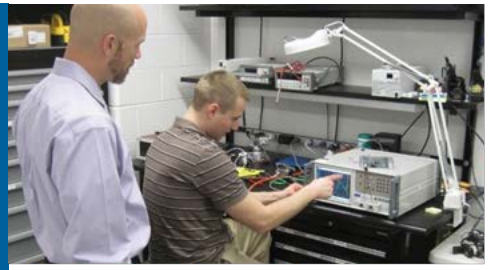
2017 DOE HYDROGEN PROGRAM AND VEHICLE TECHNOLOGIES
ANNUAL MERIT REVIEW

Argonne NATIONAL LABORATORY

EV-SMART GRID RESEARCH & INTEROPERABILITY ACTIVITIES



KEITH HARDY
DOE/ANL EV-Smart Grid Interoperability Center

6 June 2017
Washington, DC

Project ID: GI095

This presentation does not contain any proprietary, confidential, or otherwise restricted information

OVERVIEW

Timeline

- C&S support, grid connectivity R&D and international coop. initiated in FY 2010
- DOE-EC agreement to establish interoperability centers - Q1, FY 2012
- Argonne IOC launch - Q4, FY 2013
- JRC IOC launch – Q1, FY 2016
- Smart Energy Plaza Ø1 – Q4, FY 2015
- Smart Energy Plaza Ø2 – Q3, FY 2017

Barriers/Challenges

- Universal interface(s) for grid-connected devices that utilize open source solutions for connectivity and communication
- Test tools to verify interoperability
- Low-cost sensing, communication and control components/integrated systems
- *Standardization and integration of high power and inductive charging technologies*

Budget

- FY2016 - $2824K
- FY2017 - $2485K

Collaborators

- SDOs, Global InterOP
- Vehicle and EVSE OEMs
- DOE national labs and EC-JRC
- State, Commerce and Euro. Comm.

RELEVANCE

Argonne IOC activities support standard PEV/EVSE interoperability, grid integration and global harmonization

- Lead/actively contribute to numerous standards committees
  SAE J2953 (Interoperability); SAE J2954 (LD wireless charging); SAE J2894 (Charging power quality); IEEE 2030.10 (DC microgrid/Emerge alliance – DC meter standard); NIST HB44 (Wh meter and EV fueling submeter working group)
- Develop enabling technologies for grid connectivity and integrated energy management
- Cooperate with industry and governments in Europe and Asia to promote compatible interoperability requirements, verification procedures and tools

APPROACH

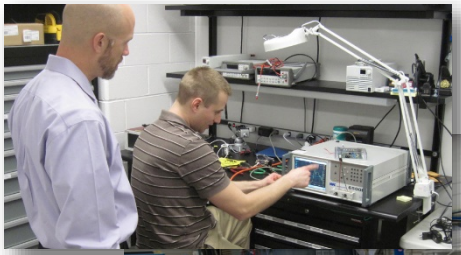
Support standards development
Committee participation, tool development and testing (SAE, IEEE, IEC/ISO, Global InterOP)

Develop grid integration capability using open source software and hardware
Open access to integration and control methods; requirements for grid-connected devices

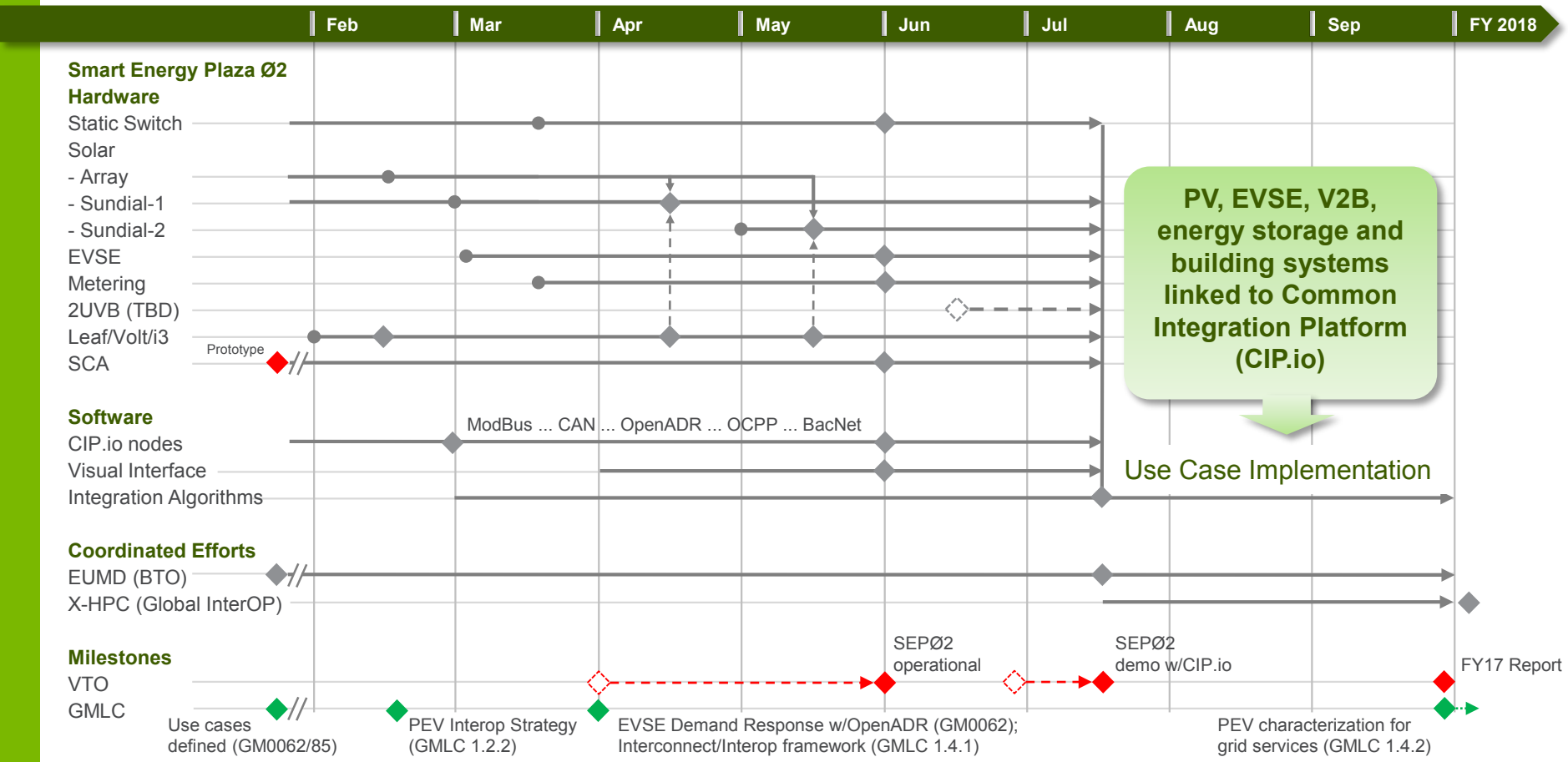
Develop enabling technologies and tools
Evaluate energy management use cases/services on the customer side of the meter

Support international harmonization
US-EU, US-China and APEC initiatives

Support Grid Modernization Lab Consortium
Interoperability, PEV-building/grid integration



SCHEDULE



Spec/prep ... Installation ... Integration
VTO milestones
GMLC milestones (quarterly reports not shown)

Any proposed future work is subject to change based on funding levels.

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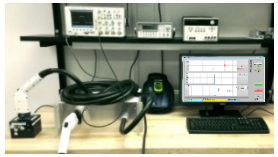
PRIOR ACCOMPLISHMENTS

Led development of SAE interoperability standards and tools

2013 | 2014 | 2015

Launched DOE EV-Smart Grid Interoperability Center at ANL



Interoperability

Wireless Charging

Standards

SAE J2953

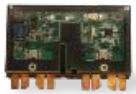
Tools

Charge Connector Compliance

Technology

Communication

Metrology



EVSE Fueling Accuracy

COOPERATIVE AGREEMENTS

Targeting universal interoperability and compliance methods

2014 — 2015 — 2016 — 2017

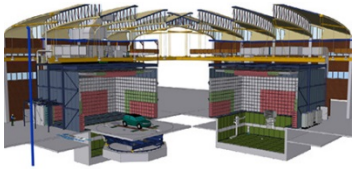
The European Interoperability Centre for Electric Vehicles and Smart Grids

European Commission

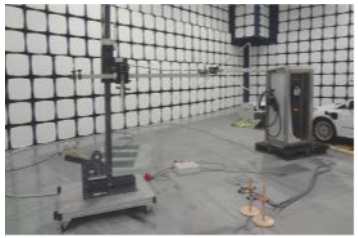
Low Temperature Testing

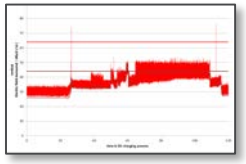
AC Interop testing and equipment evaluation

DC Interop testing



VELA-9 construction





PEV/EVSE EMC characterization

L2 instrumentation and testing at ANL

Comparative testing at JRC

BMW i3 EREV reference vehicle

Global InterOP

Audi, BMW, DAIMLER, FCA, Ford, GM, Opel, PORSCHE, VW, European Commission, Argonne National Laboratory

Interoperability requirements

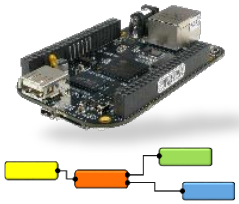
scienlab

Argonne National Laboratory

DEVELOPED TECHNOLOGIES AND TOOLS

SpEC module
EV/EVSE communication controller

Common Integration Platform (CIP.io)
Commercial HW; Open source SW



Smart Charge Adaptor (SCA)
Metering, communication, charge control

EUMDs in commercial formats
Circuit/device metering and communication

PEV/EVSE DC Emulator (170 kW)
Controlled by (2) SpEC modules

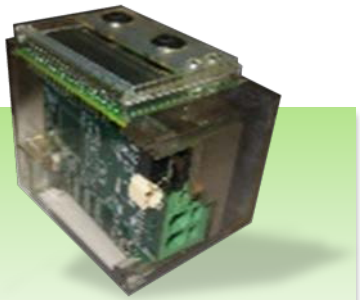
Fully instrumented reference PEV
Comparision of test facilities and procedures

NIST HB44 – EVSE Electric Fuel Delivery
(AC) Test procedure and tool development

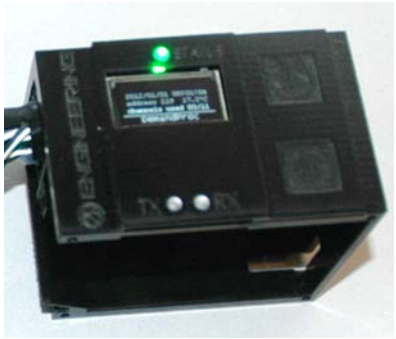
Wireless EVSE Test Fixture
Vehicle/coil manipulation; field measurement

FY 2017 ACCOMPLISHMENT

VTO-funded research led to commercialization award by BTO for building load efficiency applications



Targets low cost, revenue grade End Use Measurement Device (EUMD) with easy installation and standard network options



FY17-18 project funded by DOE Building Technologies Office will result in a certified meter available for licensing and manufacturing

Features/Capabilities:

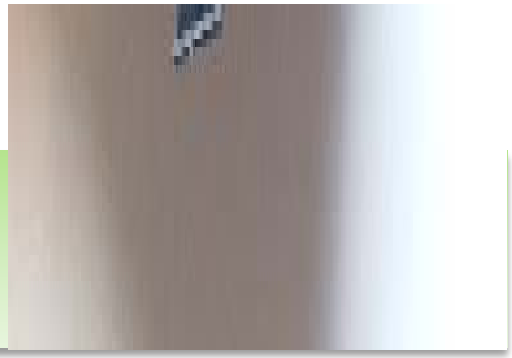
- Modular reconfigurable submeter; single/three phase AC or DC loads
- Built in 30A current sensor, 16+3 channel expanded current sensor inputs (16 expansion-3 phase base inputs)
- Can be packaged in circuit breaker format enclosure, using voltage tap points for sensing, logic power; also stand alone or DIN rail mount
- Low cost serial communication output to custom modem

Project team:

- Argonne: System design
- 2G Engineering: Hardware layout and fabrication
- Amzur Technologies: Software for user interface, energy visualization and analysis

FY 2017 ACCOMPLISHMENT

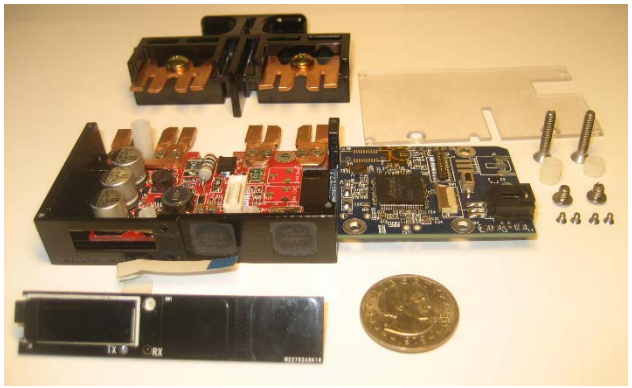
Next generation modular submeter; multi-configuration capability



Modular, daughter board design allows for flexibility in the same commercial format

Features/Capabilities:

- Accepts AC & DC inputs
- Up to 19 channels
- OLED display, touch buttons
- 2.5” x 3” x .75” size



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FY 2017 ACCOMPLISHMENT

Smart Charge Adaptor ... from Proof-of-Concept to Alpha Prototype

- Energy I-Corps Cohort 2 participant
- Duplication for lab/field testing following functional verification

Specifications

Voltage: 100 – 240 V_{rms} (AC L1/L2)
Current: 0 – 80 A_{rms}
Power: 0 – 19.2 kW
Meter accuracy: 0.5%
Charging control resolution: 0.06 A_{rms}
Communication Latency
  Update: 2 sec
  Command: <500 msec
Communication security: TLS

Features

Metering, monitoring, & control
SAE J1772 compliant
Interoperable with all PEVs and EVSE
AP Wi-Fi mode for configuration

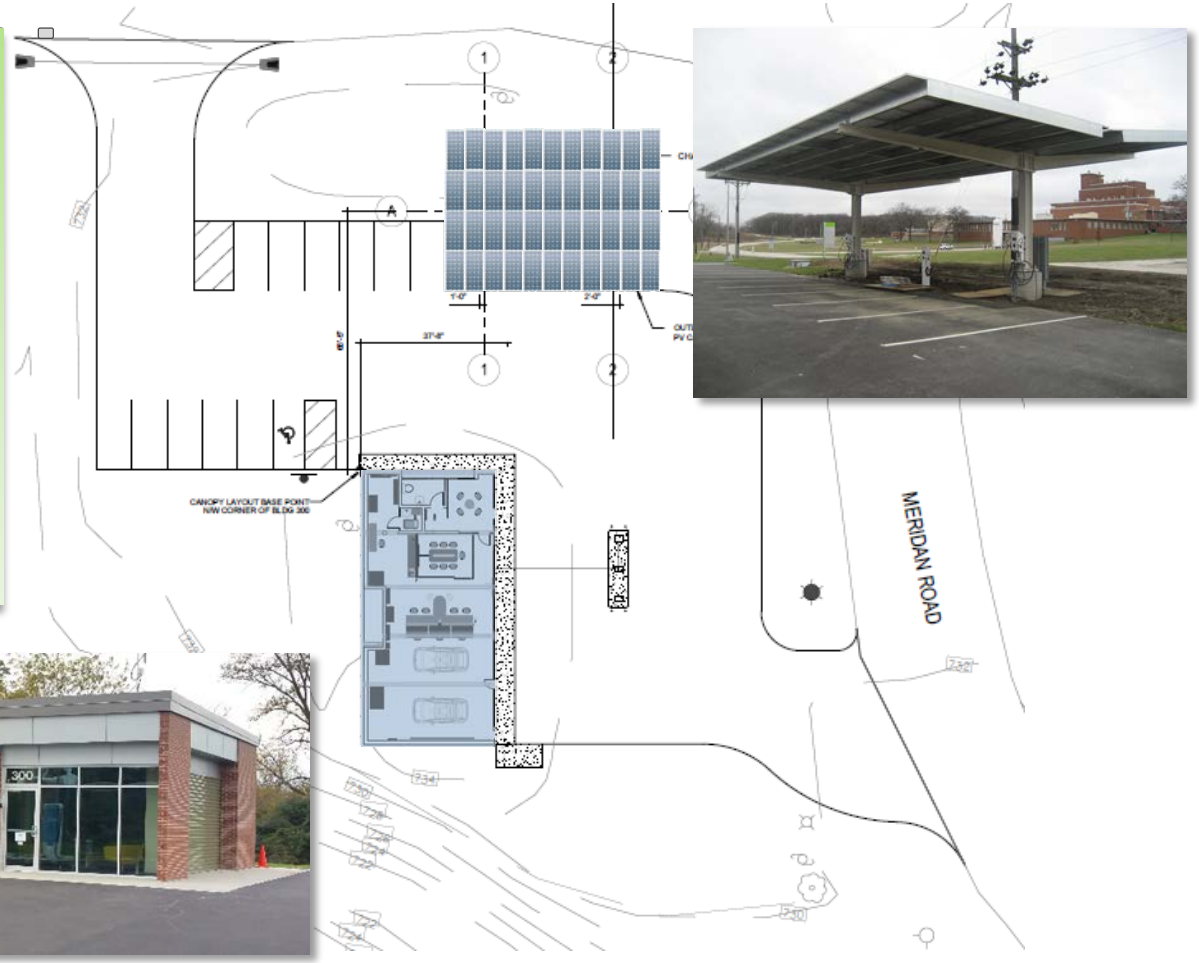
Applications

Utility Demand Response (DR) and
  Real-Time Pricing Programs
PEV Submetering
EVSE Aggregation

FY 2017 ACCOMPLISHMENT

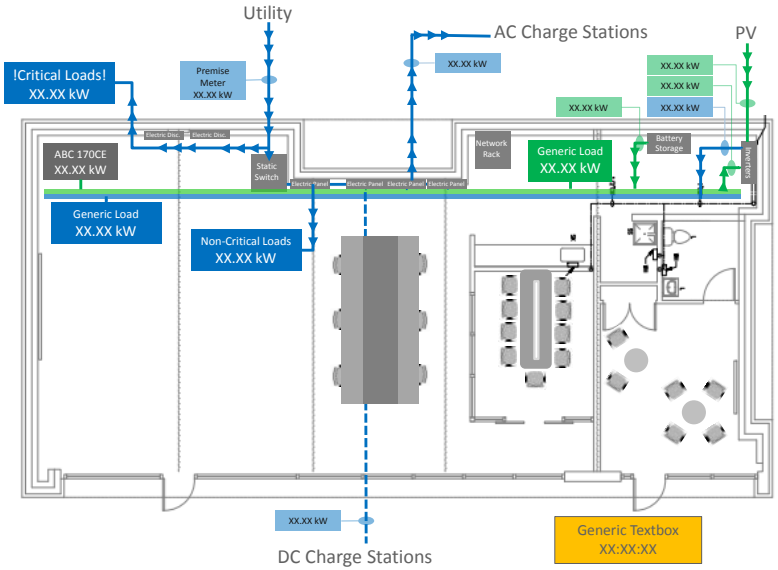
Smart Energy Plaza Ø2 – design and renovation – former gas station

- Construction and infrastructure by Argonne Sustainability Program
- 13.2 kV to site; 500 kVA to building
- 40 kW PV array; DC to building
- Island infrastructure for (4) HPC and (2) W-EVSE

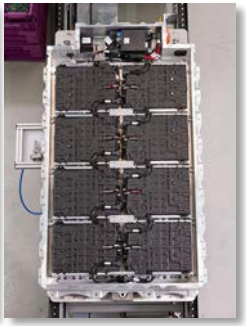


FY 2017 ACCOMPLISHMENT

SEPØ2 – flexible system configuration with integrated control



- AC (208 3Ø, 240, 480 3Ø, 600 A) and DC metered busways; real-time power flow visualization
- PEV/EVSE emulation up to 170 kW
- Grid isolation capability: 40 kW PV, BEV-V2B; building controls; PHEV-V2B and 2UVB TBD
- Common integration platform w/open source SW; supports automotive/commercial protocols
- EVSE: L2 AC, DCFC; X-HPC and WPT TBD



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FY 2017 ACCOMPLISHMENT

Reference vehicle tested at EC-Joint Research Center*

Assess the impact of ambient conditions on energy consumption and driving range. (-30°C to 50°C)

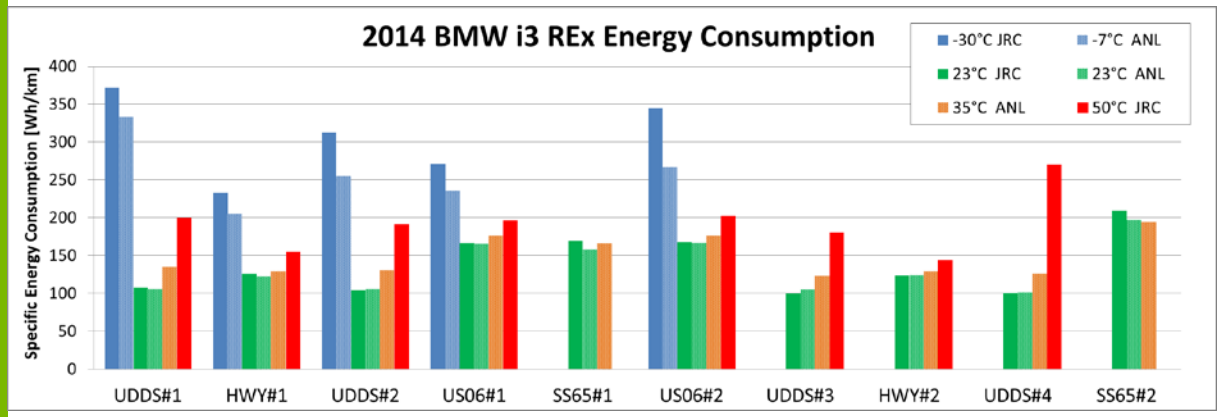
- Energy consumption increased above and below 23°C; more significant at negative temperatures due to cabin heater energy use.
- Driving range was significantly reduced at negative temperatures (>50%).

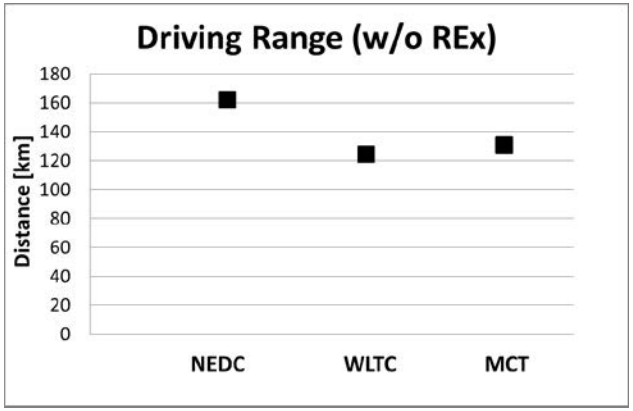
Compare different test procedures adopted in EU and US

- Energy consumption and driving range variations ~ 5% on WLTC and MCT
- Considerable performance differences ~20% for NEDC

Future work

- Temperature impact on the WLTP





* M.C. Galassi, K. M. Stutenberg, M. Garcia Otura, G. Trentadue, H. W. Scholz, M. Carriero, K. Hardy, H. Lohse-Busch, "Joint ANL-JRC Experimental Campaign: Laboratory Testing of a Range Extended Electric Vehicle (REEV)", Proceedings of the European Battery, Hybrid and Fuel Cell Electric Vehicle Congress (EEVC2017), Geneva, 14th - 16th March 2017.

Any proposed future work is subject to change based on funding levels.

REMAINING CHALLENGES AND BARRIERS

Interoperability verification tools and procedures (regional/global)

- DC charging standards not adopted, but test tools and EVSE being developed/produced based on assumptions
- Wireless power transfer (WPT); standards being defined

High power DC charging (up to 400 kW)

- Interoperability and infrastructure requirements
- Certification procedures and test equipment

Requirements for and benefits of PEV-grid integration

- Evaluation of proposed use cases (V1G and V2G)
- Coordination across standards definition organizations (SAE, IEEE, ISO/IEC)

Standard/non-proprietary EVSE-grid communication

- Necessary for interoperability and back office operations
- Proprietary protocols limit opportunities for integrated energy management

PROPOSED FUTURE RESEARCH AND COLLABORATION

Codes & Standards: SAE, IEEE, NIST committees

AC/DC charging interoperability: Scienlab/JRC – evaluation of Global (US-EU) Test Devices

'Ultra-fast' high power charging: BMW, Daimler, Ford and Volkswagen (incl. Audi and Porsche)/JRC

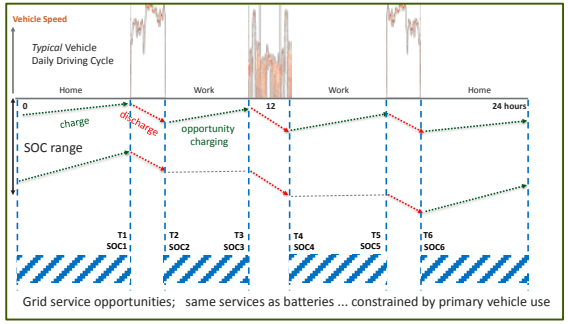
- 350 kW DC EVSE interoperability/performance testing

Grid integration/modernization: GMLC lab partners

- GMLC 1.2.2 – Interoperability vision/strategy
- GMLC 1.4.2 – PEV testing – grid 'driving cycle'
- GM0062 – building/workplace integration use cases
- GM0085 – distribution system interface requirements

Technology Transfer: Industry/state programs

- EUMD, SpEC module and SCA



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REVIEWER COMMENTS

Generally positive; actionable comments addressed

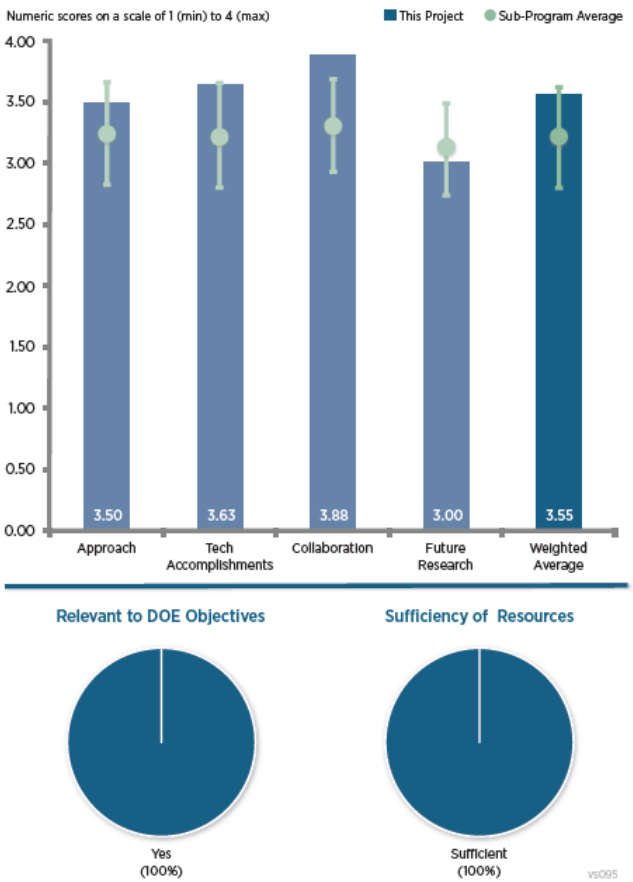

Figure 1-10 – EV - Smart Grid Research and Interoperability Activities: Keith Hardy (Argonne National Laboratory) - Vehicle Systems

- Reviewer 2: Some effort should be spent on moving hardware and software developed into industry.
  Agree – SpEC module, SCA and EUMD have been or in the process of being licensed
- Reviewer 2: Consideration should be given to developing and implementing a market transformation plan.
  Beyond the scope of the interoperability center
- Reviewer 3 – It would be helpful to have a top-down viewpoint slide
  Overview (barriers/challenges) and Relevance slides
- Reviewer 3: The reviewer noted that the chart for future work needs to be grounded with qualitative comments on what the new frontiers are and why. The reviewer found it very difficult to navigate this chart without intimate knowledge of acronyms and connected project phasing logic. In other words, the roadmap is too complex for the audience to appreciate the sufficiency of detailed subjects and steps laid out.
  Agree – Future roadmap not included
- Reviewer 4: The reviewer stated that a large variety of activities supported requiring a lot of resources. Although doing more with less, the support of these technologies could involve less product development, which could make even better use of funds available.
  Disagree – Technology development is an integral part of gaining practical experience and fostering technology transfer (which has been identified as desirable by DOE). The knowledge gained from applied engineering contributes directly to standards development, verification and industry needs. The opportunity for the technical staff to transform ideas into reality is an important factor in hiring and retaining talent.

SUMMARY

- **Relevance** – Developing and verifying standards and technology in cooperation with industry; working relationships with global manufacturers and research institutions are facilitating global harmonization of standards, test procedures and equipment.
- **Approach** – Activities are aligned with the SDOs, industry and the Grid Modernization initiative; enabling technologies developed for vehicle interoperability are being applied to grid integration.
- **Technical accomplishments and progress** – Substantial progress in tools and technology to support standards and harmonization
  - Tools: Smart Energy Plaza Ø2 grid integration testbed fully integrated by July 2017
  - Technology:
    CIP.io w/automotive and commercial protocols by June 2017;
    SCA alpha prototype demonstrated and to be duplicated for lab/field testing;
    EUMD targeting commercialization in FY 2018 (BTO funding).
- **Collaboration** – Well-connected with industry and government agencies
- **Future work** – Focused on industry needs and grid integration/modernization