Project ID: ELT278

Electric Vehicles at Scale (EVs@Scale) Laboratory Consortium

Andrew Meintz

DOE Vehicle Technologies Office (VTO) Annual Merit Review
June 22, 2022

Photo from iStock-627281636

Overview

Timeline

Start: January 2022

End: January 2027

Percent Complete: ~9%

Budget

Total project funding:	$65 M
DOE share:	$65 M
Contractor share:	$ 0
FY 2022 Funding:	$12.75 M
FY 2023 Funding:	$12.75 M

Barriers

- EVs at Scale will require close coupling of the transportation and electricity sectors creating greater interdependencies and potential benefits and risks
- A significant number of EVSEs, many at high power (> 200kW) and clustered at charging facilities are required and will posing unique challenges for control and impacts to the electric grid.
- Holistic approaches across the EV ecosystem are needed for interoperability, communications, controls, advanced high-power charging technologies, codes and standards, cybersecurity, and integration with the grid.

Partners

Argonne National Laboratory, Idaho National Laboratory, NREL, Oak Ridge National Laboratory, Pacific Northwest National Laboratory, Sandia National Laboratories

Relevance

Impact

- Transportation is key for America’s economy: annually vehicles transport 18 billion tons of freight[1] and moved people more than 3 trillion vehicle-miles[2]
- Presently, the transportation sector derives **< 1% of its energy from electricity** but accounts for nearly 30% of primary energy consumption in the U.S.[3]
- Considering a case where adoption of EVs reaches about 2/3 of the light-duty fleet in 2050 would result in **16% of annual electricity consumption**.

Objectives

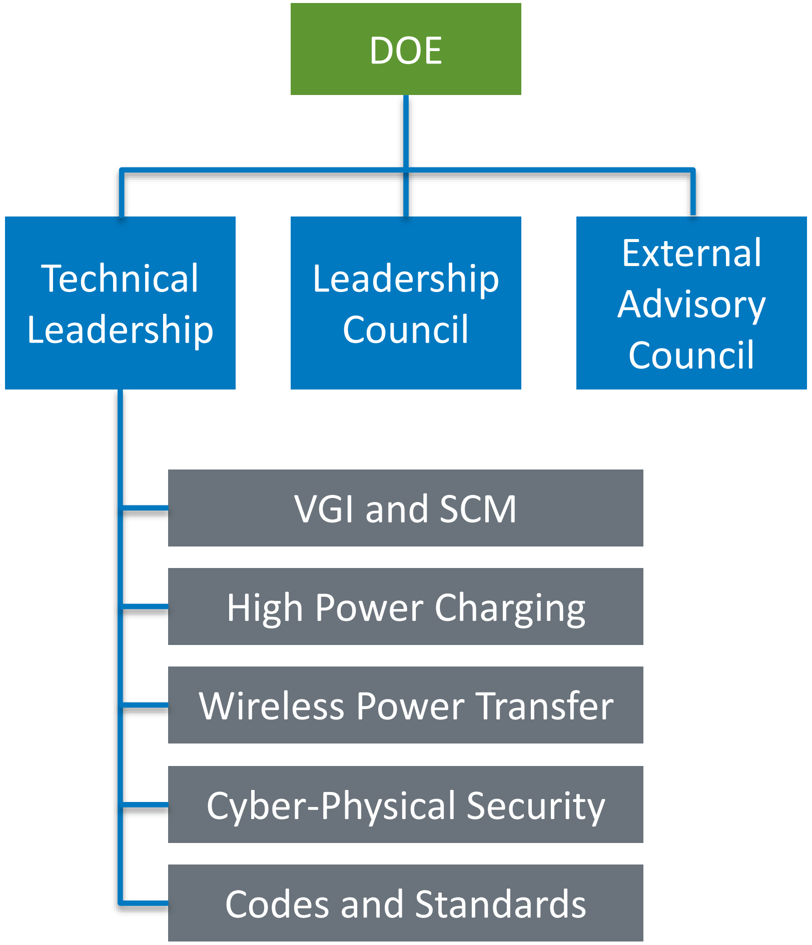
- Develop charging technologies and standards needed to meet U.S. goals of transitioning to a **nationwide fleet of on-road vehicles powered by electricity**, bringing the transportation sector closer to a net-zero-emission future
- Bring together the **national laboratories’ hardware and software expertise, capabilities, and facilities related to EV charging**, charge management, grid services, grid integration, and cyber-physical security.
- Enable **highly coordinated, precompetitive research** to be initiated and successfully conducted that is in step with rapid changes in the EV charging

Installation of smart charging system at NREL’s Flatirons Campus *(Dennis Schroeder / NREL)*

[1] Bureau of Transportation Statistics, DOT, Transportation Statistics Annual Report 2020, Table 4-1. https://www.bts.gov/tsar.
[2] Transportation Energy Data Book 39th Edition, ORNL, 2021. Table 3.8 Shares of Highway Vehicle-Miles Traveled by Vehicle Type, 1970-2018.
[3] Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States. NREL/TP-6A20-71500

Approach

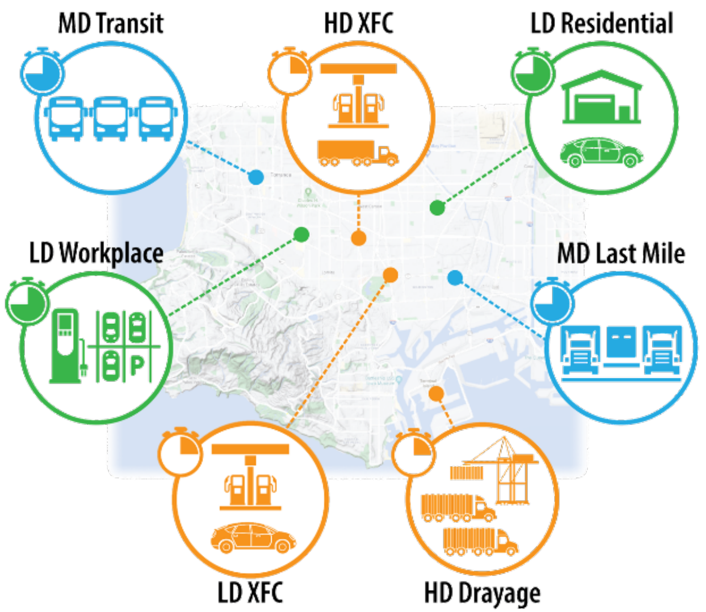
- Leadership Council
  - Andrew Meintz (NREL, chair), Keith Hardy (ANL, rotating co-chair), David Smith (ORNL), Summer Ferreira (SNL), Rick Pratt (PNNL), Tim Pennington (INL)
- External Advisory Council
  - Utilities, EVSE & Vehicle OEMs, CNOs, SDOs, Gov't, Infrastructure
- Consortium Pillars and Technical Leadership
  - <u>Vehicle Grid Integration and Smart Charge Management (VGI/SCM):</u> Jesse Bennett (NREL), Jason Harper (ANL)
  - <u>High Power Charging (HPC):</u> John Kisacikoglu (NREL)
  - <u>Wireless Power Transfer (WPT):</u> Veda Galigekere (ORNL)
  - <u>Cyber-Physical Security (CPS):</u> Richard "Barney" Carlson (INL), Jay Johnson (SNL)
  - <u>Codes and Standards (CS):</u> Ted Bohn (ANL)



Approach – VGI/SCM

Flexible charging to Unify the grid and transportation Sectors for EVs at scale (FUSE)

- **Objective:** Develop an adaptive ecosystem of SCM and VGI strategies and tools relevant to assess and reduce barriers of a wide geographic area across numerous vocations
- **Outcomes**:
  - **Broadly identify limitations and gaps** in the existing VGI and SCM strategies to strategically shift PEV charging in time across a wide range of conditions
  - **Develop and demonstrate VGI approaches** to reduce grid impacts for the **entirety of the LD, MD, and HD on-road fleet** while accounting for vehicle and energy requirements.
  - **Determine SCM and VGI benefits for consumers and utilities** for EVs@Scale across the range of conditions (geographies and seasons) found in the US
- **Team and Collaboration:**
  - NREL, ANL, INL, SNL
  - Utility partners to develop grid models in areas of study
  - Fleet partners to assess SCM operational feasibility



VGI and SCM across all vocations (personal, commercial) and charging types (en route, public, depot)

Approach – VGI/SCM

Flexible charging to Unify the grid and transportation Sectors for EVs at scale (FUSE)

- **Task Structure**
  - Scoping, requirements, and industry/stakeholder engagement
    - Identify regions of study and demonstration opportunities
  - Assessment of travel, charging energy, and grid impacts
    - EV Adoption, Travel, and Charging Energy
    - Grid Impact Assessment
    - Broadly Assess Gaps in SCM and Refine/Develop Strategies
  - Demonstrate appropriate SCM strategies, systems, and tools to reduce the potential grid impacts of EVs@Scale charging
    - Identify SCM Strategy Implementation and Specify Smart Charging Ecosystem
    - Develop Enabling Technologies
      - OptiQ: Smart Interop AC L2 EVSE
      - EVrest: EV Charge Reservation System

TEMPO

EVI-Pro

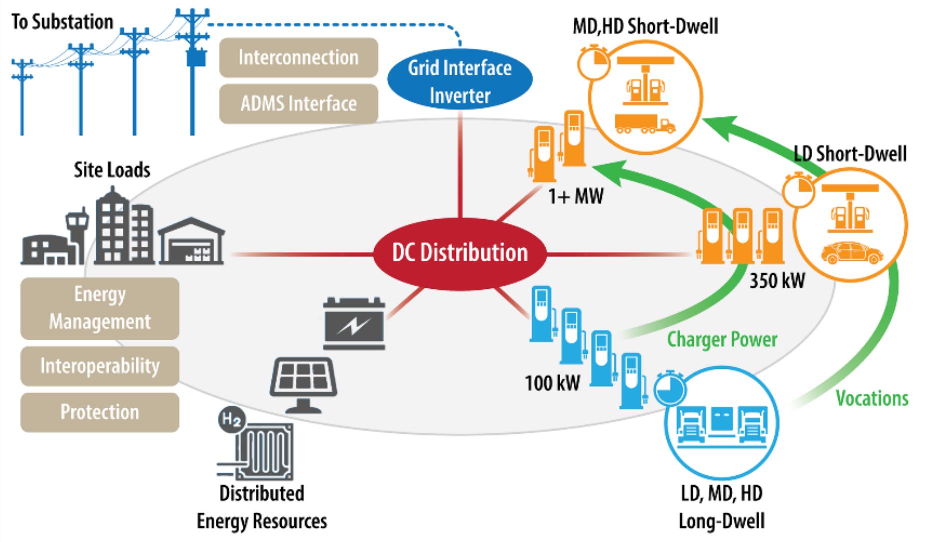
- **Deliverables**:

– Identify region(s) of study and necessary partnerships	FY22 Q2
– Acquire travel and grid data, provide implementation needs for existing SCM/VGI	FY22 Q3
– Broadly identify performance limitations/gaps for existing VGI/SCM across regions	FY22 Q4
– Develop LD PEV charging load datasets & verify utility partner grid models	FY22 Q4
– Identify Lab demonstration opportunities & high-capacity grid locations for EVSE	FY22 Q4

Approach – High Power Charging

High-Power Electric Vehicle Charging Hub Integration Platform (eCHIP)

- **Objective:** Develop a common, DC distribution architecture for high power EV charging sites that enable plug-and-play functionality and scalability for chargers and distributed energy resources (DERs) ensure interoperability and reduce upfront engineering expenses
- **Outcomes**:
  - **Broadly identify limitations and gaps** in DC distribution and protection systems that would allow for modular high-power charging systems
  - Develop and demonstrate solutions for efficient, low-cost, and h**igh-power-density DC/DC** for kW- and MW-scale charging
  - Determine interoperable hardware, communication, and control architectures for high-power charging facilities that support **seamless grid integration and resilient operation**
- **Team and Collaboration:**
  - NREL, ORNL, ANL
  - Utilities, charging equipment providers, charging service providers, fleet operators, and vehicle manufacturer



DC distribution supporting site charging integration with the grid, site loads, and energy resources for high power charging from kW-to MW-scale

Approach – High Power Charging

High-Power **E**lectric Vehicle **C**harging **H**ub **I**ntegration **P**latform (eCHIP)

- **Design and Early-Stage Development Tasks:**
  - Scoping Requirements and Industry Stakeholder Engagement
  - DC Distribution and System Architecture
  - Modular DC Universal Power Electronics Regulator (UPER)
  - EV Charging Interface and DC/DC Integration with DC Distribution
  - Station Energy Management and Coordination
  - Grid Interface Inverter and Integration with the Distribution System
  - Charging Facility Evaluation

Design: Scoping Requirements and Industry Stakeholder Engagement; DC Distribution and System Architecture

Develop: Modular DC Universal Power Electronics Regulator (UPER) through Grid Interface Inverter and Integration with the Distribution System

Demonstrate: Charging Facility Evaluation

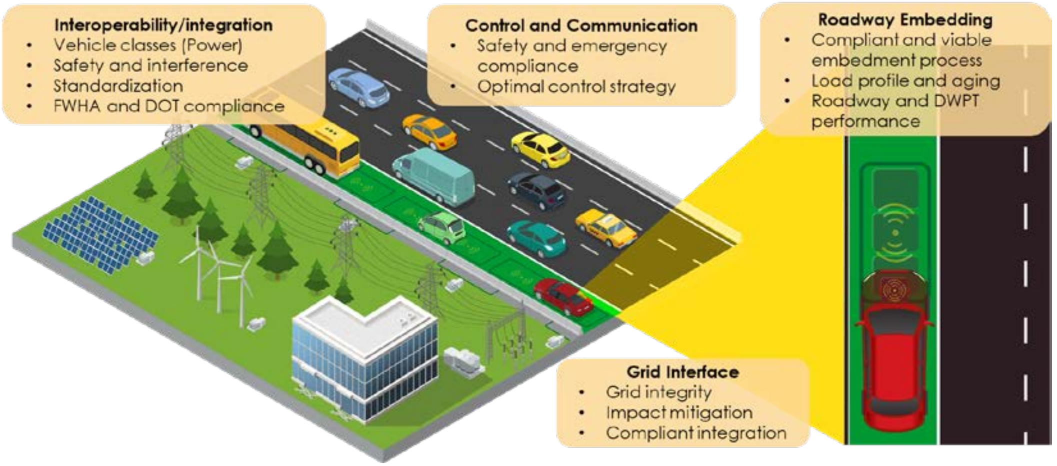
- **Deliverables:**

– Identify common charging hub requirements	FY22 Q2
– Identify inverter for DC distribution system	FY22 Q3
– SpEC integration requirements with DC/DC UPER, DC Distribution and Site Management	FY22 Q4
– Develop UPER bench-level subsystem components and demonstrate functionality	FY23 Q1
– Develop a DC distribution system to demonstrate kW charging at a 1+-MW charging hub with COTS equipment	FY23 Q1

Approach – Wireless Power Transfer

Integrating Dynamic Wireless Power Transfer Systems in Roadways

- **Objective:** Develop and validate technologies and solutions to transition high-power dynamic wireless (HPDW) charging of electric vehicles (EVs) from an early-stage proof-of-concept system to a practical roadway-integrated dynamic wireless power transfer (DWPT) system suitable for deployment at-scale.
- **Outcomes**:
  - Solutions to system- and component-level barriers for real-world deployment of HPDW systems.
  - Validated HPDW coil architectures and embedding techniques suitable for different roadways, environmental conditions, use cases, and system life-cycle.
  - Evaluation of comprehensive data from dynamic wireless charging system including
    - Life-cycle and accelerated aging impact on coupler and roadways using heavy-vehicle simulator
    - Real-world data from dynamic charging system installed at ACM
    - Safety and inter-operability
- **Team and Collaboration:**
  - ORNL, INL, NREL
  - Virginia Tech. Transportation Institute, American Center for Mobility, TDOT, MDOT, VDOT, FWHA, OEMs (Stellantis and Hyundai), and Utilities (TVA, DTE).



Considerations for at-scale deployment of high-power DWPT system

Approach – Wireless Power Transfer

Integrating Dynamic Wireless Power Transfer Systems in Roadways

- **Near Term Tasks:**
  - Engage with relevant stake holders including DOTs, FWHA, and Utilities to gather the requirements and barriers for deployment.
  - Evaluate representative asphalt mixes with different aggregates and compaction levels using the Asphalt Pavement Analyzer (APA).
  - Evaluate structural integrity and performance of roadway embedded HPDWC under accelerated aging tests using Virginia Accelerated Pavement Testing and Heavy Vehicle Simulator.
  - Conduct comprehensive characterization of roadway integrated HPDWC as a function of environmental factors, use cases, and for interoperability.
  - Conduct site and network level planning, optimization, and grid impact analysis
  - Develop EM shielding techniques for HPDWC system suitable for deployment and explore shielding geometry utilization for optimization of power transfer profile.
- **Deliverables:**
  - Report on evaluation of representative asphalt materials and the mock-ups in asphalt pavement analyzer. FY23 Q1
  - New HPDW ground side units designed with civil engineering inputs from VTTI and developed to meet the deployment challenges. FY23 Q3
  - Report detailing the comprehensive real-world characterization of HPDW system. FY24 Q1
  - Refined EM shielding design suitable for practical installation in real-world conditions. FY23 Q1
  - Evaluation report identifying barriers and impact of DWPT system load on the utility grid. FY23 Q1

Approach – Cyber-Physical Security

Cybersecurity **P**illar **U**nified **N**ational Lab **C**ollaboration (Cyber PUNC)

- **Objective:** Address challenges and barriers for high-power EV charging infrastructure security that threaten safety, infrastructure and grid operation reliability, and consumer confidence
- **Outcomes**:
  - Improvement in the implementation of the latest security methods
  - Develop methods to identify, protect, detect, respond, and recover from cybersecurity events
  - Identify vulnerabilities in new, emerging features and standards
  - Support training for the EV charging infrastructure cybersecurity workforce
- **Team and Collaboration:**
  - INL, SNL, NREL, PNNL, ANL, ORNL
  - Industry charging infrastructure manufacturers and standards organizations
  - Related Project: "EV SALaD" funded by CESER

Source: National Institute of Standards Cyber Security Framework ver. 1.1

Approach – Cyber-Physical Security

Cybersecurity **P**illar **U**nified **N**ational Lab **C**ollaboration (Cyber PUNC)

- **Near-Term Tasks:**
  - Conduct detailed PKI vulnerability and risk assessments with the SAE PKI working group
  - Develop a EVSE Network Operator Risk Management Framework Tool
  - Capture threat intelligence & adversary attack tactics using EVSE honeypots & canaries
  - Conduct lab evaluations of "Plug & Charge" security for ISO 15118 infrastructure
  - Training for the CyberAuto Challenge and EVSE network cyber defenders
  - Zero Trust technologies assessment criteria development

- **Deliverables**:

– Penetration test report provided to vendors, DOE VTO, and the SAE PKI working group	FY22 Q3
– Publish a website listing cybersecurity products applicable for EVSE devices and networks	FY22 Q4
– Provide anonymized results of the canary prototype with DOE in coordination with the EVSE network operator. Publish findings if possible due to sensitivity.	FY22 Q4
– Support the 2022 CyberAuto Challenge tutorial session and 24 hr. hands-on event	FY22 Q4
– Create a prototype EVSE CyberStrike training module	FY23 Q4
– Provide pen testing results of the "Plug & Charge" capable assets with industry	FY23 Q4

Approach – Codes & Standards

Facilitate Identifying and Addressing Gaps in EV Charging Standards

- **Objective:** Address challenges and barriers for high-power EV charging standards by identifying and filling gaps in charging equipment as well as grid impacts, interoperability, and safety topics.
- **Outcomes**:
  - Facilitate creation and improvement of codes and standards enabling 'EVs at scale' charging
  - Engage with industry stakeholders to create a consensus-based EV standards roadmap
  - Create interoperability guidelines and criteria to evaluate standards compliance/implementation
  - Supply validation test data with industry partners to support standards refinement
- **Team and Collaboration:**
  - ANL, INL, NREL, ORNL, PNNL
  - Industry charging stakeholders
  - Subcontractor subject matter experts (ANSI, University of Delaware, Rema, BTCPower)
  - Standards organizations (SAE, IEC, ISO, IEEE, ANSI), Code panels (NCWM, UL, NFPA)

Source: CharIN E.V.

DC distribution supporting site charging integration with the grid, site loads, and energy resources for high power charging from kW- to MW-scale

Approach – Codes & Standards

Facilitate Identifying and Addressing Gaps in EV Charging Standards

- **Near-Term Tasks:**
  - Support SWIFTCHARGE wireless charging consortium as alternative to SAE J2954 WPT
  - Support SAE J2954(/1, /2) high power and dynamic wireless power transfer standards group
  - Launch SAE J3271 Megawatt Charging System standard; 5 subtopics from connectors to communication to cooling to V2G uses cases w/DER to Interoperability testing procedures
  - Leverage work on SAE J3271 into IEEE P2030.13 grid/DER aspects of EVs at Scale, DCaaS
  - Continue testing of CharIN MCS V3.2 coupler components; develop master test article
  - Initiate a review and update of ANSI EVSP EV standards roadmap for 2022 standards gaps

- **Deliverables**:

– Report on MCS/J3271 physical layer communication robustness.	FY22 Q3
– Report on MCS connector thermal and mechanical interface evaluation.	FY22 Q2
– Report on SAE J3271 connection detection implementation and testing.	FY22 Q4
– Demonstrate a DC as Service distribution to multiple dispensers via cable duct.	FY22 Q4
– 2022 version of ANSI EV Standards Roadmap document based on 2013 version.	FY23 Q1
– Demonstrate two charging system architectures in HIL simulation.	FY23 Q4

Technical Accomplishments

Vehicle Grid Integration & Smart Charge Management

- Transition of prior efforts:
  - SmartVGI (ELT 201) – Enabling technologies and containerized energy management system will be incorporated into demonstrations activities
  - RECHARGE (ELT 202) – Grid analysis framework (EVI-Pro and Caldera) and Smart charging control strategies will be carried into analysis activities
  - DirectXFC (ELT 257) – Smart routing and station control approaches will be incorporated into new en route analysis activities
- Analysis Regions
  - Project team has completed its effort to identify a detailed region of study and broad regions of study.
  - The necessary partnerships have been completed and the team is proceeding with travel and grid data acquisition

Technical Accomplishments

High Power Charging

- Transition of prior efforts:
  - 1+MW Charging (ELT 204) – Power conversion architecture analysis and site-level control approaches have been incorporated into the charging hub requirements
  - SmartVGI (ELT 201) – Enabling technologies for EV-EVSE communication and containerized energy management system will be incorporated into demonstrations activities
- Initial requirements for the DC hub activity, universal DC/DC converter design, and grid integration approach have been identified toward development of the kW-Scale demonstration

Technical Accomplishments

Cyber-Physical Security Pillar

- Transition efforts
  - Consequence-Driven Cybersecurity (ELT 199) – Identified impacts and evaluation approaches have been incorporated into evaluation and analysis activities
  - Securing Vehicle Charging Infrastructure (ELT 198) – Threat modelling and red team efforts have been incorporated into evaluation and analysis activities
  - Kick-off of related EV SALaD project
- Secure EV Charging Evaluation
  - NREL hosted EV industry leaders on April 4-7 to evaluate progress on the development of more cybersecure connections between electric vehicles and charging infrastructure.
  - This effort is a precursor activity to the EVs@Scale deliverable for an adversarial evaluation report for the Cyber-Physical Security pillar milestone

Successful demonstration of an encrypted charging session between electric vehicles, charger, and charging infrastructure. *(Photo by Bryan Bechtold / NREL)*

Technical Accomplishments

Codes & Standards

- Transition of prior efforts:
  - 1+MW Charging (ELT 204)
    - Charging connector evaluation
    - Monthly MW+ Industry Engagement meeting
- Kick-off and leadership of the SAE J3271 Megawatt Charging System (MCS) standardization effort
- Support of the IEEE 2030.13
- MCS Thermal Evaluation
  - NREL, in partnership with California Energy Commission and CharIN E.V., is hosting an event
  - 4 industry participants to evaluate performance at 350, 1000, and 3000A
  - Early learning effort on reference device in support of IEC Technical Specification 63379

Researcher captures thermal image of an MCS charging system during evaluation at the MCS 2nd Event in Fall of 2021. *(Photo by Dennis Schroeder, NREL)*

IEC – International Electrotechnical Commission
CharIN - Charging Interface Initiative e.V.

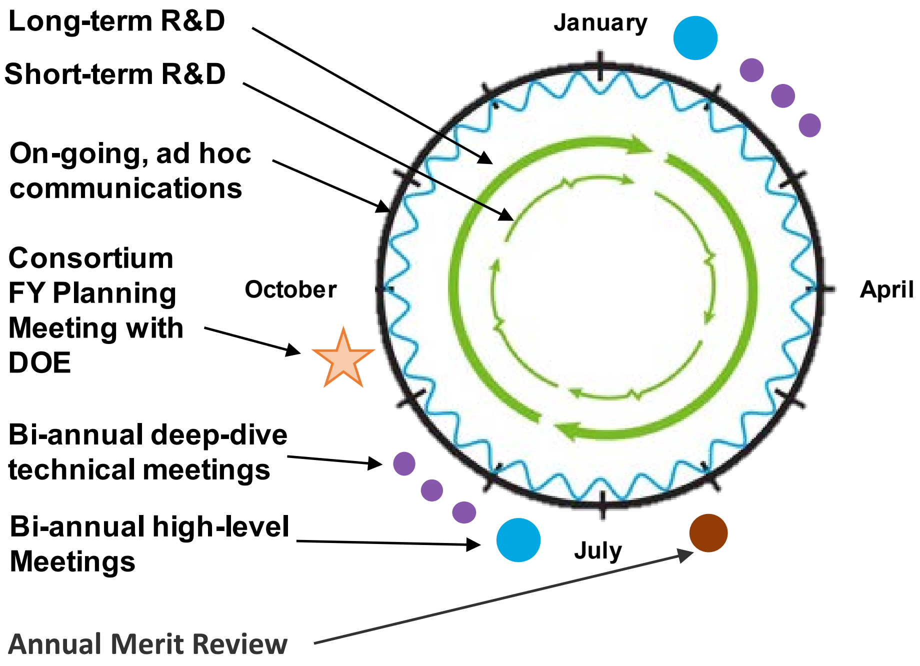
Responses to Previous Year Reviewers' Comments

- This is the first year that the project has been reviewed

Collaboration and Coordination

Consortium Approach with Multiple Industry Partners

- Consortium Laboratories
  - ANL, INL, NREL, ORNL, PNNL, SNL
- External Advisory Council
  - Utilities, EVSE & Vehicle OEMs, CNOs, SDOs, Gov't, Infrastructure
- Direct interaction for each pillar projects
  - Utilities, EVSE & Vehicle OEMs, CNOs, SDOs, Gov't, Infrastructure
  - Webinars / Project discussions
- Bi-annual high-level meetings
- Bi-annual deep-dive technical meetings
  - VGI/SCM, HPC & WPT, and CPS with CS incorporated into all meetings



Remaining Challenges and Barriers

- **VGI/SCM:**
  - EV adoption will expand rapidly though grid planning for this new load, and SCM strategies that account for vocational needs and differences are lacking
  - There is a lack of enabling technologies for smart charging in a utility environment.
- **High Power Charging:**
  - Validation of megawatt-scale charging facilities for charging up to 1+ MW with medium voltage interconnection is needed to demonstrate enabling technologies
  - Efficient, low-cost, and high-power-density DC/DC for 1+MW charging are limited
- **Wireless Power Transfer:**
  - Durability of ground side charging systems in full-scale asphalt surfaces is unknown
  - Validation of high-power dynamic wireless systems real-world conditions are limited
- **Cyber Security:**
  - Industry implementation and utilization of latest security methods is not consistent
  - Lack of methods to identify, protect, detect, respond, and recover from cyber events
  - Limited training for the EV charging infrastructure cybersecurity workforce
- **Codes & Standards:**
  - Standards don't exist for MCS charging connectors, chargers, and site equipment such as DC distribution and protection, as well as grid interconnection

Proposed Future Research

- **VGI/SCM:** Develop a focused regional travel and grid model through utility partnership, a broad regional analysis on charging impacts and demonstrate smart charging control
- **High Power Charging:** Identify common charging hub requirements for DC distribution and develop an integrated DC-DC for charging evaluation
- **Wireless Power Transfer:** Evaluate a representative asphalt materials and design considerations for embedded ground side transmitters
- **Cyber Security:** Identify vulnerabilities for proposed public key infrastructure approaches, develop a website with tools for EVSE security, and support cyber workforce development for charging infrastructure.
- **Codes & Standards:** Support MCS/J3271 connector thermal, mechanical interface and physical layer communications evaluation

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

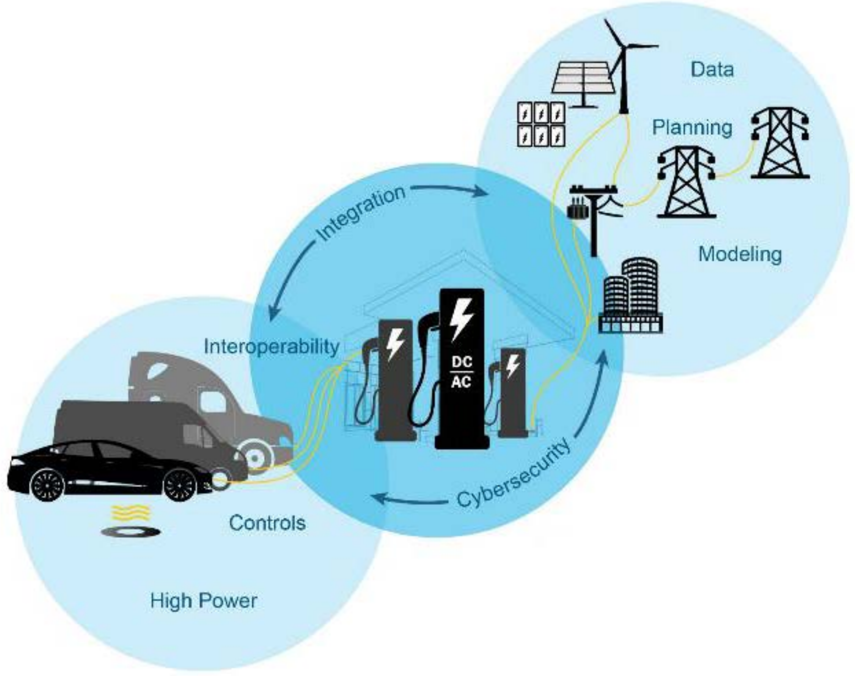
Summary

The EVs@Scale Lab Consortium will:

1) Address challenges, develop solutions, and enabling technologies for transportation electrification ecosystem **through national lab and industry collaboration**

2) Formulate and evaluate EV smart-charging strategies that consider travel patterns, charging needs, and fluctuating power generation loads

3) Overcome barriers to EVs at Scale and provide answers to fundamental questions with activates that
   - Assess potential **grid impacts and grid services**
   - **Develop and evaluate hardware and system** designs for high power and wireless charging systems
   - Create design guidelines and evaluate approaches to **secure charging infrastructure** and the grid
   - Support consensus-based **standards development** through evaluation and industry engagement



The EVs @ Scale Lab Consortium will consider these key components of the transportation electrification ecosystem

Thank You!

www.nrel.gov

NREL/PR-5400-82828

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NREL

Transforming ENERGY

Electrified Vehicle Test Procedure Development

EVs @ Scale: Codes & Standards

Related Project Review

ELECTRIFIED VEHICLES TEST PROCEDURE DEVELOPMENT (ANL)

Michael Duoba
Argonne National Laboratory

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

ELECTRIFIED VEHICLES TEST PROCEDURE DEVELOPMENT (ANL)

Timeline

Start date: 6/1/2020
End date: 5/31/2022
98% percent complete

Budget

- Total $400k (DOE)
- FY 2020: $225k
- FY 2021: $175k (carried into 2022)

Barriers and Technical Targets

1. Reducing test burden for electrified vehicles to reduces costs and accelerate progress
2. Further optimization of fuel efficiency and CO2
3. Accurate comparisons among electrified vehicles vs conventional vehicles

Partners

- Argonne National Laboratory
- SAE Standards Committees
  - All major OEMs
- EPA
- California ARB
- ISO/TC 22/SC 37 Electrically propelled vehicles
- UNECE Electric Vehicle and the Environment International Workgroup

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RELEVANCE

Test Procedures are Critical to DOE Mission

Impact

- All performance/economy claims come from a test, test must provide true results
- Reduced test burden will accelerate technology deployment
- Increased fuel economy for hybrids expected. Test allows OEMs to use more aggressive controls to save fuel.

The SUCCESS of this R&D

Depends on how it's tested here

Reported Results

Over Predict

- Technology promises too much
- Experience not matching expectations
- Attention not warranted
- Funds are misdirected
- "Poisoned Well" (diesel in USA '80s)

True Representation

Under Predict

- Technology underrated
- Attention not given
- No adoption, benefits not predicted
- Missed opportunity of benefits

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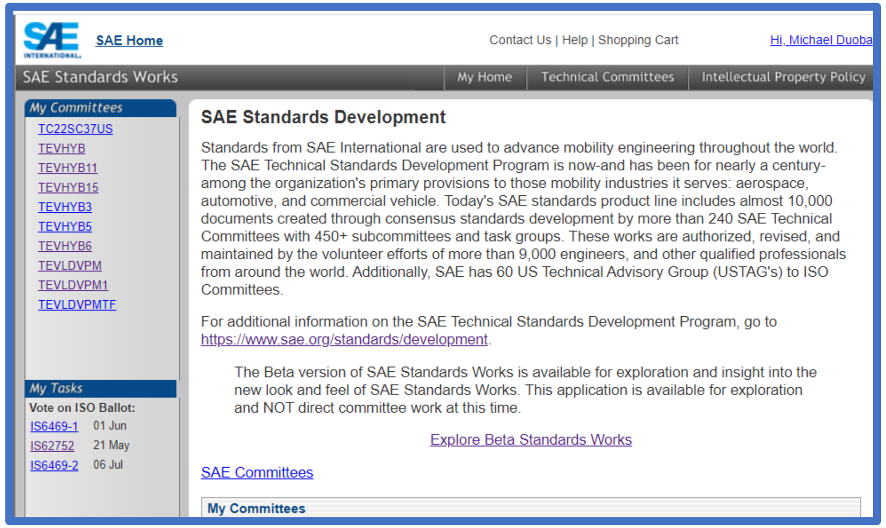
APPROACH

Take Leadership in Test Procedure Development by Harnessing 26 Years in xEV Testing Research Experience

- **Serve as doc Sponsor&Chair**:
  - **SAE J1711** ***(HEV/PHEV Economy/Emissions Test)***
  - **SAE J2908** ***(HEV/PHEV/BEV Power Test)***
- Use over 20 years of HEV/PHEV/BEV testing data
- Relate experiences, challenges, results
- Pull together a consensus of industry / government
- Balance the needs of the OEMs with the objectives of regulators and DOE



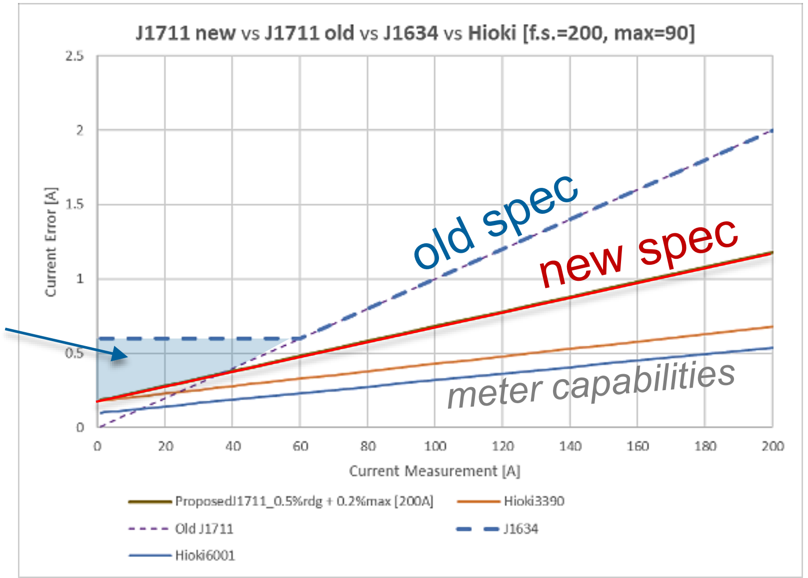
TECHNICAL ACCOMPLISHMENTS AND PROGRESS

SAE J1711: HEV/PHEV Fuel Economy Test (EPA/CARB uses for MPG)

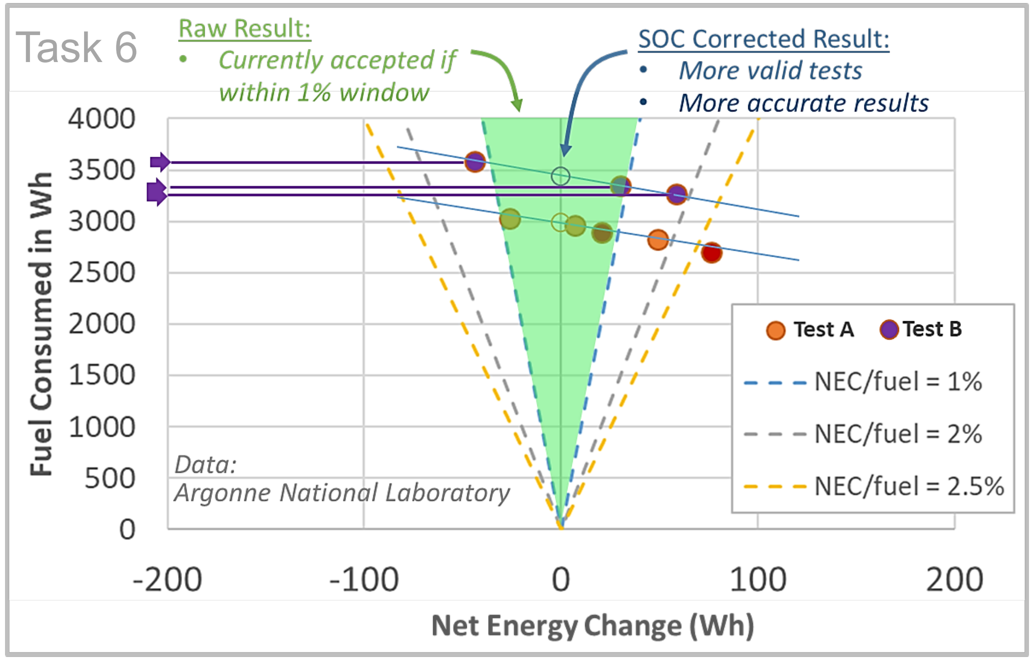
Improvements

- Simplicity: Voltage calculation easier to implement than old method
- CO2: Includes method for correcting CO2 based on fuel.
- Accuracy: better accuracy specs, especially for HEVs (net current is close to zero!)

Zone where accuracy is important for HEVs



- **Novel "SOC Corrections" for all results**
  - Better accuracy
  - OEMs can actually get higher fuel economy, more optimization



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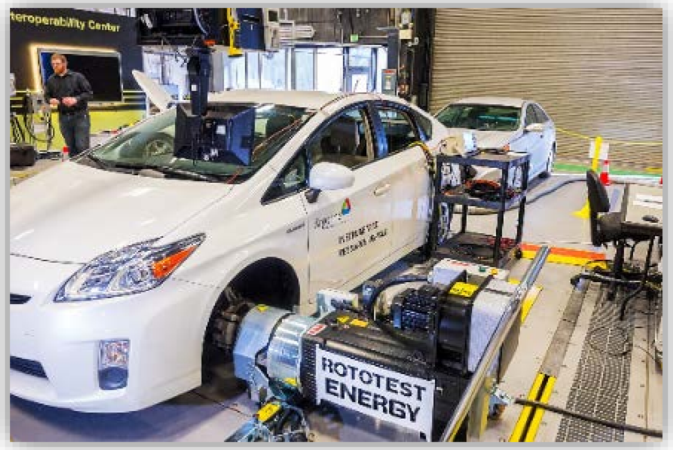
TECHNICAL ACCOMPLISHMENTS AND PROGRESS

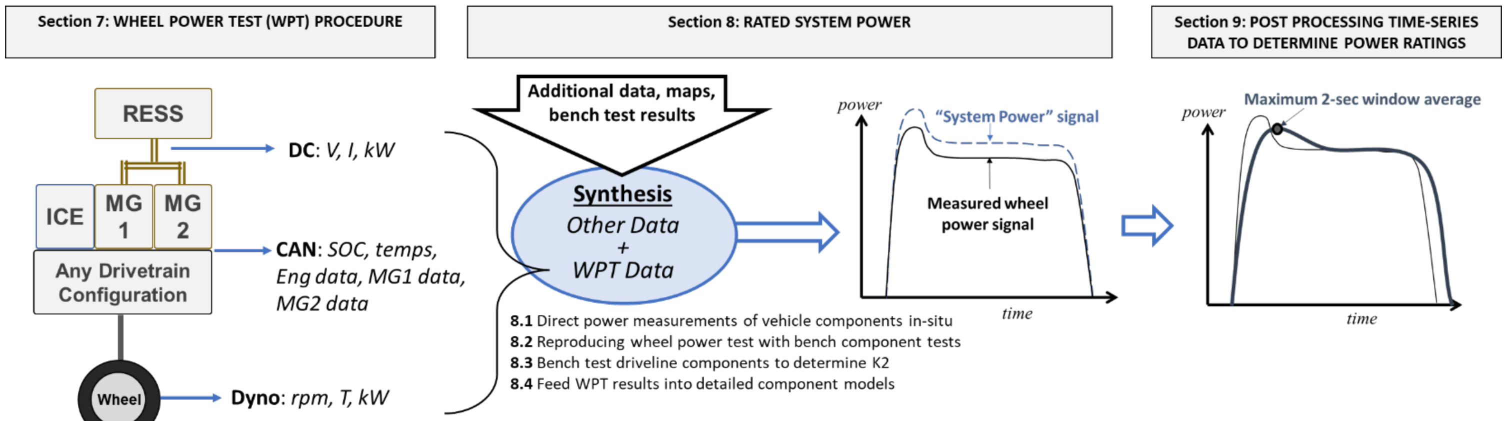
SAE J2908: HEV/PHEV/BEV Rated System Power Determination

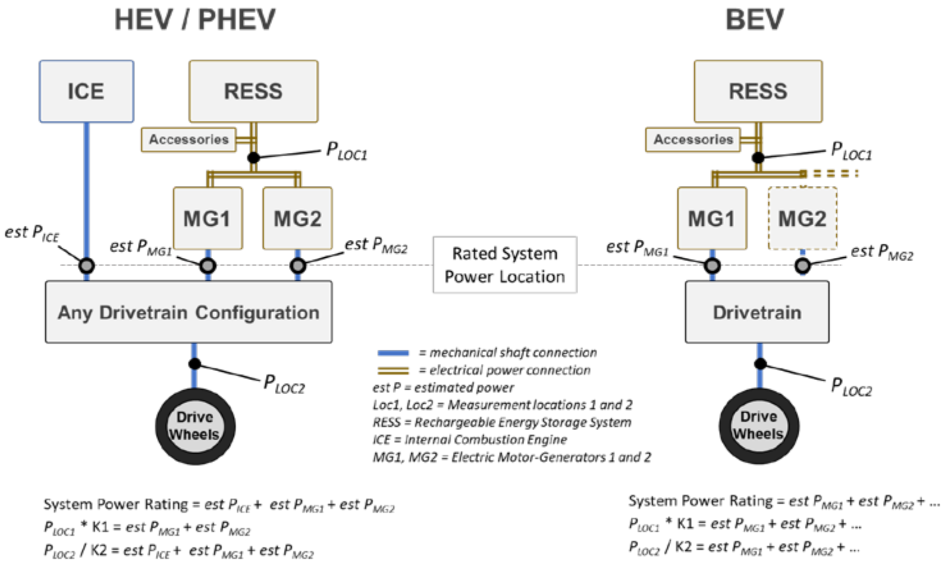


From: https://media.audiusa.com/en-us/releases/499

Intent to be adopted industry-wide

Maximum e-tron HP achieved via peak performance of the electric motor(s) at peak battery power pursuant to SAE J2908 in "S" driving program. Max HP and torque only available under certain limited conditions, including but not limited to, battery temperature and state of charge. Your results will vary. See Owner's Manual for further details and limitations.





This update **provides framework** for an "Upstream" power rating:

- Compatible with existing wheel/axle test
- Harmonized with ISO and UN GTR
- Provides flexibility for markets with no compelled regulatory requirement
- Provides basis for rating claims

COLLABORATIONS AND COORDINATION

In addition to SAE activities:

- Direct, working-level relationships with EPA and CARB since the 1990s
- Direct relationships with OEMS (Ford, GM, FCA, Tesla, among many others)
- Subject Matter Expert on ISO *(relating to both power test and HEV/PHEV economy test)*
- Member of UN EVE IWG *(relating to power test)*

PROPOSED FUTURE WORK

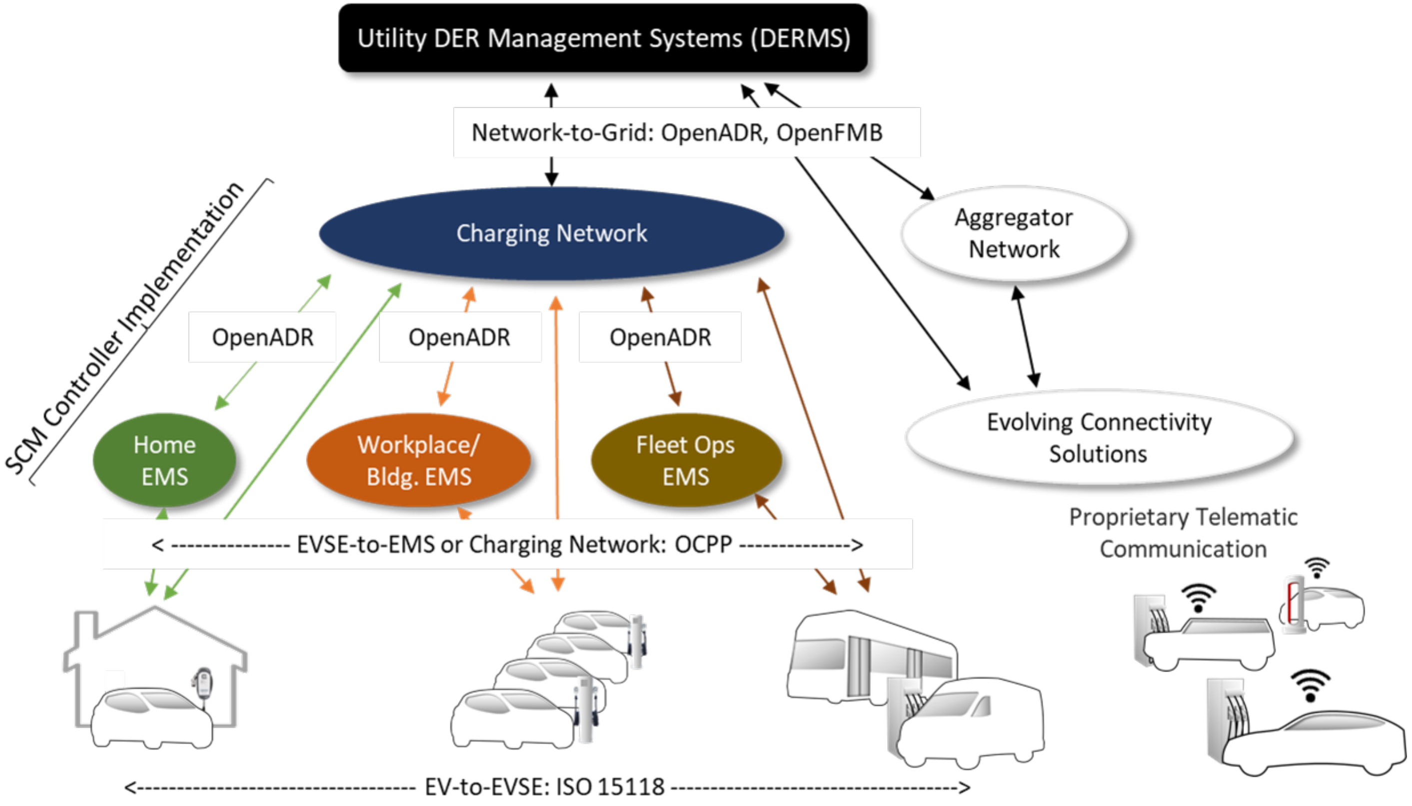
- Validation testing to ensure adoption by EPA and CARB
- Find a way to update PHEV “Utility Factor”
  - Look at fast charging impact for PHEVs
- Ensure emerging technologies are properly addressed by test procedures
  - How CAVs and electrification are linked
  - Solar panels on electrified vehicles
  - Dynamic charging of electric vehicles

Technical Back-up Slides

SmartVGI Project (ELT 201):

Smart Charge Management Implementation Approaches

Communication and control pathways that could be deployed as the population of electric vehicles increases and the business models for recharging mature. Additional pathways are possible, but these are adequate to illustrate connectivity and communication required for Smart Charge Management. Note that this representation shows two primary pathways either through an electric vehicle supply equipment (EVSE) or Telematics based solutions.

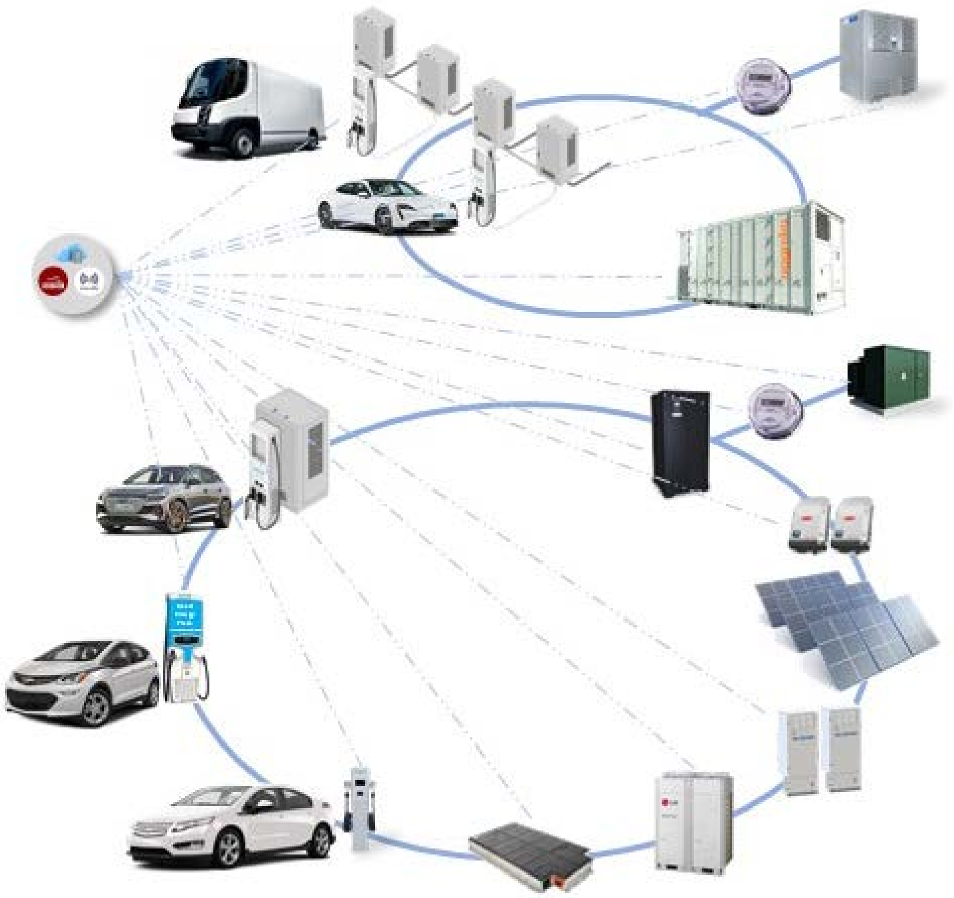


SmartVGI Project (ELT 201):

Enabling Technologies for Vehicle Grid Integration

The project has demonstrated SCM utilizing the EV-EVSE-workplace EMS communication and control pathway with an open access smart charging ecosystem as well as the enabling technologies:

- Open-source Common Integration Platform (CIP.io)
- EVSE Communication (SPeC Module)
- Smart Charge adapted and mobile app



Open-source Common Integration Platform

EVSE Communication Control Module

Smart Charge Adaptor and Mobile App

Low-Cost Sub-Meter

Smart AC Level 2 EVSE

RECHARGE Project (ELT 202):

Smart Charge Control Strategies

Strategy Name	Objective	Control Simulation	Grid Services
TOU Immediate	PEV driver responds to Time-of-Use incentives by charging at the beginning of TOU windows	Caldera	Price Signals
TOU Random	Decentralized control randomly distributes EV charging within vehicle dwell and TOU windows	Caldera	Price Signals, Capacity Deferral
Random Start	Decentralized control randomly distributes EV charging within vehicle dwell	Caldera	Capacity Deferral
Feeder Peak Avoidance	Centralized control shifts EV charging within vehicle dwell to minimize feeder peak	Caldera	Capacity Deferral
Volt/VAR	Decentralized control provides reactive power support based on local power quality	Caldera	Voltage Support
Volt/Watt	Decentralized control shifts EV charging real power within dwell to reduce nearby grid voltage concerns	Outside Caldera*	Demand Response, Voltage Support
BTM/DER	Decentralized control shifts EV charging within dwell to reduce behind-the-meter peak demand	Outside Caldera*	Demand Charge Mitigation, Max Renewables

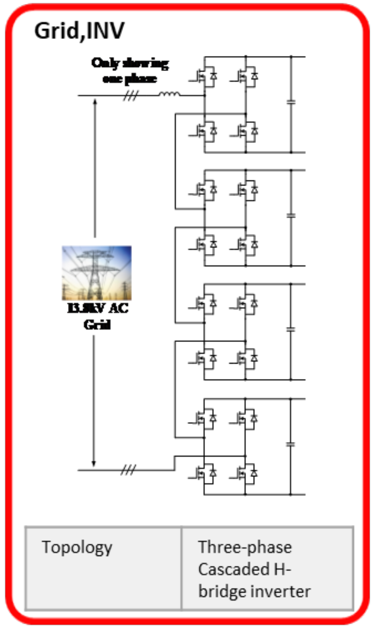
TOU – Time-of-Use

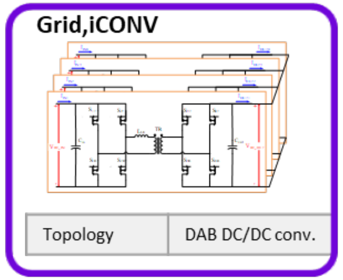
1+MW Charging Project (ELT 204):

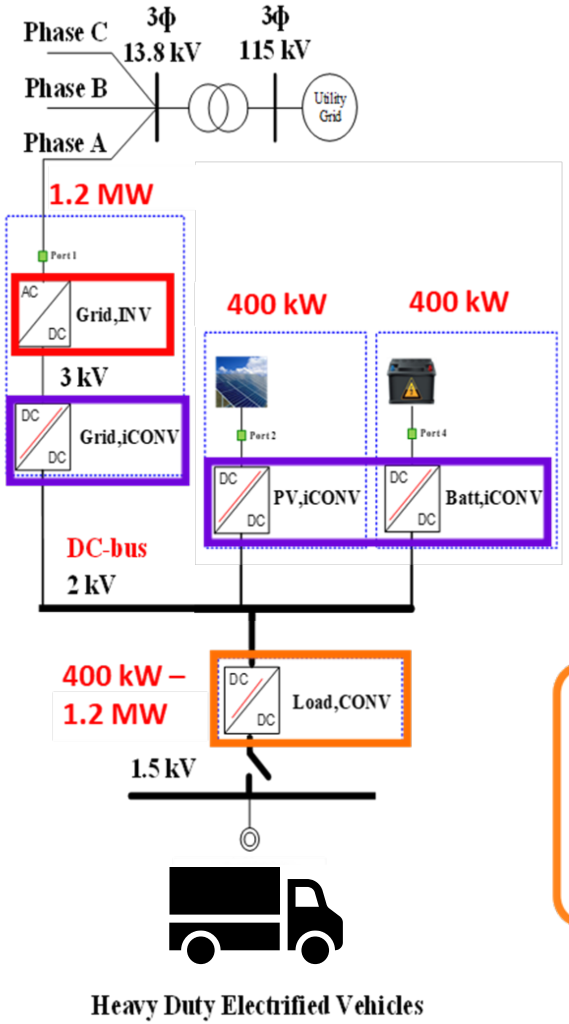
Task 1 / 2 / 3 – PE Topology Review, Simulation, and Selection

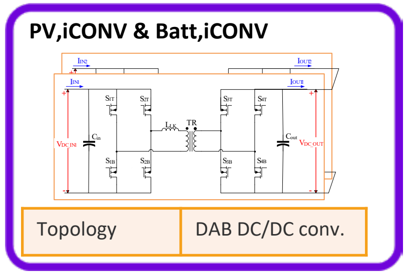
PE Models (Switches, Passives, etc.)

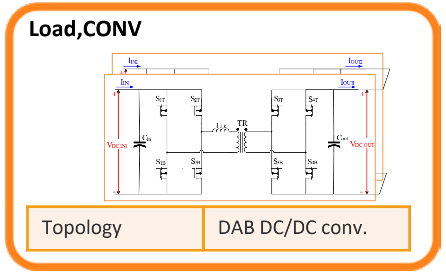
- Detailed MV Architecture investigation
  - **Detailed loss values including passives, protection, and interconnects**
  - Translation to thermal management requirements
  - **Final device selection**
- MV Gate Drive Test Hardware
  - **MV Si/SiC Device level testing providing detailed PE model input**
- Thermal Management
  - Strategy, sizing, and ancillary impact
- Cabinet level AC Grid Connection and Protection
- Cabinet level DC interconnects (DER/Load)
- DC interface to Charge connector











Reviewer-Only Slides

Publications and Presentations

- None

Critical Assumptions and Issues

- Certainly, each of the individual pillar efforts have numerous critical assumptions and issues to address; however, at a consortium level the following are considered.
  - The electric vehicle and charging infrastructure industries are accelerating their activities. This speed requires quick action from the DOE and National Labs to ensure our efforts remain relevant. The Consortium plans to address this issues through:
    - Frequent structured interaction with industry stake holders (bi-annual meetings, webinars, and deep-dives)
    - Participation in standards development and evaluation events
    - Technology demonstrations with industry participation
  - The Consortium is structured with 5 technical pillars (VGI/SCM, HPC, WPT, CPS, and Codes & Standards) though technology in this space are highly coupled. The Consortium has addressed this by identifying a technical leadership group which constitutes the PIs in each pillar which will participate in each others update activities to foster communication across the activities