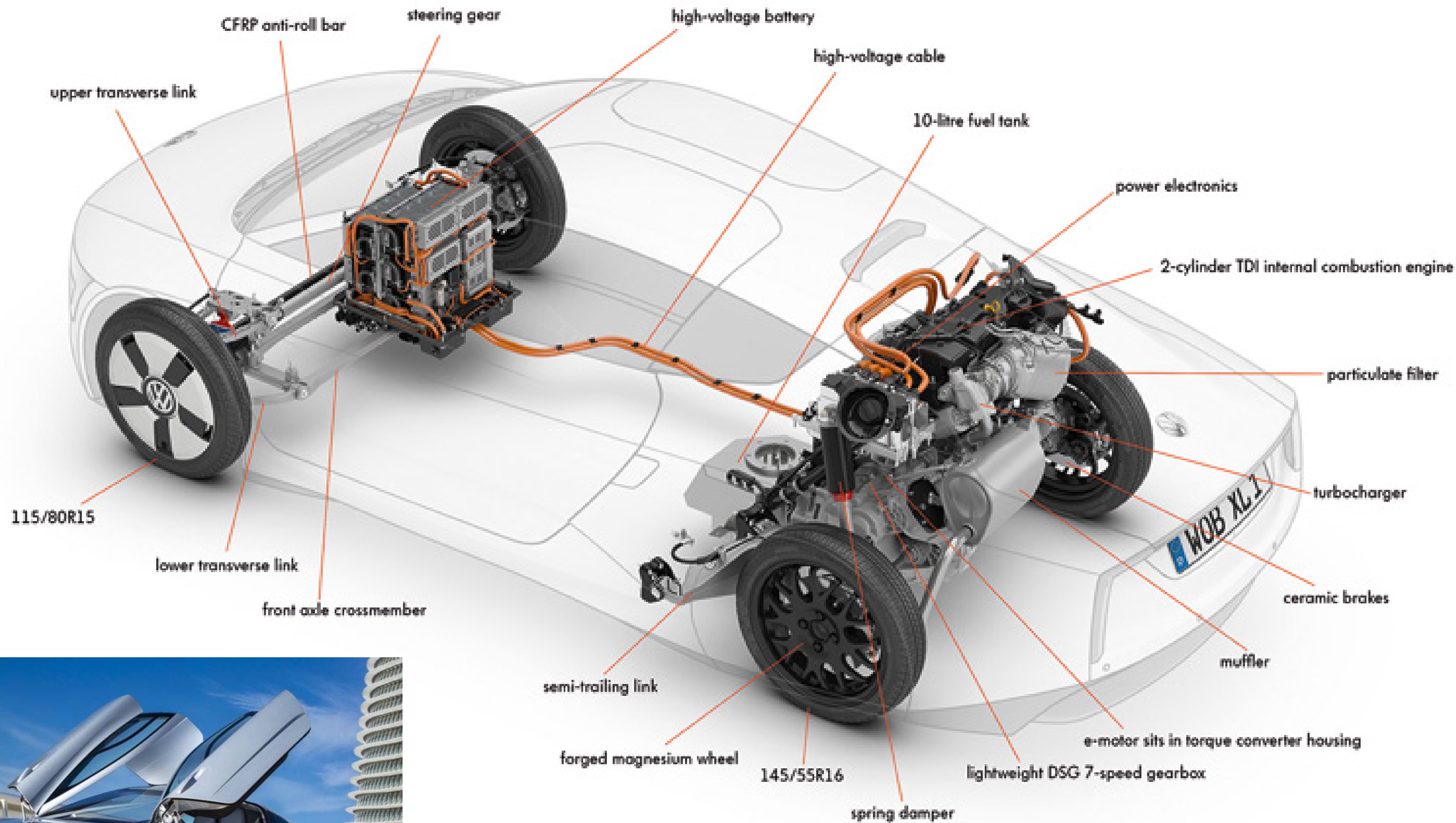


Fused Mid-Pack Service Disconnect Minimizes Exposed Voltages (1/2 pack voltage), contactors- contact weld detect, (Ford Focus EV, Nissan Leaf batteries)

Spark EV- A123 Module

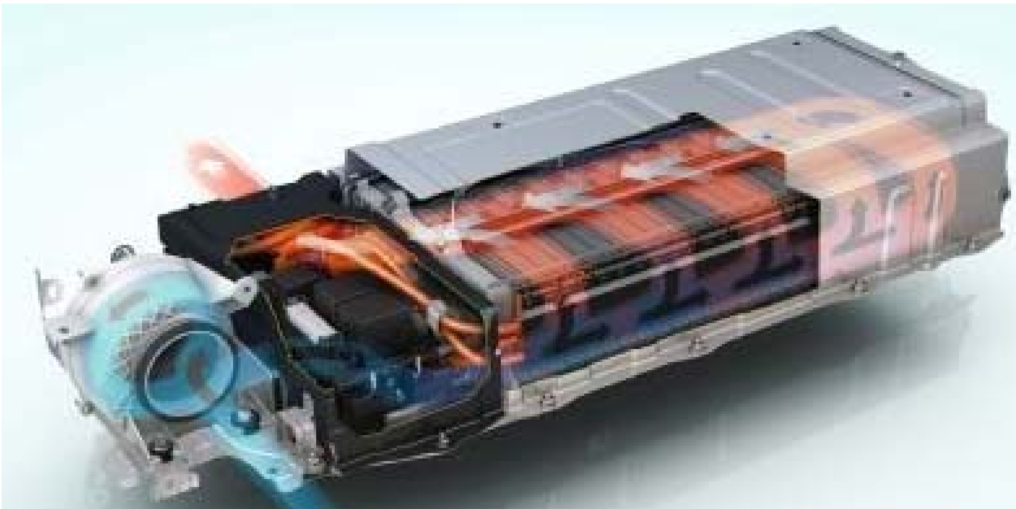


VW XL1- 268mpg; 800cc Diesel-Hybrid



Toyota Prius NiMH +PHEV Li-ion Packs

1.6kWhr, 4.4kWhr

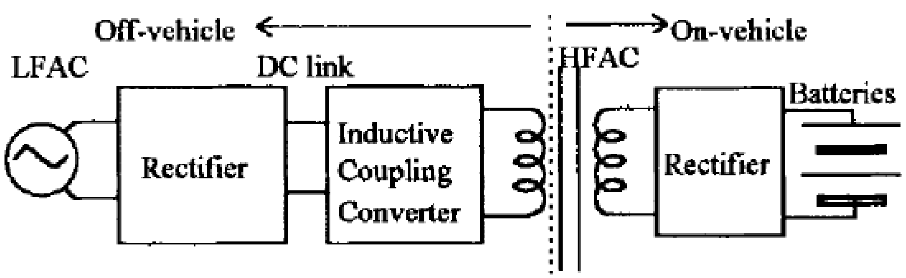


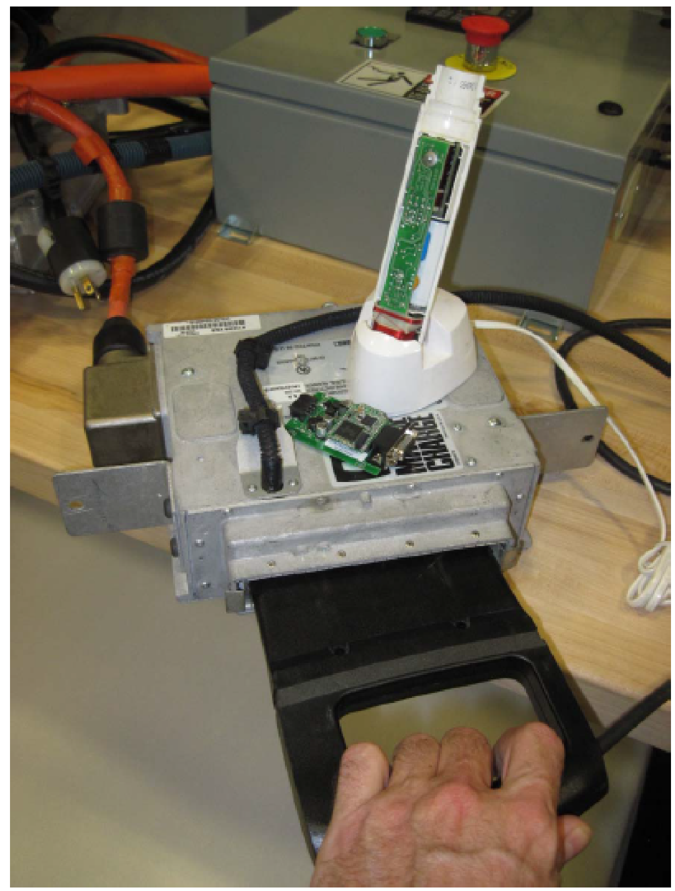
Motocyz and Brammo Batteries

Wireless Charging in Perspective

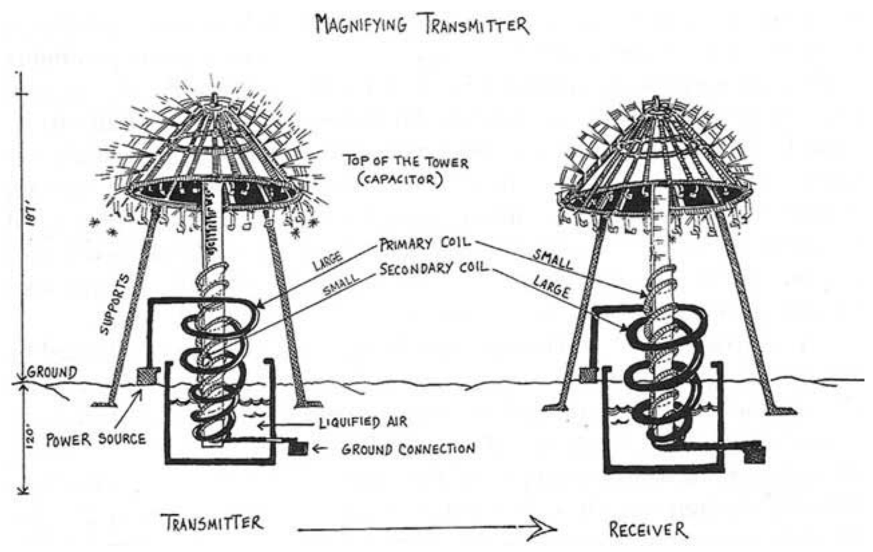
Similarities Between Vehicle Charging Methods - Main difference is where 60Hz AC input/DC output is split on power conversion

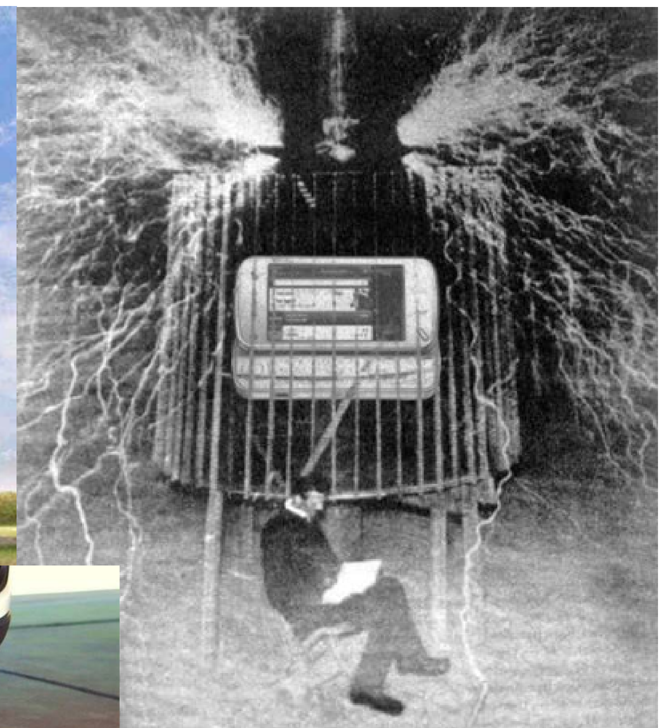
- J1772- {AC+DC conductive coupling} ~1996
- J1772-v3; 2009
- J1772-v5; 2012
- J1773- {Inductive coupling- small gap} ~1994
- J2954- {resonant coupling- large gap} 2013(?)

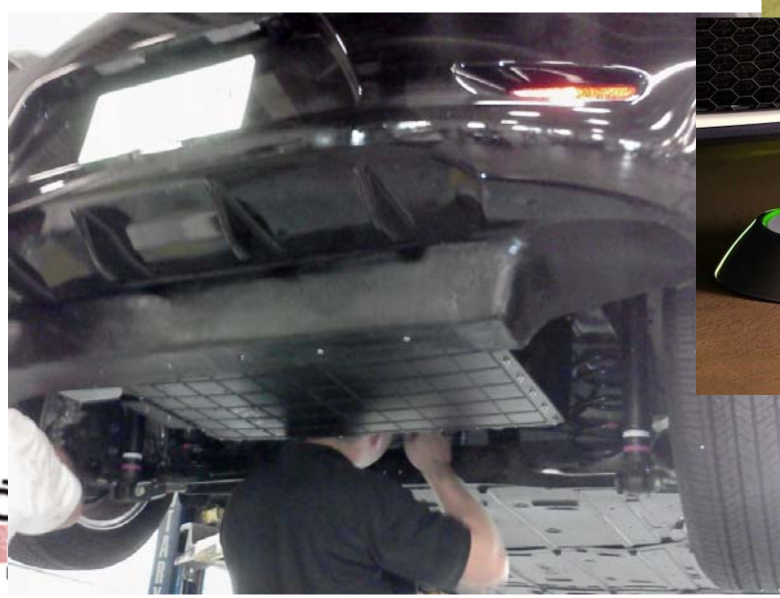




Wireless Charging Standards- SAE J2954







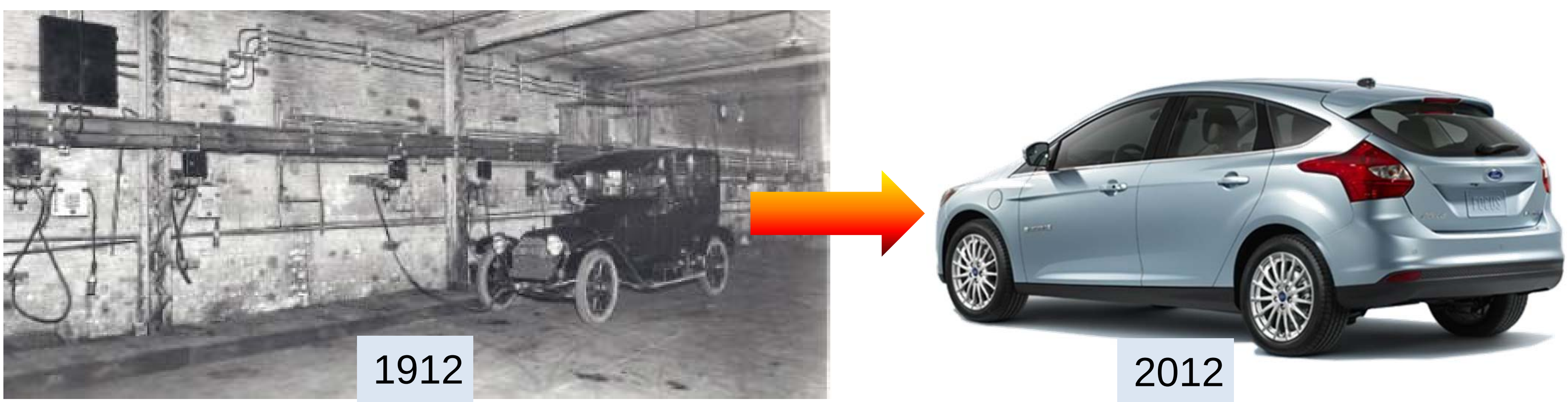
SAE J2954 TASKFORCE MAIN GROUP AND SUBTEAMS

- **OEM Advisory Team** — **J2954 Taskforce Chair** (Jesse Schneider)
  - **J2954/ DCRC/SAE Alignment & Communication** * (M. Klerer - Qualcomm / K. Sealy – Enginuitive)
  - **Safety, Performance, Robustness Testing & Validation** (H.P. Chan – GM)
  - **Magnetic Field Interoperability** (Co-Chairs: I-Teerlinck – Toyota / G. Covic – Qualcomm Halo)
  - **UL 2750 / SAE J2954 Verification Testing** (J.Bablo –UL / M. Abdul - Hak – Daimler / J. Sirota –Witricity)
  - **Bus Charging** (Johannsan- Volvo/ R. Bailey University of Tennesse)
  - **WPT Frequency Determination & EMC /EMF Definition** (R. Boyer- Delphi/ R. Kautz-Ford / P. Anderson/ R. Sutton-TDK-rf)

Lab Hardware- Reference system/Evatran Wireless

Interop Center with RF coils/power electronics on TTR

State of the Art in Hybrid Drivetrains Vehicle Charging Technologies/Standards



Long ago is here today- Detroit Taxi Fleet

Historic Material; Battery swapping-

hydraulic positioning equipment to compensate for suspension loading

ELECTRIC HANSOM, SHOWING HYDRAULIC RAM FOR SIDE ALIGNMENT AND BATTERY IN POSITION FOR LOADING.

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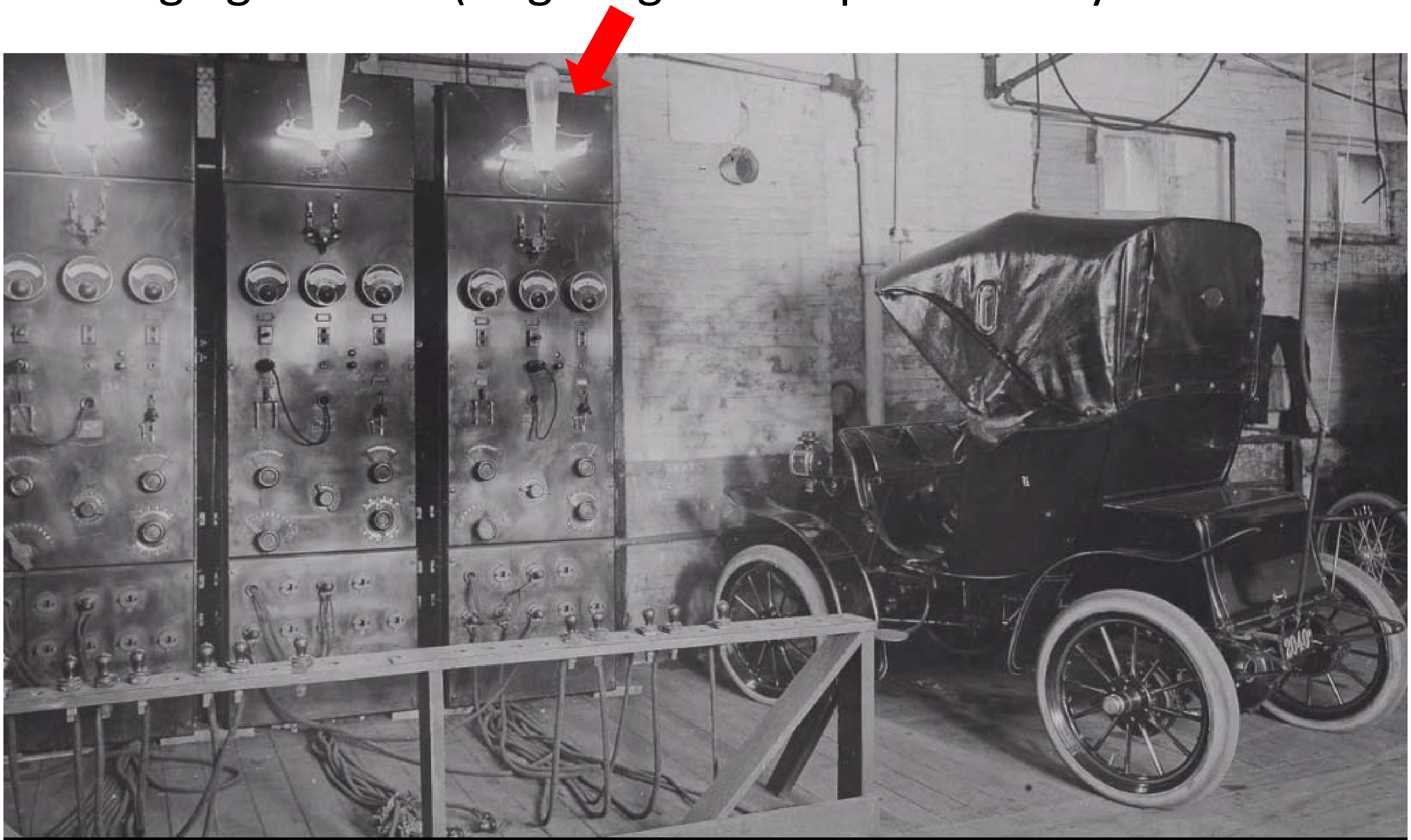
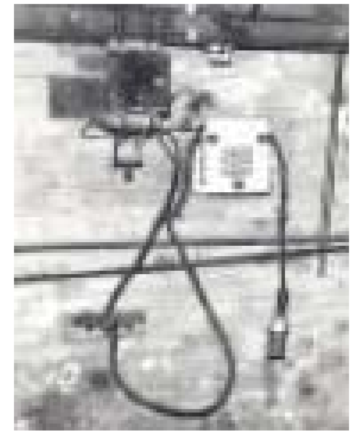
Historic Material; DC Central Garage Battery Charging stations (bright light on top is mercury rectifier tube)



Standards are the common thread that enables interoperability of new technologies

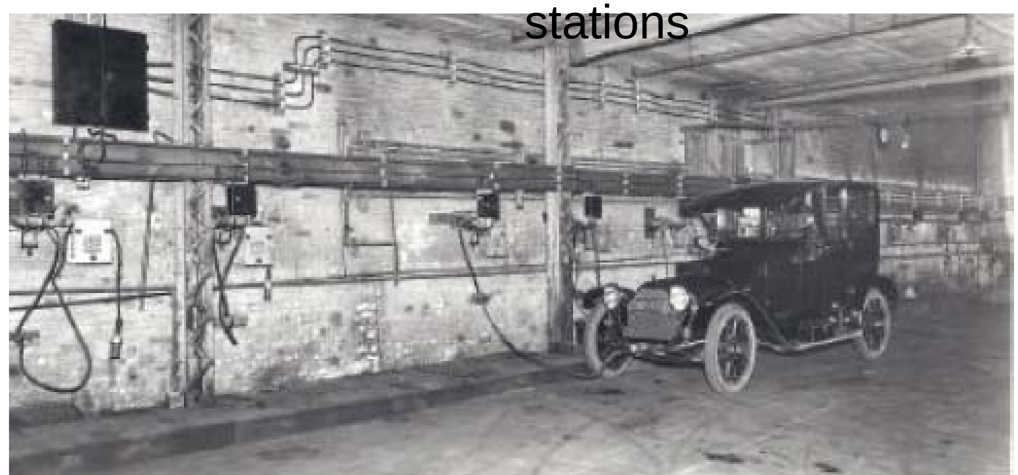
Detroit was the first American city to use electric taxi cabs, in 1914.

Are Indoor/Outdoor Charge Ports New?



Outdoor Curb-Side Charging Port

Indoor charging stations

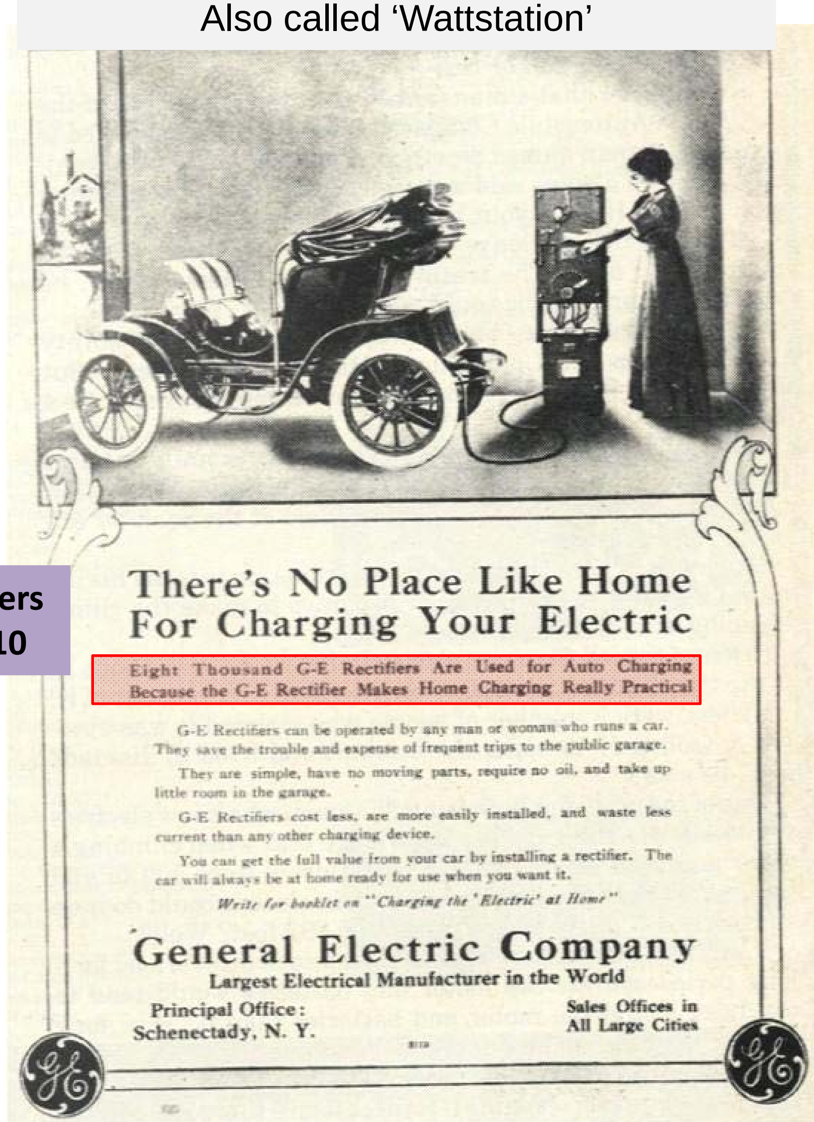


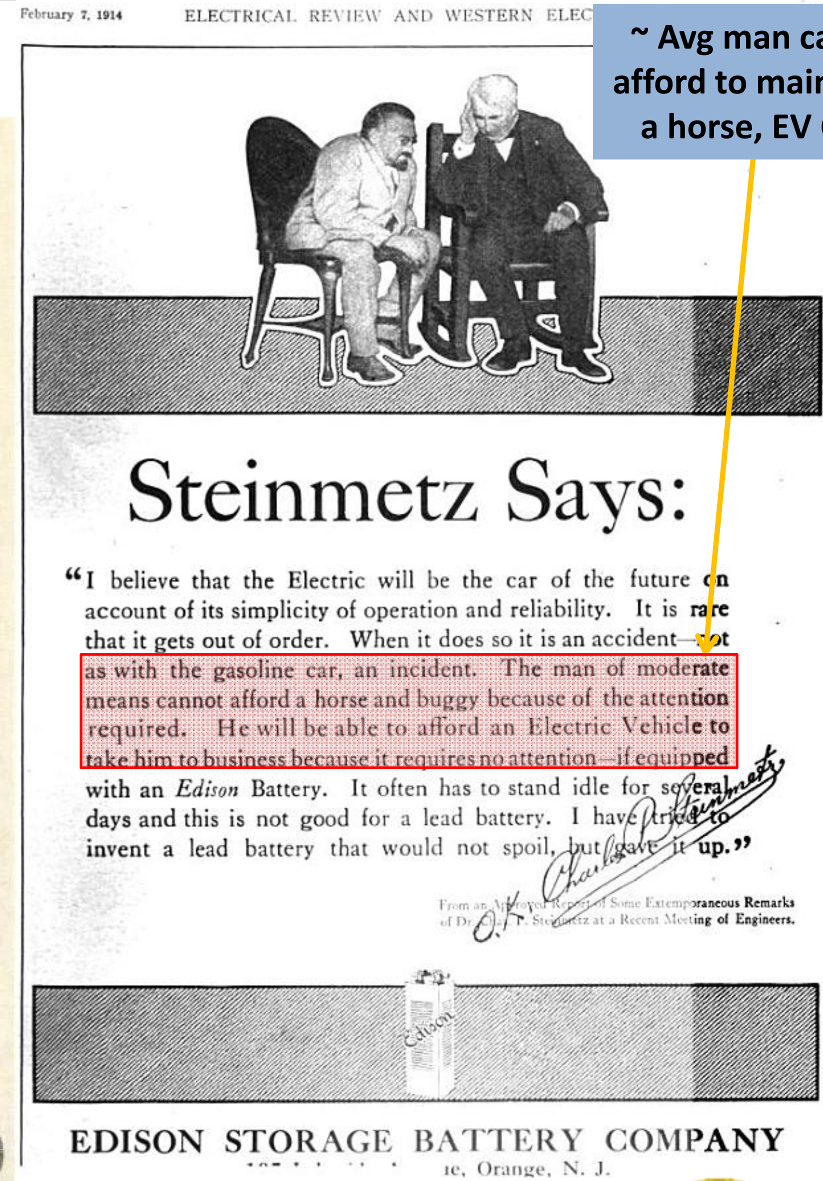
Detroit's first electric taxi accumulated >46,000 miles first two years.

6kW DC Offboard Charging- 1910

Also called 'Wattstation'

8000 Chargers in use, 1910





~ Avg man can't afford to maintain a horse, EV OK

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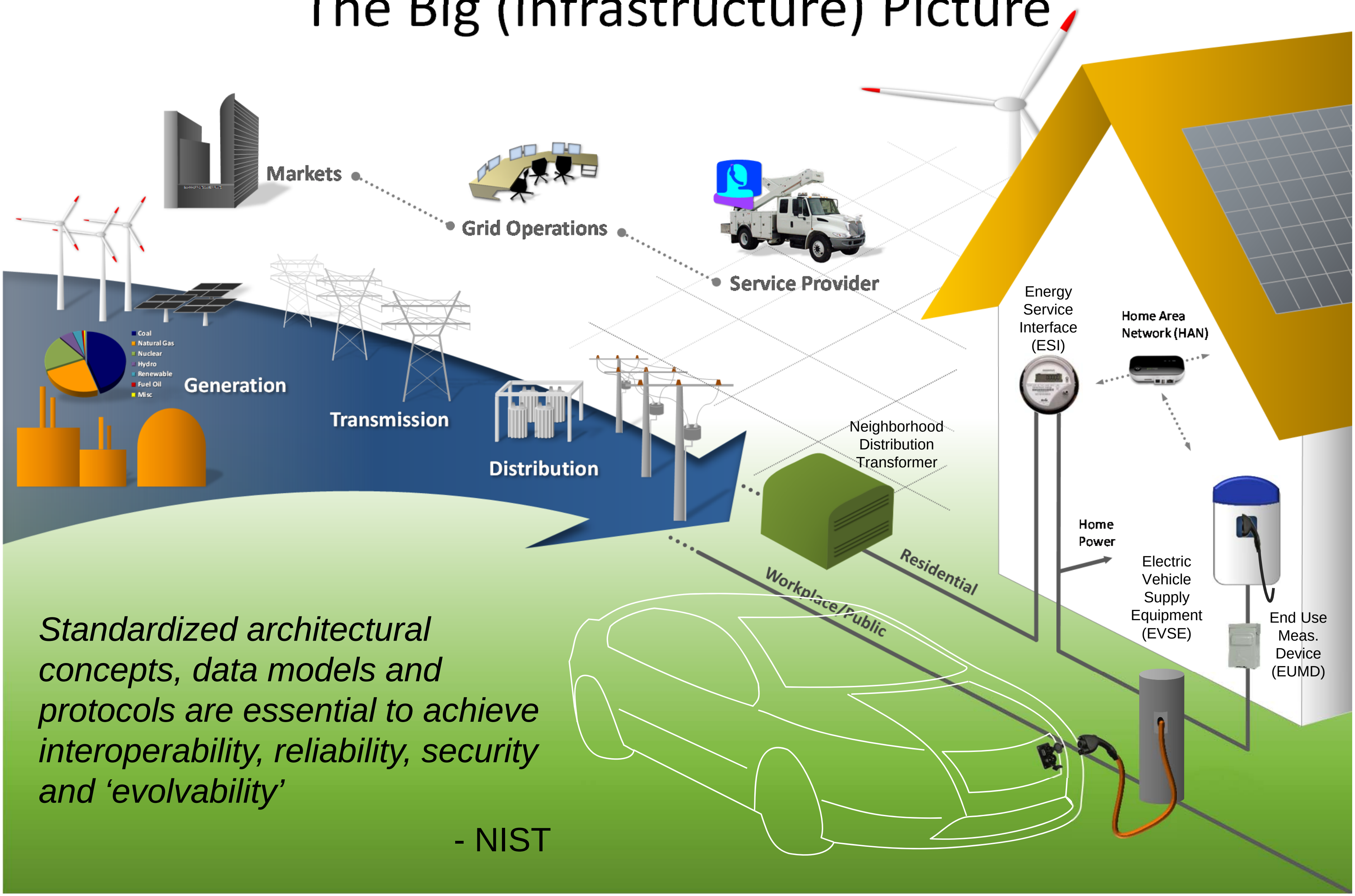
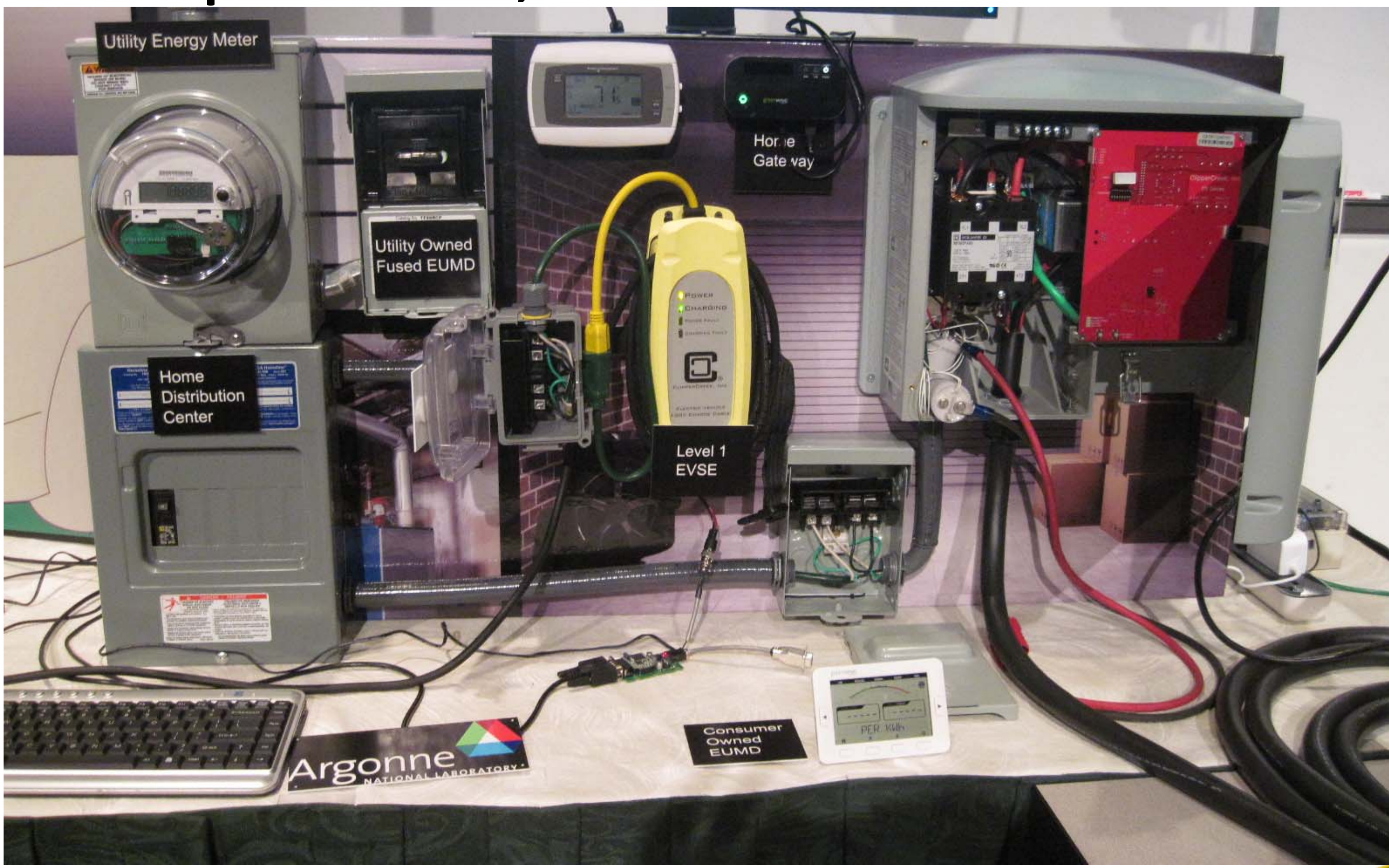
The Big (Infrastructure) Picture



Standardized architectural concepts, data models and protocols are essential to achieve interoperability, reliability, security and 'evolvability'

- NIST

Interactive Smart Grid Display- Components, Communication nodes



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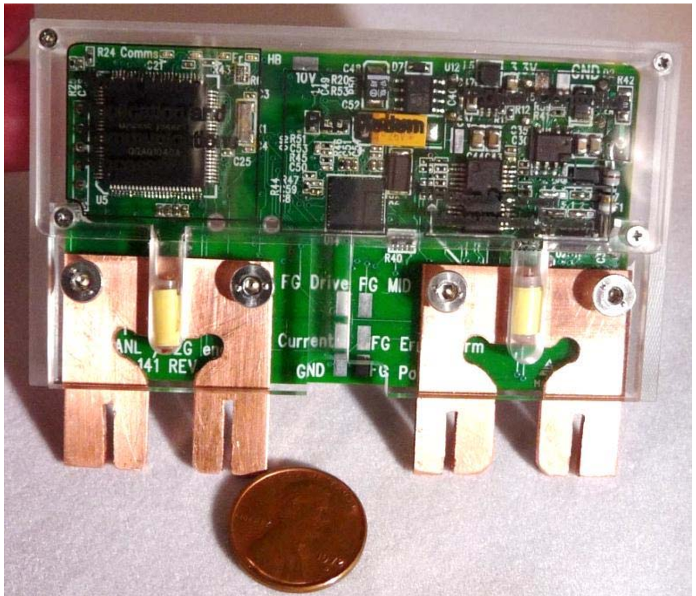
Modular Business Card Sized 60A sub-meter



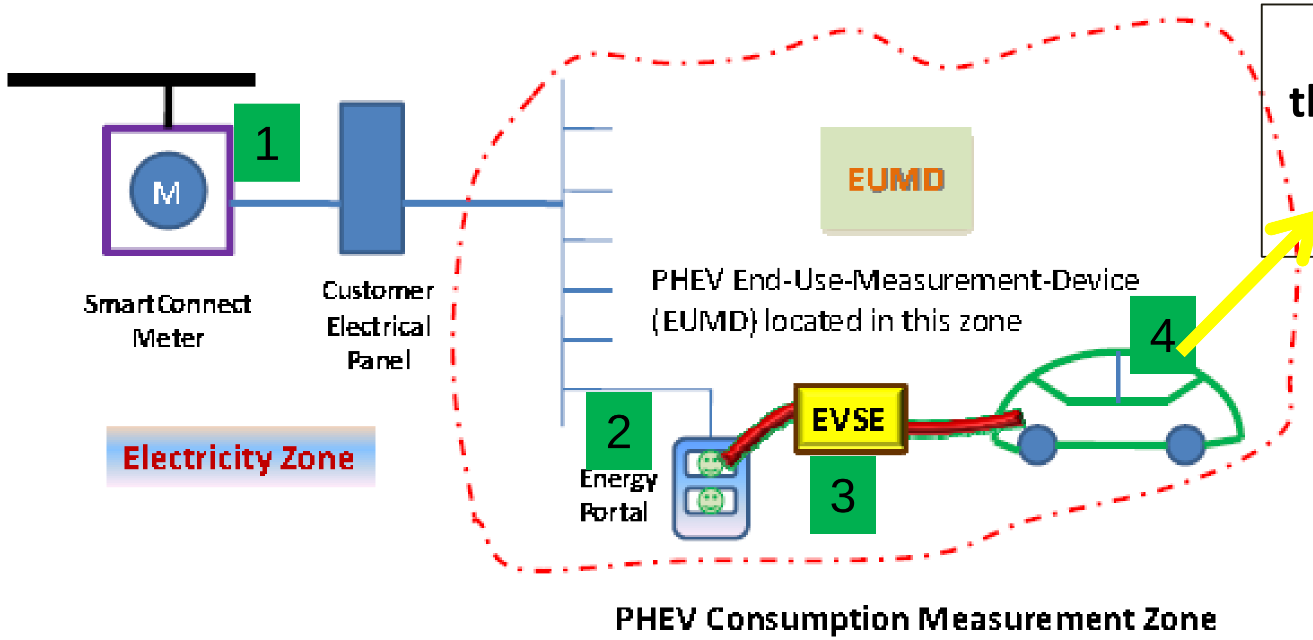
- 0.1% accuracy over full temp range
- Designed to ANSI C12 spec
- 60A low cost base (~$5 retail w/enclosure)
- SEP 1.x communication (PLC, Zigbee)
- <$20 Materials, minimal part count
- 8cm x 5cm x 2cm (~3" x 2" x ¾")
- Fully encapsulated with indicator LEDs
- Modular architecture/socket allows for mounting in 5 different locations:
  1) Transformer monitoring (power, temperature)
  2) Fused instrumented disconnect EUMD (w/main meter)
  3) Un-fused instrumented disconnect- in EVSE
  4) Level 1 EUMD, no electrician, NEMA 5-15, multi-family)
  5) Vehicle mounted EUMD, plugs into stock charger inlet

Where Does the EUMD Reside?

(Depends on your segment of the EV industry)

The EUMD measures just the branch circuit power flow to the EV, but may be located in different segments of that branch.

1) **Utilities** tend to favor locating it in an outdoor, technician accessible area, such as **next to the main meter**; possibly as a fused sub-panel with dedicated run to EVSE.
2) **Home Owners** may want it next to their service panel or in garage **near the EVSE**.
3) **EVSE manufacturers** want to build it into the EVSE, or in a socket **in the EVSE**.
4) **Auto manufacturers** may want the EUMD **on-board the vehicle** to simplify access to EUMD consumption information and eliminating association problems.



Does this mean that cars will have an under-hood cash register?

ANL SAE Standards Committees Support

Compatibility/Interoperability

•SAE J2931 (Communication, telematics, security)

•SAE J2953 (EVSE-PEV compatibility)

Power Ratings

•SAE J2907 (Motor and power electronics)

•SAE J2908 (Propulsion system)

Energy Service Provider

Customer Interfaces

ESP Interface

Home Area Network (HAN)

Electric Vehicle Supply Equipment (EVSE)

•SAE J2894 (Power Quality for charger – test methods)

•SAE J2954 (Wireless charging)

Charge Coupler

•SAE J1772-v5 (DC)

•SAE J2836 (Use cases for communication)

•SAE J2847 (Communication protocols and messaging)

Support ranges from supplying reference materials to chairing committees, supplying hardware/test fixtures and testing

Argonne NATIONAL LABORATORY   INL   NREL   Pacific Northwest NATIONAL LABORATORY   ornl

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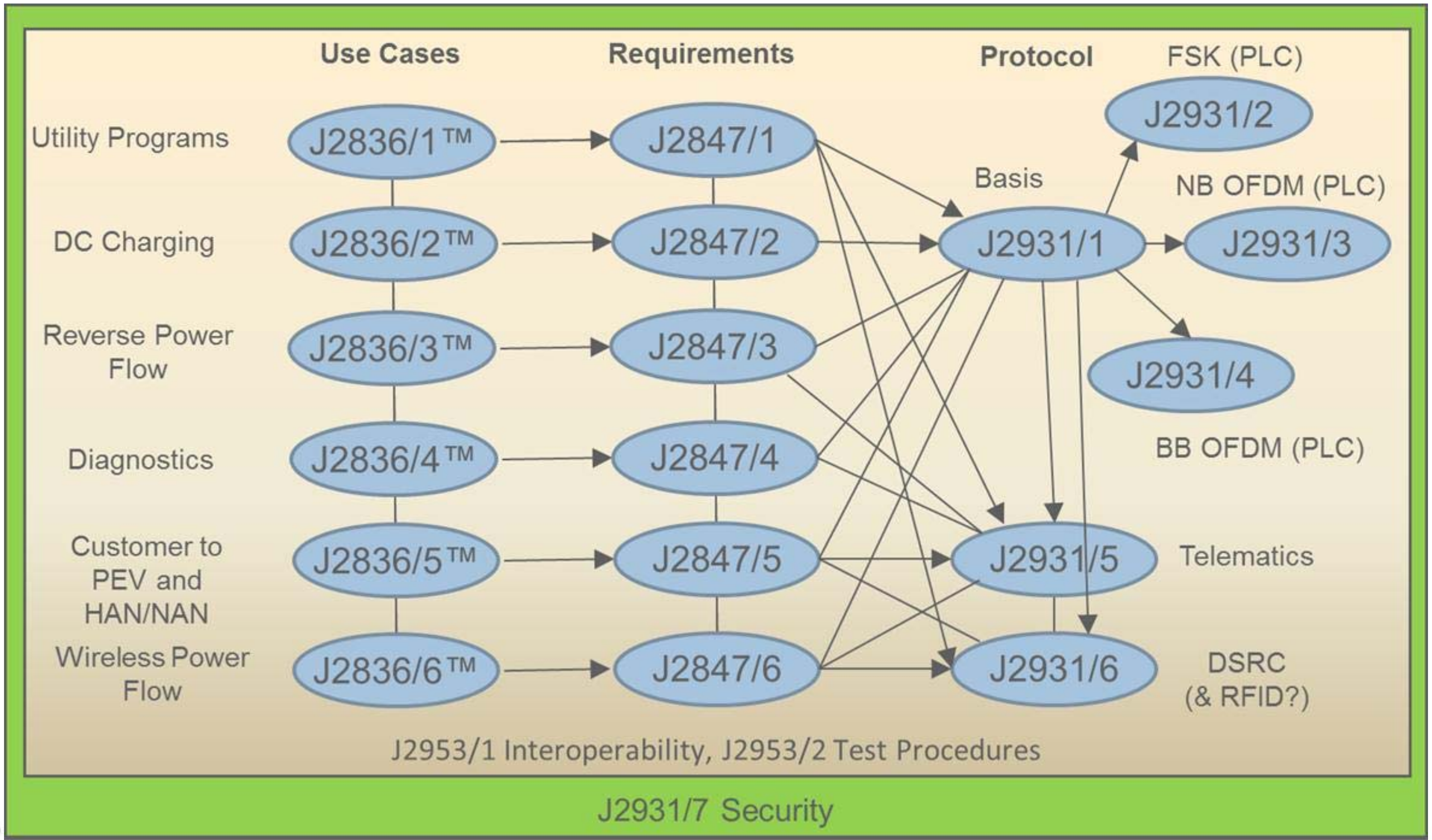
PEV Related Charging Standards

Avoiding Alphabet Soup (chart below paraphrased):
Use cases, Requirements, Protocols- Utility/AC, DC Charging,
2-way flow, Diagnostics, Customer functions, Wireless Charging All of the above covered with Interoperability and cyber security.



High Level Charging Standards Description

SAE J1772(v5), IEC61851	AC and DC coupler
SAE J2847-J2931	DC messaging/communication/protocols
SAE J2953 (ISO 15118-pt5)	PEV-EVSE Interoperability
SAE J2894/2	Charging equip. power quality/test proc.
SAE J2954	Wireless charging
IEEE P2030.1	Guide Electric Sourced Trans. Infrastructure
ANSI EVSP	EV Standards Panel- summary of standards
NIST HB44/HB130	National Working Group on Electric Fueling and Submetering Standards
ANSI C12	New section fed by submetering reqs.

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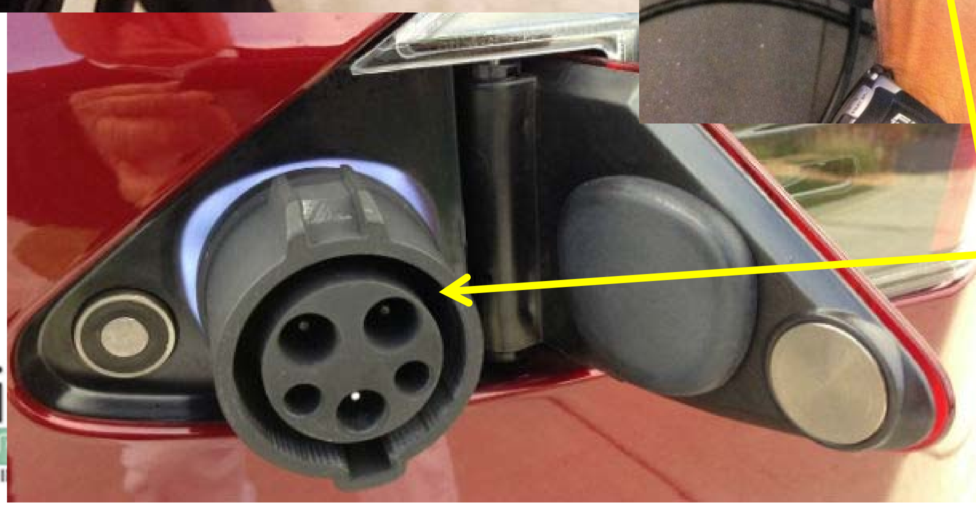
Interoperability of Three Similar But Different DC Charging Methods- Adapters When

Chademo and J1772 Level 2 DC Combo

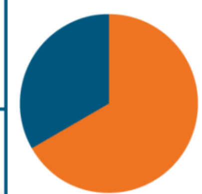
Consumer choices;
Level 1 DC combo
40kW/43 mm, <$100



SuperCharger to J1772 Adapter

Boundary Between Charging (Power) Levels is Blurred

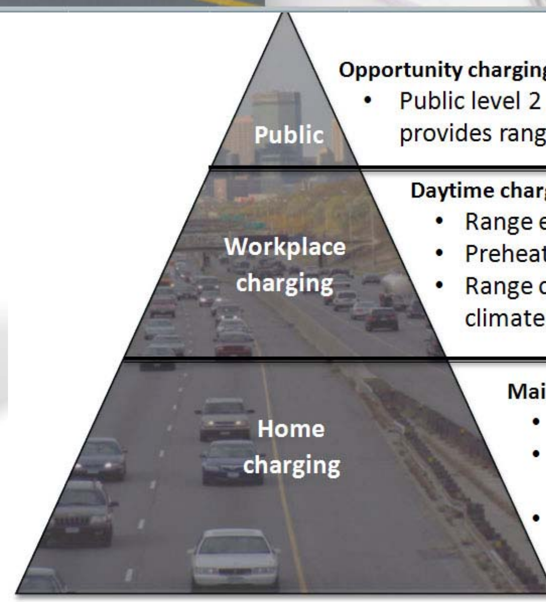
Charging Level	Setting	Supply Power	Representative Example	Where Charging Occurs
AC Level 1	Residential/ Parking Lot 5 mi/hour @ 1.7 kW	120vac/20A (16A continuous)		RESIDENTIAL 2/3 of charging
AC Level 2 (minimum)	Residential/ Commercial 10 mi/hour @ 3.4 kW	208/240vac/20A (16A continuous)		
AC Level 2 (maximum)	Commercial (up to) 60 mi/hour @ 19.2 kW	208/240vac/100A (80A continuous)		
DC Level 1	Commercial up to 500v @ 80Adc (up to) 120 mi/hour @ 40 kW	208vac/480vac 3-phase (input current proportional to output power; ~20A-200A AC)		COMMERCIAL 1/3 of charging
DC Level 2	Commercial up to 500v @ 200Adc (up to) 300 mi/hour @ 100 kW	208vac/480vac 3-phase (input current proportional to output power; ~20A-400A AC)		



RESIDENTIAL
2/3 of charging

COMMERCIAL
1/3 of charging

Transformative Value of Workplace Charging on PEV Deployment



Opportunity charging
- Public level 2 and fast charging provides range comfort

Daytime charging
- Range extension and flexibility
- Preheating and cooling
- Range comfort by climate mitigation

Main charging
- Overnight charging
- Preheating and cooling
- Range comfort by climate mitigation

http://www.workplacecharging.com/

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DC Charging EVCC-SECC- Phased Approach

Phase 1:
ABC-170 as load/battery
CAN communication

Phase 2:
Telecom 5kWhr ESS
CAN communication

Phase 3:
Production PEV,
Level 1, Level 2 DC Couplers
EVCC to vehicle CAN

IEC/SAE Combo Charger Vendors

IES, Eaton, BTCP, Aker-Wade, Efacec, Siemens and ABB.

EVSEs- J2953 Interoperability Center

~40 EVSEs, mounted on skid- testing assets
Some deployed in the field.
Testing Tools- EVE-100, Labview V.I.s

Labview based test rack; AC, DC loads and sources; J1772 signal pass through monitoring/fault injection

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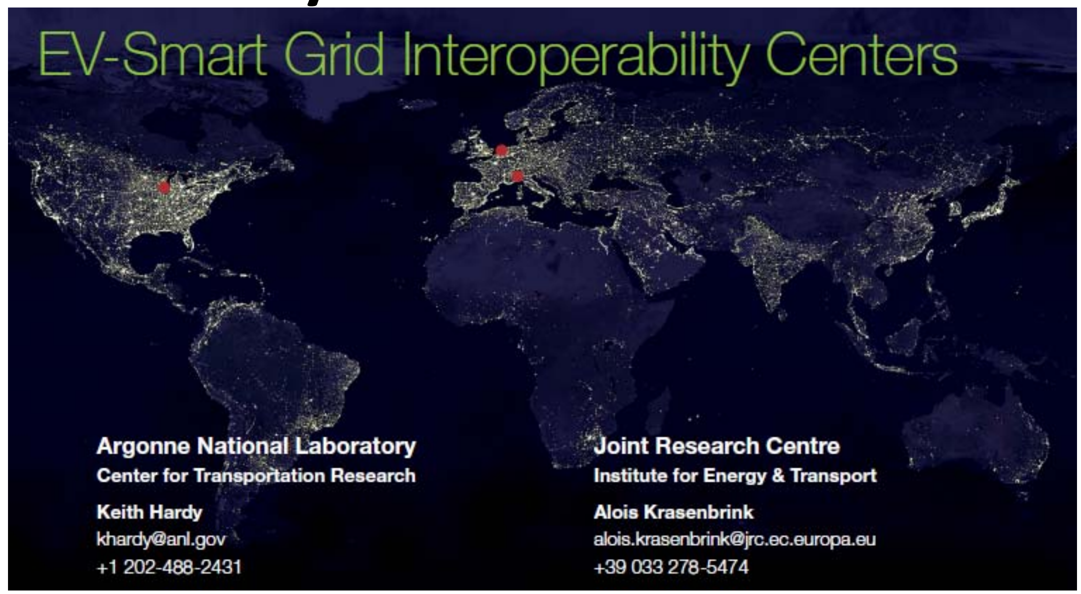
US-EU-(China) EV-Smart Grid Interoperability Center

Agreement signing at the annual Transatlantic Economic Council meeting in Washington, D.C. 2011



- **Charging systems:** Studying and validating EVSE technologies (AC, DC, and wireless) to ensure any EV can plug into any EVSE safely and reliably.
- **Communications technologies:** Developing and verifying software, embedded systems, and cyber security protocols that connect EVs and EVSE with the utility/grid operator to provide information to support billing and load management.
- **Networks:** Examining infrastructure-related systems to help ensure a robust and reliable vehicle-to-grid network – from emerging smart grid technologies to microgrids.

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