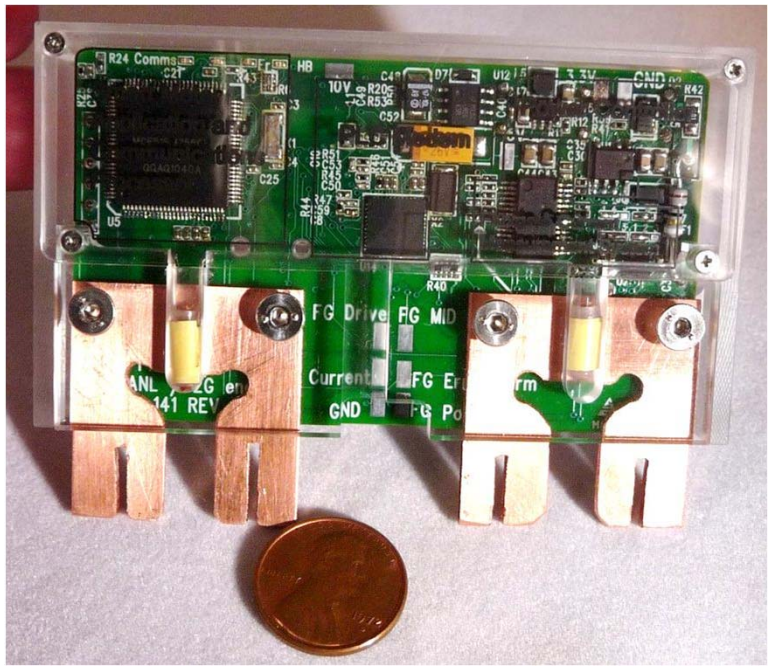
Metering Issues and Technology- DOE Grid Interaction Tech Team



Proof of Concept Low Cost EUMD

- 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
- Reconfigurable for transformer monitoring

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EPRI IWC Meeting, Detroit MI, June 22, 2011

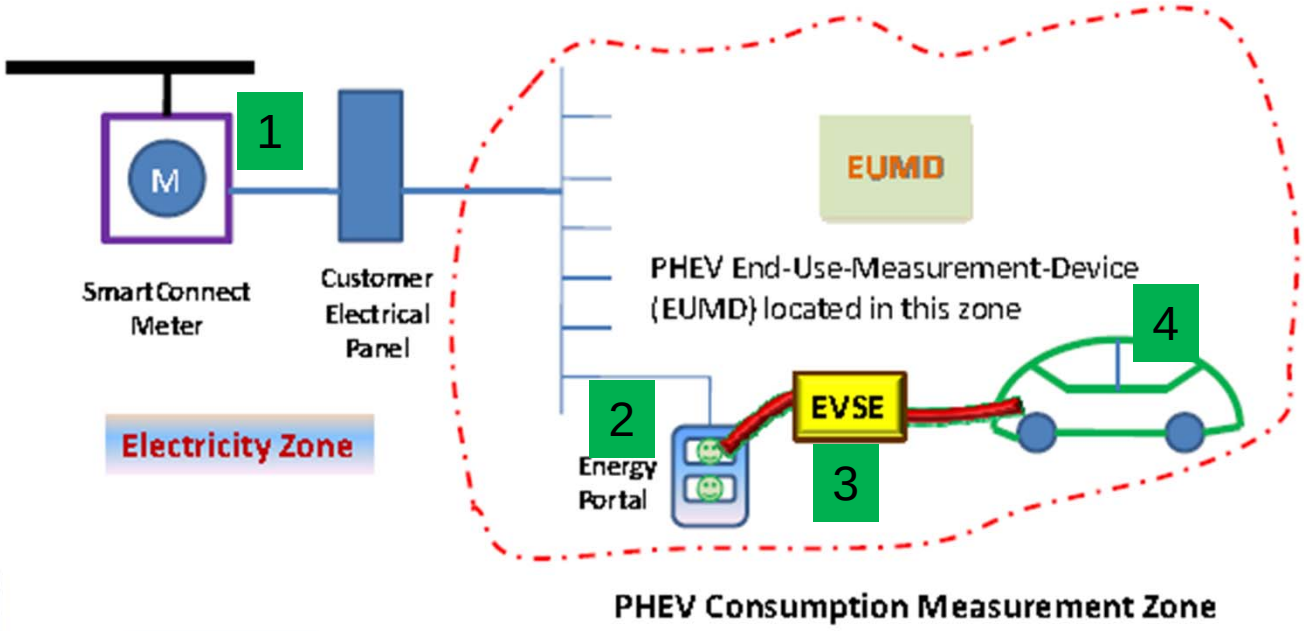
DOE FreedomCAR (now US-DRIVE) Grid Interaction Tech Team Background

- Grid Interaction Tech Team was formed in summer of 2009; similar to APEEM power electronics tech team, energy storage tech team, vehicle systems tech team
- Funded solely by DOE and comprised of
  - **DOE representatives**
  - **Ford, GM, and Chrysler automotive OEM representatives**
  - **DTE and SCE utility representatives**
  - **Technical support from the DOE National Labs (ANL, PNNL, ORNL, INL, NREL)**
- Grid Interaction Tech Team goal is to address issues and identify gaps in the areas where the electrical distribution grid and vehicles charging from the grid interact.
- Projects were proposed for identified areas, and available DOE funds divided up by the proposing/participating groups (National labs, utilities, OEMs). Focus of projects is on **pre-competitive open source research** and proof of concept with anticipated adoption by vendors, OEMs and utilities.
- Year 1 projects included Software Defined Radio (SDR) demonstration on 17,000 gate FPGA for IEEE 802.15.4g; home gateway development, HMI interface software, J2847 message validation over Maxim G3 evaluation boards, and EUMD projects.

Where Does the EUMD Reside?
(Depends on your segment of the EV industry)

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

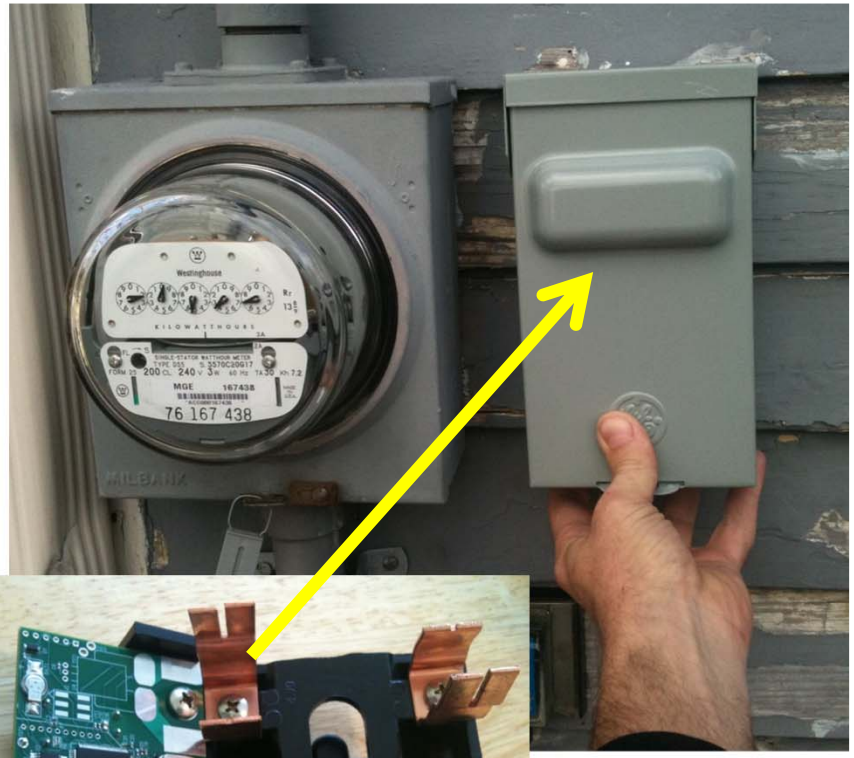
1) **Utilities** tend to favor locating it in an outdoor, technician accessible area, such as **next to the main meter**; possibly as a fused sub-panel with dedicated run to EVSE.
2) **Home Owners** may want it next to their service panel or in garage **near the EVSE**.
3) **EVSE manufacturers** want 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.

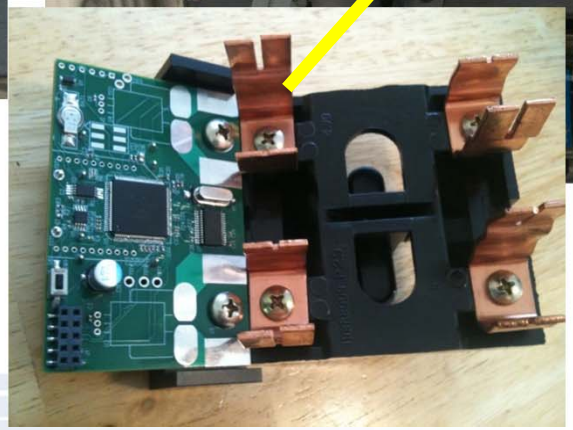


Secondary Meter vs Sub-Meter

(take-away point is that equipment cost is minimal compared to labor/installation)

60A Fused AC Disconnect, $9.99 retail
- EUMD integrated into fuse holder
(most valuable when service panel is full)





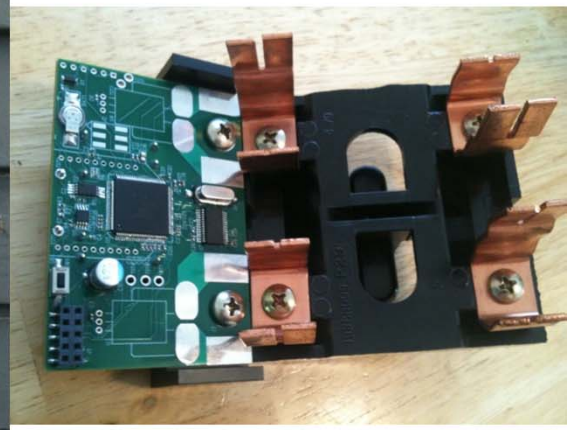
Significant labor/material cost difference between upstream side and sub-meter downstream side (level of PPE, ladder/cable cutters/splice vs electrician on inert side)

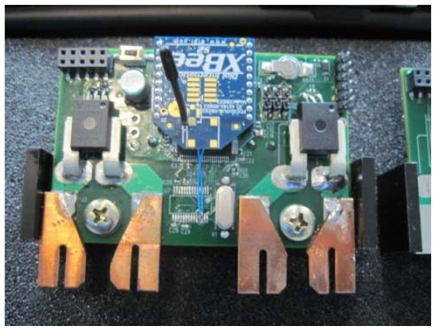
EUMD Built into EVSE vs Removable for Accuracy Verification

- Most EVSE manufacturers offer hard-wired/integrated ‘revenue grade’ metering solution/EUMD.
- Some EVSE manufacturers are investigating re-tasking COTS Smart Meter inside the EUMD itself.
- ANSI C12.1 describes premise meter base requirements and accuracy verification procedures/conditions.
- GITT proof of concept EUMD minimizes ‘meter socket’ to low cost 60A potted part for single phase 240vac, in lockable enclosure, viewable display is in HAN/EMS

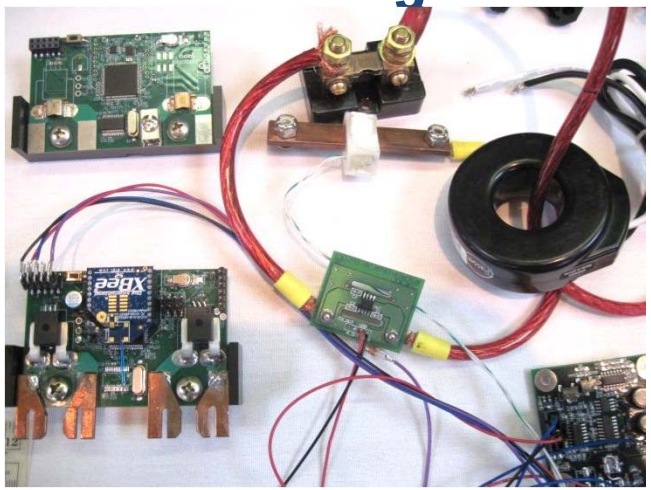
Std 100A, 200A Meter base

60A Fused/unfused instrumented disconnect - functions as disconnect **and** meter device





GITT Compact Metrology for End Use Monitoring Device



UEMD Project goals focused on three technology areas:

1) **Low cost/high accuracy(.1%) compact current sensors:**
   Benchmark each of the standard/future sensors
   - current transformer {AC only}, Rogowski coil AC}
   Allegro Hall sensor, PCB Shunt, Melexis tri-axial coreless current sensor [w/mu shield], Flux gate magnetometer w/automotive grade single IC signal condition, $1 cost

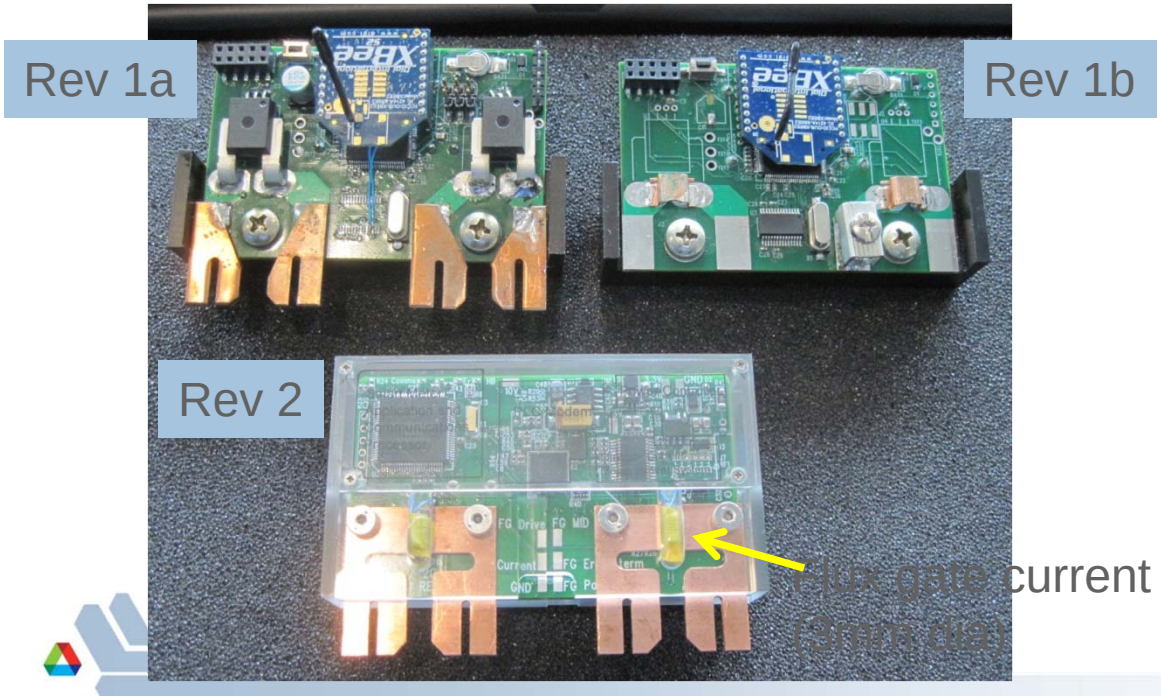
2) **Low cost flexible yet acceptable performance network communication hardware**
   - Investigate software defined radio on FPGA or ASIC
   - Implement and benchmark off-the-shelf Zigbee/Xbee solutions
   - Implement and benchmark Texas Instruments Octave universal baseband IC

3) **Simple, flexible meshed networks/SEP protocols;**
   - Implement SEP 1.1 on EUMD and gateway, interacting with Itron Openway meter
   - Development of 900 MHz IEEE 802.15.4g (UMAN) network w/4G router
   - Implement Grid2Home SEP 2.0 stack in gateway and EUMD

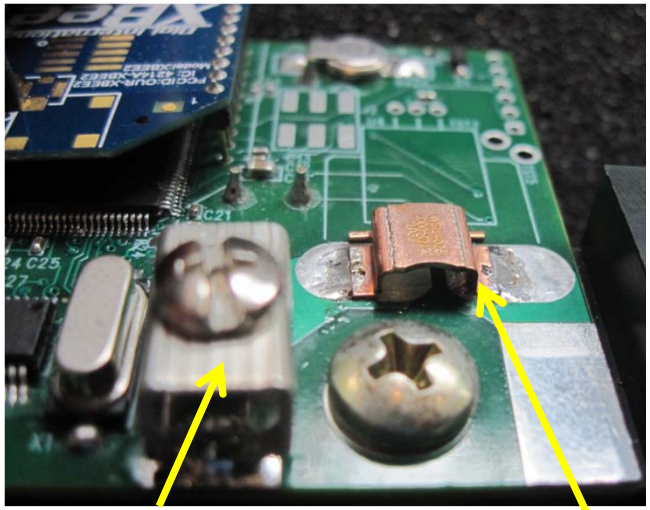
Evolution of compact metrology-
REV1a Baseline Study
(REV 1b current shunt), REV 2 Flux gates, PSOC, PLC

Basic format: 60A potted module (2” x 3” x ¾”) <$20 cost in 10,000 unit volumes

- **REV 1a** baseline sensor comparison study (Melexis hall, Allegro Hall, CT, FG, shunt), Freescale ColdFire Smart Meter process (single chip solution) Zigbee comm.
- **REV 1b:** PCB based shunt/Cirrus IC, screw terminals for Automotive EUMD, Octave universal baseband IC- PLC, FSK, 2.4GHz Zigbee, 900 MHz 802.15.4g options
- **Rev 2:** FSK-PLC communication, flux gate w/PSOC signal conditioning current sensors



Flux gate current sensors (3mm dia)



Screw terminal/PCB shunt .2” x .3” 500µΩ=30mV, $0.30 each (temp. comp.)

Complement to Demand-side Load Management could be Neighborhood distribution transformer monitoring.

Same EUMD card can be used for transformer loading measurement

1) Output current, compared to derated transformer current draw;

Power flow managed neighborhood area community network.

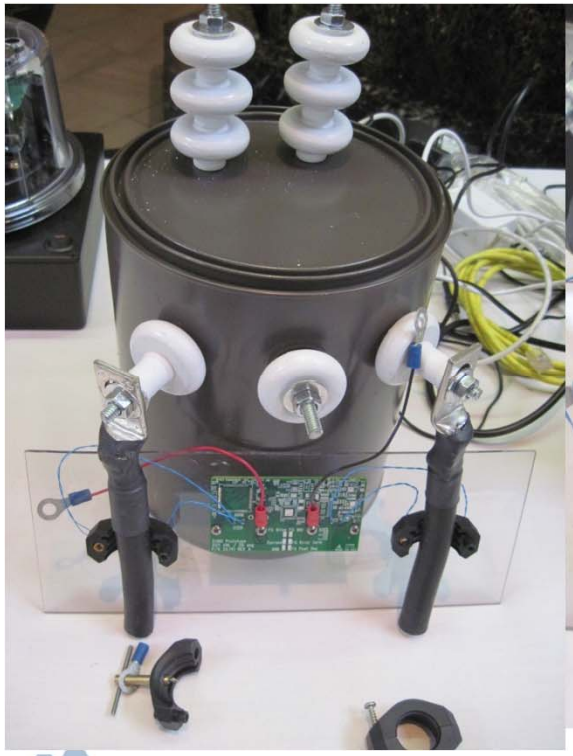
2) Line output voltage, detect sags and outages

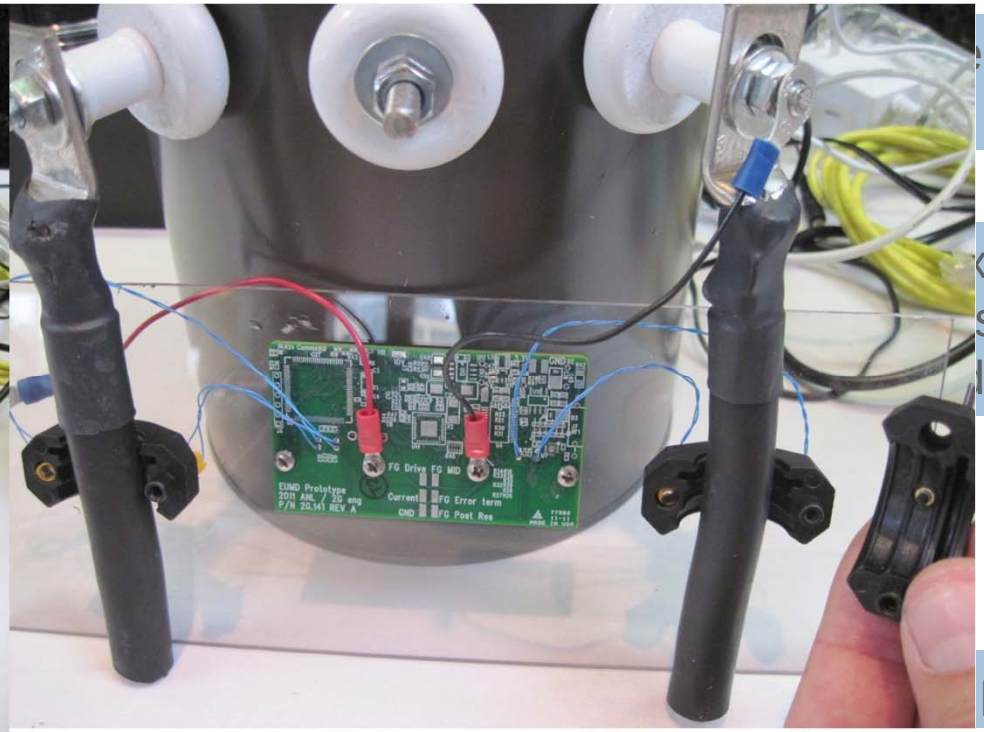
3) Transformer operating temperature

Pole mounted transformer Madison WI
single output 2/0 leads
feeds 3 residences

Potential Low Installation Labor Cost Network Connected Transformer Monitoring System

- Same ~<$20 cost EUMD card, installed with off-board sensors on transformer mock up; single output 2/0 leads with non-invasive coreless current/voltage sensors.
- Flux Gate Current sensors have no need to interrupt circuit to insert lead through torroidal core or use split core CT. Possibly self-sealing piercing voltage tap.
- Possibly installs as a 'snap on' or with a screwdriver and minimal PPE.





ntional voltage
terminal

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probe in clamp

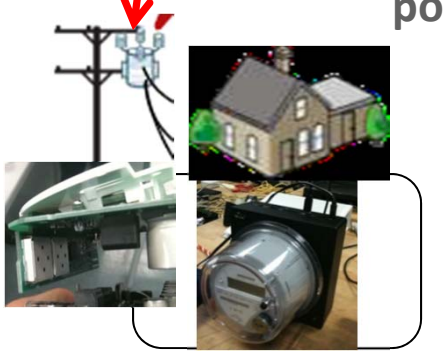
Basic Definitions of PEV Charging Systems (Utility, HAN, EVSE, PEV; SAE J2953 Compatibility Std)

1) **Utility provider-** commercial, residential setting, including Smart Grid communication

2) **Home Energy Mgmt-** Home gateway for demand reduction settings/information portal (~$50)

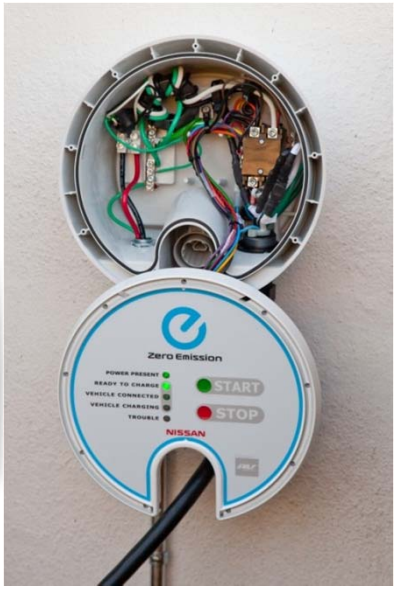
3) **EVSE- Charging Station-** Electric Vehicle Supply Equipment- either AC or DC, w/revenue & comm. (~$450-$5k)

4) **Plug-In Electric Vehicle**
- 4kWhr PHEV Prius
- 8kWhr Volt
- 24kWhr Leaf
- 53kWhr Tesla



Utility Messages
900MHz to back-haul
2.4GHz Zigbee to HAN
(Itron or SilverSpring)

HomeGateway
Digi, Greenwave Reality
HAN- Zigbee/Ethernet

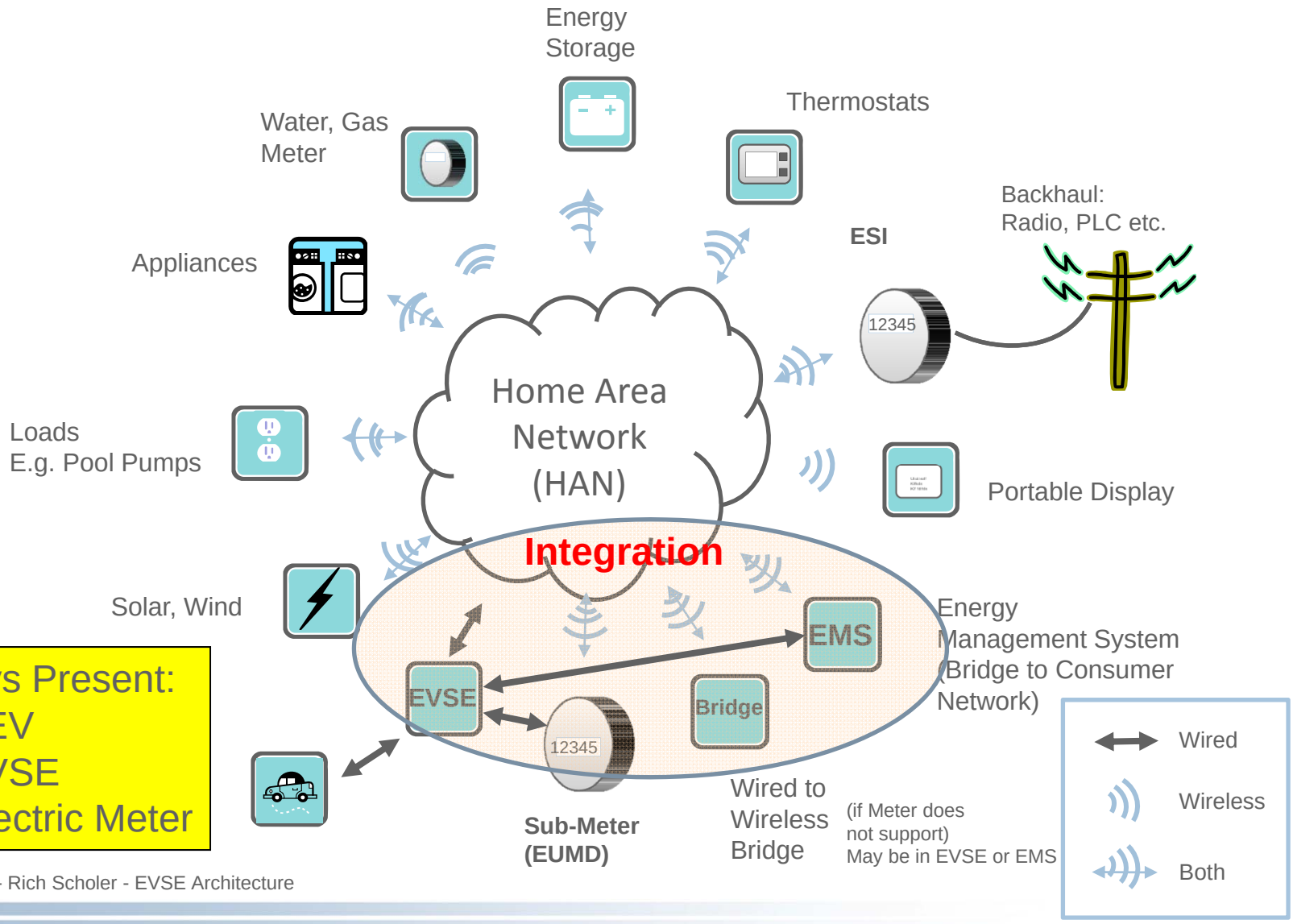


EVSE with Compact Metrology
and Vehicle-EVSE Router pass through
HAN- Zigbee/Ethernet

Emulated PEV/Physical EV,-
Connected to J1772, or (BMS, Pseudo Batt, Charger, CAN network/converter- to DUT)

Gateway is a Key Element of ESCI, Trust Center in Many Utility AMI Architectures

(i.e. AMI meter only talks to gateway, not EUMD directly)

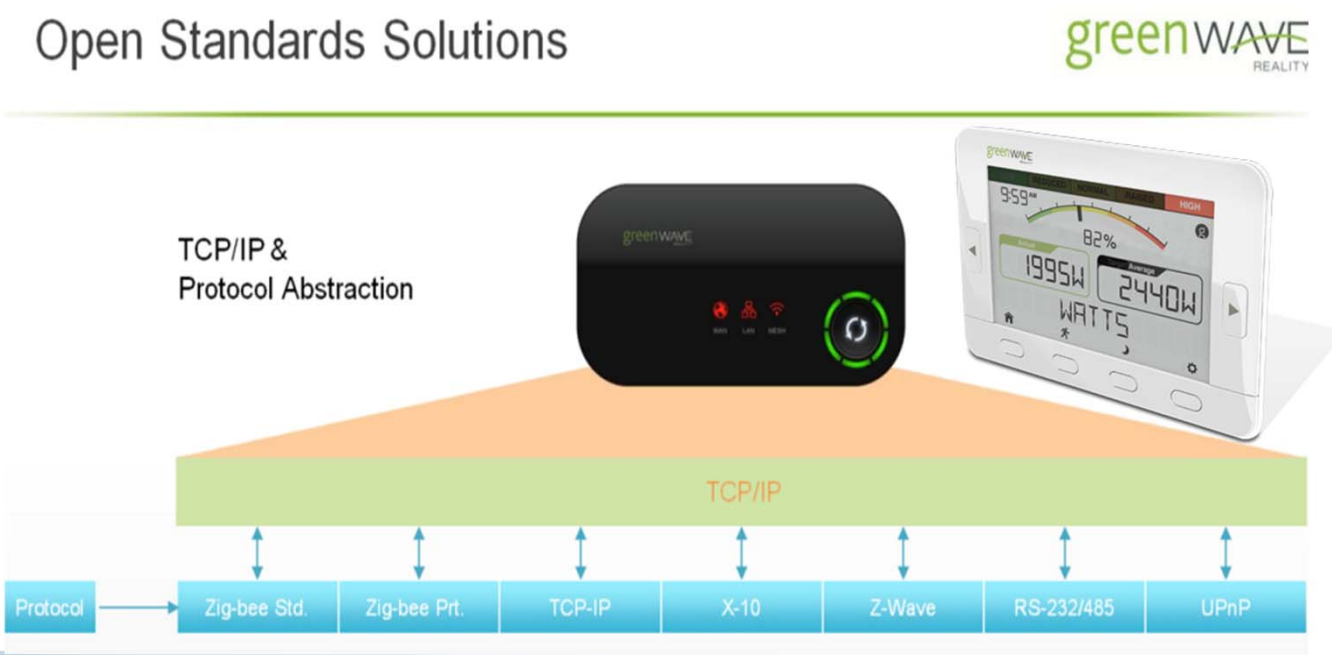


Always Present:
1) PEV
2) EVSE
3) Electric Meter

Example Home Gateway-HAN Smart Meter, EVSE/PEV, EUMD Message Information Exchange

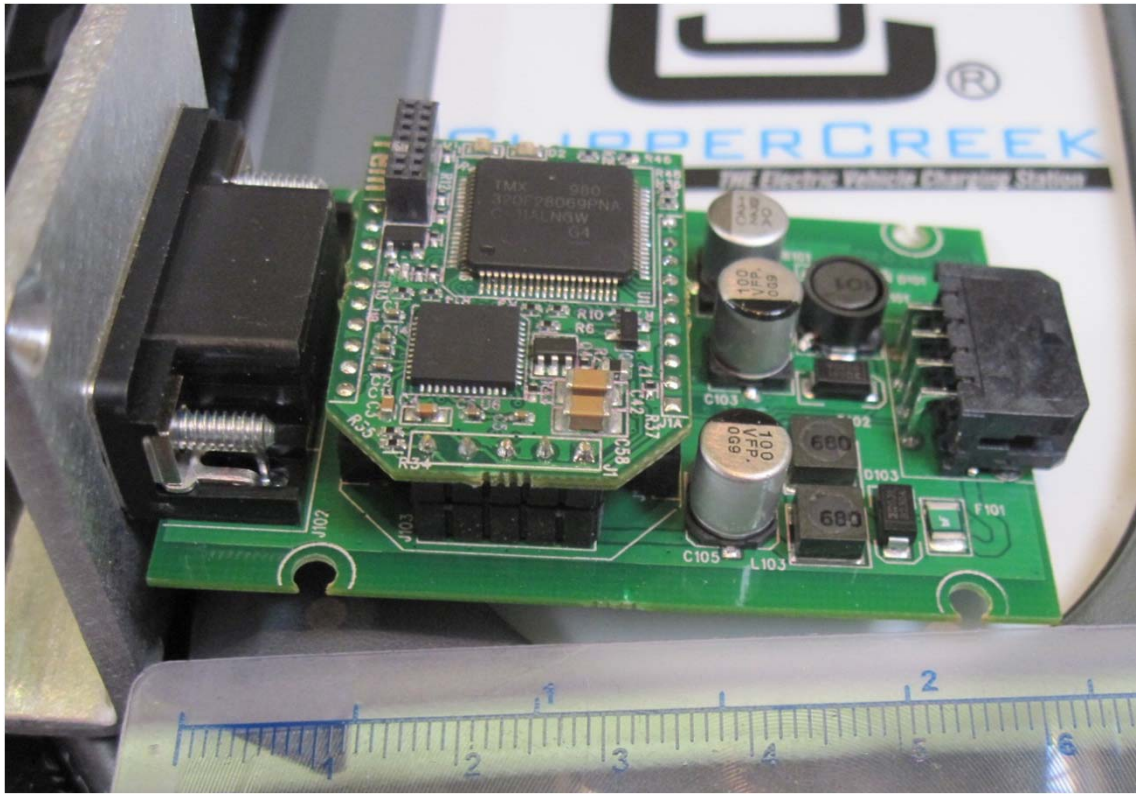
See Links Below for Details {sidebar discussion after presentation}
FCC Certified Hardware available today- multiple PHY options (zigbee, WiFi, z-wave, FSK PLC, N-OFDM PLC, Homeplug GP PLC, etc)

- Greenwave Reality (http://www.greenwavereality.com/solutions/energymgmt)
- Digi International ConnectPort Gateway: (http://www.digi.com/products/wireless-routers-gateways/gateways/connectportx2gateways.jsp#overview)
- Itron evaluation/emulation system (https://www.itron.com/na/solutions/Pages/OpenWay.aspx)



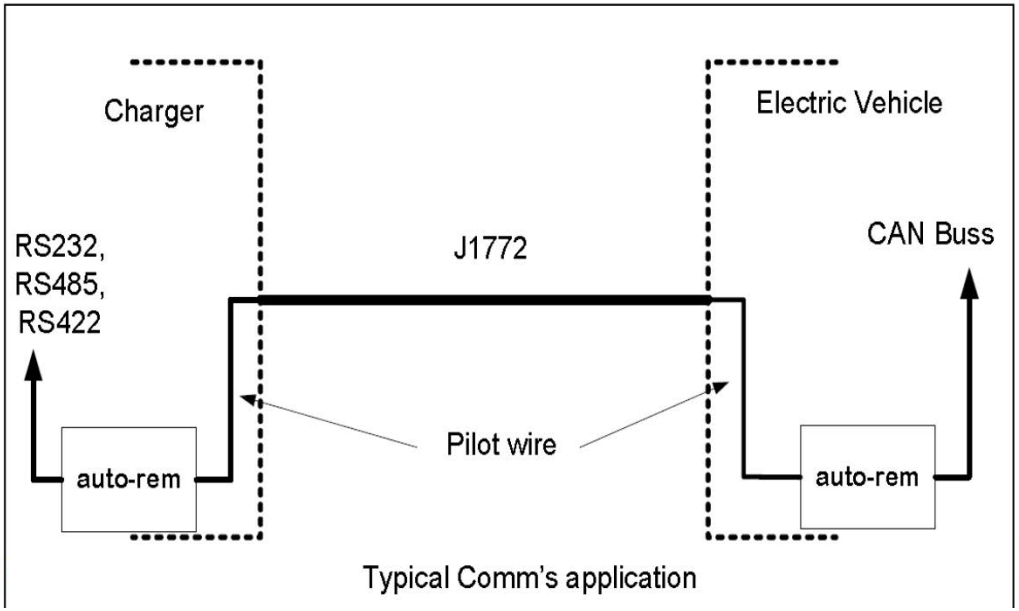
Related Communication Challenges: SAE J2931 (N-OFDM Over Pilot between PEV-EVSE) Proof of Concept Module: Auto-rem (30 units in hand)

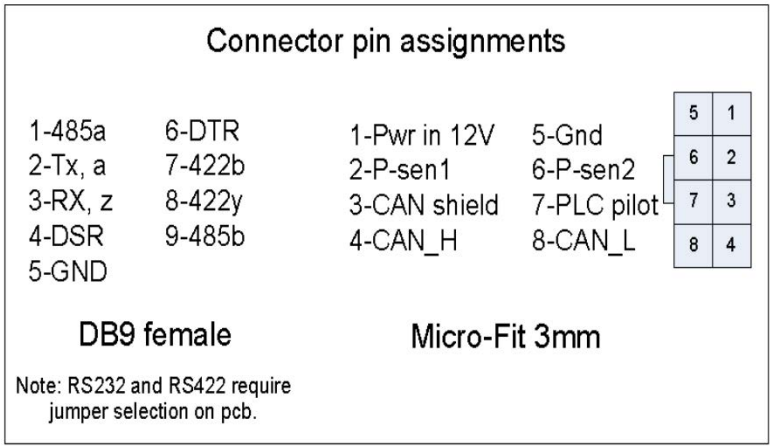
- Based on T.I. Octave universal baseband IC, with N-OFDM, CAN, Serial built in
- Able to install this module in vehicle (CAN to N-OFDM), in EVSE (serial to N-OFDM)



Auto-rem Features:

- On board filtered power supplies for direct connect to 12 volt vehicle power.
- 2 power wakeup control sense lines with >100K impedance.
- MPU controlled power shutdown.
- PLC impedance matched to support AC coupled vehicle pilot wire communications between off-board charging supply and the electric vehicle, sporting the OFDM communications protocol.
- CAN interface for vehicle side communications.
- RS232, RS485 and RS422 electrical interfaces for charger supply communications.
- Off board connectors; 1) vehicle, 8-pin Molex micro-fit 3mm, 2) DB9F for power supply





Small footprint measuring 1.6" x 2.51" w/optional extruded metal enclosure.

DC Off-Board Charging Messages

MSG NAME	Phase	Msg period	MSG ID	Startbit	length(bits)	Index	Signal	Source	Destination
INITIALIZATION									
Charger_Info	Initialization	100mS	0x05	0	16	21	Charger Energy to be delivered	DC Supply	PEV
Charger_Info	Initialization	100mS	0x05	16	13	8	Charger Power Limit	DC Supply	PEV
Charger_Info	Initialization	100mS	0x05	32	11	32	Charger Peak Current Ripple	DC Supply	PEV
Charger_Info	Initialization	100mS	0x05	44	4	35	Charger Supported Energy Transfer Type	DC Supply	PEV
Charger_Info	Initialization	100mS	0x05	48	11	33	Charger Current Regulation Tolerance	DC Supply	PEV
Charger_Info	Initialization	100mS	0x05	60	4	28	Charger Protocol Version	DC Supply	PEV
Vehicle_Info	Initialization	100mS	0x06	0	8	17	Bulk SOC	PEV	DC Supply
Vehicle_Info	Initialization	100mS	0x06	8	8	19	Full SOC	PEV	DC Supply
Vehicle_Info	Initialization	100mS	0x06	16	16	20	Vehicle Energy Request	PEV	DC Supply
Vehicle_Info	Initialization	100mS	0x06	32	13	12	Vehicle RESS Voltage	PEV	DC Supply
Vehicle_Info	Initialization	100mS	0x06	52	4	34	Vehicle Requested Energy Transfer Type	PEV	DC Supply
Vehicle_Info	Initialization	100mS	0x06	60	4	27	Vehicle Protocol Version	PEV	DC Supply
Vehicle_VIN	Initialization	100mS	0x07	0	8	99	Data Mode 4FF	PEV	DC Supply
Vehicle_VIN	Initialization	100mS	0x07	8	48	100	4FF Body	PEV	DC Supply

J2847/2 Messages

CHARGING									
Charger_Limits	Initialization and during charge	100mS	0x03	0	13	31	Charger Minimum Current Limit	DC Supply	PEV
Charger_Limits	Initialization and during charge	100mS	0x03	16	13	30	Charger Minimum Voltage Limit	DC Supply	PEV
Charger_Limits	Initialization and during charge	100mS	0x03	32	13	10	Charger Voltage Limit	DC Supply	PEV
Charger_Limits	Initialization and during charge	100mS	0x03	48	13	9	Charger Current Limit	DC Supply	PEV
Charger_Output	During Charge	100mS	0x01	0	14	23	Current Output	DC Supply	PEV
Charger_Output	During Charge	100mS	0x01	16	13	22	Voltage Output	DC Supply	PEV
Charger_Output	During Charge	100mS	0x01	32	4	15	Charger Status Code	DC Supply	PEV
Charger_Output	During Charge	100mS	0x01	36	1	24	Charger Current Limit Achieved	DC Supply	PEV
Charger_Output	During Charge	100mS	0x01	37	1	25	Charger Voltage Limit Achieved	DC Supply	PEV
Charger_Output	During Charge	100mS	0x01	38	1	26	Charger Power Limit Achieved	DC Supply	PEV