2020 DOE Vehicle Technologies Office Annual Merit Review

CHARGING INFRASTRUCTURE TECHNOLOGIES: SMART VEHICLE-GRID INTEGRATION – ANL

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Smart VGI Project

Smart energy management

Integrate vehicle charging and grid-connected devices to meet the needs
of the customer and the grid:

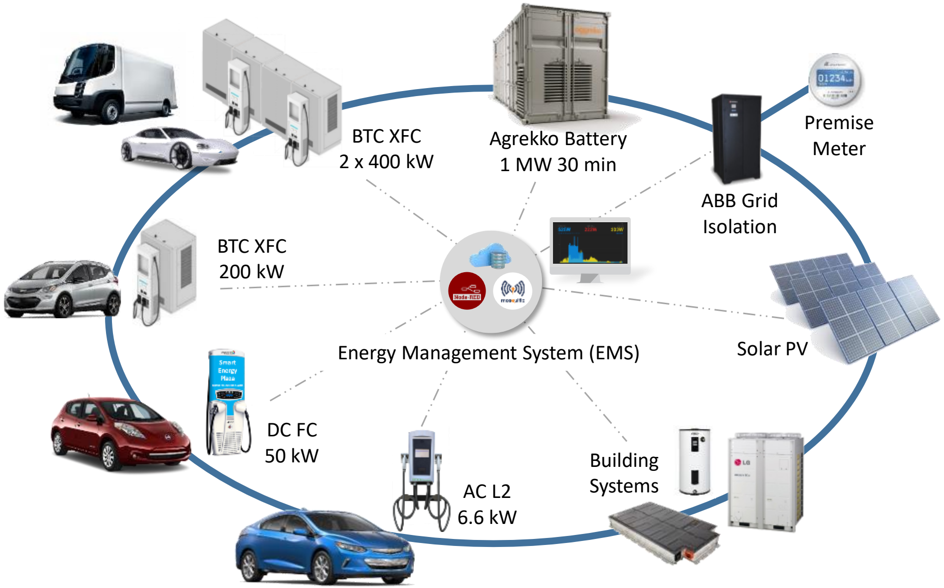
- Communication requirements
- Control algorithms for GMLC use cases (controlled and smart charging)
- Enabling technologies

Lab demonstration in FY 2021

- Public demonstration TBD

Government and industry partners

- Transatlantic focus



Overview

Timeline

- Agreement to establish interoperability centers in US and Europe - Q1, FY 2012
- Argonne IOC launch - Q4, FY 2013
- Smart Energy Plaza Ø1 – Q4, FY 2015
- Smart Energy Plaza Ø2 – Q3, FY 2017
- 3-yr Lab Call project 3D began FY 2019

Barriers/Challenges

- Lack of consensus on EV-EVSE-grid protocols and devices with ‘smart’ non-proprietary interfaces
- EV/charging infrastructure’s ability to respond adequately to support grid services
- Smart, interoperable connectivity and diagnostic tools for grid integration

Budget

- FY2018 ~ $3300K
- FY2019 ~ $3100K
- FY2020 ~ $3000K

Collaborators

- US and European vehicle and EVSE OEMs, communication software providers, energy providers/utilities, research organizations
- Idaho National Laboratory

Relevance

Objective:

Increased energy efficiency and grid resiliency via management of the charging infrastructure in a ‘grid of things’ (managed energy flow in a network of grid-connected devices)

- Maximize the benefits of VGI on the customer-side of the meter
- Respond to grid conditions/signals with minimal impact on local operations
- Identify benefits and impacts of EVs @ scale (controlled v. uncontrolled charging)
- Develop monetization scenarios of VGI for owners, utilities and aggregators

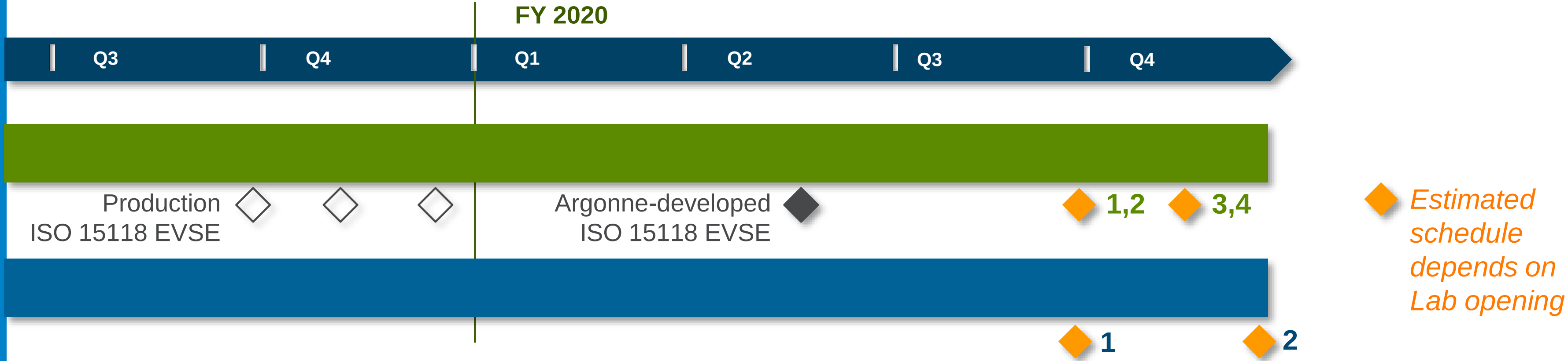
Technical achievements:

- Government-industry VGI verification event; demonstrated link between US and European labs
- Enabling technologies being commercialized, (SCA/DEVA, sub-meter, communication controller)
- In-house development of ISO 15118-capable AC L2 EVSE

Partnership with Global Grid Integration Program:

US and European automotive industry, utilities, research organizations and equipment manufacturers

MILESTONES: GMLC Use Cases w/Smart Charging



Task 1 Milestones

GMLC use cases (w/ISO 15118)

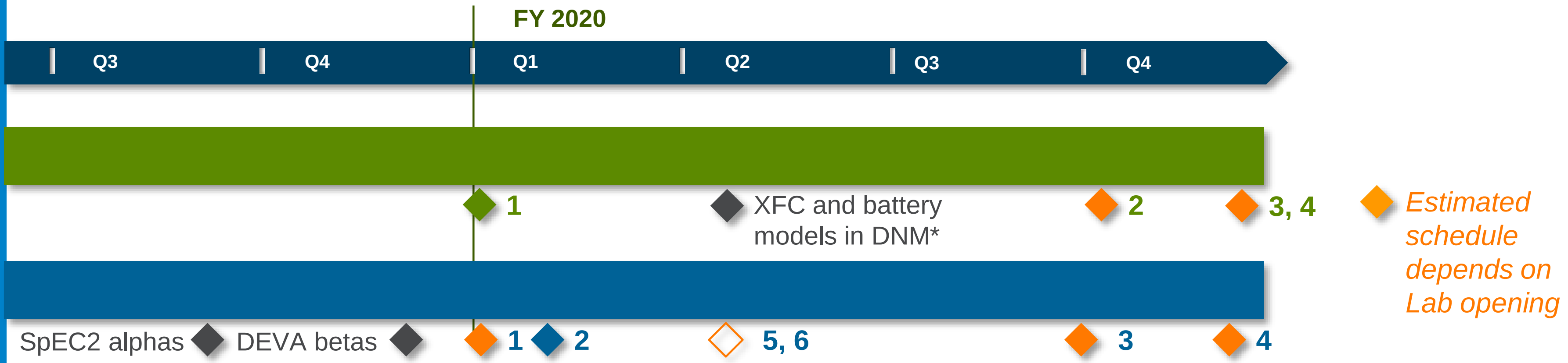
1. Demand response
2. Demand charge mitigation
3. Frequency regulation
4. Charging capacity deferral

Task 2 Milestones

GMLC+ use cases (w/ISO 15118)

1. Plug'n Charge (PnC)
2. Smart charging to balance PV

MILESTONES: Grid Resilience and Enabling Technologies



Task 3 Milestones

Optimized control for grid resilience

1. HIL methodology, design of experiments, grid scenarios
2. Ability to respond to grid signals (EV/EVSE & customer side-of-the-meter network)
3. Translate network response behavior to DNM
4. Integrate behavior in INL grid model

* Distributed Network Model

Task 4 Milestones

Early stage R&D

1. Demo multi-unit sub-metering; ANL pilot delayed
2. Demo Beta DEVA with CIP.io
3. Demo Beta SpEC2 module
4. HLC via PLC integration in DEVA
5. EUMD supply chain defined; pilot proposed
6. SCA/DEVA supply chain defined; ANL and industry pilot delayed; production pilots proposed

Approach – Technical

Task 1. Quantify benefits of smart charging (w/GMLC use cases)

Barriers: Lack of EVs and EVSE with ‘smart’ protocols, benefits of VGI TBD

Solution: Implemented ISO 15118 in CIP.io and developed AC L2 EVSE

Task 2. Demonstrate control strategies for grid integration (GMLC+)

Barrier: Use cases provided by industry partners not addressed

Solution: Expand uses cases to include industry recommendations

Task 3. Optimized control for grid resiliency/reliability; Impact of EVs @ scale

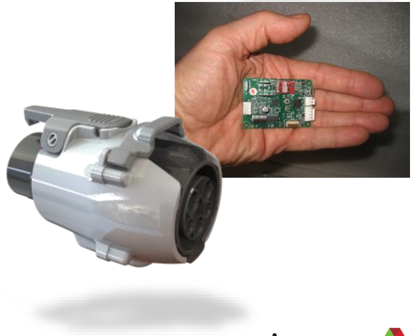
Barriers: Unknown ability of charging infrastructure to support grid; impacts at scale

Solution: Determine response times; use ANL/INL models for local/grid impacts

Task 4. Early-stage R&D; interoperability/grid integration components

Barriers: Verification of interoperability and diagnostics; VGI solution for vehicles; sub-meters for multi-EVSE installations

Solutions: SCA/DEVA, SpEC2, low-cost sub-meter systems



Demonstration of use cases and lab/field pilots depends on Lab opening

Approach – Programmatic

Transatlantic government-industry cooperation

- Workplace VGI and grid impacts
- Grid edge communication, sensing and diagnostics technologies
- Smart home product integration and testing
- VGI verification testing
- Electromagnetic studies
- Smart grid simulation
- EVSE environmental testing

ANL Smart Energy Plaza


JRC-Petten Smart Home/Grid Interoperability Lab


JRC- Ispra Vehicle & Grid Simulation Lab

Government partners: European Commission’s Joint Research Center (JRC)

Industry partners (GGIP): US and German automotive OEMs, US utility, ELAAD NL, suppliers

Commercialization partners (TCF): Qmulus LLC, Zen Ecosystems, BTC Power, Amzur Technologies

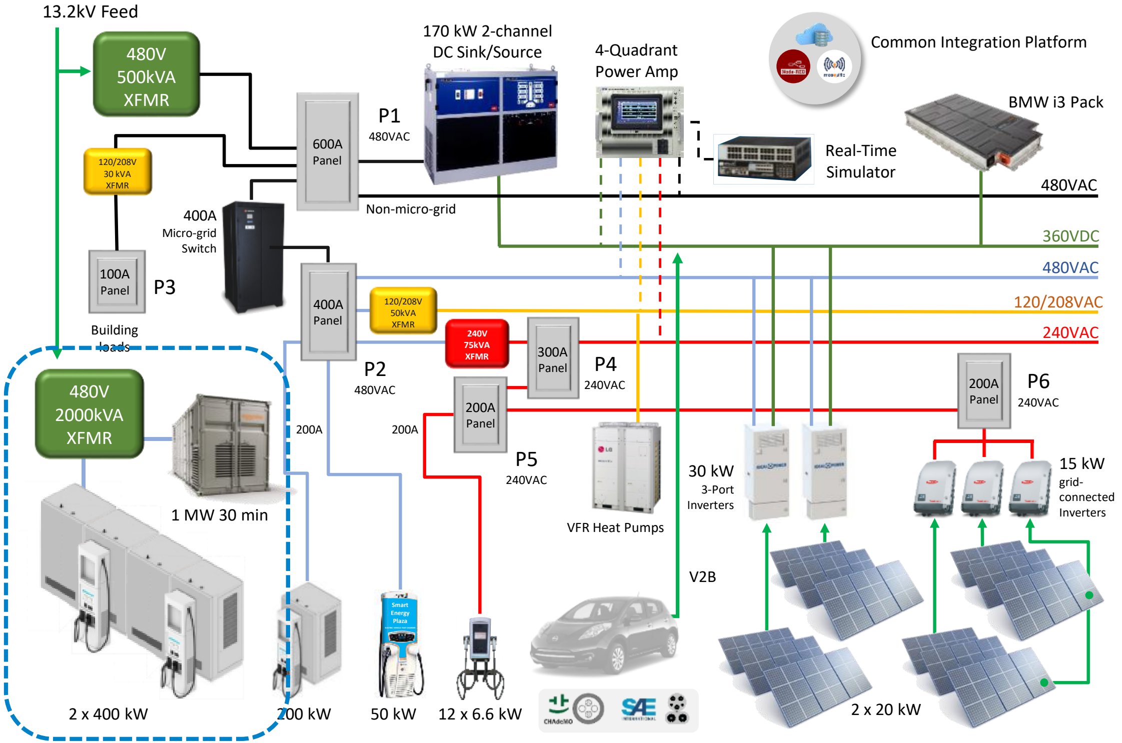
Accomplishments and progress …

- **Energy Plaza** – Acquiring or installing additional devices; prepping facility
- **Distributed Network Model** – Added XFC and battery storage
- **Enabling technologies and tools** – Progress toward commercialization; pilot programs delayed

Energy Plaza

Additions support control studies for XFC, grid impacts and MW+

- Acquisitions/installations
  - Two 400 kW DC EVSE
  - 2000/2667kVA transformer and switchgear
  - 1 MW-30 minute battery



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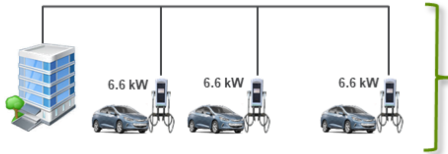
Distributed Network Model

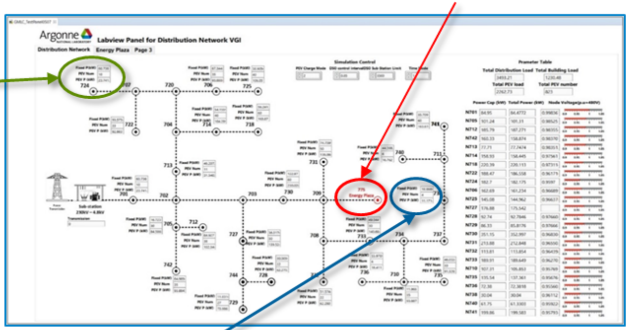
Enhancements to reflect residential and commercial charging

Virtual Node 724 (Commercial/Residential area)

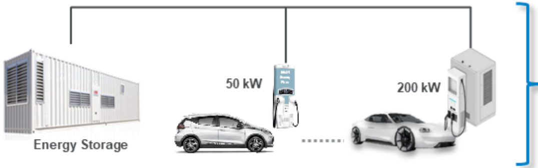


- Buildings
- 20 to 40 EVs
- AC L2 EVSE
- Power curtailment with managed charging

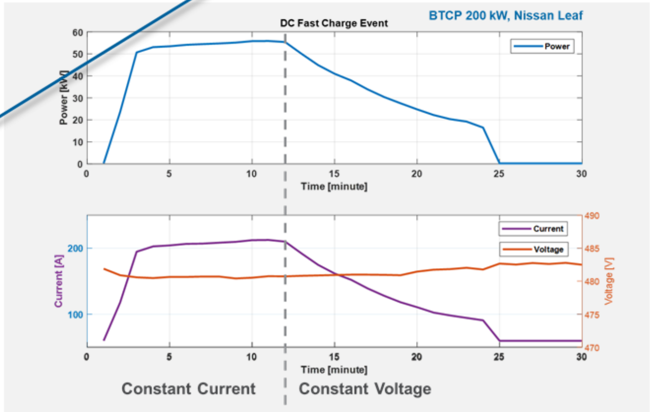
Real Node 775 (Energy Plaza)



Virtual Node 738 (Fast Charge station)



- Up to 10 EVs
- DC FC: 50 kW and 200 kW
- Max EVSE power with managed storage



Addition of XFC and Battery Energy Storage System

- Charge profile based on data from the 200 kW DC EVSE at the Energy Plaza
- Real and reactive power
- Linkage between model in Opal RT and CIP.io demonstrated

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Enabling Technologies

Connectivity, communication and diagnostics

Smart Charge Adaptor (SCA): 25 beta prototypes designed, manufactured and tested

TCF award: CRADA partners Qmulus LLC and Zen Ecosystems

- Supply chain established and commercial design started
- Cloud platform and web application developed
- ANL and CA pilot programs delayed due to COVID-19

Diagnostic Electric Vehicle Adaptor (DEVA) w/PLC: Leveraged beta SCA hardware for diagnostic application

- HomePlug Green PHY™ (HPGP) chipset: sniffer mode, Supply Equipment Communication Controller (SECC) emulation, Internet protocol (IP) communication over power lines
- Oscilloscope mode: high speed sampling of pilot/prox
- Manual operation/manipulation of EV/EVSE pilot/prox
- Alpha Firmware tested Q1 FY20

Enabling Technologies

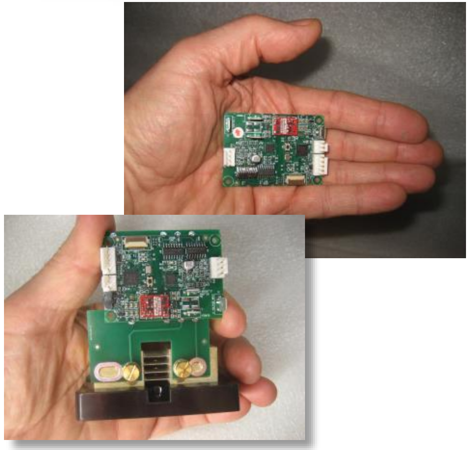
Communication and sub-metering

Communication control module (SpEC2)

- Can be configured as EVSE or EV communication controller
- Features of original SpEC module *plus*
  - sub-metering (AC or DC)
  - AC coupled HPGP circuit for communication over power lines
  - SAE J2411 (CAN) communication.
- Firmware drivers developed and alpha hardware tested Q1 FY20

DC Sub-metering (DC EUMD*)

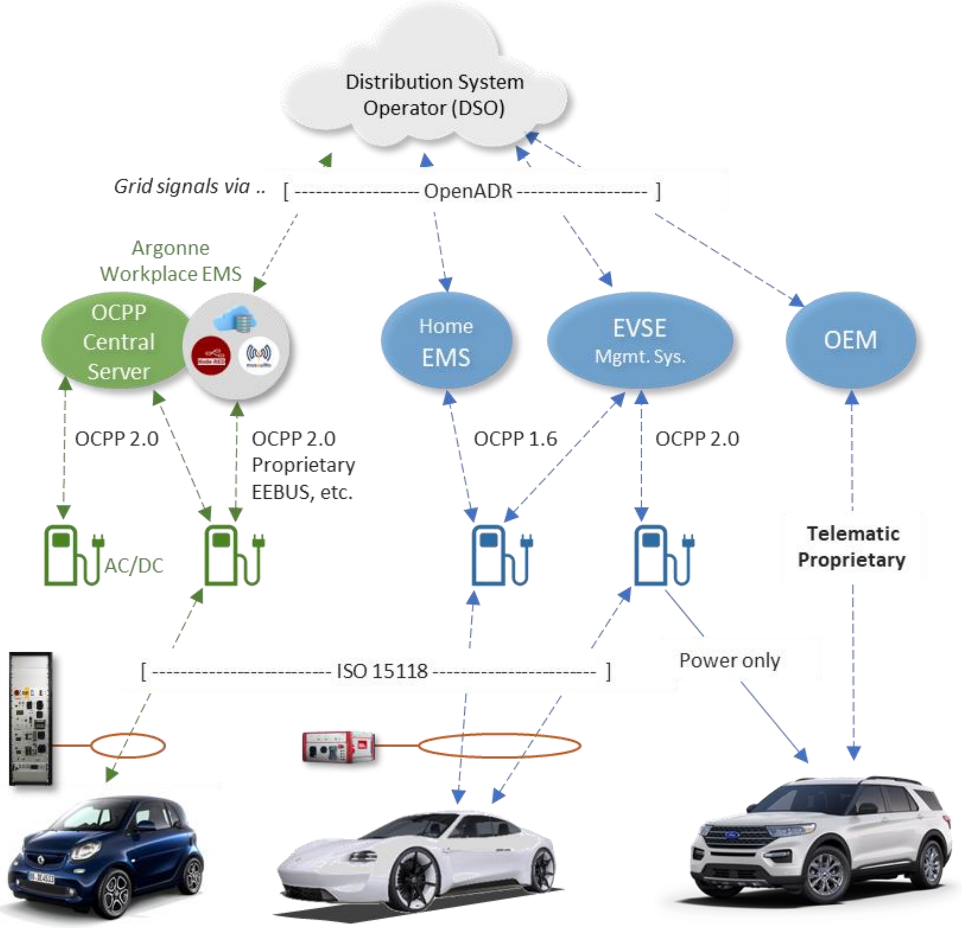
- Pilot of 25 EUMD6S (ST Micro metrology) with 10,000+ hours testing
- DC meter tested at 1000vdc/500A, -40C to +85C; <1% error HB44 target accuracy at all points.



* End Use Measurement Device

VGI Verification Event

- Some ISO 15118 stacks implemented in EVSE must be improved
- OCPP and EEBUS protocols worked for grid messages and can manage the charging process.
- More than one VGI protocol may be implemented in EVSE and energy management systems



OpenADR = Open Automated Demand Response; OCPP = Open Charge Point Protocol

Responses to Previous Reviewer Comments

Good review, but could we do more to be faster to market?

Will case studies for situations of high power demand, e.g., weather events, be addressed?
Yes, in terms of disruptions or grid operator signals at the ESI

What are the challenges from the OEM perspective?
Harmonization, 'smart' protocols, direct (telematic) v. indirect control

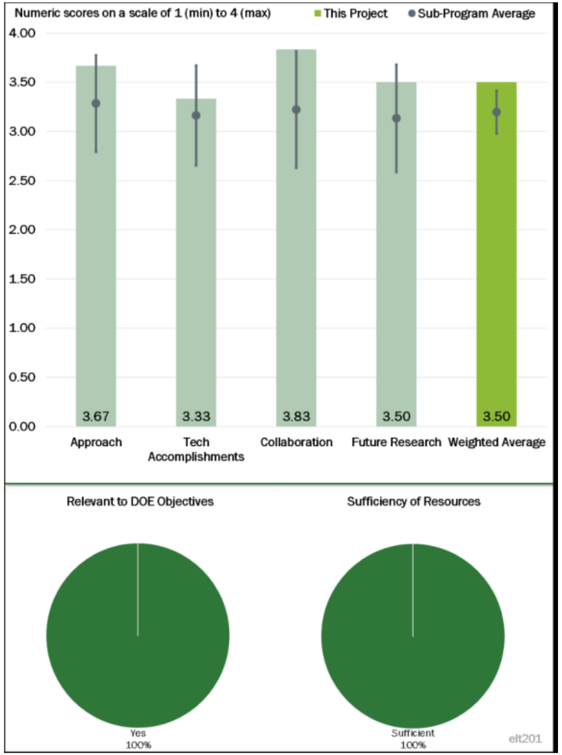
Will cybersecurity be addressed in this project?
No, but two DOE cyber projects utilize Energy Plaza hardware

Why so long to get to to lab demo?
Very limited supply of 'smart' EVs and charging equipment

Possible to collaborate with China? *No, but some sourcing of parts*

Grid resiliency versus reliability, how are they quantified?
Resiliency – ability to respond; Reliability – not addressed in SVGI

Industry stakeholders (should) get more skin in the game.
OEMs and suppliers are participating in cooperative activities and sharing the cost of commercialization projects



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Collaboration and Coordination *Continues*

Team Members	Roles	Responsibilities
ANL **INL** **European Commission – Joint Research Center (EC-JRC)**	Lead lab Contributor Collaborator	Management, development, integration and testing Grid modeling US-EU coordination: Interoperability and smart home coordination, CIP.io/Smappee implementation
Automotive: Audi, BMW, FCA, Ford, GM, Porsche, VW	Tech. advisors, contributors	V2H/VGI opportunities/technical implications and gaps; ISO-compliant vehicles/EVSE; plan for 'public' demo; Vehicle interfaces and communication requirements
EVSE – BTC Power, Porsche, Innogy	Suppliers	EVSE, communication and control interfaces
Utility/Energy: PG&E, Shell, CA Energy Commission **ELAAD NL (DSO R&D)**	Tech. advisors Contributor	Grid interface expectations, requirements, standards, gaps, technical implications and gaps; plan for 'public' demo DSO expectations; facilitating VGI with OEMs, EVSE mfrs.
SMEs: 2G Engineering, Amzur, CSS, Atrius	Collaborators/ Suppliers	Hardware/software development and support
Qmulus LLC, Zen Ecosystems, Amzur Technologies, BTCPower	Commercialization partners	Hardware/software refinements; supply chain development

Remaining Challenges and Barriers

Tasks that require access to Energy Plaza hardware

GMLC ‘smart’ use cases

- Determine capability of smart charging network to respond to grid signals and provide grid services (i.e., use cases)

Grid impact studies and demonstration

- Procurement and installation of transformer, switchgear and battery energy storage

HIL studies and coordination with INL

- Interaction of Distributed Network Model and OPAL-RT; INL data transfer specification

Lab demos of enabling technologies

- SCA and multi-unit sub-metering

GMLC use cases
- Demand response
- Demand charge mitigation
- Frequency regulation
- Charging capacity deferral
- Transactive charging
- Max. use of renewables
- Response to price signals

Future Research and Collaboration

Smart use cases, grid impact studies and field demonstrations

Lab demonstration of GMLC 'smart' use cases

- Utilize production ISO 15118 EVSE and software suppliers if possible; in-house 'smart' EVSE as needed

Grid impact studies

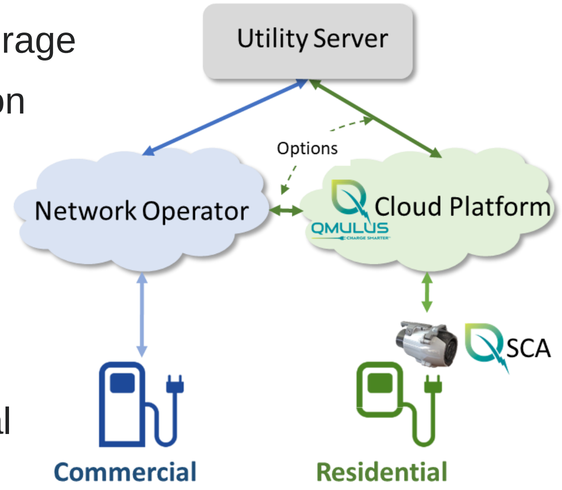
- HIL studies; workplace energy management with XFC and battery storage
- Translate from local to regional impacts with INL modeling & simulation

Lab and field demonstrations of enabling technologies

- SCA pilot at Argonne and Zen Ecosystems (to test/demonstrate the ability to aggregate EV charging for demand response applications)

Industry-led field pilots/demonstrations

- Proposals in process for 100+ sub-meters, ~1000 SCAs for residential smart charging, energy management using CIP.io



SUMMARY

Relevance

Directly supporting VTO objectives related to smart charge management and resiliency (local and distribution grid levels); key enabling technologies; industry relationships to facilitate tech transfer

Approach

Quantifying the benefits of smart charging and determining the ability to support grid services; combining physical assets and modeling to assess the benefits and impacts of EVs @ scale

Technical accomplishments and progress

Milestones delayed due to lab closure; commercialization of enabling technologies; expanded capabilities enable connection between VGI and high power infrastructure (MW+ and DCaaS).

Collaboration

Investments and technical accomplishments leading to commercialization and field demonstration of smart charge management to quantify benefits

Future work

Maintain working relationships with auto industry and suppliers; expand cooperation with grid operators and utilities