INL/MIS-24-81733-Revision-1

Slide Decks for EV@S Stakeholder Meeting at INL September 2024

September 2024

Changing the World's Energy Future

Timothy David Pennington, Todd E Combs, Andrew Meintz, Tim Pennington, Jesse Bennett, Barney Carlson, Thomas E. Carroll, John Kisacikoglu, Sam Thurston, John G Smart, Madhu Chinthavali, Theodore Bohn

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September 2024

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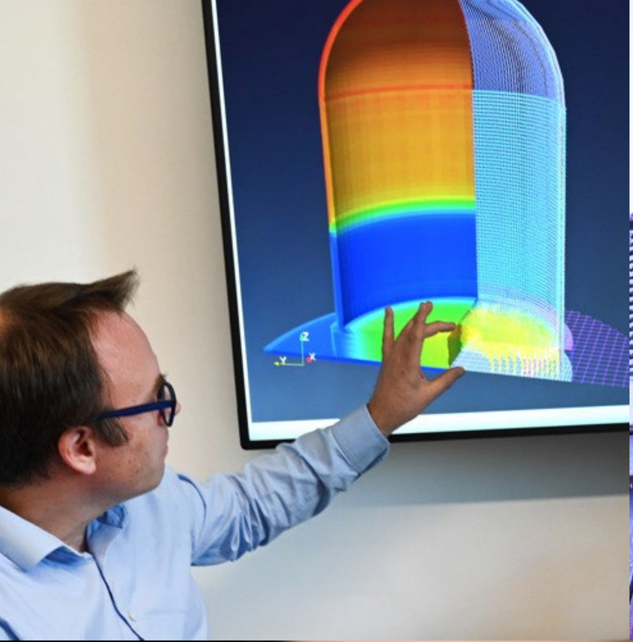
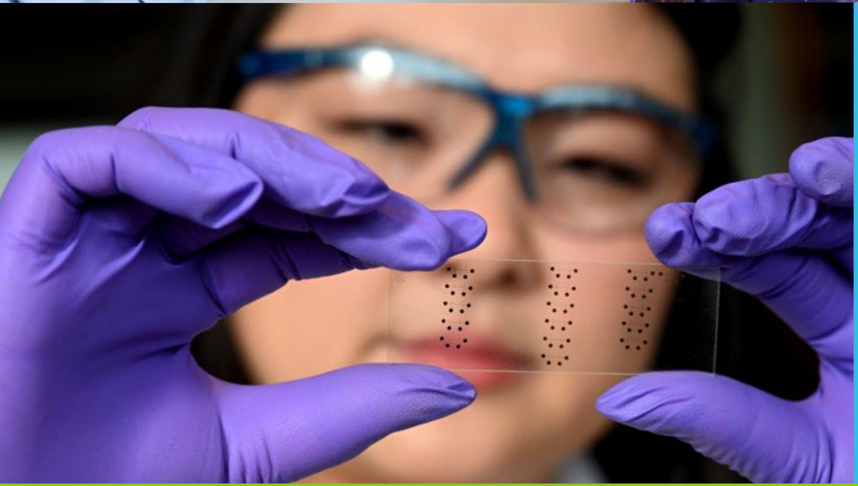


September 25, 2024

Todd Combs, PhD
Deputy Laboratory Director
Todd.Combs@inl.gov



Idaho National Laboratory –
Creating a Secure, Resilient, Clean Energy Future

Addressing the world's most pressing challenges through research, development, and demonstration

VISION

To change the world's energy future and secure our nation's critical infrastructure.

MISSION

Discover, demonstrate and secure innovative nuclear energy solutions, clean energy options and critical infrastructure.

VALUES

Excellence, Inclusivity, Integrity, Ownership, Teamwork, Safety

Our Heritage: *The National Reactor Testing Station drove nuclear innovation in the U.S. and around the world*

1st

Nuclear power plant

U.S. city to be powered by nuclear energy

Submarine reactor tested; training of nearly 40,000 reactor operators until mid-1990s

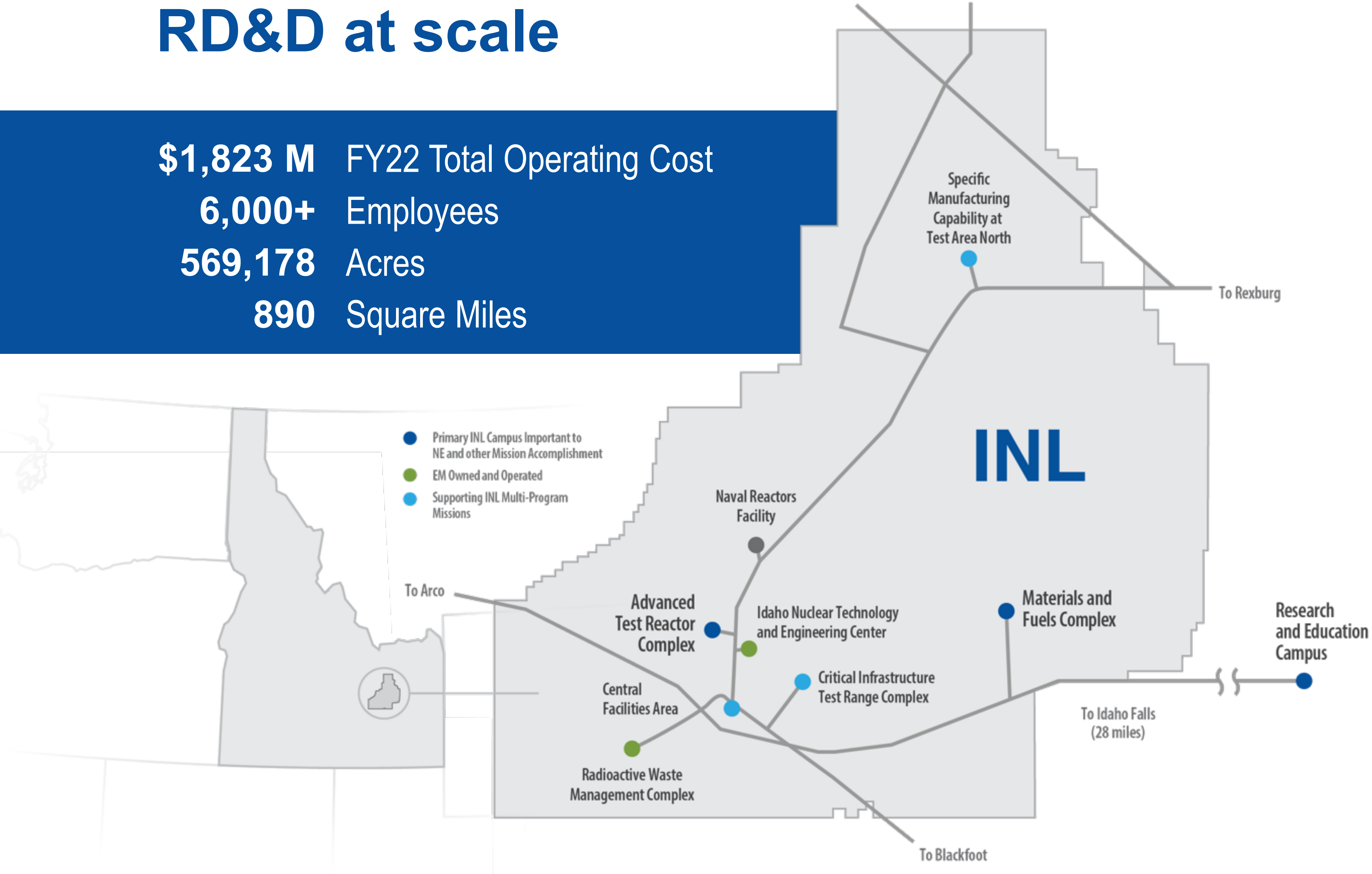
Mobile nuclear power plant for the army

- Demonstration of self-sustaining fuel cycle
- Basis for LWR reactor safety
- Aircraft and aerospace reactor testing
- Materials testing reactors

IDAHO NATIONAL LABORATORY 75TH ANNIVERSARY

Unique INL site, infrastructure, and facilities enable energy and security RD&D at scale

$1,823 M FY22 Total Operating Cost
6,000+ Employees
569,178 Acres
890 Square Miles



4 Operating reactors

12 Hazard Category II & III non-reactor facilities/ activities

50 Radiological facilities/activities

17.5 Miles railroad for shipping nuclear fuel

44 Miles primary roads (125 miles total)

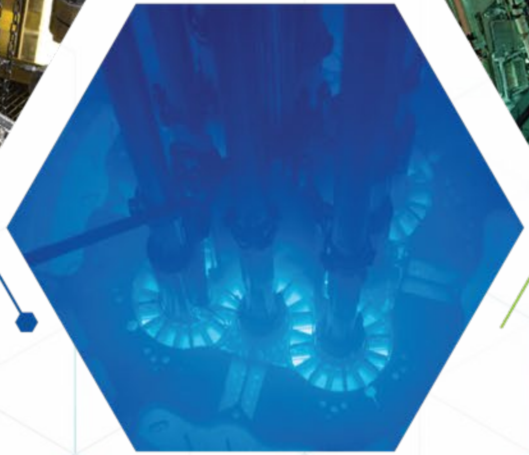
9 Substations with interfaces to two power providers

126 Miles high-voltage transmission lines

3 Fire Stations

Creating a secure, resilient, clean energy future

Nuclear Science & Technology



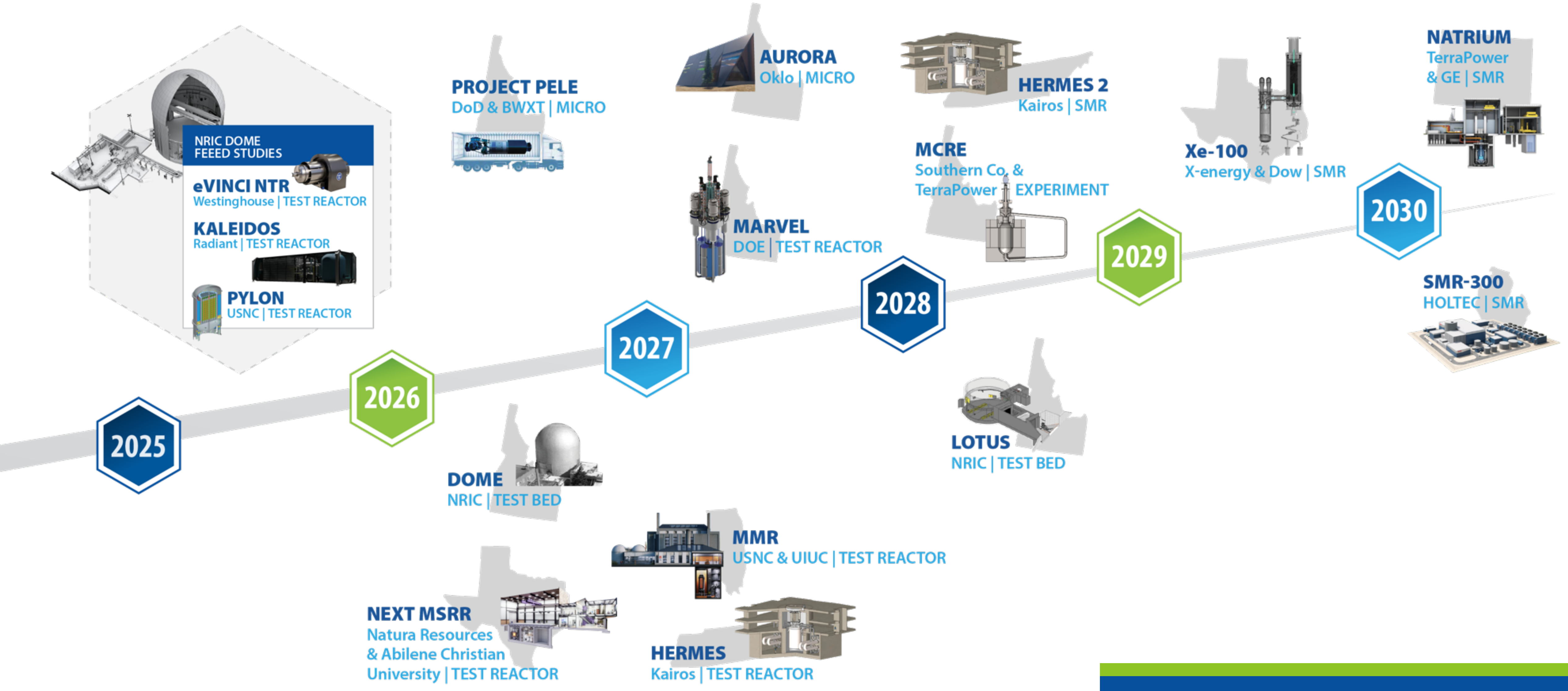
Advanced Test Reactor Complex

Materials and Fuels Complex

Energy & Environment Science & Technology

National & Homeland Security Science & Technology

Accelerating advanced reactor demonstration and deployment



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EVs@ Scale

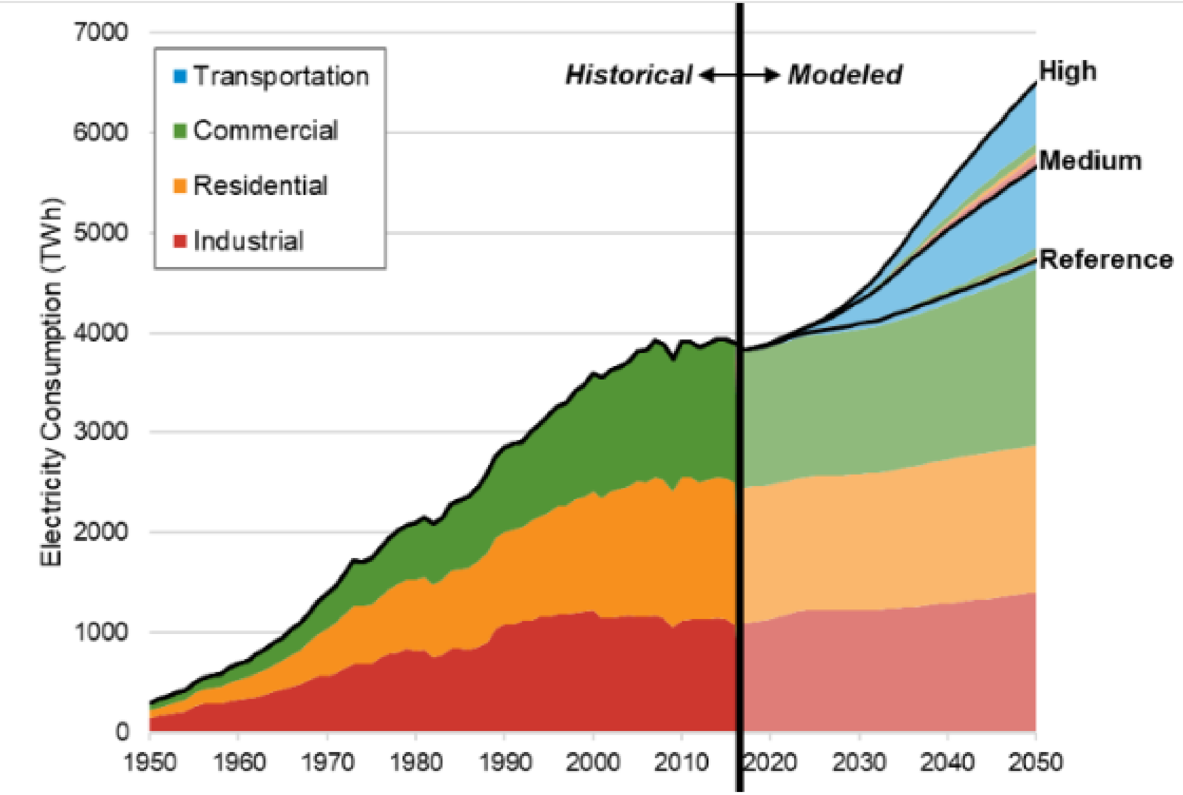
U.S. Department of Energy

Consortium Overview and Stakeholder Engagement

Andrew Meintz

Sept 25, 2024

Impact of Transportation Electrification



Historical and Projected annual electricity consumption

EVs@Scale Consortium RD&D will support electrification by answering:

- How will electricity generation and the transportation sectors work together?
- What research can we do to ensure a safe, smooth, and seamless transition?
- How could a grid-integrated charging network support intermittent generation?

Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States. NREL/TP-6A20-71500

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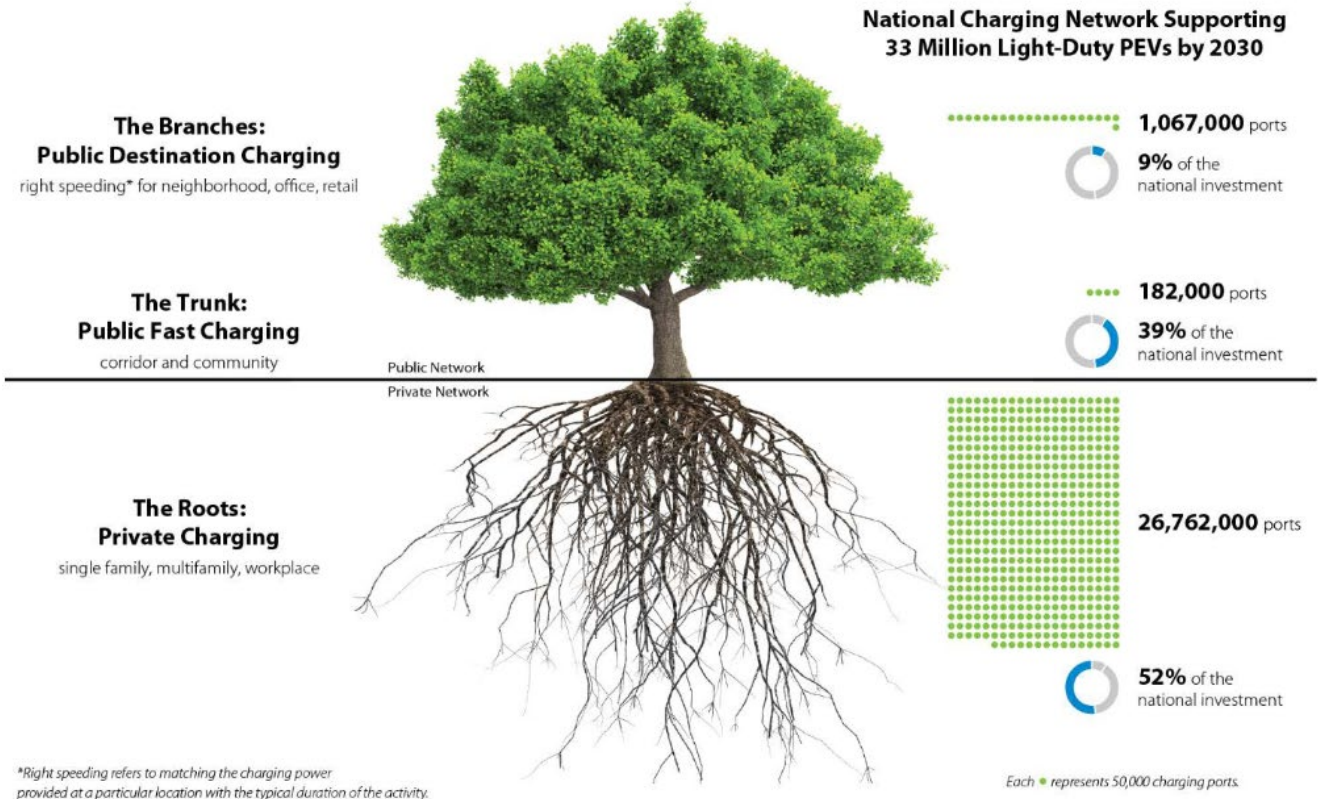
Building the 2030 National Charging Network

27 million new charging ports are required which has been estimate that a $53–$127-billion cumulative national charging infrastructure investment, including $31–$55 billion for publicly accessible charging infrastructure, is necessary to support charging infrastructure needs under the baseline scenario.



The 2030 National Charging Network: Estimating U.S. Light-Duty Demand for Electric Vehicle Charging Infrastructure; NREL https://www.nrel.gov/docs/fy23osti/85654.pdf

Consortium Objectives

- **Vehicle-Grid Integration:** Achieve seamless integration and charging for EVs@Scale to enable synergistic coupling of the energy and transportation sectors.
- **Interoperability:** Advance the connectivity, compatibility, and scalability of systems and technologies operating across the interfaces of an open, standards-based EV charging ecosystem.
- **Reliability and Resiliency:** Improve the reliability of charging and enhance the ability of the electric grid to provide dependable power and robustly react and recover from adverse events
- **Cybersecurity:** Advance the cyber-physical security posture across the EV charging ecosystem.

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

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So why are we here today?

So why are we here today?

- Identify your route
- Route for distance and elevation
- Plan your campsite and access to water
- Don't forget your bear canister

EVs @ Scale and ChargeX Consortium

Establishing a secure and scalable infrastructure is necessary to support the transition to an electric fleet in 2030

- Optimizing charging to ensure demands placed on the grid by EVs consistently meet consumer expectations
- Enable greater safety, grid operation reliability, and consumer confidence.
- Formulating technologies, practices, and standards to enable high-power, low-cost, and ubiquitous charging options

Work together as EV industry stakeholders to measure and significantly improve public charging reliability and usability by <u>June 2025</u>

- **Define the Charging Experience:** define and publish KPIs, set targets, and measure performance
- **Triage Charging Reliability and Usability:** understand root causes and quickly identify solutions
- **Develop Solutions for Scaling Reliability:** design new diagnostics and tools to scale interoperability

Consortium Structure

Leadership Council

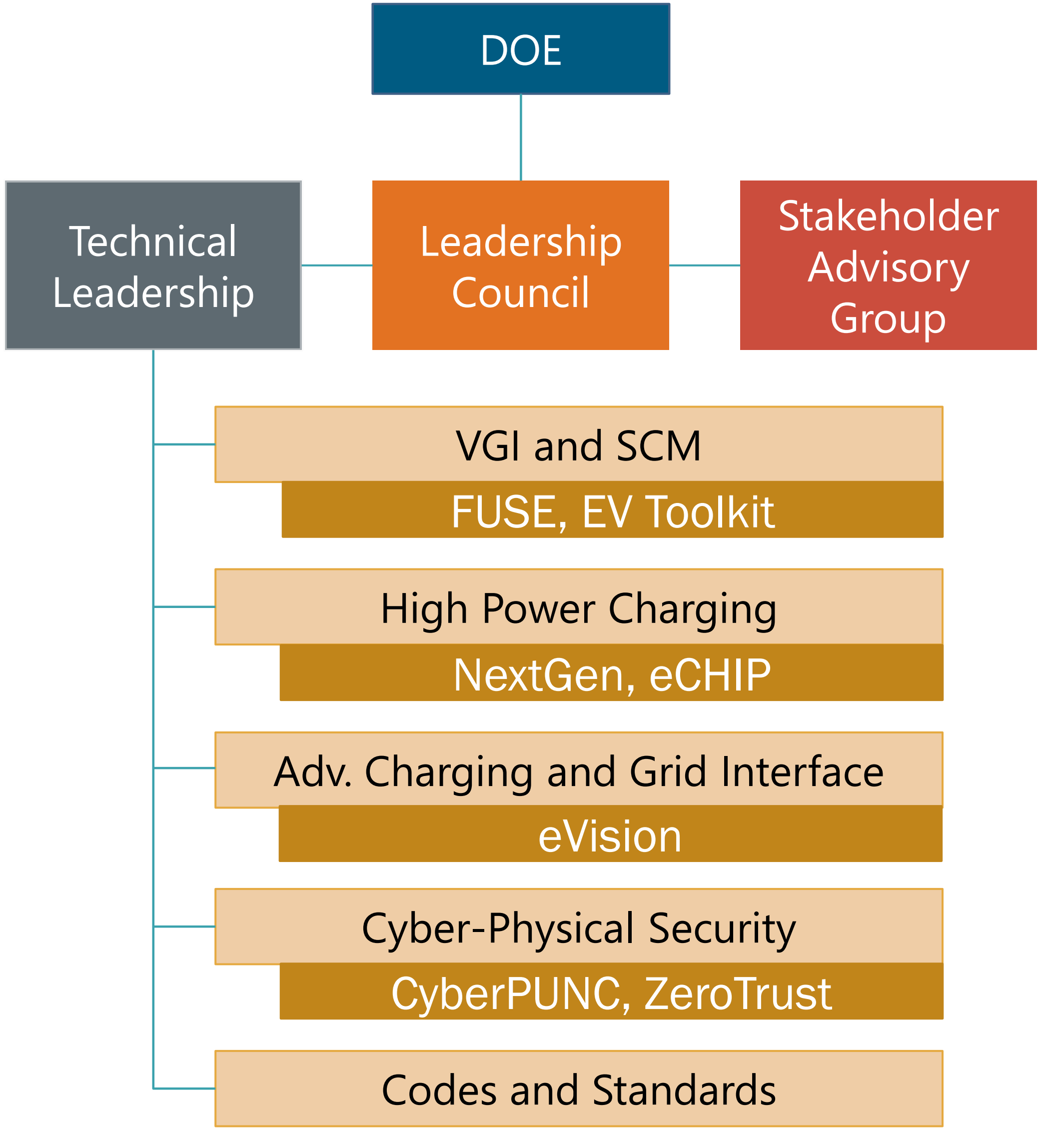
- Andrew Meintz (NREL, chair), Tim Pennington (INL, rotating co-chair), Don Stanton (ORNL), Summer Ferreira (SNL), Lori Ross (PNNL), Dan Dobrzynski (ANL), Tom Kirchsetter (LBNL)

Stakeholder Advisory Group

- Utilities, EVSE & Vehicle OEMs, CNOs, SDOs, Gov't, Infrastructure

Consortium Pillars and Technical Leadership

- Vehicle Grid Integration and Smart Charge Management (VGI/SCM): Jesse Bennett (NREL), Jason Harper (ANL)
- High Power Charging (HPC): John Kisacikoglu (NREL)
- Advanced Charging and Grid Interface Technologies (ACGIT): Madhu Chinthavali (ORNL)
- Cyber-Physical Security (CPS): Richard "Barney" Carlson (INL), Craig Rodine (SNL)
- Codes and Standards (CS): Ted Bohn (ANL)



EVs@Scale Lab Consortium Stakeholder Engagement and Outreach

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Semi-Annual Stakeholder Meetings

- Open Virtual Forum
- Common Understanding / Direction
- Long / Short Term Plans
- RFI and Stakeholder Feedback
- Visibility
- High Level Information Exchange
- Comprehensive Situational Awareness
- Long / Short Term R&D Results
- FOA Information

DEEP DIVE TECHNICAL MEETINGS

- Detailed Technical Discussions
- Stakeholder Feedback
- Active Pool of Project Stakeholders
- Support for RFI Process
- Project Plans and Progress
- R&D Agility
- Short Inception IABs
- Tech Transfer

DEDICATED ENGAGEMENT WEBSITE

- Continuous Stakeholder Engagement
- Formal and Informal Communications
- Enable Project Participation
- Meeting Logistics
- Ease of Information Exchange
- Project Updates and Review
- Record of Information

Collaboration and Coordination

Stakeholder Advisory Group

– Utilities, EVSE & Vehicle OEMs, CNOs, SDOs, Gov't, Infrastructure

Direct interaction for each pillar projects

– Utilities, EVSE & Vehicle OEMs, CNOs, SDOs, Gov't, Infrastructure

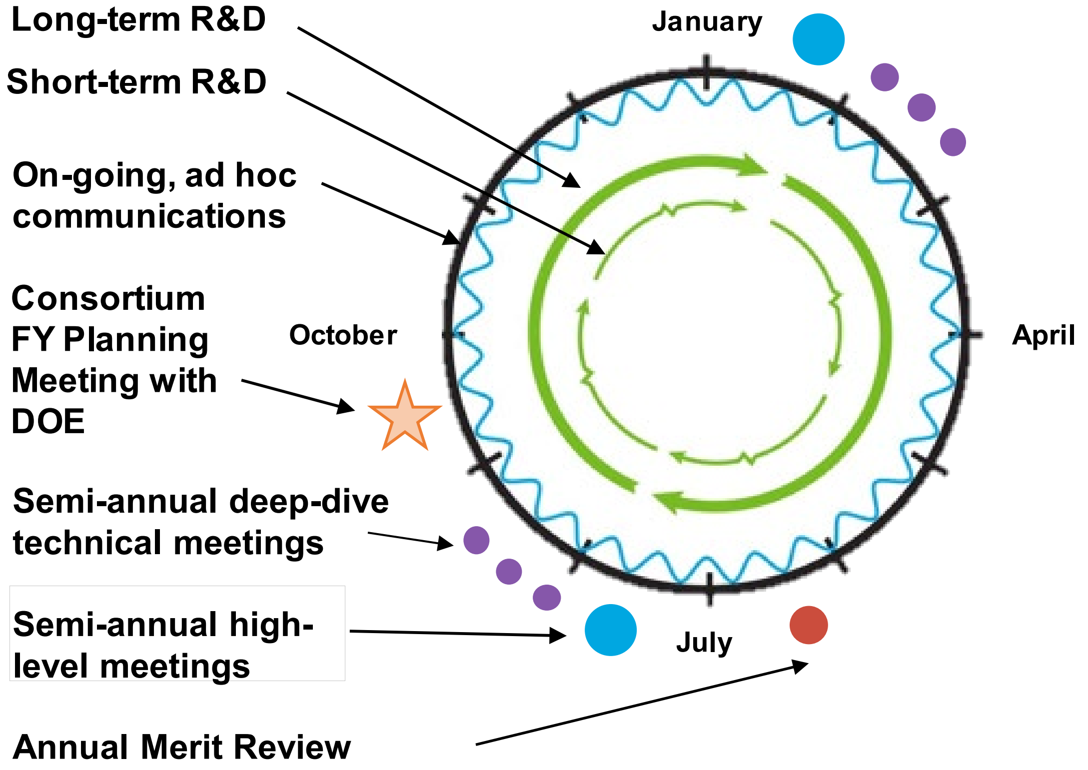
– Webinars / Project discussions

Semi-annual high-level meetings

– Rotation among labs with discussion on all pillars

Semi-annual deep-dive technical meetings

– VGI/SCM, HPC & WPT, and CPS with C&S incorporated into all meetings



Two semi-annual high-level meetings were held in April 2023 and Sept 2024 with attendance reaching 100 stakeholders with several attending the follow-on deep dive discussions

Summary

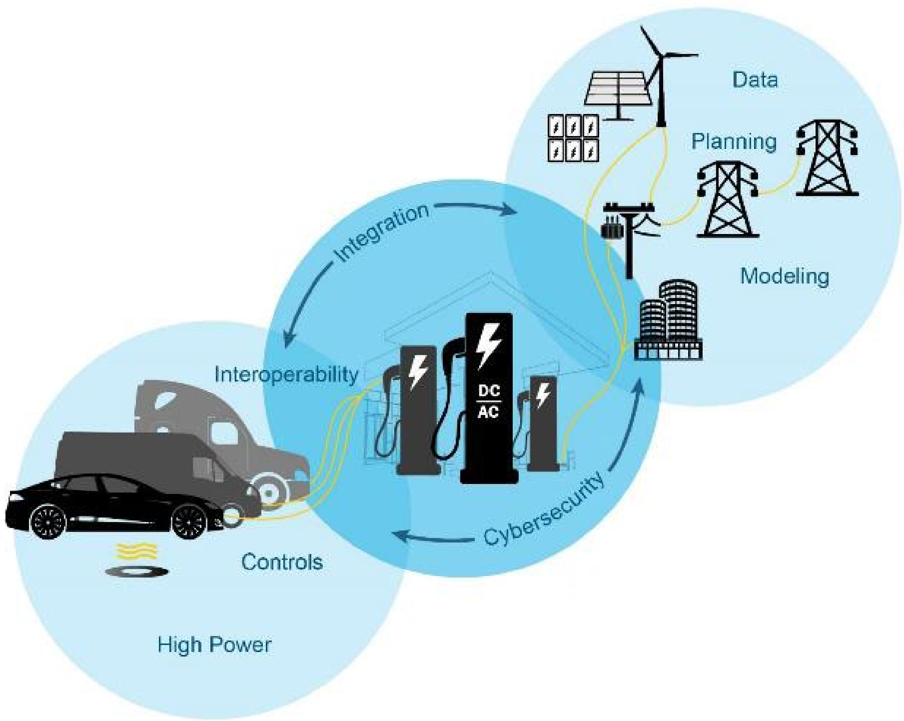
EVs@Scale U.S. Department of Energy

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@Scale and provide answers to fundamental questions with activities 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

We need __your input today and tomorrow__ to tell us where we can improve on delivering these outcomes !

Upcoming Stakeholder Engagement Events

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We have the following upcoming stakeholder engagement events planned and will send out invites to registrants of this event for the deep-dives next week.

Fall 2024: Deep Dive Meetings

- Codes & Standards Pillar
  - Date TBD
- Cyber-Physical Security Pillar
  - CyberPunc, and ZeroTrust Projects
  - November 6, 2024
- SCM&VGI Pillar
  - FUSE and VGI Toolkit Projects
  - October 31, 2024
- High-Power Charging Pillar
  - NextGen Profiles and eCHIP Projects
  - November 12, 2024
- Advanced Charging and Grid Interface Tech. Pillar
  - Date TBD

Spring 2025: Semi-Annual Meeting

- Sandia will host in Albuquerque, NM
- Late March or early April

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VGI – Toolkit Project

SCM/VGI Pillar

Tim Pennington

On behalf of Andy Satchwell – Berkley Lab

Sept. 25, 2024

VGI Toolkit Overview

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Background
- Project began as an independent "Lab Call"
- Generated by interest from several DOE offices
- Recognized existing capabilities at National Labs which could be brought to assist stakeholders
- Now included in the SCM/**VGI Pillar**

Barriers and Technical Targets
(from Summary Report on EVs at Scale and the U.S. Electric Power System, November 2019)
- Supporting "proper planning for [electric vehicle] EV penetration and the resulting charging demand to support a growing light-duty EV fleet."
- Assessing impacts that "vary geographically and are use-case specific."
- Additional analysis of "distribution capacity expansion," "medium- and heavy- duty EV market growth scenarios," and "the impact on energy generation and generation capacity."

Partners
- Lead: Berkeley Lab
- Co-leads: Argonne National Laboratory, Idaho National Laboratory, National Renewable Energy Laboratory, Oak Ridge National Laboratory, and Pacific Northwest National Laboratory

Why do we need an EV modeling toolkit?

“I suppose it is tempting, if the only tool you have is a hammer, to treat everything as if it were a nail.”

– Abraham Maslow, 1966

(and other variations by Warren Buffet, Mark Twain, etc.)

- There are a number of entities responsible for vehicle grid integration (VGI) planning and deployment with diverse perspectives, objectives, and experiences.
- Opportunity to equip stakeholders with modeling tools, data, and analytical insights.

Relevance

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Objectives

- Provide insights into transportation and energy use problems for a broad range of internal and external stakeholders.
- Make essential vehicle and market data, modeling and simulation, and integrated and applied analyses available to the public.

Impact

- Develop an understandable, accessible, and user-friendly toolkit that draws on existing DOE-funded tools, datasets, and analyses.
- Engage with targeted users and audiences throughout the project to solicit feedback on their needs and questions, and ensure the toolkit is intuitive and user-friendly.

Electricity system impact and planning

Benefit-cost analysis

Future EV adoption and load impacts

EV infrastructure siting

Project Participating Laboratories

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BERKELEY LAB

Lawrence Berkley National Laboratory is leading the overall organization and project management.

Argonne NATIONAL LABORATORY

Argonne National Laboratory is leading the tool inventory and providing support across all tasks.

INL Idaho National Laboratory

Idaho National Laboratory is co-leading the data and report library and providing support across all tasks.

NREL Transforming ENERGY

National Renewable Energy Laboratory is leading the website and toolkit design, and providing support across all tasks.

OAK RIDGE National Laboratory

Oak Ridge National Laboratory is co-leading the tool inventory and providing support across all tasks.

Pacific Northwest NATIONAL LABORATORY

Pacific Northwest National Laboratory is leading the data and report library and providing support across all tasks.

Milestones

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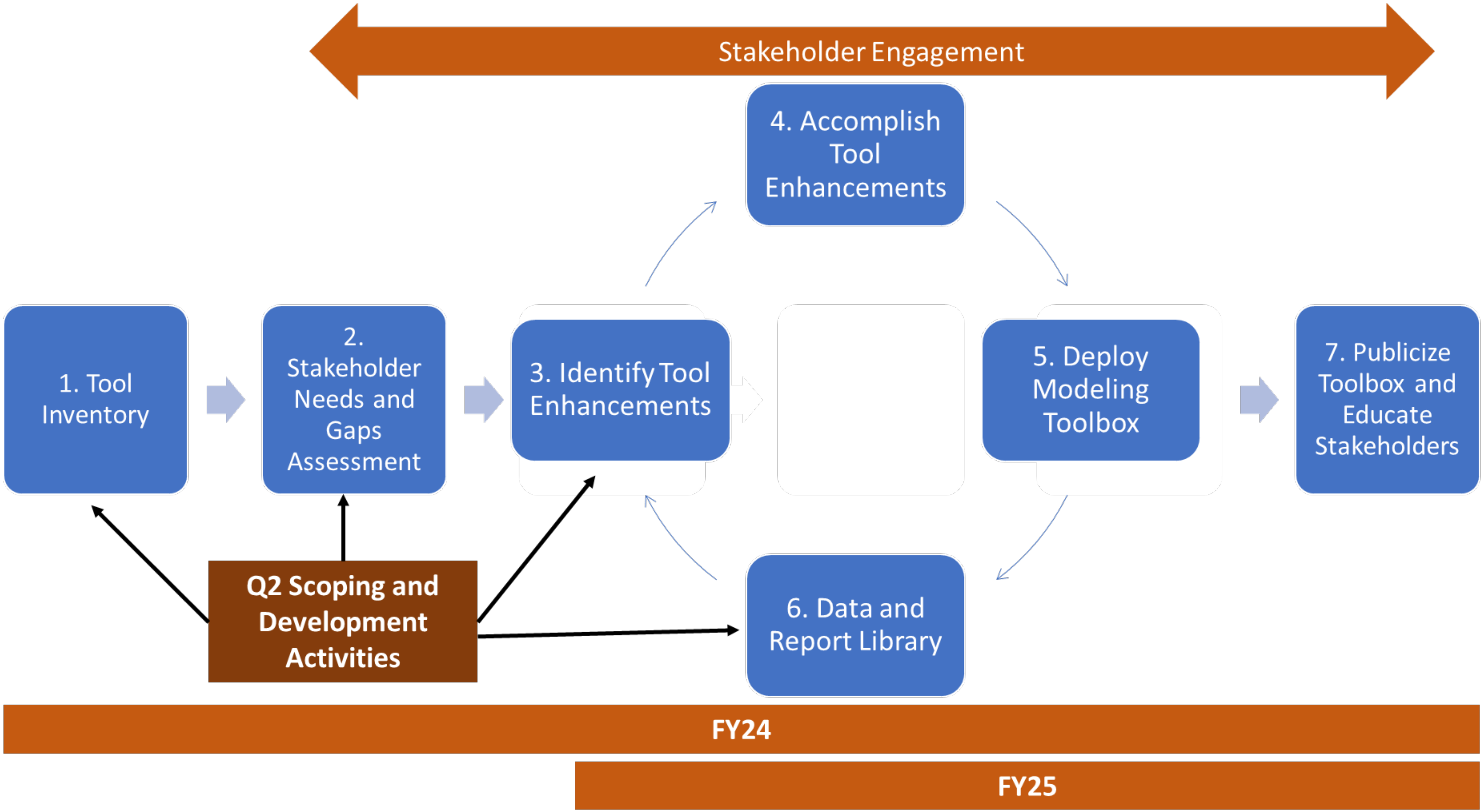
We have completed early-stage development tasks and are beginning the toolkit design and enhancements tasks.

Task	FY24 milestones	FY25 milestones
1. Tool inventory	Database of existing lab capabilities to inform DOE's decisions about tool enhancements [Q2, **complete**]	Annual update to FY24 database to capture new capabilities [Q1]
2. Stakeholder needs and gaps assessment	Memo to DOE categorizing stakeholder needs and information gaps [Q2; **complete**]	Continual stakeholder engagement throughout project via one or more workshops and/or industry engagements [Q4]
3. Identify tool enhancements	DOE decision on tool enhancements that will be undertaken in FY24 informed by Tasks 1 and 2 [**Q3, complete**]	DOE decision on tool enhancements that will be undertaken in FY25 informed by Tasks 1 and 2, and FY24 work [Q2]
4. Accomplish tool enhancements	Publish enhanced tools and datasets with stakeholder-friendly features and new functions based on Tasks 1, 2, and 3 [**Q4, In process**]	Publish enhanced tools and datasets with stakeholder-friendly features and new functions based on Tasks 1, 2, and 3 [Q4]
5. Deploy modeling toolkit	Website development roadmap [Q2, **complete**]; Release toolkit to the public including Task 6 library and decision support [Q4, **in process**]	Update toolkit with linked or internally-hosted tool enhancements from Task 4 [Q4]
6. Data and report library	Draft overview of data and report library content and structure [Q2, **complete**]; Post curated library as examples of tool usage and case studies [**Q4, in process**]	Update curated library based on new tools in Task 4 [Q4]
7. Publicize and educate stakeholders	Deliver publicity materials and disseminate toolkit via e-mail communications and as part of public events/conferences; develop and post toolkit supporting information [**Q4, in process**]	Deliver publicity materials and disseminate toolkit via e-mail communications and as part of public events/conferences; develop and post toolkit supporting information [Q4]

Approach



Stakeholder Engagement
4. Accomplish Tool Enhancements
1. Tool Inventory
2. Stakeholder Needs and Gaps Assessment
3. Identify Tool Enhancements
5. Deploy Modeling Toolbox
7. Publicize Toolbox and Educate Stakeholders
Q2 Scoping and Development Activities
6. Data and Report Library
FY24
FY25

Stakeholder Needs and Gaps

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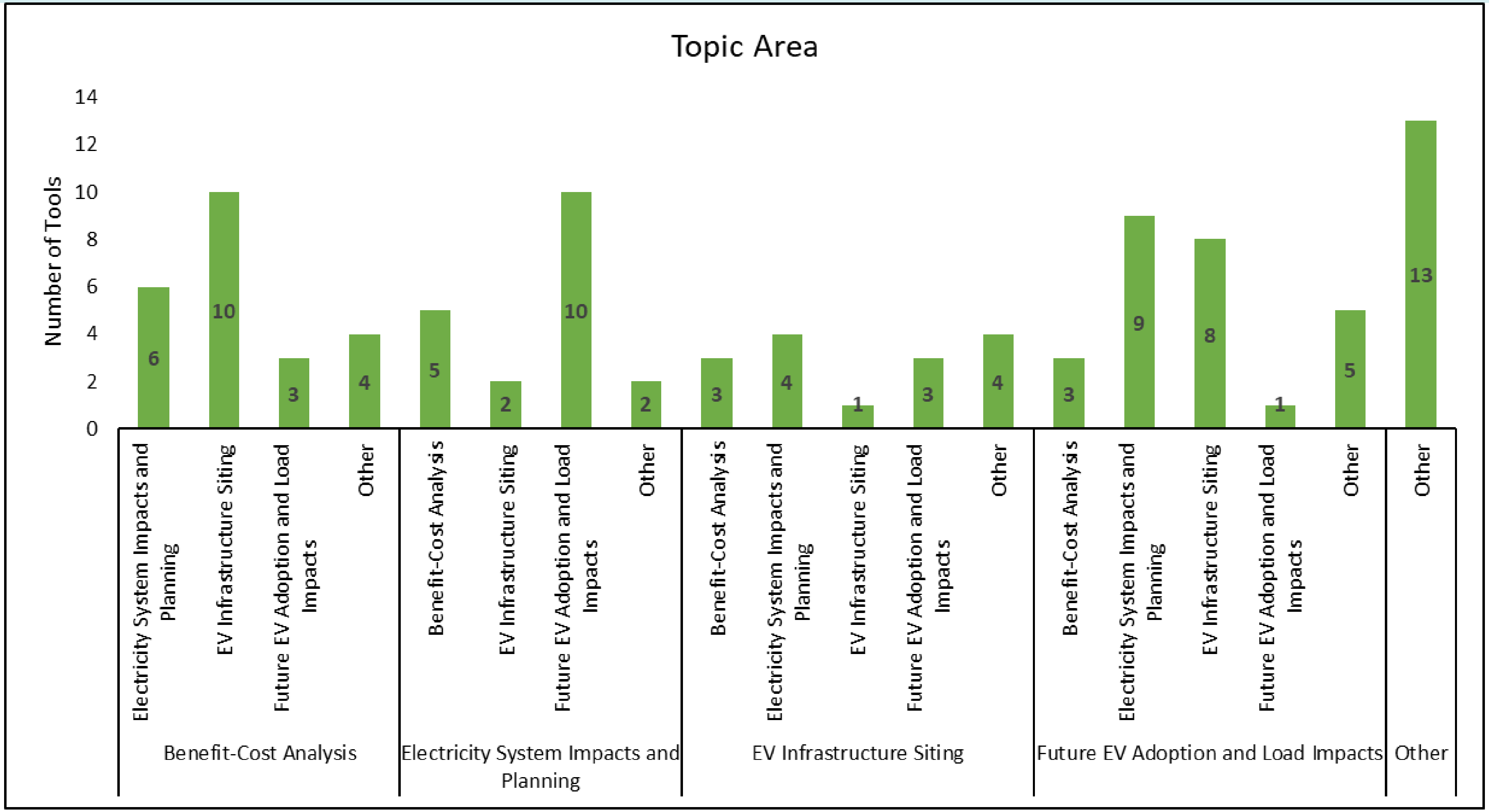
Stakeholder needs and gaps appropriate for the toolkit can be grouped broadly into the four Toolkit Themes:

- **EV adoption**: identifying future growth in EVs by vehicle type and considering technological, market, and consumer drivers.
- **EVSE deployment/siting**: in connection with EV adoption forecasts, identifying charging infrastructure and EVSE siting to support adoption. This category includes customer enrollment in utility programs, rate design alternatives, and EVSE deployment programs.
- **EV grid impacts**: answering, “Where, when, and how much?” This category includes short- and long-term forecasts of load (ideally on an hourly basis) and grid infrastructure impacts at spatial detail consistent with the stakeholder’s needs (e.g., feeder-level detail for distribution system impacts).
- **VGI costs and benefits**: especially interconnection costs and other site-specific costs. Benefits include avoided electricity infrastructure costs and also air quality. Costs and benefits should be quantified at the highest spatial detail possible and/or appropriate for the stakeholder’s needs.

Tool Inventory

Inventoried national lab tools, models, and datasets with details on spatial and temporal detail, alignment with key vehicle grid integration (VGI) deployment topics, and perceived user-friendliness and scalability.



Category A tools by audience and topic area

	Electricity System Impacts and Planning		Benefit-Cost Analysis		Future EV Adoption and Load Impacts		EV Infrastructure Siting	
Audience	**Lab Name**	**Resource Name**	**Lab Name**	**Resource Name**	**Lab Name**	**Resource Name**	**Lab Name**	**Resource Name**
Utilities	ANL	CHECT	ANL	CHECT	NREL	OCHRE	ANL	JOBS
	INL	CalderaCast	ANL	JOBS	NREL, PNNL, LLNL	HELICS (Heirarchical Engine for L	INL	CalderaCast
	NREL, PNNL, LLNL	HELICS (Heirarchical Engine for La	PNNL	ESET	PNNL	GridPIQ	PNNL	ESET
	PNNL	GridPIQ						
State DOT	ANL	Geospatial Energy Mapper (GEM)	ANL	JOBS	NREL	ADOPT: Automotive Deployment	ANL	JOBS
	INL	CalderaCast	NREL	Engage [Capacity Expan	NREL	EVI-RoadTrip: Electric Vehicle Inf	ANL	Geospatial Energy Mapp
	NREL	ADOPT: Automotive Deployment C	NREL	FASTSim: Future Autom	NREL	FASTSim: Future Automotive Syst	INL	CalderaCast
	NREL	Engage [Capacity Expansion Web /	ORNL	MA3T (Market Acceptar	NREL	Transportation-Related Consume	NREL	EVI-Equity: Electric Vehic
	NREL	EVI-Pro Lite (EVI-X Toolbox)	PNNL	CHIP - Charging Hub Inv	ORNL	MA3T (Market Acceptance of Adv	NREL	EVI-Pro Lite (EVI-X Toolb
	NREL	NEVI U-Finder: National Electric V			PNNL	CHIP - Charging Hub Investment	NREL	EVI-RoadTrip: Electric Ve
							NREL	NEVI U-Finder: National
State Utility Regulators	ANL	Geospatial Energy Mapper (GEM)	NREL	Engage [Capacity Expan	NREL	EVI-RoadTrip: Electric Vehicle Inf	ANL	Geospatial Energy Mapp
	NREL	Engage [Capacity Expansion Web /			PNNL	GridPIQ	NREL	EVI-Equity: Electric Vehic
	NREL	EVI-Pro Lite (EVI-X Toolbox)					NREL	EVI-Pro Lite (EVI-X Toolb
	PNNL	GridPIQ					NREL	EVI-RoadTrip: Electric Ve
Third-Party Companies	ANL	CHECT	NREL	T3CO (Transportation Te	NREL	T3CO (Transportation Technolog	NREL	NEVI U-Finder: National
	NREL	ADOPT: Automotive Deployment C	ANL	CHECT	NREL	ADOPT: Automotive Deployment		
	NREL	NEVI U-Finder: National Electric V	NREL	FASTSim: Future Autom	NREL	FASTSim: Future Automotive Syst		
	NREL, PNNL, LLNL	HELICS (Heirarchical Engine for La	ORNL	BREVO (Battery Run-do	NREL	Transportation-Related Consume		
	ORNL	BREVO (Battery Run-down under E	PNNL	CHIP - Charging Hub Inv	NREL, PNNL, LLNL	HELICS (Heirarchical Engine for L		
					PNNL	CHIP - Charging Hub Investment		

Category A tools by audience and Topic area (High “user-friendly” & ”ease of use”)

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Audience	Electricity System Impacts and Planning	Benefit-Cost Analysis	Future EV Adoption and Load Impacts	EV Infrastructure Siting
Utilities	4	3	3	3
State DOT	6	5	6	7
State Utility Regulators	4	1	2	4
Third-Party Companies	5	5	6	1

**Color gradient indicates where each value falls within the range*

- This table identifies gaps in Category A
  - What we should prioritize in Category B
- Most notably, only 1 tool available for:
  - State Utility Regulators to conduct Benefit-Cost Analysis
  - Third-party companies to site EV infrastructure projects

Recommendations for DOE:

1. **Prioritize red/pink cells** (e.g., prioritize State DOT/Benefit Cost analysis in down-selecting Category B)

2. For tools identified as High “user-friendly” & ”ease of use”, yet require further enhancements, **suggest a further review of what is needed (Group A1)**

3. For all other tools in this category, **suggest allocating additional (minimum) investment to ensure that they are directly and specifically for VGI (Group A2)**

Category B tools by audience and topic area ranked (examples)

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Audience	Electricity System Impacts and Planning			Benefit-Cost Analysis			Future EV Adoption and Load Impacts			EV Infrastructure Siting		
	Overall Rank	Lab Name	Resource Name	Overall Rank	Lab Name	Resource Name	Overall Rank	Lab Name	Resource Name	Overall Rank	Lab Name	Resource Name
Utilities	1	NREL	EVI-Rental	27	PNNL	EVAM	23	ORNL	ODS-Route (Operating Domai	22	ORNL	TCO (Total Cost of Owners
	22	ORNL	TCO (Total Cost of Ownershi	32	ANL	ATEAM	25	ORNL	VGI-TECS (Vehicle Grid Integr	23	ORNL	ODS-Route (Operating Dom
	25	ORNL	VGI-TECS (Vehicle Grid Integr	38	ANL	Energy Plaza Metering Data	28	ORNL	OR-AGENT (Optimal Regional	32	ANL	ATEAM
	27	PNNL	EVAM	49	ANL	Next-Gen Profiles: Fleet Utiliz	34	NREL	dsgrid: Demand-Side Grid To	41	LBNL	HEVI-LOAD
	28	ORNL	OR-AGENT (Optimal Regional	51	LBNL	BEAM CORE	35	NREL	HEM (Holistic Energy Model)	49	ANL	Next-Gen Profiles: Fleet Uti
	34	NREL	dsgrid: Demand-Side Grid To	63	NREL	DRIVE: Drive-Cycle Rapid Inv	37	NREL	SAM: System Advisor Model	51	LBNL	BEAM CORE
	35	NREL	HEM (Holistic Energy Model)	65	NREL	EVI-InMotion: Electric Vehicl	40	ORNL	G_CIE (Grid CO2 Intensity Est	53	NREL	ResStock
…												
State DOT	27	PNNL	EVAM	2	PNNL	GUS (Guide for Utility Service	23	ORNL	ODS-Route (Operating Domai	23	ORNL	ODS-Route (Operating Dor
	28	ORNL	OR-AGENT (Optimal Regional	27	PNNL	EVAM	28	ORNL	OR-AGENT (Optimal Regional	31	ORNL	Grid Capacity Model
	48	LBNL	TX odometer data	31	ORNL	Grid Capacity Model	33	PNNL	EFECT	36	ORNL	WPC (WorkPlace Charging
	67	NREL	EVI-Ratio: Electric Vehicle Inf	60	ORNL	Battery Charger Thermal Mod	36	ORNL	WPC (WorkPlace Charging) r	39	LBNL	ATLAS
	68	NREL	FESTIV: Flexible Energy Sched	68	NREL	FESTIV: Flexible Energy Sched	39	LBNL	ATLAS	42	ANL	POLARIS
	71	NREL	dGen (Distributed Generation	71	NREL	dGen (Distributed Generation	42	ANL	POLARIS	50	NREL	CADET
…												
State Utility Regulators	25	ORNL	VGI-TECS (Vehicle Grid Integr	38	ANL	Energy Plaza Metering Data	25	ORNL	VGI-TECS (Vehicle Grid Integr	4	ANL	Smart Charging Manageme
	29	ORNL	CV-DRNet (Commercial Vehic	57	NREL	Transportation Secure Data (	34	NREL	dsgrid: Demand-Side Grid To	53	NREL	ResStock
	34	NREL	dsgrid: Demand-Side Grid To	63	NREL	DRIVE: Drive-Cycle Rapid Inv	40	ORNL	G_CIE (Grid CO2 Intensity Est	54	NREL	EVI-Pro:HD
	38	ANL	Energy Plaza Metering Data	70	NREL	Sienna	47	NREL	EVI-Pro	59	NREL	OpenPATH: Open Platform
	40	ORNL	G_CIE (Grid CO2 Intensity Est	75	NREL	FleetREDI	53	NREL	ResStock	61	ORNL	CV-TECS (Commercial Vehi
…												
Third-party Companies	22	ORNL	TCO (Total Cost of Ownershi	26	NREL	TEMPO	24	ORNL	Vehicle Model	22	ORNL	TCO (Total Cost of Ownersh
	24	ORNL	Vehicle Model	30	NREL	EVI-EnSite: Electric Vehicle In	33	PNNL	EFECT	30	NREL	EVI-EnSite: Electric Vehicle
	26	NREL	TEMPO	32	ANL	ATEAM	35	NREL	HEM (Holistic Energy Model)	32	ANL	ATEAM
	29	ORNL	CV-DRNet (Commercial Vehic	43	NREL	MDAO4Grid	36	ORNL	WPC (WorkPlace Charging) r	36	ORNL	WPC (WorkPlace Charging)
	35	NREL	HEM (Holistic Energy Model)	45	INL	CalderaICM (Infrastructure C	37	NREL	SAM: System Advisor Model	39	LBNL	ATLAS
	37	NREL	SAM: System Advisor Model	46	LBNL	BILD AQ (Benefits of Infrastru	39	LBNL	ATLAS	41	LBNL	HEVI-LOAD
…												

** Not all tools are shown; full list is available as Excel spreadsheet*

Website Design

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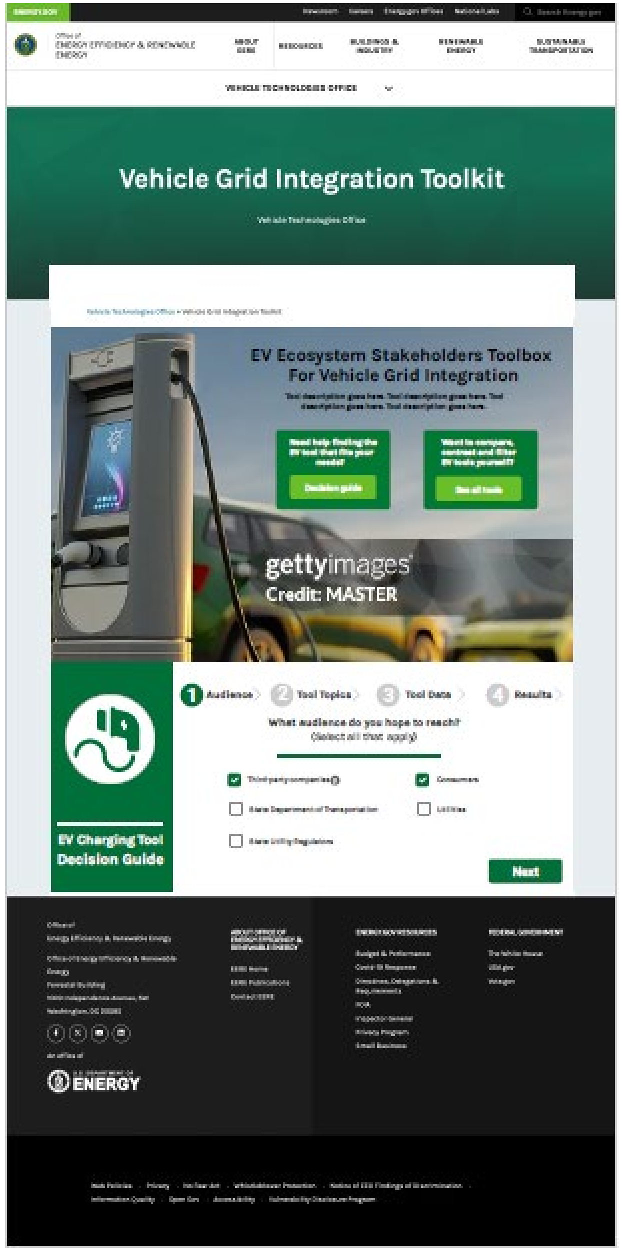
- Drafted a website plan outlining deliverables, development needs, timing, and decision point requirements. Website design and site architecture planning are in progress.
- Informed by efforts in Tasks 1 – 4 and in conjunction with Task 6, the Modeling Toolbox (Task 5) will be a public-facing website that provides:
  - Descriptive information about the models, tools, and other resources that are part of the toolbox;
  - A decision tree to help users make informed decisions about the tool(s) most suited for their needs; and
  - Access to tools (links) and related resources, including the Task 6 Data and Report Library.
- Established resources for development and technical stack.
- Drafted preliminary site architecture along with look and feel.
- Collaborated with other task leaders to prioritize website needs and capabilities.



Alternate Designs

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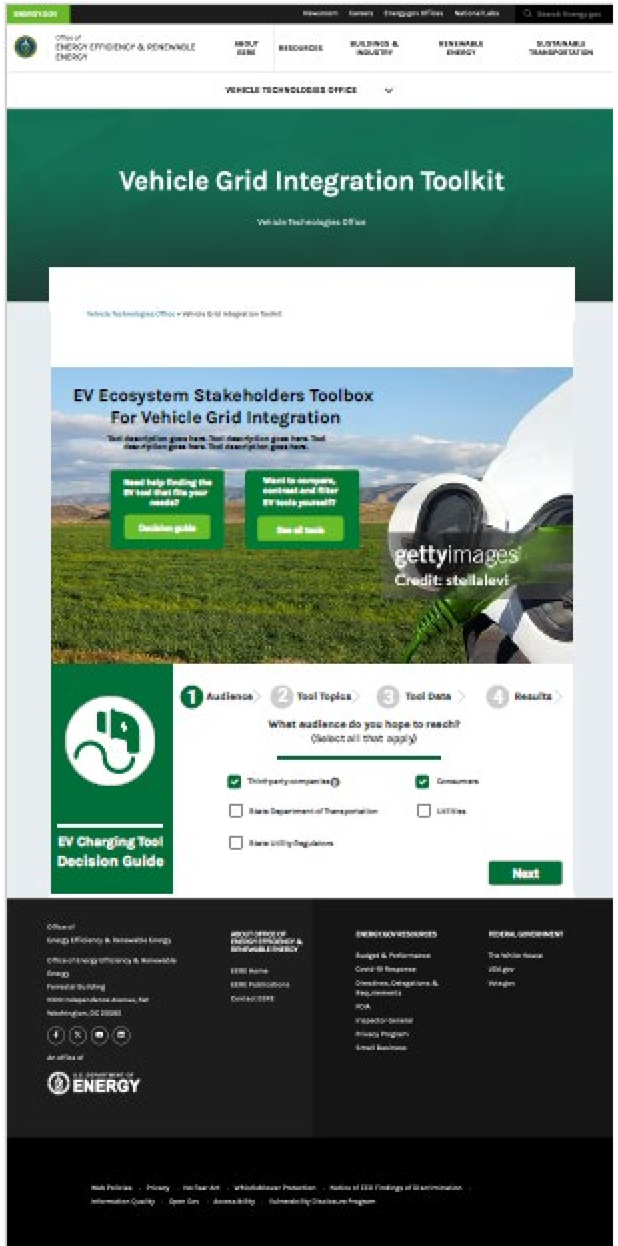


Data and Report Library

Drafted an overview of the data and report library content and structure that will serve as a companion to the toolkit and include access to data, analysis, and reports that serve as examples of tool usage.

Example of resources available on Tool library pages (hosted on LiveWire project pages)

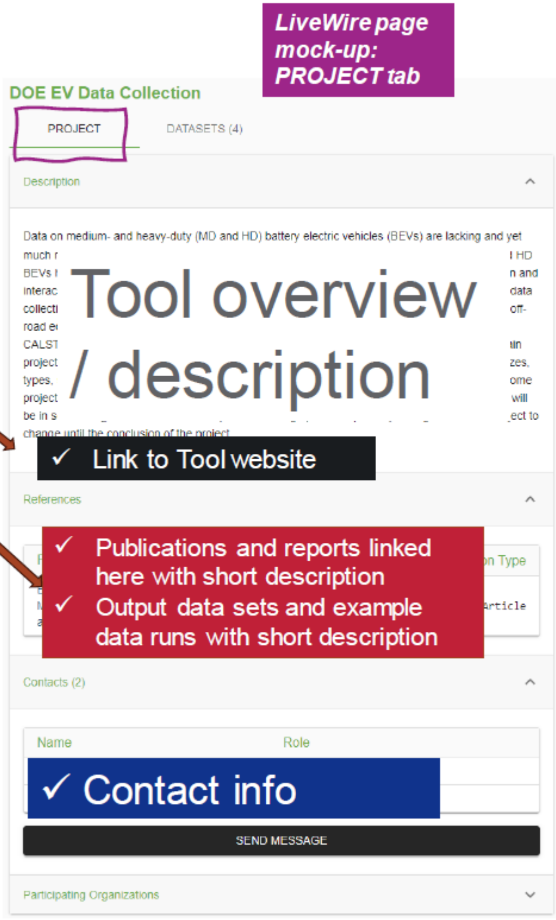
Tool access / download
- Link to Lab-hosted tool website

Example data runs
- Forecast of EV adoption numbers
- Time series powerflow values

Example input data sets
- Vehicle registration data
- Socioeconomic
- Vehicle prices
- Utility feeder circuit data

Reports and analysis
- Impact of charging activity at the feeder level and secondary circuit level
- EV charging during fault conditions

Contact information
- For questions on how to use the tool
- To inform tool developers of research conducted using the tool



Remaining Challenges and Barriers

Tool enhancements

The extent to which enhancements are "user-friendly" is highly subjective and will require testing and validation with stakeholders and toolkit users.

Website design

Website host and "ownership" is a key decision that impacts roles and responsibilities for future maintenance and incorporating toolkit improvements beyond FY25.

Toolkit dissemination

Toolkit audience is large and EV stakeholder space is fragmented, which can impact our ability to drive users to the website.

Successful Stakeholder Involvement – EVs@Scale – VGI Toolkit

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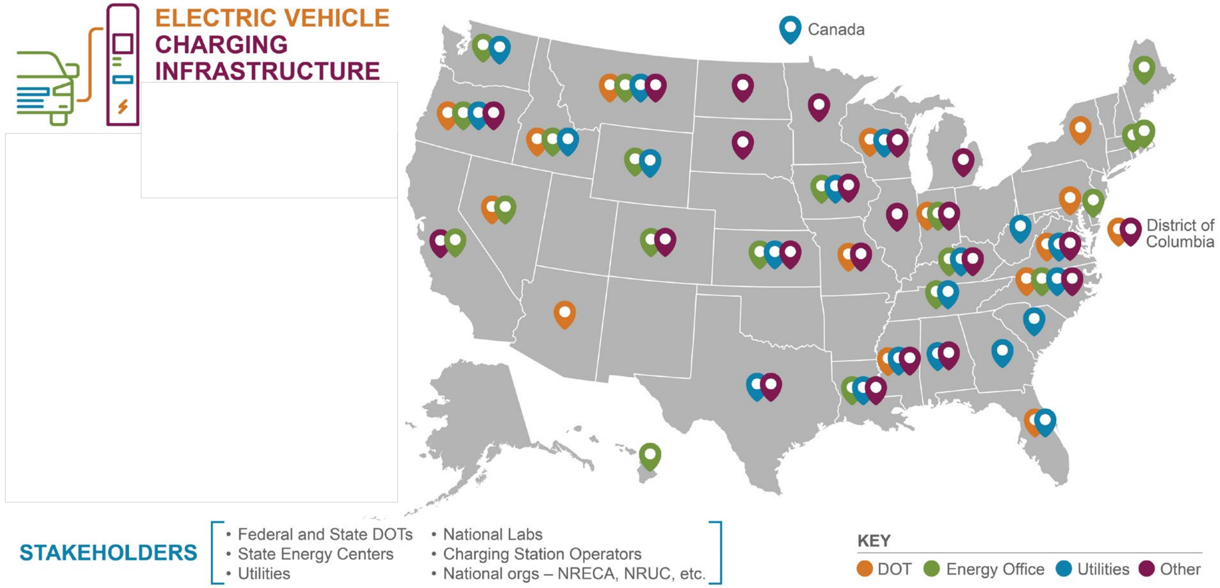
- **Utilities**
  - Engaged several individual utilities of different types
  - NRECA
  - SEPA
  - EEI
  - EPRI
- **PUCs**
  - NARUC
  - NERC
- **DOTs**
  - Federal DOT – Volpe Center
  - State DOTs
- **DOE Offices**
  - Vehicle Technology Office
  - Deputy Assistant Secretary for Transportation's Office
  - Office of Electricity
  - Joint Office of Energy and Technology
  - Cybersecurity Energy Security Emergency Response



Typical EVs@Scale Partnerships Include:

- Mutually beneficial topic areas
- Lab research for EVs@Scale funded by DOE*
- Early access to cutting edge research and lab facilities
- NDAs to ensure sensitive information is secure
- In-kind contributions provided by Industry Partners

*Subject to change based on annual funding levels

VGI Toolkit Partnership Opportunities

- **Website Beta Testers**
  - Would you like to help us ensure the website directs users like you to the correct tool?
- **Tool Beta Testers**
  - Are these tools helpful to you?
  - What additional features would make it better?
  - Is it easy to use for a user like you?
- **Gap Analysis Input**
  - Are there still other tools you need which the labs are well positioned to provide?
- **We need all stakeholder types.**

Interested in Partnering with VGI Toolkit?

Contact VGI Toolkit PI: Andy Satchwell, Berkley Lab

Andy Satchwell - asatchwell@lbl.gov

Thank You!

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Back-up Slides

Questions for feedback from the audience

1. Who are potential users that would benefit from the toolkit?
2. What are key questions that could be informed by the toolkit?
3. What are intuitive and accessible features and capabilities that would make the toolkit user-friendly?

Technical Backup Slide – State Utility Regulators and State Energy Offices

Key VGI Deployment Question	Primary Source
What are projected charging load profiles and forecasted load growth, including when (e.g., daily and hourly), where (e.g., distribution feeder), how large, and how uncertain impacts are? How do projections account for grid constraints (e.g., hosting capacity)?	[1],[2]
What are best practices in forecasting EV load, including technological, market, and consumer drivers of EV adoption and charging decisions?	[1],[3]
What is the appropriate role for the regulated electric utility vs. third-parties in EV charging markets, including siting, investment, and operation? What, if any, role should the state PUC have in regulating EV charging station owner/operators?	[1]
What are the system benefits associated with EV charging? How should regulators best ensure charging stations mitigate adverse impacts on the electric grid while maintaining affordability?	[1]
Who has access to what data and how is it shared and protected?	[2]
What rate designs and other load management strategies are appropriate to achieve policy goals, including to maximize potential grid benefits and promote desire charging behavior through price signals?	[2],[3],[4]
What is future EV adoption among low-to-moderate income customers, and what are other ways to promote equity in EV deployment and programs?	[4]
What does an equitable transition to EVs look like, including improved mobility, electrification of buses and public transit, and total costs for used EVs?	[4]
What are the air quality impacts of EVs and how are those impact distributed among communities and households?	[4]

Primary Sources:
[1] DOE and national lab workshop
[2] Voices of Experience
[3] EV Grid Assist Webinars
[4] RFF ZEV State Workshop

Technical Backup Slide – Third Party Providers and Charging Network Operators

Key VGI Deployment Question	Primary Source
Where is there existing power and transportation sector capacity to add charging?	[1],[2]
What are the additional costs required to enable VGI through different communication and control mechanisms? What is the value of VGI ($/EV/year) to the grid, and what are appropriate customer participation incentives? What are the expected revenues associated with VGI?	[1]
What are the main barriers to customers participating in VGI solutions (e.g., postpone EV charging in response to grid needs, rate design)?	[1],[2]
What data is available to make managed charging more seamless, less intrusive, easier to adopt?	[1]
What tools or approaches can reduce time and costs (including interconnection costs) for site selection?	[1],[2],[3]
What is the right charging station site design, including type of vehicles being served, right charger type, location, and number of charging spaces?	[3]
Primary Sources: [1] DOE and national lab workshop [2] Voices of Experience [3] EV Grid Assist Webinars [4] RFF ZEV State Workshop	

Technical Backup Slide – Electric Utilities and Power System Operators

Key VGI Deployment Question	Primary Source
What are some considerations and best practices for load forecasting for electric vehicles, including when and where load will increase? What are considerations for EVs in our IRP or planning processes?	[1],[2],[3]
What are best practices in managing the interconnection requests associated with the build out of a national EV network?	[1],[2]
What are the bulk power and, especially distribution, system impacts of EVs and the locations and time of day (or time of the year) where VGI may have the greatest benefit?	[1],[2],[3]
What are the projected demand, load shapes, and capacity needs associated with developing charging stations, especially for medium and heavy-duty vehicles?	[1],[2], [3]
What are the benefits and concerns of installing on-site DER and storage near larger or more remote charging stations?	[1]
What rate design and program features encourage customers to be responsive? Under what circumstances are customers responsive?	[3],[4]
How could EVs impact resiliency of the power systems and how could managed charging improve resiliency (e.g., at the system-level or at the load level via V2X)?	[1]
Primary Sources: [1] DOE and national lab workshop [2] Voices of Experience [3] EV Grid Assist Webinars [4] RFF ZEV State Workshop	

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

Jesse Bennett

September 25, 2024

EVs@Scale FUSE - Overview

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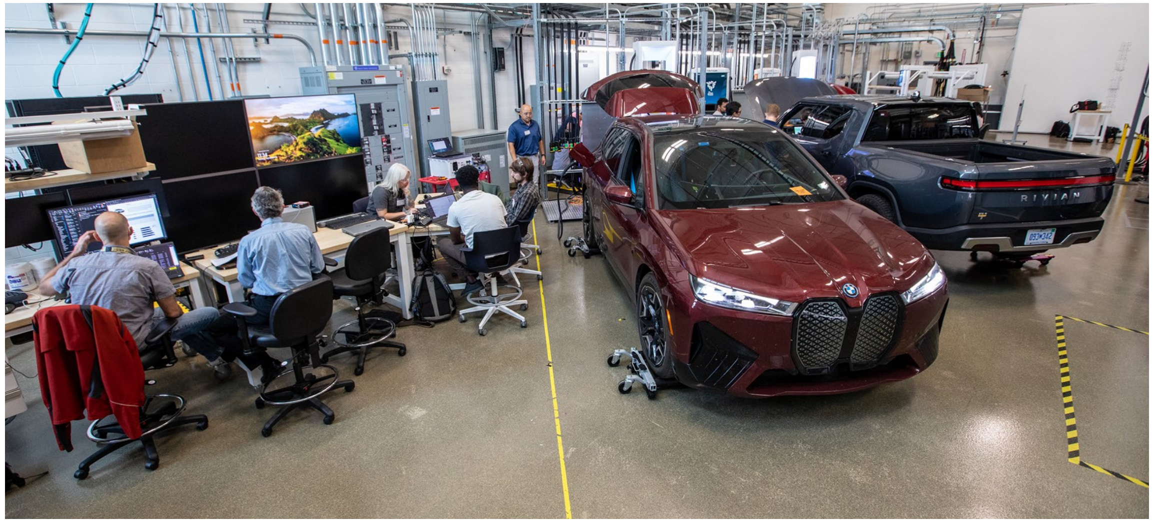
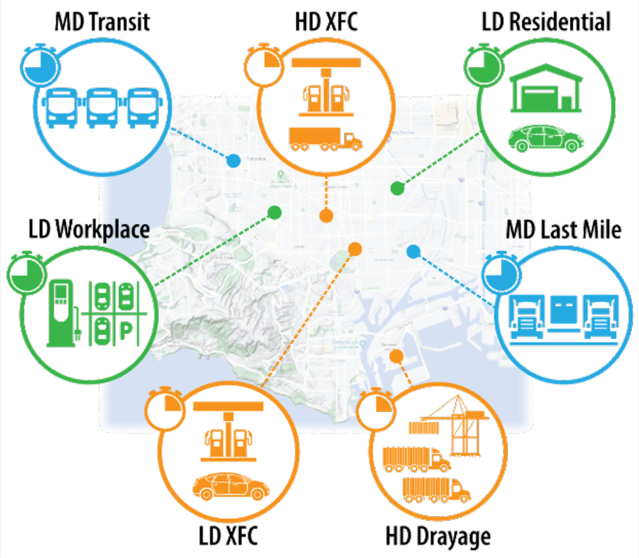
Objective:

- Develop an adaptive ecosystem of smart charge management (SCM) and vehicle grid integration (VGI) strategies and tools relevant to assess and reduce barriers to electrification throughout a wide geographic area and 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 enabling technologies and demonstrate VGI approaches to reduce grid impacts throughout the entirety of the LD, MD, and HD on-road electric fleet while accounting for vehicle operational 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





EVs@Scale FUSE - Team and Partners

Team:

- **National Renewable Energy Laboratory (NREL)**
  - Vehicle Charging, Grid Impact Analysis, SCM/VGI Development and Demonstration
- **Argonne National Laboratory (ANL)**
  - SCM/VGI Development and Demonstration
- **Idaho National Laboratory (INL)**
  - Vehicle Charging Analysis, SCM/VGI Development
- **Sandia National Laboratories (Sandia)**
  - Grid impact Analysis

Industry Partners/Data Sources:

- **Electric Distribution Utilities**
  - Dominion Energy (100+ distribution feeder models throughout VA)
- **Vehicle Travel Data**
  - Wejo (~400 million LDV trips in VA for Sept. '21 and Feb. '22)
  - GeoTab (Altitude API Access MD/HD vehicle operations)

NREL

Jesse Bennett
Matt Bruchon
Shibani Ghosh
Yukihiro Hatagishi
Abdullah Hashmi
Yi He
Zhaocai Liu
Nadia Panossian
Priti Paudyal
Emin Ucer
Wenbo Wang
Mingzhi Zhang

INL

Manoj Sundarrajan
Jean Chu
Tim Pennington
Steven Schmidt

Argonne

Jason Harper
Dan Dobrzynski
Nithin Manne
Bryan Nystrom
Salman Yousaf

Sandia National Laboratories

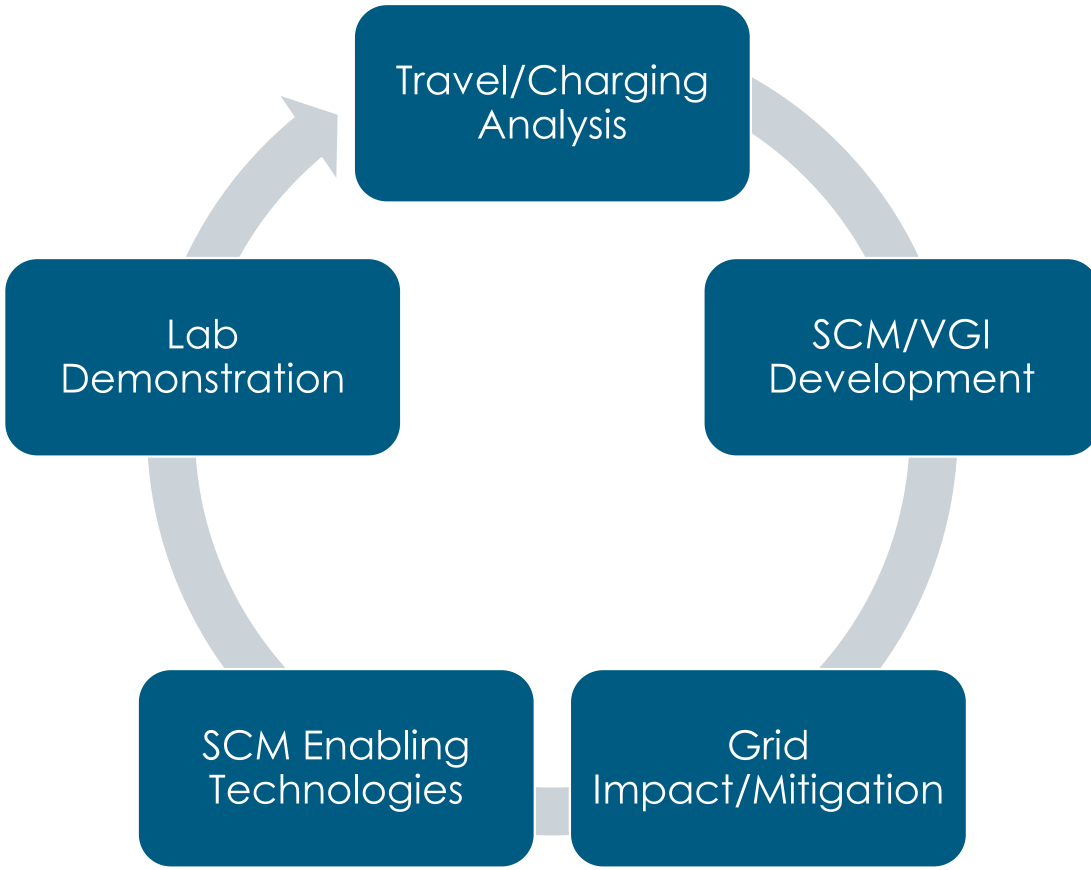
Jeewon Choi
Matt Lave
Andrea Mammoli
Emily Moog
Will Vining

EVs@Scale FUSE - Approach and Outcomes

- **This project will analyze and demonstrate SCM and VGI approaches to reduce grid impacts from EVs@Scale as a result of the charging needs of the LD, MD, and HD on-road electrified fleet.**

- **SCM/VGI Analysis**
  - Assess the potential charging demand for EVs@Scale and determine the uncontrolled charging grid impacts.
  - Develop and analyze the effectiveness of various VGI and SCM strategies at mitigating the grid impacts of charging EVs@Scale

- **SCM/VGI Demonstration**
  - Expand on existing SCM/VGI strategies to adapt to the evolving needs EVs@Scale throughout a wide range of vehicles and vocations.
  - Develop enabling technologies to demonstrate the potential for new and existing SCM and VGI in a laboratory and real-world environment.
  - Coordinate with Codes and Standards Pillar to determine the potential of existing technologies and need for future developments.



Topics of Interest

1. SCM Controls
2. Enabling Technology/Demonstrations
3. Transportation and Charging Needs
4. Mid-route/Concentrated Charging
5. Grid Impact Assessments
6. Partnership Opportunities

SCM Controls: New NREL Objective Functions

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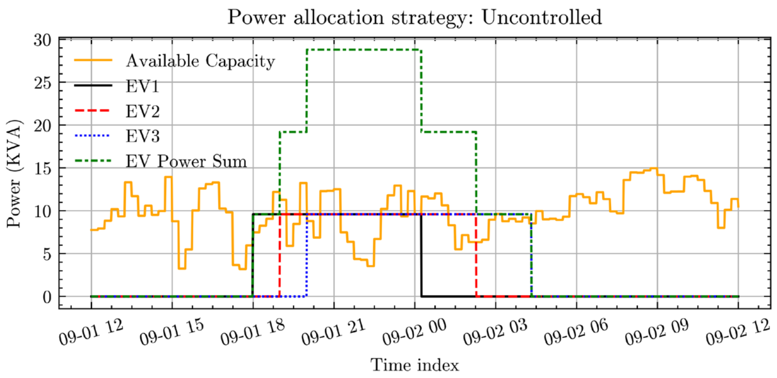
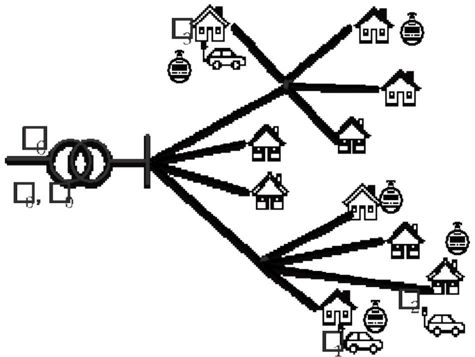
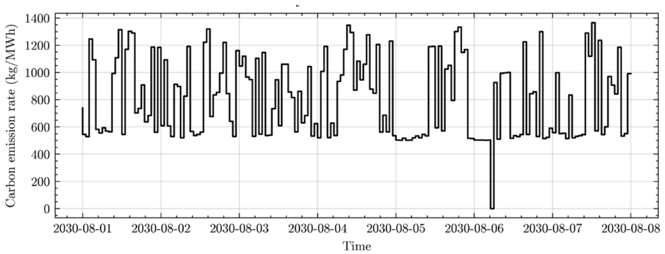
New FY24 Objective Functions

- **BTM Depot DER**
  - Mitigate transformer upgrades at large charging depots with behind-the-meter (BTM) distributed energy resources (DER) assets to limit net peak demand from grid
- **Distribution Transformer**
  - Coordinate EV charging under a single service transformer to avoid coincident peaks and overloading equipment
- **Renewables and Emissions**
  - Schedule EV charging to either coincide with renewable sources of generation or during times of low emissions
  - Emissions forecasts from NREL's Cambium 2030 mid-case

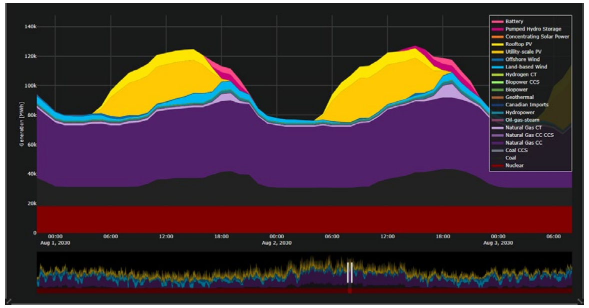
Strategy Name	Objective Function: EV Charging…
TOU Immediate	begins immediately at start of TOU within dwell
TOU Random	randomly distributed within dwell during lowest TOU
Random Start	randomly distributed within dwell
Feeder Peak Avoidance	distributed within dwell to limit feeder peak
Volt/VAR	provides reactive power support
Volt/Watt	power adjusted to support local voltage quality
Day-ahead Pricing	scheduled to minimize costs per PJM LMP
BTM Depot DER	schedule to avoid transformer upgrade with PV/ESS
Distribution Transformer	scheduled to reduce coincident charge/overloads
Renewables/Emissions	scheduled to coincide w/ renewables/low-emissions





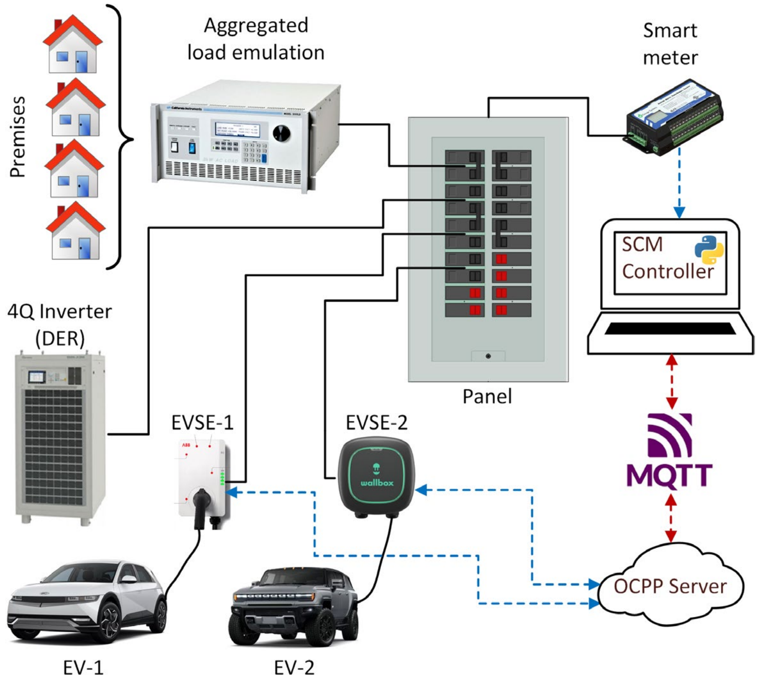


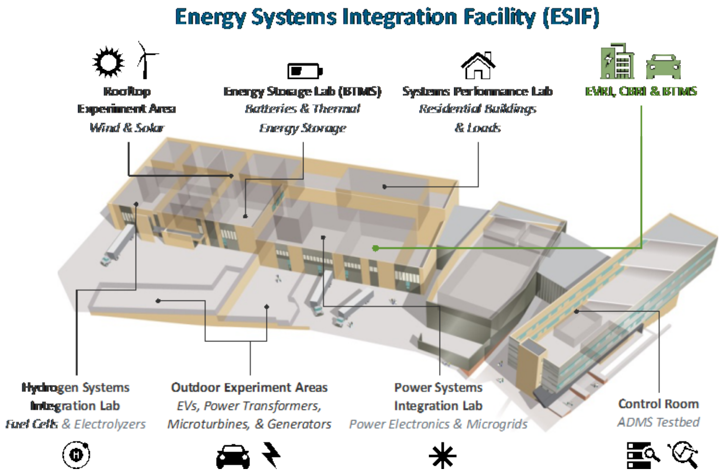
Week-long Marginal Carbon Emission Rates



Daily Energy Mix Variation of PJM

- **SCM Testbed Verifies SCM Performance**
  - SCM controls adapted from simulation to support real-world signals and dynamic response
  - SCM controller receives OCPP signals and other necessary meter data
- **ESIF* Serves as SCM Proving Ground**
  - Transformer control is designed in preparation for field demonstration in utility environment
  - Multiple EVSE represent different houses on a single secondary bank from one transformer
- **SCM Controls Prepared for Field Demo**
  - Transformer control responds to EV connection signals, EVSE current, and home load fluctuations
  - SCM optimizes EV charging to avoid exceeding a power ceiling (mitigating transformer overloads)





*NREL's Energy Systems Integration Facility (ESIF)

Enabling Technology: Verifying SCM Performance

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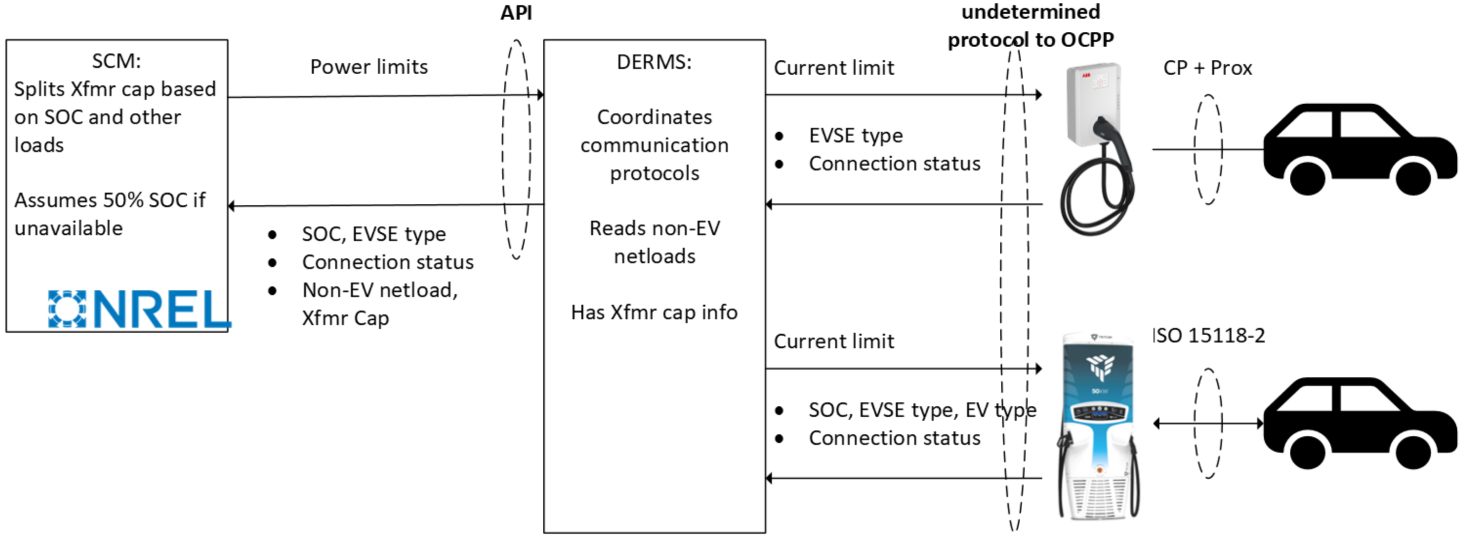
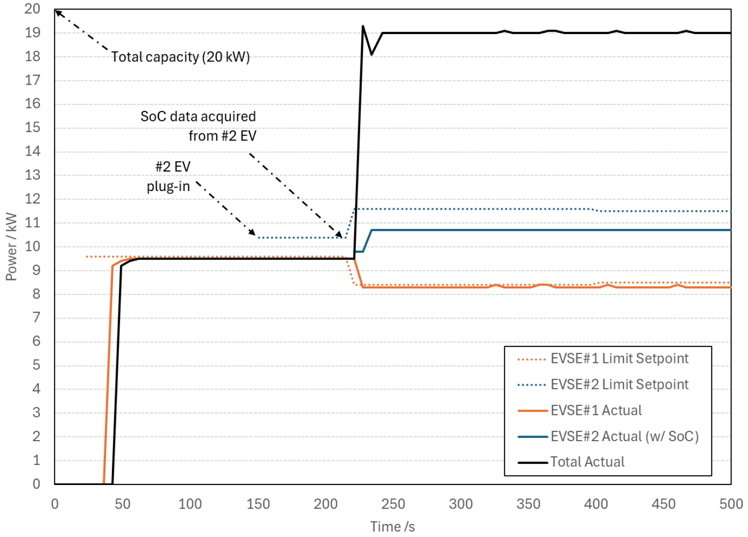
- **Transformer Control Objective**
  - Establishes power ceiling (e.g transformer nameplate capacity)
  - Monitors building loads (eGauge) to determine remaining capacity for EVSE*
  - EVSE sends connection signal to SCM via OCPP to initiate charge session
  - DC EVSE may send SOC via ISO 15118-2 to inform weighted power distribution**
  - SCM optimizes all present EVSE loads within remaining transformer capacity
- **Next Steps:**
  - Dynamic building load tests
  - Field Demonstration at HCE
  - SCM developed for DERMS integration

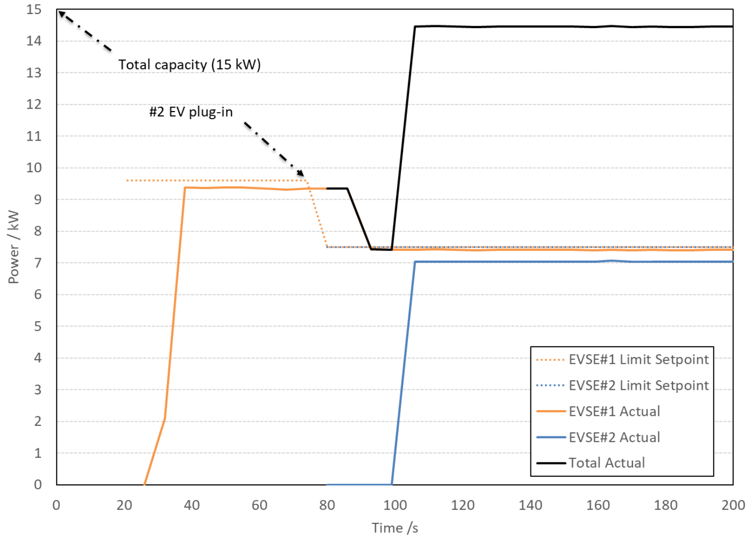
*not present in initial test results shown

**feature currently not supported in standards for AC EVSE





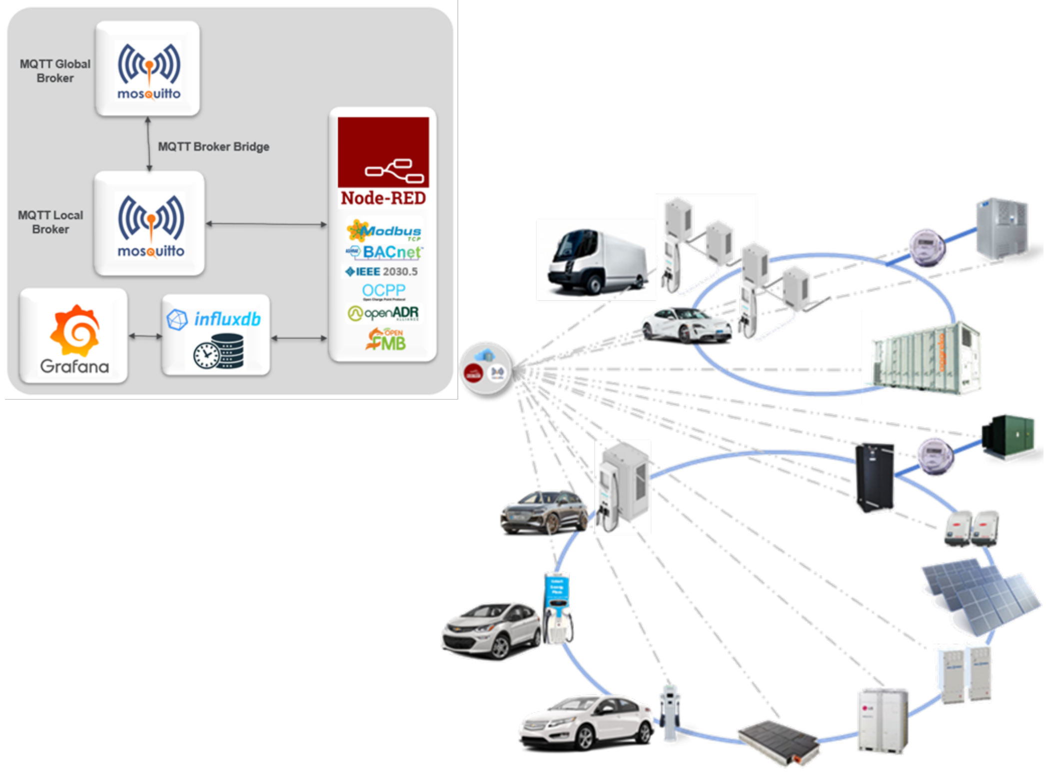
SCM Result With SoC



SCM Result Without SoC

Enabling Technology: Argonne's CIP.io Link Development

- **Open Source Development of a Local OCPP Controller for Charging Sites (cloud CSMS agnostic)**
- Based on Argonne's common integration platform (CIP.io): https://github.com/Argonne-National-Laboratory/CIP.io
- Will operate as a local OCPP 1.6J or 2.0.1 CSMS and allow bridging to any cloud based CSMS
- CIP.io Link will also allow for integration of site meters and other IP based devices and allow users to create their own control logic.
- Documentation will cover full implementation from:
  - Wiping windows based PC and installing Linux
  - Installing all necessary open-source applications via CIP.io script
  - How to customize the setup
  - Example flows
- Available on GitHub by end of 2024

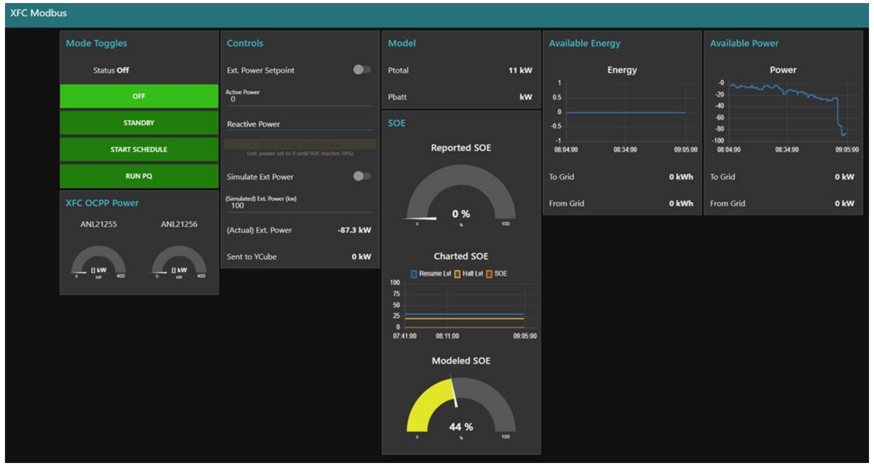


SCM Controls: Argonne BESS Research and Demonstration

Co-located Storage utilized at Smart Energy Plaza to Support EV Charging:

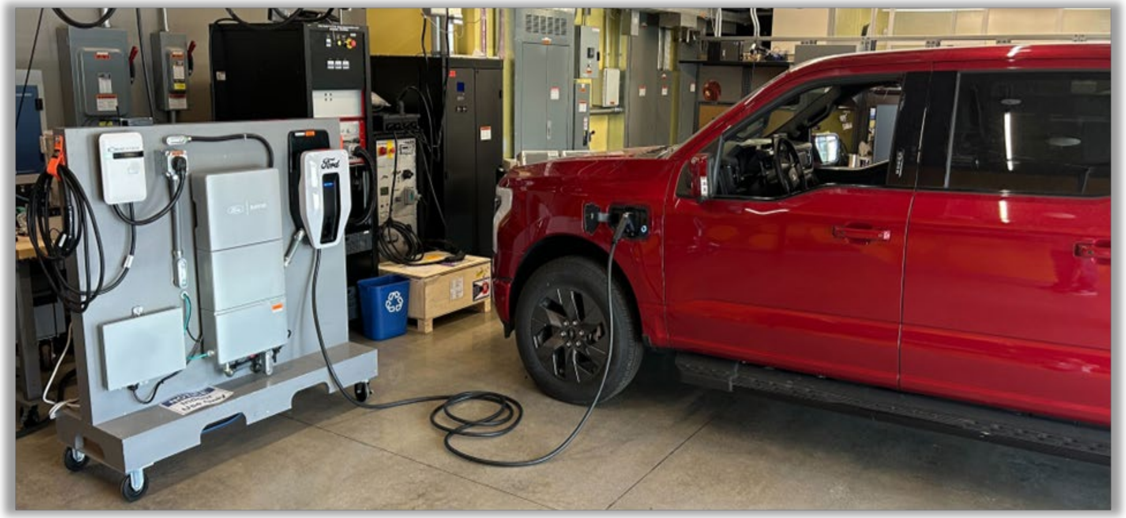
- Limit the site's power demand to 60 kW
- Accept excess PV power generation
- Mitigate high-power charging demand due to XFC stations

Site Controller Developed to Measure and Control BESS



Battery Type	Lithium Ion
Rating	1 MW
Voltage	480 V, 3-Phase
Energy Capacity	610 kWh
Ambient Temp	-20 °C to +50 °C
Size	20-foot container 20' L x 8' W x 9' 2" H

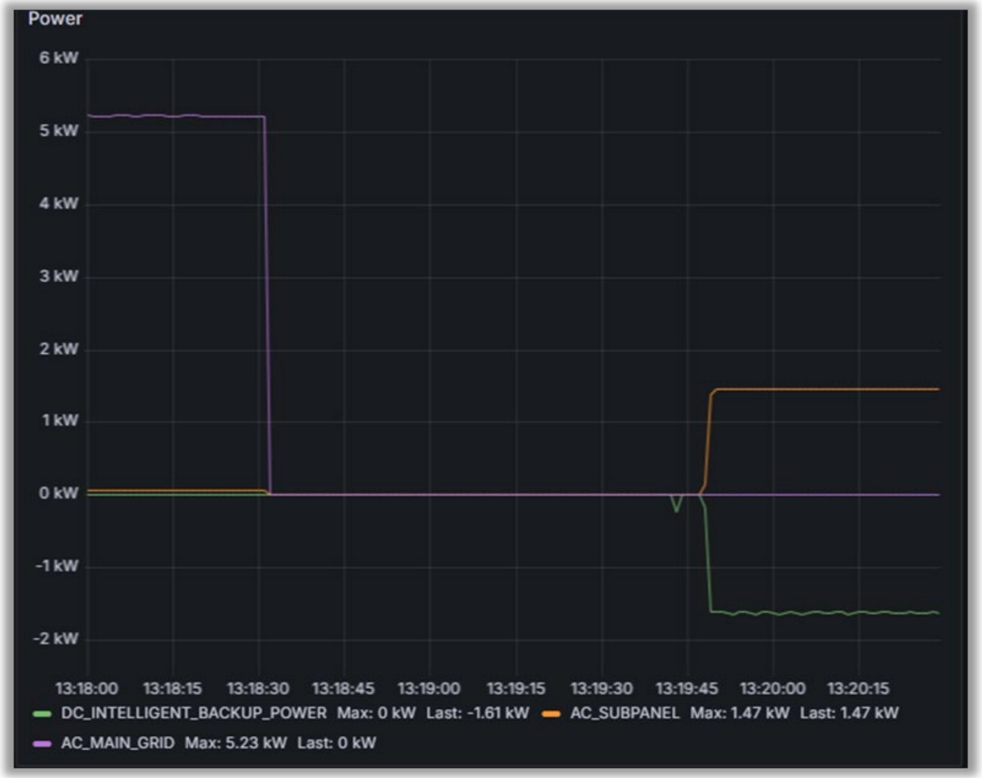
Enabling Technology: V2H Characterization – Ford Intelligent Backup (ANL)



- The Argonne Smart Energy Plaza housed the equipment and vehicles in use for the collection of data and scenarios.
- Grid power was supplied to the equipment via a 240V, 50A circuit.
- Various loads were tested, 1.2kW heating and L2 EVSE to provide various levels of power demand.
- Continuing characterization

Grid Down Scenario - Power Readings

- DC and AC external meters
- Loss of Grid Power (magenta) shows 1 minute and 29 seconds required for the backup loads panel to become active.



Field Demonstration: Deployment of Opti-VGI at Argonne

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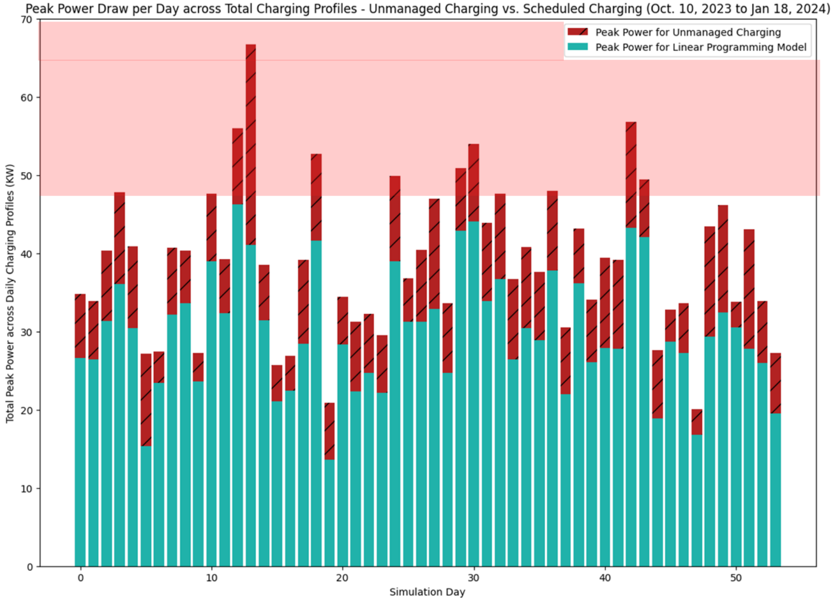
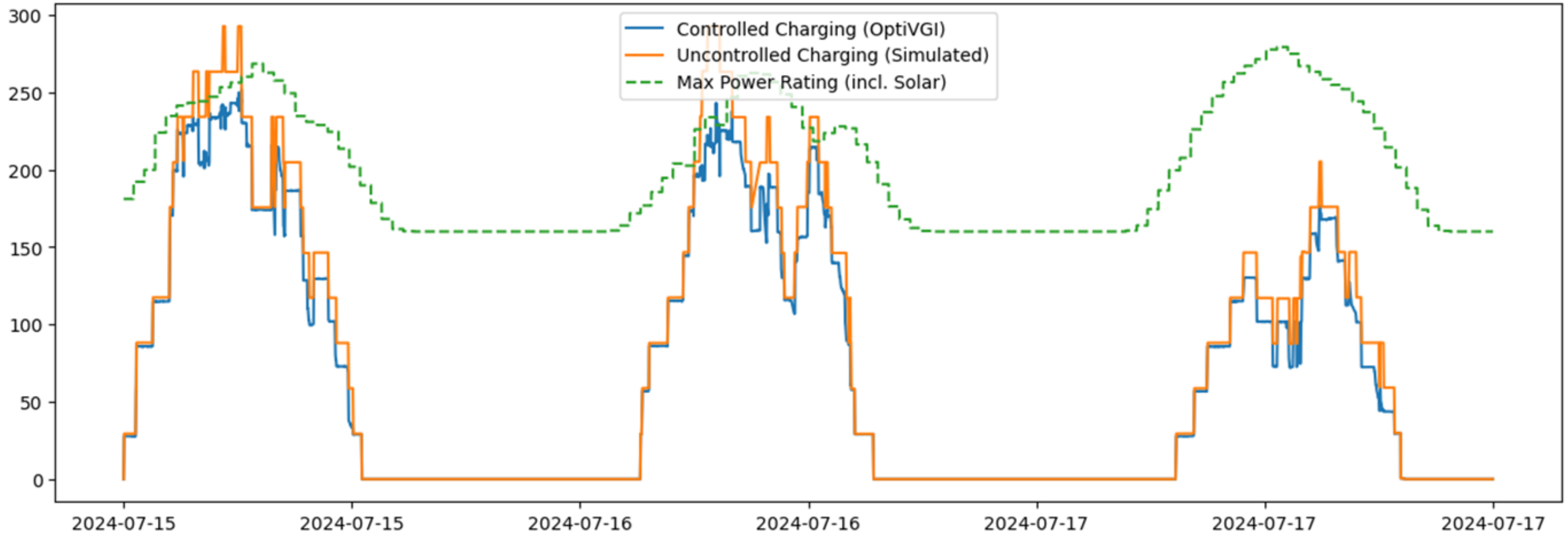
- Opti-VGI is an EV Smart Charging Management System that is integrated with the EV charger reservation system (EVrez) at Argonne National Laboratory.
- **Problem:** Due to oversubscription of CB panel at Smart Energy Plaza, EV charging curtailment is needed on cloudy days
  - Simulations on historical charging data using a scheduling algorithm shows SCM can successfully reduce peak demand by ~22% to stay within constraints, while still meeting driver's energy by departure time.
- **Solution:** Generate optimized schedules for charging EVs that account for:
  - Hardware limitations of existing electrical infrastructure
  - Forecasted solar panel power generation to leverage PV at Smart Energy Plaza
  - Driver preferences such as departure time and requested energy
- Opti-VGI is an extensible framework that can be used to test various demand-response algorithms and analyze driver charging habits.
- Deployed in production setting at Smart Energy Plaza to optimize charge schedules of employees while meeting constraints of local infrastructure



Field Demonstration: Argonne Opti-VGI Deployment Results (Real World)

- Peak demand reduction by 15% during peak hours
- Optimized usage of solar power during midday hours



<u>Insights from Analysis of Data</u>

- Most people who missed their requested energy left early, and would have likely met their needs if they stayed till the scheduled end time.
- Most EVs don't charge at the EVSE ampacity limit, but at a slightly lower rate, which leaves a lot of available energy that could have been provided to other vehicles. This may be done on purpose or due to control pilot duty cycle sampling error.
- Next steps would be to improve the algorithm to compensate for this error

Transportation and Charging Needs (NREL)

- **Completed work**
  - Updated EVSE access assumptions for each dwell location and vehicle class
  - Integrated concentrated charging locations into EVI-Pro results
    - Concentrated charging locations determined by Sandia analysis of low-/no-access household locations serve charging needs with less access
  - Simulated charging loads across seven categories of vehicles
    - Includes light-duty (LDV) passenger cars, and medium-heavy duty (MHDV) across multiple vocations requiring short and long dwell charging
    - Coordinated with INL to determine mid-route charging needs
  - Analyzed coincidence of charging demand for four categories of vehicle across geographic regions, times of day, and duration of load reduction
- **Outreach**
  - School bus charging study accepted for publication by *Transportation Research Record*
  - Coincidence analysis and "long-dwell" charging load modeling study presented at Transportation Symposium on Environment, Energy, and Livable Economies
  - "Long-dwell" study submitted to 2025 Transportation Research Board conference, under revision for journal submission (*Applied Energy* planned)

Modeled types of EV charging demand

Classes	Vocation	Charging dwell types
LDV	LD passenger cars	Concentrated chargers (Sandia & NREL), XFC (INL & NREL), home, work, public (NREL)
MHDV	Local delivery	Depot
MHDV	Transit buses	Depot, terminals
MHDV	School buses	Depot
MHDV	Drayage	NREL & INL: depot, destination, mid-route XFC
MHDV	Regional freight	NREL & INL: depot, destination, mid-route XFC
MHDV	Long-haul freight	NREL & INL: depot, destination, mid-route XFC

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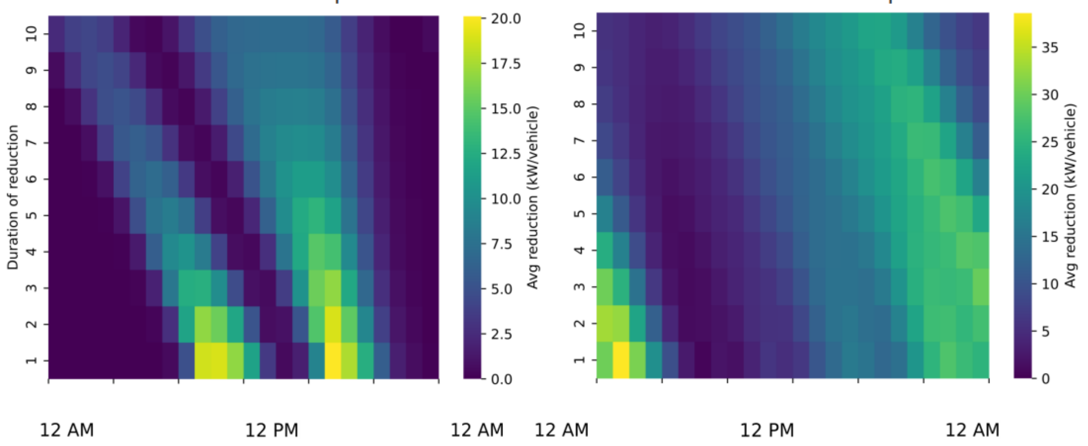
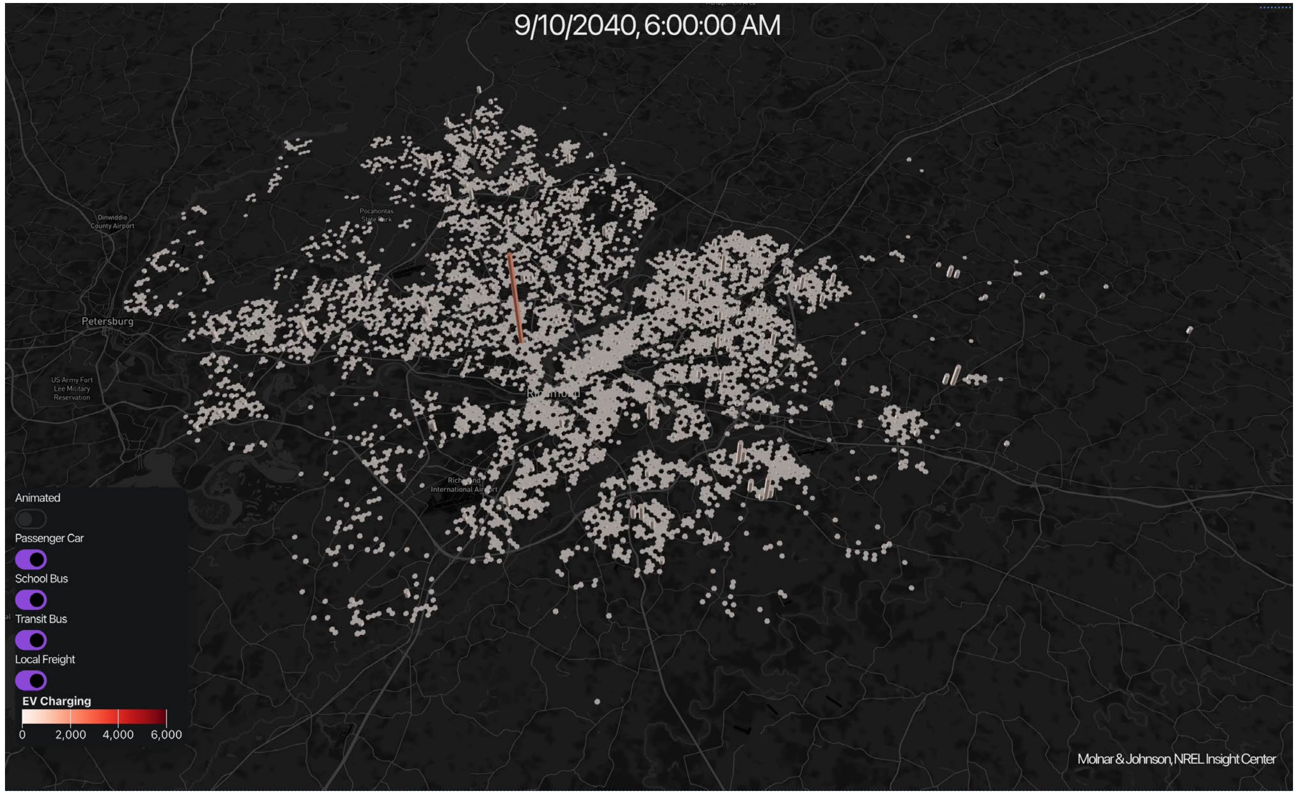
- **Next steps**
  - Support the use of charging load datasets to develop and test SCM strategies
  - Extend coincidence analysis to consider which types of vehicles offer value as SCM targets at various times of day for various regions
  - Apply coincidence analysis to develop simplified guidelines (e.g., load factors) to help improve EVSE interconnection practices

Example flexibility matrices from coincidence analysis

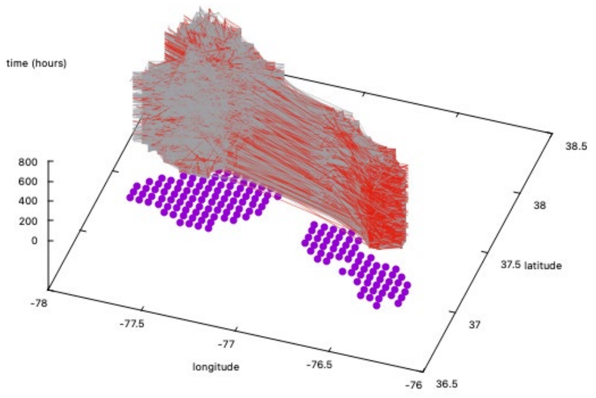


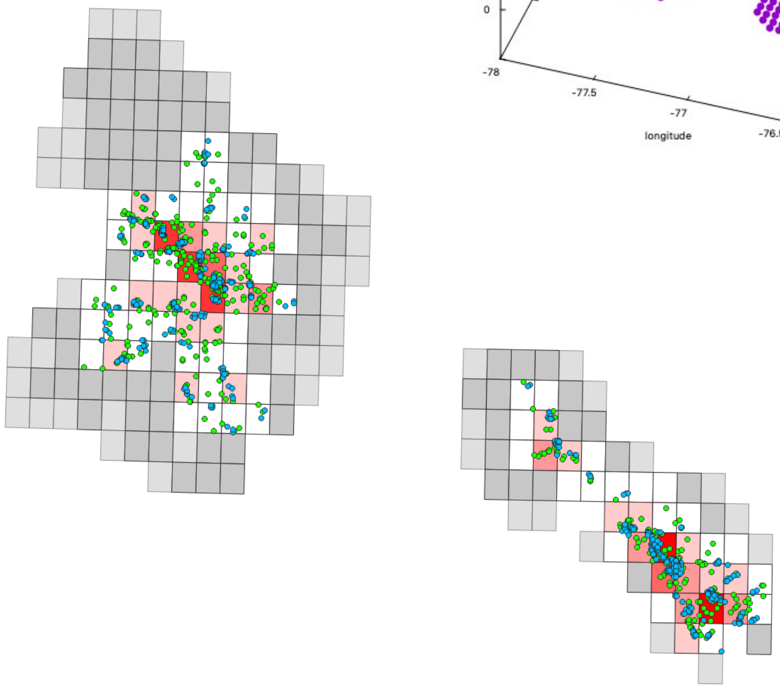
"Long dwell" LDV + MHDV charging loads (Richmond, fall weekday)



Concentrated Charging Analysis (Sandia)

- Development of efficient route-finding tools to calculate trajectories between addresses
- Detailed trajectories for non-access customer traffic with home & work anchor points
- Optimal location of concentrated EVSE
- Focus group workshop and national survey to measure likely behavior of non-access customers
- Development of framework to calculate inconvenience to EV users resulting from charging
- Preliminary calculations of inconvenience statistics





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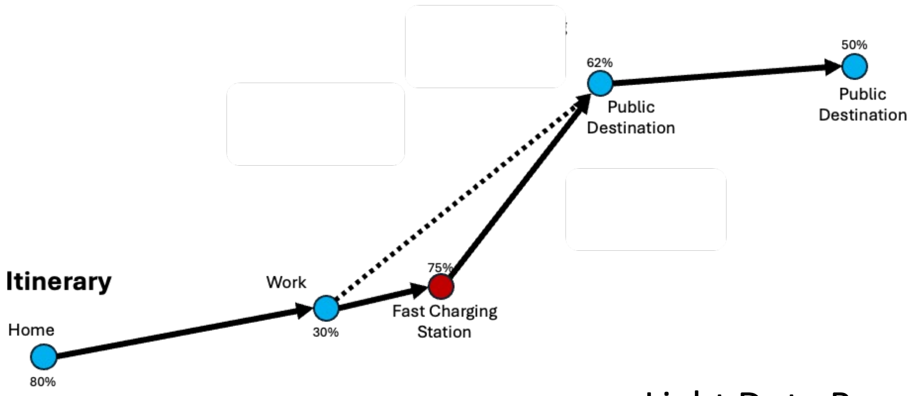
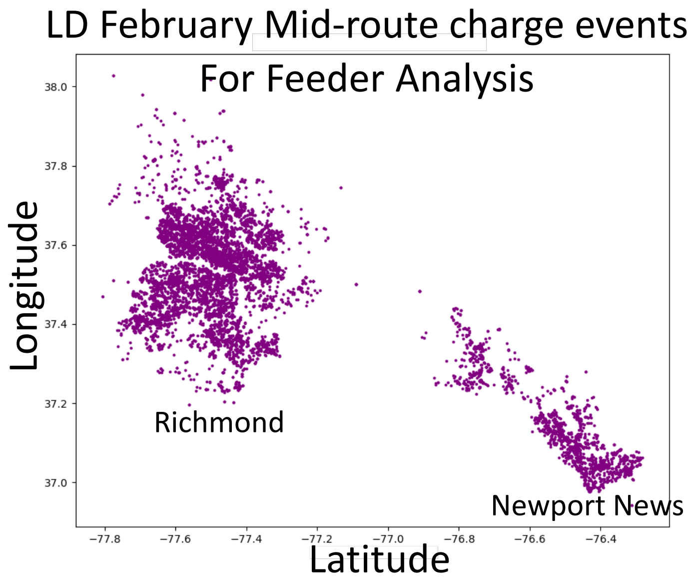
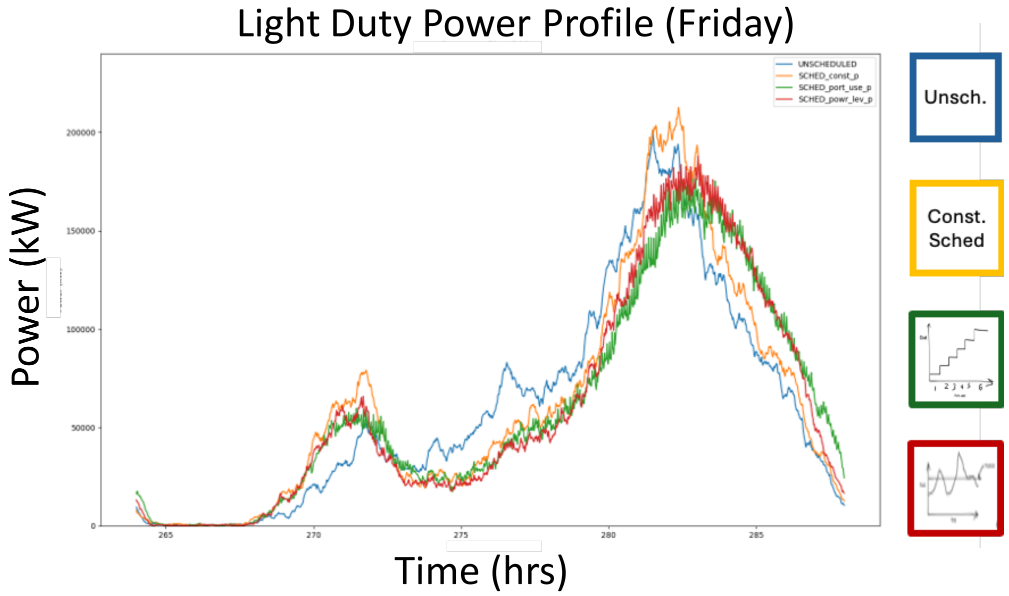
Caldera Software Toolkit for Mid-route Charging

- **Purpose:**
  - Caldera software used to model thousands of electric vehicles
    - ”Agent” vehicles with pre-determined itineraries
  - Provides a tool for collecting charge-events across a city’s infrastructure
  - Feeder analysis
  - Station demand-balancing strategies



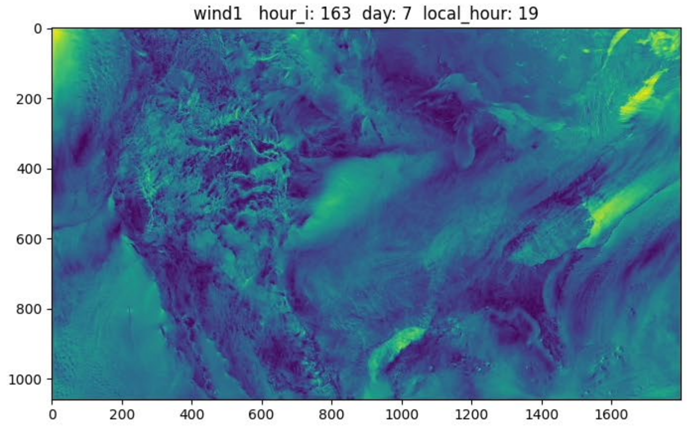


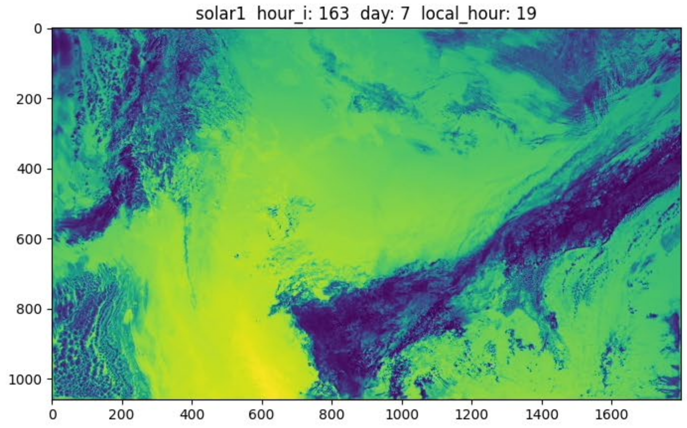
- **Recent Work:**
  - LD Load-balancing analysis using cost incentives:
    - 500,000 light-duty vehicles in Richmond and Newport News
    - 318 fast charging stations (350 kW)
    - Analysis of demand-balancing strategies using cost incentives
  - LD Mid-route-charging for Feeder Analysis (NREL collaboration)
    - 59,000 stranded itineraries before mid-route was available
    - Modeled mid-route charging to complete the itineraries
    - February and September scenarios
  - HD (NREL collaboration):
    - 5000 trucks, including both long-haul and drayage
    - 87 truck-stop charging stations with four 1 MW ports each.



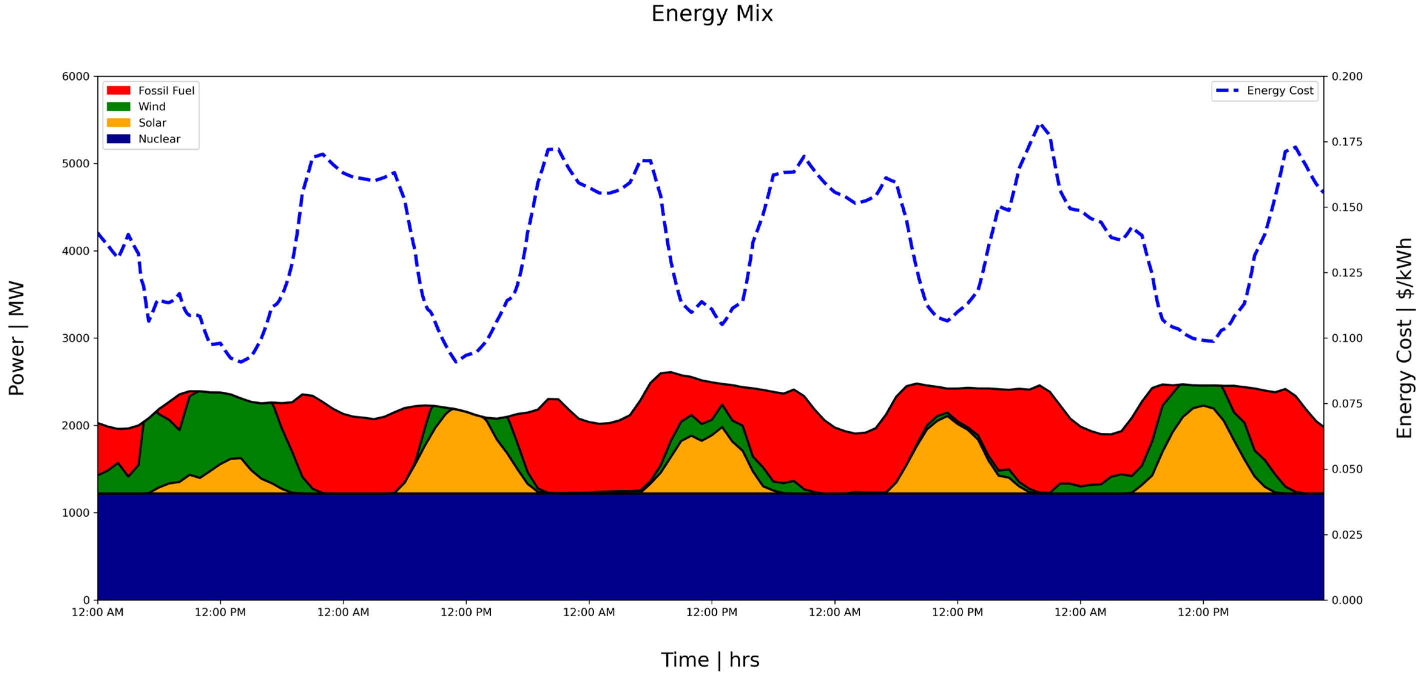
Regional SCM analysis

- **Objective:**
  - With high renewable penetration comes imbalance in supply and demand due to the nature of renewable energy generation.
  - SCM presents opportunity to fill the imbalance by aligning EV load with renewable generation.
  - Traditional control strategies like TOU and Random start aren’t flexible enough and doesn’t fit all scenarios.



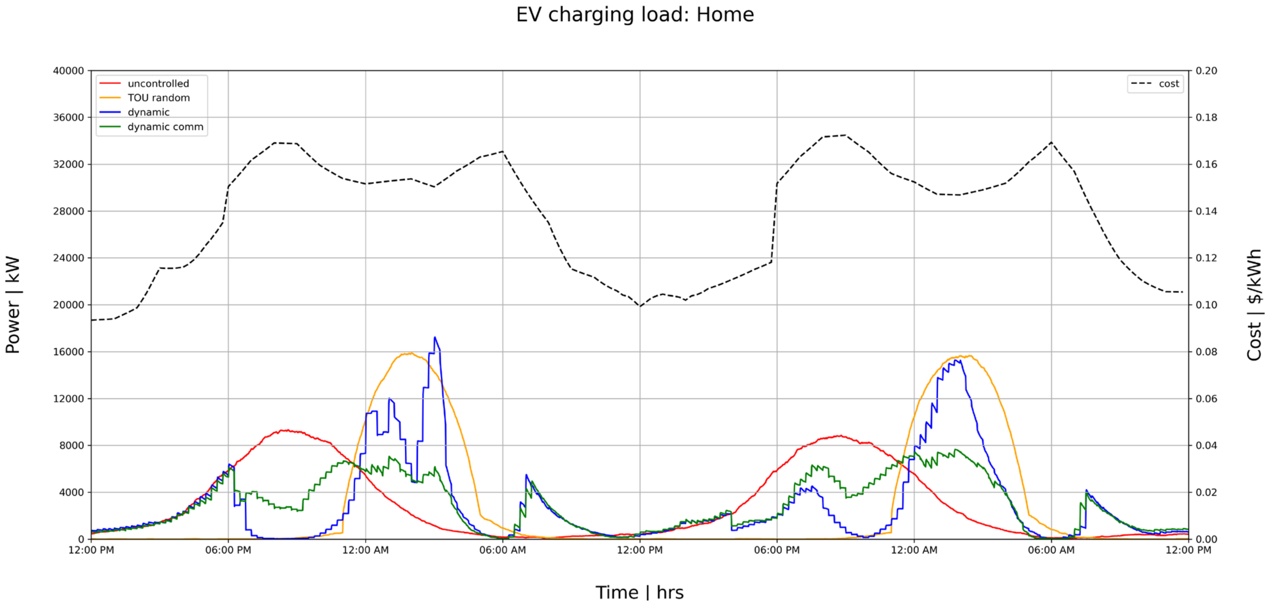


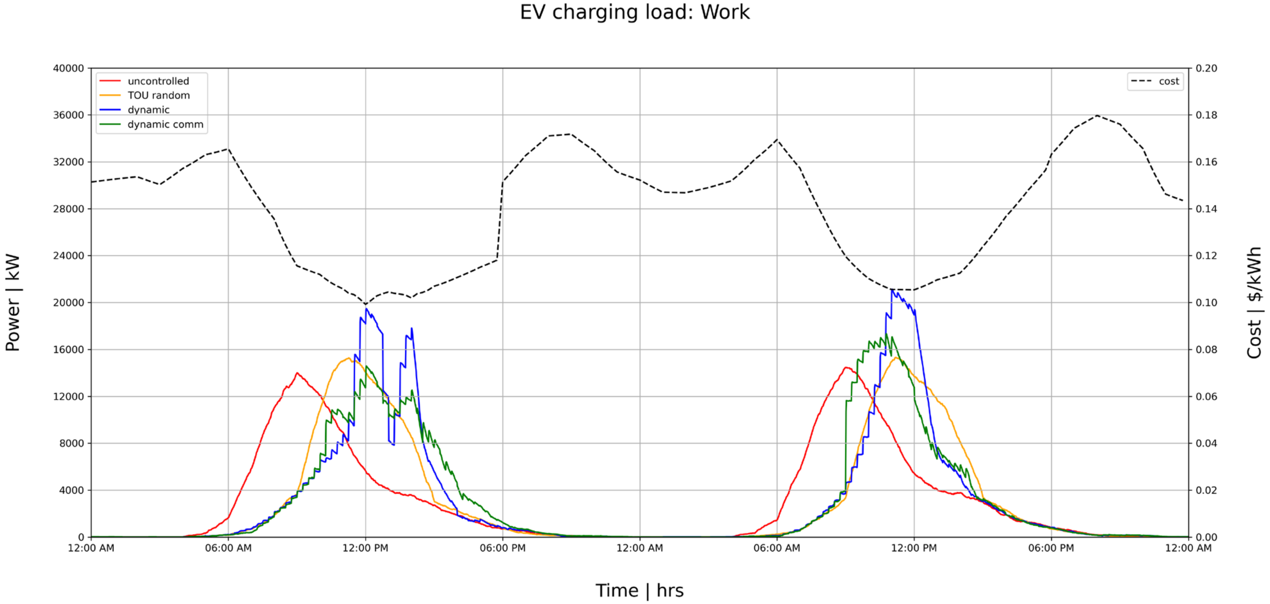
- **Latest Work**
  - Granular Weather Forecast models
    - 48 hour forecast of wind and solar updated at the beginning of each day obtained from NOAA.
  - Energy Cost models
    - Cost of energy based on Levelized Cost Of Energy (LCOE) cost of the generation mix.
    - Cost function = $FC_S\ S_{gen} + FC_W\ W_{gen} + FC_N\ N_{gen} + VC_F\ F_{gen}$
      - Where, FC = Fixed Cost, VC = Variable Cost, S = Solar, W = Wind, N = Nuclear, F = Fossil Fuel
  - 2 new smart charge management strategies
    - Cost-based dynamic control
    - Cost-based dynamic control with communication



Regional SCM analysis results

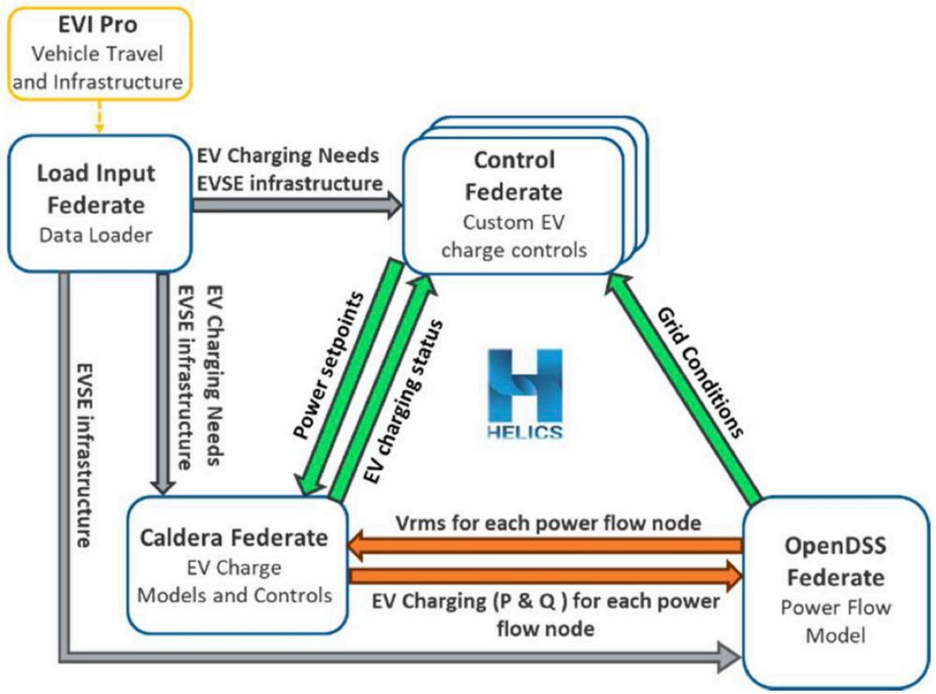
- **Cost-based Dynamic control**
  - EVs control charging based on 12-hour cost forecast.
- **Cost-based Dynamic control with communication.**
  - EVs control charging based on 12-hour cost forecast communicating the optimized charge profile back to the utility.
  - The utility creates a new cost forecast based on the charge profile from optimized EVs and the later EVs will use the newer cost forecast to optimize their charging.
- **Initial Observation**
  - In Cost-based Dynamic control, EV charging peaks during the cheapest cost period creating a new increased peak.
  - In Cost-based Dynamic control with communication, the peaks were reduced in comparison with no communication control, achieving better utilization of renewable energy.
- **Next Steps:**
  - Update the centralized aggregator controller objectives to work with cost metrics.
  - Create metrics to compare the benefits of the various control scenarios.
  - Evaluate the control strategies on several scenarios and regions.





Grid Impact Assessment (NREL)

- **Grid Impact Co-simulation**
  - Three day time series power flow at 15 minute intervals with charging needs provided by transportation/charging team
  - Simulations performed across 60+ feeder models in VA (Newport News/Richmond)
  - HELICS co-simulation coordinates multiple federates to simulate charging
    - EVI-Pro inputs from the grid team identify charging needs and dwell periods
    - Control Federate houses SCM objective functions to optimize charge sessions
    - Caldera simulates charge sessions and passes real/reactive power to OpenDSS
    - OpenDSS performs power flow analysis and determines grid impacts with different controls



- **Simulation Focus**
  - Uncontrolled – Evaluate grid impacts for all 60 feeders without SCM
  - Feeder Peak – Assess each controls ability to reduce feeder peak (TOU, Central, LMP)
  - Market/Emissions – Quantify emission reduction benefits (TOU, LMP, Emission)
  - Transformer – Determine mitigated transformer overloading (Transformer, Depot)
  - Voltage Quality – Review voltage benefits from each approach (Volt/VAR, Volt/Watt)

Grid Impact Assessment (NREL)

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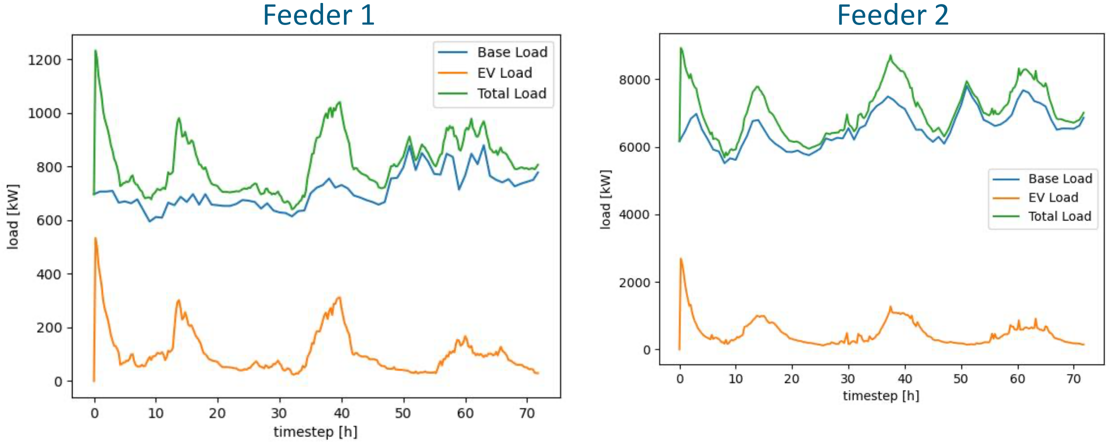
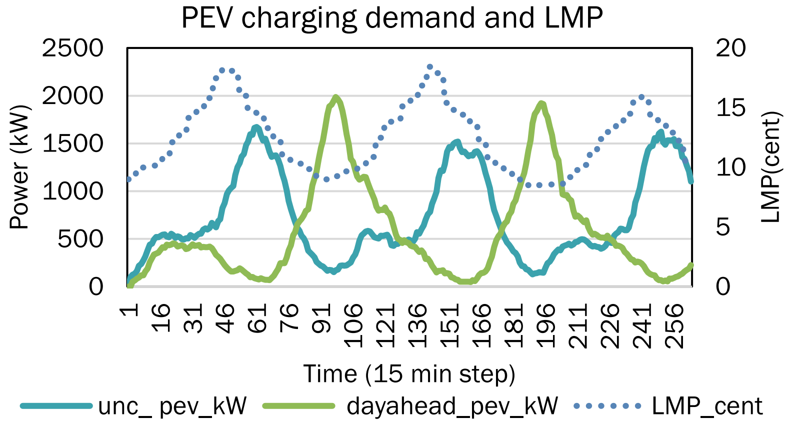
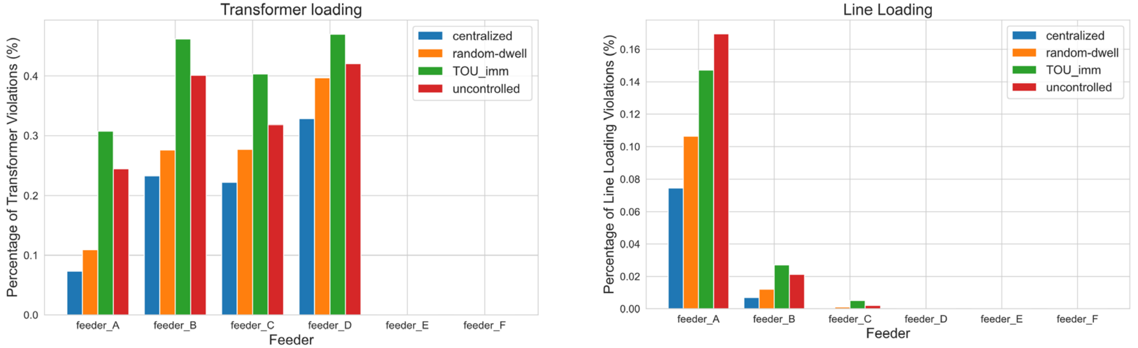
- **Grid Impact Considerations**
  - Load Profiles: Detail charging and SCM performance
  - Equipment Loading: overloaded transformers/conductors
  - Voltage: voltage drop across feeder (+/- 5%)
- **Uncontrolled Results**
  - Significant EV charging peaks have impact on feeder loads and often coincide with existing base load peaks
- **New SCM Performance – LMP Response**
  - More dynamic LMP rates distribute charging incentives
  - Distributed incentives distribute charging without a timer peak
- **Detailed Results – Equipment Loading**
  - Transformer overloading is most severe for TOU immediate
  - Line overloading may occur more due to uncontrolled charging
  - Overloading events vary across feeders and distribution transformer overloading appears to be a leading indicator







Successful Partnerships – EVs@Scale FUSE

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- **Dominion Energy**
  - Dominion Energy has partnered with FUSE to provide feeder models for grid impact analysis and FUSE shares research findings specific to service area
- **Geotab**
  - FUSE acquired access to Geotab transportation data and multi-lateral NDAs protect sensitive information
- **Balancing Authorities**
  - FUSE has partnered with multiple balancing authorities to share and discuss findings and guide future transportation/charging/SCM research
- **Holy Cross Energy**
  - FUSE has partnered with Holy Cross Energy to expand their current SCM program with cutting edge SCM communication architecture and objective functions
- **Ampcontrol**
  - FUSE has partnered with Ampcontrol to assess their load management software for fleets and provide feedback

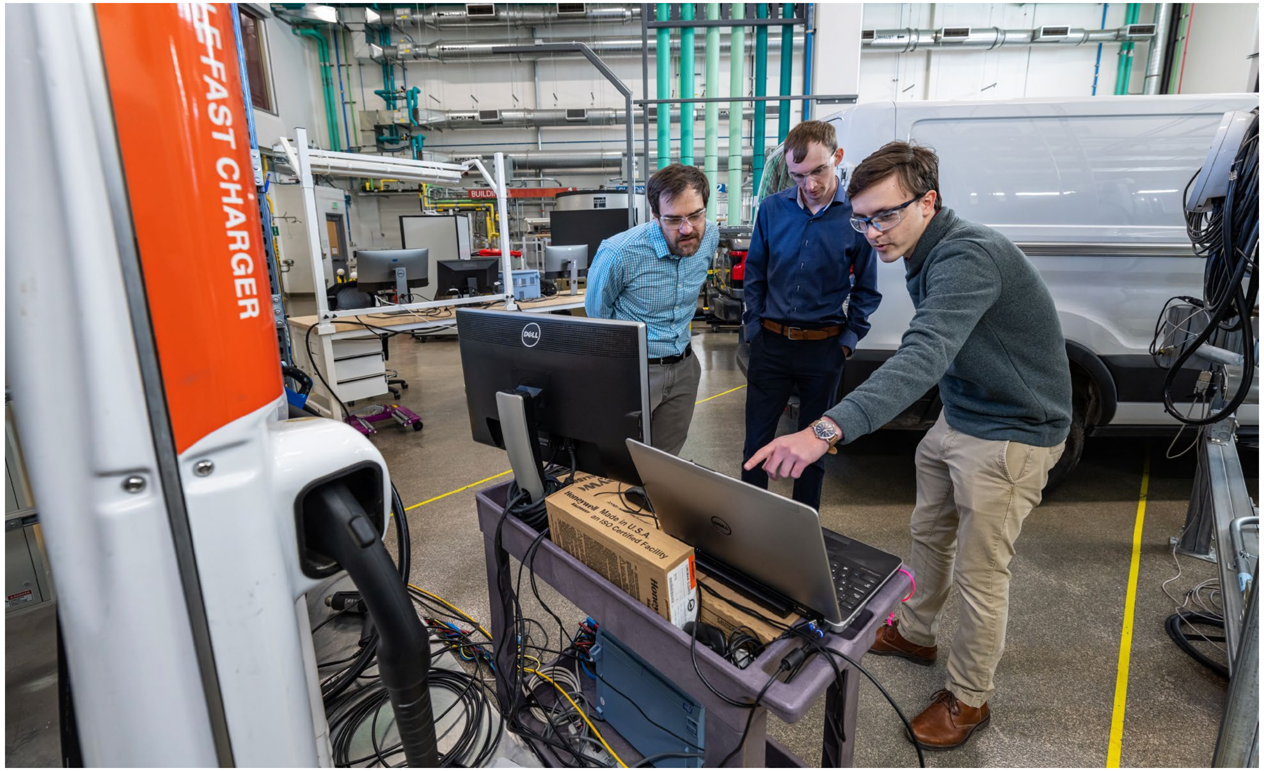
Typical EVs@Scale Partnerships Include:

- Mutually beneficial topic areas
- Lab research for EVs@Scale funded by DOE*
- Early access to cutting edge research and lab facilities
- NDAs to ensure sensitive information is secure
- In-kind contributions provided by Industry Partners

*Subject to change based on annual funding levels

FUSE Partnership Opportunities

- **DERMS Integration Opportunities**
  - Would you like to integrate FUSE SCM into DERMS?
- **Utility Distribution Planning**
  - How can FUSE help inform your distribution planning?
- **Fleet SCM Demonstration**
  - Do you have a fleet that could benefit from FUSE SCM?
- **Utility and/or PUC guidance/coordination**
  - Would you like to discuss research results with FUSE?



Interested in Partnering with FUSE?

Contact FUSE PI: Jesse Bennett, NREL

Jesse.Bennett@NREL.gov

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Thank You

Join us for the

SCM/VGI Deep Dive

Thursday October 31st

Additional Details to Follow

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U.S. Department of Energy

Cyber-Physical Security Pillar

Barney Carlson: Idaho National Lab

Sept. 25, 2024

Cyber-Physical Security Pillar Overview

Objective: Contribute to the continuously evolving cyber-physical security methods and solutions needed to ensure EV charging infrastructure safety, reliability, & resiliency

Projects:

- *CyberPUNC* assessments, mitigation R&D, cyber workforce training
- *Zero Trust Architecture* for EV charging infrastructure

Barriers Addressed:

- Rapidly expanding features, standards, & cyber provisions:
- Lack of holistic understanding of EV ecosystem vulnerabilities
- Inconsistent implementation of effective security methods
- Insufficient EV Charging Infra. (EVCI) cyber workforce
- Unknown potential cyber impacts of NACS
- Potential ISO 15118-2 & -20 compatibility vulnerabilities
- Lack of cyber metrics & verification methods for EVCI
- Lack of EV Charging Infra. cyber mitigation tools and solutions
- Previously secured & new vulnerabilities with Quantum computing capabilities
- Poor charging resiliency - lack of resiliency metrics, detection, response, recovery, controls, & evaluation

INL Idaho National Laboratory | Sandia National Laboratories | Pacific Northwest National Laboratory | Argonne National Laboratory | NREL Transforming ENERGY | Oak Ridge National Laboratory

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CyberPUNC Project

Barney Carlson: Idaho National Lab

Sept 25, 2024

CyberPUNC Project: Presentation Outline

EVs@Scale U.S. Department of Energy

CyberPUNC: Results & Accomplishments:

- Initiated technology transfer of the ***Cerberus*** cybersecurity mitigation solution to industry collaborator
- Continued success and growth of *CyberAUTO* Challenge; significant focus on EVs and EVCI
- Published report on cybersecurity of EV charging ecosystem mobile applications
- Published EVSE cybersecurity specific control catalog within DER-CF
- Published: "*Addressing Cybersecurity Risks Between EVSE and Charge Point Management Systems*"
- Drafted report on EV PKI and protocol emulation conducted in the range
- Began work on certificate naming scheme for conducting tests
- Initial cybersecurity evaluation in progress of three bi-directional chargers (V2G & V2H)

CyberPUNC: Future Efforts – What's Next

- **Direct partnership opportunities for industry to benefit** by collaborating with EVs@Scale Consortium
- Complete cybersecurity evaluation of the three bidirectional chargers
- Continue PKI integration for the latest security methods and best practices
- 2025 *CyberAUTO* and 2026 *CyberINFRASTRUCTURE* Challenges
- ***Evaid***, an agent-based cybersecurity resource development tool

Direct Partnership Opportunities with EVs@Scale

EVs@Scale
U.S. Department of Energy

The consortium is actively looking to support industry via partnering opportunities

- Cybersecurity and Cyber-physical security opportunities with EVs@Scale
  - Conduct cybersecurity evaluation on DC and V2G charging hardware prototype or production systems
    - Lab capabilities to enable evaluations include:
      - CCS-1 EV emulator: 1. V2G using ISO 15118-2 (2015) 120kW, 2. DC high-power charging up to 400kW
      - High-power DC charging stations (from 150kW to 350kW)
      - Open-source tool named “AcCCS” to evaluate the CCS communications network
      - Concentrated depot/community charging (e.g. 100x 11-22 kW)
  - Develop cybersecurity provisions for resilient, distributed DC microgrid-backed EV charging
  - In person or virtual assessments of the EVSE cybersecurity controls in the DER-CF
  - CSO / CNO cybersecurity evaluation collaboration
  - Technology transfer opportunity of proven mitigation solution for DC charging infrastructure

Direct Partnership Opportunities with EVs@Scale

(continued)

The consortium is actively looking to support industry via partnering opportunities

- Cybersecurity and Cyber-physical security opportunities with EVs@Scale
  - Advise and evaluate the security implementation in EVs, EVSEs, and CCS communications network
  - Partner on conducting HIL analysis with mobile applications in the charging ecosystem
  - Advice and lessons learned sharing on cybersecurity best practices implementations
  - Feedback on certificate naming mechanisms and testing opportunity inputs
  - Cloud Security: explore cybersecurity requirements for public cloud hosted CSMS

CyberPUNC – Publication on Cybersecurity Risks

Publishing a report titled, "*Addressing Cybersecurity Risks Between EVSE and Charge Point Management Systems*"

- **Report Details:**
  - Performed Open-source Intelligence gathering with a concentration on charge network back-end communications
  - Review the US-based charge network operators seeking FedRAMP authorization
  - The report highlights weaknesses found, cyber hygiene best practices, and the differences between global and US based industry leaders.
  - Tools used during OSINT research include: Shodan, Censys, Nmap, ipcrawler, autoenum, ffuf, gephi, and others.

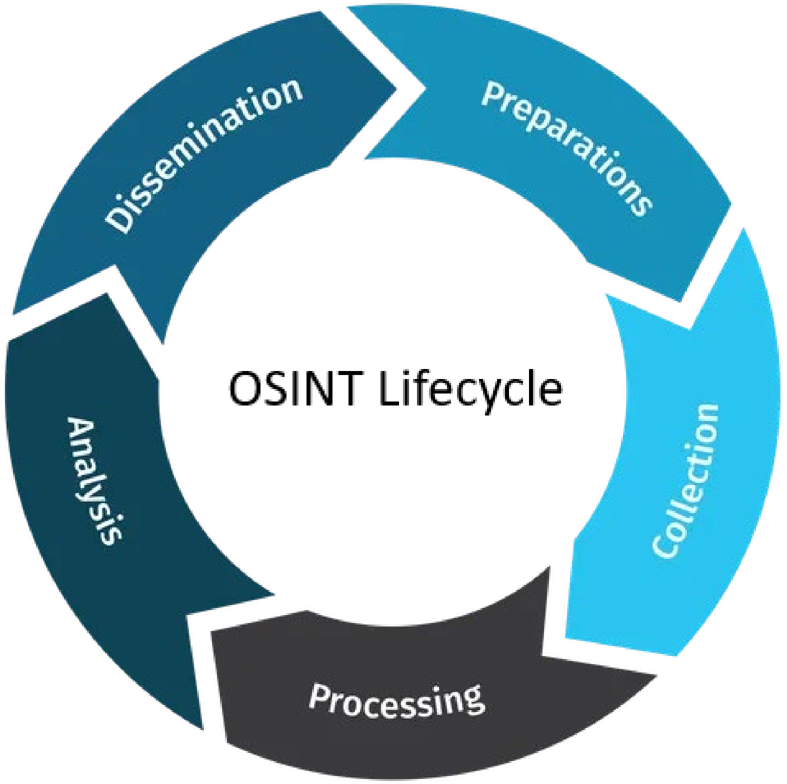

Image Credit: Sans.org

CyberPUNC – Publication on Cybersecurity Risks (continued)

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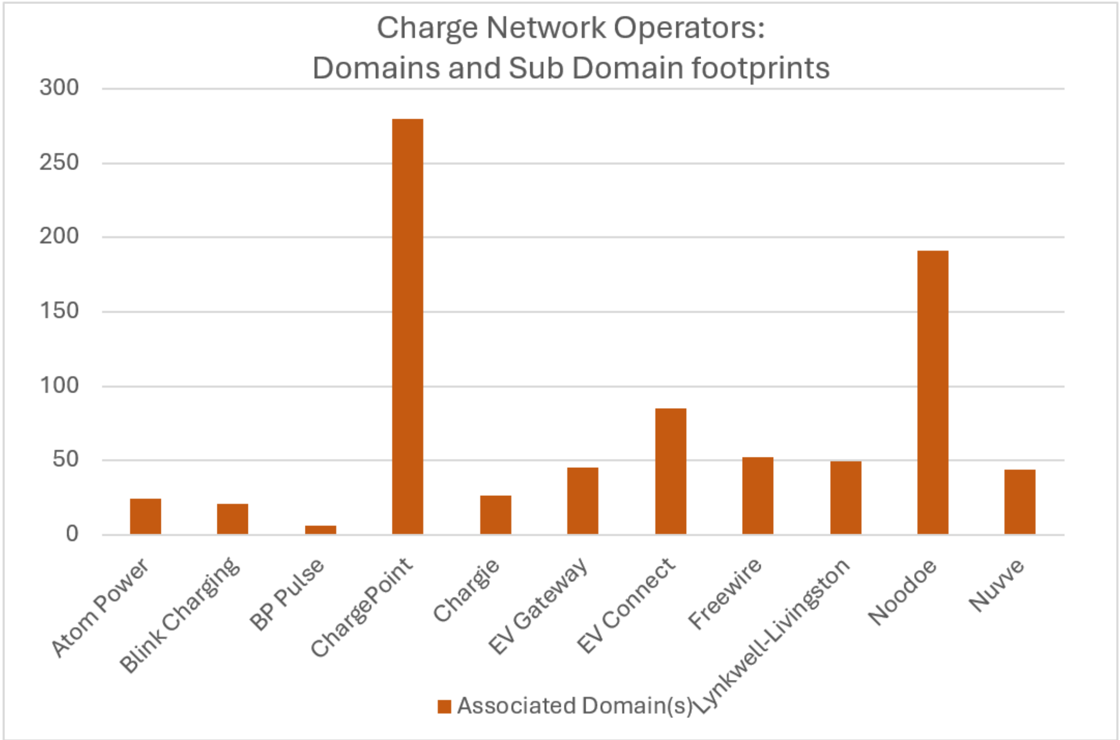
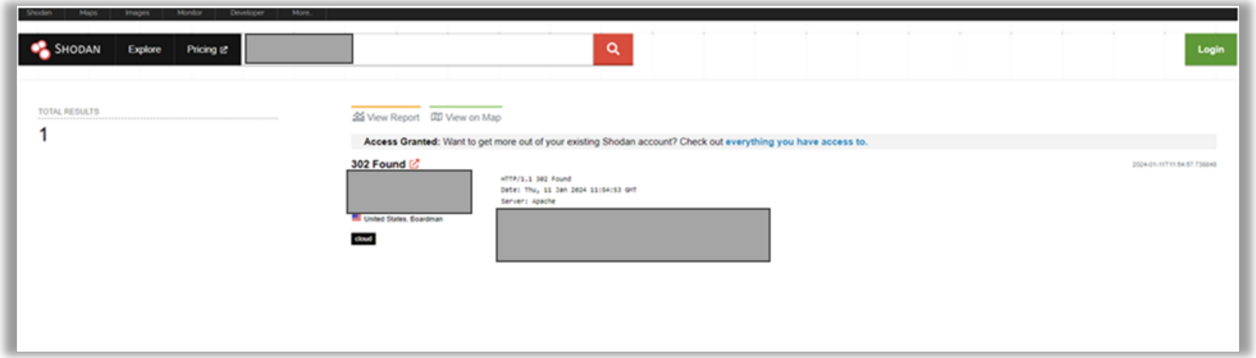


Public-facing presence for US based companies.



- Insecure EVCI discovered with keyword searches in Shodan

Column1	Column	Col	Column4	Colu	Colum	Column
OppUserCercate	Master	No	User CA Certificate (OCPP)	R/W	String	
15118ContractCaCertificate	Individual	No	Contract CA Certificate (Mo Root CA for 15118)	R/W	String	
ChargePointPublicAddress	Master	No	Public address of the ChargePoint if set, this address is put into the SOAP WSA-fromfeld. If left empty, the public IP gets determined by the applicat	RW	String	
NetworkConfigDHCPHostname	Master	No	Hostname string sent to DHCP server along with a DHCP request	R/W	String	
StaticNetwork Config Address	Master	No	Static LAN IP of the ChargePoint	R/W	String	
StaticNetwork ConfigNetmask	Master	No	Netmask to use for the LAN of the ChargePoint	RW	String	
StaticNetwork Configateway	Master	No	Gateway to use for the LAN of the ChargePoint	RW	String	
StaticNetwork ConfigDNS	Master	No	DNS server to use for the LAN of the ChargePoint	R/W	String	
WANRoutePassword	Master	No	[redacted]	R/W	String	admin01
WANRouterDeviceName	Master	No		R/W	String	
SocketType2State	Individual	No	State of TYPE2 socket at connector 1.	R	String	
SocketSchukoState	Individual	No	State of Schuko socket at connector 1.	R	String	
POL Power	Master		POL Power	R/W	String	
Signaled CurrentLimit	Individual		The current in Ampere that is signaled to the vehicle via PWM	R	String	
ChargingSchedule Allowed Charging RateUnit	Master	Yes	A list of supported quantities for use in a ChargingSchedule	R	String	Current
PhasesConnected	Individual	No	This parameter shows, how the number of phases connected to the ChargePoint is configured.	R	String	
WLANSSID	Master	No	WLAN SSID of the WLAN the ChargePoint shall be connected to	R/W	String	
WLANPassword	Master	No	WLAN password of the WLAN the ChargePoint shall be connected to. The Chargepoint automatically chooses the right encryption of the WLAN	R/W	String	
WLAN NetworkConfigDHCPHostname	Master	No	Hostname string sent to DHCP server along with a DHCP request	R/W	String	
WLANStaticNetwork ConfigAddress	Master	No	Static WLAN IP of the ChargePoint	R/W	String	[redacted]
WLANStaticNetworkConfigNetmask	Master		Netmask to use for the WLAN of the ChargePoint	R/W	String	
WLANStaticNetwork ConfigGateway	Master		Gateway to use for the WLAN of the ChargePoint	R/W	String	
WLANStaticNetwork ConfigDNS			DNS server to use for the WLAN of the ChargePoint	R/W	String	
DlmState			DILM State	R	String	

- Sample logs with potentially sensitive data exposed

Image Credit: Argonne National Laboratory and shodan.io

Argonne NATIONAL LABORATORY

CyberPUNC Project – Securing EV Charging Mobile Applications

EVs@Scale
U.S. Department of Energy

Background

- Mobile devices are widely used to manage/monitor EVs or EVSEs
- Mobile apps are critical component of the EV ecosystem
- Mobile apps can be potential points of entry for cyberattacks

Current Focus and Progress

- Make inventories of mobile apps used in EV ecosystem
- Research common architecture or structure used by the apps
- Use Mobile Application Vetting (MAV) developed by DHS Cybersecurity and Infrastructure Security Agency (CISA) for:
  - Identifying app vulnerabilities and potential risks to mobile devices
  - Assessing risks or impacts to EV ecosystem

Future Directions

- Increase the number of inventories for security assessment
- Analyze types of common vulnerabilities and suggest mitigations
- Capture network traffic through hardware-in-the-loop testing to confirm findings from the MAV scans or discovery of new findings

Implementing the latest security methods and best practices

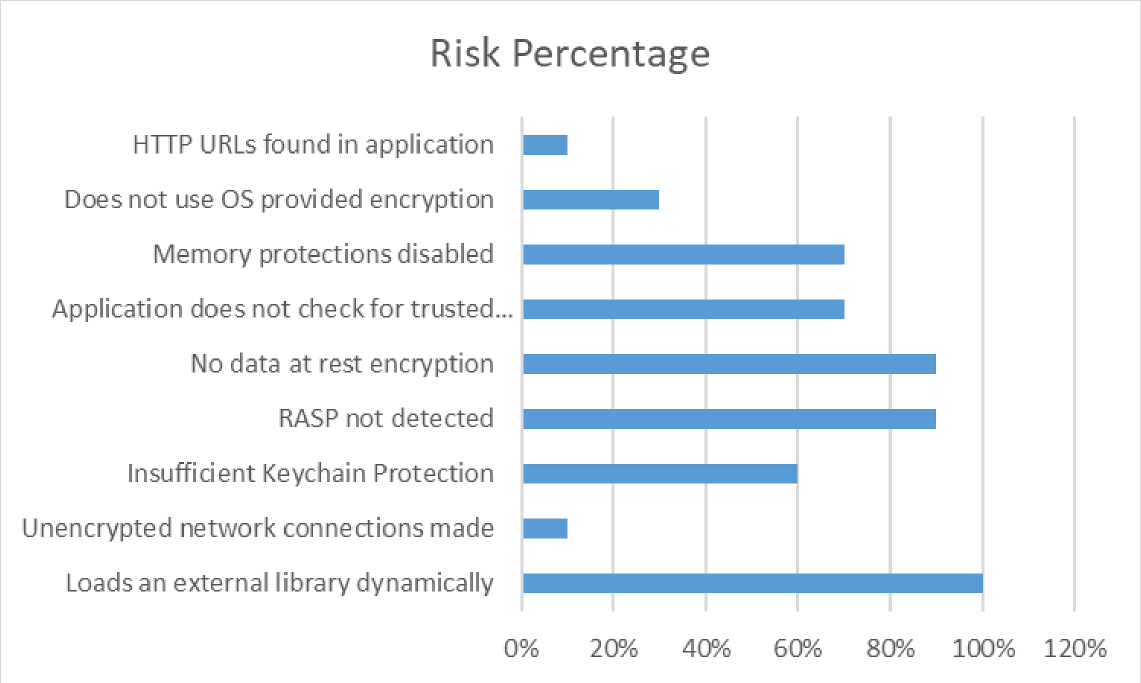


Figure: Risk percentage breakdown across charging ecosystem mobile applications

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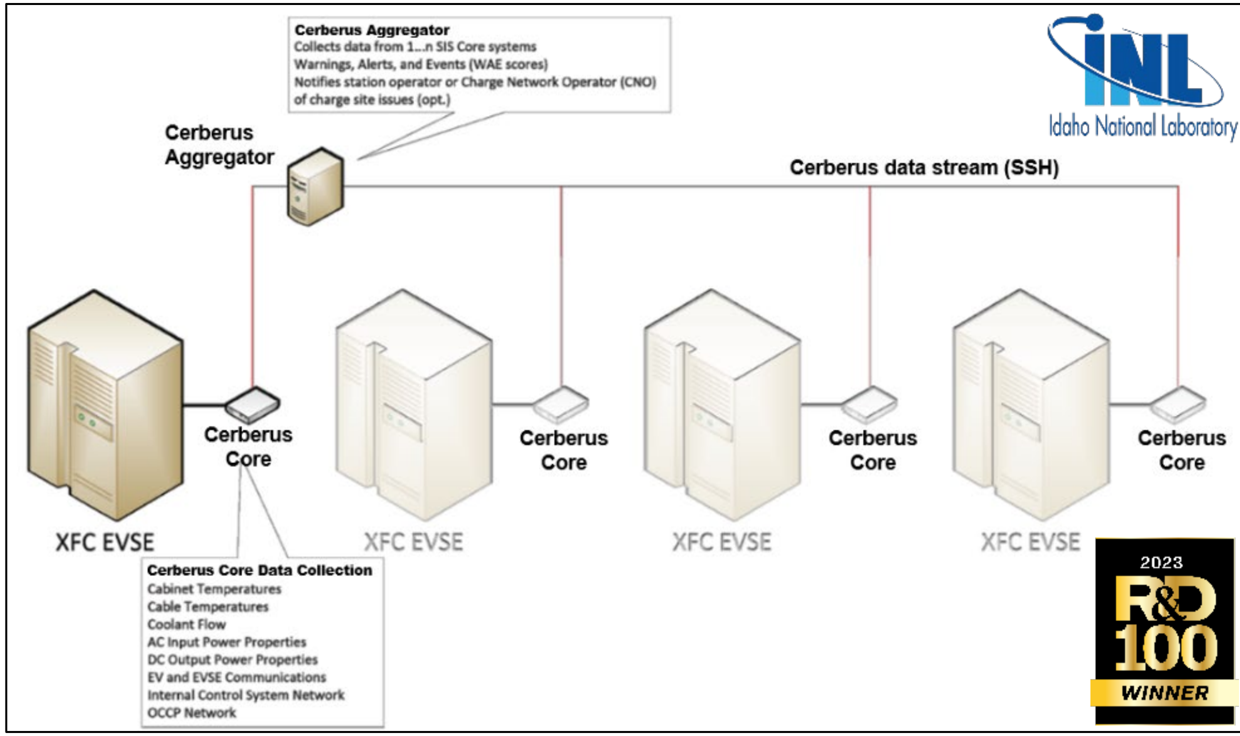
CyberPUNC – Cyber Mitigation Tools & Solutions

EVs@Scale
U.S. Department of Energy

Cerberus: Technology Transfer initiated of a cyber-physical mitigation solution

- *Cerberus* is a cybersecurity solution for high-power DC charging infrastructure capable of detection, response, and recovery from malicious or anomalous events
- Technology transfer initiated with industry
  - Legal agreements in place
  - Technical details provided:
    - System architecture
    - Hardware requirements
    - Software modifications for charger specific hardware and communication protocols
  - Plans drafted for:
    - lab testing and validation of proper functionality
    - In field demonstration at local site
    - Intention for wider roll-out to numerous sites



CyberPUNC Project – Cyber Tools and Solutions for EVSE

EVs@ Scale
U.S. Department of Energy

Background

- Prior national lab work collected insights on subset of industry tools and capabilities
- Opportunity to map tools and capabilities to EVSE security functions and needs

Current Focus and Progress

- Previously constructed a dynamic database (OpenEI platform) for engaging with industry using initial security tool surveys
- Finalized EVSE specific cyber assessment question sets that align with DER-CF (cyber framework assessment tool)
- Finalized action items and mitigations, metrics, and maturity levels for EVSE cyber assessment questions
- Began incorporating into the DER-CF

Future Directions

- Conduct facility-specific EVSE cybersecurity assessment with controls
- Identify gaps in current controls and bridge the gaps
- Maintain and update EVSE cybersecurity controls and build connections between needs and solutions

Implementing the latest security methods and best practices

DER-CF

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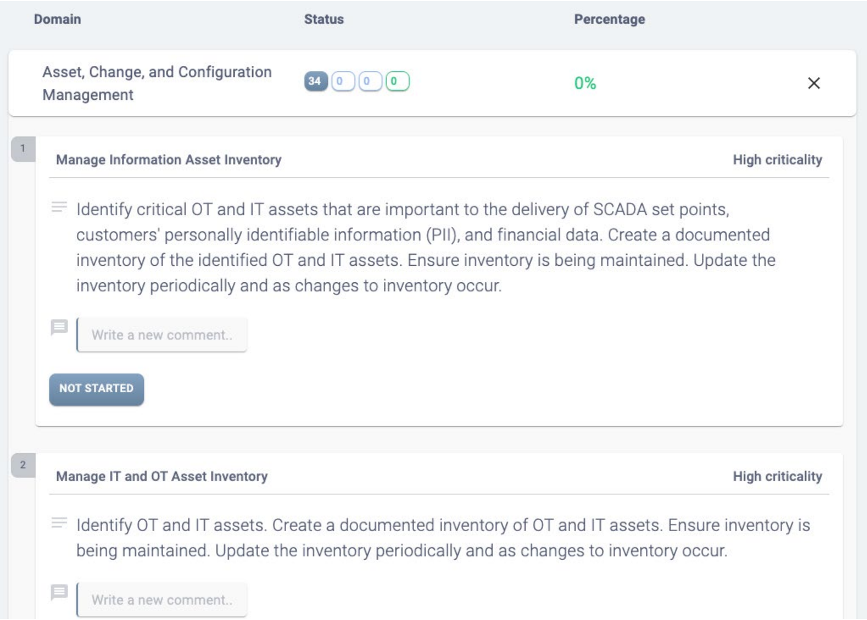
CyberPUNC Project – Cyber Tools and Solutions for EVSE

EVs@Scale
U.S. Department of Energy

Controls Catalog is a First Step towards Priority Actions

Domain	Domain	Sub-domain	Control
Technical Management	Configuration Management	Access Control	Does the EVSE protect the confidentiality of the communication on the Wide Area Network (WAN) interface by encrypting it using a
Technical Management	Systems/Device Management	fail-safe procedures/cryptographic protection	If passwords are used on the EVSE, are they stored in readable plaintext?
Technical Management			Are the hashing function open-sourced and proven to be collision resistant one-way hash functions?
Governance	Threat and Vulnerability Management		Is there a process to verify no known vulnerable hash functions are used?
Technical Management	Account Management	Anomalous behavior in system logs	Is the EVSE able to detect messages that have been modified or verify the integrity?

Responses lead to metrics



Metrics guide priorities

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CyberPUNC Project - Secure EV charging w/PKI Integration

EVs@Scale
U.S. Department of Energy

Background

- Baseline cybersecurity requirements include ISO 15118-2 certificate profiles, OCPP standards
- Research supports and extends EV charging industry PKI events, platforms, and priorities per SAE

Implementing the latest security methods and best practices

Current Focus and Progress

- Using open-source Emulytics (minimega/Phēnix/SCORCH) tools for PKI/protocol simulation and testing within NREL Cyber Range
  - Implemented VMs emulating EV, EVSE, and CSMS (CNO platform) endpoints for NEVI mandated protocols: ISO 15118-2, OCPP 2.0.1. Focusing on PKI integrations for device authentication and encrypted communications
  - Tested scenarios including of denial of service on charge network operator, and OCSP server
- Began using MaEVe CSMS for end-to-end PKI interactions (e.g. contract certificate revocation)
- Continued integration with SAE prototype PKI provider (EonTi RA).
  - Creating an extensible naming scheme to support certificate/bundle generation, code CI/CD, experiment configuration, and live and cyber range-based testing.
  - Using COTS charging controllers as HIL with stand-alone and range-hosted CSMS (CESER T34PKI Project).
  - Developing metadata and metrics to convey static and dynamic PKI properties/posture in experiments.
- Synthesizing process and findings in technical report.

Outreach

Energy Exchange (March 24)
GridTECH Connect (June 24)
CharIN Testival (June 24)
IEEE PES GM (July 24)
DEFCON (August 24)
RE+ (September 24)

Future Directions and Partnership Opportunities

- Platform development: interface with pilot and production PKI providers; potentially incorporate OCPI.
- Testing: trial and refine our certificate naming scheme and tooling in test events and experiments.
- Industry engagement: align with JOET/CESER and SEA-ITC EVPKI on PKI industry direction and testing.

Sandia National Laboratories

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CyberPUNC Project - Secure EV charging w/PKI Integration

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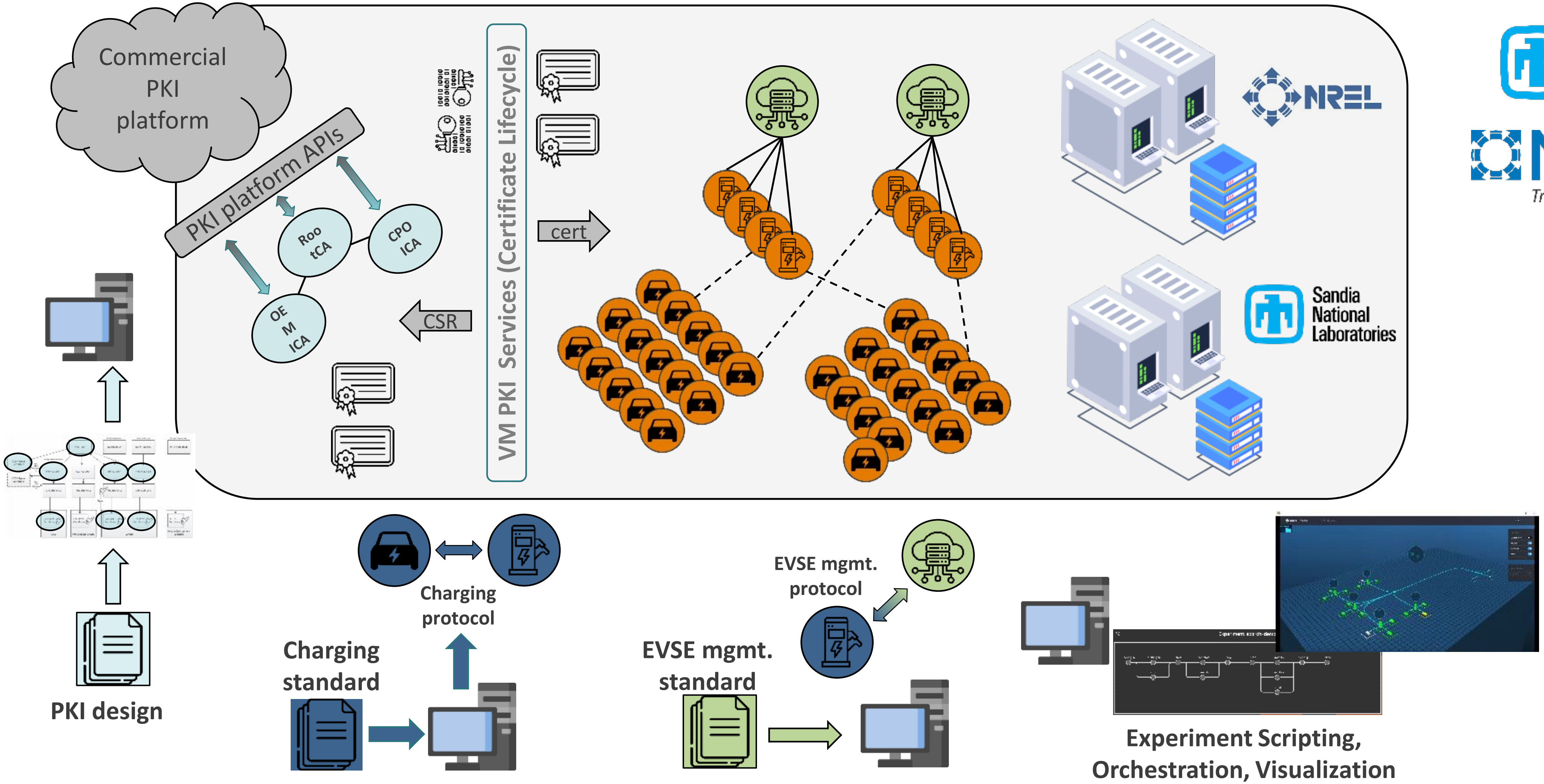
EV charging PKI emulation on minimega/Phēnix



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Experiment Scripting, Orchestration, Visualization

CyberPUNC – Cybersecurity Workforce Training

CyberAuto Challenge: Training the Next-Generation of Cyber Workforce

- **July 22-26, 2024 *CyberAUTO:*** ICE vehicles, EVs, EVSE, energy management, and more
  - www.cyberauto-challenge.org
- Annual 1-week long collegiate event in Michigan focused on automotive cybersecurity
- 2018 to the present: increased focus on electric transportation and charging infra.
  - EVs, AC & DC EVSE, CCS communications, and OCPP 1.6J
  - In-vehicle / in-EVSE evaluations and training: Automotive Ethernet, CAN bus, OCPP, ISO 15118, reverse engineering, Ghidra, attack strategies/methodologies, capture the flag challenges, root access
  - Vulnerability assessments:
    - EVSE internal communications network access and EV port scans through the CCS-1 control pilot via *AcCCS* tool
    - Accomplished root access of EVSE 64-bit main control board
- **2025 CyberAUTO** will be July 2025 in Battle Creek, MI
- *New event:* 2026 ***CyberINFRASTRUCTURE Challenge*** will be focused on EV charging infrastructure (including bi-directional), microgrids, DER, and all of the associated communications
  - contact: Karl Heimer (karl.heimer@outlook.com)

CyberPUNC – V2X Cybersecurity Evaluation in progress

EVs@Scale
U.S. Department of Energy

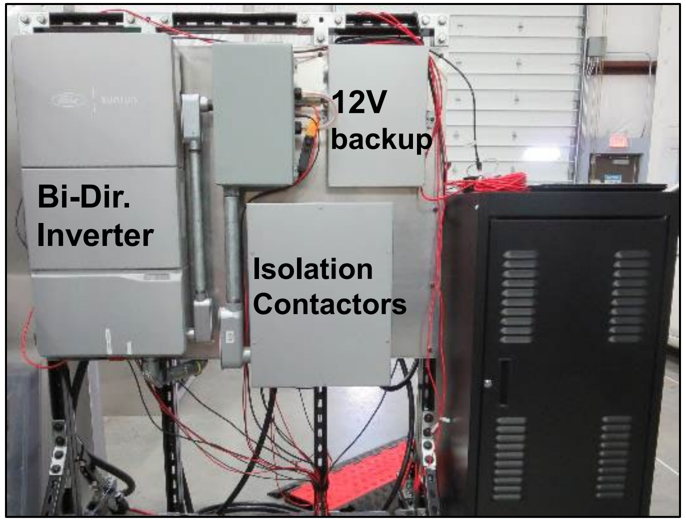
Bi-directional Charging (V2X) Cybersecurity

- Communications security: energy management, EV to EVSE comm., internal systems controls, remote management and control
- Grid security, safety, operational performance

- Three systems installed in EVIL laboratory
  - V2G, V2H; Light duty, medium duty; CCS-1, CHAdeMO

Vehicle to Grid (V2G)

Vehicle to Home/Load (V2H)



Idaho National Laboratory

CyberPUNC – CCS-1 Bi-directional (V2G) EV Emulator

Bi-directional Charging (V2X) EV Emulator supports V2G research in the EVs@Scale Consortium

- Developed to enable:
  - Cybersecurity evaluation and vulnerability exploitation of V2G charging infrastructure
  - Charger characterization across a wide range of operating conditions
  - Capable of emulating numerous vehicles
- Capabilities:
  - Up to 120kW (350A DC max., 500V DC max.)
  - CCS-1 inlet port and vehicle-side contactors
  - EVCC with ISO 15118-2 (2015)
  - Bitrode battery emulator and 1.5F capacitor to smooth fast transients

CyberPUNC – Review & Next Steps

EVs@Scale
U.S. Department of Energy

Review

- Initiated technology transfer of the *Cerberus* cybersecurity mitigation solution to industry collaborator
- Continued success and growth of *CyberAUTO* Challenge; significant focus on EVs and EVCI
- Published report on cybersecurity of EV charging ecosystem mobile applications
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- Initial cybersecurity evaluation in progress of three bi-directional chargers (V2G & V2H)

Next steps

- **Direct partnership opportunities for industry to benefit** by collaborating with EVs@Scale Consortium
- Complete cybersecurity evaluation of the three bidirectional chargers
- Continue PKI integration for the latest security methods and best practices
- 2025 *CyberAUTO* and 2026 *CyberINFRASTRUCTURE* Challenges
- *Evaid*, an agent-based cybersecurity resource development tool

Thank You!

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Back-up Slides

Questions (for lunch time feedback)

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Questions for feedback from the audience

- Who in the audience works on cybersecurity with their organization?
- What are the critical cybersecurity gaps that would benefit from EVs@Scale collaboration / support?
- Is there a better way for EVs@Scale consortium to work/collaborate with industry? (pre-competitive technology)
- When do you think the first large-scale (large impact) cybersecurity exploit event of EV charging infrastructure will occur?
- What do you think the end goal for EVs@Scale consortium should be?

Idaho National Laboratory | Sandia National Laboratories | Pacific Northwest National Laboratory | Argonne National Laboratory | NREL Transforming ENERGY | Oak Ridge National Laboratory

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Securing Electric Vehicle Charging Infrastructure Using Zero Trust and Post-Quantum Cryptography

Thomas E. Carroll, PNNL

September 25, 2024

Cyber-Physical Security (CPS): Zero Trust Overview

Never assume, always verify

Objective: Develop, demonstrate, and evaluate Zero Trust approaches to bolster EV Infrastructure security by reducing the attack surface.

Motivation:
- Chargers have a high degree of connectivity, which erodes perimeter defenses
- Zero Trust strategies may more effectively mitigate the risks and challenges of the complex EV charging ecosystem

Outcomes:
- **Design architecture** for incremental deployment and infrastructure integration
- **Prototype architecture** in a testbed
- **Characterize and assess** prototypes to address vulnerabilities
- **Develop blueprint**

Industry Partners:

PATERO CISCO NETFOUNDRY

What is Zero Trust?

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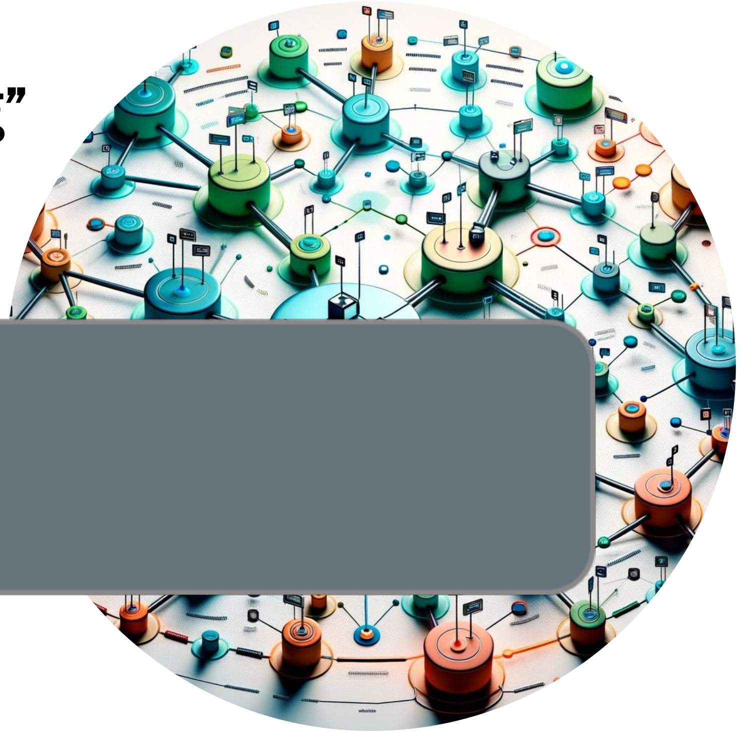
Zero Trust architecture implements network security approaches following the tenet "Never trust, verify everything"

- Zero Trust's goal is to reduce implicit trust
  - Removal of implicit trust limits compromise scope
  -
- Op
  - Independently considers each access request
  - Uses policy, identity and environment in each access request decision
  - Ensures adherence to "least privilege" and "separation of duties" principles

Zero Trust doesn't mean No Trust



Implicit trust – a vulnerability resulting from limited verification | Least privilege – authorization level | Separation of duties – privileges limited based on role

Design Assumptions

- Emphasis is on the relationships between the charger/infrastructure and promote operator access
- Keep the standard EV-EVSE interaction unchanged
- Chargers are unaltered
- Network will proctor the security controls
- Leverage commercial and open-source solutions
- Identify and address gaps as necessary

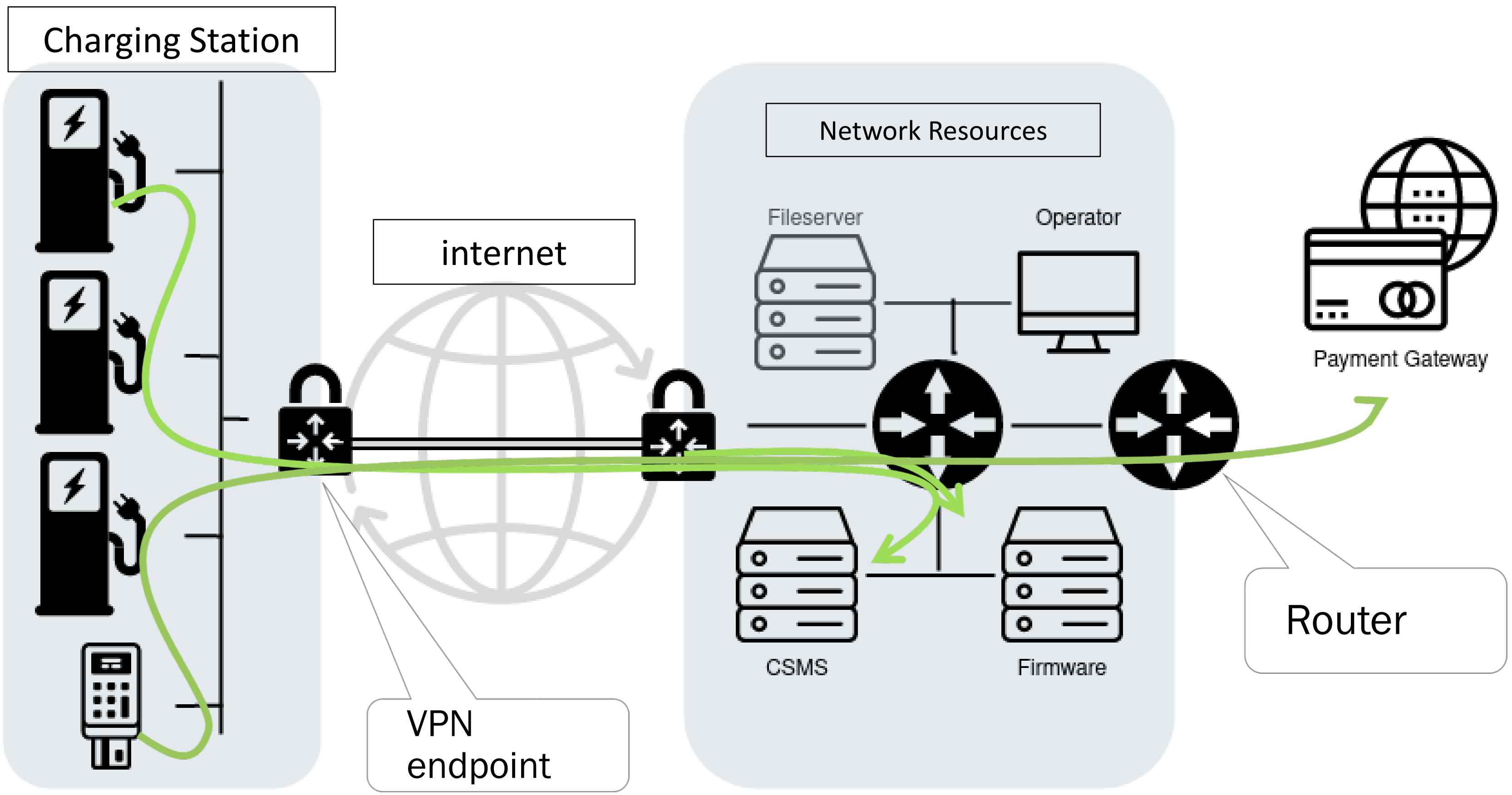
Insights

- Zero Trust doesn’t solve all your cybersecurity ills
- Zero Trust guidance & cyber security standards require interpretation
- Multiple approaches exist for implementing zero trust; choose an approach that align best with your organizational needs, processes and staff knowledge, skills, abilities and experiences.
- A single product is unlikely to meet all requirements and design objectives
- Plan for the costs and time required for integrating multiple products
- Integration complexity will vary between different products
- Organizational workflows may need to be adapted

Security Objectives

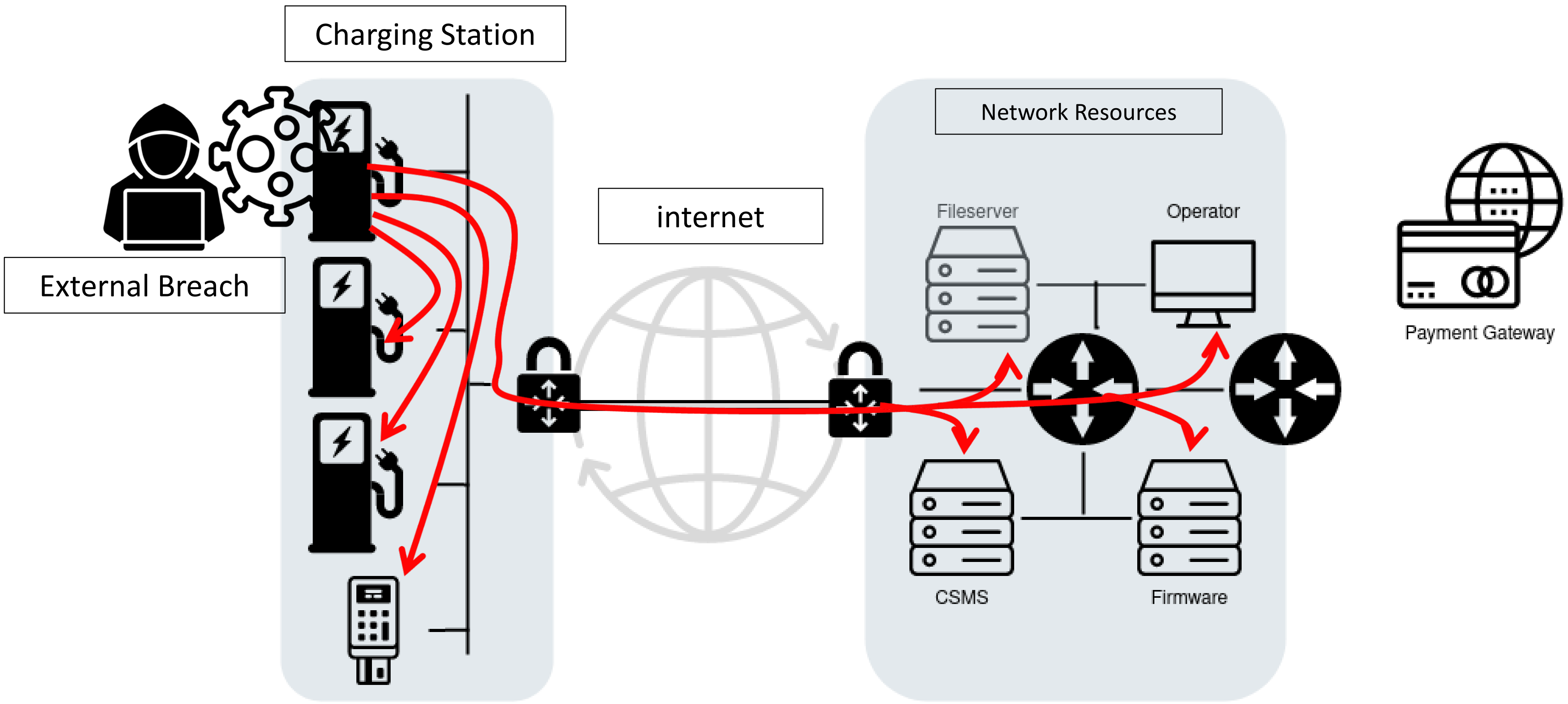
Security Objectives	Implementation
Deny by Default	Only permit interactions explicitly defined by policy
Principle of Least Privilege Access	Only permit what's necessary; enforce resource access from endpoints by contexts of port, IP, and domain names, groups, and zones
Authentication and Authorization	Associate users and devices with their identities using centralized identity management; ensure authentication and authorization decisions are identity based
Secure Communications	Ensure end to end encryption
Reduce Network Exposure	Minimize communication to only those interfaces that are essential for operational needs.
Employ Trusted Network Infrastructure	Avoiding the use of public and third-party infrastructures (i.e. ISP) for services such as DNS and NTP and employing such infrastructure to a trusted cloud or platform for more control over how traffic is routed
Monitoring	Ensure audit records

Conventional EV Service Provider + WAN

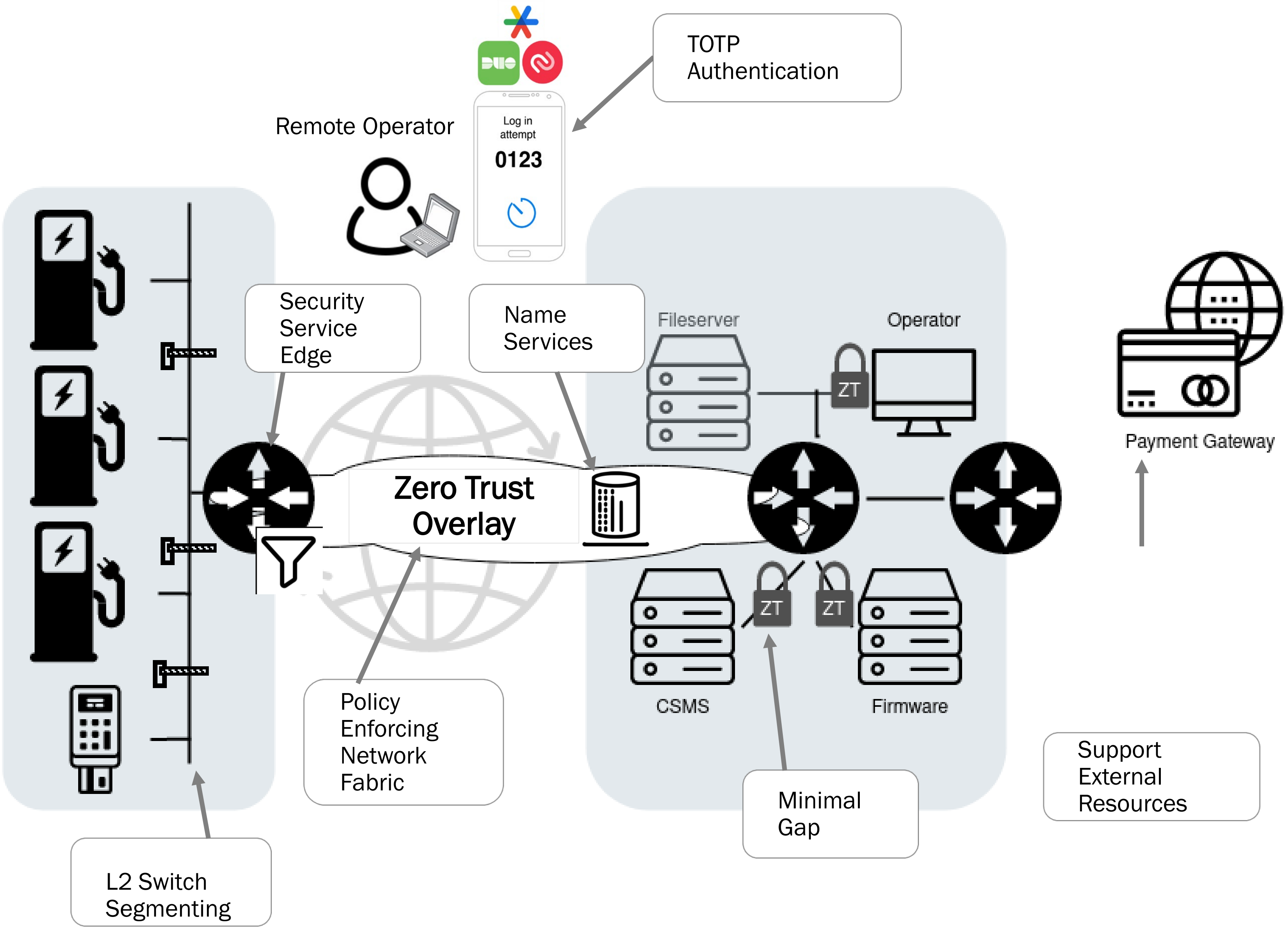


CSMS – Charging Station Management System - software for remote and real time charge point operation control (e.g., OCPP 2.0.1).

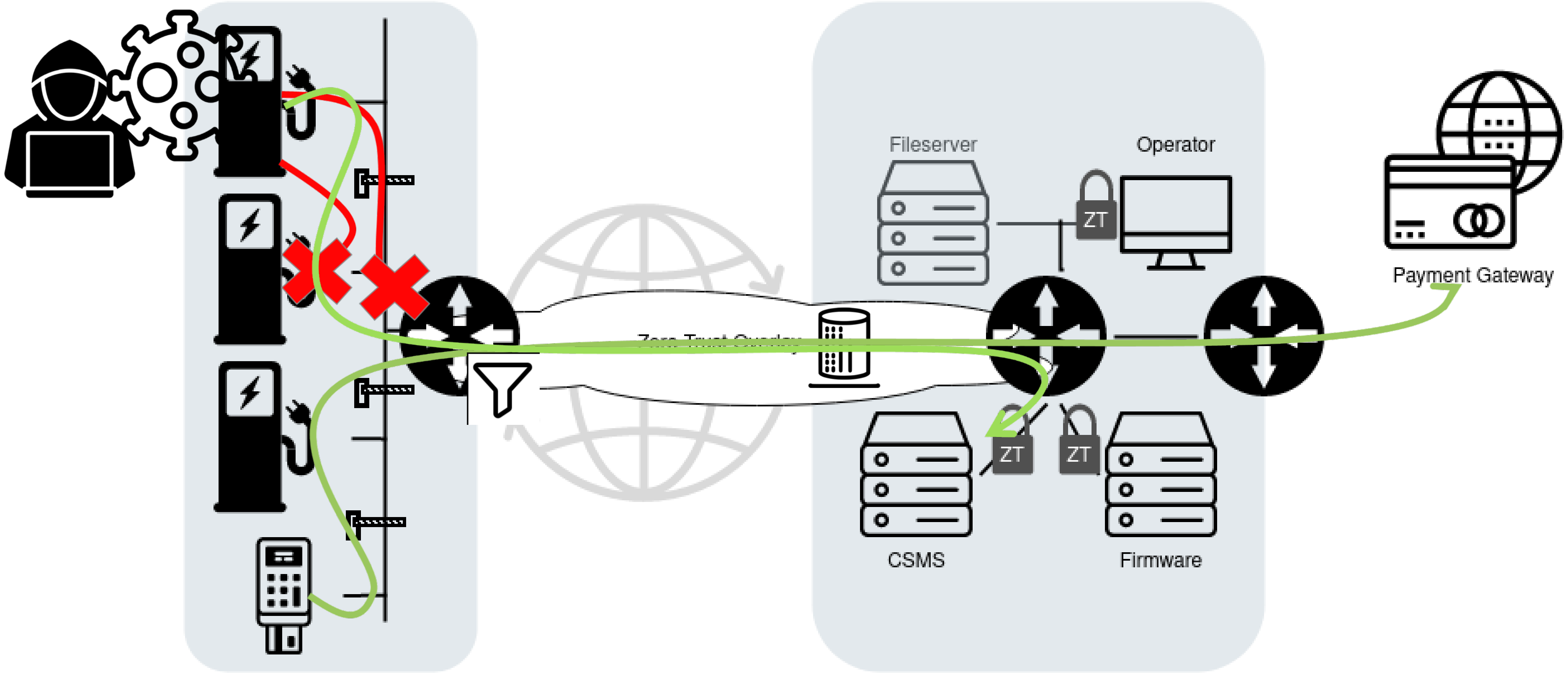
Breach to a Conventional EV Service Provider + WAN



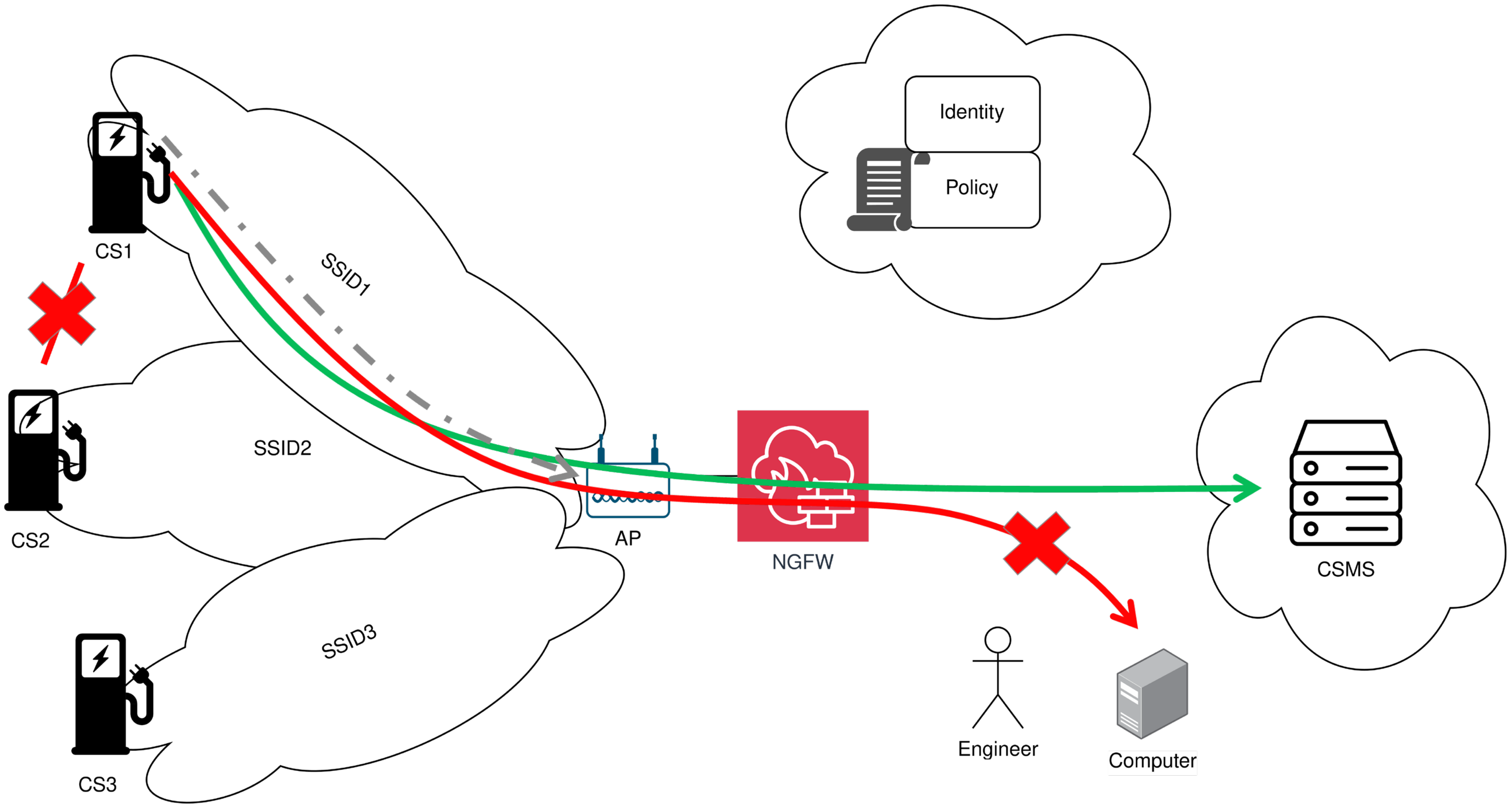
Architect: Zero Trust Architecture for EV Service Provider



Zero Trust Architecture to Prevent Breach to a Conventional EV Service Provider

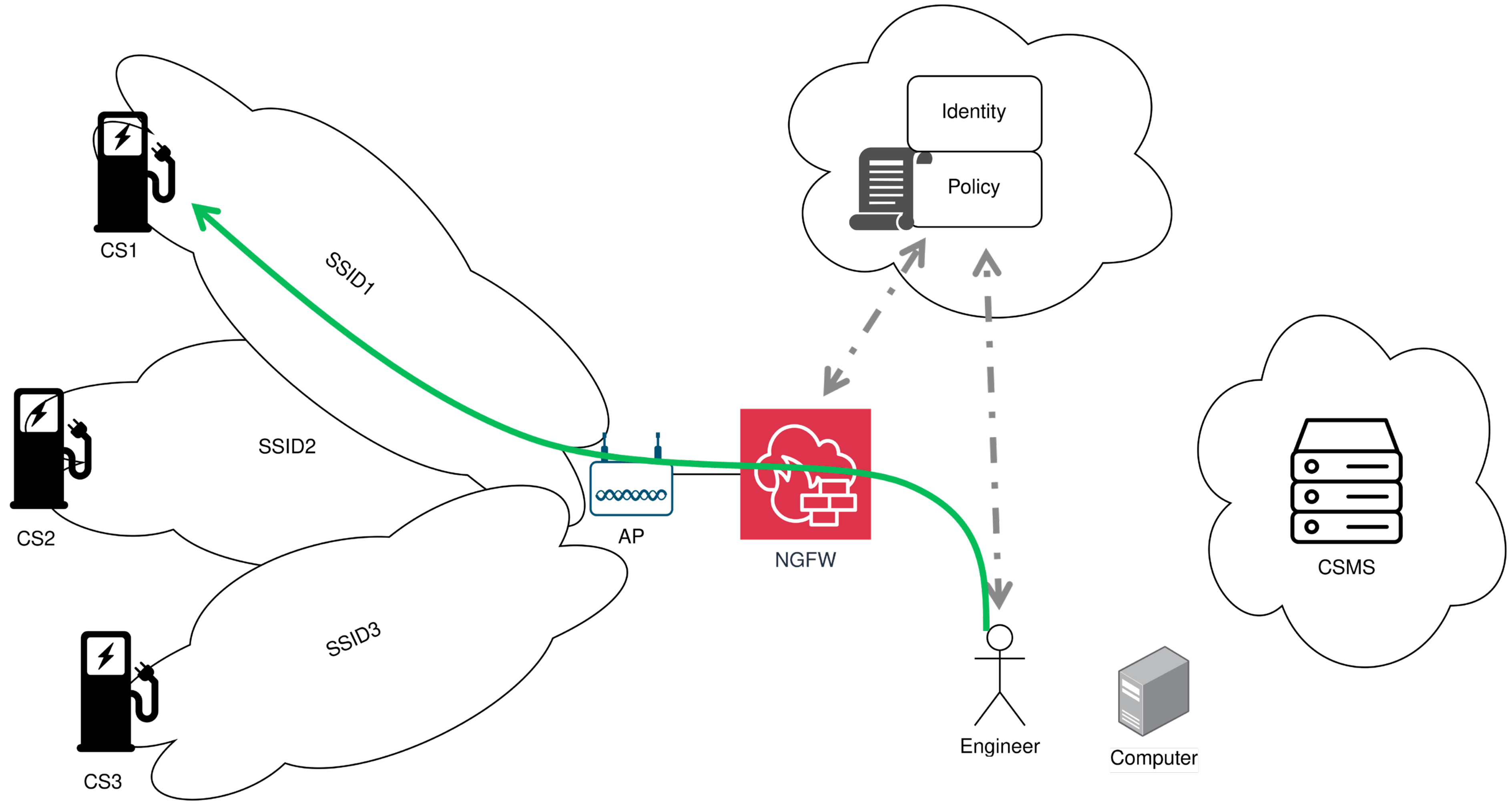


Zero Trust and WiFi – Alternate 1



AP – Access Point: a network device that receives and transmits data wirelessly
CSMS – Charging Station Management System: service for remote and real time charge point operation control (e.g., OCPP 2.0.1).
NGFW – Next-Generation Firewall: network security device that provides capabilities beyond a traditional, stateful firewall
SSID – wireless network identifier

Zero Trust and WiFi - Alternate 1



AP – Access Point: a network device that receives and transmits data wirelessly
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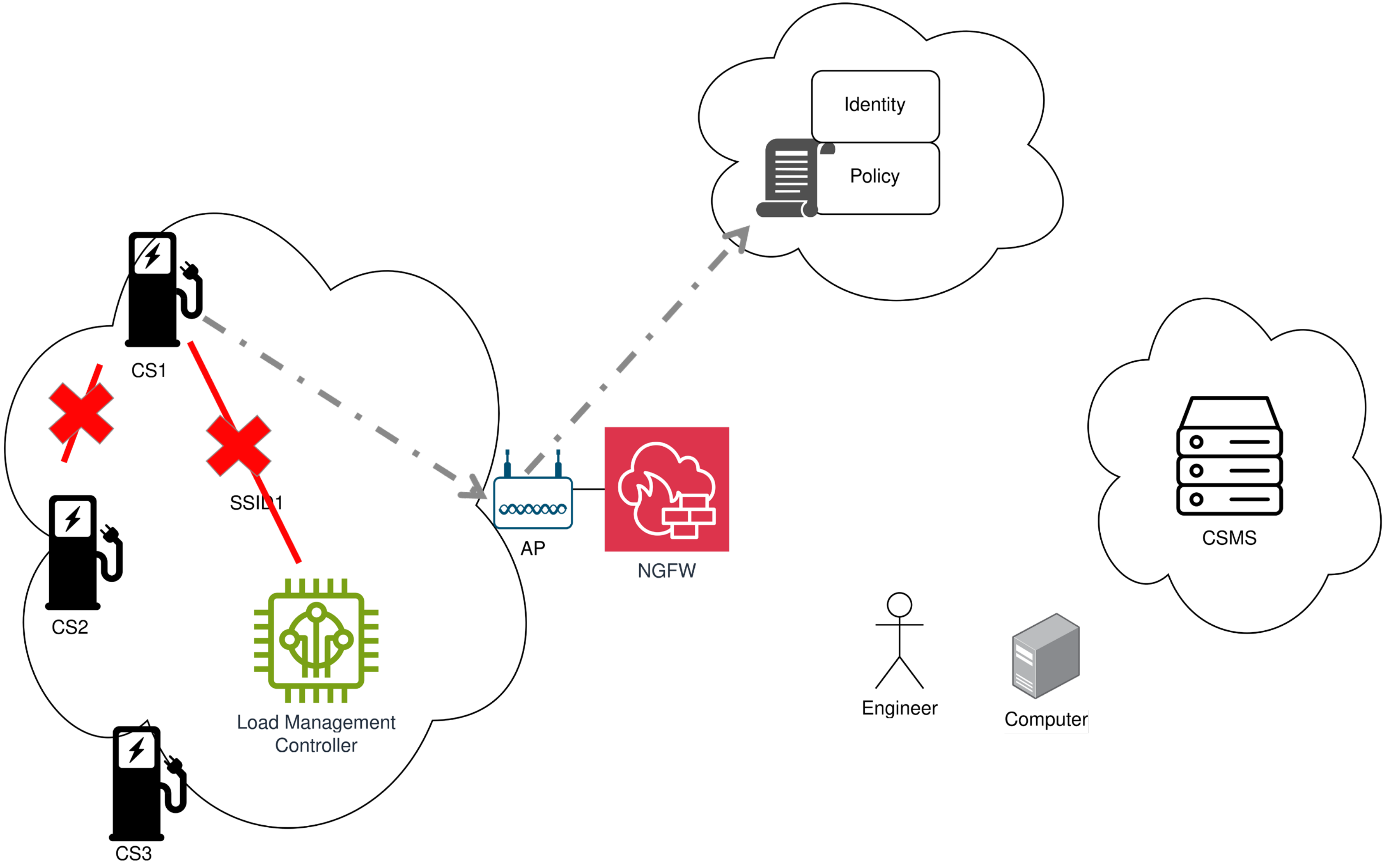
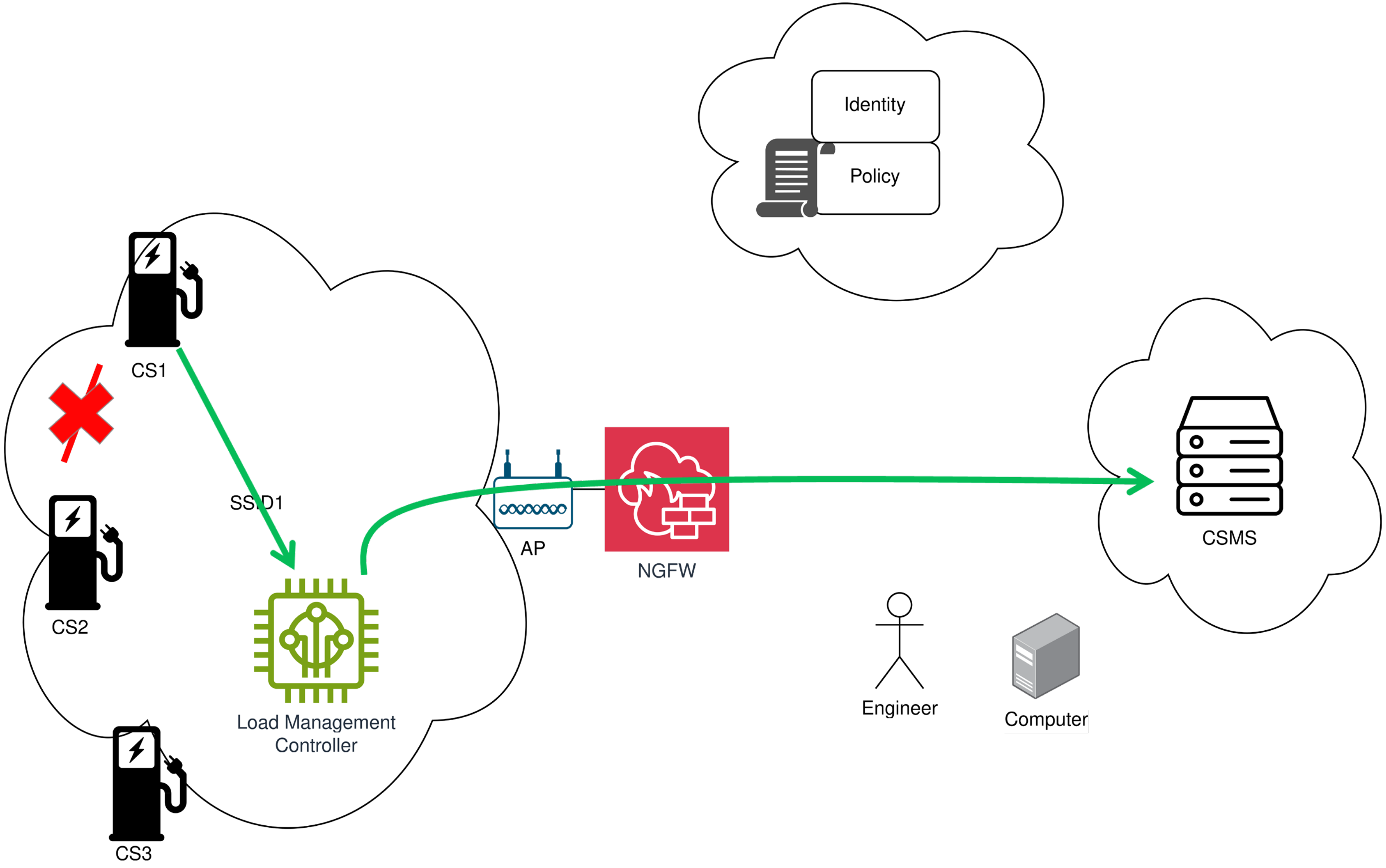
SSID – wireless network identifier

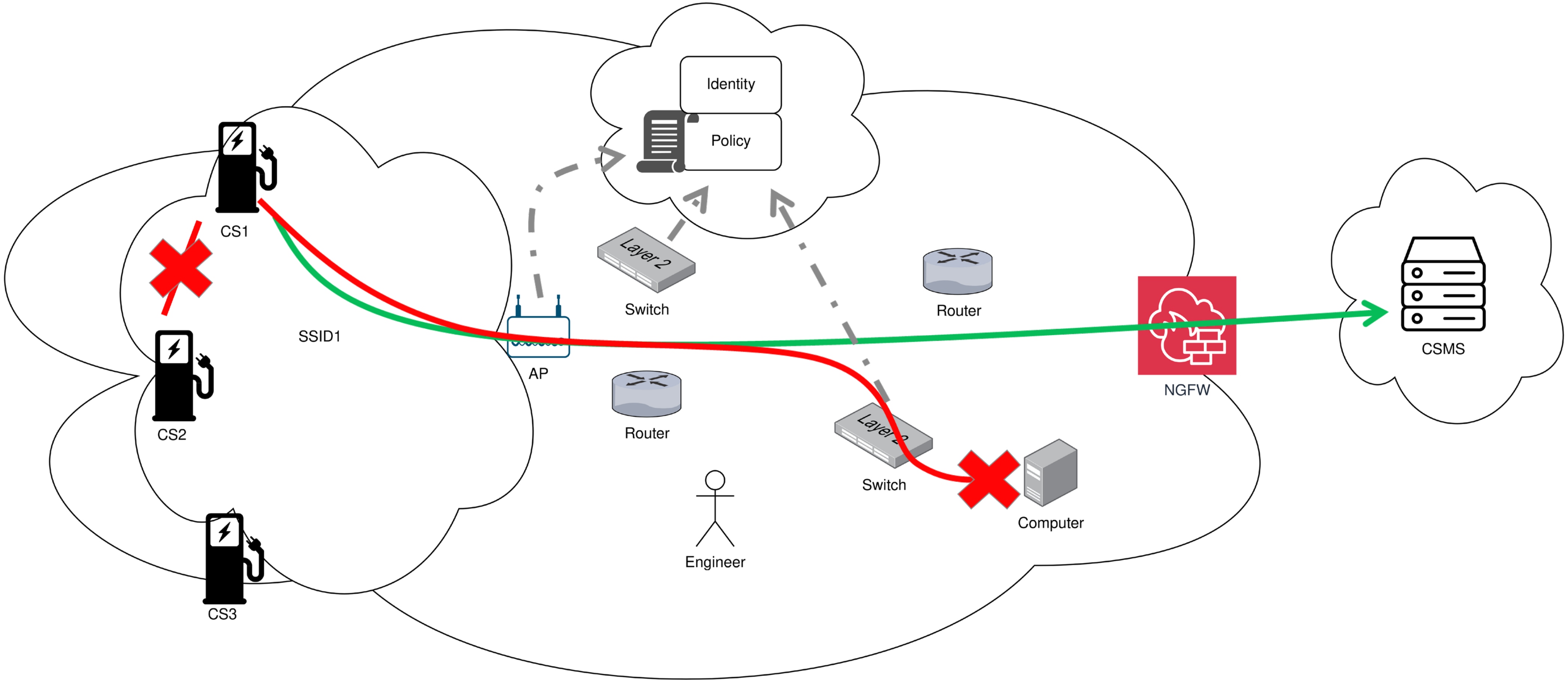
Zero Trust and WiFi – Alternate 2a



Zero Trust and WiFi – Alternate 2b



Zero Trust and WiFi – Alternate 3



Case Study: Tunnel Vision

- CVE score of 7.6 (High)
- Exploit that enables the re-routing of VPN traffic through a route that is owned by the adversary
  - Traffic no longer encrypted by VPN tunnel
  - Traffic can be sniffed by adversary

New TunnelVision Attack Allows Hijacking of VPN Traffic via DHCP Manipulation

May 09, 2024 Ravie Lakshmanan Encryption / Data Privacy — Trending News

NEWS

TunnelVision hack allows attackers to bypass VPN protections

The TunnelVision vulnerability has been around since 2002 according to security researchers.

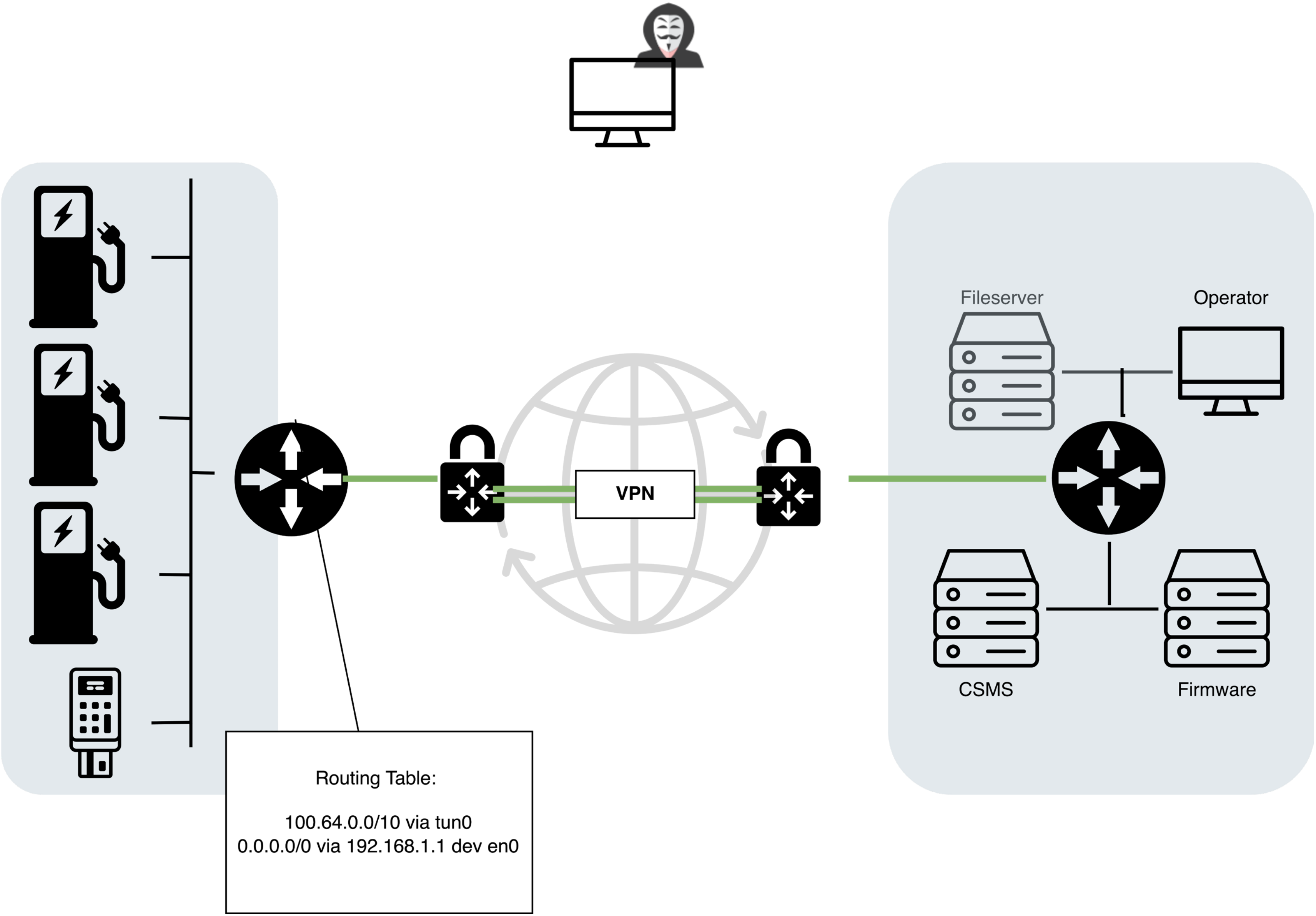
By Sam Singleton
Assistant Editor, PCWorld | MAY 8, 2024 2:00 AM PDT

DAN GOODIN, ARS TECHNICA SECURITY MAY 10, 2024 12:56 PM

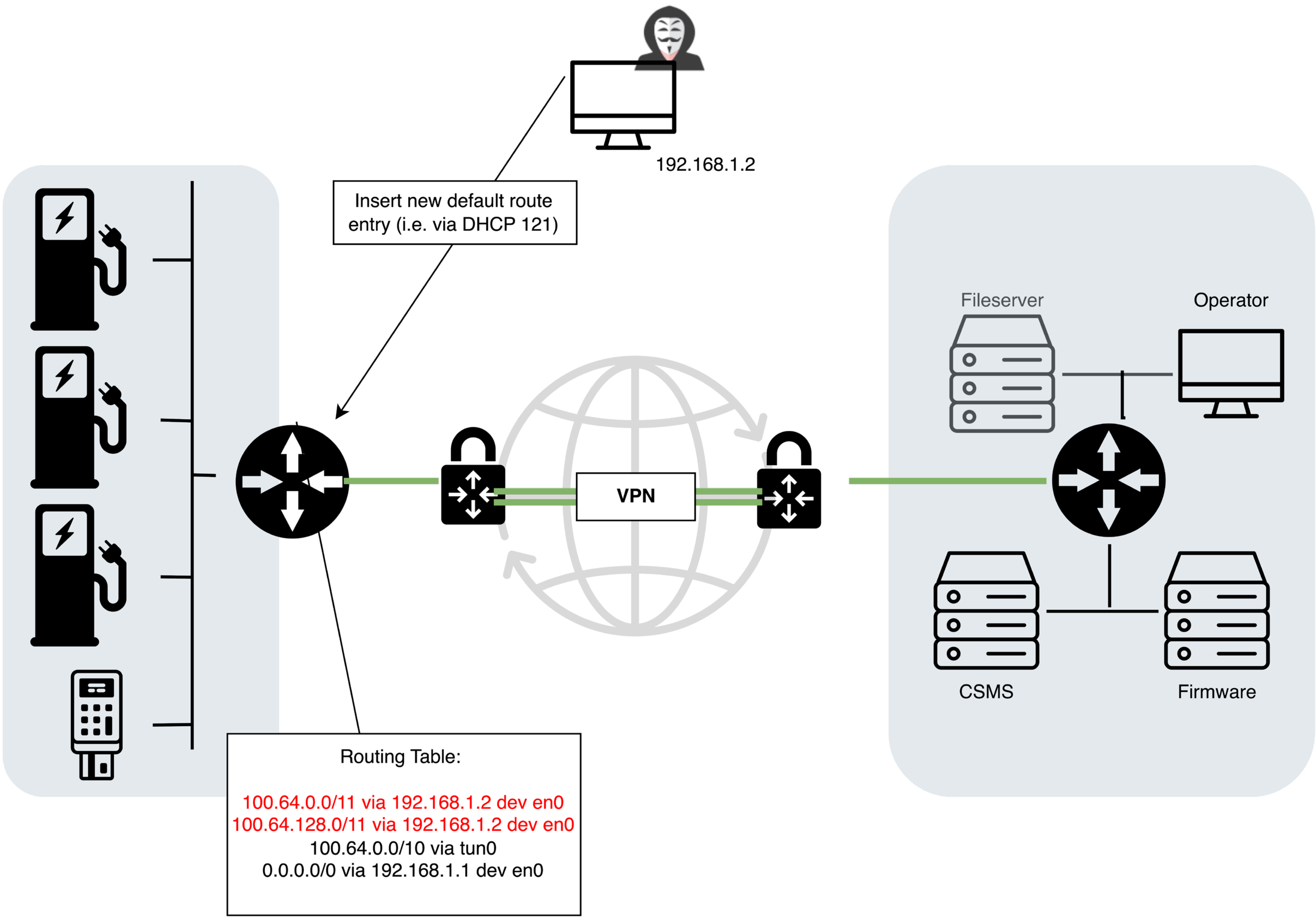
'TunnelVision' Attack Leaves Nearly All VPNs Vulnerable to Spying

TunnelVision is an attack developed by researchers that can expose VPN traffic to snooping or tampering.

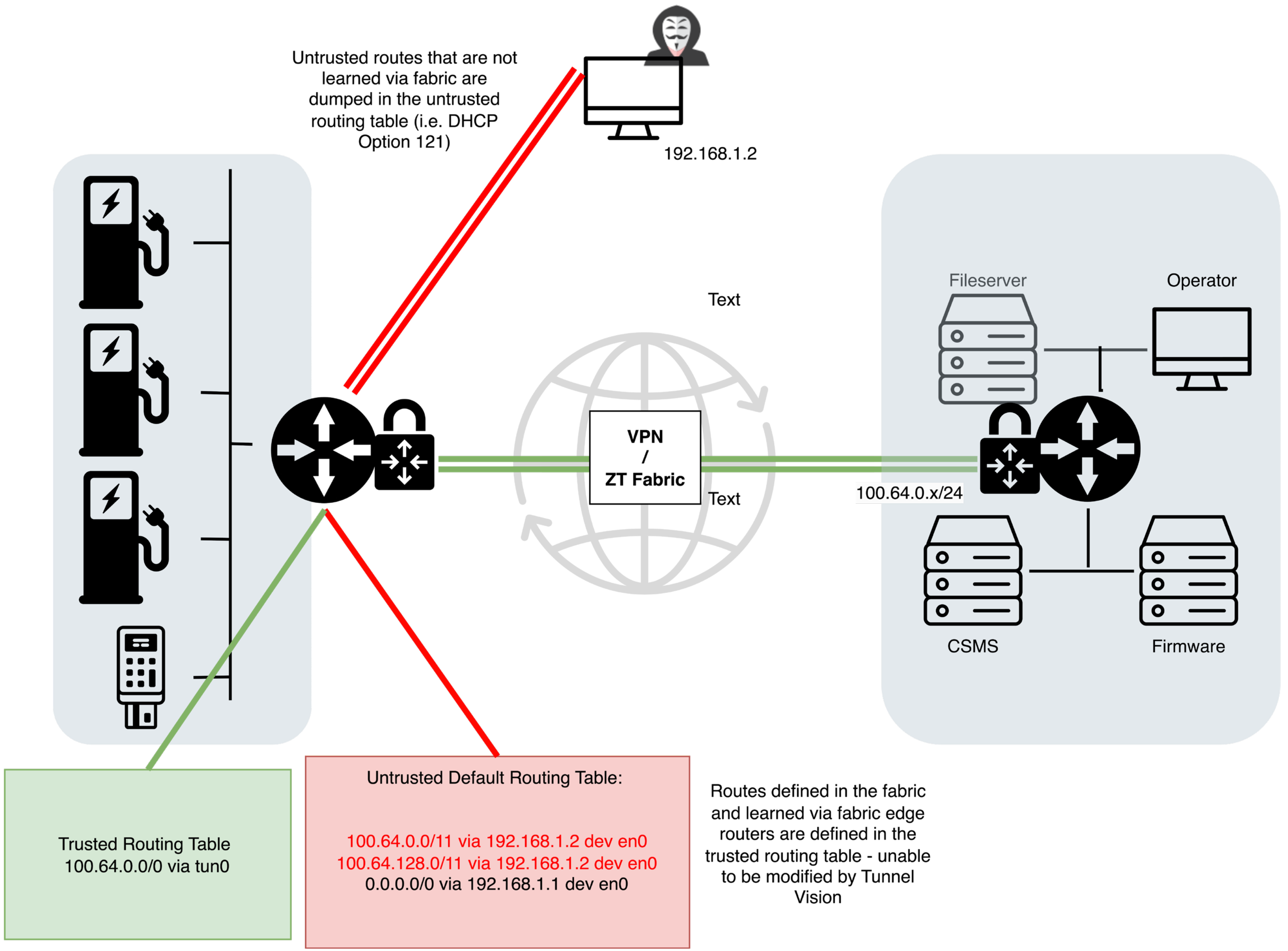
Case Study: Tunnel Vision



Case Study: Tunnel Vision



Trusted Routing via Fabric



Post Quantum Cryptography (PQC) Overview

Post Quantum Cryptography is designed to be secure against both quantum and traditional computing threats.

Objective: Study the impact of PQC and develop guidance for an orderly transition

Motivation:

- A Cryptanalytically-Relevant Quantum Computer (CRQC) could potentially break traditional public-key cryptography in a relatively short amount of time
- Cryptosystem transitions are non-trivial

Outcomes:

- Identify conventional public-key cryptography applications
- Assess PQC impacts with a test-and-measure approach
- Identify challenges
- Develop guidance for an orderly PQC transition

PQC Background

Quantum bit (qubit) can be 0, 1, or 0 and 1 at the same time

⟶ Quantum register stores a superposition of 2^n states, whereas a conventional register stores just 1 value

A QRQC will efficiently attack today's digital signatures and key exchange schemes

⟶ The foundations of trust, communication, and data protections are compromised

PQC are cryptosystems that are designed to be secure against quantum and conventional computers

- Execute on conventional computers
- Rely on different underlying mathematical foundations

Why start now?

- Q-Day uncertainty
- Cryptosystem transitions can take a decade or more
- Vehicles and infrastructure are long lived

Goal: Achieve full PQC adoption before it becomes critical

State of the PQC Standards

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Of August 13th, PQC standards FIPS 203, FIPS 204, and FIPS 205 are effective!

- FIPS 203: ML-KEM (Kyber) for secure key establishment.
- FIPS 204: ML-DSA (Dilithium) for general-purpose digital signatures.
- FIPS 205: SLH-DSA (SPHINCS+) geared for "sign-once, verify-many" digital signature use cases.

Upcoming developments

- FN-DSA (Falcon) is under development
- **Round 4** to select an alternate key encapsulation mechanism; 3 candidates, with an announcement expected in Fall 2024.
- Selection process for additional digital signature schemes focusing on alternatives to structured lattices, with shorter signatures and faster verification; **Round 2** expected in Fall 2024.

Other developments

- **X25519Kyber768** has been successfully deployed
- Open Quantum Safe library is widely utilized for quantum-safe cryptographic implementations
- Ongoing work in support WebPKI and TLS adaption

PQC Takeaways

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- **Current Hardware Compatibility**: Existing hardware can effectively execute PQC algorithms for ISO 15118 and OCPP functions due to long-lived connections and generous protocol timeouts.
- **Protocol Enhancements**: Protocol fields carrying signatures and certificates may need extension to accommodate PQC requirements.
- **TLS 1.3 Adoption**: TLS 1.3 is likely essential to support PQC.
- **Software and Storage Considerations**: Additional or updated cryptographic libraries and enhance private key and certificate storage capabilities.
- **Certificate and Key Management**: EV chargers will likely require multiple certificates using different cryptosystems, necessitating robust certificate management strategies.
- **Consumer Cloud API Challenges**: Increased data size from PQC could create significant issues for consumer cloud interfaces due to high connection volumes and the interaction between TLS and TCP.
- **Future Decisions**: In the longer term, consider whether deploying ECDSA P-521 and edDSA infrastructure remains sensible in the context of evolving PQC standards.

Zero Trust & PQC Conclusion and Next Steps

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Review

- Completed report discussing a reference architecture and evaluation based on a selected solution set
- Explored the application of Zero Trust in WiFi networks
- Finalizing a report on how PQC adoption impacts EV charging use cases
- Directing two university design teams working on EV-EVSE Zero Trust
- Industry partner relationships are deepening with each engagement

Next steps

- Summarizing Zero Trust application and developing guidance as “blueprints”
- Demonstrate PQC integration in EVerest
- Engage and build relationships with stakeholders – Identify field deployment partners

Partnerships

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Successes

- **Collaborated on Zero Trust architectures for EV Charging Infrastructure**
  - Collaborated to design, prototype and evaluate reference architectures with partners **Cisco**, **NetFoundry**, and **Patero**.
- **Reviewed Cybersecurity and Zero Trust Plans**
  - Collaborated with a **PLM** , an electric power engineering consulting and design firm, to enhance security strategies for EV charging.

What We Can Offer

- Sharing a comprehensive understanding of Zero Trust approaches tied to EV charging infrastructure
- Conduct a review of network architectures to identify areas of implicit trust and recommend Zero Trust security strategies
- Evaluate alternatives using a vendor-neutral approach

Our Interests

- **Collaborating with technology providers** to demonstrate the application of zero trust, evaluate its effectiveness, and offer feedback.
- **Conduct field studies** to deepen understanding of operational concerns over extended periods.
- **Engaging with charging station operators and network providers** to understand their concerns, processes, workflows, and priorities regarding zero trust and network security; testing and evaluating prototype Zero Trust solutions.

Thank You!

Thomas.Carroll@pnnl.gov

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Questions

- Where is Zero Trust implementation on your organization's cybersecurity roadmap?
- What are the challenges slowing your Zero-Trust-for-EVCI adoption?
- What information, research, or resources would help you adopt Zero Trust or strengthen network security?

Thank You!

Thomas.Carroll@pnnl.gov

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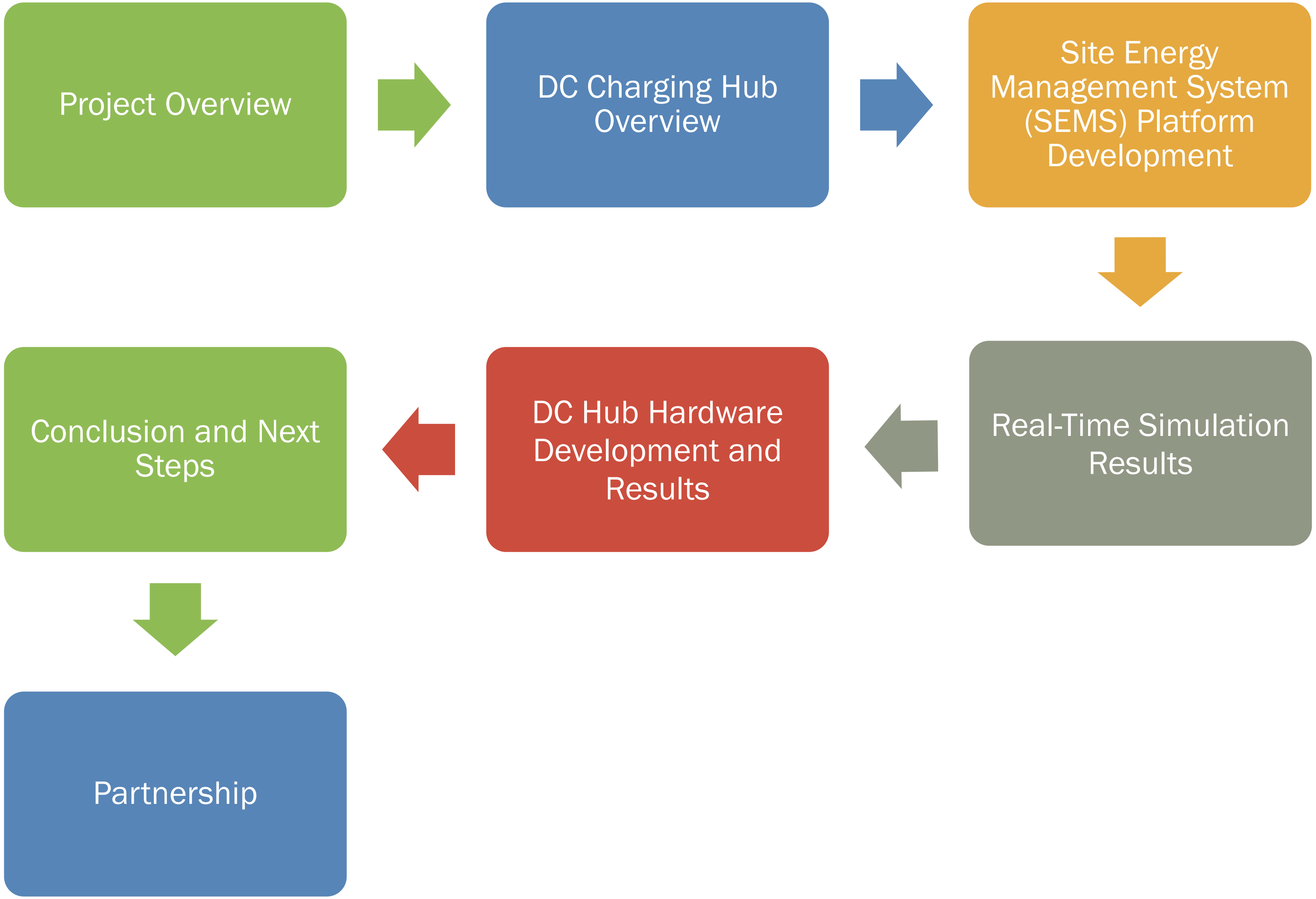
High-Power Electric Vehicle Charging Hub Integration Platform (eCHIP)

John Kisacikoglu, Ph.D.
Team Lead, EV Grid Integration
NREL

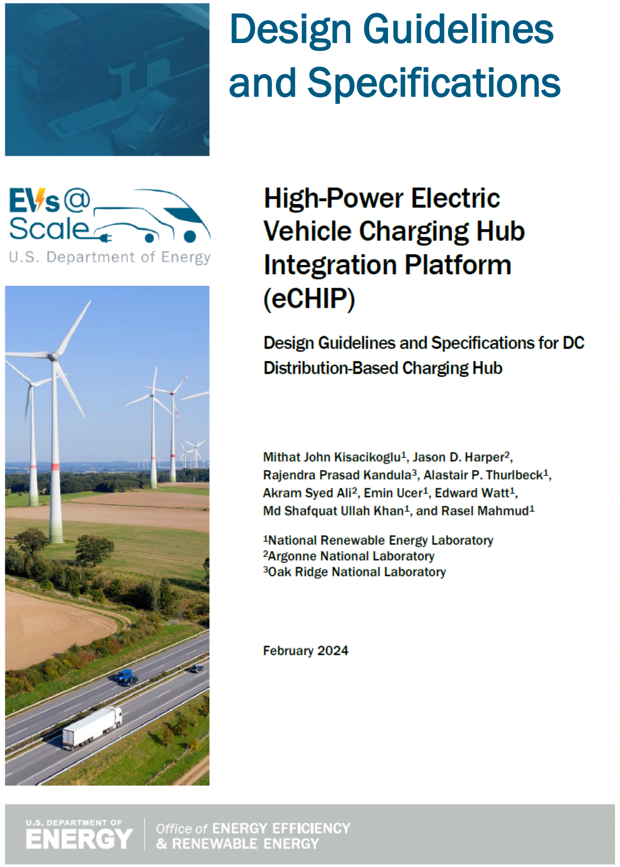
September 25, 2024

Outline


Project Overview
DC Charging Hub Overview
Site Energy Management System (SEMS) Platform Development
Real-Time Simulation Results
DC Hub Hardware Development and Results
Conclusion and Next Steps
Partnership

eCHIP Report Publication Outcomes

- Two eCHIP public reports are prepared.
- Providing more in-depth technical information about summary of our progress.


Design Guidelines and Specifications

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

Design Guidelines and Specifications for DC Distribution-Based Charging Hub

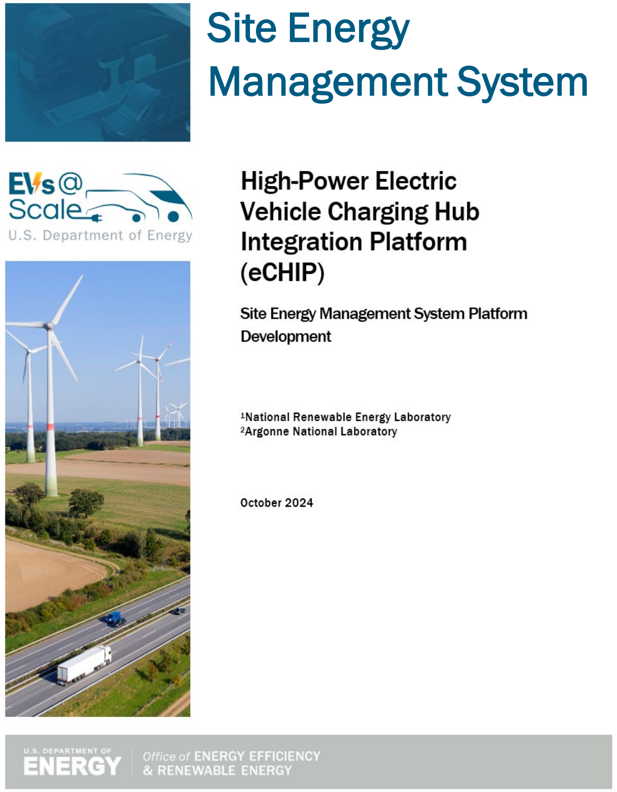
Mithat John Kisacikoglu[1], Jason D. Harper[2], Rajendra Prasad Kandula[3], Alastair P. Thurlbeck[1], Akram Syed Ali[2], Emin Ucer[1], Edward Watt[1], Md Shafquat Ullah Khan[1], and Rasel Mahmud[1]

[1]National Renewable Energy Laboratory
[2]Argonne National Laboratory
[3]Oak Ridge National Laboratory

February 2024

U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

https://www.nrel.gov/docs/fy24osti/86326.pdf


Site Energy Management System

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

Site Energy Management System Platform Development

[1]National Renewable Energy Laboratory
[2]Argonne National Laboratory

October 2024

U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

In press

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

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Objective: Develop plug-and-play solution allowing charging site to organically grow with additional chargers and DERs through predefined compatibility with standards that will ensure interoperability

Outcomes:

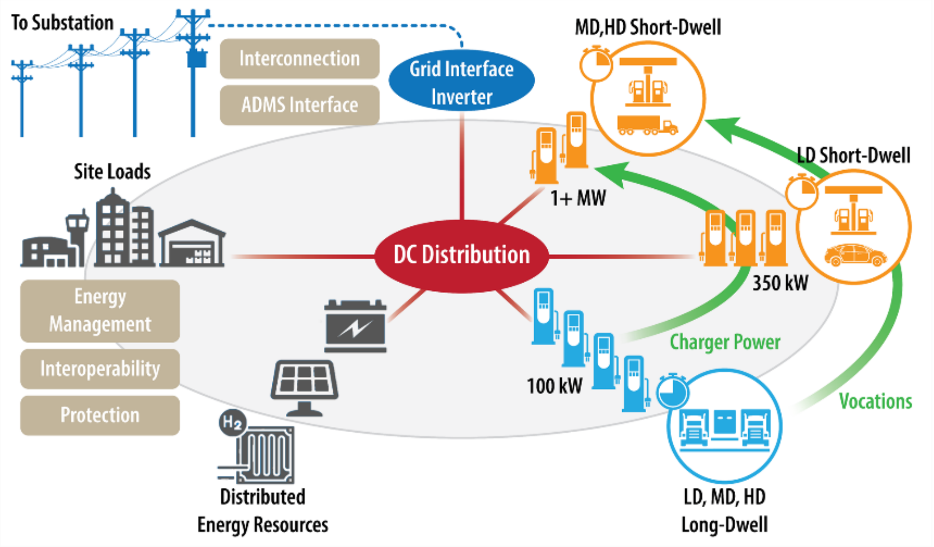
- Determine interoperable and scalable hardware, communication, and control architectures for high-power charging facilities
- Broadly identify limitations and gaps in DC distribution and protection systems that allow for modular HPC systems
- Develop and demonstrate solutions for efficient, low-cost, and high-power-density DC-DC for kW- and MW-scale charging

- John Kisacikoglu (PI)
- Yukihiro Hatagishi
- Derek Jackson
- Namrata Kogalur
- Vaibhav Pawaskar
- Alastair Thurlbeck
- Emin Ucer
- Ed Watt

NREL

- Akram Ali
- Jason Harper
- Saransh Jain
- Bryan Nystrom

Argonne NATIONAL LABORATORY



Hub Operation Analysis using EVI-EnSitePy

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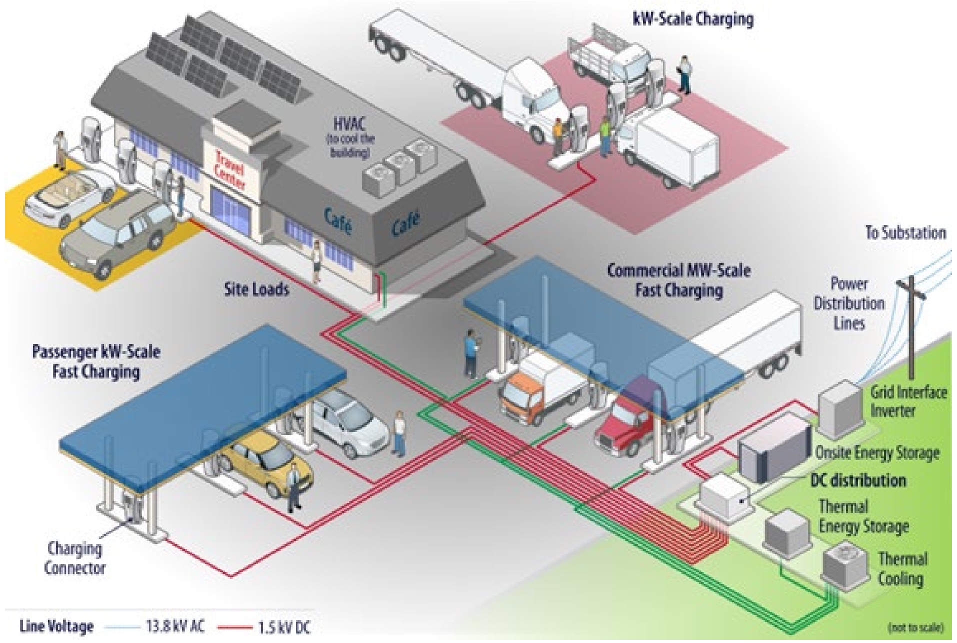
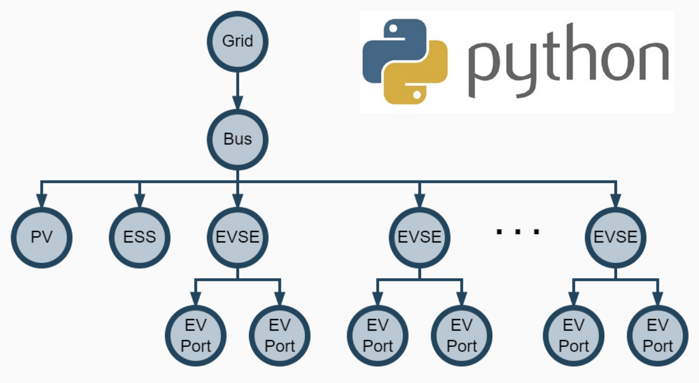
EVI-EnSitePy developed under eCHIP uncovers advantages of DC hub operation:

- Different hub configurations (AC or DC)
- Different distribution voltage and site/port power levels
- Cost analysis based on capital and operational expenses
- Grid peak-demand requirements
- Deep visibility on station operation
  - Charging time
  - Queuing time
  - Utilization
- Site control system implementation
- Utilization of custom charging profiles



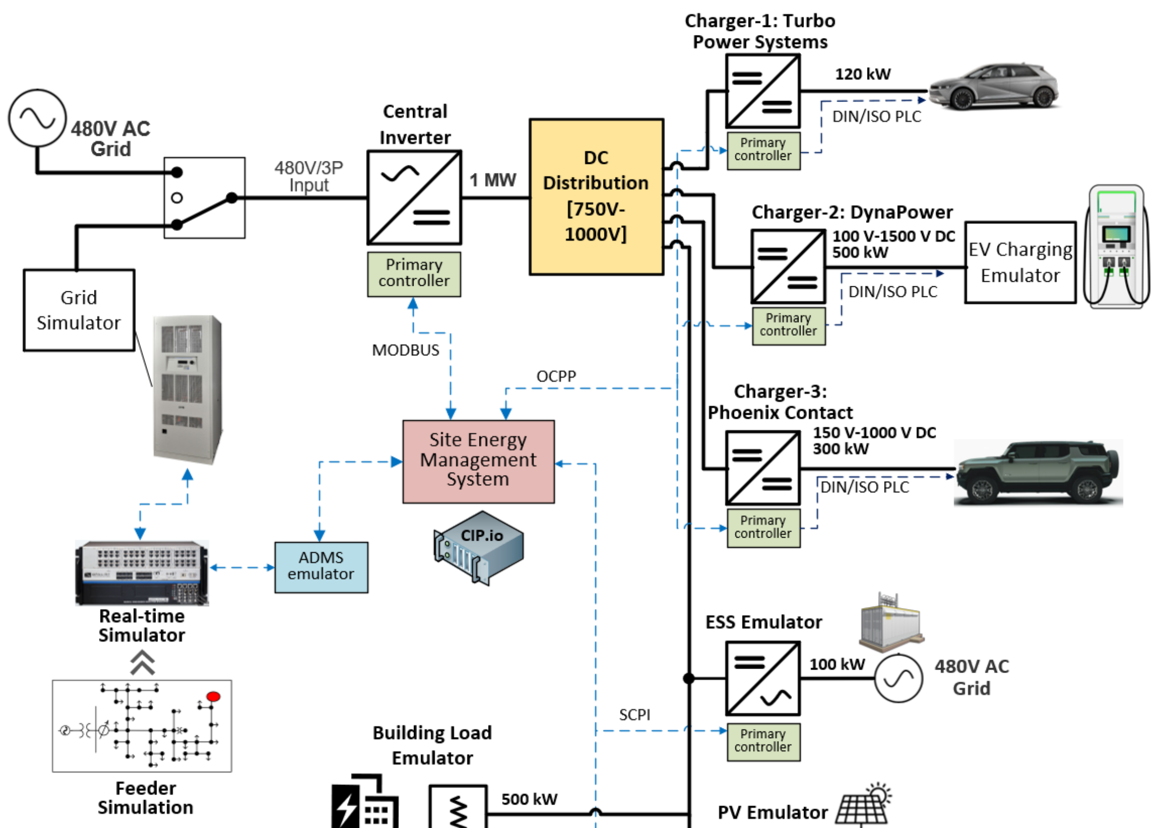


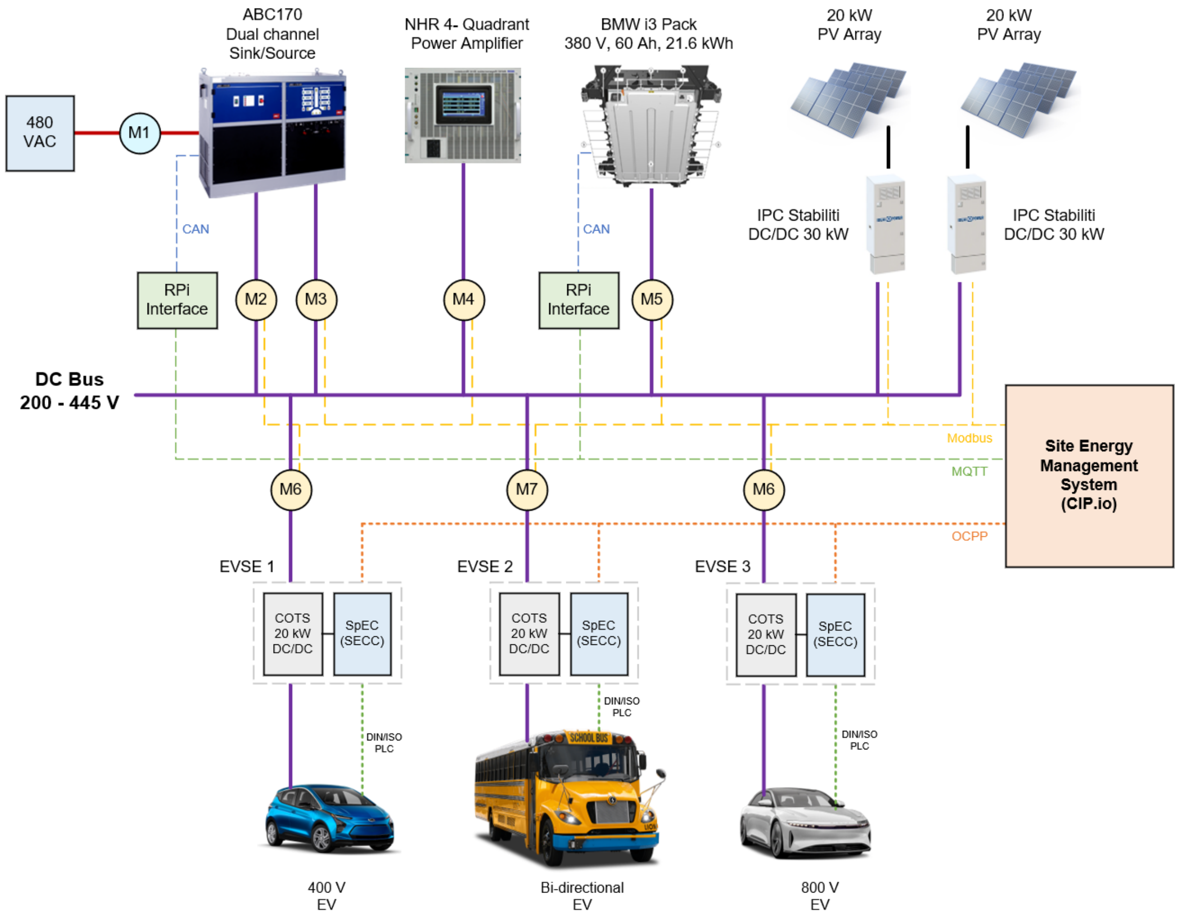
Charging Hub with On-Site ESS and Solar PV

EVI-EnSite
https://www.nrel.gov/transportation/evi-ensite.html

[1] D. Jackson, E. Ucer, M. J. Kisacikoglu, and A. Thurlbeck "A Comparison of AC and DC Distribution Architectures for EV High Power Charging Facilities," ECCE, Oct. 2024, to be presented.

DC Charging Hub Overview

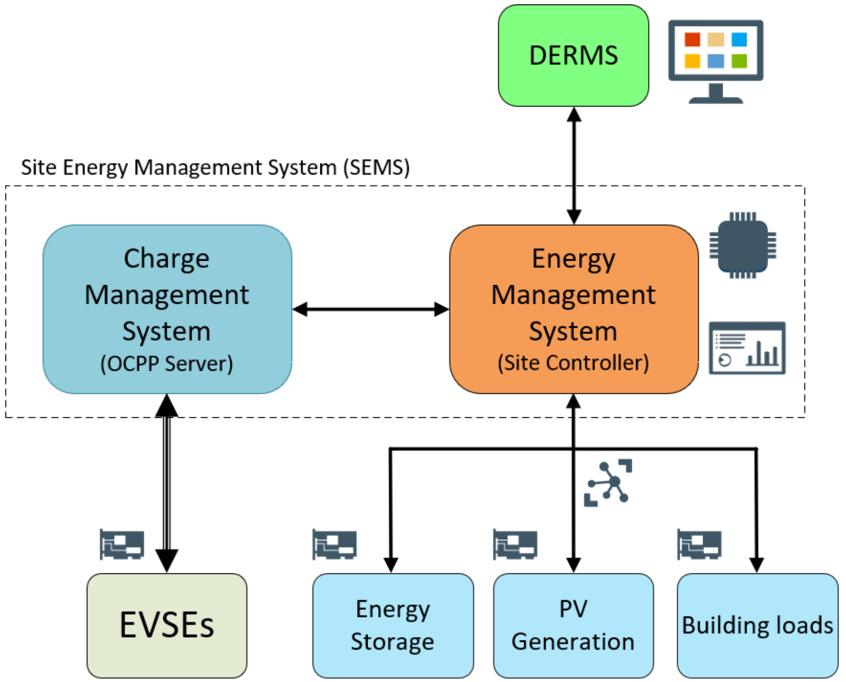


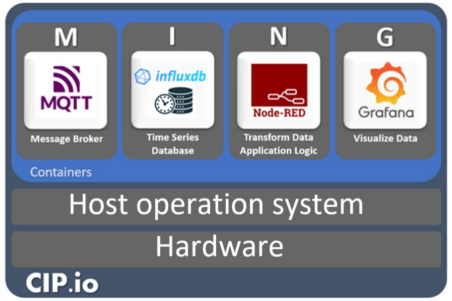


Site Energy Management System (SEMS) Platform

SEMS platform is developed by Argonne and NREL

- Real-time monitoring and control of DC hub
- OCPP 1.6J and 2.0.1 for EV charging
- MQTT for non-standardized DC hub integration monitoring and control
- Controllers will handle communication for DC chargers and EV
  - SpEC module, Vector, Pionix, Raspberry Pi, etc.
- **Custom site-control applications are created in Node-RED, Python and C/C++**





https://github.com/Argonne-National-Laboratory/CIP.io

SEMS Site Controller Approaches

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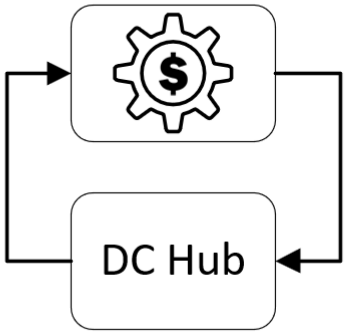
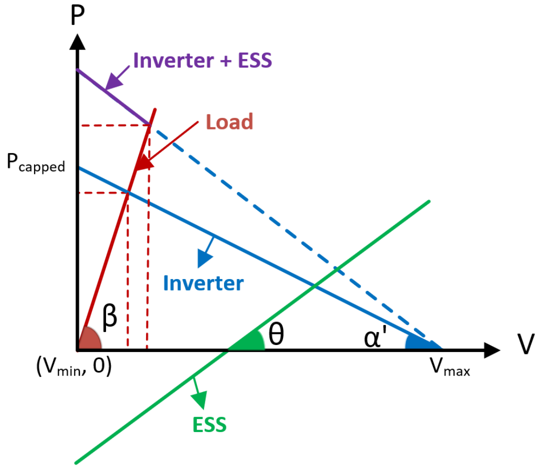
Optimized



- Optimized for long-term performance
- Customizable to support complex objectives
- Centralized and slower operation
- Real-time connectivity requirement
- Requires forecasting

+

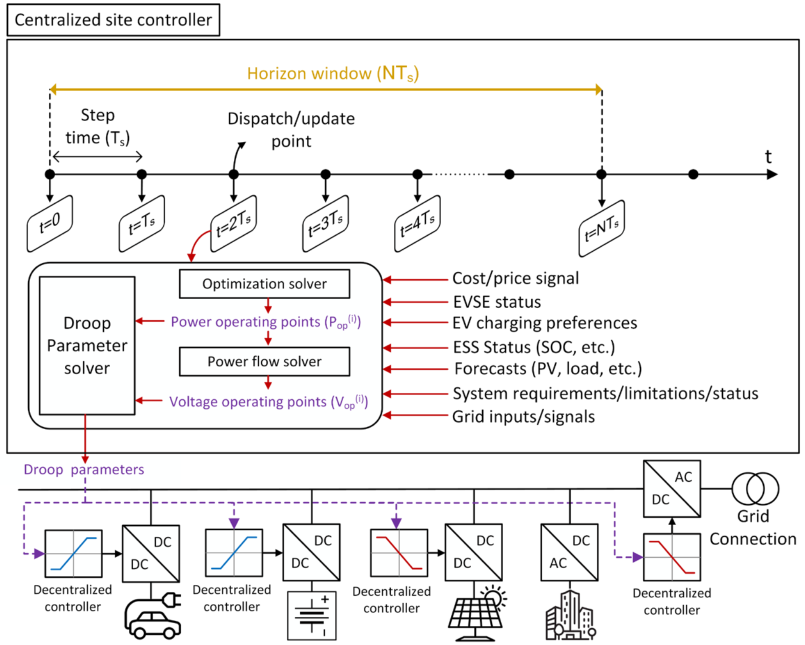
Droop-based



- Decentralized and faster operation
- Minimal communication requirement
- Sub-optimal performance
- Limited scope for defining operational objectives

=

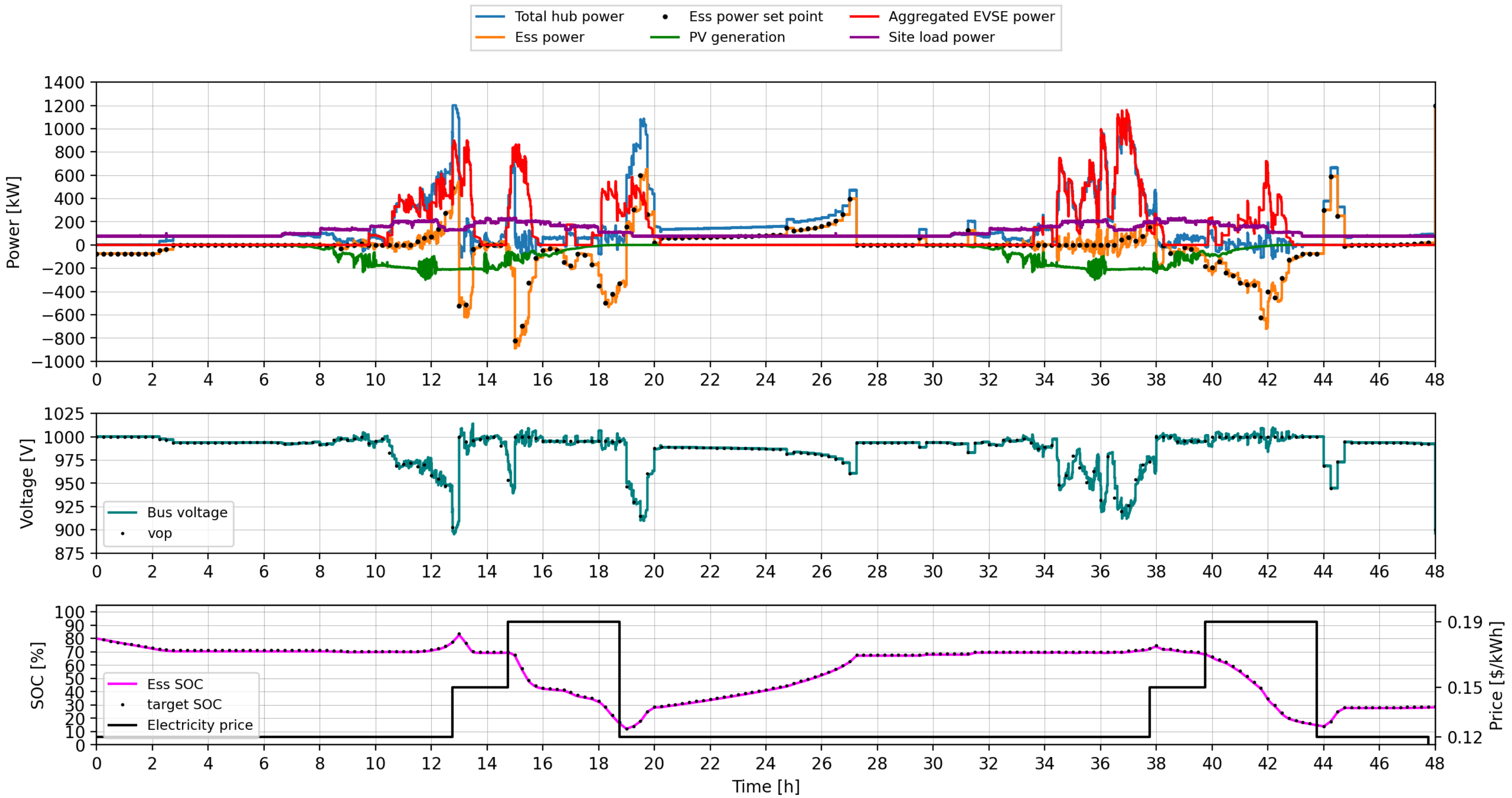
Hybrid Controller



- Multi-layer, hierarchical
- Maximizes longer term operational benefits
- Maintains robustness and fast response
- Reduces communication need
- Requires forecasting

[2] E. Ucer, et al. “Controller Hardware-in-the-loop Modeling and Operation of a High-power DC Charging Hub,” ECCE, Oct. 2023
[3] E. Ucer, et al. “Hybrid Energy Management with Real-Time Control of a High-Power EV Charging Site,” ECCE, Oct. 2024, to be presented.

Simulation in EVI-EnSitePy using Hybrid Controller



DC hub assets:

- 1 Grid-tie inverter
- 10 EVSEs
- 1 ESS
- 1 PV
- 1 Site load

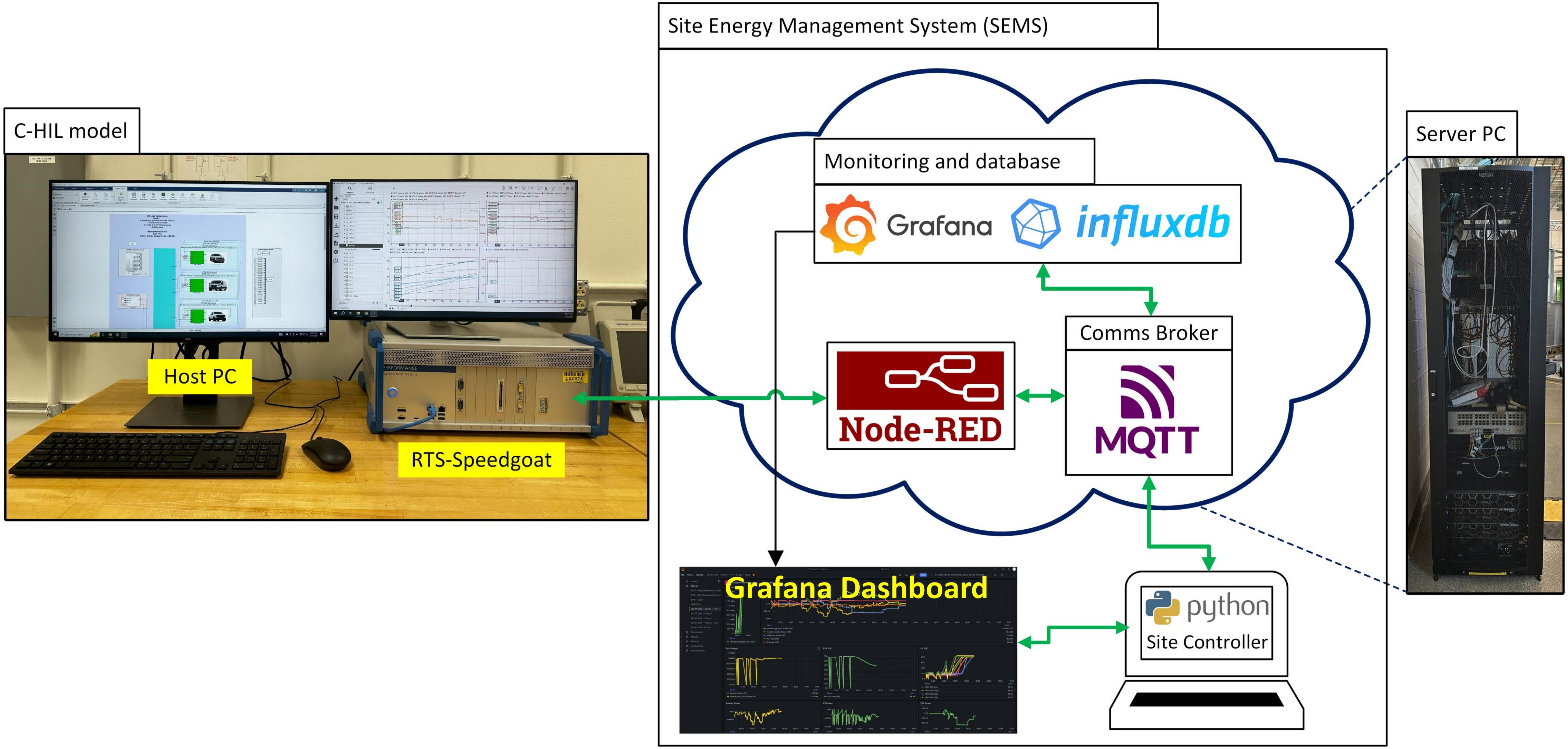
DC hub specifications

Component Type	Power Rating	Voltage/Current/Energy Ratings
Inverter	1,200 kVA	Input: 3-ϕ, 480 VAC Output: 1000 VDC
DC Bus	-	1000 VDC
EVSE Type-1	150 kW rated	Input: 1000 VDC Output: 400 VDC
EVSE Type-2	175 kW rated	Input: 1000 VDC Output: 400 / 800 VDC
EVSE Type-3	350 kW rated	Input: 1000 VDC Output: 400 / 800 VDC
EV Type-1	235 kW max	800 VDC, 70-80 kWh
EV Type-2	108 kW max	400 VDC, 60-70 kWh
EV Type-3	155 kW max	370 VDC, 90-100 kWh
ESS	1,500 kW max	1000 VDC, 2 kWh
PV	235 kW max	-
Site load	269 kW max	-

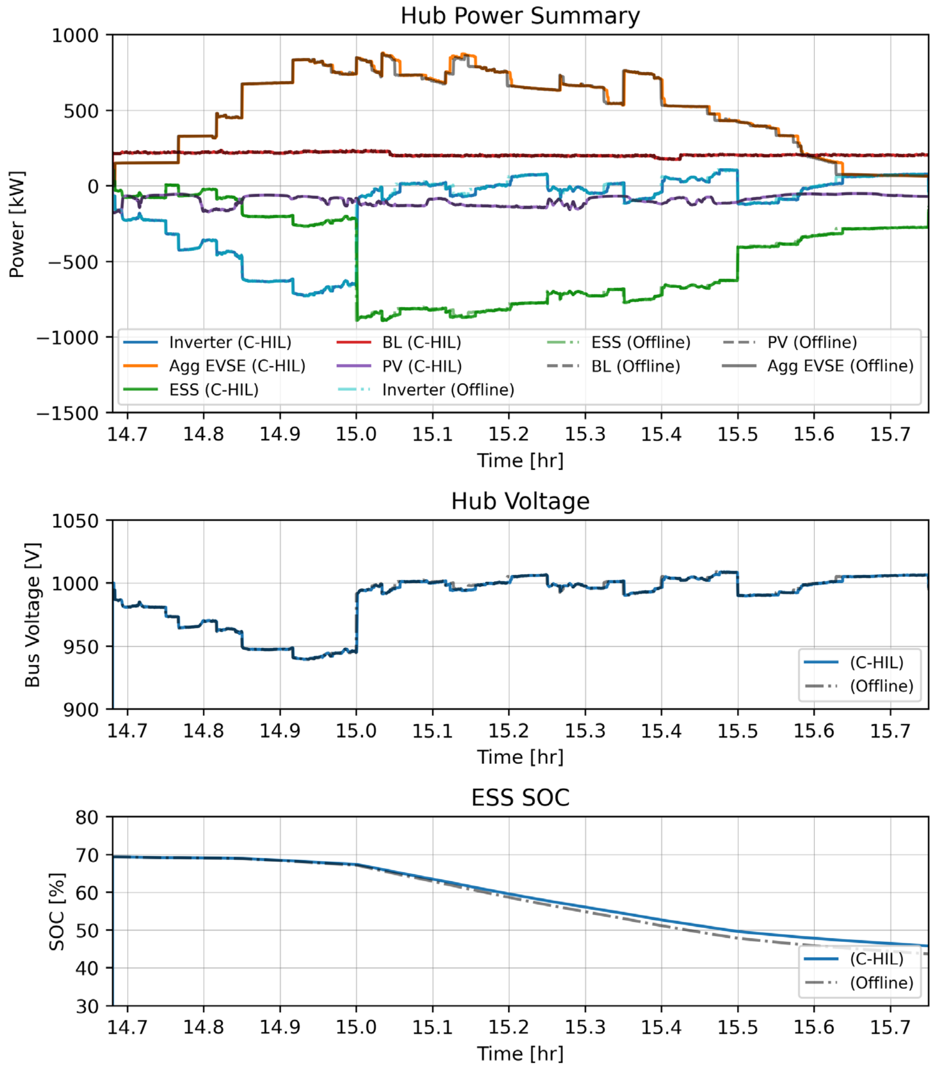
- Minimizing total cost of energy received from utility grid.
- EVSE charging uncontrolled.
- Load forecasting is incorporated into model predictive control.
- ESS power setpoint is updated every 15 min, with new droop coefficients calculated based on updated operating point.

[3] E. Ucer, et al. “Hybrid Energy Management with Real-Time Control of a High-Power EV Charging Site,” ECCE, Oct. 2024, to be presented.

Real-time Simulation Platform and SEMS Integration

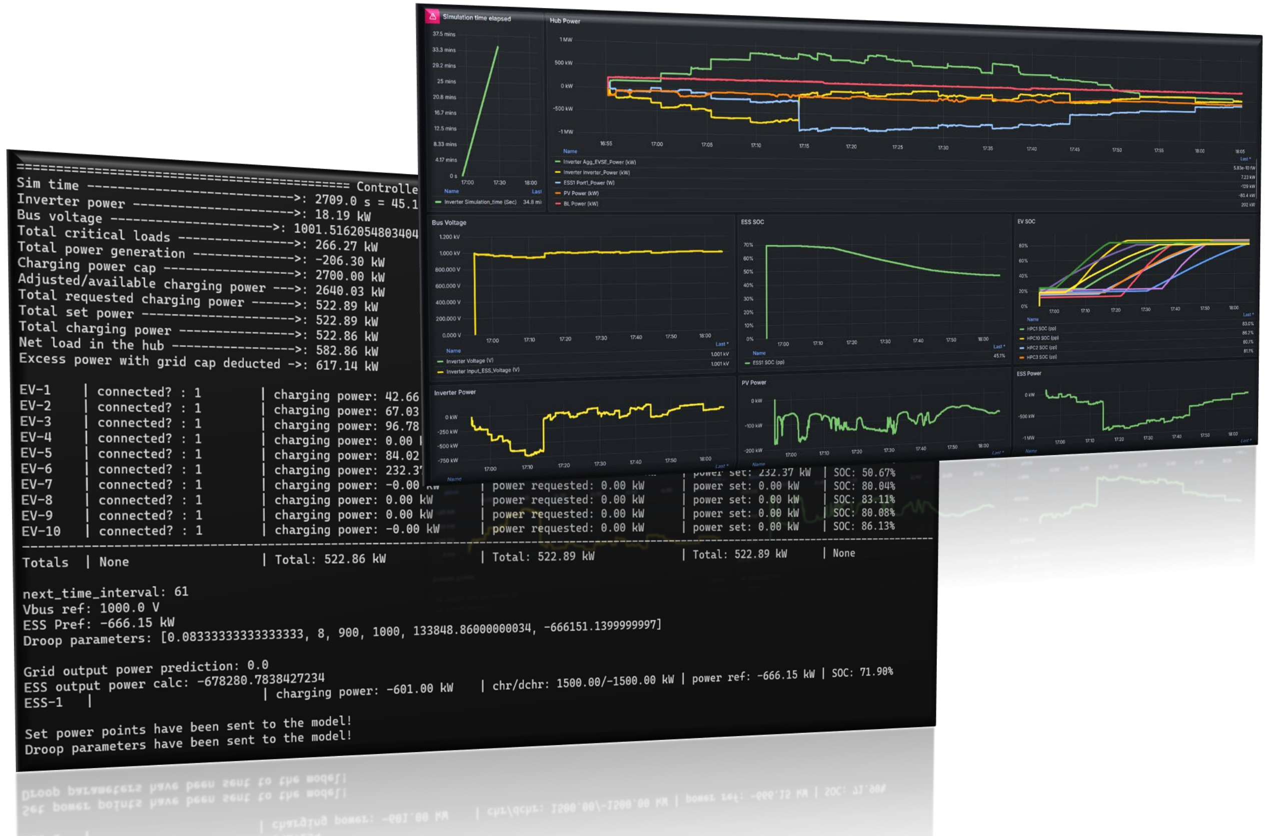


Validation of Real Time Simulation Model



Real-time and offline simulation results comparison

- 1h window was selected from offline 2-day simulation.
- Results closely match offline simulation except for minor differences due to modeling fidelity changes.



Snapshot of SEMS real-time control console and Grafana dashboard

Experimental Implementation: Decentralized Droop Control

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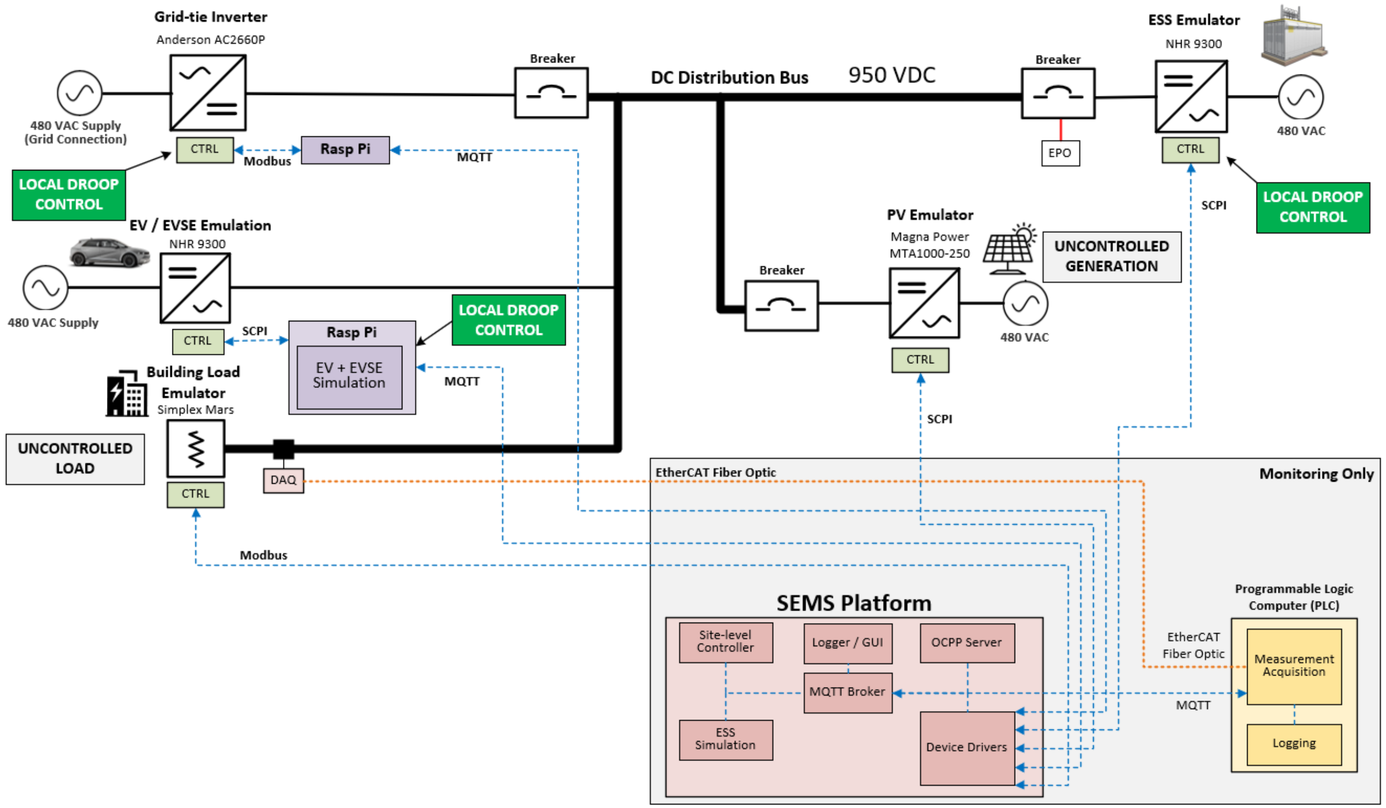
- Droop controllers implemented at each DC hub node.
- Inverter and ESS set a bus voltage reference in response to their measured output current.
- EVSE sets a charging power limit in response to its measured bus voltage.
- PV and building load operate as uncontrolled generation and load.







Anderson AC2660P (GTI); NHR 9300 (EV/EVSE Emulation); Simplex Mars (Building Load); Magna Power MTA1000-250 (PV Emulation); NHR 9300 (ESS Emulation)

Decentralized Droop vs Centralized Rules-based Control

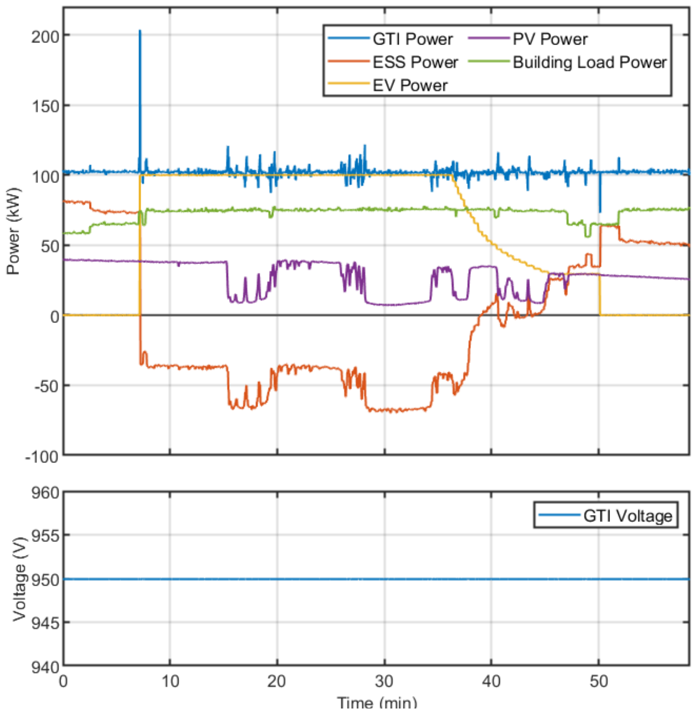
- With droop control, there is no centralized controller.
- Local controllers implement their respective droop functions, and DC hub operates autonomously.
- In rule-based control, a centralized controller continually dispatches the ESS power in response to the measured loads and generation.

Centralized Rule-based Control

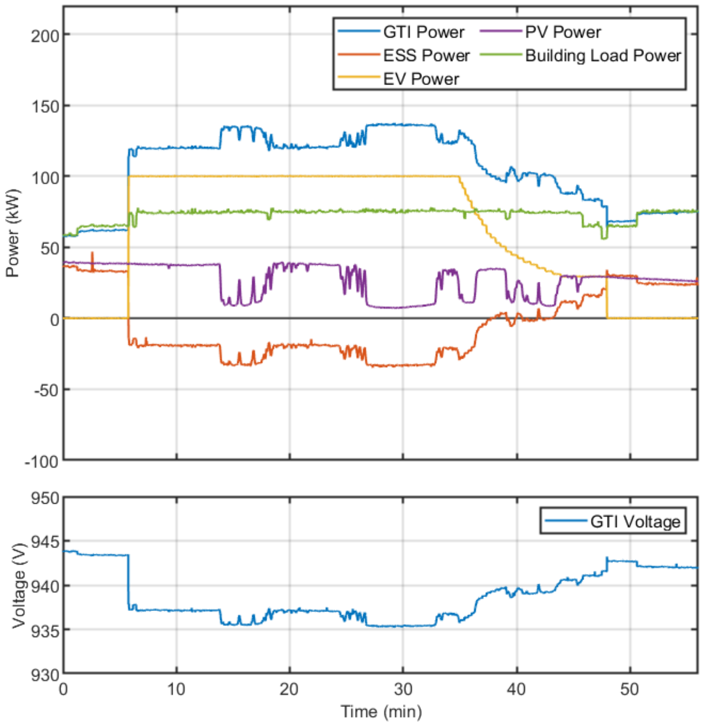
- Ensures equipment is fully utilized
- Requires communication
- Slower response to transients

Decentralized Droop Control

- No real-time site-level communication or central controller required
- Improved resiliency
- Very fast transient response
- Cannot achieve optimal energy management and full site utilization
- Connected equipment must tolerate a range of bus voltages (swinging bus voltage)



Centralized Rule-based Control



Decentralized Droop Control

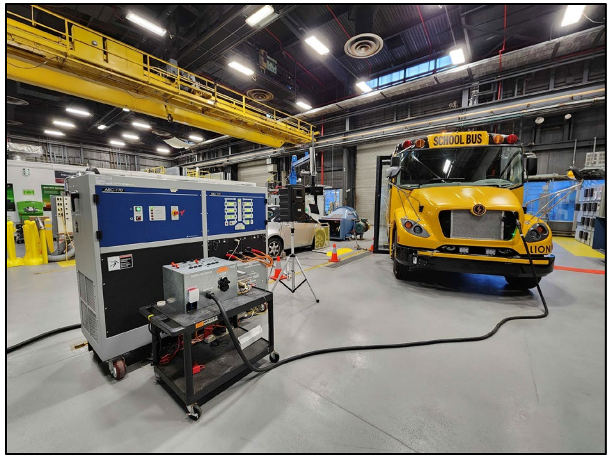
Bidirectional Power Transfer (BPT)

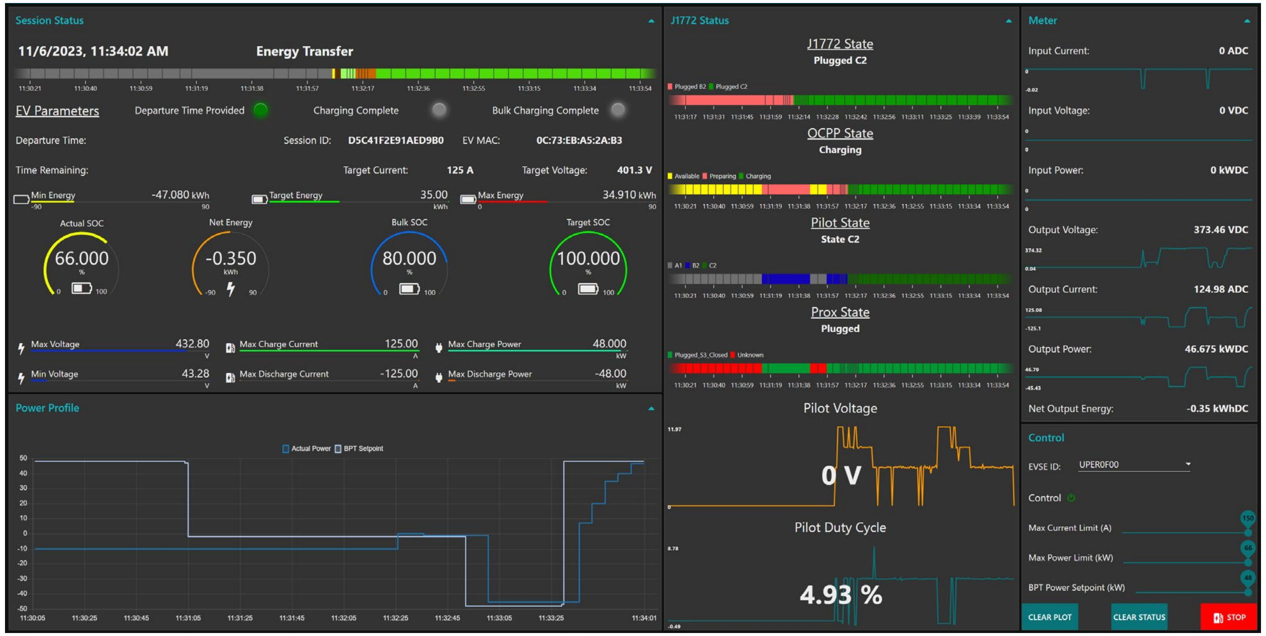
- Successfully demonstrated SpEC performing a dynamic BPT charge/discharge session
  - **Lion Electric bus** using ISO 15118-2 BPT message set
  - ±48 kW charge and discharge
  - Custom Node-RED dashboard for real-time dynamic monitoring and control

- Tested bi-directional capabilities of COTS DC/DC modules at 400V using ABC-170 as source and sink

- Exploring other non-standard BPT methods using DIN 70121 and ISO 15118 where some vehicles allow discharging up to a certain power and time limit

- Based on discharge tests done by PIONIX to check the bidirectional charging readiness of existing commercial EVs

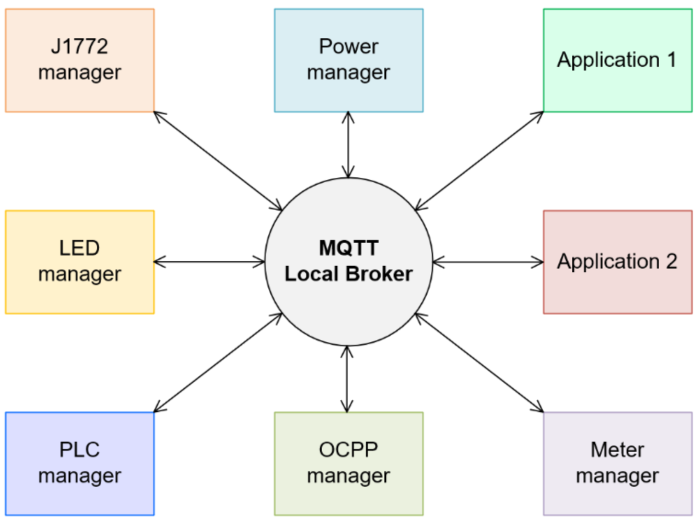




Low-Power DC-coupled EVSE

- **SparQ - Low-Power DC-coupled EVSE**
  - Develop EVSE framework for COTS DC/DC modules to demonstrate HPC charging
  - Compact 20 kW UL certified DC/DC modules
  - Bi-directional power transfer ready
  - ANL SpEC module as SECC
  - Support DIN 70121, ISO 15118
  - Support OCPP 1.6J and 2.0.1
  - Modular MQTT architecture for applications

SpEC Modular Architecture

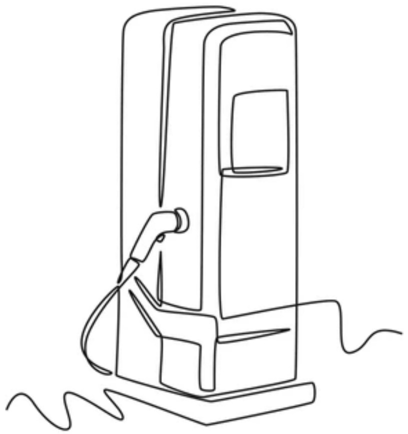


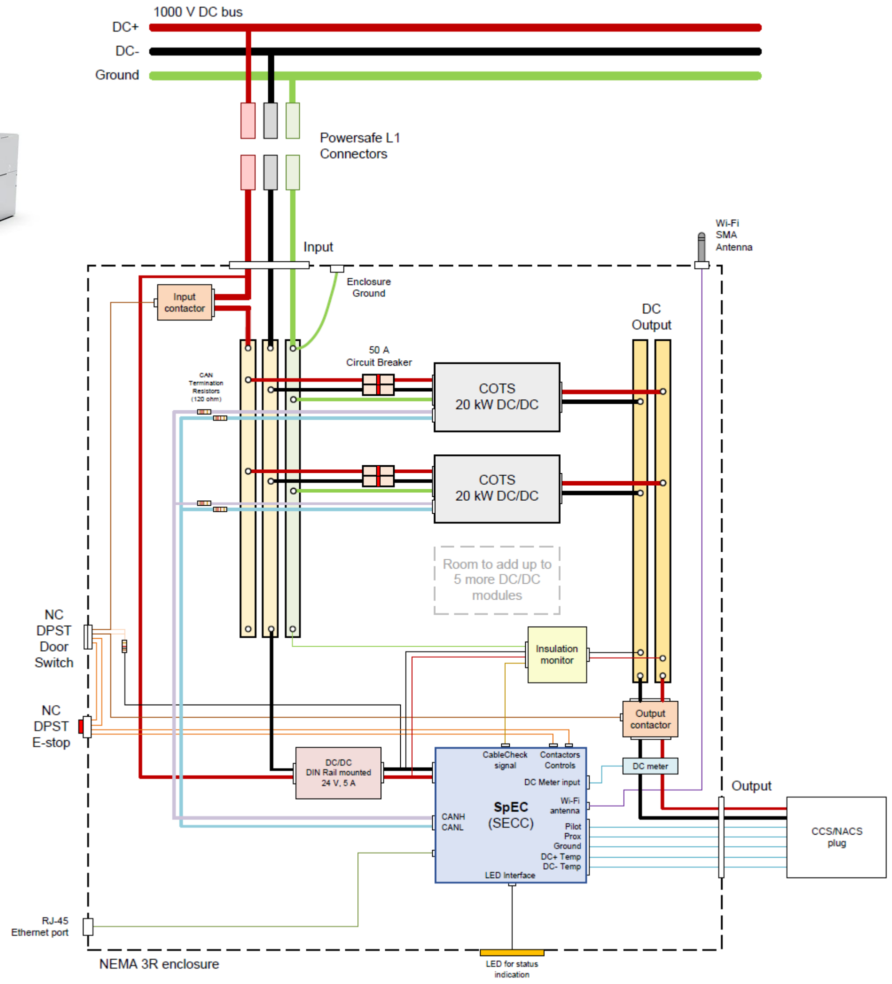
Argonne NATIONAL LABORATORY

SPARQ

Compact size:
15" x 9" x 3.5"

CE CB UKCA
RoHS





High-Power Charging Stations - Challenges and Barriers

Challenges / Barriers	eCHIP Project Solution
Interoperability of different hardware, communications, and controls.	Open-source SEMS platform to interface between hardware from multiple manufacturers using a variety of communication protocols. Any desired site control strategy can be deployed on the SEMS platform.
For a DC distributed charging hub, **DC protection** is more challenging and less mature than AC protection.	A DC load-center is currently being acquired which includes mechanical DC protection devices for all connected hub components. Exploring other protection mechanism as well.
SEMS: Difficult to ensure **scalable**, reliable, fast, and optimized operation <u>all at the same time</u> → **Increasing data, computation and communication needs** with increased size and complexity.	High-fidelity real-time simulation capability within **ARIES platform** at NREL for easier scalability and high-speed communication. Deploying time-synchronized, distributed, modular data acquisition approach. Exploring PLCs and industrial computers for robust SEMS deployment.

Conclusion and Next Steps

Conclusions and Demonstrated Benefits

- DC Hub experimental test platform combines an open-source SEMS with a DC-coupled hardware system.
- Various controller architectures have been evaluated.
- Hybrid control approach optimizes long-term operations while simultaneously enhancing autonomy, robustness, and responsiveness through its voltage-based droop control.
- Droop-control has been demonstrated successfully on DC hub on grid-tie inverter, emulated ESS and EVSE.

Next steps

- Implementation of hybrid controller on experimental platform
- Scaling up C-HIL platform using larger RTS within **ARIES**
- Continued focus on demonstration on various real-world use cases

Successful Partnerships

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Power Electronics Control Integration

- Dynapower
  - DC/DC charger development with custom control integration
- Turbo Power Systems
  - DC/DC EVSE with custom control integration

Site-Level Operation

- Total Energies
  - DC hub modeling, techno-economic analysis
- Eaton
  - COTS SEMS controller integration to EVSE hardware

Utility Partnerships

- Colorado Springs Utilities and Smarter Grid Solutions
  - DERMS integration into SEMS platform

Automotive Partnerships

- Lion Electric
  - School bus V2X demonstration

Typical EVs@Scale Partnerships Include:

- Mutually beneficial topic areas
- Lab research for EVs@Scale funded by DOE*
- Early access to cutting edge research and lab facilities
- NDAs to ensure sensitive information is secure
- In-kind contributions provided by Industry Partners

*Subject to change based on annual funding levels

Partnership Opportunities

- **Site Energy Management System Opportunities**
  - Are you developing SEMS solutions?
  - How can we work together to integrate SEMS solutions in the field?
- **Power Electronics Control Integration**
  - How can we work together to integrate our control solutions to your power electronics hardware?
- **DERMS Integration Opportunities**
  - Would you like to integrate SEMS into DERMS?
- **Automotive Sector Opportunities**
  - Would you like to partner with us on implementation of bidirectional power transfer?

Interested in partnering with us?

Contact eCHIP PI: John Kisacikoglu, NREL

John.Kisacikoglu@nrel.gov

Thank You!

Join us for the

HPC Deep Dive on

Tuesday November 12, 2024

John.Kisacikoglu@nrel.gov

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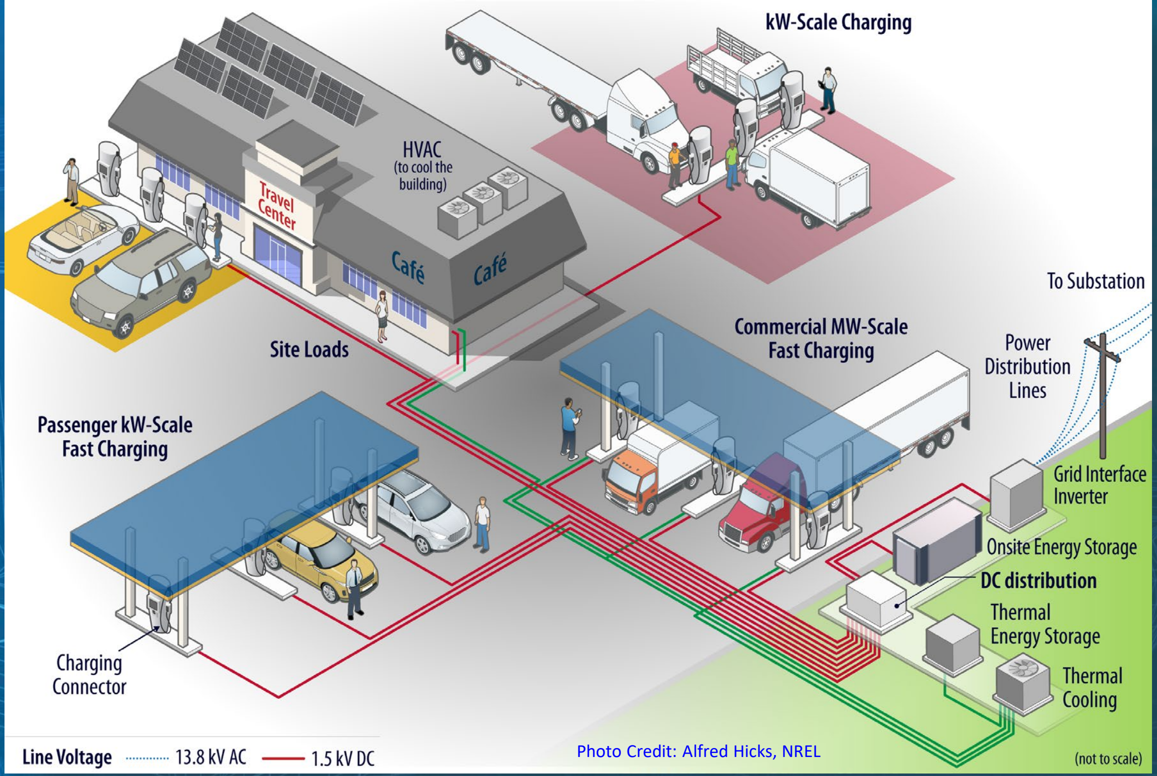


Photo Credit: Alfred Hicks, NREL

EVs @ Scale

U.S. Department of Energy

Semi-Annual Meeting @ INL:

Next-Gen Profiles

Sam Thurston

Sept 25th, 2024

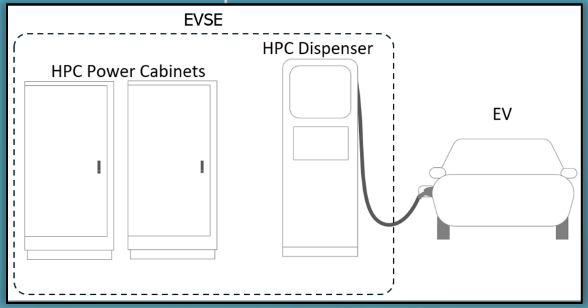
Next-Gen Profiles Overview & Objectives

- Project Specific Objectives:
  - Assess a portfolio of EVs, EVSEs, and Fleets that are expected to utilize High Power Charging (150-400kW) to understand charging rates, time, grid impacts, and asset utilization.
  - Provide DOE, project partners, stakeholders, and the public with insight into the capabilities of HPC, and performance of todays charging infrastructure.

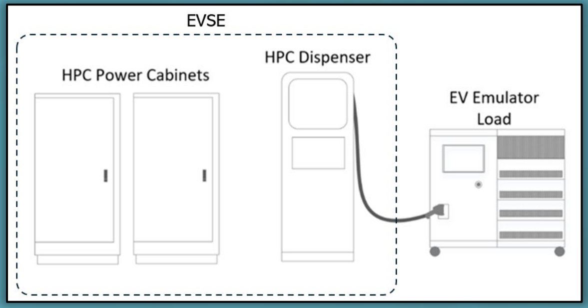
- EVs@Scale Targeted Objectives:
  - 1. Vehicle-Grid Integration: Achieve seamless integration of EV charging, provide data to help make VGI decisions
  - 3. Reliability & Resiliency: Create analysis tools & methods

- Considerations when assessing HPC:
  - Procedures: Standardized, benchmarking, industry reviewed
  - Test Conditions: Nominal vs off-nominal, edge cases, SCM,
  - Equipment: Conductive or wireless, LD/MD/HD, model year, trim, etc.
  - Analysis: Unique & thoughtful methods of performance characterization

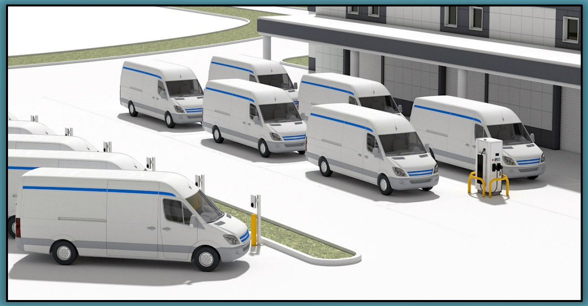
1. EV Profile Capture



2. EVSE Characterization



3. Fleet Utilization



Project Timeline

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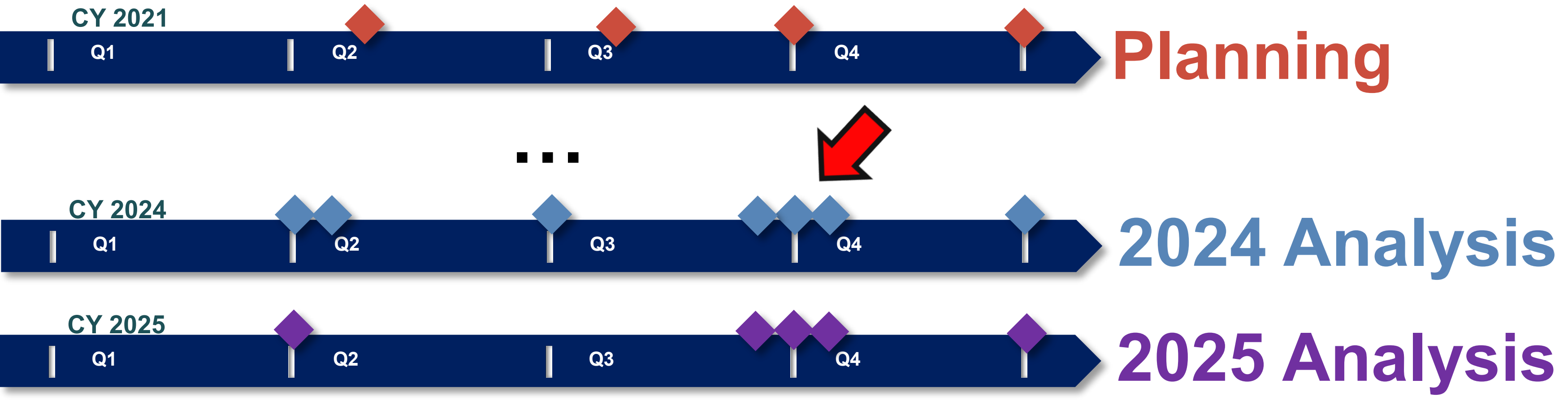


- Completed
- Ongoing
- Future Work

Year 1-3 Milestones

- Y1: Scope definition, procedures, industry buy-in & input — Completed
- Y2: Asset acquisition, data collection — Completed
- Y3: Asset acquisition, data collection, off-site testing, published technical reports — Completed

Year 4 Milestones

- Update test procedures — Completed
- Acquire new assets (EV, EVSE, Fleet data) — Completed
- Integrate grid models with EV profiles — Completed / Ongoing
- Complete conductive profile sets capture — Ongoing
- Complete EVSE Characterization (Low Power V2X incl.) — Ongoing
- Analyze fleet data — Ongoing
- Written Report(s) — Future Work

Year 5 Milestones

- Acquire new test assets — Future Work
- Complete conductive profile sets capture — Future Work
- Complete EVSE Characterization (HP V2X, NACS, MCS) — Future Work
- Analyze fleet data — Future Work
- Written Report(s) — Future Work

Technical Accomplishments 2023-2024

CY2023 Final Reports & CY2024 Procedures Revision

Development
- 4 technical reports completed end of CY2023
- 1 procedures revision completed CY2024 Q1
  - Industry reviewed & comments appiled

Securing Additional Testing Assets

- Confirmed Assets
  - 27 EV
    - 22 LD
    - 2 MD
    - 2 HD
    - 20 Wired
    - 2 Wireless
  - 16 EVSE
    - 7 In-Lab
    - 3 Out-Lab
    - 6 Fleet
    - 14 Wired
    - 2 Wireless

Development
- Acceptance of assets capable of less than 200kW charging (150-400kW range)
- Added 6 EVs, 2 EVSEs, 5 Fleets in 2024
- Increasing analysis capabilities for 2024 reports

Finalized Dissemination Policy

Public
- High-level publicly available reports
- Lowered Cadence Anonymized time-series data

Project Partner Group
- 10Hz Anonymized time-series results

Project Partner Private
- 10Hz Full time-series results to specific partner
- Custom analysis for partner upon request

Balancing incentives and impact
- Aim to maximize collaboration and participation
- How do we provide valuable data to stakeholders without de-incentivizing participation?

Project Outputs in 2024

Next-Gen Profiles Technical Update Report 2024:

- Technical reports containing EV profile capture, EVSE characterization, and fleet utilization updated asset data
- Data-driven reports, updating previous reports with new assets added in 2024.

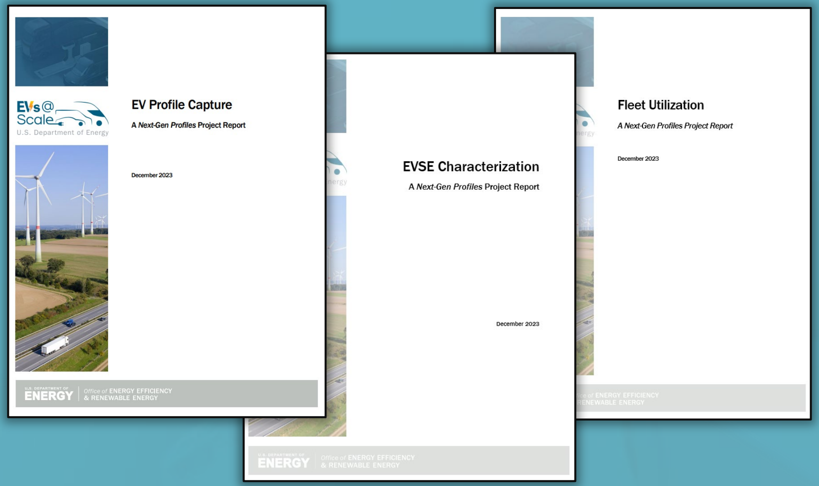
Publicly Anonymized Low-cadence time-series data

- EV, EVSE, Fleet identifying information removed, anonymous nomenclature mapped from report
- Time-series cadence lowered from 10Hz to 0.1Hz
- Posted to OSTI or some other public forum

Private Anonymized Full-Cadence time-series data

- EV, EVSE, Fleet identifying information removed, anonymous nomenclature mapped from report
- Time-series cadence kept at 10Hz
- OEMs who provided project assets have access to all other assets anonymized data

Consolidated Findings Technical Report 2024



Time-Series Anonymized Full-Cadence Data (10Hz)

Charge Session Meta-Data					
Vehicle Property		EVSE Property		Events	
Unique ID	EV1_22_LD_>500V	Charger Model	EVSE1_H1	Charge-Event # (Transaction ID)	
Vehicle Model		Station or EVSE ID		Station Plug	
Firmware Version				Odometer Reading	
Model				Plug-In Timestamp	10:57:30.0
Platform				Un-Plug Timestamp	11:55:00.0
Updated				Session Cost	
				Local OCPP Central Service	
				Curtailment Power [kW]	N/a
				Curtailment Curent [A]	N/a
				Curtailment Start Time	N/a
				Curtailment End Time	N/a

10-100%, EV1 Cold PreCond

Time Series Charge Data		
Time (10 Hz)		480VAC Cabinet 1
Date [YYYY-MM-DD]	Time [hh:mm:ss.0]	Voltage [V(RMS)]
2023-03-27	00:00:00.100000	275.72
2023-03-27	00:00:00.200000	275.67
2023-03-27	00:00:00.300000	275.59
2023-03-27	00:00:00.400000	275.44
2023-03-27	00:00:00.500000	275.42
2023-03-27	00:00:00.600000	275.36
2023-03-27	00:00:00.700000	275.42
2023-03-27	00:00:00.800000	275.44
2023-03-27	00:00:00.900000	275.61
2023-03-27	00:00:01.000000	275.67
2023-03-27	00:00:01.100000	275.69
2023-03-27	00:00:01.200000	275.66
2023-03-27	00:00:01.300000	275.65
2023-03-27	00:00:01.400000	275.61
2023-03-27	00:00:01.500000	275.64
2023-03-27	00:00:01.600000	275.52
2023-03-27	00:00:01.700000	275.43
2023-03-27	00:00:01.800000	275.35
2023-03-27	00:00:01.900000	275.46
2023-03-27	00:00:02.000000	275.53
2023-03-27	00:00:02.100000	275.61
2023-03-27	00:00:02.200000	275.61
2023-03-27	00:00:02.300000	275.72
2023-03-27	00:00:02.400000	275.73
2023-03-27	00:00:02.500000	275.77
2023-03-27	00:00:02.600000	275.67

EV Profile Capture:
Testing Procedures & Results

Overview: EV Profile Capture

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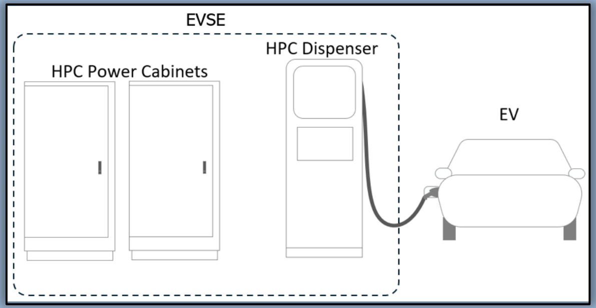
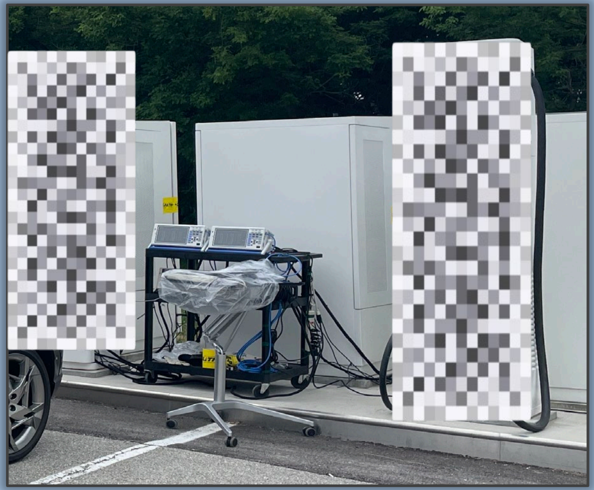
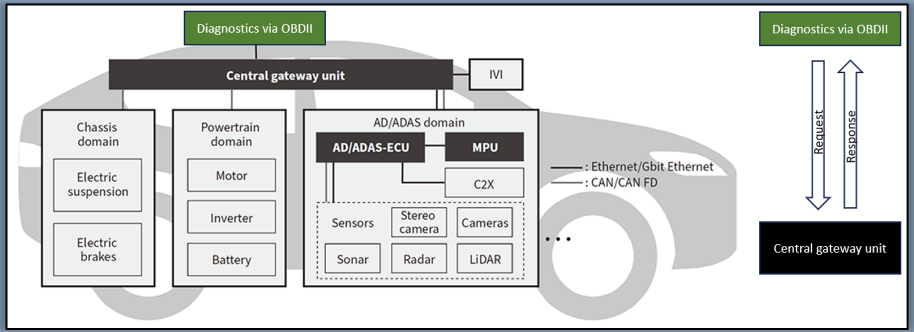
- EV Assets: Production EVs, rated 150-400kW DC charging
- EVSE Assets: Production DCFC (500A, 1000VDC), typically dual cabinet topology, multiple handle types
- Nominal test conditions:
  - 10-100% EV state of charge (SOC)
  - Nominal (23°C/75°F) ambient temperature
  - EV pre-driven/preconditioned for 30-40min prior to plug-in
- Off-nominal test conditions:
  - 25-100%, 50-100% EV state of charge
  - Hot (40°C/100°F), Cold (-7°C/20°F) ambient temperature
  - EV temperature soaked for 4-hours, or pre-driven 30-40min
  - OCPP curtailed (65A for 2min)
  - Single power cabinet (EVSE Power Limited)
  - Boost converter utilized (800-volt EVs only)
  - WPT Profile Capture





EVSE Condition Categories		Condition Metric Requirement	Tolerance
EVSE Power Limited		No Limit, Dual Tower (Nominal)	–
		Limited, Single Tower	–
Boost Converters		Not Utilized (Nominal)	–
		Utilized	–
Outside Ambient Temperature		23°C (Nominal)	± 2°C
		40°C (Hot)	± 2°C
		-7°C (Cold)	± 2°C
Smart Charge Management Scheduled	Request	FALSE (Nominal)	–
		TxProfile	–
	Duration	No Limit (Nominal)	–
		2 Minutes	–
	Scheduling	No Request (Nominal)	–
		2 (min) After Charge Session Start	± 1 (min)
	Value	No Limit (Nominal)	–
		65A (AC Input Current)	–
WPT Alignment	X-Direction	<5% coil length offset (Nominal)	± 2%
		10% coil length offset	± 2%
		25% coil length offset	± 2%
		40% coil length offset	± 2%
	Y-Direction	<5% coil length offset (Nominal)	± 2%
		10% coil length offset	± 2%
		25% coil length offset	± 2%
		40% coil length offset	± 2%
	Z-Direction	Unloaded (Nominal)	± 2%



EV Profile Capture: Comparing EV Performance

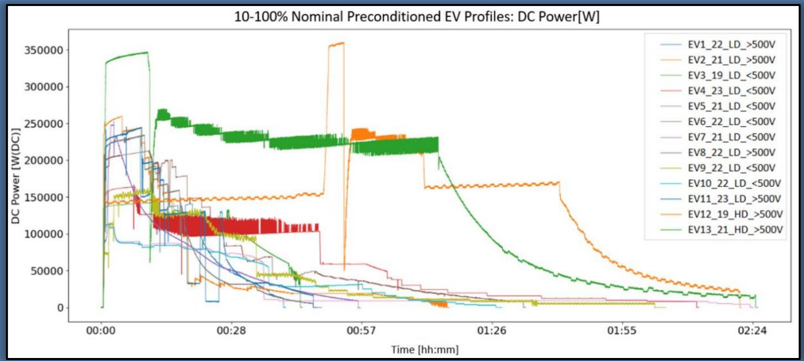
EVs@Scale
U.S. Department of Energy

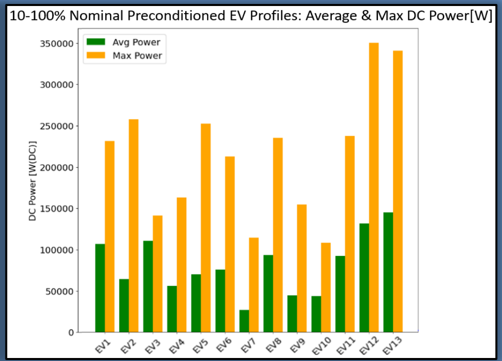
Goal: Capture the diversity of charge profiles under similar conditions through different means of performance metrics.

Findings:

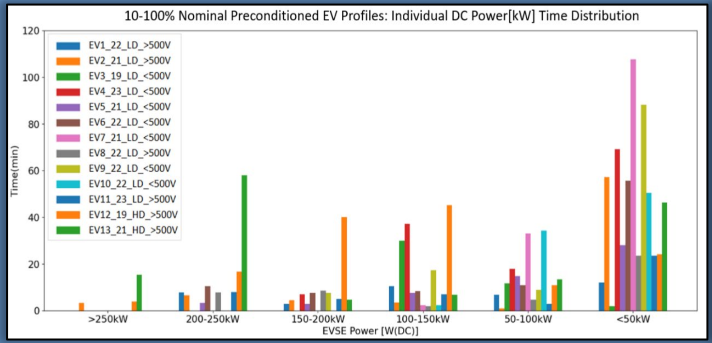
- DC Power profiles:
  - Unique, constant current vs constant voltage zones, plateaus, etc.
  - Ratio between peak power vs avg Power
- DC Power distribution:
  - Time spent
- DC Current Draw & Temperature:
  - 400V vs 800V battery topologies
  - Those with higher DC current profiles typically results in higher CCS Connector temperature
- Tabular data:
  - Snapshot view of comparing EV performance
  - Peak power, average power, time spent at power levels, total charge time, etc.

DC Power profiles, Average power, Mac power [kW]





DC Power Distribution across all EVs [time spent at kW range]



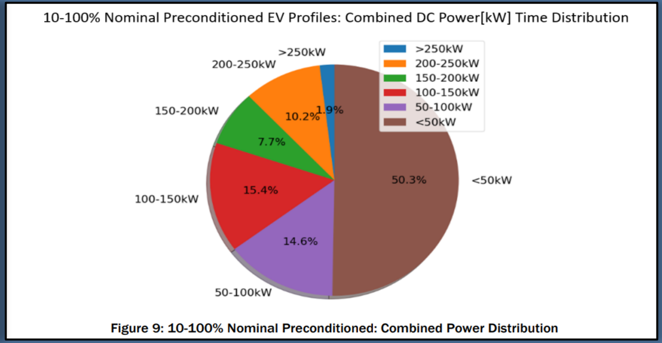
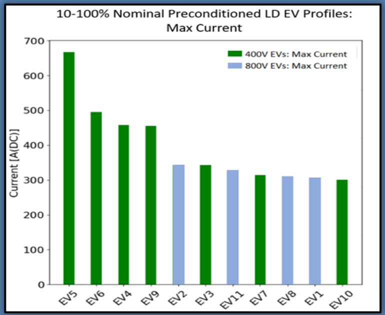
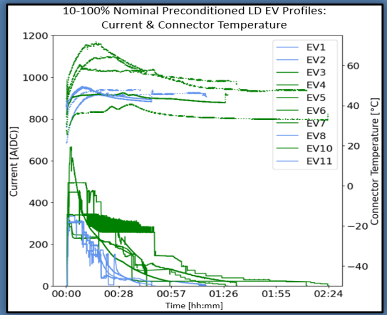


Figure 9: 10-100% Nominal Preconditioned: Combined Power Distribution

DC Current draw & thermal impacts





Tabular Data of all EVs

EV	Peak Power [kW]	Avg Power [kW]	Time Spent <100kW [min]	Time Spent 100-150kW [min]	Time Spent >150kW [min]	Total Charge Time [min]
EV1	200-250	~105	18.7	10.6	10.5	39.8
EV2	250-300	~65	58.1	3.5	14.3	75.9
EV3	100-150	~110	13.5	30.0	0.0	43.5
EV4	150-200	~55	87.0	37.2	6.9	131.1
EV5	200-250	~70	42.7	7.5	6.1	56.3
EV6	200-250	~75	66.5	8.4	18.0	92.9
EV7	100-150	~25	140.6	2.4	0.0	143.0
EV8	200-250	~95	28.1	1.9	16.4	46.4
EV9	150-200	~45	97.0	17.3	7.6	121.9
EV10	100-150	~45	84.5	2.3	0.0	86.8
EV11	200-250	~95	26.4	7.0	13.0	46.4
EV12	350-400	~130	34.9	45.1	60.7	140.7
EV13	300-350	~145	59.6	6.7	77.9	144.2

EV Profile Capture: Grid Utilization

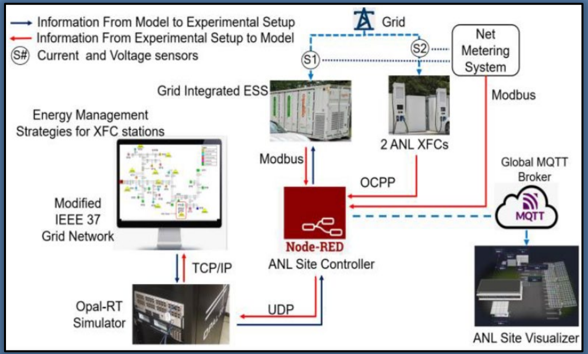
EVs@Scale
U.S. Department of Energy

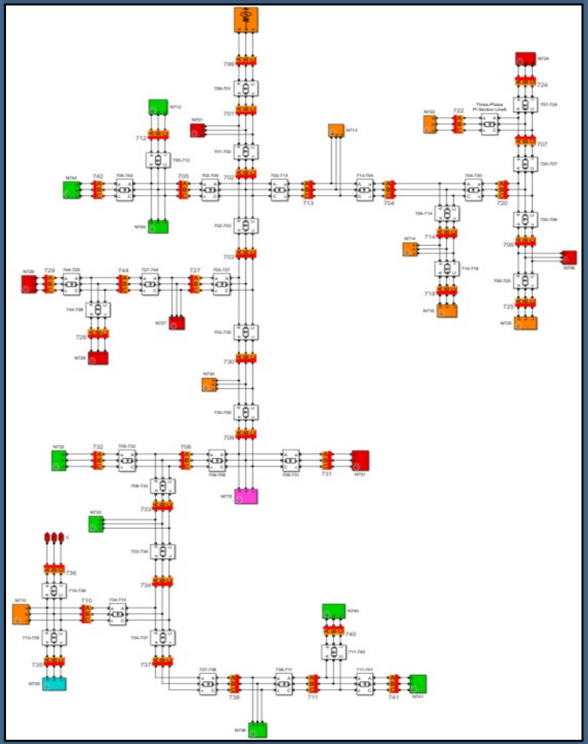
Goal: Integrating captured EV profiles captured into advanced grid modelling for utilization analysis

Findings:

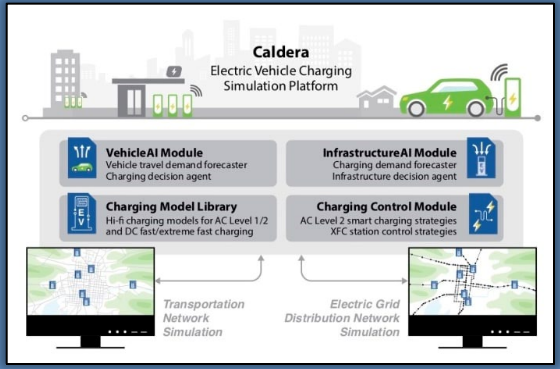
- Models:
  - ANL: IEEE HIL Grid Model
  - INL: Caldera Simulation Platform
  - NREL: EVI-X Modelling Suite
- Progress:
  - Integrated HPC profiles into models
  - Performed statistical analysis of real-world start/end SOC
  - Model & setup megawatt charging sites within model
  - Developed mixed-use (fleet/public) use case for simulations
  - Performing grid impact studies

ANL IEEE HIL Grid Model





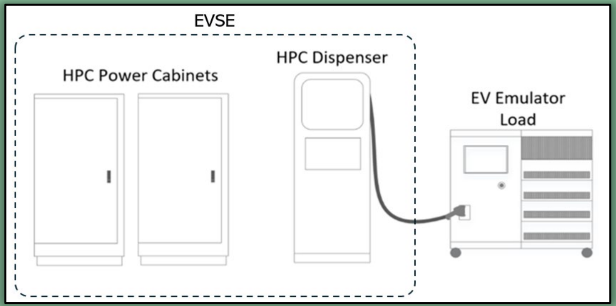
INL Caldera Models



NREL EVI-X Simulations

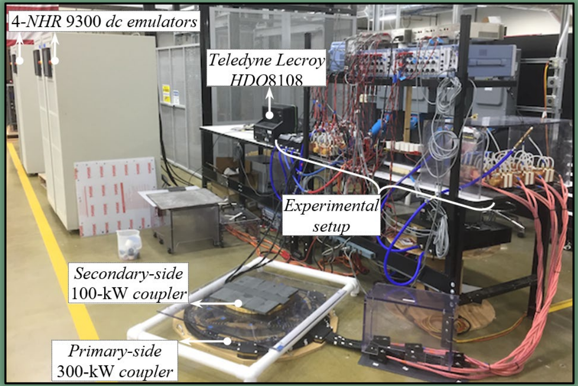
EVSE Characterization: *Testing Procedures & Results*

EVSE Characterization: Overview



EVSE Condition Categories		Condition Metric Requirement	Tolerance
Outside Ambient Temperature		23°C (Nominal)	± 2°C
		40°C (Hot)	± 2°C
		-7°C (Cold)	± 2°C
Smart Charge Management Scheduled	Request	FALSE (Nominal)	–
		TxProfile	–
	Duration	No Limit (Nominal)	–
		2 Minutes	–
	Scheduling	No Request (Nominal)	–
		2 (min) After Charge Session Start	± 1 (min)
	Value	No Limit (Nominal)	–
		65A (AC Input Current)	–
WPT Alignment	X-Direction	<5% coil length offset (Nominal)	± 2%
		10% coil length offset	± 2%
		25% coil length offset	± 2%
		40% coil length offset	± 2%
	Y-Direction	<5% coil length offset (Nominal)	± 2%
		10% coil length offset	± 2%
		25% coil length offset	± 2%
		40% coil length offset	± 2%
	Z-Direction	Unloaded (Nominal)	± 2%
Grid Condition	Voltage	480VAC (Nominal)	± 2%
		528VAC, 110% Nominal (Swelled)	± 2%
		432VAC, 90% Nominal (Sagged)	± 2%
	Harmonics	No Harmonics (Nominal)	± 2%
		5% Voltage Distortion	± 2%
	Frequency	60Hz (Nominal)	± 2%
		61.2Hz (Increased)	± 2%
		58.8Hz (Decreased)	± 2%

Initial Power Transfer	Requested Power Transfer				
	Discharge 100%	Discharge 50%	0kW	Charge 50%	Charge 100%
Discharge 100%					X
Discharge 50%				X	
0kW	X				X
Charge 50%		X			
Charge 100%	X				



- <u>EV Assets:</u> EV Emulator (50-1000VDC), rated for 350kW
- <u>EVSE Assets:</u> Production DCFCs (500A, 1000VDC), typically dual cabinet topology.
- <u>Nominal test conditions:</u>
  - Voltage: 300V, 400V, 650V, 750V, 850V
  - Current: 50 to 500A, 10A increments
  - Nominal (23°C/75°F) ambient temperature
  - Grid supply: 480VAC, 60Hz, no harmonics
- <u>Off-Nominal test conditions:</u>
  - Hot (40°C/100°F), Cold (-7°C/20°F) ambient temperature
  - Grid supply: [538, 432]VAC, [58.8, 61.2]Hz, 5% harmonic distortion
  - SCM: 65A, 2min duration, *TxProfile, 2m*in into charge
- <u>Wireless Power Transfer:</u>
  - X-direction, Y-direction, Z-direction offsets.
- <u>Vehicle-to-Grid (V2G):</u>
  - 2024: Low power, test full capability
  - 2025: High power, test full capability (Ahead)

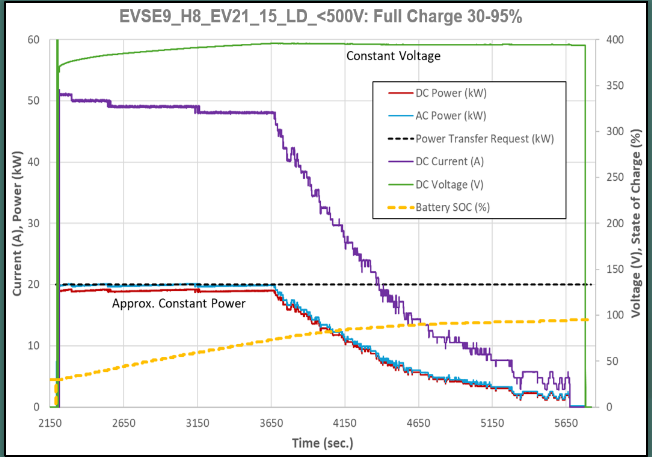
EVSE Characterization: Low Power V2X Charge/Discharge Findings

Goal: Perform charge and discharge sessions capturing high fidelity data, analyzing EVSE performance in multiple areas.

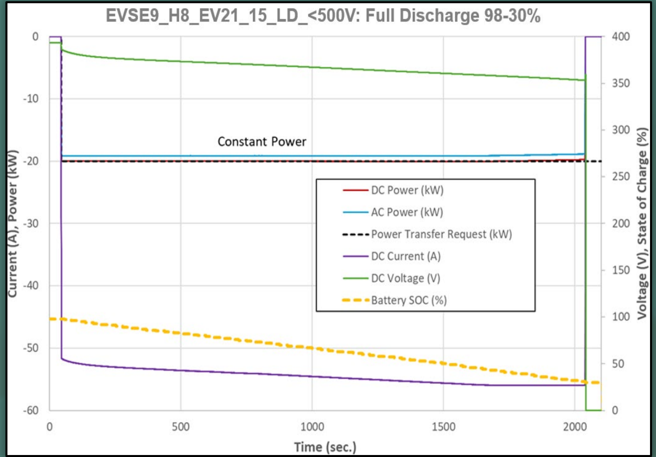
Findings:

- Typical Charge curve (constant current & constant voltage), peak power ~19kW, peak current ~52A, 400V battery.
- Discharge curve doesn't plateau like charging curve does. Grid considerations come to mind, as these are much different than charging curves.
  - How would this look at higher power? Ex. 350kW
- Power factor stays above 0.92, however noticeable drop-off above 3% AC voltage distortion
- Current THD also has noticeable drop-off in power quality, spiking up to ~40% current distortion.
  - Current THD should be no more than 5%, typical expected voltage THD at INL is ~2.5-3%
  - Manufacturer insisted product meets power quality standards when input waveform is good

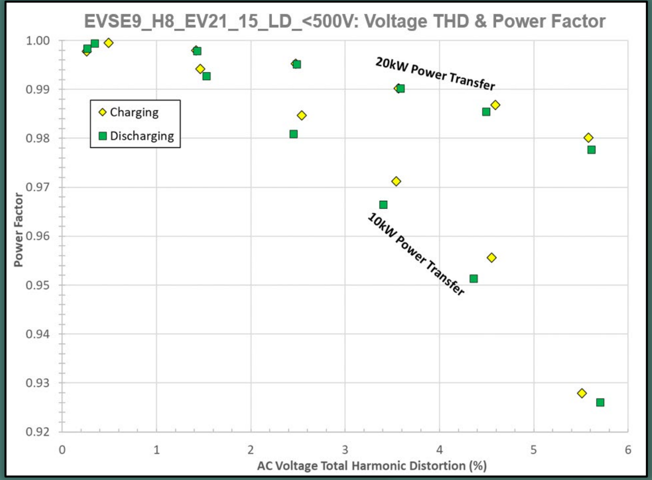
LP V2X EVSE Full Charge [V, A, kW]



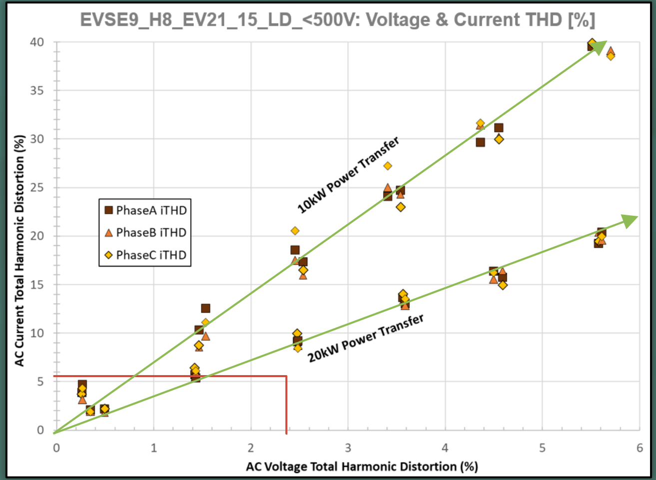
LP V2X EVSE Full Discharge [V, A, kW]



LP V2X EVSE Power Factor

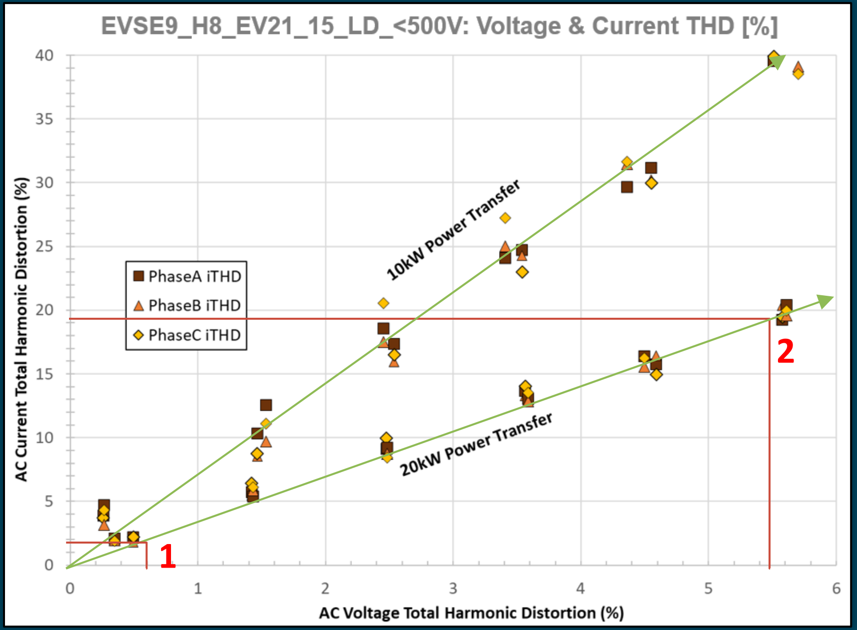


LP V2X EVSE Current THD [%]



EVSE Characterization: Low Power V2X Current Distortion Impact

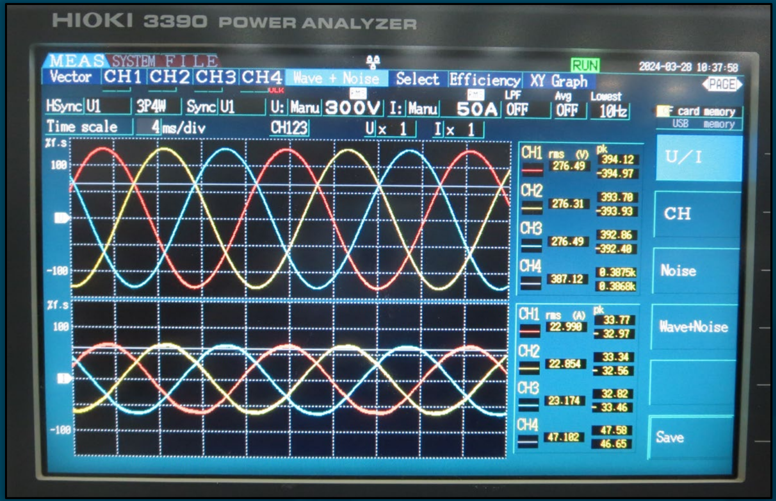
LP V2X EVSE Current THD [%]



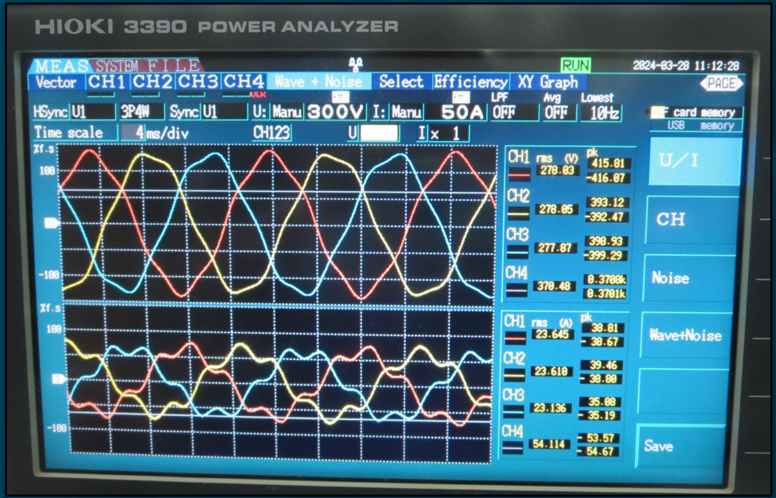
1

2

0.4% AC Voltage THD



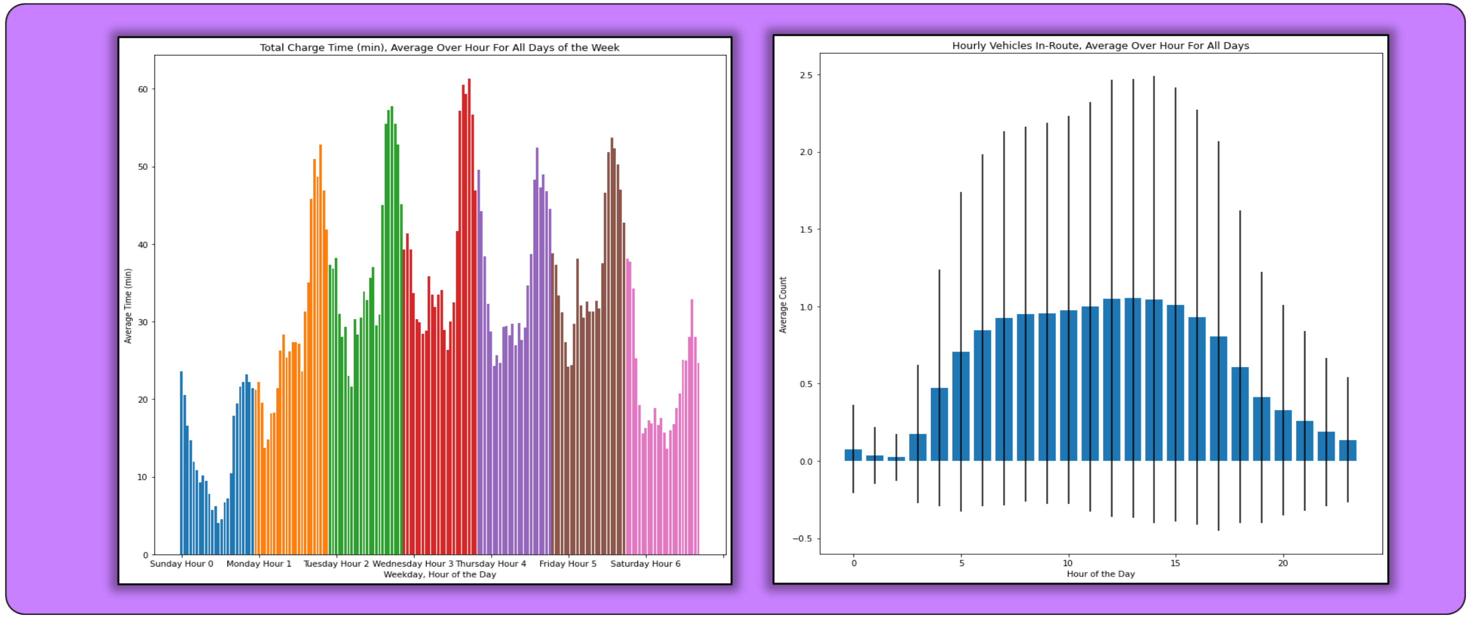
5.5% AC Voltage THD

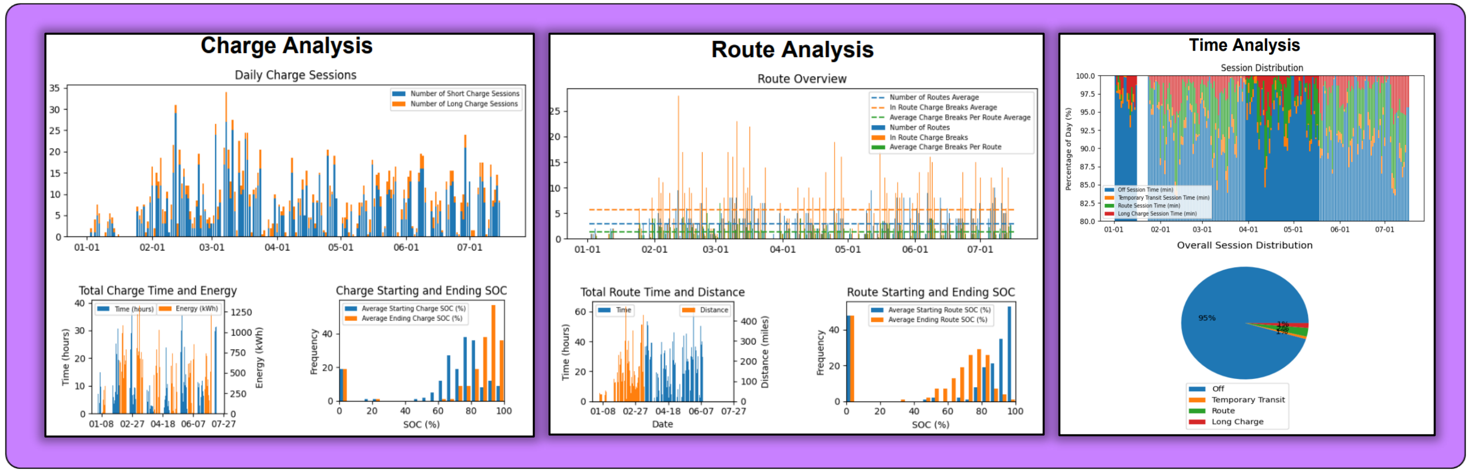


Fleet Utilization:
Testing Procedures & Results

Overview: Fleet Utilization

- *“We’ve collected EV & EVSE profile data, but how are these assets being used in real world applications?”*
- Assets:
  - EV and/or EVSE Fleets
  - Using data collected by fleet from EV and/or EVSE
- Types of Data:
  - **Data Categories**: Charge, Route, Other
  - **Time-series data**: Hourly
  - **Graphical Data:**
    - Hourly, Daily, Weekly, Monthly, Annually.
    - Averages or totals
  - **Types of Analysis:**
    - Utilization Rates
    - Avg Start/End SOC
    - Average Power [kW]
    - Weekday usage rates [%], etc.
  - Relies heavily on OEM collaboration





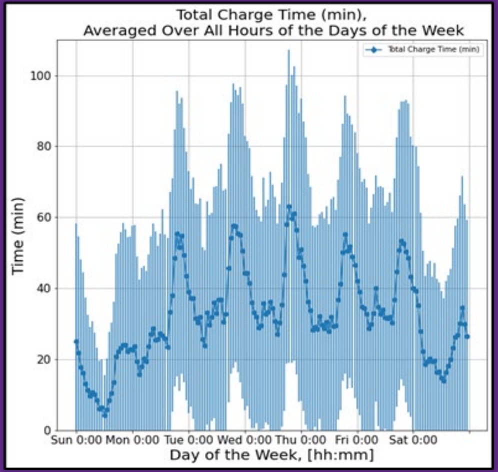
Fleet Utilization: Charge Time Analysis

Goal: Average a year's worth of charging data to create a "typical week's usage" for charging time, compare 2 fleets

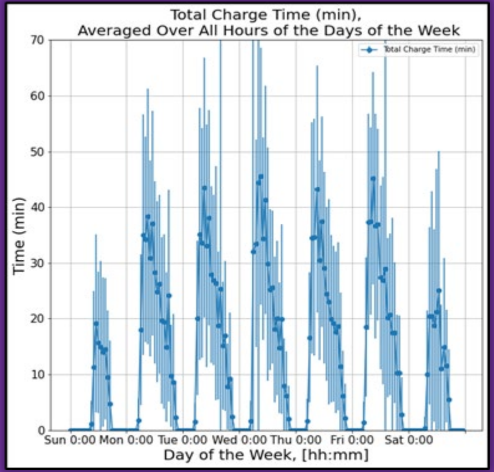
Findings:

- EV Fleet has higher overall utilization
- Both have lower weekend charging utilization
- EV has higher night-time charging than day-time, opposite of the EVSE fleet

Weekly Averaged Charge Time [min]



EV Fleet 1



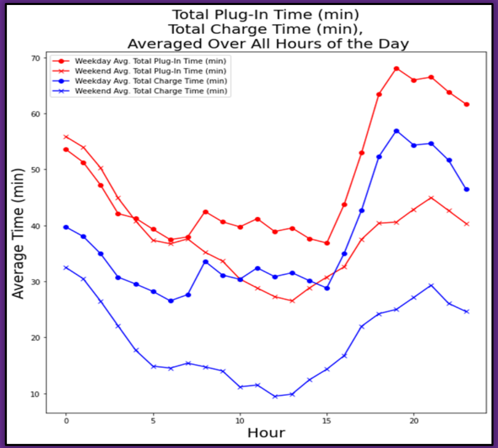
EVSE Fleet 1

Goal: Average a year's worth of charging data to create a "typical day's usage" for charging time, for a single fleet

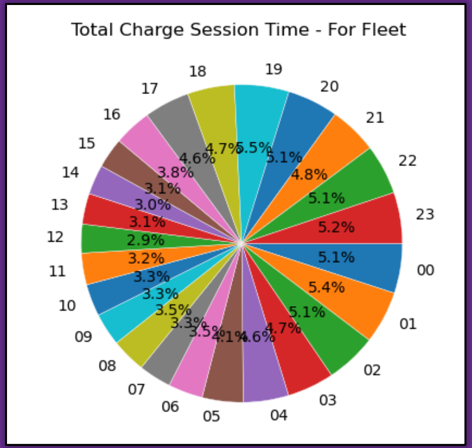
Findings:

- SMA & CMA calculated for plug-in time & charge time. Scalar offset between plug-in & charging.
- Percentage breakdown shows hourly usage, mostly overnight charging spiking at 7pm.

Daily Averaged Charge Time [min]



EV Fleet 1: Daily plug/charge time



EV Fleet 1: Charge time % breakdown

Conclusion

Final Touch Points

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Thus far:

- Collected very insightful, thoroughly detailed data and analysis surrounding EV, EVSE, and Fleets
- Published 4 technical reports containing results for assets tested from CY21-23
- Revised test plan & procedures entering CY24 & received industry feedback

Moving forward:

- Looking to increase our scope, continue gathering data, receive feedback from industry on what is valuable to be gathered
- NACS, V2X, MCS target scope extensions moving into CY25-26
- Technical update reports 2024 & Time-series data posted end of CY2024

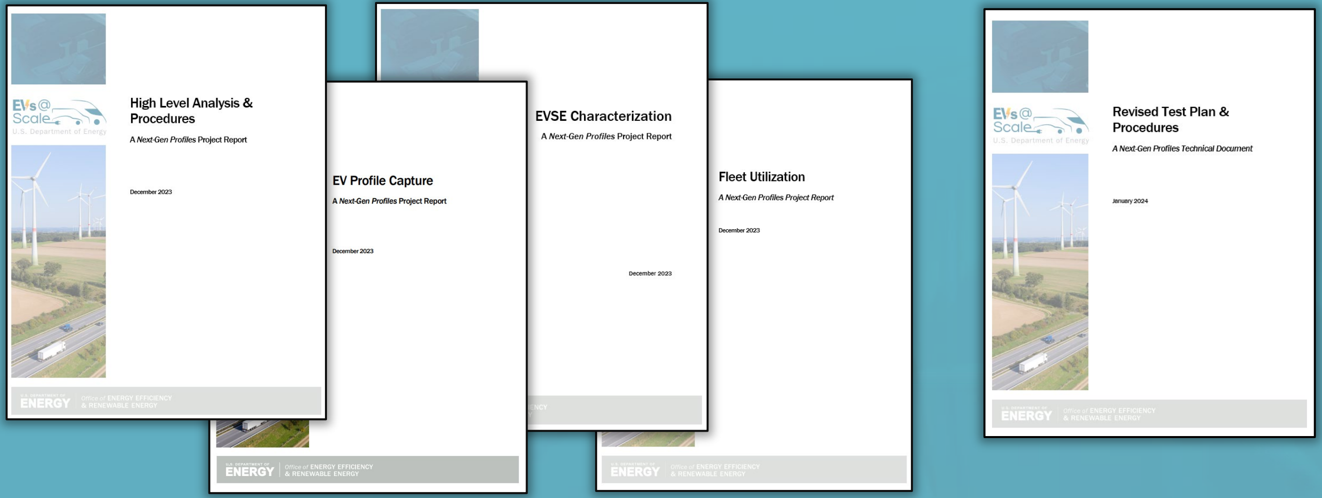
How to get involved!

- OEMs interested in participating in this study please reach out sthurston@anl.gov

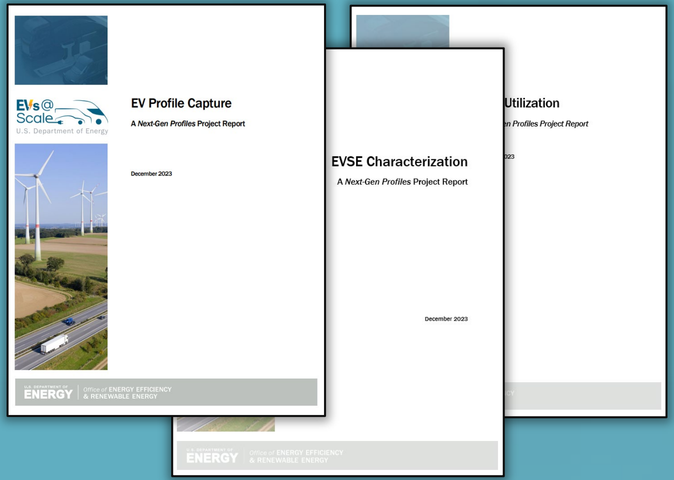
Publicly accessible as of September 2024

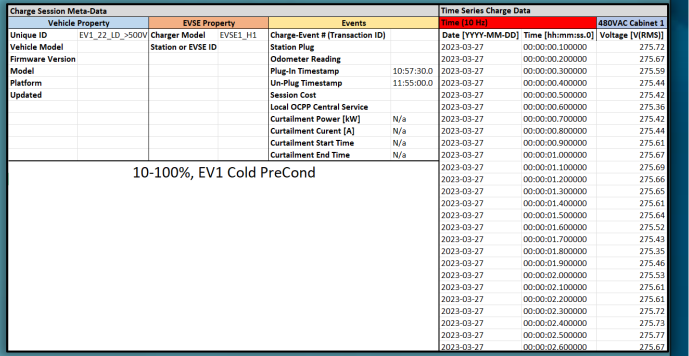
NGP Technical Reports 2023

Revised Procedures 2024



Planned project outputs at end of CY2024





Open Project Partnerships

- **EV Profiles: High power EV/EVSE partnership**
  - HPC (150-400kW) EVSE & EVs
  - Megawatt-level (800-1000kW+) EVSE & EVs

- **EVSE Char: High power and/or Bi-directional EV charging infrastructure partnership**
  - EV emulator capable of high-power charging up to 400kW (500A max., 920V DC max.)
  - EV emulator capable of CCS-1 bi-directional charging up to 120kW using ISO 15118-2 (2015)

- **Fleet telematics data partnership**
  - Looking to add another fleet to our portfolio, granting access to data portal for NGP specific analysis

- **Data Analysis partnership**
  - Lots of data collected within NGP. Partner would use data to perform different areas of analysis for EV, EVSE, and/or Fleet pillars with an industry perspective.

Interested in Partnering with NGP?

Contact NGP PI: Sam Thurston, ANL

sthurston@anl.gov

Thank You!

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U.S. DEPARTMENT OF ENERGY

EVGrid Assist

ACCELERATING THE TRANSITION

VGI Vision

U.S. DEPARTMENT OF ENERGY

EVGrid Assist

- Enhance learnings through informational webinars and peer-to-peer sharing, drawing from emerging research and real-world demonstrations and experience
- Provide pathways for stronger vehicle grid integration (VGI) coordination between electric utilities, regulators, manufacturers, technology providers, and other stakeholders
- Collaboratively identify solutions to emerging VGI challenges
- Develop resources and provide data, tools, and analyses that support decision making
- Build capacity and provide technical assistance to support stakeholders as they develop and implement solutions.

U.S. DEPARTMENT OF ENERGY EVGrid Assist ACCELERATING THE TRANSITION | U.S. DEPARTMENT OF ENERGY

The Future of Vehicle Grid Integration

Background

- Shared vision for a beneficial, EV-integrated future where EVs are safely and securely connected, reliably served, and harmonized with the electric grid
- Informed by stakeholder input
- Each pillar details specific attributes, which provides guide posts, offers direction for stakeholders as they develop products, identify opportunities for standardization, and design new policies, rates, and services, among other activities.

VGI Shared Vision and Attributes

VGI Vision: By 2030, millions of electric vehicles, charging at home and work, at charging depots and along the route, are integrated with the electricity system in a way that supports affordable and reliable charging for drivers and enables a reliable, resilient, affordable, and decarbonized electric grid for all electricity customers

Attributes of a Realized Vision

PILLAR 1. UNIVERSAL VALUE

Investments in grid infrastructure to support EV charging enhance grid resilience and provide shared benefits to ratepayers regardless of EV ownership.

PILLAR 2. RIGHT-SIZED INFRASTRUCTURE

A responsive, decarbonized electric grid harnesses the flexibility and mobile storage of EVs to minimize peak load impacts and increase the utilization of grid and charging assets.

PILLAR 3. STANDARDS-SUPPORTED INNOVATION

Harmonized grid, vehicle, and charger standards and clearly articulated grid requirements allow innovation to flourish and new products to be integrated into a robust, interoperable system.

PILLAR 4. CUSTOMER-CENTERED OPTIONS

Customers have a wide range of products and services to accomplish their charging needs and are compensated when they provide services to the grid.

PILLAR 5. SECURE COORDINATION

Cyber and physical systems that connect the vehicle, charger, and electric grid are appropriately secure to mitigate manmade or/and natural disruptions.

https://www.energy.gov/eere/evgrid-assist-accelerating-transition https://www.energy.gov/eere/evgrid-assist-accelerating-transition

SCAN ME
to learn more and sign up for announcements.

U.S. DEPARTMENT OF
ENERGY

ChargeX Consortium Overview

CHARGEX consortium

LED BY

Argonne NATIONAL LABORATORY

INL Idaho National Laboratory

NREL Transforming ENERGY

8/31/2024

John Smart

Casey Quinn

Kristi Moriarty

Dan Dobrzynski

CHARGEX consortium

Vision

Any driver of any EV can charge on any charger the first time, every time

Mission

Bring together EV charging industry members, national laboratories, consumer advocates, and other stakeholders to measure and significantly improve public charging reliability and usability in North America **by June 2025**

Scope

Focus on complex issues that require multi-stakeholder collaboration and national lab support to solve and simplify

Scope of Work

Defining the Charging Experience	Reliability/Usability Triage	Solutions for Scaling Reliability
• Define KPIs • Develop and verify implementation instructions	Create fixes for: • Communication • Hardware	Improve: • Diagnostics • Interoperability testing methods

Outcomes

- Labs produce recommended practices, prototype tools
- Industry adopts practices and tools, improves standards

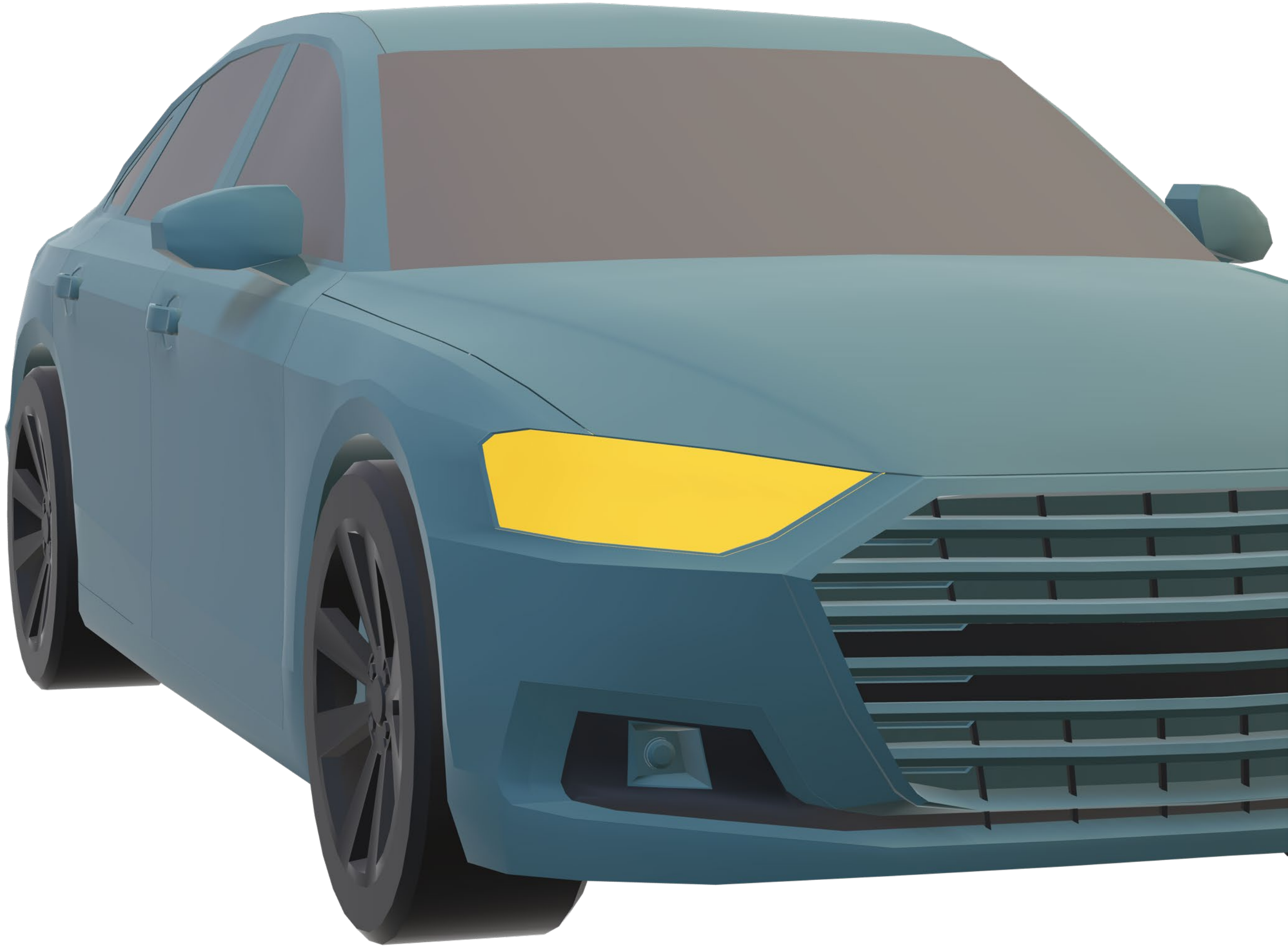
DC Fast Charging Use Case

Focus on the EV/Charger Interface

Connector / adapter / inlet reliability and safety

EV/charger communications and diagnostics

Interoperability testing methods and tools



AC Level 2 Smart Charging Use Case

Responding to U.S. national priority: Vehicle/Grid Integration

Participants (87 as of 8/31/2024)

Charger Manufacturers and Suppliers	ABB e-Mobility, Amphenol, Autel, Bosch, BTC Power, Dover Fueling Solutions, Eaton, Evalucon, EVBox, Heliox, IoTecha, Qualcomm, Siemens, SK Signet, Wallbox
Customer-Facing Charging Station Operators	Apple Green Electric, Blink Charging, bp pulse, ChargePoint, Electrify America, Enel X Way, EVgo, FLO, Francis Energy, HeyCharge, KIGT, Koulomb, NovaCHARGE, NYPA, Rove, SWTCH, Xeal Energy
Charging Network and Software Providers	ampcontrol, AMPECO, ampUp, ChargeMate, Driivz, EV Connect, Noodoe, PIONIX, Switch
Auto Manufacturers	American Honda, BMW of North America, Ford Motor Company, General Motors, Lucid, Mercedes-Benz North America, Rivian, Stellantis, Subaru of America, Tesla, Toyota Motor North America, VinFast Auto, Volvo Car USA
3rd-Party Roaming Hubs and eMSPs	AeonCharge, Bluedot, ChargeHub, Emobi, Hubject
Field Services and Analytics Firms	Atlas Public Policy, ChargerHelp!, Energetics, EVSession, Field Advantage, ReliON, Uptime Charger, WattsUp
Consumer Advocates	Cool the Earth, Consumer Reports, EVinfo, J.D. Power, Plug In America
Fleets	Hertz
Payment Industry Stakeholders	Discover Global Network, Nayax, Payter
Standards Organizations and Technology Alliances	CharIN North America, COVESA, EPRI, Open Charge Alliance, SAE Sustainable Mobility Solutions
Research Organizations and Universities	American Center for Mobility, EPRI, Transportation Energy Institute, University of California, Davis; University of Washington
State Agencies	California Air Resources Board, California Energy Commission, Caltrans

Project Progress and Next Steps

Argonne NATIONAL LABORATORY | INL Idaho National Laboratory | NREL Transforming ENERGY

CHARGEX consortium

Defining the Charging Experience

Goal: establish customer-focused key performance indicators (KPIs) to standardize how industry measures the customer charging experience

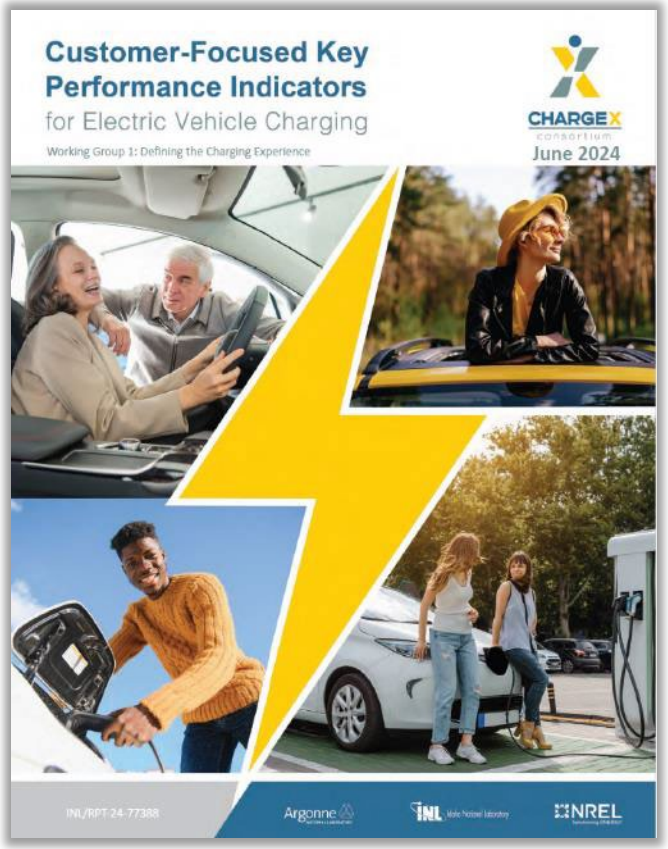
Progress:

- Published a report detailing KPIs on chargex.inl.gov
- Drafted implementation guide for interim KPIs

Next steps:

- Verify and publish implementation guide for Interim KPIs
- Conduct implementation pilot

Hand off ownership of KPI development to standards development organization in Fall 2024



Ensuring Adapters are Reliable and Safe

Goal: ensure performance and conformance standards catch all major failure modes

Progress:

- Completed rigorous failure mode and effects analysis for 4 different types of CCS/J3400 adapters
- Yielded numerous recommended actions to harden design and conformance standards for adapters

Next steps:

- Connector / adapter / inlet hardware testing
- Communicate recommended actions to UL and SAE committees (J3400, J3400/1, UL2202, UL2251, UL2252)

Failure analysis completed for four adapter types

Increasing Charge Start Success with Seamless Retry

Goal: institute process to automatically retry session initialization after failure to avoid unplug/replug

Progress:

- Developed recommended practices for seamless retry
- Electrify America, BTC Power, and Ford Motor Company demonstrated at CharIN North America Testival in June 2024

Next Steps:

- Publish recommended-practice report
- Work with partners to perform additional demonstration

Streamlining Timeouts

Goal: identify timeout issues in EV-EVSE communications and recommend solutions

Progress:

- Identified root causes of timeout issues in EV-EVSE communication and drafted recommended-practice report

Next Steps:

- Publish recommended-practice report by Oct 31

Enable Diagnostic Data Sharing

Goal: institute common set of error codes and supporting diagnostic information across industry to accelerate problem resolution

Progress:

- Published charger-focused Minimum Required Error Codes (MRECs) and implementation instructions on developer-friendly website*
- EVgo demonstrated subset of MRECs at CharIN North America Testival in Nov 2023
- Drafted Minimum Required Diagnostic Information (MRDI) for diagnosing the root cause of faults communicated by MRECs

Next Steps:

- Full MREC implementation and verification by multiple companies
- Develop MRECs for EVs and smart charge management
- Implement in open-source code repository EVerest
- Verify and publish MRDI

* see inl.gov/chargex/mrec

Improving Rigor of Interoperability Testing

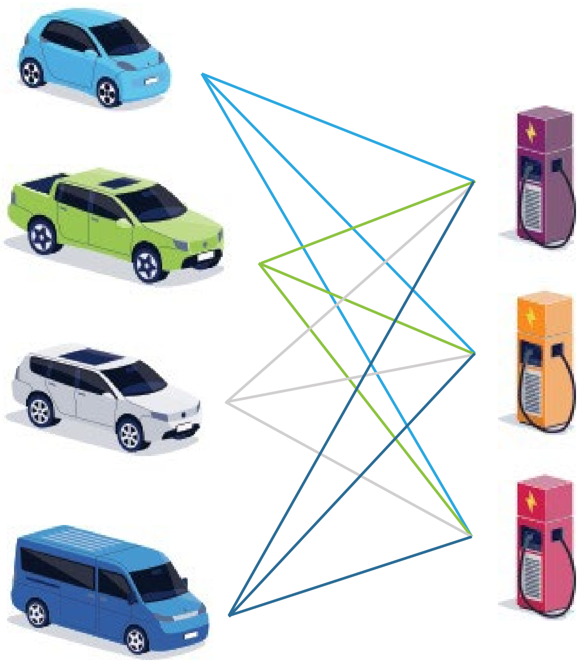
Goal: Develop comprehensive set of interoperability test cases to accelerate EV and charger product development

Progress:

- Completed a comprehensive EV/EVSE Interoperability Test Plan
- Demonstrated subset of test plan in prescribed testing program at CharIN North America Testival in June 2025

Next Steps:

- Update test plan for adapters, J3400, MRECs, smart charging
- Conduct second prescribed testing program at CharIN North America Testival – California in Nov 2025
- Refine test plan based on learnings from testing events and feedback from individual companies

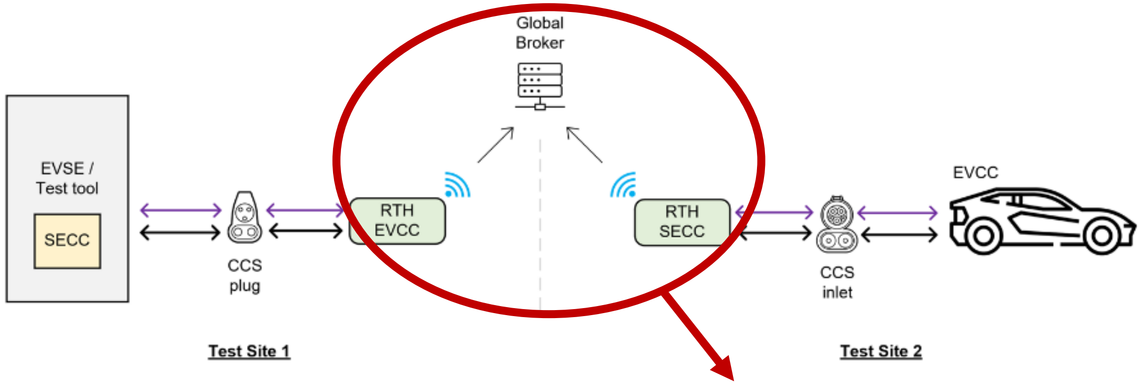


Creating Remote Test Harness (RTH)

Goal: Develop first-of-a-kind testing system to conduct remote interoperability testing with EVs and EVSE at separate locations

Progress:

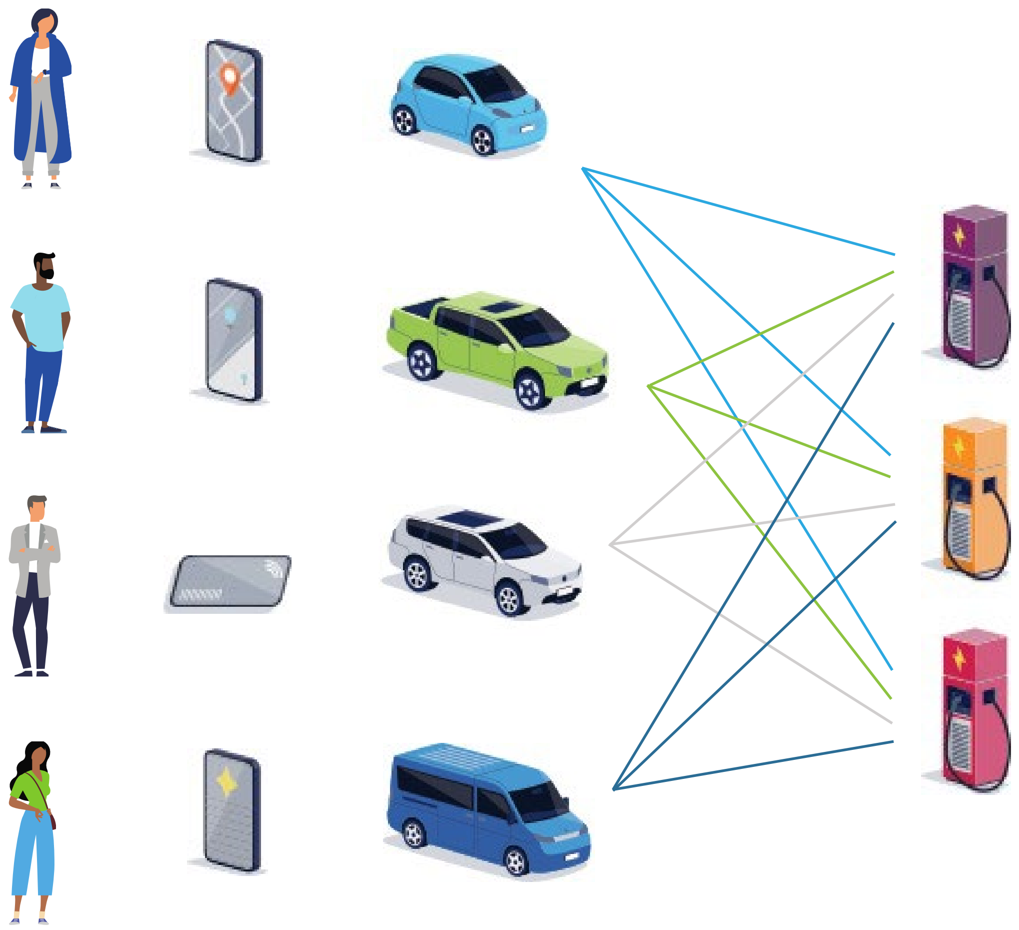
- Developed prototype RTH
- Successfully tested communication between two RTH devices over the internet



Next Steps:

- Develop, test, and demonstrate RTH minimum viable product
  - EV-to-RTH and EVSE-to-RTH interfaces
  - Hardened enclosure
  - User interface

Any Driver, Any EV, Any Charger



FIRST TIME,

EVERY TIME

chargex.inl.gov

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Idaho National Lab:

Lab Tours & Demonstrations

Sept 25, 2024

Overview: Tours and Demonstrations

5 tour stops: 20min. duration each

1. V2X Café: demonstration of DC bi-directional charging (V2G)
2. Cerberus: demonstration of a cybersecurity mitigation for high-power charging
3. Microgrid in a Box: tour of INL's "Relocatable/Resilient Alternative Power Improvement Distribution (RAPID MIB)" capability.
4. Battery Test Center: tour of INL's large independent battery assessment facility
5. Caldera: demonstration of INL's CalderaCast web tool with imminent public launch.

1. EVIL’s V2X Café

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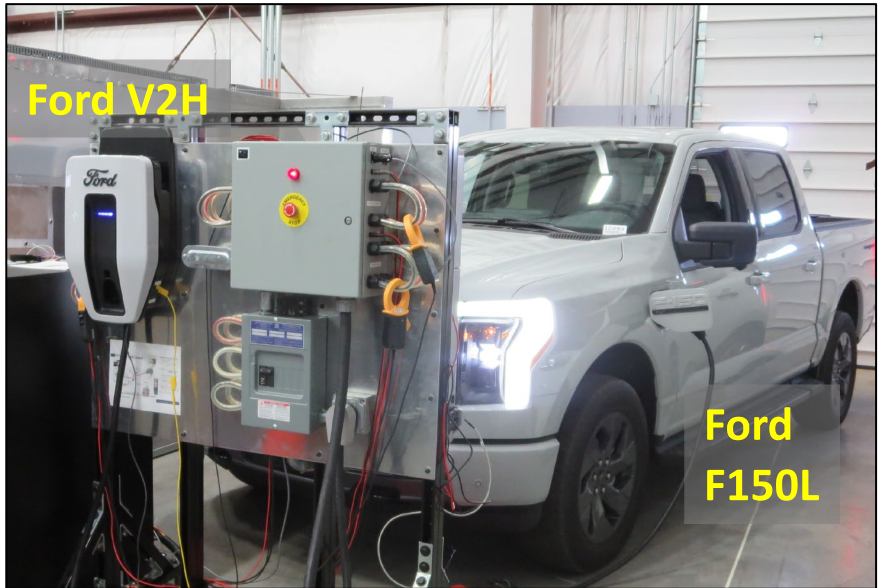
Demonstration of bi-directional charging (V2G) with Barney Carlson

- BorgWarner 60kW V2G with Synop Energy Management system
  - EV emulator: Dana EVCC, CCS-1 inlet, Bitrode battery emulator
- Ford 9.6kW V2H (*Inteligent Back-up Power*)
  - 2024 Ford F150 Lightning
- Fermata 20kW V2G with Fermata Energy Management system
  - 2015 Nissan LEAF



2. Cerberus: Cybersecurity Mitigation solution for EVCI

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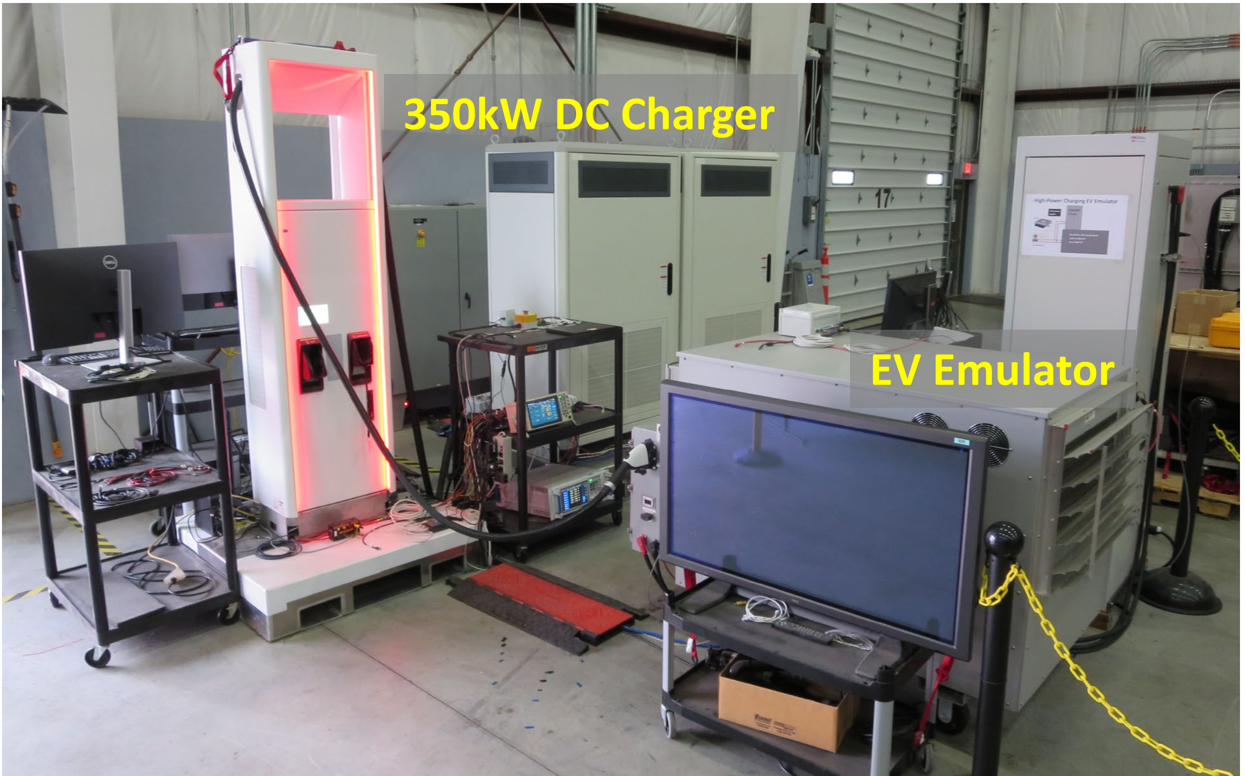
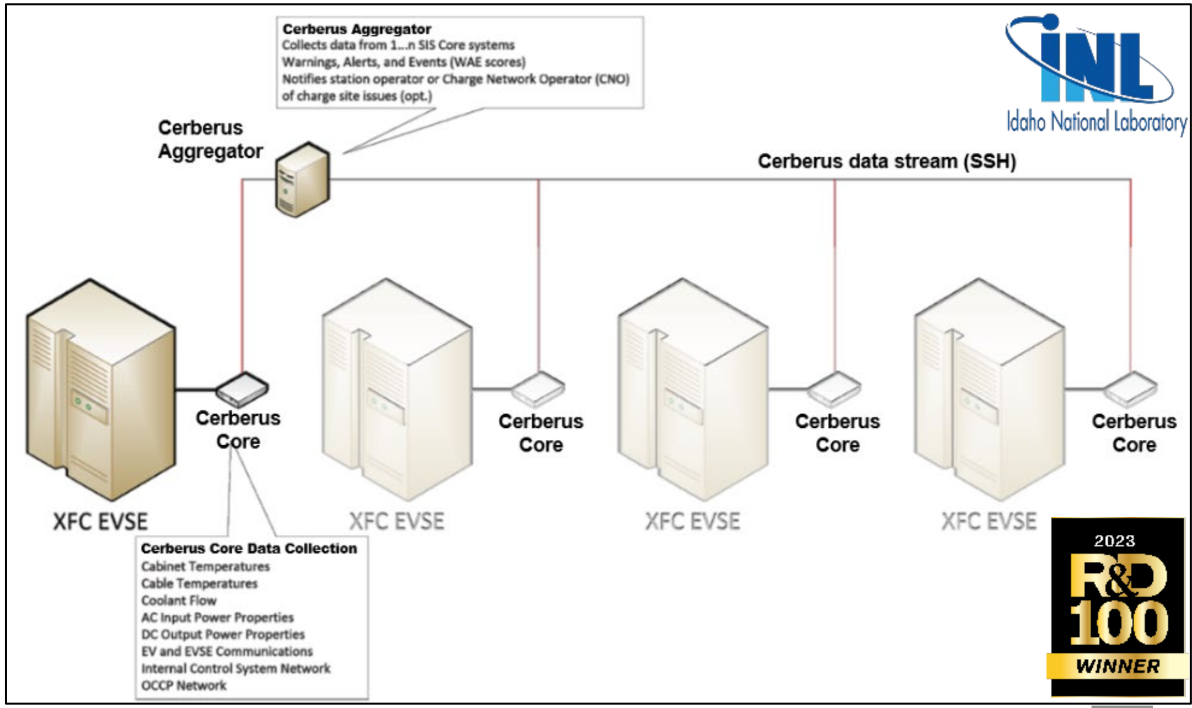
Demonstration of Cerberus at EVIL (Electric Vehicle Infrastructure Lab) with Kenneth Rhode

- 3 exploits will be launched against a 350kW charger
  - 1. CCS cable thermal management, 2. power electronics control, & 3. instantaneous load shed
- Cerberus enabled demonstrates effectiveness and <u>dis</u>abled highlights potential impact severity



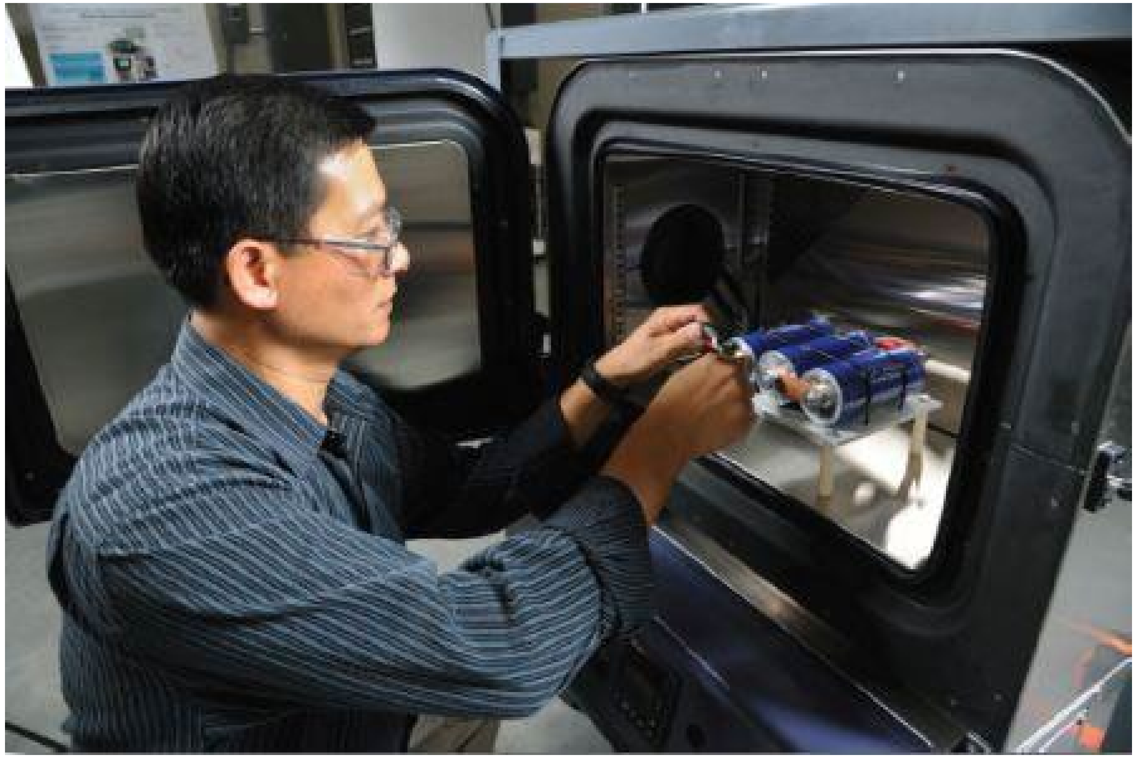


Tour of RAPID MIB

- RAPID-MIB is a portable, smart, self-contained microgrid with battery storage originally designed for remote locations like military bases. As utilities face new challenges from advanced technologies like renewables, electric vehicles and nuclear energy, RAPID-MIB supports the clean energy future by stabilizing the grid.

Tour of the Battery Test Center

The test facility provides 17,500 square feet of laboratory space equipped with tools that allow testing of several hundred batteries at the same time, ranging from small cells to full-sized battery packs used in today's light-duty vehicles, stationary energy storage applications and other critical support areas.



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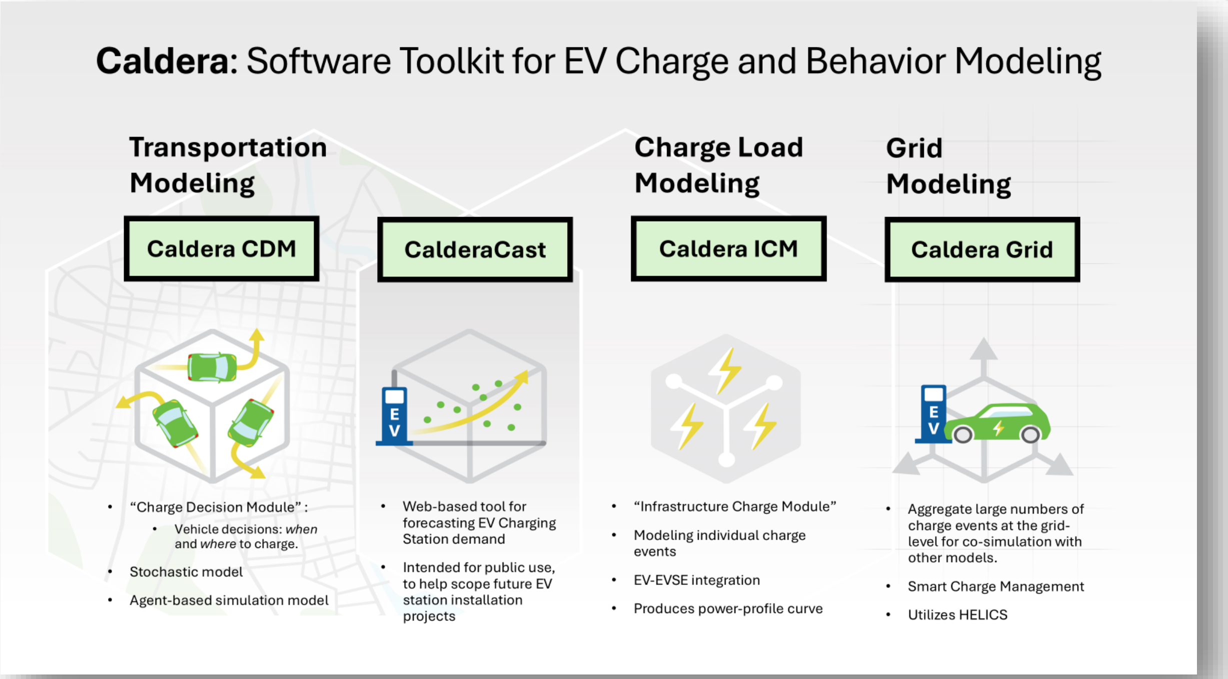
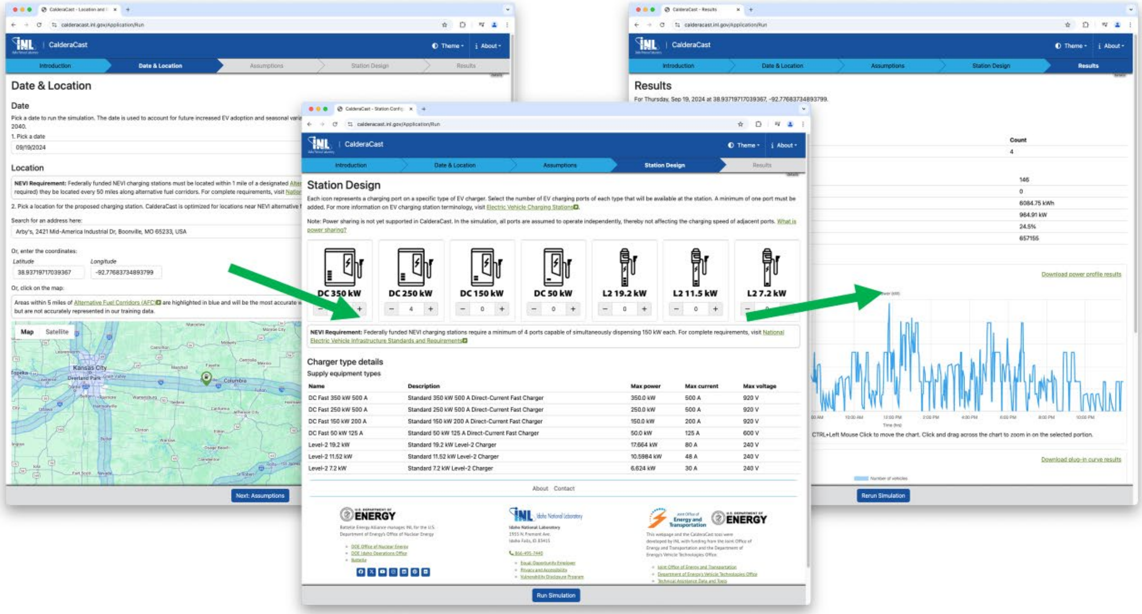
Demonstration of CalderaCast Web Tool

- *CalderaCast is a specific implementation of INL's EV Charging Software Suite designed to provide a user-friendly web tool capable of forecasting load at a proposed fast-charging station along an alternative fuel corridor.*



CalderaCast



Logistics: Tours and Demonstrations

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Instructions

- **Safety is top priority**
  - –Closed toe shoes are required in lab areas
  - –No shorts
  - –No food, drink, chewing gum, or tobacco allowed in lab areas
  - –No photographs allowed
  - –Don't touch lab equipment
  - –Stay with the tour group (do not stray off)
  - –Safety glasses and hearing protection are NOT required (but we can provide)

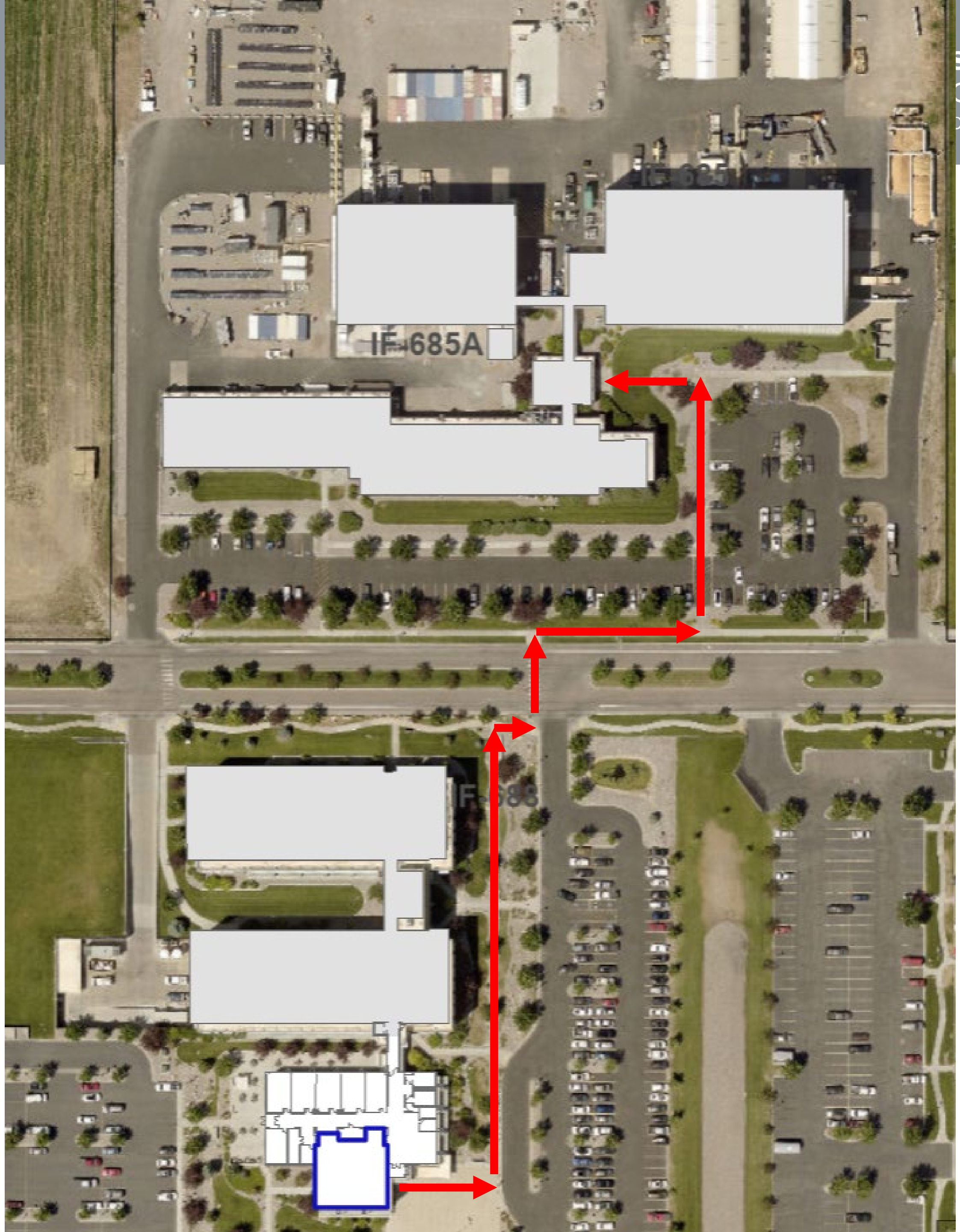
- You must be badged to attend the tours which are inside of secured INL laboratories. Please display your INL Provided Visitor Badge or HSPD12.

- If you are not touring, thank you for your attendance, we will see you tomorrow a few minutes before 8:00 AM.

Walking to ESL for Tours and Demos

Directions to ESL

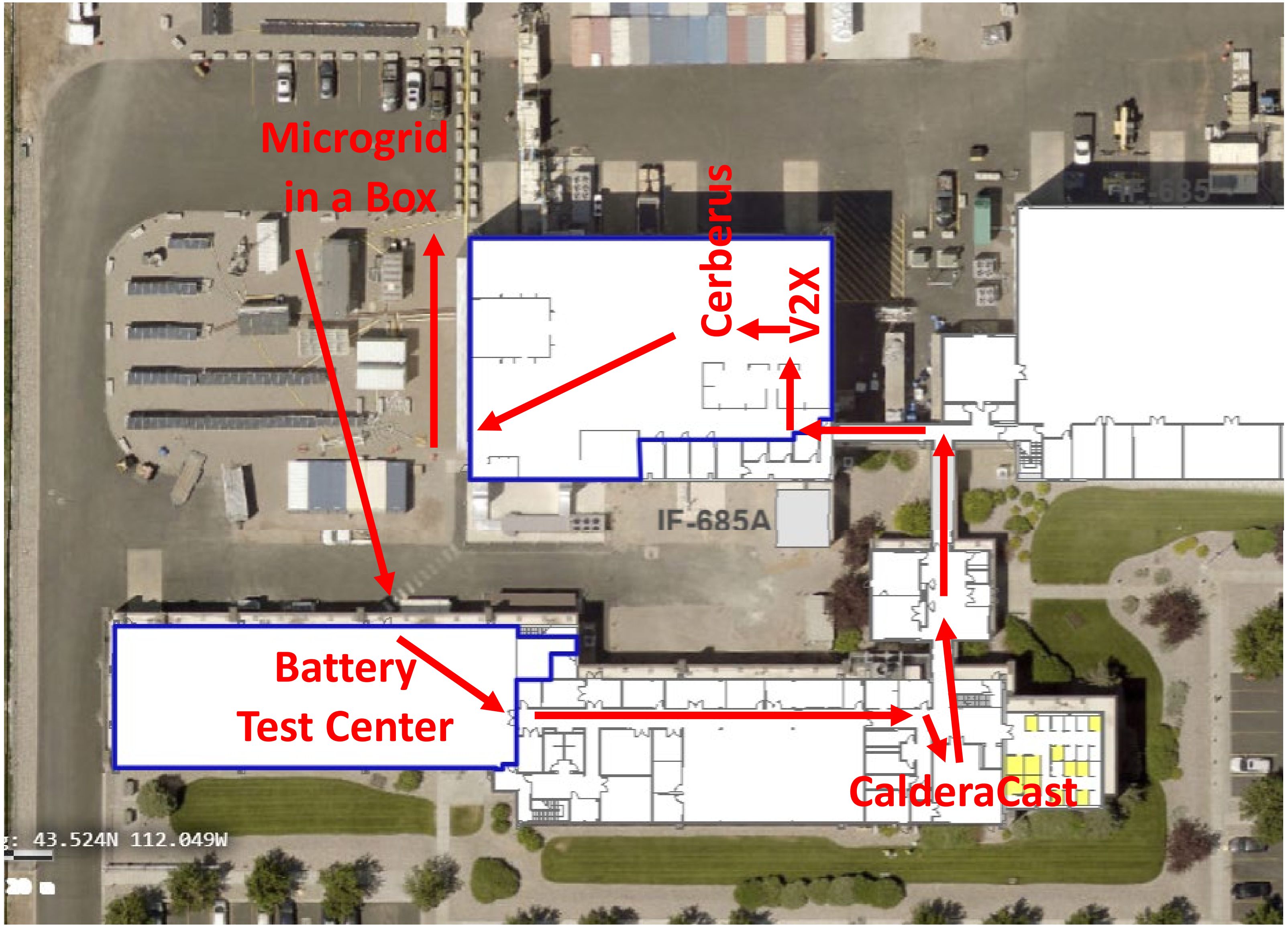
- *Stick together as a pillar group.*
- *Follow your INL Escort*
- *Exit Meeting Center Lobby*
- *Follow sidewalk North to Blvd*
- *Cross MK Simpson turn right*
- *Take first left across parking lot*
- *Continue north and then left to ESL Main Entrance*



Tour and Demo Locations at ESL

Tour Rotation

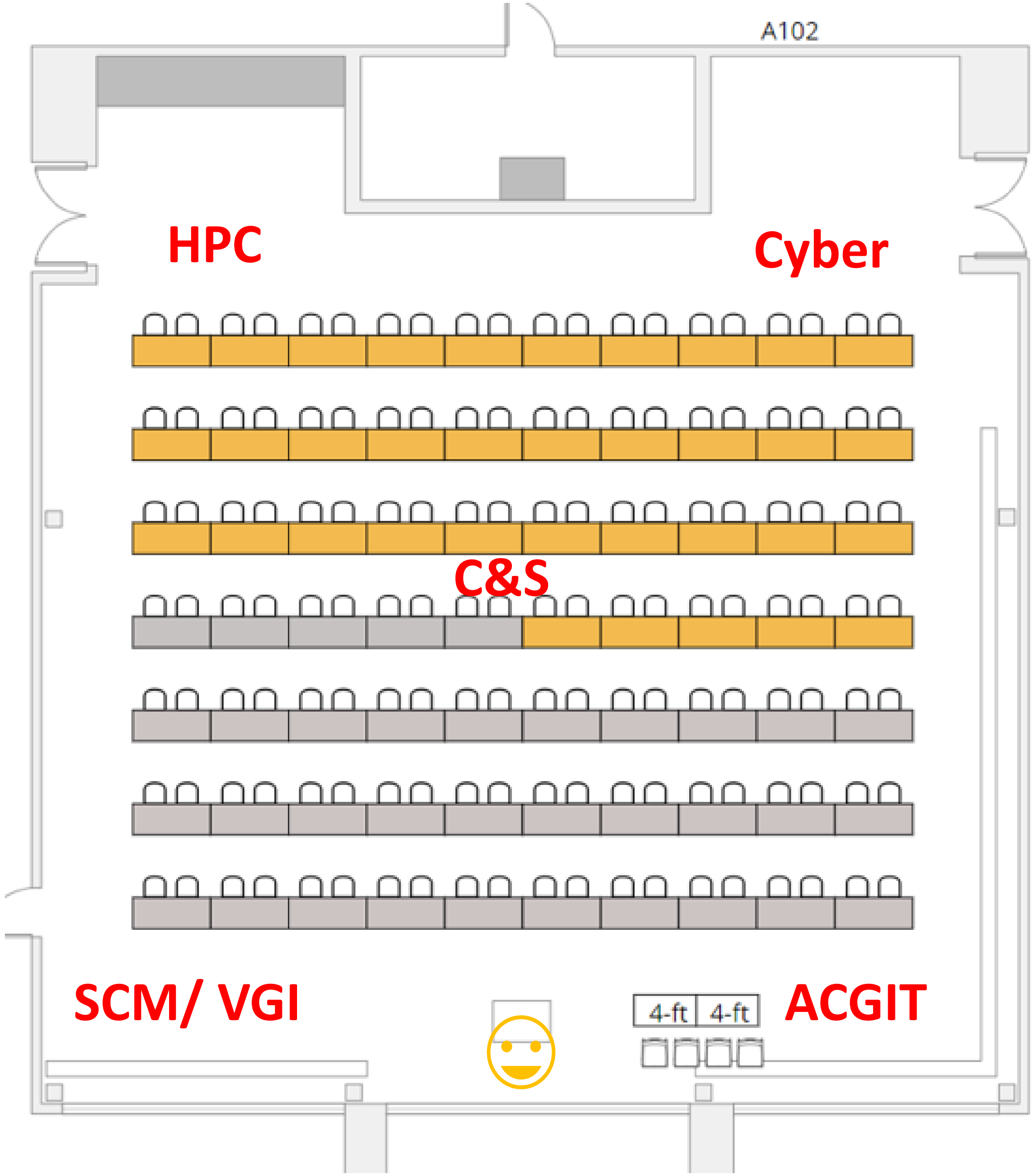
- *Follow your INL Escort to your first tour location*
  - *SCM/VGI @ V2X*
  - *HPC @ Cerberus*
  - *Cyber @ Microgrid in a Box*
  - *ACGIT @ Battery Test Center*
  - *C&S @ CalderaCast*
- *Rotate Clockwise after 20 minute Demonstration or Tour*



Split into Pillar based Tour Groups

- Please join a Tour Group aligned with the pillar area that best matches your work or interests.
- If the groups becomes very uneven we will have to manually shift some attendees.
- Wait for your INL Escort to depart toward your first stop on the tour.

- **SCM/VGI: Front Right**
  - Jesse Bennett - Pillar Lead
  - John Smart - INL Escort
- **HPC: Back Right**
  - John Kisacikoglu - Pillar Lead
  - Eric Dufek - INL Escort
- **Cyber: Back Left**
  - Tom Carroll - Pillar Member
  - Griffin Egner - INL Escort
- **ACGIT: Front Left**
  - Benny Varghese - Pillar Member
  - INL Escort - David Smith
- **C&S: Center**
  - Ted Bohn - Pillar Lead
  - INL Escort: Anudeep Medam



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Advanced Charging and Grid Interface Technologies Pillar

Bi-Annual Meeting Stakeholders Meeting

Madhu Chinthavali

Prasad Kandula, Michael Starke, Omer Onar, Benny Varghese,Thomas Carroll

Don Stanton, Tim Pennington, Lori 'O' Neil

9/26/2024

Advanced Charging and Grid Interface Technologies Overview

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Vision **:**The Advanced Charging and Grid Integration Technologies (ACGIT) Pillar in an incubator of critical technologies with focus on basic R&D of high-risk, high-return technologies and systems to advance the resiliency of EV charging stations and equipment.

Goal : The ACGIT Pillar centers on the proof-of-principle of advanced hardware components, subsystems, and systems, including scoping, benchmarking, and demonstration of advanced technology prototypes. Integrated virtual platforms and tools are utilized to evaluate prototypes with the technology readiness level (TRL) of selected technologies raised to 3-5.

Advance Components

- Identification of gaps in components : semiconductors, breakers, aux power systems
- Establish testing practices and protocols
- **Evaluating early-stage reliability of the subsystem components**
- Advanced magnetics with high insulation and low PD (partial discharge) while maintaining compact size/weight that will ensure reliable component life

Charging station Subsystems: development

- **Library of power stages:** Standardization techniques to achieve Plug-n-play
- **Communication and data interfaces for in-situ monitoring**
- **Diagnostics and Prognostics**

Charger prototyping

- **Novel topologies** that can achieve efficiency improvements, cost reduction or/and control simplifications
- Converter control architecture to handle multiple modules

Advance Controls and software platform development

- **Software architecture** and platforms for resource integration
- Real time management of resources beyond the chargers
- Multiple control schemes for multiple grid services for autonomous or coordinate secondary control

Use case development and pilot demonstration : Virtual and @scale

- **Use cases** for charging stations- large scale applications
- Real time, CHIL test beds for use case validation for future charging station architectures
- Evaluation of novel station architectures using @scale test beds

Synergistic cross cutting technology opportunities with other programs - OE,GMLC

Advanced Charging and Grid Interface Technologies: Thrust Areas

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Address System Integration Challenges and Resiliency of EV ECOSYSTEM

Vehicle, Charger and Grid Interface Technologies

- ***Topologies : Advance component technologies*** *and controls for novel charging functionality*
- *High power* ***equipment prototyping*** *for heavy-duty vehicle and similar applications such as aircraft*
- ***Flexible, modular, multiport Interface configurations for LD, MD, HD, off-road, and e-VTOL applications***

Resilient Charging and Resource Integration Platforms

- **Autonomous controls for charger, Power quality issues**
- ***Energy storage, photovoltaic, and other technology integration solutions for*** Application of V2X
- ***Novel controls station level strategies.***
- ***Data Privacy and Ownership and DATA strategy***

Prognostics and Diagnostics and Advanced Algorithms

- **AI/ML techniques for anomaly detection**
- **Subsystems and power stages diagnostics**
- **Subsystems and equipment prognostics**
- **Optimization for of operation-based controls for station**

Networked Charging Station Architectures Infrastructure

- **Novel energy infrastructure architectures**
- ***EV substation design and development for future large scale muti-vehicle stations***
- ***Interface protection, safety and interoperability***
- **Networked/coordinated station segments**

Pillar Approach

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Identify Resiliency Challenges

- *Identifying EV charging operational threats*
- *Establish technology baseline and state of the art*

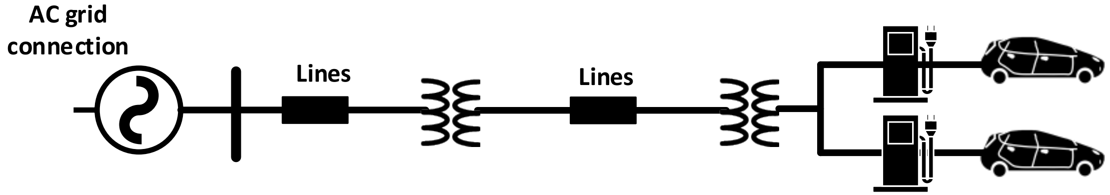
Research Project

- *Establish research to validate resiliency challenges and solutions*
- *???*

Tools and Testbed Development

- *Establish tools and facilities and equipment required to validate resiliency challenges and solutions*
- *????*

Resiliency Challenges

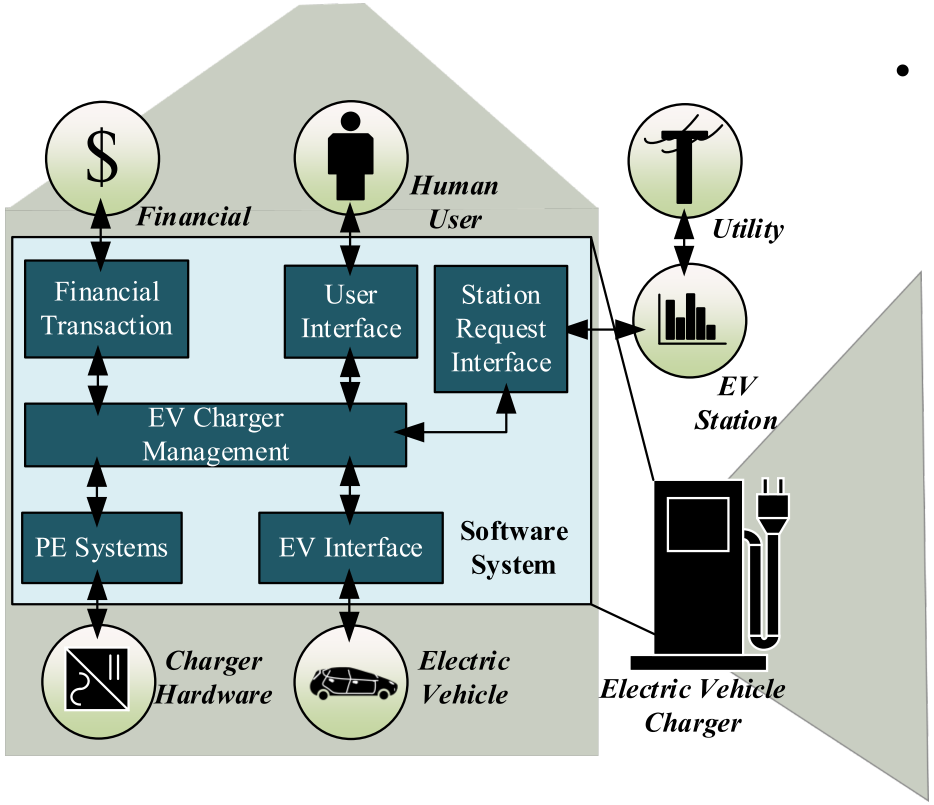


Grid Interconnection

- Line faults
- Transformer failures
- Grid outages
- Capacity limitations

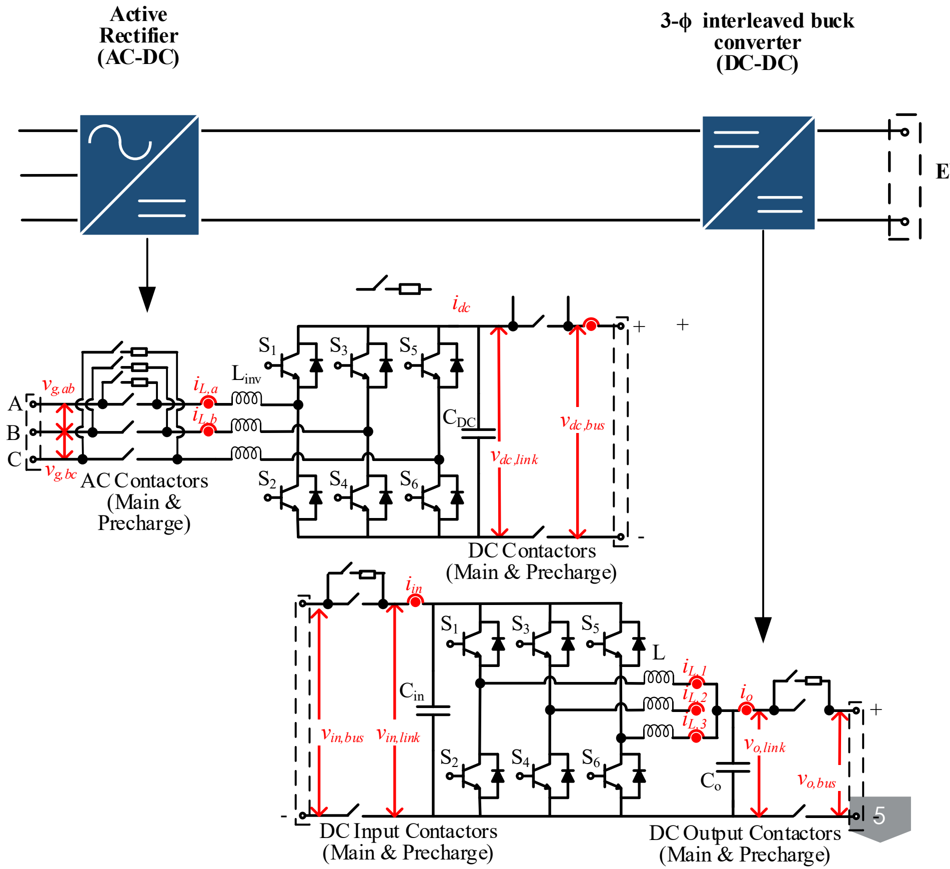
EV Charger Failures

- Software issues
- Cable fractures
- Communication Failures
- Bad actor Intrusions



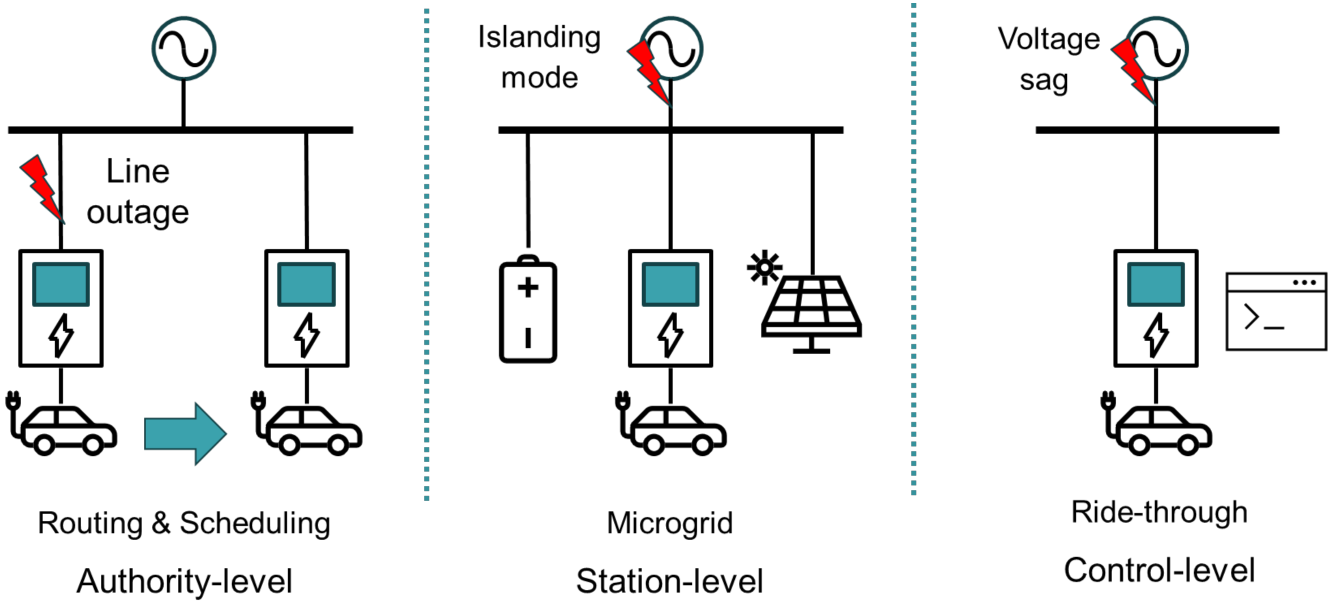
Converter Failures (Considering Different Topologies)

- Control Responses (external and internal failures)
- Component Failures



Solutions for EV charging resilience in response to grid disturbances

What role can EV charging stations (multi-MW) can play in supporting grid during transients?



Three major supporting roles

- **Primary frequency** control
  - Inertial support (0.25 cycles – 0.1 S)
  - Fast Frequency response (0.1-10s)
- **Secondary frequency** control (> 60 s)
- **Tertiary frequency** control (minutes)

Charge ramp rates limited by EV BMS, EV charging stations may only provide limited primary frequency response by simply dropping the load – not V2G

EV charging stations with stationary storage can provide full primary frequency response, but need **Grid-forming technology**

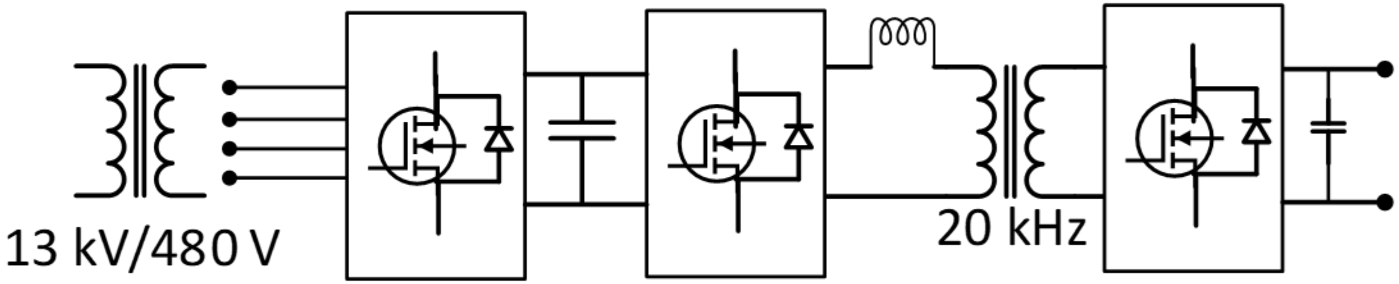
Project 1: Grid Forming Charger: Prasad Kandula

- **Objective:** is to develop a fully integrated charger/storage system with the grid interface converter enabling advanced functions such as operating as an islanded system, responding to grid transients

- **Gaps**: Fully integrated charger capable of providing grid support functions (respond to frequency variations etc) and ability to operate under islanded/grid connected modes.

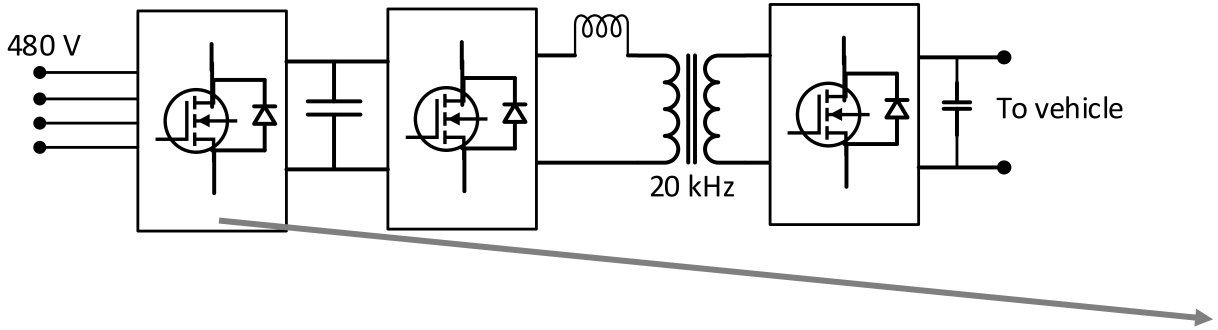
- **Main challenges:**
  - Grid interface converter providing advanced functionality while considering DC side dynamics, transient free synchronization/islanding, supply for local unbalanced loads.
  - Coordination of multiple DC/DC converters and co-ordination of multiple grid forming converters to ensure oscillation free operation.

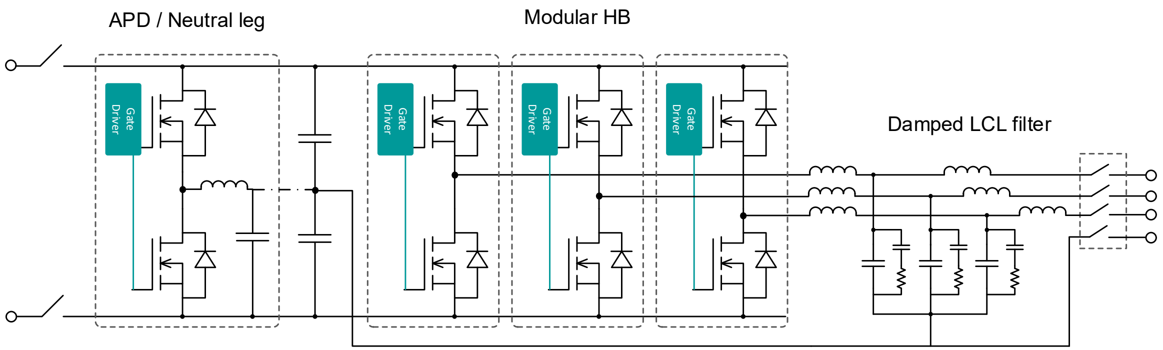
- **Projected Outcomes:** Use charging systems to improve Grid or local system resiliency



Integrated charger (Grid to vehicle) with Advance Grid Controls : Grid Forming Charger

Integrated charger (Grid to vehicle) with Advance Grid Controls : Grid Forming Charger

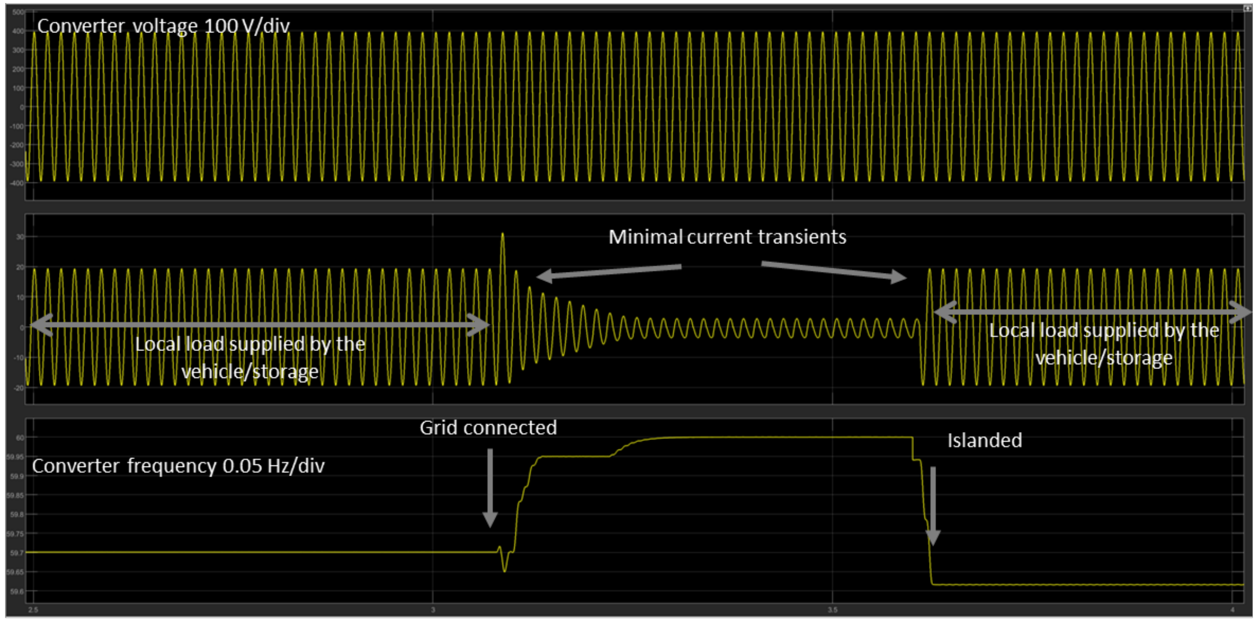




30 kW 3-ph 4-wire 480 V AC converter

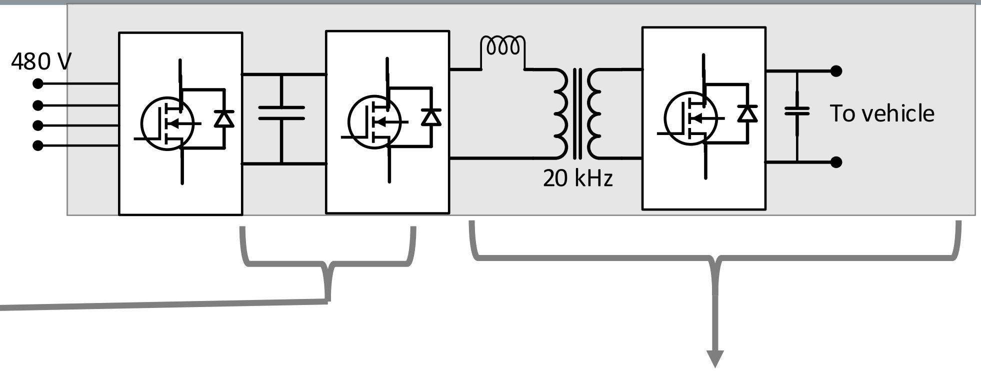
Features

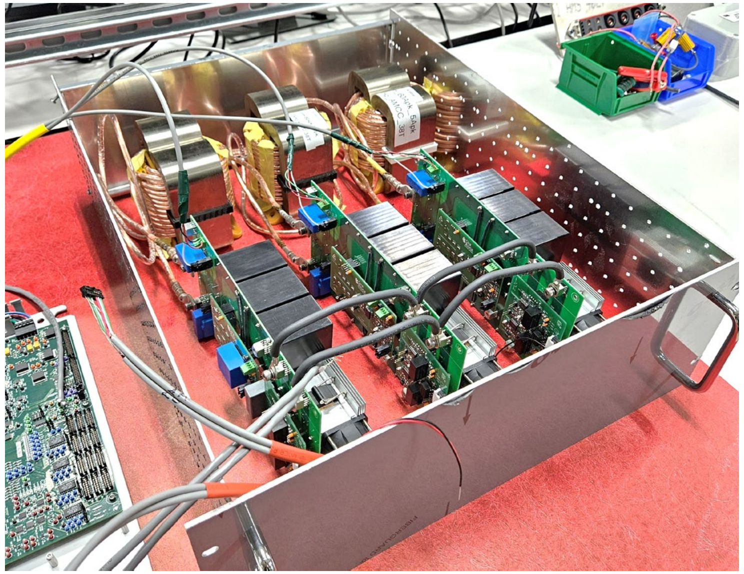
- Bi-directional ,1 KV class, 480 V AC, 1000 V DC
- 4-wire grid interface, Grid-forming operation
- Grid connected mode:
  - Inertial support under grid disturbances
  - AC droop controls
- Islanding mode:
  - Ability to form local micro-grid
  - unbalanced operation capable
- Adaptive virtual impedance
- Integrated vehicle comms and isolation monitoring



CHIL results for the charger supplying local AC load

Integrated charger (Grid to vehicle) with Advance Grid Controls : Grid Forming Charger



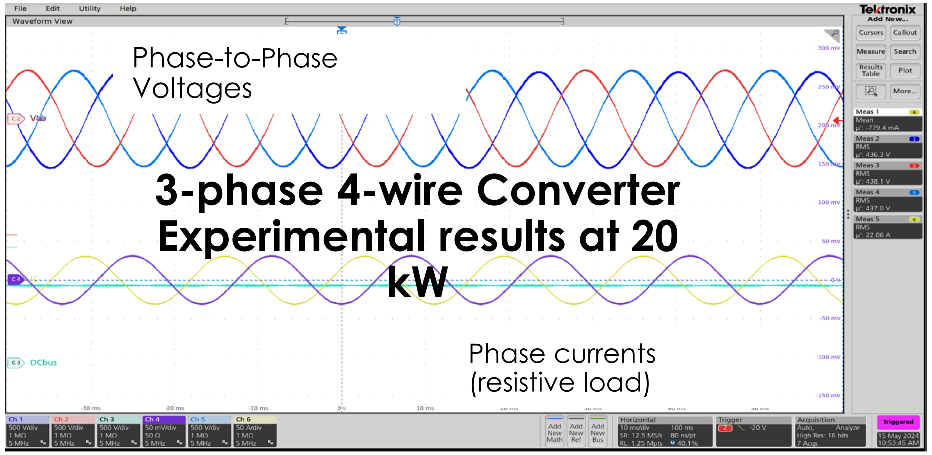


A 30 kW 3-ph 4-wire 480 V AC inverter prototype

A 150 kW Dual Active Bridge Prototype

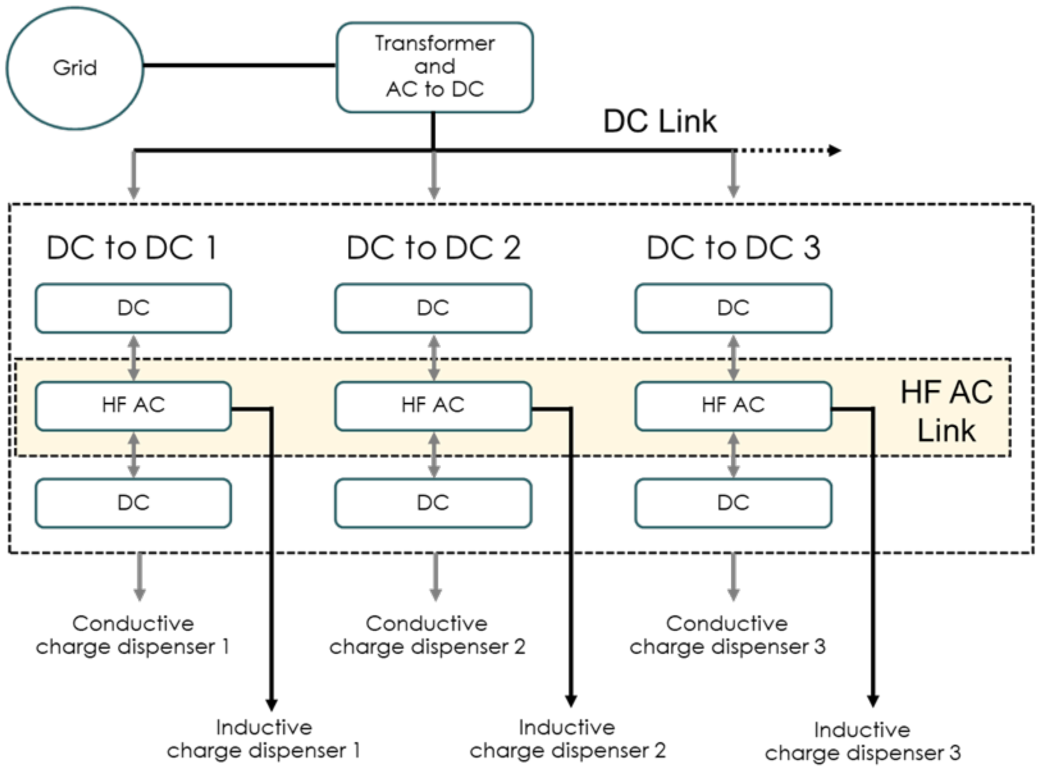
30% lower volume than the first version

V1: 36”x 20” x 11”
V2 : 30” x 18” 10” (30% reduction)



Project 2: Hybrid Wired and Inductive HFAC Charger : Omer Onar

Objective: To develop and validate a universal power electronics architecture with high-frequency AC link to enable interoperability and increased utilization of grid and vehicle interface technology with optimized footprint and cost



Gaps:

- **Interoperable:** can supply high power conductive or inductive charge dispensers
- **Compact:** optimally shared PE architecture with HF AC link: Hybrid Wired/Inductive
- **Reliability**: increased reliability with modular restructuring of architecture

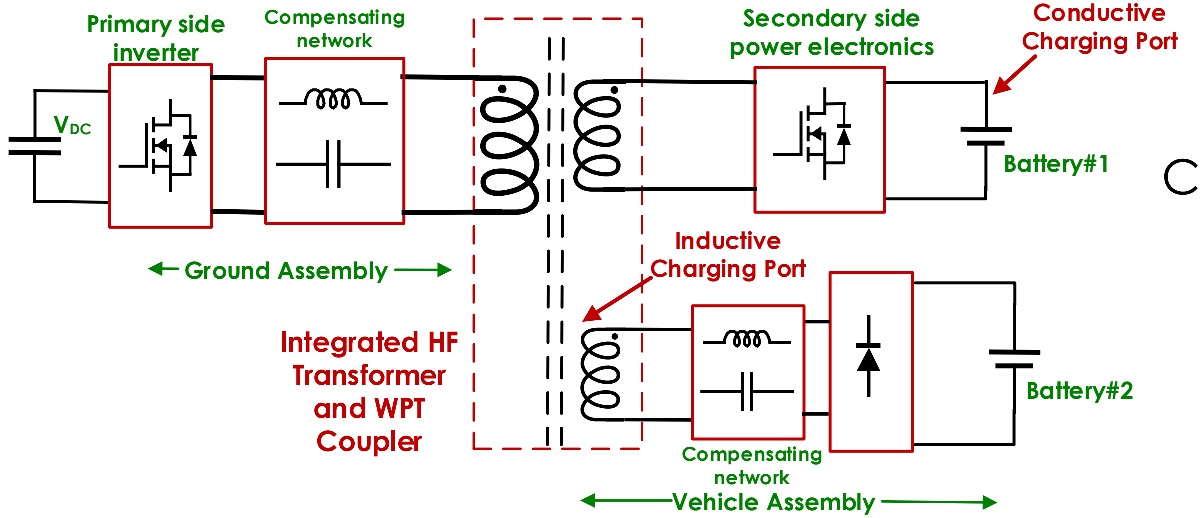
Main challenges:

- Planar coil designs and flux shaping
- Control complexity for power sharing

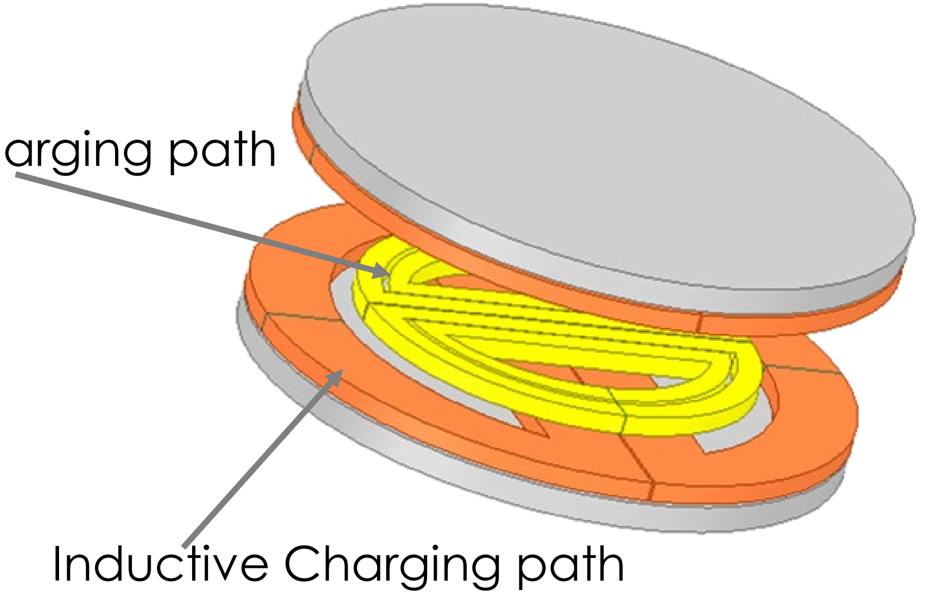
Outcomes: Modular, Scalable, and Interoperable

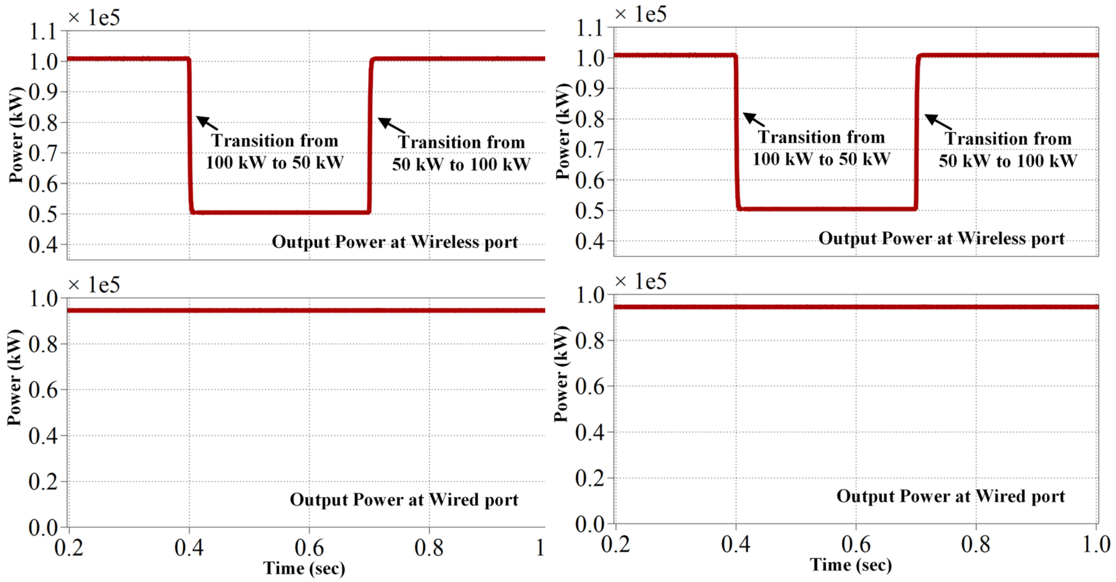
- Power can be tapped at DC and HF AC points
- Suitable for conductive and inductive charge dispensers
- Increased utilization, interoperability, and flexibility

Technical Accomplishments : Flexible Multi-port Vehicle and Grid Interface Architecture – DC/HFAC/DC (Flex-Charge)



Integrated high Frequency power electronics inverter stage





Integrated WPT coils and High Frequency Isolation Transformer at 85 KHz

Transmitter has 2 sets of coils – DD and QQ

- inductive receiver has a DD coil
- conductive receiver has a QQ coil

Project 3: Megawatt Scale Charging Resiliency
Michael Starke

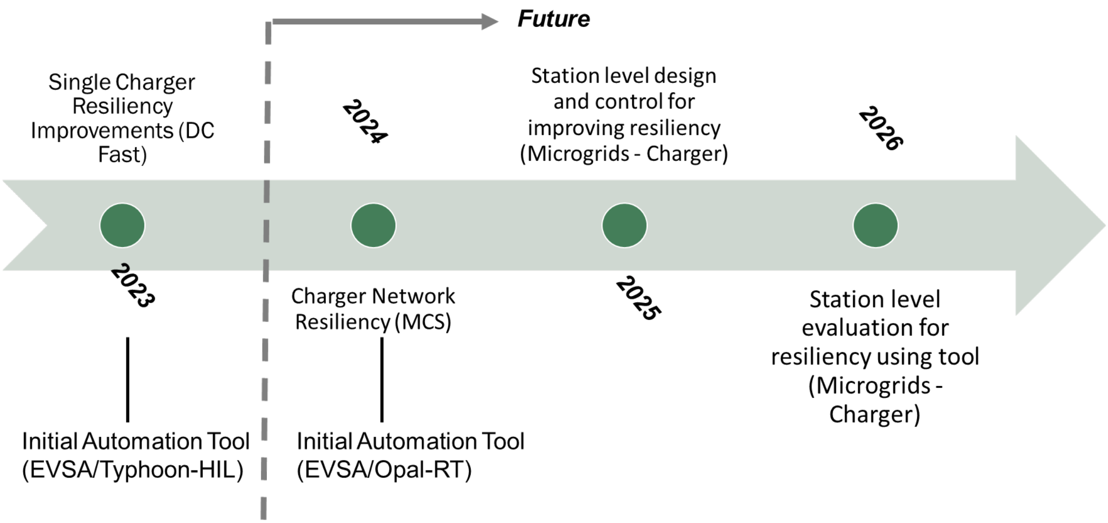
Objective: Develop resiliency improving approaches for heavy duty (HD) class EV charging systems.

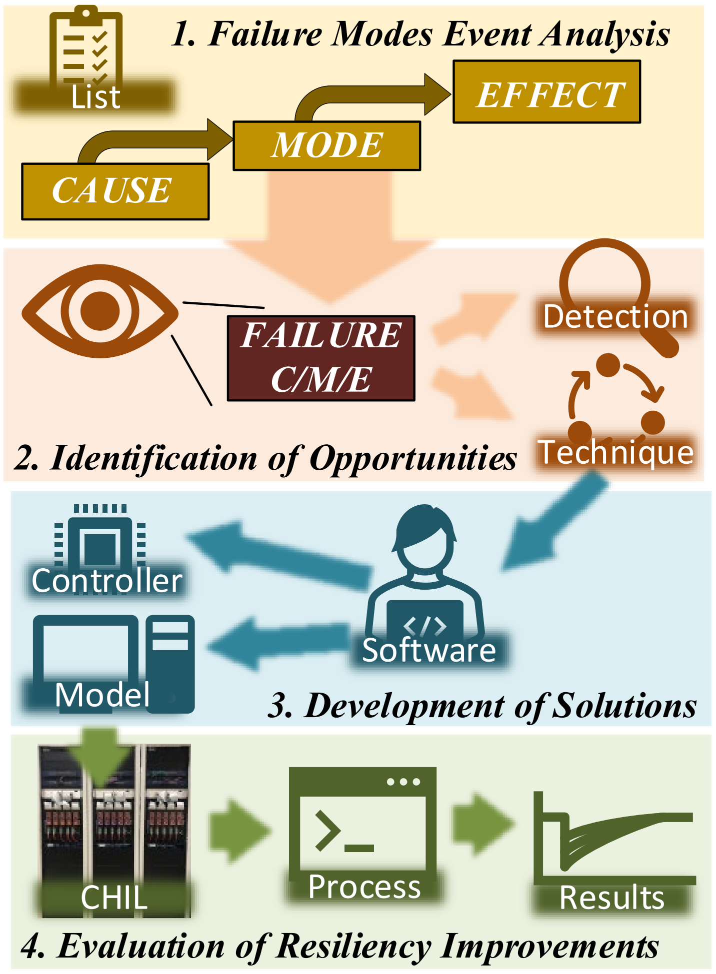
Gaps: Resiliency methods and evaluation tools for supporting MCS architectures

Challenges:

- MCS architectures and topologies are in still in development with resiliency often not considered.
- Many different resiliency improving options to consider.
- Modeling should be able to adopt new architectures and topologies quickly and evaluate them with real-time solutions efficiently.

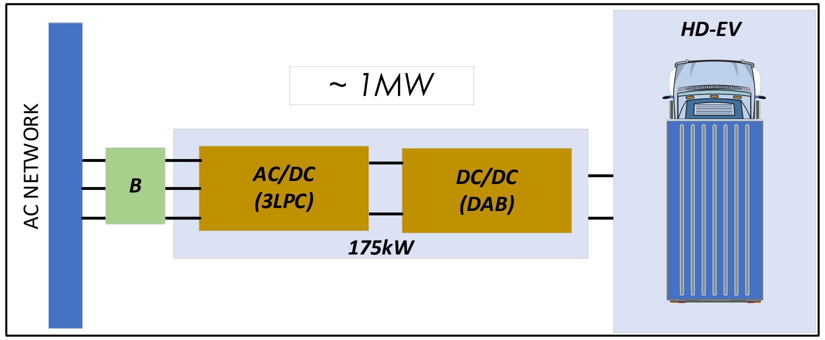
Outcomes: Resiliency improving techniques developed and proven in real-time simulation environment

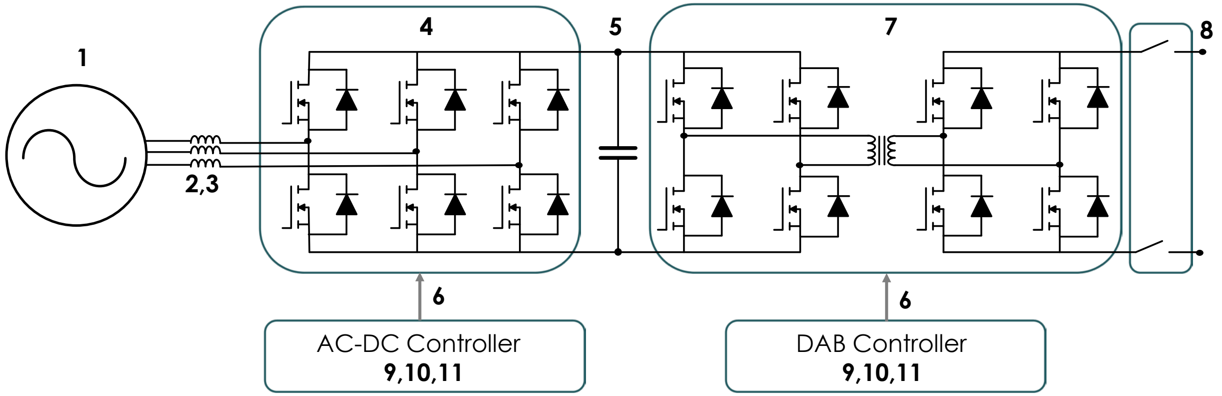




Megawatt Scale Charging Resiliency

MCS Schematic





MCS Power Electronics Topology

List of Important MCS Components

ID	Component	ID	Component	ID	Component
1	Grid	5	DC-Link Capacitance	9	Controller Circuitry
2	AC Filter	6	Sensors	10	Controls
3	AC Contactor	7	DAB Converter	11	Communication
4	AC-DC Converter	8	Charging Cable		

Component	Failure Mode	Cause of Fault	Fault Detection	Fault Impact	Fault Response
Grid	Grid Overvoltage Transient	• System dynamic response after fault • Lightning strikes or switching transients	Grid voltage sensing	• Impact on DC voltage control, low voltage oscillation introduced for higher voltages • Component(inductor, capacitor, switches) damage	• Fault ride through w.r.t IEEE 1547 • Components and controllers designed for full range of acceptable overvoltage • Shutdown if overvoltage not cleared in time
	Grid Undervoltage Transient	• Faults upstream (transmission level) appear as undervoltage events	Grid voltage sensing	• Impact on DC voltage control • Increased AC-side current	• Fault ride through w.r.t IEEE 1547 • Controller designed for full range of acceptable undervoltage • AC Current limiting might be necessary, thus limiting EV power • Shutdown if undervoltage not cleared in time
	Grid Underfrequency/ Overfrequency Transient	• Imbalance between generation and load	Grid frequency calculation	• Properly designed AC/DC controller should be able to handle acceptable frequency issues with no impact	• Fault ride through w.r.t IEEE 1547 • Design AC/DC controller for full range of acceptable frequency operation • Shutdown if transient not cleared in time

Device fault ride through (DFRT) strategy

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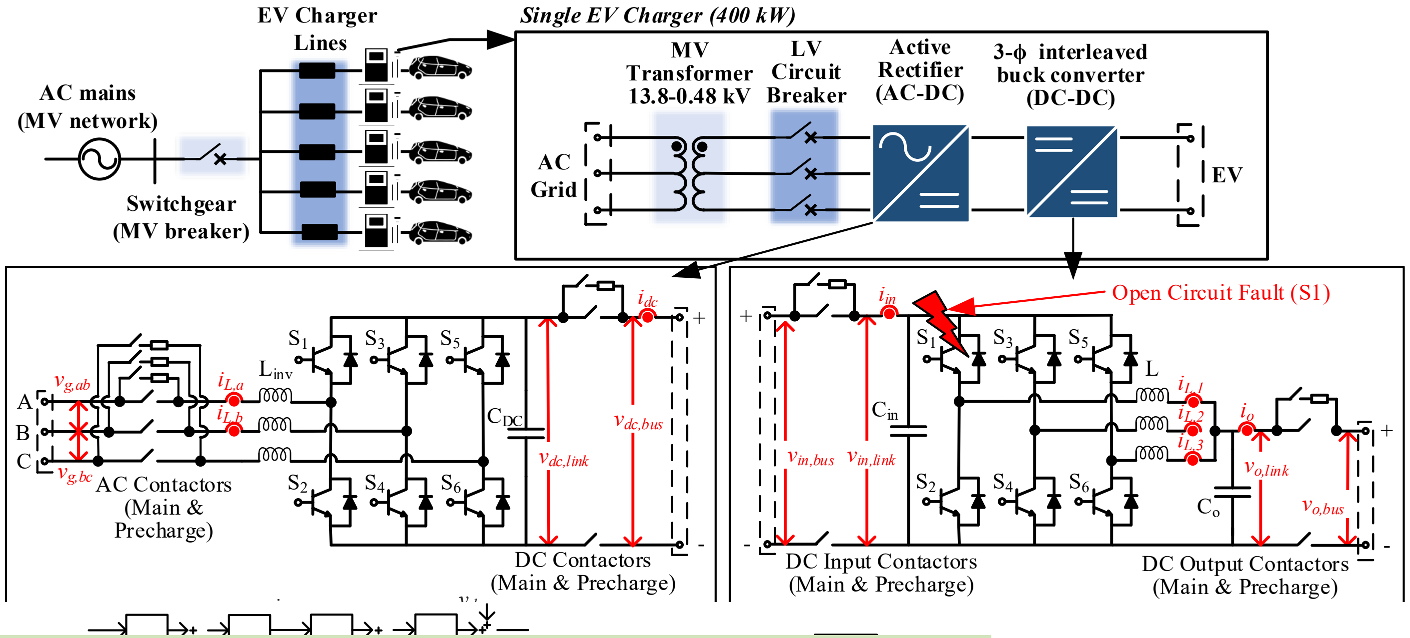


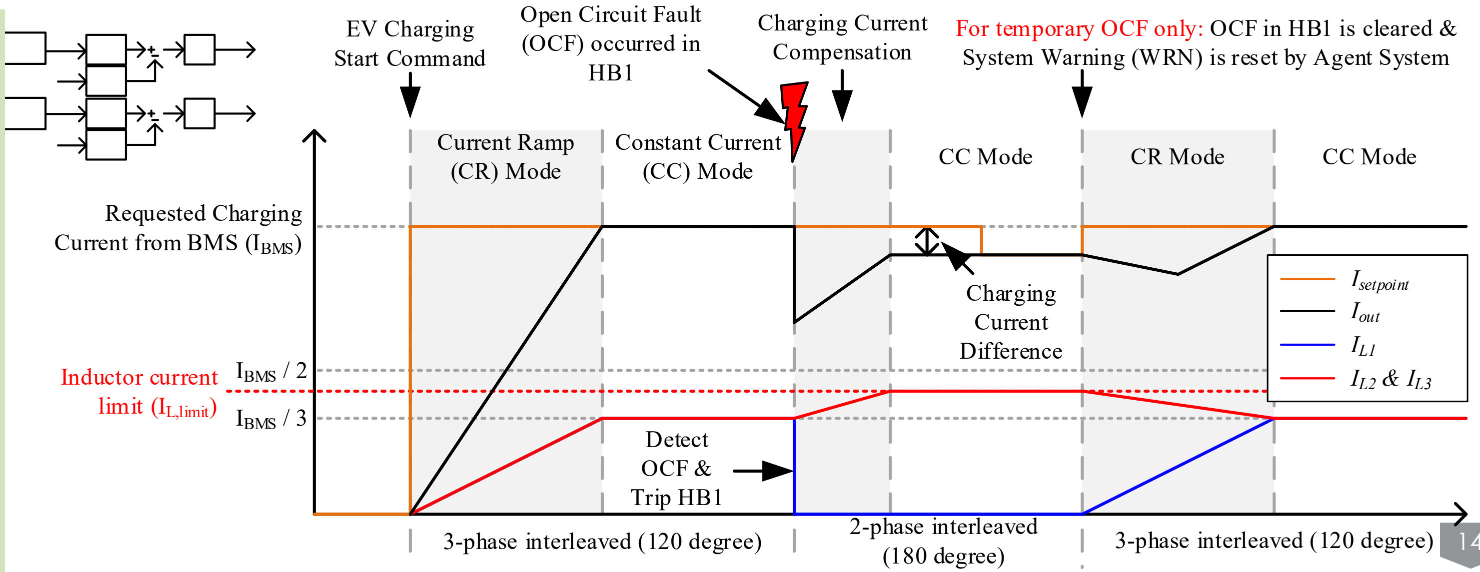
Objectives

- Fast protection and DFRT
- Active status monitoring
- EV charging management

2024 Energy Conversion Congress and Exposition Prize : First Prize Paper Award

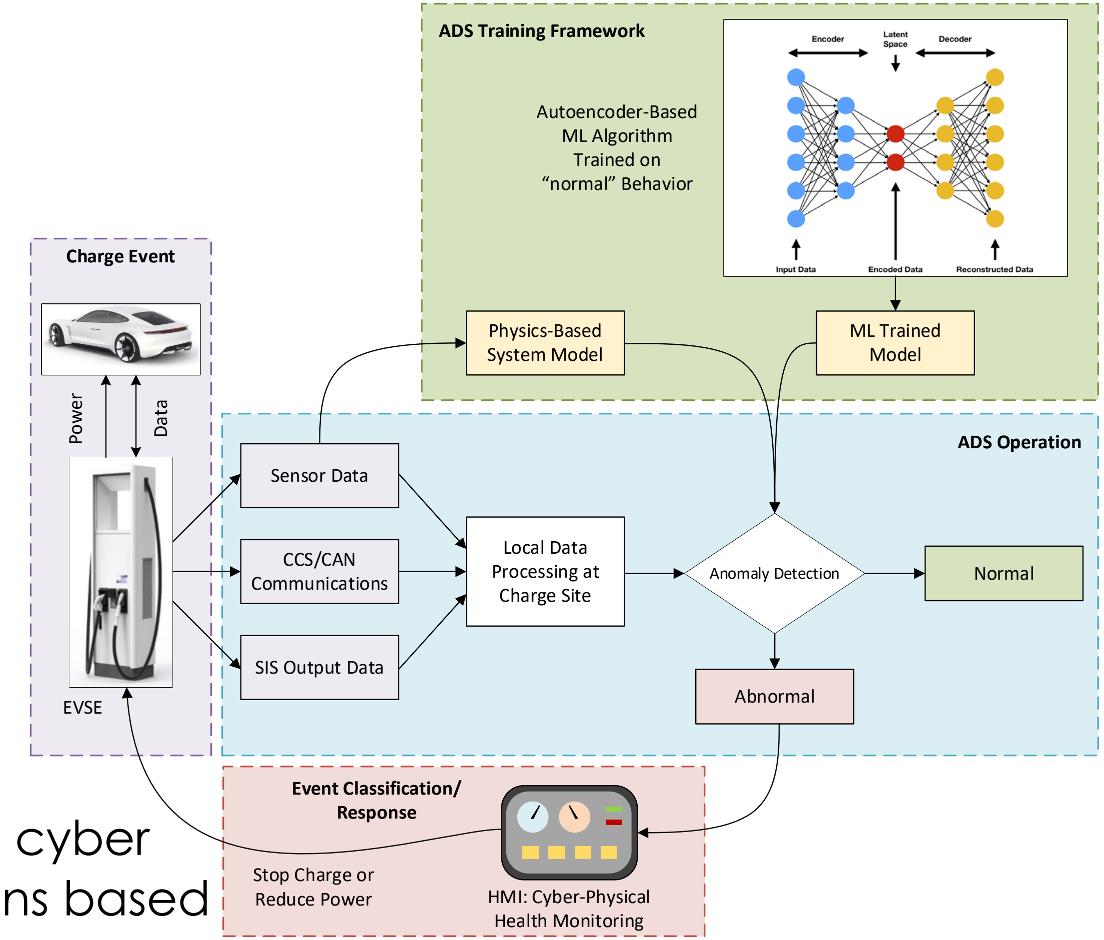
Paper Title: Improving EV Charging Resilience under a Device Fault Condition

Authors: Namwon Kim, Michael Starke, Benjamin Dean, Grid Systems Architecture, Oak Ridge National Laboratory, Oak Ridge, USA



Project 4 : EV Charging Anomaly Detection and Resilience Monitoring Benny Varghese: INL

- **Objective:** To improve resilience of EV charging infrastructure with a focus on Anomaly Detection and Resilience Monitoring
- **Industry gaps:** Limited MCS infrastructure deployment or hardware test-bed environment
- **Main challenge:** Availability of high-fidelity data streams across a large area covering multiple charging station operators
- **Projected outcomes:** Understanding resilience requirements and developing detection methods to identify anomalous behavior in EV charging stations



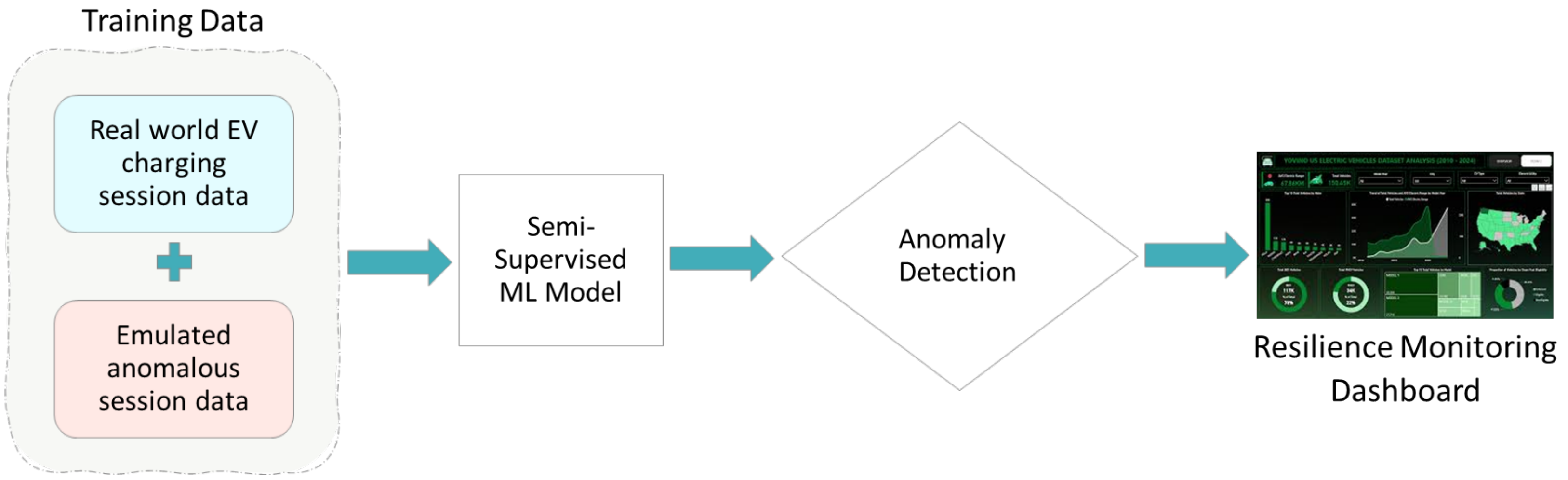
- Anomaly detection system frameworks explored to detect cyber and/or physical anomalies in EVSEs and EV charging stations based on the following data streams:
    - Physical sensor measurement data from the EVSE – voltage, current, temperature etc.
    - Input CAN communication to the EVSEs
    - OCPP communication between CSO and EVSEs

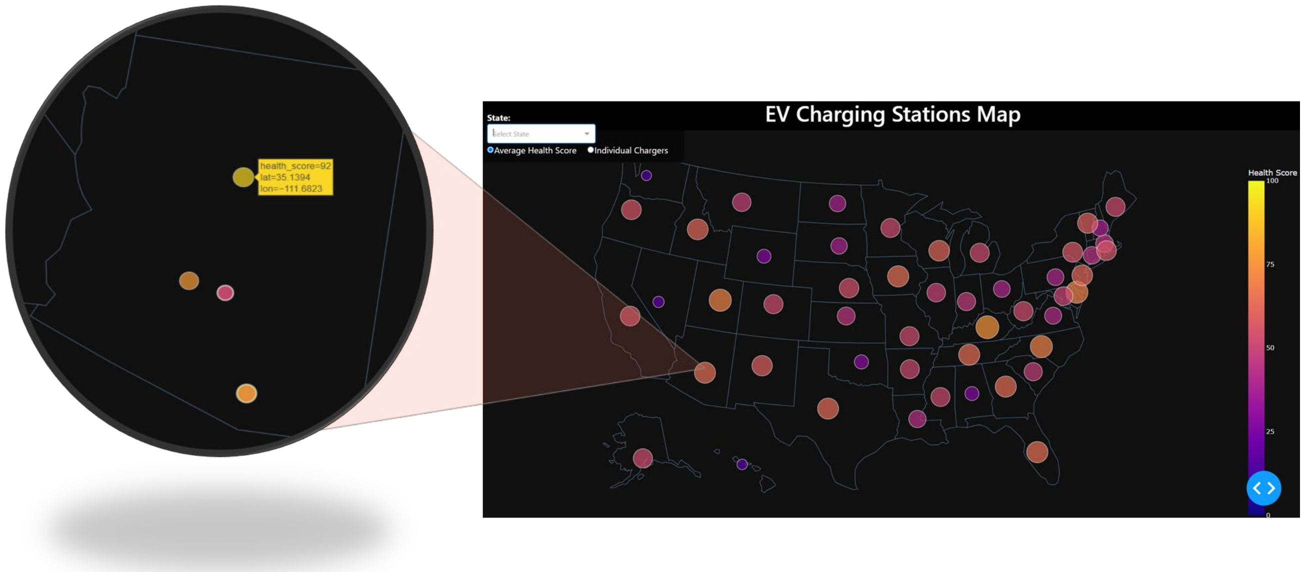
Project 4 : EV Charging Anomaly Detection and Resilience Monitoring Benny Varghese: INL

Ongoing and Future Work:

- Develop a Resilience Monitoring dashboard for EV charging infrastructure
- Real world data for ~6000 charging stations and ~12000 DC charging ports across the US
- Current data limited to CCS and CHAdeMO ports
- 6 months of aggregated charging session data via OCPI
- Dataset for ML training includes real world data along with fault data emulating cyber-physical anomalies and other resilience events

- Industry collaboration with Paren (EVSession)
- Academia collaboration: Virginia Commonwealth University (VCU)





Project 5: Charging station controls for MCS architectures
Thomas Carroll

Pacific Northwest NATIONAL LABORATORY

EVs@Scale U.S. Department of Energy

- **Objective:** Identify and evaluate architectures, controls, and strategies for resilient and secure MCS depots
- **Adapt to site and service application:**
  - Station Interruption frequency average
  - Station Interruption duration average
  - Station Interruption service recovery
- Resilience may also be further evaluated by determining whether vehicles are charging in accordance with a defined set of expectations
- Resiliency reduces deviations from expectations when disturbances occur or stress is encountered

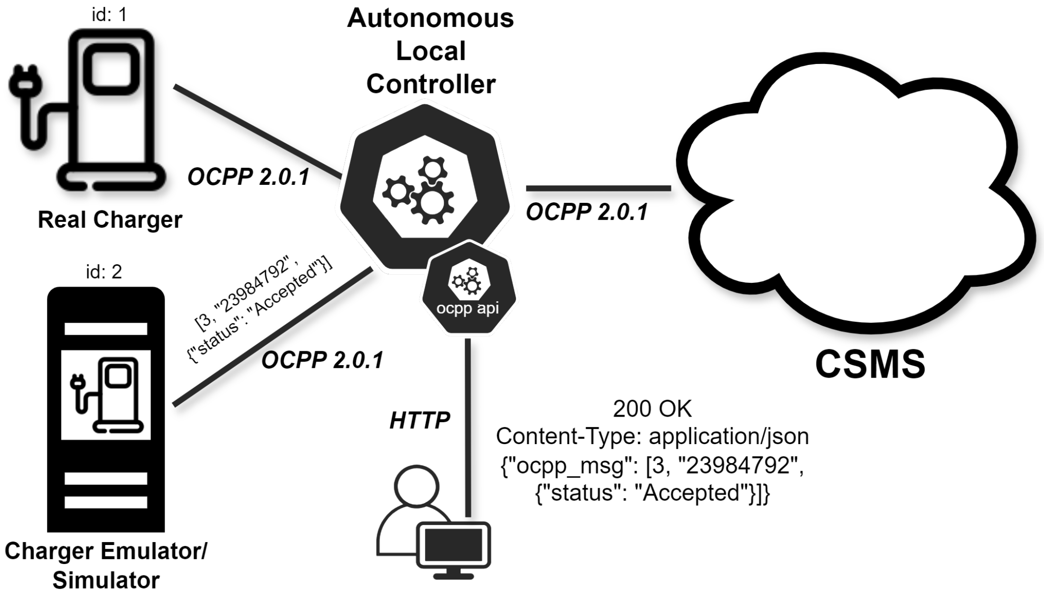
Source: https://electrek.co/2024/05/06/wattev-opens-us-first-megawatt-charge-station-with-1-2mw-speeds-and-solar/

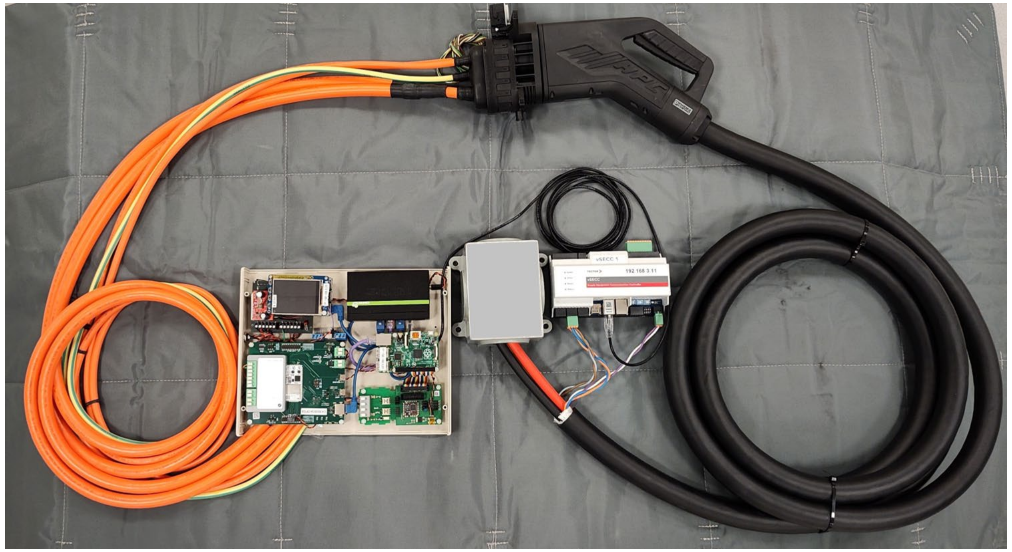
Use Case

- **The facility features off-grid megawatt charging capabilities.**
- **Three 1.2 MW Megawatt Charging Systems (MCS) installed**
- **A 5 MW solar field spans 100 acres**
  - This enables the MCS charging to be decoupled from the grid
  - Room for expansion up to 25 MW
- **3 MWh, 4 MW Energy Storage System**

Prototype OCPP API Gateway

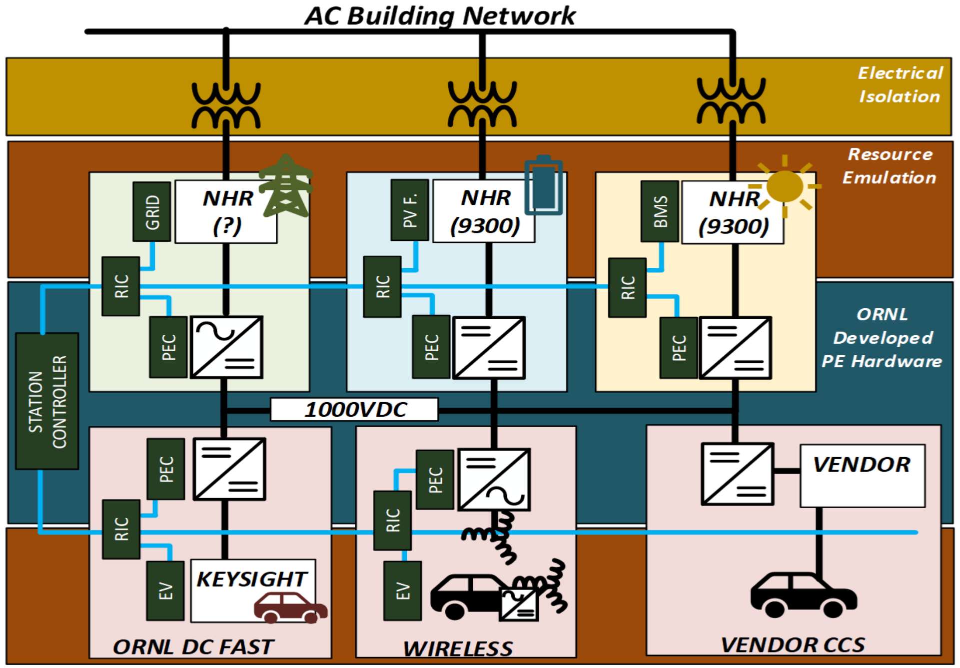
- **Prototype Extensible OCPP 2.0.1/2.1 Framework:** Designed to facilitate seamless integration and experimentation with OCPP-compliant systems.
- **Bridge Between Simulation, Real Hardware, and Software:** Facilitates interoperability among simulators, real-world chargers, dynamic load management controllers, and Charging Station Management Systems (CSMS).
- **Prototyping of Advanced Programmatic Features:**
  - Integration of fleet operation and charging management, including setting State of Charge (SoC) targets based on vehicle
  - Automatic restart of charging sessions following unexpected disruptions.
  - Dynamic load management based on priority to optimize revenue or power distribution.





Unique Capabilities Generated by Labs to Support: Multiport Charging Station Test Bed at ORNL: 3 Ports Up to 500 kW

ORNL RT-simulation system for RT evaluation of control solutions and @scale test beds for advanced technology prototypes evaluation



Unique Capabilities Generated by Labs to Support :EV Charging Infrastructure @ INL

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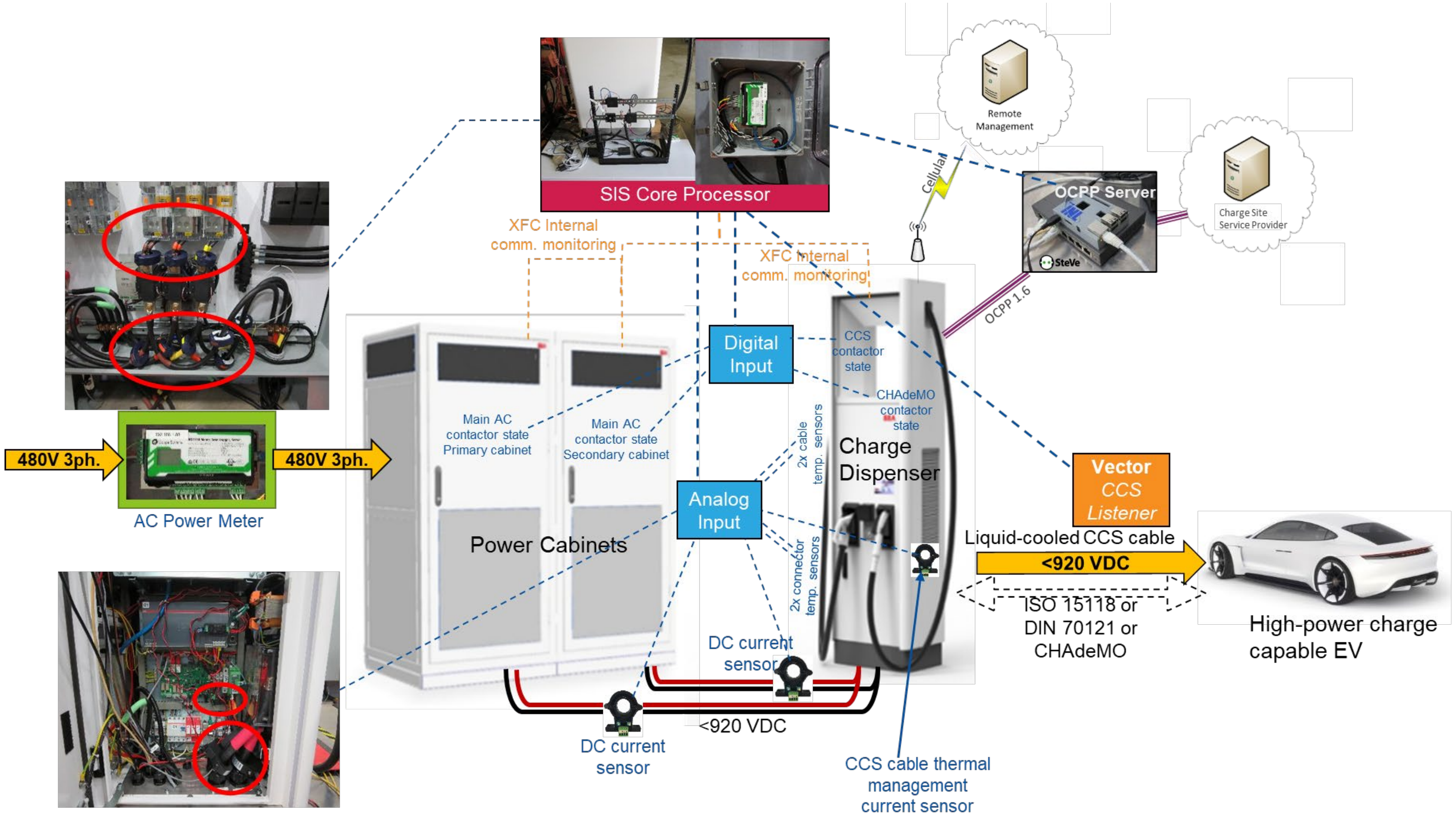
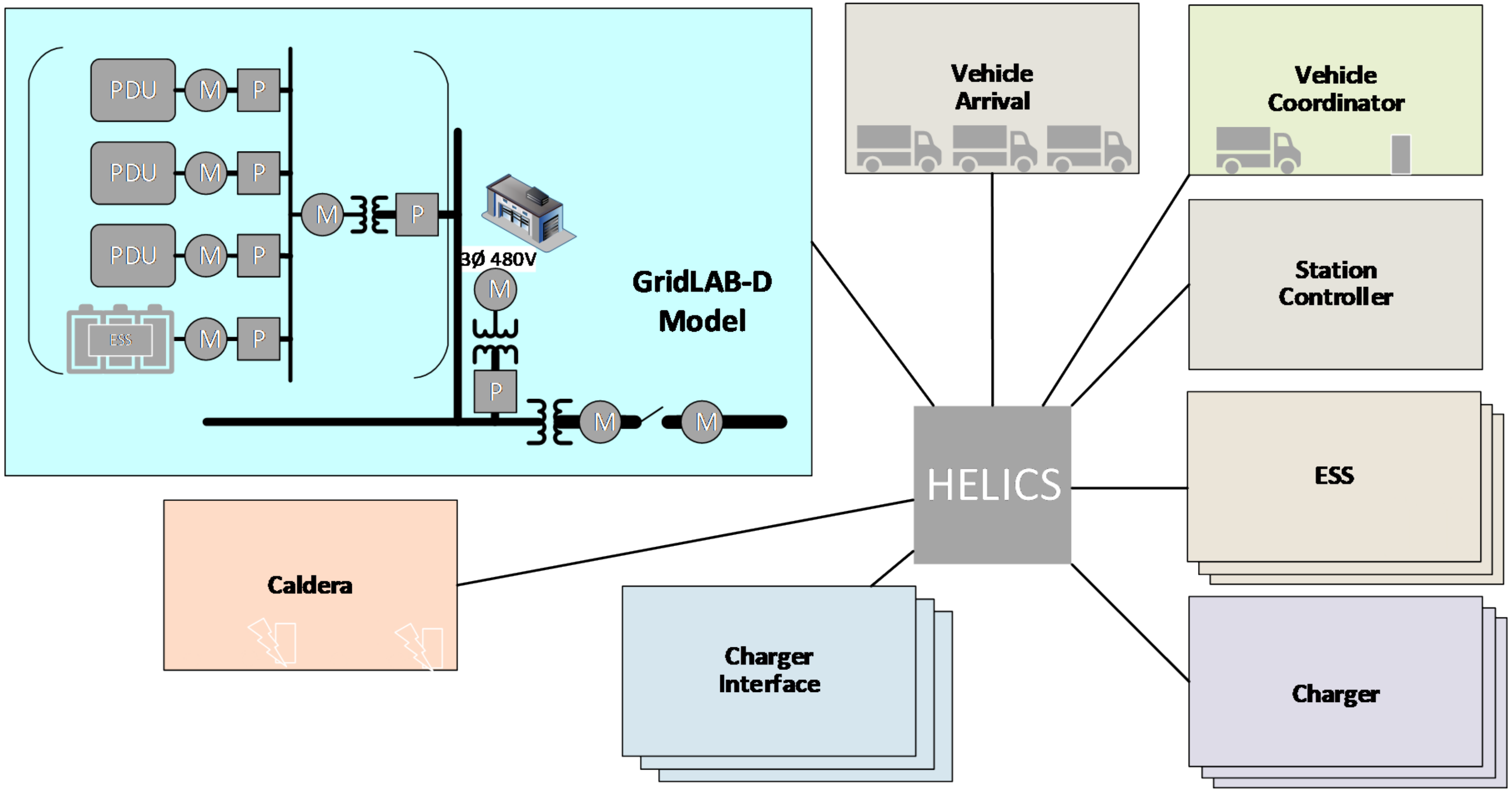
Hardware Testbed at INL



Unique Capabilities Generated by Labs to Support *PNNL simulation system large scale modeling*

- GridLAB-D simulation
- INL's Caldera EV charging simulation
- Fast Charger Emulator
- OCPP Service Framework
- Resilience Through Data-Driven, Intelligently Designed Control (RD2C)



Successful Partnerships – EVs@Scale Advanced Charging and Grid Integration (ACGIT)

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Wireless Power Transfer (WPT) for EV Charging

- Ongoing collaboration with **Porsche** beyond the successful demonstration of the 270kW ORNL patented polyphase WPT system.
- **BMW** has jointly developed a 22kW polyphase WPT system. Additional collaboration ongoing.
- **BorgWarner** has joined efforts with ACGIT to develop new polyphase topologies for manufacturing.
- Active WPT projects with **Cummins Inc**., **Stellantis**, **Volkswagen**, **Mitsubishi**, and **US Army GVSC**

Partnership Opportunities – EVs@Scale Advanced Charging and Grid Integration (ACGIT)

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- **Converter Technologies**
  - ACGIT technologies and testbed are being used in conjunction with **BETA and UPS** to create a multimodal charging infrastructure that supports both ground electric vehicles and electric aircraft based on Combined Charging System (CCS).
  - **DynaPower** is engaged in transitioning ACGIT EV charging power electronics tech. to product proof of concept opportunities.
  - **evtransportationalliance.org:** The R&D performed under ACGIT is being shared with the alliance for engaging utilities, industry partners
  - **HONDA**: Is interested in exploring data related and systems integration R&D
- **MW Charging Station Resiliency**
  - **Pilot / Flying J** is working with the ACGIT team to explore ways to extend resiliency improving platform and control techniques to MW EV charger stations. Identification of potential resiliency challenges across an EV charging station and DER integration.

Interested in Partnering with ACGIT?

Contact ACGIT Pillar Lead: Madhu Chinthavali, ORNL, chinthavalim@ornl.gov

Don Stanton: Electrification Program Manager, stantondw@ornl.gov

Thank You

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Codes and Standards Support

Theodore Bohn
Argonne National Laboratory

September 26th, 2024

Outline

- Initiative Overview
- Codes and standards activity priorities enabling EVs at Scale
- ‘Divide and Conquer’ approach by lab teams to cover multiple standards areas
- Standards areas covered by each participating laboratory
- Focus areas and progress in standards development in FY24, goals for FY25
- Summary of FY24 deliverables/milestones
- Conclusion and Next Steps

Codes and Standards Support Initiative Overview

Objective: Codes & standards support priorities focus on development of the most critical standards for EVs at Scale, i.e., high power DC charging, storage (microgrid, DERMS) integrated with DC charging, vehicle-grid integration, high power scalable/interoperable wireless charging, vehicle-oriented system standards and energy services to support transparent optimized costs/delivery.

Outcomes:

- Complete drafts of SAE J3400 NACS, J3271 Megawatt Charging System (MCS), AIR7357 TIRs
- Develop and demonstrate a reference implementation of J3271 MCS EVCC/SECC controller
- Develop phase two of Open API Energy Services Interface (ESI) implementation
- Complete a study w/summary reports in support of identified high importance standards
- Active participation in SDO standards meetings/committees to close gaps in EVs@S standards

Argonne National Laboratory
- Theodore Bohn
- Mike Duoba
- Jason Harper
- Dan Dobrzynski

Idaho National Laboratory
- Richard Carlson
- Anudeep Medam
- Tim Pennington
- Benny Varghеese

NREL National Renewable Energy Laboratory
- Yashodhan Agalgaonkar
- Jesse Bennett
- Yuki Hatagishi
- John Kisacikoglu
- Namrata Kogalur
- Jonathan Martin
- Andrew Meintz
- Vivek Singh
- Isaac Tolbert
- Ed Watt

Oak Ridge National Laboratory
- Veda Galigekere
- Omer Onar
- Don Stanton

Pacific Northwest National Laboratory
- Brian Dindlebeck
- Lori O'Neil
- Richard Pratt

Codes and Standards Activity Priorities Enabling EVs at Scale

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Constant Evolution: The group of lab team members focus is on stds **most** relevant to EVs at Scale

Priority Areas: *(it is now year ~3 of 5 year EVs@Scale)*

- EVs at Scale standards support focus is mostly on scaling charging capabilities. I.e. how to serve more vehicles in more locations without exceeding resource limits, for a spectrum of vehicle sizes/classes (from light to medium to heavy duty; commercial and passenger cars)
  Charging rates from 30A to 3000A for conductive/wireless methods, AC or DC, µgrid, etc

- Electric power delivery oriented standards areas; V2G, local DER, integrated storage, system controls including the Energy Services Interface method of bi-directional information exchange leading to contract based optimization of resources, DC as a Service, communication protocols

- Vehicle Oriented **System Standards** (including non-road, electric aircraft) that include on-vehicle systems (power take-off, refrigeration units, battery management, battery safety, etc.),

‘Divide and Conquer’ Diverse Coverage of Standards by Lab Teams

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5 Lab Teams in FY2024 Covering ‘Top 10’ Standards Areas:

National Lab participants each proposed support/development within the ‘top ten’ areas for EVs@S

General Standards task areas (shorthand summary)

- **NREL** focus on MCS coupler testing, system architectures/impacts study, J3400, P2030.13
- **ORNL** focused on wireless (WPT) topics for standards; new topics in FY25
- **INL** on WPT, P2030.13 (grid side of charging)
- **PNNL** on heavy vehicle charging stds, P2030.13
- **ANL** on ‘umbrella’ (chair of multiple stds groups) coverage of ongoing W&M stds, ANSI meter stds, IEEE P2030 series (.5, .11, .13, etc), NACS, MCS ‘everything’, SST/DCaaS, emphasis on communication and reliability, (summary chart of active EV charging/safety standards; testing/data in support of standards)

Top 10 Priority Areas for FY2025

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1) **J3271 MCS,** including technical/testing/interop tasks
   Includes AIR7357, IEEE P80005-4, xMCS, rMCS (mining, aero, etc)
2) **J3400 RP-V2** more of the same, safety/testing concerns; identify stakeholders capable of offering a compliance mark…and what the process should be, who/how; compliance testing procedures (NACS) Building codes impact of VGI….
3) **J3400/1 TIR adapter** compounded J1772/NACS safety headaches, UL2252 parallel safety standard
4) **IEEE P2030.13(v2)/P3105 Solid state transformers;** specifications of MV fed systems, DC distribution, circuit protection, AHJ oriented test/certification in lieu of UL listing (not applicable for >1500v MV). Set up rules for acceptable solutions (a book to point at)
5) **ESX Energy Services** exchange that is included in **P2030.13, UL3141 and V2G** related standards/use cases.
6) **Weights and Measures related** standards group and applications; RSA examination, EPO30/results sheet for field verification, HB44-3.40, 3.41 NUEMS, OIML G22, SP2200 regional transfer standard
7) **SAE J2953/3 Interoperability** for AC/DC charging digital communication.
8) **International programs and EVSP roadmap support;** global harmonization concerns, (IEA Task 53),
9) **Portfolio** of important standards that are not in just one area, or have a task associated with it:
   J2894, J3072, UL1741 SC (V2G), J2990, J2997, SAE Communication ‘spectrum’(spaghetti chart),
10) **Heavy duty wireless, Dynamic wireless**, light duty/infrastructure (and W&M)

Snapshot of Standards Engagement/Progress in 2024; Next steps

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Status excerpts on active standards committees support by topic 4E resources, via labs/contractors

- **EVSP EV Standards Roadmap;** Published June 2023; FY24-25 quarterly update maintenance (ANSI contract)

- **IEEE P2030.13 DCaaS Functional Specification for charging system feed;** published/for sale; version 2 proposed

- **SAE J3400 RP (NACS);** Published September 2024, RP V2 published in December 2024? (after 'some' testing)
  J3400/1 CCS-NACS Adapter safety; TIR to be published Sept-Oct 2024; discussing testing procedures

- **MW Level stds (J3271, AIR7357, IEC80005-4, rMCS/xMCS{3000v/12-24MW});** J3271 RP weekly meetings (Oct 2024 published), interoperability test stand, MTU Pettibone vehicle reduced-to-practice, open source EVCC-SECC controls

- **Energy Services Exchange (ESX) implementation;** based on P2030.13, Phase 2 under way (OpenADR3.0), website up

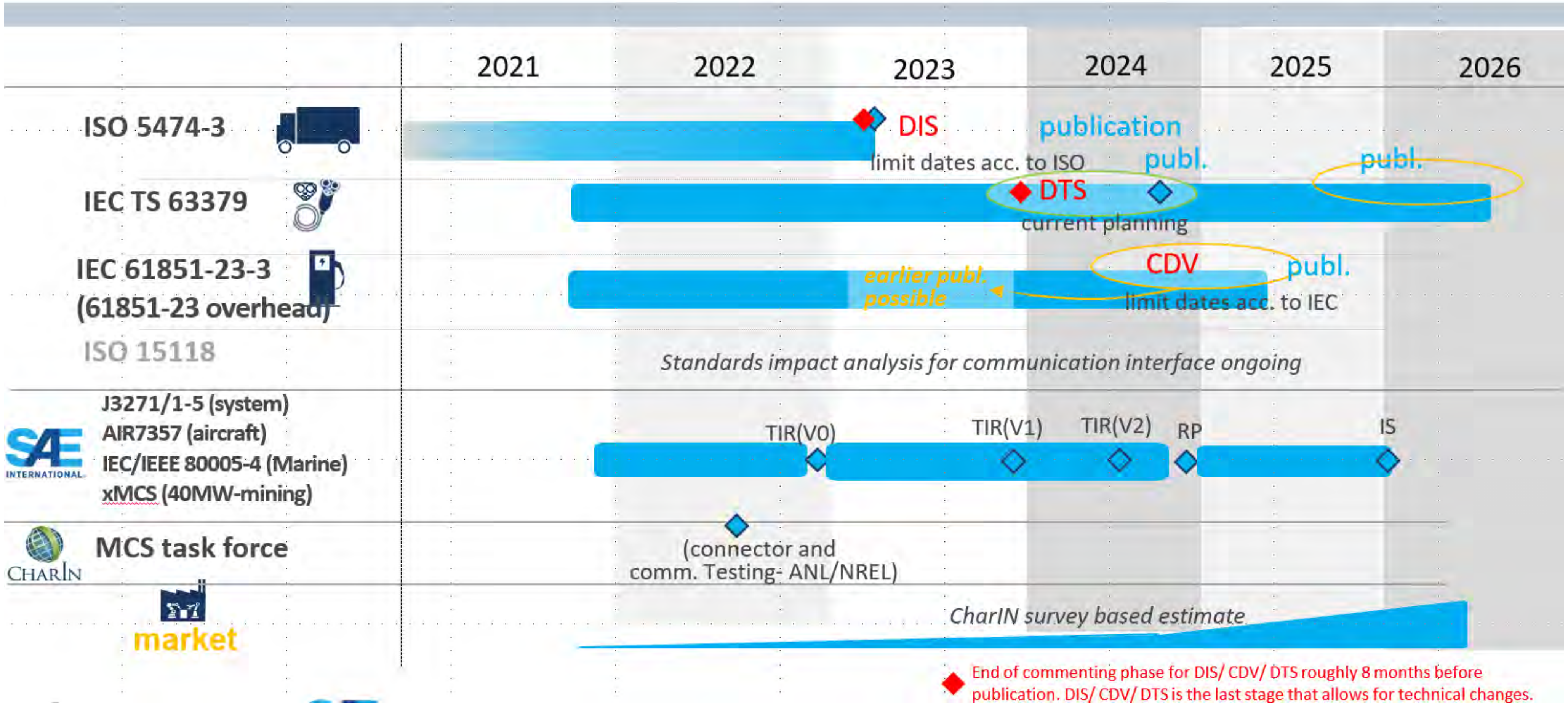
- **Weights and Measures;** Meter drift study, GUI for off-the-shelf HB44 test tool; HB105 transfer standard guide

- **'Other' SAE/IEEE standards on interoperability, reliability, safety, recycling, etc:** moving forward/expanding scope

- **Mike Duoba EV Variability study/project(s)** expanded study is planned {SAE J1634, J1711, J2908, etc}
- **Wireless Power Stds**; J2954/1 light duty published; J2954/2 Heavy Duty TIR released, J2954/3 dynamic charging

Harmonization of High Power Charging SDO Committees/Standards

Working together as a global team: National Lab participants in these and other standards areas need to have consensus between overlapping standards. There is not one 'global' Standards Defining Organization' so all the SDOs have to harmonize standards as a foundation for global interop.



SAE J3271 MCS Interoperability Test Stand- 1200v/350A

- Fixture based in HV cage at 2G Engineering (leveraging HB44 testing fixtures); Vector vSECC-MCS controllers
- Chroma 62180-1200 two quadrant 18kW/1200v/40A power supply with CAN, Ethernet, USB and other comms
- NHR 9300 is also a 1200v two quadrant power supply, 480vac input, 100kW/335A (constant power curve below)
- ANL Power Pyramid air cooled modular load bank; 1200v/120kW mobile shelving example below; **up to 2500A**

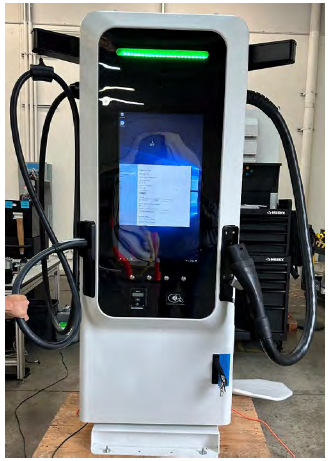
9

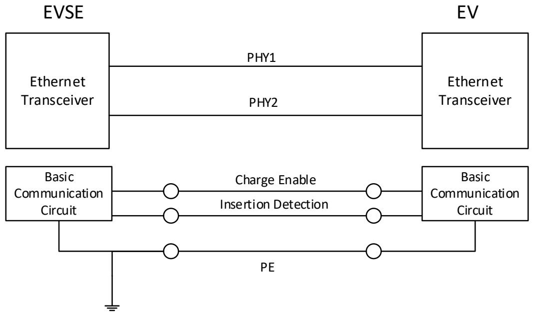
MCS Hardware-Software Development Testing

- **SAE J3271 Coupler manufacturers (8), ~UL2251 certification**
  Amphenol, Cavotec, Evalucon, Huber+Suhner, Phoenix Contact, Rema, Staubli, T.E.
  - 13 Companies developing MCS communication controllers
  ~32+ companies MW MCS EVSEs in development/pilot projects
- ABB, AiP, Alpitronic, Autel, BTCP, Cavotec, (CAT), Charge America, Siemens, ChargePoint, DesignWerk, Heliox, Hitachi Energy, iCharging, Imagen Energy, Kempower, Nxu, Power Electronics, Samsung, Siemens, StarCharge, Tritium, Vestel, Zerova, AK power
- Dual output J3400/J3271 NACS-MCS demonstration w/200A-1500A cables
  Platform for open source communication controllers and interoperability testing.







EVSE/Meter Drift Study Updates

- 25 test articles; 9 bench DC meters, 8 AC, 8 DC EVSEs running for 1.5 years now; monthly samples
- Continuing reference meter evaluation (4 power analyzers, 12 compared voltage/current/power channels), 10x 6.5 digit precision DMMs, precision AC/DC reference sources; 1500v/600A)
- Array of current sensors (50A to 5000A)- photo below of comparison on series current source/conductor through 13 flux gate sensors (same current conductor through all sensors; compare measurement variability)

HB44 Training-Workshop; LA Sept 2024; 35 in person 150 online

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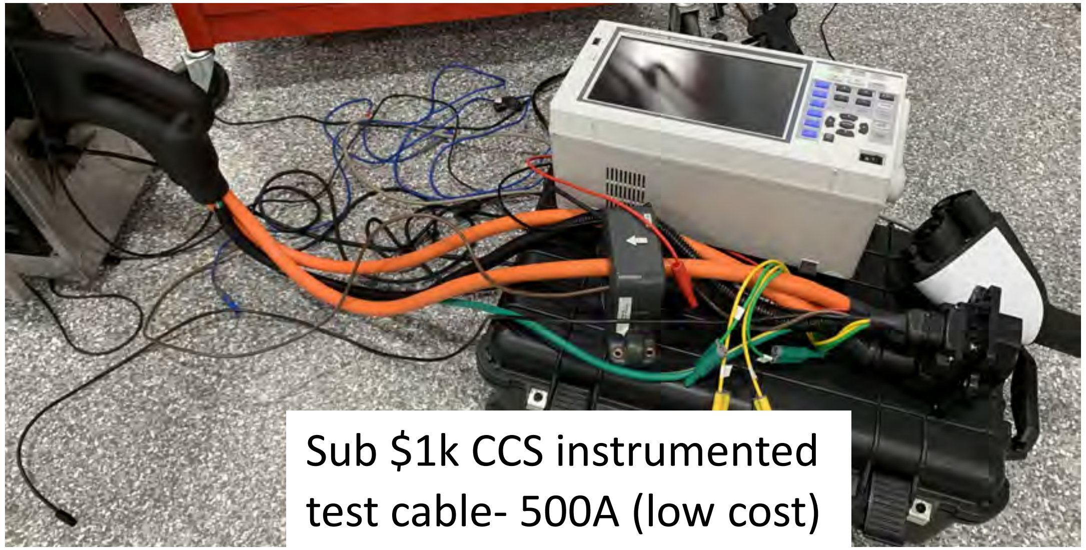
- Large and small (30A-500A DC) testing sessions; air cooled loads and vehicles (J3400 600A cord to Cybertruck); MCS on display, group tour of BTCPower manufacturing/testing facilities

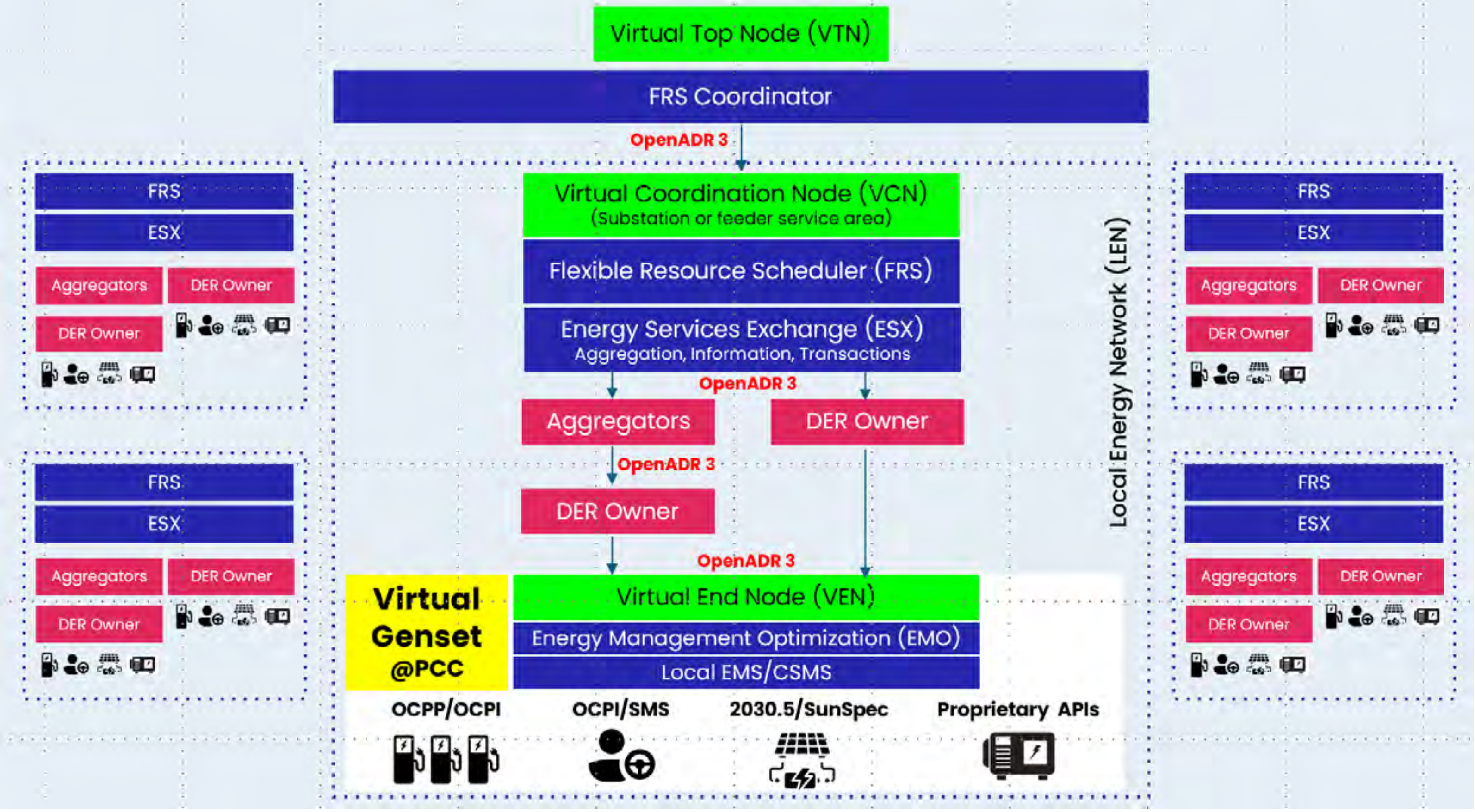
Backpack sized 25kW AC ‘Load bank’- $150

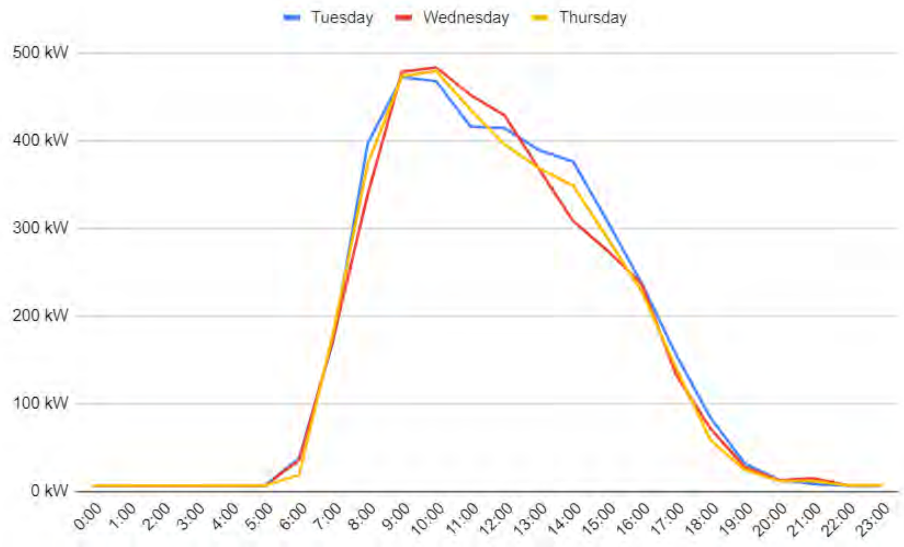


Sub $1k CCS instrumented test cable- 500A (low cost)

200kW DC Load bank 30hp fan power…

- **ESX Recent Progress**
  - Easy to remember website has been launched; https://esx.energy/ Features and demonstration description; 'Join Us' tab
  - Phase 2 of the project moving along; implementing features (VTN, public API, OpenADR3.0,..) described at last EVs@S meeting
  - Key ESX features include: Real-Time Management; Standardized Information; Integration and Coordination





Barclay's workplace charging 500kW 50% curtailment event, New York City

EVoke-ANL Energy Services Exchange (ESX) Timeline

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2018

PLUG & PLAY
DER CHALLENGE

GMLC launches DER Plug and Play Challenge

2019

Smart Electric Power Alliance

Energy Services Interface Task Force (ESI-TF)

2020

evoke launches as Charge Network Operator

2021

SEPA EV Managed Charging Whitepaper

2022 - 2024

EVoke resellers install 000s stations in NYC

2022

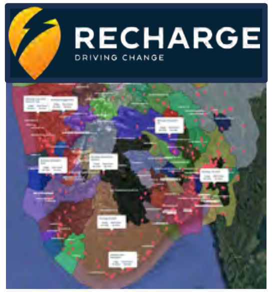
ANL/DOE fund ESX Phase 1

Argonne NATIONAL LABORATORY

2023

NYC POC 1500+ chargers mapped to 82 load zones highlighted in Europe

Norway POC over 5,000 DCFC mapped to DSOs



ESX presentation EVs @ Scale meeting

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2024

Phase 2 funding

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ESX Progress, Milestones

COMPLETED

Q1 ESX Business Requirements Document / UI/UX mockups / API schema / DB schema

Q2 ESX Advanced Load Management APIs based on OCPP – fixed limit, peak shaving scheduled load, demand response

Load Management integrated with ESX based on OpenADR 3 and FAST-DERMs principles with Con Ed 82 load zones and 1800 chargers

OCPI support notifications & opt out
Q3 ESX generates NEVI EV-ChART data format in realtime with OpenADR 3

IN PROCESS

Q3-Q4 Field Test

@ at a corporate campus

Over 600 EV drivers

96 L2 EV chargers

500kW average daily peak load

1.44 MW solar PV

Real world demonstration in day ahead & real time markets

Documentation

15

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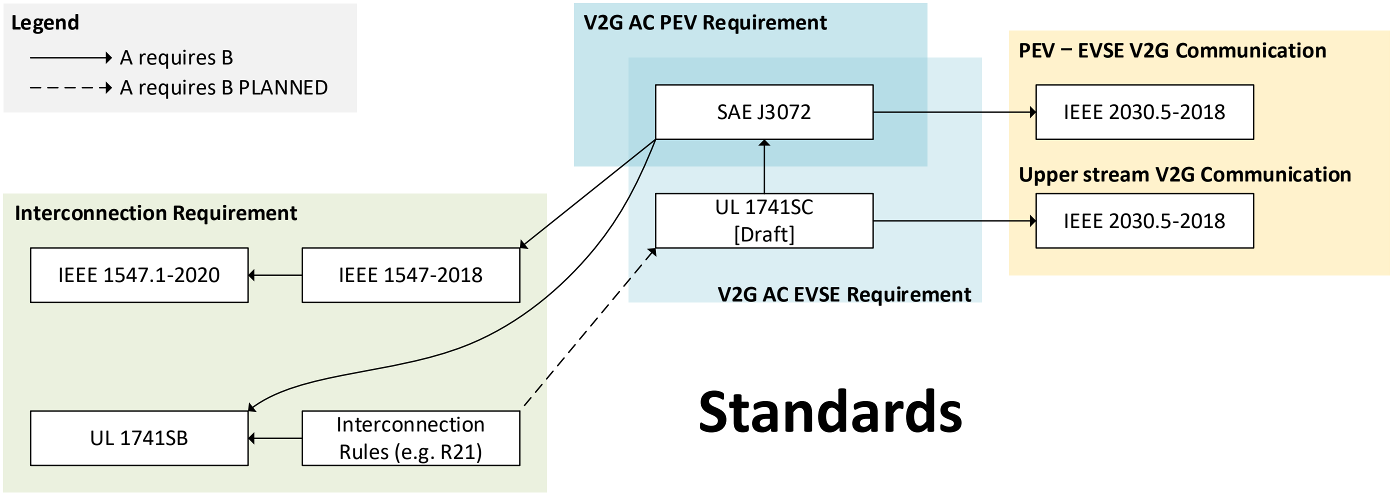
Accomplishments

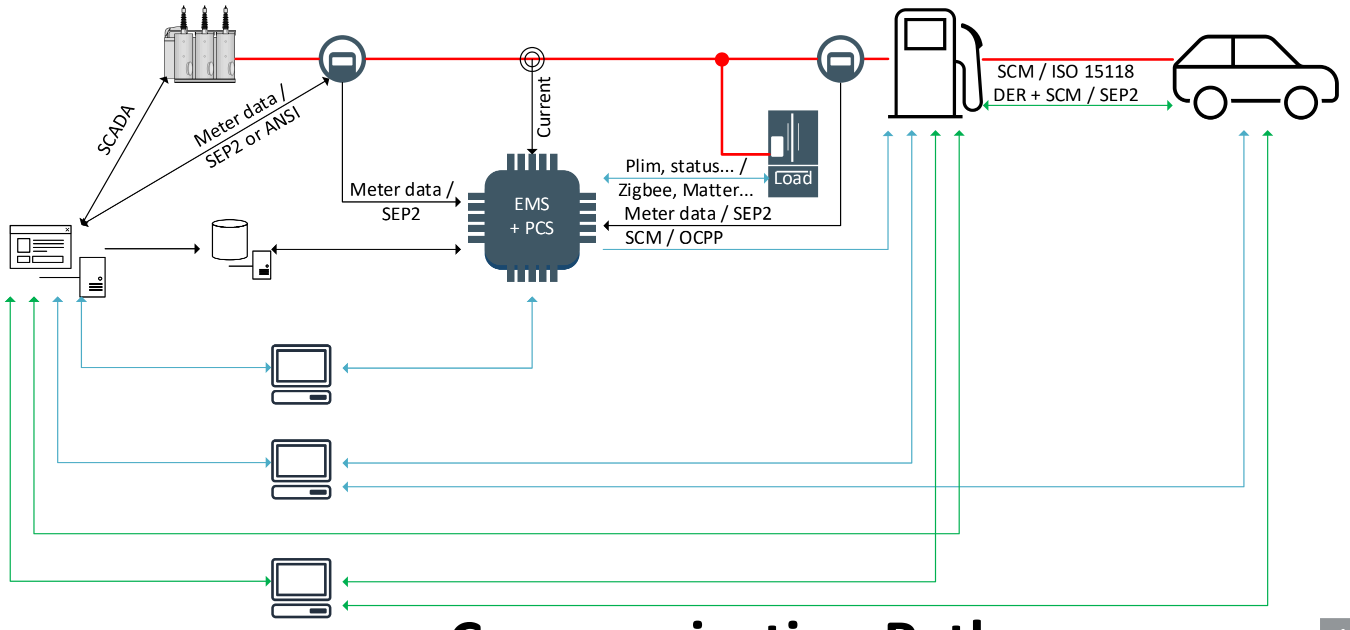
- NREL investigated V2G inclusive programs and standards and has identified V2G AC ecosystem.
- NREL confirmed that the UL 1741SC is an enabler standard for the V2G AC.

Next step

- The research outcome will be presented in an industry-led forum.
- Support UL 1741SC development
- Evaluate UL 1741SC with a focus on conformance perspective



Standards



Communication Path

NREL – SAE J2894 Autonomous Response

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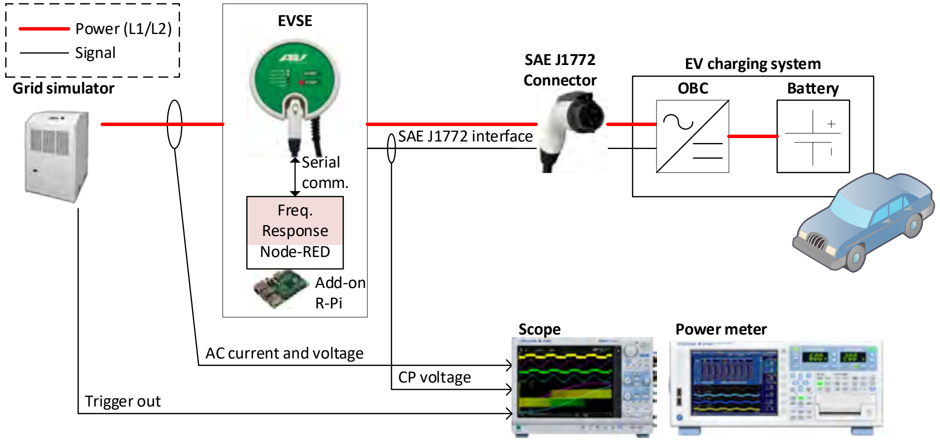
Accomplishments

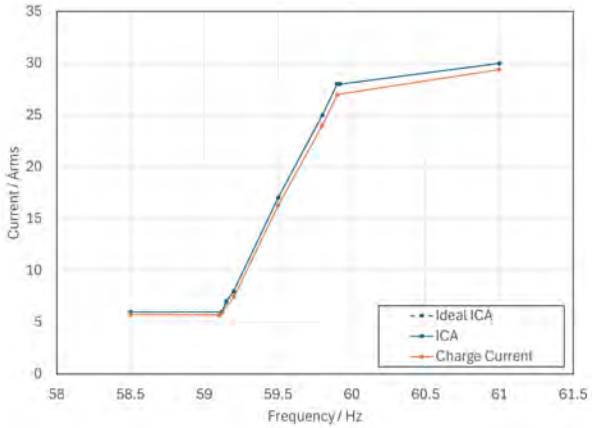
- NREL implemented a localized frequency response (F/D) to an EVSE and evaluated the response of EV and EVSE.
- NREL harnessed the result and modelled the EV and EVSE response for further analysis.

Next step

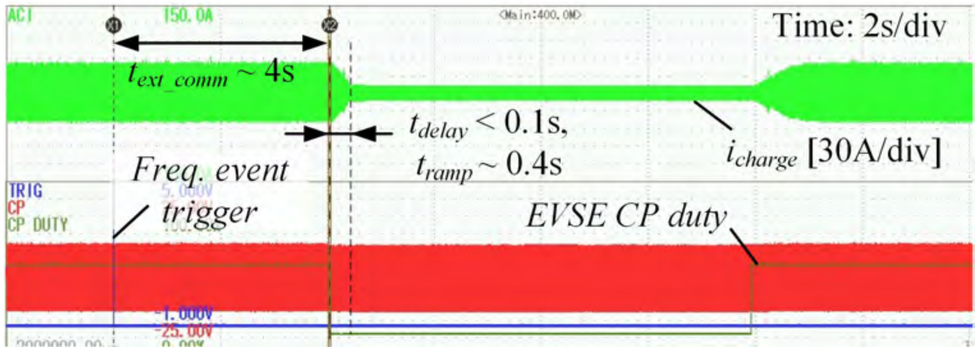
- Evaluate the value of the approach with the model.
- Work with SAE and industry.



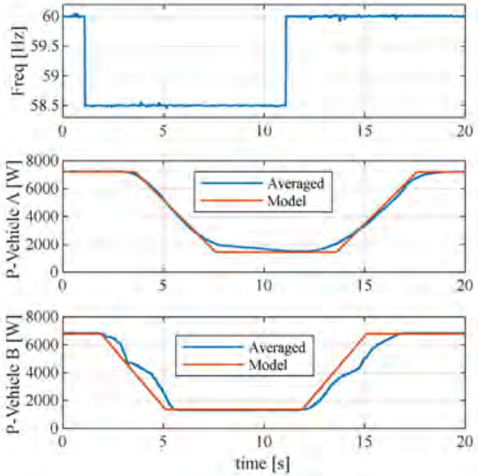
Evaluation Setup



F/D Result at Ipre = 32 A



EVSE + EV Response



Extracted Model

Investigating Variances of J1634 Procedures

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- Testing cycles at different:
  - **SOC states**
  - Thermal states
- → **Mostly similar results**

Reoccurring Differences:

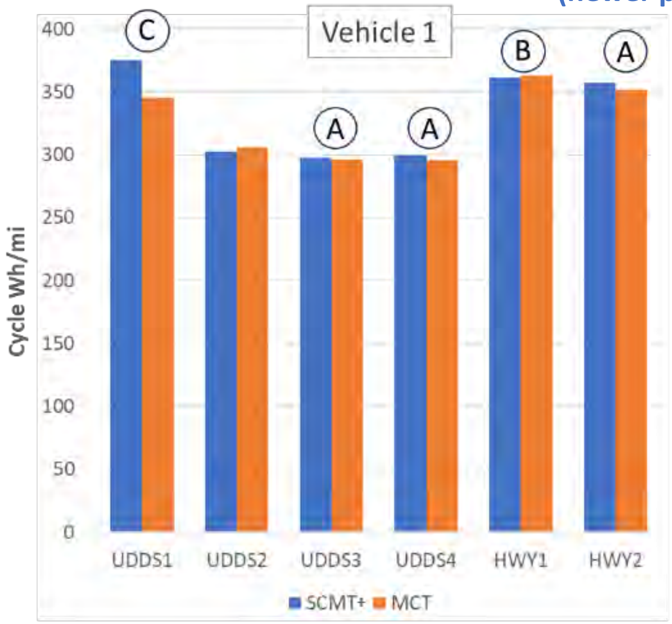
A: Cycles at lower SOC, increased efficiency

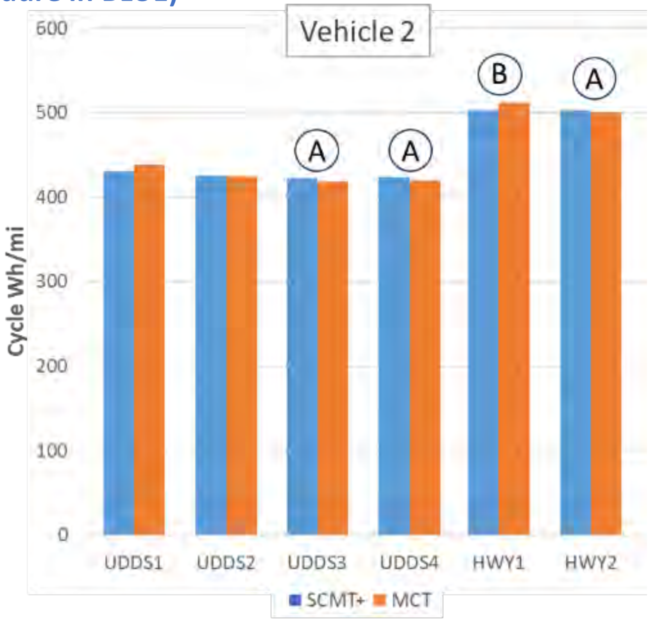
B: 1st HWY in SMCT slightly better because higher warmup state

New Issue:

C: Why such a large discrepancy in first cycle (MCT and SMCT should be same here)

(newer procedure in BLUE)





PNNL C&S Pillar Updates

- **J3271 – Megawatt Charging System for Electric Vehicles**
  - 10BASE-T1S is the official PHY Layer as chosen via IEC 61851-23-3/TC 69
  - Investigating Bilingual CAN FD-10BaseT1s coexistence
  - Future work
    - 10BASE-T1S Testing
    - CAN FD coexistence testing
- **Other C&S Support**
  - NISTIR 8473 - Cybersecurity Framework Profile for Electric Vehicle Extreme Fast Charging Infrastructure
    - Published 10/2023
  - CharIN EVSE Threat Model published

INL- Codes and Standards Update – SAE J2954 and IEEE 2030.13

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- **SAE J2954/2 released, and J2954/3 work in progress**
  - Update reflects heavy duty electrification charging needs
  - New power transfer levels and air gaps for heavy duty electric vehicles
  - Addresses static WPT requirements, J2954/3 to address dynamic wireless power transfer (DWPT)
  - No bidirectional power transfer
  - Recommends methods for evaluating safe operating electromagnetic emissions
  - Differential Inductive Positioning System (DIPS) chosen as alignment methodology for the light duty J2954 standard
  - Enables automated parking and charging for autonomous vehicles
  - Uses low-frequency, low-intensity magnetic fields from multiple coils on the GA to determine alignment

- **P2030.13 DC as a Service guidance; published, version 2 planned (overlap w/MV fed system stds)**
  - Provides guideline for development of functional specification for fast charging station management and control systems
  - Includes integration of local energy sources, including renewables such as solar PV generation and battery energy storage systems
  - Includes energy management and grid interaction functions

Megawatt Charging Connector Evaluation Team; J3400 Test Team

Andrew Meintz, PI

Isaac Tolbert, Researcher

Jonathan Martin, Researcher

Namrata Kogalur, Researcher

J3400 NACS Test Team:

Joshua Major;
https://research-hub.nrel.gov/en/persons/joshua-major

Douglas DeVoto

NREL
Transforming ENERGY

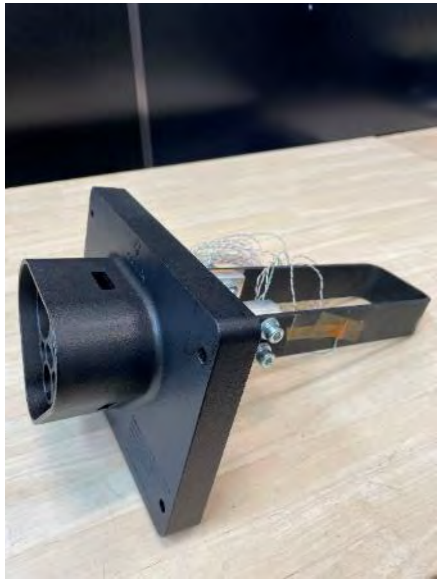
NREL MCS Connector Testing Complete; Report Published

4th MCS evaluation event, 4 hardware providers:

- **Interoperability Evaluation:**
  - 350A, 1000A, 3000A steady-state evaluations, with misalignment force evaluation
  - Performed at 25C ambient temperature
  - "Round robin" testing of prototype production-intent connectors and inlets
- **Reference Device Evaluation**
  - 1500A and 3000A reference inlet designs evaluated at rated current
  - Performed at 25C and 40C ambient temperature
  - Reference inlet prototype designs paired with prototype production-intent connectors
- **Mechanical Evaluation:**
  - Insertion force
  - Withdrawal force
  - Touch safety

- **Event 1 (2020)**
  - Fit and Ergonomics Evaluations
  - Thermal Interoperability Evaluation
- **Event 2 (2021)**
  - Thermal Interoperability Evaluation
- **Event 3 (2022)**
  - Thermal Interoperability Evaluation
- **Event 4 (2023)**
  - Thermal Interoperability Evaluation
  - Reference Device Evaluation
  - Fit Evaluations/Mechanical Evaluation

***MCS Event 4 Report** available at:*
https://www.nrel.gov/docs/fy24osti/89238.pdf



MCS 1500A Reference Inlet

MCS Test Fixtures/Procedures Leveraged for J3400 (NACS) Testing

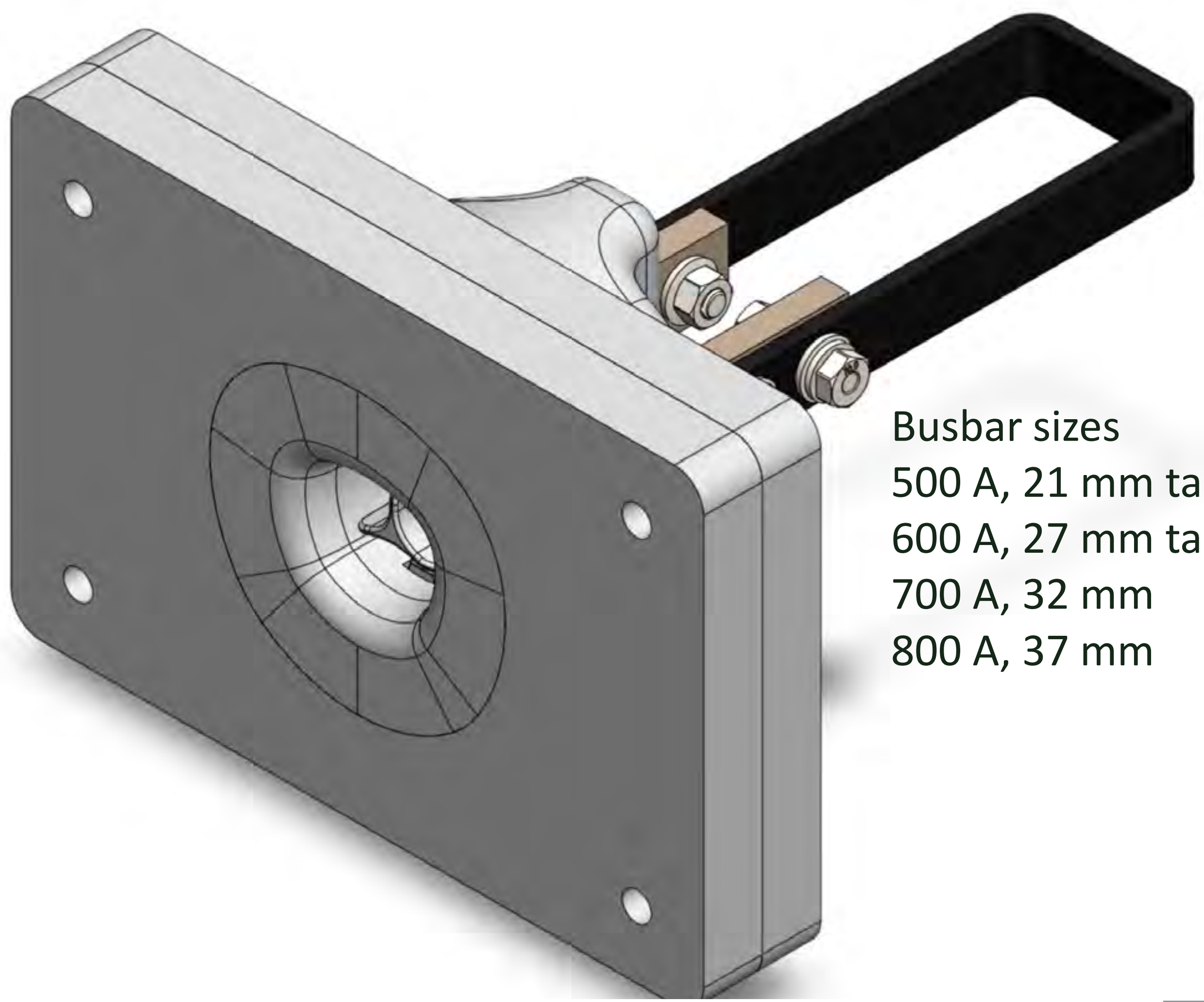
J3400 Connector/Adapter Testing

- **Interoperability Evaluation:**
  - 200A-800A
- **Reference Device Evaluation**
  - Performed at 25C and 40C ambient temperature
- **Mechanical Evaluation:**
  - Insertion force, Withdrawal force, Touch safety

Custom Amphenol J3400 Reference Inlet,

500A, 12v 3-25W heaters on each pin

Custom CNC Fabricated J3400 Reference Inlet



Busbar sizes
500 A, 21 mm tall
600 A, 27 mm tall
700 A, 32 mm
800 A, 37 mm

Maersk/Prologis Denker 96 Stall/9MW Charging Plaza (CCS)

- https://ngtnews.com/new-prologis-maersk-unit-depot-can-charge-96-electric-trucks-simultaneously

- 9MW Total resource with 2.75MW flex fuel (NG, H2) linear generators, 18MWhr battery storage (microgrid)
- Note the cluster of battery, EVSE, generator blocks repeated (~6x 16 stalls?)
- Noted that 20,000 trucks serve POLB/POLA, many hubs like this are needed
- It is off the Harbor (110) Freeway in Los Angeles on Denker Avenue,

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Example of Industry Collaboration; SAE HD Charging Industry Consortium; CAT/Other High Power Automated Connection Systems (FY25 Goals)

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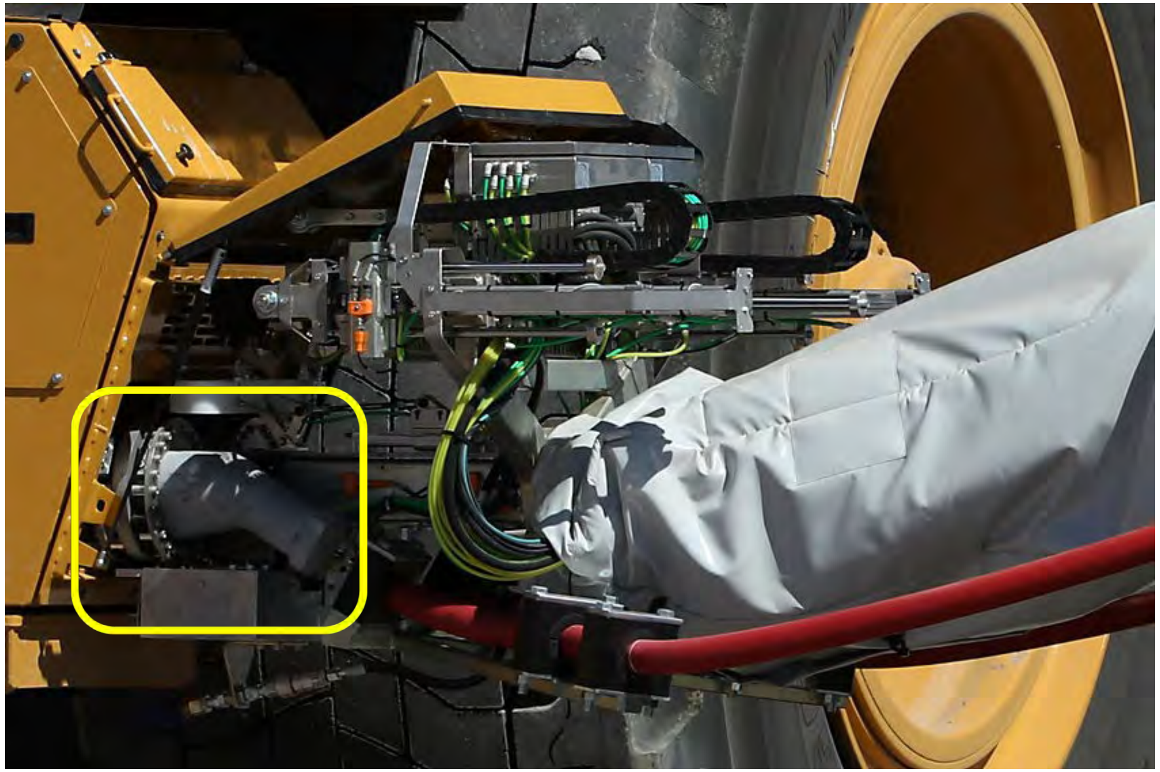
New SAE ITC consortium! Heavy Duty Charging Consortium

The SAE ITC HDCC formed to accelerate electrified commercial vehicle adoption and deployment by focusing on seamless and unified charging experience across all OEMs/EVSE by issuing standards that address interoperability challenges. Founding members include Accelera by Cummings, Allison Transmission, Navistar Inc., and Volvo Trucks North America. Visit the website to learn more.

CAT 2-6MW Automated Energy Transfer Solution for Mining Trucks (robotic actuated MCS-like couplers; 1-3 pair?)
https://www.cat.com/en_US/news/machine-press-releases/caterpillar-demonstrates-new-automated-energy-transfer-solution-for-battery-electric-large-mining-trucks.html



Conclusion and Next Steps

Review

- Initiative Overview
- Standards Support Areas
- Significant areas of standards development activities
- Implementation/validation of technology-requirements as part of standards

Next steps

- Continued monthly MW+ Charging Industry Engagement interactions/feedback
- Continued weekly SAE J3271(AIR7357) meetings, RP document by end of 2024
- Continued monthly standards work group participation; drafting standards, etc
- Expand into Medium Voltage fed charging systems; standards, testing, best practices (monthly meetings)
- Engagement in Interoperability for MCS, SST, DCaaS, J3400, J2953/3, etc

- Codes and Standards Deep Dive web based meeting **October 21st**
  Contact: Tbohn@anl.gov, Codes and Standards Pillar Lead

FY2024 Milestones/Deliverables

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Milestones (shorthand)

- Report on conceptual/functional requirements for P2030.13 w/simulations
- MCS physical layer communication robustness test plan; test results (J3271/2)
- SAE J3400 NACS TIR published; RP draft version launched/evolving; J3400/1…
- IEEE P2030.13-J3271/4 based 'PowerBroker' Energy Services Exchange (ESX) implementation as an Application Programming Interface (API) (phase 1-2) complete

Deliverables (shorthand)

- Quarterly/annual progress reports
- MCS coupler thermal-mechanical testing results report
- (critical input to…) peer review draft of SAE J3271 (part 1-5) MCS RP
- (critical input to…) final draft of IEEE P2030.13 Functional specs
- Monthly MW+ Charging industry engagement webinar based forum for input, SST TAWG

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Breakout Session 1
9:15-10:00
Thursday 26 September 2024
"Common Challenges
Stakeholder / EVs@Scale Alignment"

Advanced Charging & Grid Interface Technologies Pillar
A110

Discussion Activity

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Over the last two days you have heard a lot about what the Evs@Scale Consortium is working on. We would like to hear about what you and your organization is working on.

Think – Pair – Share activity:

1) Please find a partner in this room (if possible one lab staff and one stakeholder)
2) THINK - Consider the following question independently:

   <u>"What is the top challenge with the EV Charging Ecosystem that you work on daily?"</u>

3) PAIR - Discuss your answer with your partner and ask them to explain the challenge in more detail.
4) SHARE – Each participant will share to the whole group a summary of this challenge.

Discussion Activity – cont.

How can the EVs@Scale National Laboratory Consortium help address these challenges?

Are there projects you heard about at this meeting which may align with your work?

Open to discussion on what those opportunities might be.

Feel free to have open Q&A about the pillar also, but please do it in a way that includes all participants in the breakout.

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Thank You

Join us for the ACGIT Deep Dive

Date TBD this Fall.

EVs@Scale

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Breakout Session 2
10:15-11:00
Thursday 26 September 2024

“Working with the Consortium”

Advanced Charging & Grid Interface Technologies Pillar
A110

Ways of working with National Labs in the EVs@Scale Consortium

- **Engage and attend open meetings**
  - Semiannual Stakeholder Meetings (thanks for being here!)
  - Pillar deep dive meetings (Coming in Oct and Nov,)
- **Join a project team**
  - Start by agreeing to review analysis/prototypes/reports and provide your feedback
  - Provide data/models/designs/software for EVs@Scale labs to analyze/assess/incorporate (this may necessitate an NDA)
  - Provide hardware for characterization/evaluation/testing (this may necessitate an MTA)
- **Partner with one or more lab on funding**
  - Form a team and submit a proposal for a FOA, NOFO, SBIR, etc
- **Create an enduring partnership with one or more labs**
  - License the technology created at a lab to use in your work, or for commercialization
  - Organize with a lab to establish a bilateral CRADA
  - Fund a lab to do specific research on your behalf with an SPP

What is all that lab jargon?

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- **On the last slide several ways of teaming up with the consortium involved acronyms what do they mean?**
- **(NDA) Non-Disclosure Agreement**
  - Ensures the confidentiality of proprietary or confidential business information that may be shared between the lab and a private partner.
  - May be bilateral or multilateral to protect information shared across a larger team
- **(MTA) Material Transfer Agreement**
  - Defines the terms of use and protection required for specific materials which are transferred between labs and private partners.
- **(FOA) Funding Opportunity Announcement – also known as – (NOFO) Notice Of Funding Opportunity**
  - A request for proposals issued by a government agency to identify and award projects that align with their interests
  - Usually require a private party to be the prime contractor, national labs are encouraged as members of the teams
  - Usually require cost share from private parties, and national labs are prohibited from contributing cost share
- **(CRADA) Cooperative Research and Development Agreement**
  - CRADAs enable Labs and one or more non-federal partners (usually industry) to collaborate on an R&D program
- **(SPP) Strategic Partnership Projects SPP (formerly known as Work for Others)**
  - Work for private parties using highly specialized or unique DOE facilities, services or technical expertise

Working with the EVs@Scale Consortium

What are some specific examples of opportunities to work with the labs in this pillar?

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Thank You

Join us for the

ACGIT Deep Dive

Date TBD this Fall

EVs@Scale

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Breakout Session 1
9:15-10:00
Thursday 26 September 2024
“Common Challenges
Stakeholder / EVs@Scale Alignment”

Vehicle Grid Integration/
Smart Charge Management
A111

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EVs @ Scale

U.S. Department of Energy

Thank You

Join us for the

SCM/VGI Deep Dive

Thursday October 31st

12:00PM – 3:00PM (Mountain Time)

EVs@Scale

U.S. Department of Energy

Breakout Session 2
10:15-11:00
Thursday 26 September 2024

“Working with the Consortium”

Vehicle Grid Integration/
Smart Charge Management
A111

Ways of working with National Labs in the EVs@Scale Consortium

EVs@Scale
U.S. Department of Energy

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Working with the EVs@Scale Consortium

EVs@Scale
U.S. Department of Energy

What are some specific examples of opportunities to work with the labs in this pillar?

Successful Partnerships – EVs@Scale FUSE

- **Dominion Energy**
  - Dominion Energy has partnered with FUSE to provide feeder models for grid impact analysis and FUSE shares research findings specific to service area
- **Geotab**
  - FUSE acquired access to Geotab transportation data and multi-lateral NDAs protect sensitive information
- **Balancing Authorities**
  - FUSE has partnered with multiple balancing authorities to share and discuss findings and guide future transportation/charging/SCM research
- **Holy Cross Energy**
  - FUSE has partnered with Holy Cross Energy to expand their current SCM program with cutting edge SCM communication architecture and objective functions
- **Ampcontrol**
  - FUSE has partnered with Ampcontrol to assess their load management software for fleets and provide feedback

Typical EVs@Scale Partnerships Include:

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FUSE Partnership Opportunities

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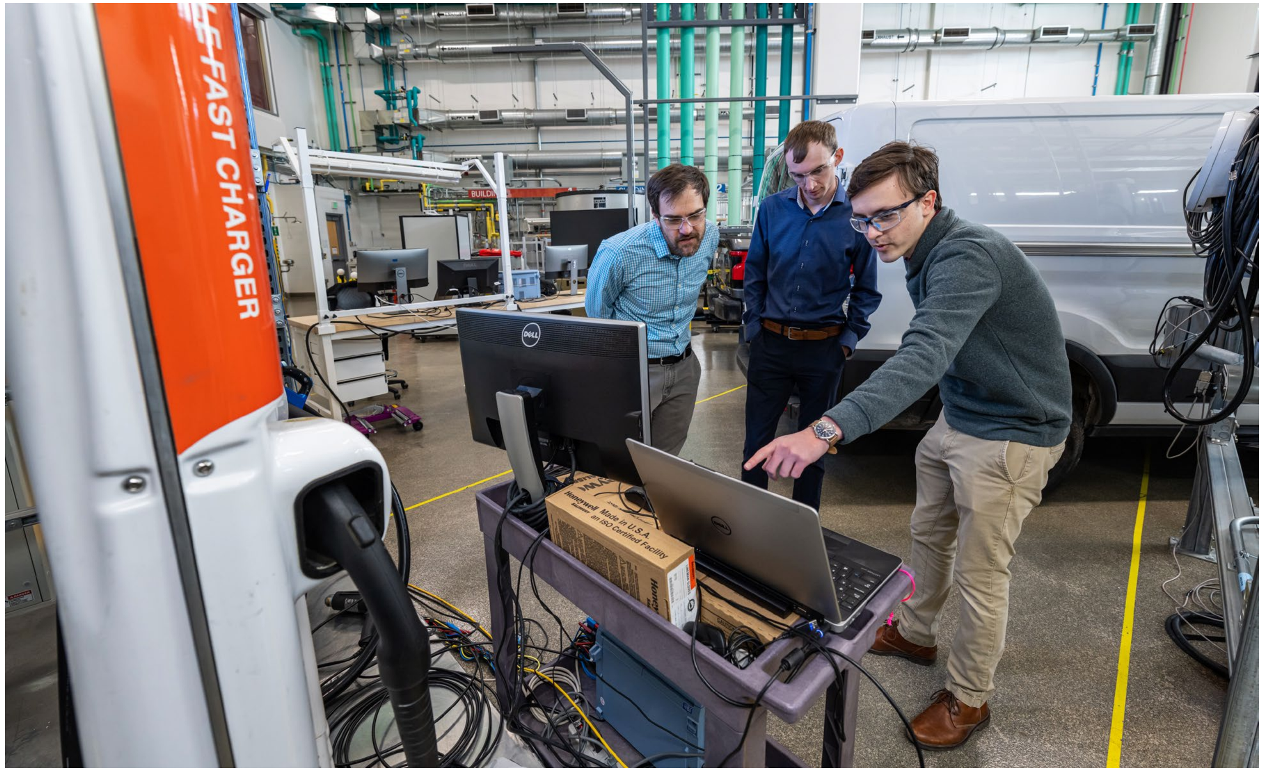
- **DERMS Integration Opportunities**
  - Would you like to integrate FUSE SCM into DERMS?
- **Utility Distribution Planning**
  - How can FUSE help inform your distribution planning?
- **Fleet SCM Demonstration**
  - Do you have a fleet that could benefit from FUSE SCM?
- **Utility and/or PUC guidance/coordination**
  - Would you like to discuss research results with FUSE?



Interested in Partnering with FUSE?

Contact FUSE PI: Jesse Bennett, NREL

Jesse.Bennett@NREL.gov

Successful Stakeholder Involvement – EVs@Scale – VGI Toolkit

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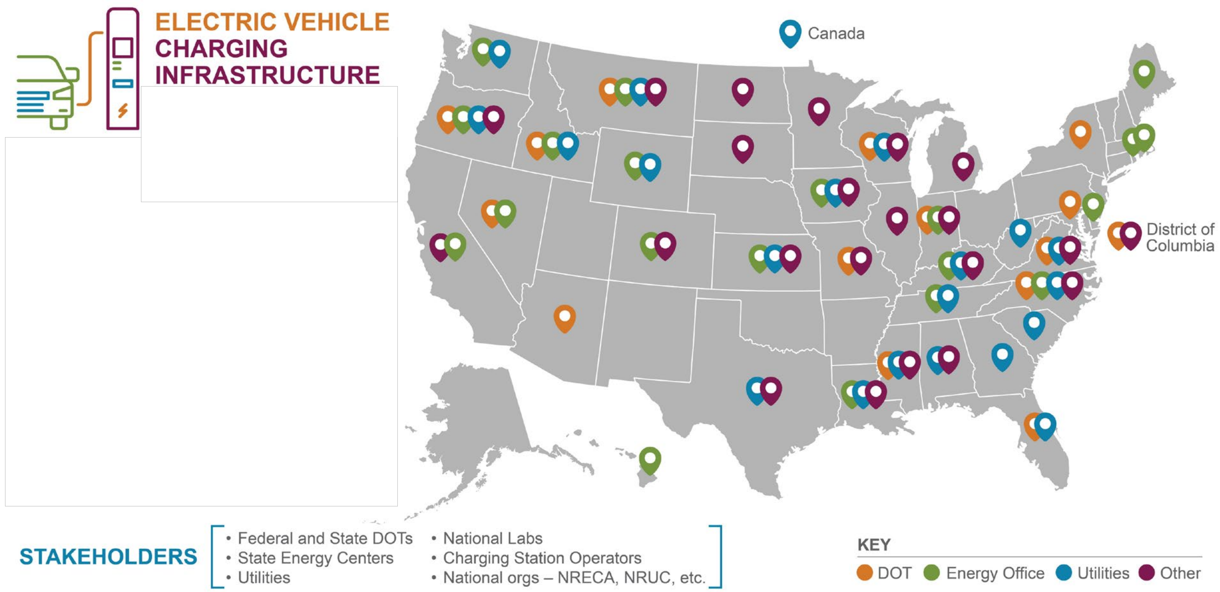
- **Utilities**
  - Engaged several individual utilities of different types
  - NRECA
  - SEPA
  - EEI
  - EPRI
- **PUCs**
  - NARUC
  - NERC
- **DOTs**
  - Federal DOT – Volpe Center
  - State DOTs
- **DOE Offices**
  - Vehicle Technology Office
  - Deputy Assistant Secretary for Transportation’s Office
  - Office of Electricity
  - Joint Office of Energy and Technology
  - Cybersecurity Energy Security Emergency Response



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VGI Toolkit Partnership Opportunities

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U.S. Department of Energy

- **Website Beta Testers**
  - Would you like to help us ensure the website directs users like you to the correct tool?
- **Tool Beta Testers**
  - Are these tools helpful to you?
  - What additional features would make it better?
  - Is it easy to use for a user like you?
- **Gap Analysis Input**
  - Are there still other tools you need which the labs are well positioned to provide?
- **We need all stakeholder types.**

Interested in Partnering with VGI Toolkit?

Contact VGI Toolkit PI: Andy Satchwell, Berkley Lab

Andy Satchwell - asatchwell@lbl.gov

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U.S. Department of Energy

Thank You

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12:00PM – 3:00PM

(Mountain Time)

EVs@Scale

U.S. Department of Energy

Breakout Session 1
9:15-10:00
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"Common Challenges
Stakeholder / EVs@Scale Alignment"

High Power Charging Pillar
A112

Discussion Activity

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EVs @ Scale

U.S. Department of Energy

Thank You

Join us for the

HPC Deep Dive

Tuesday November 12th

9:00AM – 12:00PM (Mountain Time)

EVs@Scale
U.S. Department of Energy

Breakout Session 2
10:15-11:00
Thursday 26 September 2024

"Working with the Consortium"

High Power Charging Pillar
A112

U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Ways of working with National Labs in the EVs@Scale Consortium

EVs@Scale U.S. Department of Energy

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EVs@ Scale U.S. Department of Energy

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Working with the EVs@Scale Consortium

EVs@Scale
U.S. Department of Energy

What are some specific examples of opportunities to work with the labs in this pillar?

Successful Partnerships

EVs@Scale
U.S. Department of Energy

Power Electronics Control Integration

- Dynapower
  - DC/DC charger development with custom control integration
- Turbo Power Systems
  - DC/DC EVSE with custom control integration

Site-Level Operation

- Total Energies
  - DC hub modeling, techno-economic analysis
- Eaton
  - COTS SEMS controller integration to EVSE hardware

Utility Partnerships

- Colorado Springs Utilities and Smarter Grid Solutions
  - DERMS integration into SEMS platform

Automotive Partnerships

- Lion Electric
  - School bus V2X demonstration

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Partnership Opportunities

EVs@Scale
U.S. Department of Energy

- Site Operators
  - In need of fleet, depot, port operators interested in looking DC hub operations and providing operational data
- Site Energy Management System Opportunities
  - We are in need of partnership with SEMS or building energy management system developers?
  - Can we work together to develop SEMS platforms and integrate solutions in the field?
- Hardware Integration for EVSE and Site
  - We are in need of power electronics hardware developers to integrate our control solutions to your hardware.
  - Partners implementing isolation monitoring at high voltage
  - Partners implementing site integration and connectivity for increased up-time
- DC Microgrid and DC as a service
  - Partners experienced in DC microgrid and DC as a service field implementations
- Automotive Sector Opportunities
  - Would you like to partner with us on implementation of bidirectional power transfer?

Interested in partnering with us?

Contact eCHIP PI: John Kisacikoglu, NREL

John.Kisacikoglu@nrel.gov

Open Project Partnerships

- **EV Profiles: High power EV/EVSE partnership**
  - HPC (150-400kW) EVSE & EVs
  - Megawatt-level (800-1000kW+) EVSE & EVs

- **EVSE Char: High power and/or Bi-directional EV charging infrastructure partnership**
  - EV emulator capable of high-power charging up to 400kW (500A max., 920V DC max.)
  - EV emulator capable of CCS-1 bi-directional charging up to 120kW using ISO 15118-2 (2015)

- **Fleet telematics data partnership**
  - Looking to add another fleet to our portfolio, granting access to data portal for NGP specific analysis

- **Data Analysis partnership**
  - Lots of data collected within NGP. Partner would use data to perform different areas of analysis for EV, EVSE, and/or Fleet pillars with an industry perspective.

Interested in Partnering with NGP?

Contact NGP PI: Sam Thurston, ANL

sthurston@anl.gov

EVs@Scale

U.S. Department of Energy

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U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

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Cyber Physical Security Pillar
A113

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EVs @ Scale

U.S. Department of Energy

Thank You

Join us for the

Cyber Deep Dive

Wednesday November 6th

11:00AM – 2:00PM (Mountain Time)

EVs@Scale
U.S. Department of Energy

Breakout Session 2
10:15-11:00
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“Working with the Consortium”

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A113

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EVs@Scale U.S. Department of Energy

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Working with the EVs@Scale Consortium

What are some specific examples of opportunities to work with the labs in this pillar?

Direct Partnership Opportunities with EVs@Scale

The consortium is actively looking to support industry via partnering opportunities

- Cybersecurity and Cyber-physical security opportunities with EVs@Scale
  - Conduct cybersecurity evaluation on DC and V2G charging hardware prototype or production systems
    - Lab capabilities to enable evaluations include:
      - CCS-1 EV emulator: 1. V2G using ISO 15118-2 (2015) 120kW, 2. DC high-power charging up to 400kW
      - High-power DC charging stations (from 150kW to 350kW)
      - Open-source tool named “AcCCS” to evaluate the CCS communications network
      - Concentrated depot/community charging (e.g. 100x 11-22 kW)
  - Develop cybersecurity provisions for resilient, distributed DC microgrid-backed EV charging
  - In person or virtual assessments of the EVSE cybersecurity controls in the DER-CF
  - CSO / CNO cybersecurity evaluation collaboration
  - Technology transfer opportunity of proven mitigation solution for DC charging infrastructure

Direct Partnership Opportunities with EVs@Scale

(continued)

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- Cybersecurity and Cyber-physical security opportunities with EVs@Scale
  - Advise and evaluate the security implementation in EVs, EVSEs, and CCS communications network
  - Partner on conducting HIL analysis with mobile applications in the charging ecosystem
  - Advice and lessons learned sharing on cybersecurity best practices implementations
  - Feedback on certificate naming mechanisms and testing opportunity inputs
  - Cloud Security: explore cybersecurity requirements for public cloud hosted CSMS

EVs @ Scale

U.S. Department of Energy

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Codes & Standards
A114

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Codes & Standards Deep Dive

October 21st , 2024

More details to follow

EVs@Scale

U.S. Department of Energy

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“Working with the Consortium”

Codes & Standards
A114

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